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on

Marine Safety and Environment/ Ship Production

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First Joint Conference on Marine Safety and Environment/
ship Prodution

Shipping, and therefore harbours and shipbuilding, is of crucial importance for the worlds economy and the welfare of the population. Without ships international business would be impossible at the scale of today, e.g. in the E.C. more than 65% of the cargo is carried by seagoing vessels, and of all the cargo handled in Rotterdam more than 60% is carried by ships using inland waterways. So shipping, harbours and shipbuilding are in many ways the prime movers for the economy.

The sea, sometimes called the worlds last economical resource, is becoming more and more vulnerable to pollution, also from ships, but remains at the same time, because of the fast changing environmental conditions, unpredictable and sometimes dangerous.

Thus Safety and Environment are requiring a continuing awareness of shipping, harbours and shipbuilders from different angles. Nowadays society is demanding an integral approach from this mode of transportation, not only logistics but also with regard to the safety of the entire system and its effect on the environment, under any circumstance or prevailing condition.

Simultaneously Ship Production is covered during this-conference. Shorter delivery times, methods for standardization, and quality requirements are influencing the production cost and hence the price of the ships. Governments are planning to impose more stringent rules and regulations on shipyards to improve the safety of the ship.

These proceedings contain the views of policy makers and engineers which will have to solve these problems.

You will find that in these proceedings the following areas are being covered regarding safety and environment:

-ports and harbours
- transfer and handling of cargo
- ship operations
- design, building and maintenance of ships
- insurance and classification
- governmental and regulatory bodies

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We trust that the information contained in these proceedings are of benefit to its-readers.

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MARINE SAFETY AND ENVIRONMENT

SHIP OWNERS VIEW AND RESPONSIBILITY

(M.A. BUSKER)

Close to 80% of everything the world population uses and consumes, is transported over sea. In weight a quantity of some '4 billion tons per annum.

To provide that transport facility some 70.000 ships above 300 GRT are in use.

All these vessels in their normal operation produce -   cargo residues
                                                          engine sludge
                                                          exhaust gasses
                                                          normal waste
                                                          metals from anti-fouling paints.

Related to their specific transport functions:
- because of the breathing of the cargo,
   tankers release some 3000' tons of hydro car-
   bons per annum to the atmosphere.
- fishing vessels produce fish waste estimated
   at **100** - 400 million tons p-a.
- reefer vessels release some 50 tons of CFK's
   per annum.

The repair, new construction and final scrap-
ping of the vessels create an environmental
problem of its own.
By nature of the diversification and geographi-

cal spread of these activities, with substanti-
al variations in the development of the local
regulatory machinery, it is not possible to
quantity the effects on the environment on a
global scale.

Please note we have excluded all vessels below
300 GRT and inland waterway, non sea going,
vessels.

After this quantification, based on figures
produced by some high profile internationally
recognized institutes, it *is* time to ask our-
selves: IS THERE A PROBLEM? The answer is:
"yes, but.."

The International Maritime Organization has
created the machinery to tackle this problem
with Marpol 73/78 and the annexes.

Substantial improvements have been made. From
an environmental point of view it is signifi-
cant that over the years the focus has shifted
away from pollution by oil only.

There is a growing awareness of the effects of
the environmental impact of pollutants we do
not see, or are not perceived as a personal
nuisance.

The interest for the conservation of the mari-
time environment is growing.

In The Netherlands "Green Peace" has 1 million
paying members.
The public reaction following the Exxon Valdez
accident has been a clear signal.

In general one can observe that in the indus-
trialised world the efforts of IMO in the 60
and 70, leading to action by governments and
industry, are now rapidly obtaining popular
support and consequently a broader political
base.

The negative effect of this awakening interest,
is the inducement for politician to look for
political i.e. short term solutions, rather
than to follow the arduous path of internatio-
nal consultation and conventions, to arrive at
long term solutions.

The major negative effect of this is a growing
tendency to lay the burden of responsibility
with the shipowner.

The pollution resulting from routine operations
mentioned so far, cannot be. prevented, only be
influenced by the shipowner.

In order to do that successfully there will be
required:
- a well maintained vessel
- the necessary technical provisions

- good operating procedures
- thight company discipline
- a competent crew.

All these things are well within the capabilities of the traditional shipping companies. Unfortunately to every requirement a bill is attached.

As obviously the parties interested in the maritime environment are not prepared to foot the bill by paying more for maritime transport, we see a continuous battle to cut costs.

The result of this being:
- an aging fleet as rates do not justify newbuilding
- very little R & D
- a constant streamlining of organizations
- a decline in discipline, due to new forms of labour agreement
- a different standard and level of competence of crews.

All developments not inducive to an atmosphere of greater care for the environment.

A different source of pollution is the accidental pollution. Here we see a strong focus on oil tankers. This for the simple reason that oil is highly visible and perceived as being

very bad because of, amongst others, the pollu-
tion of holiday beaches and seabirds dying.

Before passing judgement, things should be put
in perspective.
Of the estimated 2 million tons of oil that
flow into the sea every year, shipping is res-
ponsible for 24% or about 500.000 tons.

Of the total:
- 12% is caused by non tanker shipping
    7% is the result of tanker operations
    5% is the result of tanker accidents.

If we analyse the cause of the accidents, human
failure is the principal cause. This either in
the sense of an operational mistake, lack of
maintenance or disregard of procedures.

How can we improve this situation?

The secretary general of IMO has expressed his
concern and made a public statement, that ship-
owners were not capable to keep their own house
in order.

In doing so a greater role for governments is
implied. A recent example of government action
is the USA Oil Pollution Act '90,
In an effort to protect the US tax payer
against the effects of an oil pollution caused
by a tanker accident, the very fundament of the

maritime insurance has been abandoned.

The Elizabethan Act of **1601** states:
".... that upon the loss or perishing of any ship there followeth not the undoing of any man, . ..'I.

Under OPA 90 the principle of limitation of liability has been abandoned. The direct result of this being that well organized oil companies, with high standards of discipline, have abandoned their trade to the USA with their own ships.
The same cargoes, with the same pollution potential, will now be carried in vessels of one ship companies.
Because it is the shipowner that is held liable, instead of the cargo interests, this responsibility could easily be shifted.

In conclusion the OPA 90 can only be seen as a retrograde step in the battle against marine pollution.

On this side of the Atlantic, the EEC port state control agreement is a positive step ahead. However, do we control the right issues.
In .general a bad ship with a competent crew will seldom come to harm. The reverse of this situation is a formula for disaster. Still the quality and competence of a crew are virtually impossible to ascertain in a-routine in-

spection.

Last but not least, the role of the salvor.
In 3 serious tanker accidents in **1991** some **100.000** tons of oil were lost into the sea. By extinguishing the fires, towing the distressed vessels to a less hazardous location and transferring the cargo, some 600.000 tons of oil were prevented to flow into the sea.

Please note all this took place in the open ocean, as in spite of all the talk about "safe havens" none such haven was made available!

The legislators have recognized the importance of the above and in the LOF '80, the standard salvage contract, a provision is made that even, if not successful, the salvor will be compensated for expenses made in efforts to avoid pollution.
In the new salvage convention '90, most likely a typing error has made the **1980** achievements null and void. That is called progress.

In summary:
- Holding the shipowner responsible does not solve the problem and is in fact counterproductive.

- The key element in both accidental and operational pollution is the competence of the crew and the level of discipline in the com-

panies.

- As long as society is not prepared to pay
  for the transportation of their goods,
  society is directly responsible for pollu-
  tion caused by bad maintenance and lack of
  competent and disciplined crews.

- Internationally co-ordinated positive action
  will be the only means to control an inter-
  national activity like shipping. Per defi-
  nition it will take a long time before re-
  sults are achieved and will be noticeable.

  Conclusion:

  As long as we are not prepared to ensure a
  reasonable level of earnings for the ship-
  ping companies, the pollution problems will
  increase and safety standards will decline,
  in spite of legislation.

Sources:

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The state of the marine environment, UNEP '90

Tanker spills: prevention by design

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Oil Tankers and the environment - Lloyd's Register

Het systeem aarde - KIVI

The principles of marine insurance

THE VIEW OF A CLASSIFICATION SOCIETY ON THE CHANGING SHIPPING SCENE

by Dipl.-Ing. Robert Kruse
Executive Board Member, Germanischer Lloyd

ABSTRACT

A Society's 125th Anniversary seems to be an appropriate occasion for viewing the role of classification in the changing shipping scene. Such an event gives reason for looking back on the past and for position finding. It is not a matter for this most topical conference to view the past. However, it should be mentioned that at least during the past 150 years, the technical development has permanently brought its influence to bear upon the shipping scene. Owing to the steady development of steels, construction methods, machinery and, lately, the introduction of electronics, ships nowadays are among the most sophisticated products in our highly technicalized world. The classification society has at all times been actively involved in this process and played a dominant part. The idea for its foundation by shipowners and underwriters among other aspects was that the safety concepts for ships were to be developed and their introduction supervised by the classification society. As far as newbuildings are concerned, this necessarily leads to rules and regulations being worded such as not to obstruct new developments. The technical possibilities available have to be integrated and, following the principle of equivalence, it must be possible to also realize unconventional ideas.

This demonstrates that within a changing shipping scene, the classification of newbuildings does not present any problems. To mention only a few examples: safety concepts for a high degree of automation are developed, taking into account the whole range of technical possibilities available. This then results in a reduced number of crew as stipulated by the industrialized countries. With the aid of modern computation methods, it is possible to adapt ship design to all kinds of requirements. Also, it is possible to apply optimization programs, e.g. for the stowage of 11 containers athwartships below deck in a Panmax ship. Optimization of the new double skin tankers does not cause any problems.

The situation is different, however, regarding the attendance to the fleet in service. It proved that owing to the steadily increasing average age of, in particular, bulkers and tankers, the conventional survey procedures were no longer adequate, as in older ships, the inspections required to be carried out in the course of a class period occasionally left undiscovered certain corrosion damages, signs of fatigue, etc. This resulted in an increasing number of failures of these ships.

Since mid-1991, the classification societies associated in IACS have been taking these facts into account by amending their rules accordingly. Also, in their specific instructions to the surveyors, they mentioned all possible weak points, and fixed details on admissible corrosion limits. By introduc-

ing an additional auditing procedure, GL have assessed the condition of all older ships of these damage prone types and in some cases initiated immediate action for restoring the required safety level.

The accidents having occurred during the past few years have meanwhile induced IMO to intervene in the determination of hull survey scopes. In this regard, the IACS rules at present in force are once more being revised. The results of these efforts will then presumably be passed as an international regulation. The flag states will then be ultimately responsible for ensuring that these regulations are duly observed. If authorized by the competent authorities, the classification societies then have to carry out the relevant surveys on their behalf. It will be essential to avoid duplications of surveys.

We very much regret this development, much more so as with the majority of ships the classification rules are duly observed, thereby absolutely safeguarding the safety of old ships as well. Only some few ship managers and ship operators do not observe the regulations stipulating that in case of any problems arising which may affect the vessel's class - such as corrosion or cracks - this will be remedied in cooperation with the classification society. A few make the vast majority suffer!

In general, it can be stated that the majority of accidents (i.e. 80% or so) are attributable to human failure. This means that for achieving a higher standard of safety, it will not be necessary to introduce new rules and regulations; rather, the existing ones will have to be observed more strictly. It is intended to ensure this by introducing quality assurance systems. As a first step, the management firms associated in the International Association of Shipmanagers decided to introduce a relevant Code defining all steps to be taken for ensuring reliable attendance to ships. This system is then assessed and certified by impartial auditors. Following the necessities of the market, such procedures have already been introduced by shipowners as well. The procedures also duly take into account the classification requirements. The classification societies expect that the routine checks will ensure that their requirements will in future be observed more carefully.

Within IMO, too, regulations are at present being prepared. For some years now, IMO has been publishing non-binding management guidelines for the safe operation of ships and for pollution prevention. A new Chapter of the SOLAS Convention is now intended to be introduced for operational aspects to be covered, with details specified in a mandatory code. The systems are based on the ISO 9000 series. This enables a large variety of activities to be listed systematically and instructions to be given for their strict implementation.

The classification societies associated in IACS, too, have declared the introduction of such systems to be binding. Although in the proper sense, classification is quality assurance, this system is intended to enable the whole range of activities performed to be audited as to completeness, quality and performance. This audit is then preferably to be performed with the participation of IMO and the international underwriters' associa-

tions. The certificate issued following the audit shall demonstrate to the flag states, among other aspects, the quality of the work performed on their behalf. This could well replace the previous procedure of checkings with the classification societies by the individual states. The objective is to restore the confidential relationship between the classification societies and the flag states/underwriters. For them to cooperate with and rely on the services of the classification societies continues to be necessary as only the classification societies maintain a worldwide network of surveyors capable of meeting the increasingly more exacting demands. It will thus be possible by one single survey to cover the interests of all concerned: the flag states, the insurers, and the classification societies.

With this in mind, it will also be necessary to harmonize the different classification societies' standards. These efforts will have to be coordinated by IACS, where unified requirements are formulated, experience is exchanged and joint approaches are discussed for dealing with unreliable shipowners. This includes procedures to be applied in the case of changes of class, as far as the observance of recommendations is concerned.

Beyond this, within IACS, unified standards are established for the implementation of flag state regulations. This alone will ensure an equal treatment of all ships by the different societies.

Regarding the cooperation between the classification societies and IMO, it may be stated that IMO sets basic standards for ship design, e.g. the introduction of double skins for tankers. Subsequently, the classification societies will determine the structural details, including the dimensioning of the structural elements, in accordance with their own rules. It remains to be seen to what extent IMO will include the classification societies' safety philosophies in its discussions. Thereby, it would for the first time enter the domain of the classification societies. Considering the past experience, such a step is not required, as all IACS classification societies are fully aware of their responsibility in performing these functions and as the basic principles for them have already been harmonized within IACS. Any further details introduced on the statutory side would hamper the versatility required for continuous progress in technology.

As far as newbuildings are concerned, classification has become increasingly important. Many shipyards try to meet the requirements with a minimum staff of engineers by having complex computations and research activities performed by the classification society. As a result of this division of functions, considerable progress has been made in the handling of sophisticated ships. For Germanischer Lloyd, for instance, strength analyses of hull structures and the calculation of global and local vibrations are among the routine optimization processes for new ship types: considering their high propulsion powers and the extreme locations of their deck houses, in particular, prognostics on vibrations are an absolute necessity. Later corrections by the trial-and-error method are much too expensive.

Marine Safety and Environment
The role of the Royal Netherlands Navy

Commodore RNLN R.M. Lutje Schipholt C.Eng. FIMARE

Introduction

Not surprisingly the Navy is not immediately associated with safety and
environment at sea. Gunfire and sinking ships spring more to mind. But of course
since more than the 500 years of it's existence the Netherlands Navy assured the
safe and unobstructed freedom of the seas as advocated by Hugo Grotius.

That the experience and means of our Navy are also used to rescue people at sea
in peacetime is widely accepted without realising the efforts and organisation
that lies behind this task. While at least five ministries and as many volonteer
societies are preoccupied with dividing among eachother the coastguard duties of
ensuring safety along our coast, the coordination of disaster relief when, say,
a ferry sinks, is left to the Navy and the evacuation of victims to our naval
helicopters. At those moments it is afterall effectiveness that counts.

Also the clearance of mines at sea, in peace `and wartime is of course a task of
the Royal Navy. And that this task of safequarding navigation at sea is still
continuing, also in our waters, is shown by the regular catch of mines by our
minehunters or fisherman. It is mostly the task of our underwater demolition
teams to disable these dangerous souvenirs of the past that land in the
fishnets. For that purpose the Navy runs a very specialised diving school and
dive medical centre.

Some areas of naval activity in the marine safety field warrant some special
attention, in view of the interesting technical features they have. The first
one is hydrography, a special task of the Royal Netherlands Navy. In particular
the modern developments in data acquisition and (sea)mapping will be described.

Secondly modern naval practices in training for safety at sea will be explained.
Our own training school, with the most modern training aids, prepares our
personel for damage control and repair at sea. A subject which is, with the
increasing danger for our environment of oil and chemical transport over sea,
vhile crew size and expertise are shrinking, of vital interest to all marine
engineers.

Lastly some specialised fields of technical know-how in the Royal Netherlands Navy will be highlighted of more general interest to all marine engineers involved with marine safety. These technical investigative results stem from damage-analysis and -prevention studies associated with the typical wartime tasks and environments of our ships i.e. withstanding battle damage and sometimes extreme pressures. and stresses, high speed and excellent seakeeping under all circumstances. This has lead to advanced calculations of strength and stability but also to hydrodynamic and control engineering solutions which might well have direct applications in a wider maritime field.

Bathyscan seamappingsystem

The Hydrographic Service of the Royal Netherlands Navy has realised for quite some time that a much higher density'of depth measuring points of the seabed is necessary, especially in certain areas of the North Sea, in order to satisfy the much higher sea chart accuracy requirements of today and tomorrow. This in view of the bigger draught of modern ships. This would require with conventional echosounding equipment, a considerable increase in capacity or numbers of hydrographic ships. This was for practical and economic reasons not feasible and the decision was taken in 1988 by the Navy to acquire equipment that could take depth measurements in the sea over a wider path.

There are basically two techniques for obtaining this bathymetric information over a wide path. Most systems are so called multibeam systems with a number of transducers mounted in parallel in a bananashape. Mostly these are hullmounted transducers under the ship. The total pathwidth to be obtained with this type of system is about 2.5 times the waterdepth. Depth measurements have in this case a spacing of about 2 meters.

Another technique as in the Bathyscan chosen by the Royal Netherlands Navy, is the interferometric side scan sonar. The basic principle of this system is the measurement of phase shift of reflected sonar transmission by the "target" by two transducers at a small distance apart. By using a multitude of interfero-meters the Bathyscan can measure with great accuracy the angle of reflection from the seabed in relation to the vertical. Since the distance to the seabed is a function of reflection time and the known sound propagation characteristics in water, the water depth and seabed shape can be accurately measured over a wide area.

In the system used by our Navy the transducers are mounted in a body towed through the water at a depth of 6 meters alongside the ship. In order to obtain an angle measurement accuracy of 0.2 degree, on both sides of this "fish" multiple interferometers are mounted. One transmitter and four receivers on each side to be exact. The reasons for us to select a technique using a towed body are: ease of maintenance, transportable, replacement is possible, and the "fish" can be towed under a thermocline layer.

The data acquisition system in the "fish" sends 300 KHz pulses alternatively with port- and startboard transducer. Also mounted in the towed body is an echosounder and sensors for measuring roll, pitch, wave motion, course and depth of the "fish". The reflected pulsesignals are received by the interferometers and transmitted with the other sensor signals through the towing cable to the ship. The interferometer signals, corrected and using the other sensordata, will be transferred to distance and angledata of points on the seabed. About thousand depth measurements in a second are recorded with the associated positions. The ship position is also accurately recorded in the Bathyscan system. This ship position will later during data analyses be transferred to the actual "fish" position correlated with the appropriate seabed measurements of the towed body. The depth, corrected for roll, pitch and wave motions will be presented graphically on a colour VDU as a seabed presentation. Apart from the seabed shape presented as a change in colour, with a resolution of 1 meter, the motion sensors can be continuously monitored on the screen. Built-in test equipment will transmit automatically system faults.

The collected data will be worked out in the processing system in a square network of depth information, the squares being five by five meter. The depth, with a resolution of 0.1 meter for each square, will be determined by averaging the about 30 validated depth measurements of that square. From this basic and accurate depth information various endproducts can be automatically produced such as: depth charts on a scale l:l000O, magnetic tape with all recorded depths or a selection there off and a 3D plot as quality control.

It is obvious that the amount of data recorded with this new system is immense compared to the old depth measuring system. For example 2000 signals are transmitted per "ping" of the sonar. These signals with the associated distance values and other sensor data are filtered by the pre-processor in order to eliminate undesirable peaks.

Then depth data will be generated with a horizontal interval of about 0.5 meter. . The resulting data of about 7 Mbyte per hour will be stored on magnetic tape. Data storage takes place on a commercial 8mm videotape with a maximum storage capacity of 2.3 Gbyte. Datareduction does take place, but nevertheless one week of measurements at sea results in about 20 Mbyte of data. But then, with great accuracy, a measurement path of 100 meters at both sides of the "fish" at a time is achieved. Not only data accuracy but also data acquisition time is greatly improved by this new system. It is selfexplanatory that not only a supertanker but also a Navy minehunter, that has the task to search for possible ground mines, is greatly helped by accurate depth charts, on which all obstructions are precisely recorded.

Electronic chart systems

Integrated navigation and one man bridge management are the main topics in modern navigation these days. The development around ECDIS (Electronic Chart Display and Information Systems) plays an important role in these concepts. Fully developed these systems integrate all navigational chart information with position and on demand other relevant information for safe navigation. The Netherlands Hydrographic Service (of our Navy) has been involved in the development of the electronic chart from the very beginning. Worldwide standardization of the systems is of vital importance. The first set of hydrographic specifications was drafted some 4 years ago under the chairmanship of the Netherlands Hydrographer. Nowadays the International Hydrographic Organization (IHO) axid the International Maritime Organization (the IMO) work close together in finalizing a set of standards before the end of 1993. Close co-operation with the industry is essential to test the preliminary specifications. In the beginning of 1991 H.NL.M.S. Buyskes, one of our North Sea surveying vessels was equipped with a testbed system. The system was built by the Netherlands industry (Rietschoten & Houwens - Radio Holland) and the necessary chart data was supplied by the Hydrographic Service.

Furthermore the TNO's Institute for Perception played an important role in these test. In other countries, Norway, Germany and soon in the US, similar tests are organized. With the introduction of GPS for positioning, update possibilities of the system through IMO's-INMABSAT, electronic chart systems have a great potential in improving the safety of navigation.

Every effort is made through the international organizations to speed up the process of coming to the final specs for ECDIS. Not surprising again it is also for our Navy of direct interest to acquire, by modern electronic means, precise topographical information. In combination with the precise seabed mapping, this will also enable us to locate unlawfully dumped material that can threaten our environment.

Training for safety

Damage by fire, flooding or otherwise is a threat to all ships at sea, and to naval ships in action in particular. But also in peacetime a small frigate with 200 man on board, various missiles and ammunition and propelled by aeroderived gasturbines at high speed and in close proximity of other ships, poses a challenge to safety.

Possible damage has to be controlled in order not to develop quickly into a disaster. This can be done by a well trained crew with modern means, if properly organised.

In general the quick reaction fire brigade on board consists of the engineering department personel. The size of this force can of course vary from submarine to frigate or minesweeper. But one thing they all have in common and that is that professional fire fighting and damage control training has been a basic feature of their naval education. The rest of the crew with lesser training in fire fighting and damage control, but all with basic skills in this, will assist if the calamity is bigger thang can be handled by the engineers. Also the cook or the steward, the supply officer and the boatswain know what to do. To train the whole crew as one team is one of the responsibilities of the captain.

But the man in actual charge is the Chief Engineer with his deputy. This is done in all warships from the machinery controlroom, from where all machinery, including the ventilation, can be operated. Not only remote control, but also comprehensive information and communication is available there. Damage control stations fore and aft in the ship are manned to take local control and action. Fire fighting equipment in use with us is not different from the merchant navy. Perhaps thermal imaging equipment to localise the source of fire in dense smoke, extensive use of air breathing equipment, also for all crew members as a personal safety and escape device, are less common on civilian ships.

But what is different is the sophisticated communication and data information exchange equipment on board of a warship. Good and quick information exchange and a subsequent ultra quick reaction lies.at the heart of succesful damage control. At the moment we are experimenting on our newest M-class frigates the use of data exchange on VDU's with keyboard and trackerball. Helmets with built in communication equipment are on trial as well.

The Falklands War was in fact the first time after World War 2 that any battle experience was obtained. The impact of missiles is a threat of this day and age. And it creates a great fire hazard in practice. And that creates on modern ships a tremendous smoke. The use of a closed circuit air conditioning and modern insulation materials and plastic furniture does not help!. In that respect the dangers to all modem ships at sea are similar. In view of this experience the navy has separated the airconditioning in independent compartiments. Four to six air (and smoke) tight compartments on a frigate. Also the amount of air breathing equipment has been increased. More in general, if fire prevention, fire containment and fire fighting are the three elements of fire control, a systematic approach has been chosen to make balanced improvements in all these three areas. Not only smoke containment, but also smoke prevention by careful trials and selection of cable and pipe insulation materials and bulkhead construction. Not only breathing equipment, but also quick reaction fire detection and extinguishing systems were tried and selected. Combined with a comprehensive sensor data display and checking system. Of course modern equipment to counter flooding or to remove water are part of the total damage control as well.

To practice and understand the proper use of equipment, thorough training of our crews is essential. For that purpose a specialised school in Den Helder is owned and run by my Navy.

As explained <u>all</u> crew members receive there the basic fire fighting and personal safety training for about one week. Advanced fire fighting training for the specialists in full sized representative ship compartiments can be trained in real life conditions. Also repairing flooding damage can be excercised in a moving simulator built by the Rotterdam Drydock Company. Only a well trained team will be able to avoid becoming very wet indeed. Realistic environment simulation provides the real life stressors.

Team training in command and control of damage containment and repair is done on a different simulator.
This trainer is a mock up of a frigate control centre where realistic scenario's can be computer simulated.

Nothing can simulate reality as well as a real ship. Part of the work-up of the crew is an extensive damage control training and excercise under the guidance of the training school. At a British work-up centre in Portland this is finished off in teams with other ships, submarines and aircraft. It seems a big effort. But as an insurance against uncontrolled fire and other shipboard damage it is never enough. A trained crew, a fire, smoke and damage resistant ship and modern fire fighting equipment are the key to safety at sea. Improvements in information display and communication are the most promising route to further enhancing safety in ships. Expert systems supporting the operators in the most efficient damage control are a promise for the future. But not a very distant future.

Safety in combatcircumstances

A basic diffence between a merchant ship and a naval vessel is that it might be exposed to the actions of enemy weapons.

It has to fulfil its mission under those circumstances and must be able to keep floating and if possible fighting when hit.

This is an extra design parameter which plays a decisive role in the total design process from forward design to detailed design. If a explosion takes place several destructive effects on the ship will result. When the explosion is in the air, outside or inside the ship, a blast wave will hit the structure. "When the explosion is in the water the ship will be hit by a pressure wave which will propagate through the structure and cause fierce movements and extra loadings on equipment on board.
Another weapon effect is the impact of thousands of fragments. They can penetrate the structure with very high velocities.
During design all these effects have to be taken into account and since there is always a limitation of money, weight and volume, the solutions have to be balanced by a proper trade-off.

During the design-process computer models are made of the ship.
Resistance properties against fragments and blast waves are included in this model. Additionally a functional model is made in which all equipment and their functional relations are included.
In this way an assessment can be made what the effect on the combat capability will be when a certain equipment is damaged-
Then the model is exposed to a threat environment like, for example, a fragment distribution.

As **a** result an assessment can be made of the combat capability remaining after such a hit. Possible improvements can be evaluated with this modelling technique.
Of course a ship can not be designed in such a way that it will survive all possible weapon effects. Therefore studies are made of the residual strength after a hit in order to be able to bring the ship and its crew back to the harbour. Models of the ship with assumed configurations will indicate where the weak points are.

These design tools are of great importance and a lot of effort is undertaken to validate and improve them.

Research programs are underway to study damage mechanism related to these type of loadings to be sure that the algoritms in the codes are correct. This research includes tests in blast tunnels where a blast wave is simulated, shock machines where violent movements associated with an underwater explosion can be studied and detailed analysis by finite element calculations.

That this is not simple might become clear when you realise that the explosion is a phenomenon in the microsecond range, the shock wave in the milliseconds and the response of the ship in the second range. This is a time span of ten to the power six.

Whenever there is a possibility life tests are done in order to validate the models and see if they predict the damage correctly. Obviously we do not use our latest frigates for destructive tests. For that purpose a second world war frigate was sacrificed.

This is all done in order to try to improve the safety of ship and crew in wartime conditions which is one of the design requirements for a naval ship. Prevention of course is better.

Ultimate Stability Criteria

In cooperation with the navies of the Unites States, Canada, Australia and the United Kingdom the Royal Netherlands Navy sponsors a study into the improvement of stability criteria for frigates.

The aim of this project is to develop rational criteria for ship capsizing. These intact stability criteria wil be applicable for the design of frigates operating in moderate to heavy seas. The methodology involved may be applicable also to other hull forms.

Whereas criteria in use today are typically based on transverse stability characteristics in calm water and beam excitation due to for example wind or turning, new criteria should reflect the influence of the environment in a more rational manner. Especially wave induced effects are to be included in a consistent way.

Theoretical research has progressed to the stage that numerical tools can be
used with some confidence to obtain an indication of a ship's behaviour
in rough seas. Mathematical models, such as the time domain program FREDYN, will
be used extensively to study the capsize behaviour of frigates in waves.

The MARIN study is structured such that
(a) The overall dynamic behaviour of a frigate is expressed in a complex
    mathematic model.
(b) Using this model a large number of simulation runs is performed with
    systematic variation of design, operatioual and environmental parameters.
(c) The effect of changes of each parameter on dynamic stability is assessed and
    the mechanisms responsible for capsizing are identified; the so called
    capsize modes.
Examples of capsize modes are:
* Broaching
* Loss of stability in following seas
* Wave excitation in beam seas
A complicating factor is that capsize modes do not always occur separately. Loss
of stability in folowing seas can be followed by a broach.

Two parent hull forms were selected: A modern frigate hull form with wide aft
sections and flare, and a traditional hull form, both designs with around 4000
tonnes displacement.
The next phase of the study will result in simplified relations between design,
operational and environmental parameters' in the one hand and the likelihood of
capsize on the other hand.

These relations could then be used to obtain simple criteria for capsize.
This study will also provide guidance for the ship designer. He will be able to
assess the effect of changes in the design parameters on capsizing probality.
The present criteria for naval ships will be thoroughly analysed in advance of
proposing new criteria however.

Safety margins in submarine design

In the structural design of a submarine or any other deep diving vessel the establishment of the safety margin against buckling collapse of the pressure hull is the main design effort.
The collapse load which can be carried by 'cilinders under external pressure is heavily influenced by the shape perfection of the cilinder. Small imperfections, eg. deviations from the perfect circular shape, leads to a drastic reduction in collapse load.

In former submarine design procedures the pressure hull was dimensioned without taking into account the influence of the secondary structure on both the stresses and buckling behaviour. SeFundary.structures in this context are all structural parts which are not rotational symmetric, for example internal decks, penetrations and above all the outerhull as applied on the RNLN diesel electric submarines.
A common simplified design assumption in the past was to assume that all these kinds of secondary structure would not have a negative influence on the buckling load carrying capability of the cylinder. Or a positive one for that matter.
In the design of the deep diving new RNLN Walrus class submarine the use of high-strength steel enforced some new techniques, because it was found that this simplified procedure would not guarantee the required safety margins against buckling.

The secondary structure stiffens the pressure hull structure resulting in an increase in buckling strength. This beneficial effect is however only fully effective if the secondary structure does not collapse prematurely relative to the pressure hull.
However on the other hand, it also has a decreasing influence on the buckling strength since the secundary structure surrounding the pressure hull is not rotation-symmetric.
Because of this it impresses non circular deformations on the pressure hull.
These non circular deformations combined with production out of roundness of the cylinder, decreases in turn the buckling strength of the pressure hull.

As part of the design of the Walrus class submarine, the RNLN started a
elaborate program to establish the safety margins against buckling when the
influence of the secundary structure is taken fully into account.
This program consisted of three parts.
Non linear buckling calculations were performed in finite element (FEM) modules.
Large FEM models were used, consisting of the pressure hull between two
bulkheads and **all** the secundary structure. The non-linear relation between
stresses and external pressure for the specific construction was established.
Complementary to these **FEM** calculations extensive full scale straingauge
measurements were performed on a segment of the submarine. These results were
used to validate the stress distribution as calculated with the FEM models.
Also buckling experiments on scale models of cilinders incorporations all kind
of secundary structures and out of circularities **were** performed.
These experiments were necessary because the accuracy of the computational
schemes in calculating the buckling collapse load can only be verified with
scale experiments, never with the real submarine!

Fig 14: Buckling Model Tests

The program resulted in much improved quantification of the safety margin
against buckling collapse for submarines with complex constructional geometry
like double skins. Based on this'work and other ongoing research the ENLN is in
the process of establishing an enhanced design procedure for submarine pressure
hulls. Of course all these theoretical calculations had the happy final result
that our Walrus class submarines have a depth capability unsurpassed in any
conventional submarine in the world as proven safely in practice. And that is an
essential feature of such a boat. The theoretical knowledge has however a wider
application.

Summary and conclusions

Marine safety is translated in a very special way in the navy. Our environment,
the sea, is however the same as that of our civilian brothers. Our advanced
technology is universal and of the high standard expected of the Netherlands. It
is that knowledge that makes us a respected and attractive international
partner.

But also nationally it should not be restricted to ourselves. It is therefore with pleasure that we participate in this symposium of the Delft Technical University, the breeding ground of most of our know-how. On our support you can count if your quality of the past 150 years is maintained.

Mr. Kurt Anderoen, President

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ABSTRACT

In the past the European shipyards were second to none. However during
the seventies and eighties they were overhauled bY more productive
Yards in the Far East - and most of the European Yards have not
been able to compete since then.

In the discussion regarding the European reactions to this fact,
parallels are drawn to the steel industry. It is argued that the
past position can be regained if the Europeans would compete on
price and quality instead of creating a "Fortress Europe" or trying
to survive on subsidies. Put all effort and all resources into:
financial engineering, logistics, Computer integrated manufacturing,
innovative product design, precision engineering, production
engineering interaction, quality and safety, dealing with people,
and management and leadership.

Europe's market share will be decided by her competitiveness on
a global market with free world trade - hopefully.

SHIP BUILDING IN EUROPE QUALITY AND COMPETETIVENESS.
GLOBALIZATION.-REGIONALIZAATION

"East is East, and West is West, and never the twain shall meet'
(Kipling: The Ballad of East and West).

My first argument in this paper is rather simple: When demand
. exceeds supply, the producer can relax or even continue to sleep
like the princess in The Sleeping Beauty.
If on the other hand, supply exceeds demand the producer can
wisely choose to meet the realities of the market and compete on
price and quality - or he might choose to build a fence. Behind
this fence he might try to sleep on, if the taxpayers are willing
to contribute. The day they say no, there will be no doubt, the
producer will be going to rack and ruin.

I dare not say that the young prince.has come to Eastern Europe,
but the Iron Curtain is for sure not a reality any more - Eastern
Europe is facing the market mechanisms. The same situation
occured to the West European shipbuilding industry several years ago,
when we met the Far East. But my question is: Did we react rationally,
when Kipling't East and West met?

My answer is: no - for a long time economists in the West did
not take notice Of rapid growth in the economy in Japan, South
Korea,Taiwan,HonglEongandSinga~re. We overslept when the
conditions for a global market became a reality - and I am tempted
to to say that to0 strong a respect for traditions so that what
really happened was that the Bast 'capitalized" on the Western
technical innovations.

My second argument is: We cannot meet globalization with regionali-
zation - only in the short term is it possible to survive on sub-
sidies. The lessons from the steel industry and agriculture should
be learned: trade flows are, by and large, dictated by economics
rather than by government interference or unfair business practices.

The global market works - the challenge is to work <u>with</u> it rather
than <u>against</u> it - this is what all involved in shipbuilding should
realize, management, government and the EC-Commission.

If the European shipyards shall have a future, the tools are:

- Financial Engineering
- Logistics
-ComputerIntegrated   manfacturing
- InnovativeProduct Design
- Precision engineering
-Production engineering Interaction
- Quality and Safety -
- Dealing with People
-Management and Leadership

West

The need for rebuilding the merchant marine was immense after
the SecOnd World War. British and Norwegian shipping companies
dominated the European scene, but in all countries with a
maritime tradition the construction of ships was accellerated
to the extend permitted by the economy.

The ships grew bigger and bigger, and the tankers made their entry
in a larger scale. The technical standard was set by Shell, especially
in cooperation with yards in Northern Europe. The Greek shipowners
invested strongly, and with her 46.000 tdw. 'Tipa Onasis" changed
our conception of how large ships could become. The expanding industry
in Europe had immense needs for energy.

Not only oil was to be moved, soon transport of gas became a must.
Also in this area Europe had the lead at first. Moss-Rosenberg,
Technigaz, and other European firms created competing designs which
to this very day dominate the market. But one thing is to design,
another is to produce - to build.

In the first 20 pears after World War II both economists and
politicians had realised that expansion of Europe's economy to
a large scale was dependent upon the shipyards - and for the
managers of the shipyards this was not a secret and their
influence on politics could certainly be seen. The shipyards
had an important strategic role and they definitely contributed
to full employment.

In the beginning of the seventies more than 400,000 persons were
employed at the shipyards in Western Europe and, twice as many in
the supply industry. This did not diminish the political impact.

East

Much was different in the Far East, still the similarities are
obvious. Like Europe, Japan had to rebuild its fleet after the
war and comparatively speaking this was much more important
to Japan because the country was and is totally dependent on
sufficient and competitive seaborne transport.

Japan "inherited" the technology developed especially by USA
for mass production of the Liberty ships.

That Japan attached enormous importance to the industrialisation
of shipbuilding can clearly be seen in the fact that they invited
two Americans to play a leading role in development of this in-
dustry: the planning specialist Elmer Hann and the expert in
efficiency and quality control Edwards Dercing.

Dr. Bisashi Shinto became their "student", and he was the one
who formulated the theoretical basis for modern shipbuilding in
Japan - and elsewhere. He applied Boeing's design technology to
shipbuilding and began with quality circles already in the fifties.

In 1964 the Japanese share of the market surpassed 40% - and
Japan built more than the nearest five countries combined.

The oddity is, that no economist had foreseen this success -
and when it was a reality it took us all very long time to realize
the fact.

The European reaction to "The Ballad of East and West"

In the fifties USA had the leading role in international ship-
building - but the trend was obvious - and can be seen in
Raisers goodbye.

It took Europe many Fears to realise that Japanese shipbuilding
had been industrialised - and thereby was competitive.
This might be due to some international incidents, incidents
that prevented us from seeing through the smokescreen.

The Suez crisis in 1956 meant that the demand for oil transport
exploded. The existing yards could not comply with the demands.
For this reason a lot of money was invested in new yards in
the sixties.

The shock Can8 with the oil crisis from 1973 to 75: There were
too many--tankers on the market.Much less had to be transported,
the growth in economy and in consumption of energy diminished
raPidly -and Japan was still ahead.Thiruas finally realized
in Europe did were to this situation -well,we can
all remember: it was un-European to drive in a car from Japan.
If you did, you could risk bumps and scratcher when the car
was parked.

Many shipyards declared themselves bankrupt - and it took only
a few years before almost every big yard in Europe was State-
owned. Competition was not in focus, no, attention was given
to employment.

In Sweden - which in many ways was number one among the European
shipbuilding nations - all the yards were closed, the working
force could be used elsewhere. Norway and Holland too experien-
ced the consequences from the crisis - and several new yards
in France, Spain and Portugal had no orders.

On top of this South Korea became active in the market. They
had constructed the biggest yard seen so far - and this was
the beginning of an enervating price war between Japan and
South Korea.

Every shipyard lost money, but Europe Suffered most Strongly
from the crises - Europe's share of the market was halved.

Not only had the European yards new owners a- the State -
but on top of this new managers - often politicians. The
aquaintance with the market was decreased, and totally
unrealistic decisions could be experienced, dispositions that
often contrasted to the rationalizations the Japanese under-
took.

To this must be added that Europe was paralyzed by the events
in 1968. Profit was a word with very strong negative conn-
tations - and there was a tendency to replace industrial
politics by social politics.

The European answer to the rationalization in the Far East was
to cry: unfair competition" - and the medicine for Europe was
"subsidies'.

The situation today

The market price has gone up - and money can be made on ship-
building, but the real money is made in the Far East. Several of
the European yards are still suffering losses.
The subsidy policy is threatening the progress.

The differences between the shipbuilding industry in the Far
East and in Europe have certainly not been diminished since the
crisis began - the only thing constant is our refusal to face the
realities in a constructive way.

When we compare productivity in Eastern and Western Europe there
is no doubt, we are far ahead in the West. But somehow we are
reluctant to acknowledge that the gap between Western Europe and
the Far East is of the same dimension when shipbuilding is
concerned.

Still, the differences are obvious at all levels:

The welding machinery in Japan is much better, the steel to be
welded is of much higher quality and much more welding is produced.
But that is only one example. The leaders are more experienced
and much more and much better trained. At the top they are few,
they can cooperate and most of them are highly experienced ship-
builders.

In Europe most welding in shipyards is still based on hand carried,
covered electrodes. In Europe we have problems with the steel, it
has to be preheated, when high quality weldings must be achieved.

The management structure at the European yards is generally such
that the peed for overhead is much bigger than in Japan. Often
the goal is to provide employment for more and more people -
without regard to efficiency. This ultimately requires increased
subsidies.

If you visit some of the European yards you will see 20 years of
negligence in investment and maintenance. Many yards are cramped
and the main impression is often that of disorder and mess.
Their contribution to an improvement of the image of the industry
is rather small. Quite the opposite, the combination of decay
and a grandiose and excessive administration creates a bad image.

Furthermore, I believe that the industry does not manage to respond
with concerted and constructive proposals, when the EC advertises for
initiatives. Instead of concentrating effort and money in development
of productivity the demand is for further subsidies.
A few percent of the amounts spent on direct production subsidies
would make a dramatic impact if it was used for Research and
Development.

The future

It is normally difficult to predict the future but that is not
the case for European shipbuilding if we continue our policy:
The European shipyards will survive as long the governments
(read:taxpayers)are willing to pay the bill,which by the
way is getting bigger every day.

On the other hand, the cure is very simple: Put an end to the
subsidizing policy.This will lead to purge similar to the
one mentioned in the ancient mythology where king Angias'
stable was full of dung from 3,000 oxen. Eeracles d out
the stable by leading the water from two rivers through,

We are at the crossroads. We can continue along the road paved
with subsidies, we can remain in "Fortress Europe" - or we can
confront ourselves with the realities of globalization. Two

rivers are not needed - only <u>financial engineering, logistics,</u>
<u>computer integrated manufacturing, innovative product design,</u>
<u>precision engineering, production engineering interaction,</u>
<u>quality and safety, dealing with people. management and leader-</u>
<u>ship.</u>
If Europe leads the way I am convinced that Japan and Korea
can also be persuaded to refrain from unfair trading.

Financial engineering

Shipping is almost by definition international, and currency
fluctuations are therefore of immense importance. USD and YEN
are dominating and their exchange rates often vary substantially.

No yard can expect to stay in business unless these problems are
dealt with, and included in the proposal to the shipowner with equal
care as traditional engineering is included.

The development in the exchange rates for some of the important
currencies is shown in fig. 1:

Figure 1:   DEVELOPMENT IN IMPORTANT CURRENCIES
1st Aug. 89 to 1st Mar. 92
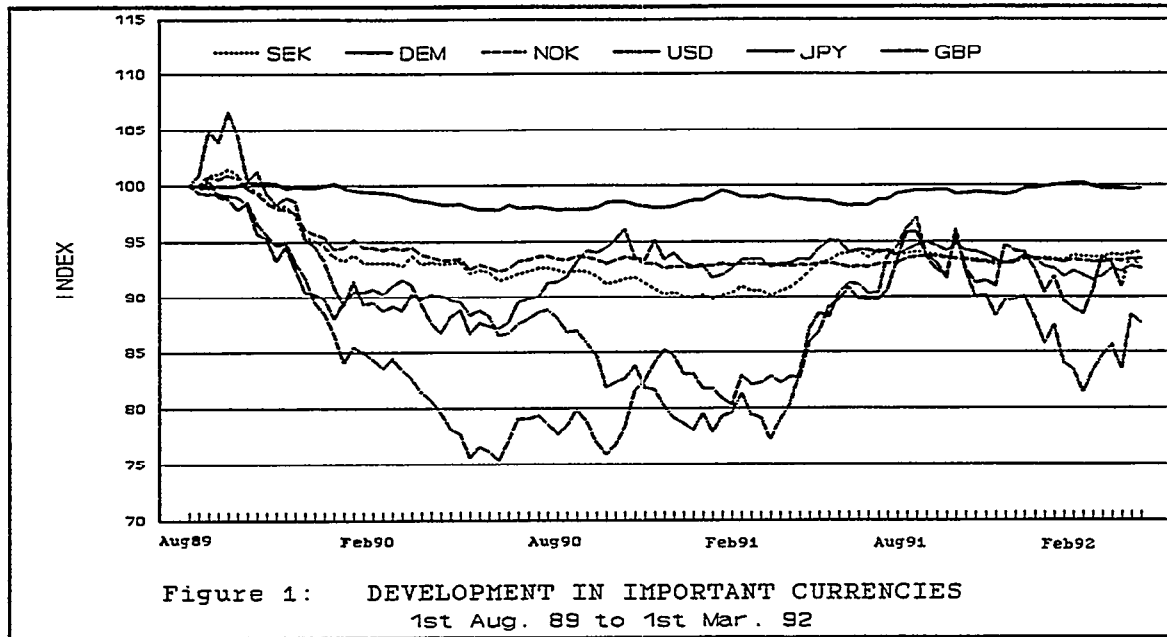
For a shipbuilding contract which normally runs for a long period,
the forward rates are highly important. In fig. 2 the development
in forward rates is shown under the condition that the exchange
rates on the spot market are constant. A fluctuation of more than 5%
of the contract price for a vessel can be realized in six months,
even with constant spot rates.
The development in VLCC prices since 1975 is shown in fig. 3, 4
and 5.

An owner will today expect that the shipyard presents proper financial solutions tailormade to fulfil his needs. Financial engineering is a discipline with steeply growing importance.

USD/DKK

Figure 2:   2 YEARS FORWARD RATES ON USD
Fixed USD/DKK base at 6,50

Figure 3: DEVELOPMENT IN VLCC PRICES IN VARIOUS CURRENCIES
250,000 dwt

Figure 4:   DEVELOPMENT IN VLCC and VW GOLF CURRENT PRICES IN DEM
basic VW model and a 250,000 dwt VLCC

Figure 5:   DEVELOPMENT IN VLCC CURRENT PRICES IN USD, DEM AND YEN
250,000 dwt
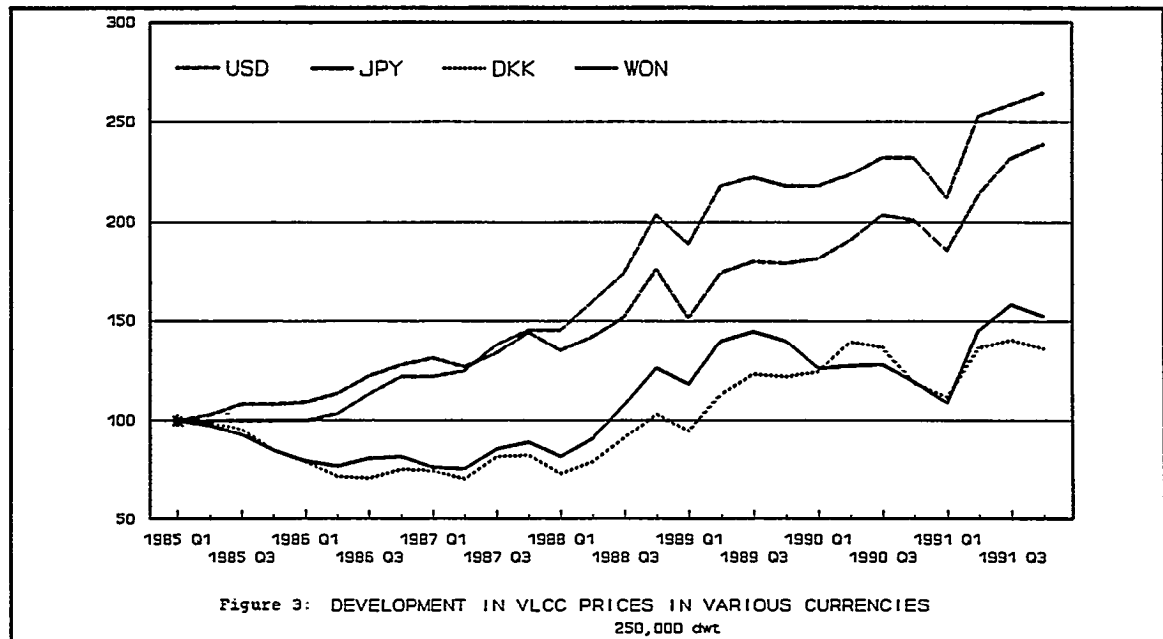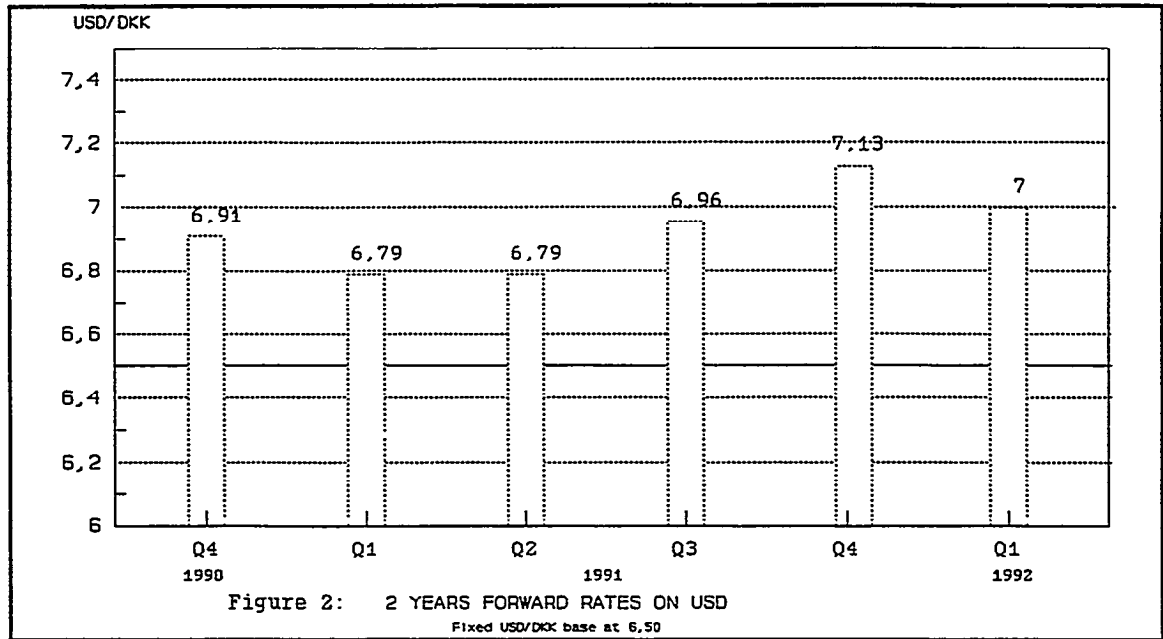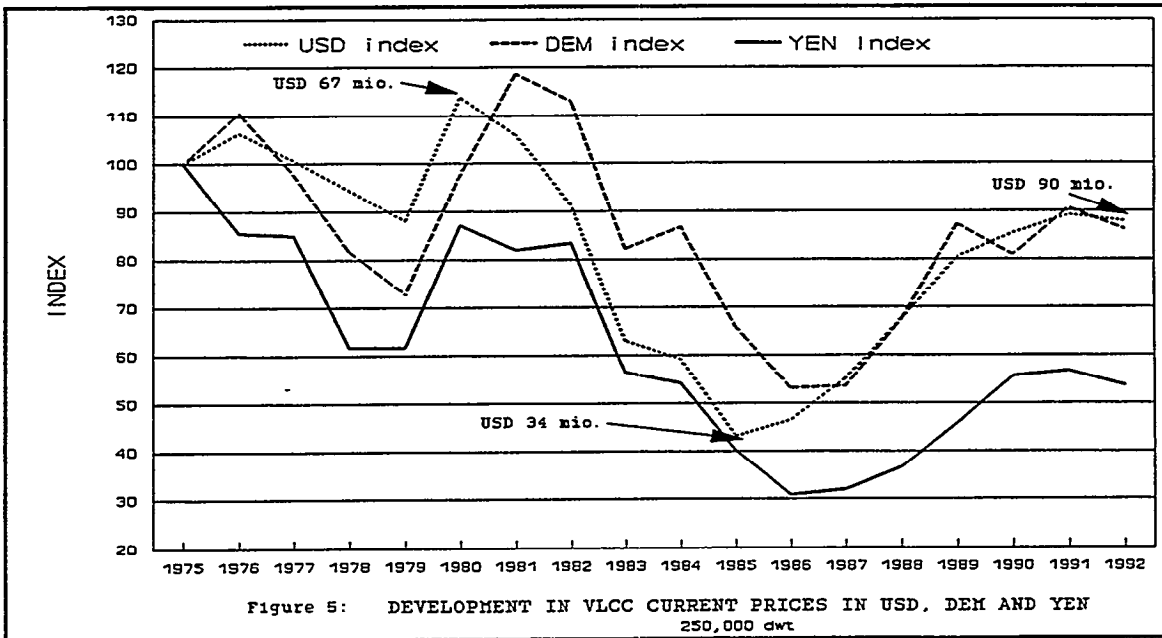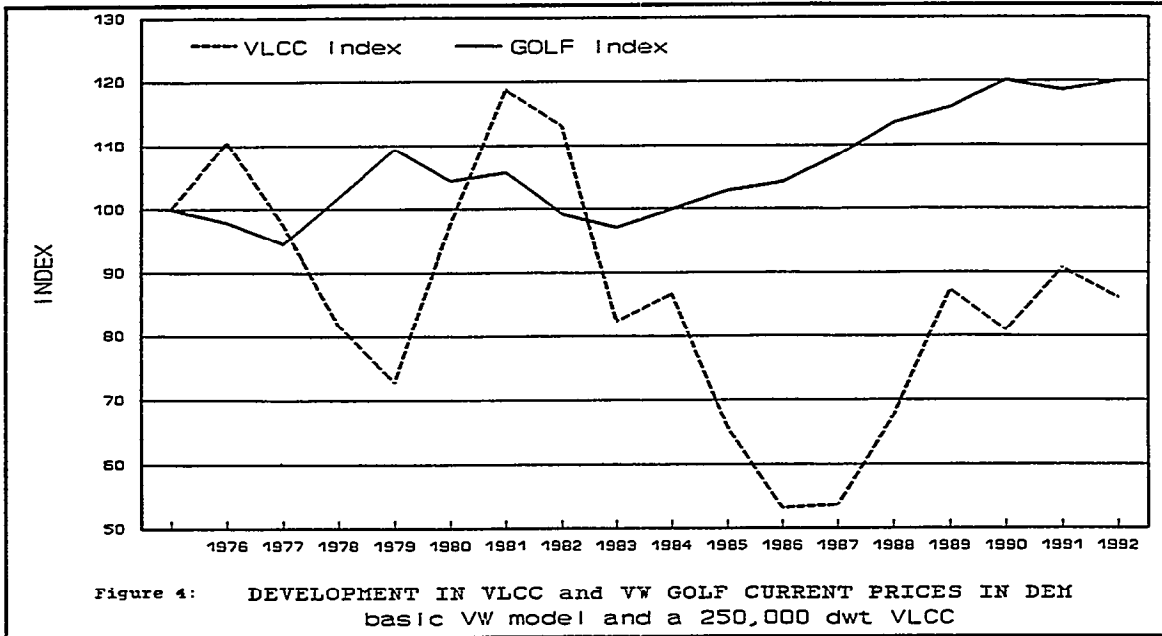
Clearly the rate of exchange for YEN and USD against DEM is extremely important for the European Shipbuilding Industries. Shipbuilding has no market where the DEM is of real importance.

The unnatural high rate of interest for DEM, which is the result of the German unification, has reduced the value of USD and YEN dramatically and thereby affected the competitiveness of the European shipyards similarly.

At the same time the German Government infused 3,6 billion DEM of taxpayers'money into the German shipyards over and above the limit set by the EC-Commission.

The action of the German Government will create new shipbuilding capacity which is certainly not needed and for which there is no market. The result being that world market prices for newbuildings will be further reduced.

The European Shipbuilding Industries will suffer greatly. While the German yards on average are generously compensated by the tax-payers for the adverse exchange rate situation.

Logistics

Costs are influenced heavily by logistics as some 60 - 65% of the cost price of a ship are material. How they are specified, where they are bought, how they are transported, sorted, inspected and made ready for installation should be organized in a logistics function.

Computer systems and advanced means of communications can solve most of the traditional tedious problems, but it is still up to responsible people to ensure that material shortage is fully eliminated. It can be done, and prosperous yards of the future will be masters in this discipline.

The average material purchases 1988 - 1992 for a competitive shipyard in Europe is shown in fig. 6.

AVERAGE MATERIAL PURCHASES 1988 — 1992

OTHERS   18,1 %

- SWEDEN
- NORWAY
- AUSTRIA
- FINLAND
- KOREA
- POLAND

JAPAN   21,7 %

EC — COUNTRIES 60,2 %

FIG. 6
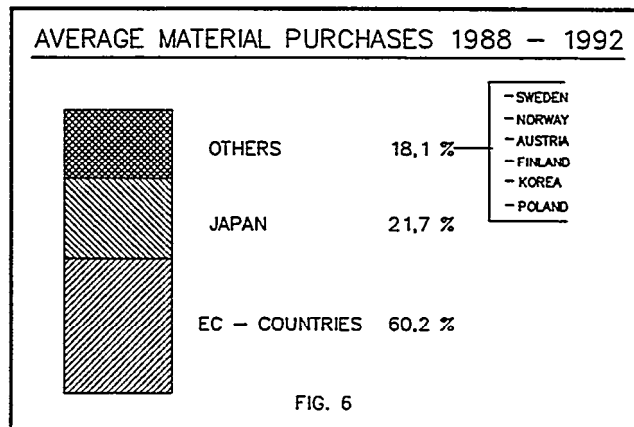
It is obvious that a requirement that European yards should buy all their equipment in Europe will lead to a disastrous loss of competitiveness.

40 procent of all equipment is bought outside the EC. However, the
competitive European suppliers are selling even more to the shipyards
in the Far East. So they would also suffer from trade restrictions.

It is in the interest of European shipbuilders and their supply
industry to resist all "Fortress Europe" proposals.

Computer Integrated manfacturing (CIM)

With all due respect to the importance of any other discipline, CIM is
definitely the most significant difference between "the good old days"
and modern shipbuilding. So much has been gained by computers already
and even more can be seen as potential. Only our capacity for imagi-
nation puts up a limit.
The positive CIM effect correlated to time is shown in fig. 7.

A full 3 dimensional topological model of the ship and all its out-
fitting has opened a whole new era for modern shipbuilding influen-
cing virtually everything from the preparation of the first schedules
through computation of fluid dynamics, structure definition, strength
and noise calculations, cost estimates, work content calculations,
bills of materials, simulation of fabrication, generation of drawings
and NC data for cutting, welding, painting, and transportation automation
to production of quality documentation and user manuals.
Japanese shipyards and some in Europe have worked intensively to
develope and implement relevant CIM-systems for 8 to 10 years.
Results are now clearly appearing and widening the gap between in-
efficient and efficient yards.

Developments within other industries and related technologies will
facilitate increasingly profitable utilization of CIM.
Super computing, ultra high speed data communication, new mathematics,
sensors, neural networks, artificial intelligence are all contributing
very efficiently and opening new possibilities for improving the
competitiveness of the advanced shipyards.

FIG. 7
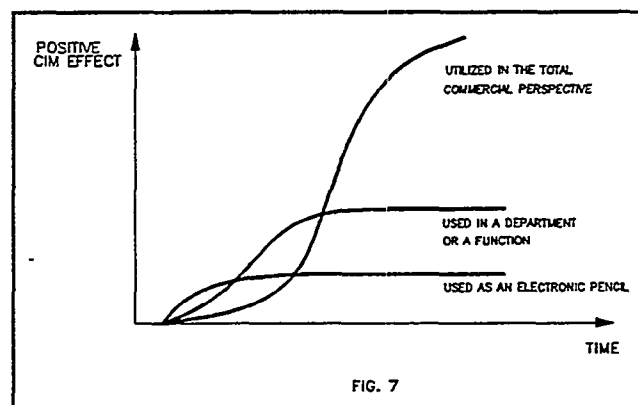
Innovative product Design

The time it takes to generate a new design is certainly critical for
any industry but because of the size and the price of ships it is even
more important for shipbuilding. At the same time a modern ship is
the most complex unit anyone can dream of. It contains all the
functions and facilities of modern civilization, and on top of that
it has the ability to operate under each and every condition imaginable
on our planet. And it works 24 hours a day and more than 360 days a
year- usually for 15 - 20 years so no wonder that life cycle
considerations have a very special meaning to shipbuilding.

Given these facts, innovation in product design becomes essential.
It has to take into account the possibilities in virtually all new tech-
nological development, and relate these to the needs of the customer and
the specific needs of the yard's production facilities - and time
is still critical. Optimization requires skills, tools, experience, and
creativity. We find here the challenge which has got to be considered
as the very core of the company culture. Facilitating team spirit and
joining all forces is the name of the game.

The following simple index summarizes innovative product design:

$$\text{Design index} = \frac{\text{Value of product for the owner}}{\text{Total cost for the yard to produce}}$$

FIG. 8
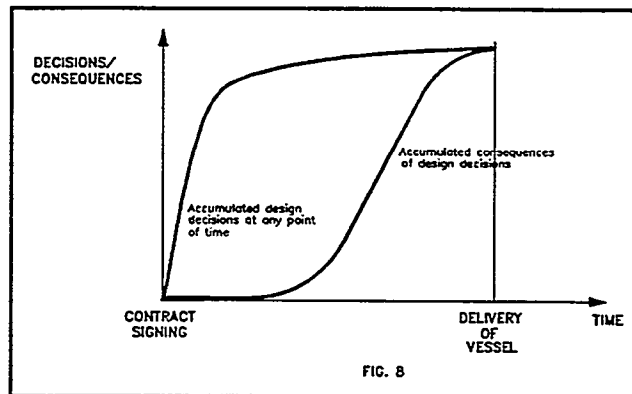
Precision Engineering

Carefully detailed design and optimized tolerances are the most
important measures to achieve efficient production utilizing a
high degree of automation leading to a highly reliable final product in
which fatigue problems have been minimized.

The ship should be designed and constructed on a "Precision Engineering" basis: it should be designed to accepted tolerances, without regard to potential variations in materials, and built to meet those tolerances.

To demonstrate the idea an example has been given in fig. 9:
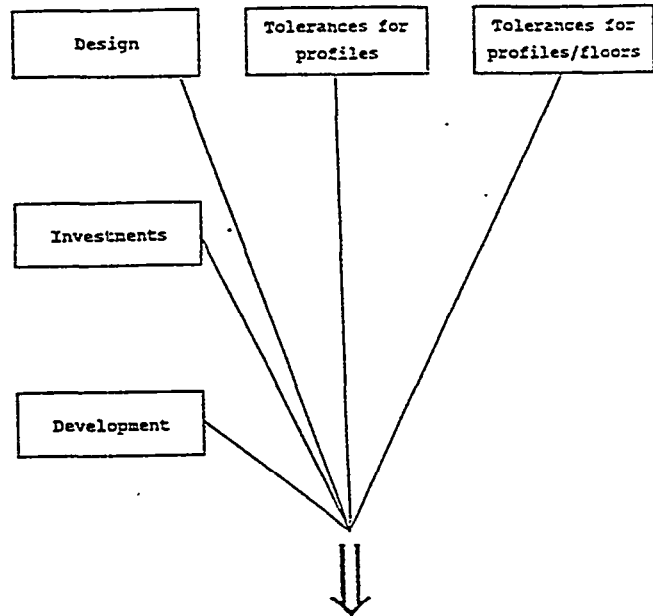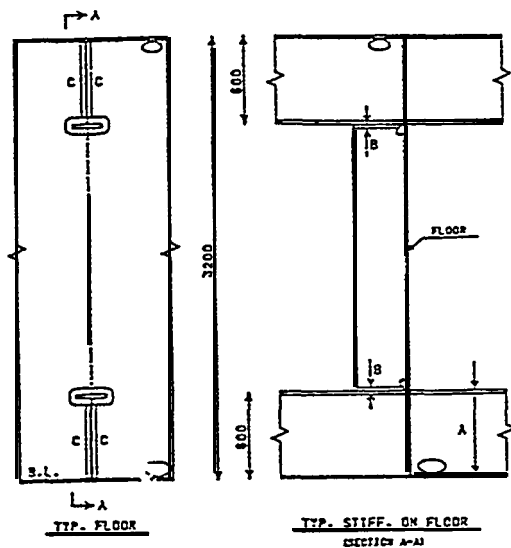
TOLERANCES
IN MM

A. BXGii T-BAR :   ± 0.9
B. GAP STIFF./T-BAR: 0
                         - 1.5
C. GAP FLOOR/T-BAR :   - 1.0
                        - 2.0

• Better ships (2-10 times less stress concentration)
• Efficient shipbuilding by application of robotics (30-50% increased productivity)

The size of a ship is not that easy to measure simply because of the dimensions. There is no fancy weight available - ships are the biggest things man can move.

Still the individual components have to be fitted together with an accuracy allowing the newest and most sophisticated welding methods to be used, and although the propeller diameter might be close to 10 m the shaft and bearing have still to be measured in 1/100 of a millimetre.

Application of NC equipment for cutting, marking, positioning and welding has opened for a new higher level of accuracy and this again is allowing new assembly methods to be applied. This means dramatic cost reductions but it means also a better structure with much less built-in tension and much better strength and fatigue abilities. Application of lasers will further expedite this development.

This will lead to competitive advantages in several important areas: Costs, vibrations, strength, maintenance.

Production Engineering Interaction

Very often the term "Production Friendly Design" is used to describe a potential which should be so obvious that it is self-evident: Decisions made at the design stage is a determining factor, also for production. The tool to achieve this is interaction between Design and Production handled by the Production Engineering Function. This will determine how much can be automated, whether access is easy or complicated, whether there is room for supplies or space is too narrow to allow efficient operation. The process requires skills at the highest level and very good tools, but most of all: The right attitude by people involved.

I am sure that the attempt to develop a design common for several yards in *Europe* having individually very different production facilities, is doomed to be a failure although politically it seems to be preferred. A common design will result in compromises, which will subsequently create awkward problems in the production for most yards. One single unfortunate design feature can increase the consumption of man hours with 15 - 20% for a given yard.

Quality and Safety

Much has happened in the QA field over the last years - even in our part of the world. It is probably the area where there is broadest acceptance of the Japanese achievements. Quality can never be inspected into a product, and quality control departments have definitely done a lot of harm in this respect. There is one way only, and that is to make one and all understand his specific responsibility. Through such understanding very valuable improvements are gained and gradually the close relations between quality and safety become the driving mechanism in mobilizing the organization such as: Zero defects and Zero accidents are no longer an unrealistic dream.

In Japan and in some places in Europe "green materials" for blocks to be erected in the dock or on the slipway is unknown today. The precise fitting together is a matter of course.

Dealing with People

In an organization no resource is so important and vital as the human resource. A shipyard is certainly not different, but once again we have extreme possibilities of either being the very best or the worst.

To build ships can be dirty, hard work, even dangerous, if proper concern is forgotten, but it can also be the opposite and we have an advantage as only few industries: The final product.

It should be obvious, that our people deserves neat and clean
conditions and the best equipment. Likewise, we have to give
them training, not only to improve their skills, but to motivate
them. We have to make sure that a bonus is always the response
to a well done job and the incentive to further productivity
increases.

The organization must have entrepreneurs and teamworkers, and
"dead wood" as a result of social politics should be totally
avoided.

Management and   L eadership

There is a very big difference between a manager and a leader.

A shipyard can be operated by managers, no doubt, but if
improvements are asked for, leaders must be an integrated part of
the organization. Balancing team workers and entrepreneurs is
critical. It is the most difficult of all disciplines. Top management
will be judged by their ability in this fine art - the shipyards'
vitality or even survival will depend on it.

The Past, the Present and the Future - once more

The above described tools are certainly necessary in our fight
for survival - but every improvement can be destroyed by a misleading
industrial policy. Let me illustrate this by "the welding window".

The welding window is a picture used to summarize the demands of
all welding parameters if a welding shall be of the right quality.
In fig. 10 a drawing has been made to illustrate the welding window's
relative area in Japan and in Europe.

Why is the European window that much smaller? Primarily, because
it is much more difficult to weld the European steel. At times the
European window is even negative - in that case it is necessary to
preheat the steel to 80 - 120 C to achieve a satisfactory welding.
Or expressed in a different way: the productivity in Europe is
smaller, and the demands for qualifications of the welder are much
higher.

When welding in European steel, many more faults are likely to
appear and the final quality might be substandard if severe quality
control is not enforced.
It may unfortunately turn out to be very difficult to utilize
laser welding in European steel qualities whereas it *is* quite feasible
in steel of Japanese standard quality.

To this must be added that the Japanese yards are paying the same price
for the better steel that we are for the lesser quality.

The result is that the man hour consumption for welding may well be
10 percent higher in Europe only due to differences in steel
quality.

Why are we in such a situation? Because the steel industry in
Europe "succeded" in convincing the politicians that the industry

could only survive if it was protected and supported by subsidies and import restrictions - and behind the erected walls there was no need, and no incentive to develop a quality product.

```
                            ┌----------------- parameters
                            ¦                  ¦
        ┌───────────────────¦──────────────┐   ¦
        │                   ▼              │   ¦
        │       ┌────────────────────┐     │   ¦
        │       │                    │     │   ¦
    ───►│       │                    │◄────¦───┘
        │       │                    │     │
        │       │                    │     │
        │       └────────────────────┘     │
        │              └ European steel    │
        │                                  │
        └──────────────────▲───────────────┘
                           ¦              └ Japanese steel
  parameters---------------┘
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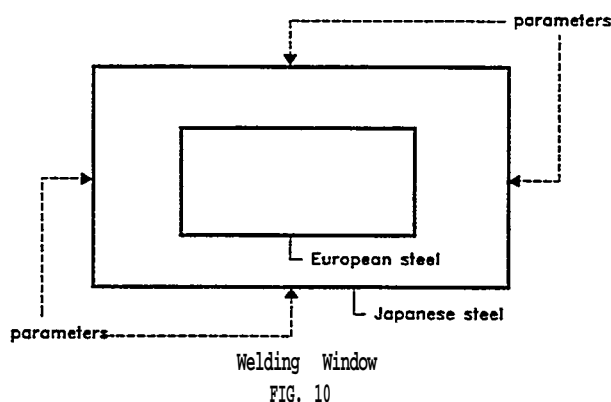
Welding Window
FIG. 10

CONCLUSION

It is my sincere hope that the European Shipbuilding Industry will regain its past position as world leaders in competitiveness, quality and product innovation.

This position may be achieved if we act as I have argued in this article. We have to realize that the Japanese yards do not owe their present position as leaders to unfair trading practices. They are efficient and competitive. That is our starting point.

It is a must for real European progress and the free world trade that all destorting subsidies be ended. Such subsidies include the following:

        Subsidies based on aid to developing countries for ships for use in international trade.

        Subsidies based on phoney currencies to fool the OECD rule for rate of-interest subsidies.

        Unrealistic investment subsidies to former East German yards owned and integrated economically with Western yards.

        Huge subsidies to re-open yards which were subsidized by EC to be closed a short time ago.

Important persons have said that Europe has the right to a certain part of the world market for shipbuilding, and if this market share cannot be achieved on commercial terms it must be provided by political means.

I totally disagree.

The market share Europe deserves and should have must be decided by her competitiveness and nothing else.

The EC-Commission has recently proposed to assist the European Maritime Industries by establishing European Maritime Forum in . which shipowners and the supply industry will also be represented.

The proposal has been welcomed by a majority of shipbuilders in Europe. A minority, to which I belong, warns:

If the intentions are to build a "Fortress Europe" with trade distorting standards, European built ships for European owners, European equipment for European shipyards, to support the in-efficient yards at the cost of the efficient ones etc. etc., it is believed that the forum will be another nail to the coffin for the dream of a COMPETITIVE European Shipbuilding Industry.

My final words: The naval architects, the marine engineers, the skilled labour, the unskilled labour in Europe equal very well those in the Japanese shipyards. When European Shipbuilders lose it is caused by politics and management weaknesses.

CONFERENCE ON MARINE SAFETY AND ENVIRONMENT

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DELFT,l-5 JUNE 1992

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SAFETY AND ENVIRONMENTAL PROTECTION

IN THE PORT AND INDUSTRIAL ZONE OF THE PORT OF LEHAVRE

-=-=-=-=-=-

Gerard VELTER

operations Director
of the port of LE HAVRE Authority

-=-=-=-=-

This expose` provides a general overview of the Port of Le Havre and its Port Industrial Zone.

The port's geographical situation and economic role are described.

Safety and enviromental protection in the Port Industrial Zone is analyzed through the examination of the following :

- facilities and accommodations offered in the port for ship reception, especially for the transit of dangerous goods,

- conditions for the organisation of safety and pollution control through a look at the general applicable regulations and emergency pollution control and accident plans.

- the port establishment's policy concerning port and industrial development and environmental protection.

Subjects dealt with range from industrial risk prevention tbrough the application of the SEVESO guidelines to the problems of protecting sensitive natural environments.

The conclusion defines the stakes present which are the results of the rapid development of port and industrial technologies and the growing sensitivity on the part of populations and public authorities concerning safety and environmental problems.

I - General Overview

The word "havre" means shelter in french.

As indicated by its name, Le Havre was a port before it became a port city.

King Francis I founded Le Havre In 1517.

The port, which, like the city, was almost completely destroyed in 1944, has been entirely reconstructed and widely developed.

Thus, Le Havre, the port and the city, have become a modern unit.

Situated at the immmediate outlet of the Paris Region, the Port of Le Havre has an exceptional position in the center of the North European seacoast which allows it to offer excellent passage conditions for transoceanic trades which sail down the English Channel - it is the first port to be touched on import and the last on export. Its position allows it to guarantee the shortest service for all European countries (Spain - Italy - Northwest Europe).

LE HAVRE A EUROPEAN MAIN PORT
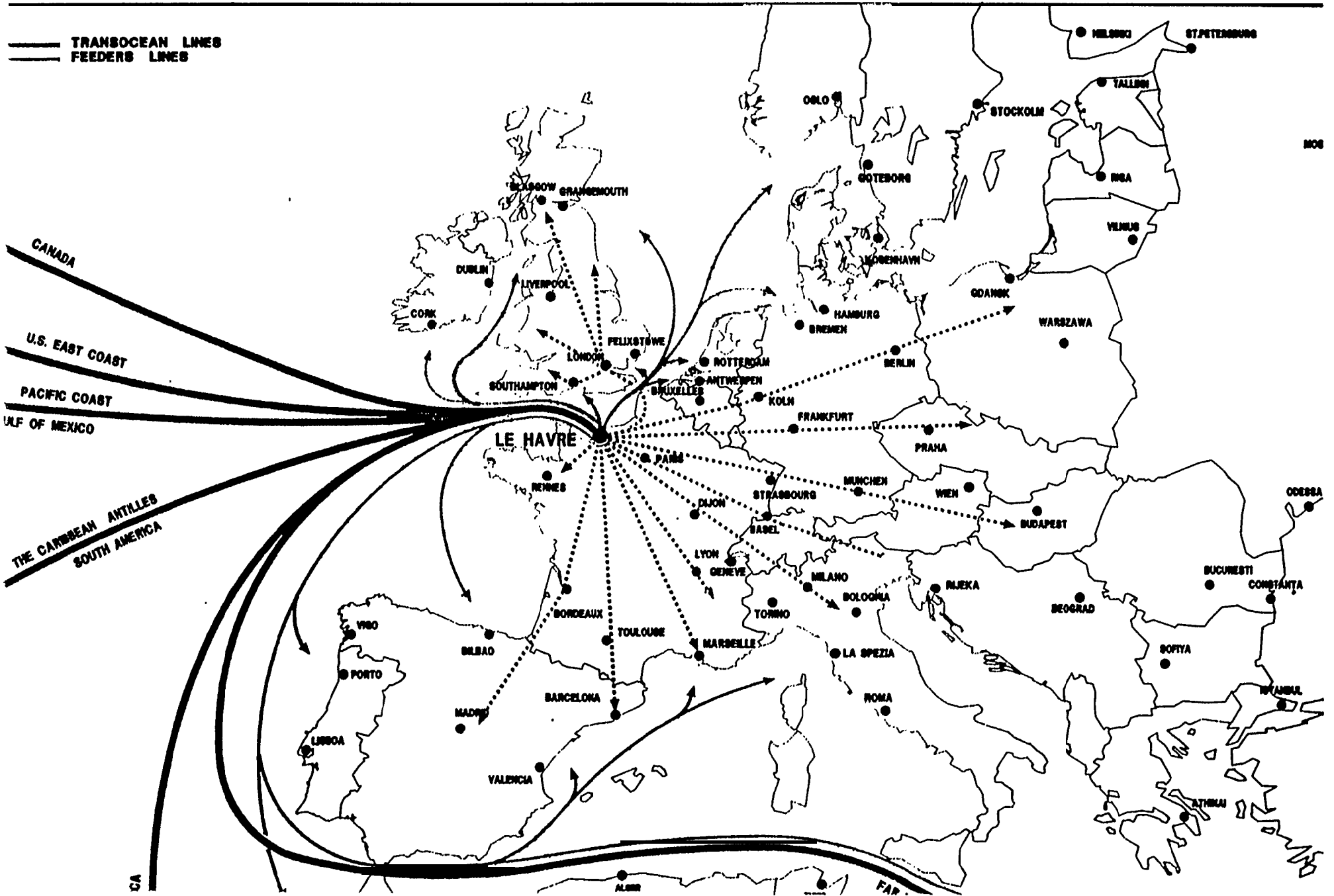
Le Havre is first among French ports in terms of external trade. It ensures :

  -55% of container traffic for all French ports

  -and 40% of oil supplies.

In all, 58 million tons of goods, 8,000 ships and 1 million passengers transited in the Port of Le Havre in 1991. In addition, the port is backed up by a vast industrial zone set up by the Port of Le Havre Authority which covers almost 8,000 hectares and offers sites suitable for all types of industrial activity.

It is a deep-sea port, directly accessible to ships from the high seas 24 hours a day.

The Francois ler Lock, which serves the Industrial Zone, is accessible to 250,000-ton ships.

Thanks to investments and a competitiveness plan put into effect by the Le Havre Port Community, the Port of Le Havre has, for several years, shown one of the best rates of traffic growth of all large European ports.

It is presently in fifth place among large European ports in terms of overall tic and holds 10% of the general cargo market for all of Northwest Europe.

II - Accommodations Available to Ships

II.1 - Facilities

Energy trades make up 70% of port activity in tonnage.

Goods which might possibly present a risk to the environment, in varying degrees, make up more than three quarters of all goods transiting through the port.

Given the nature of products transiting in a large port, safety and environmental protection must be considered with the upmost seriousness.

The design of port facilities and equipment as well as the drawing up of relevant safety rules condition to a large degree the success of procedures in this area.

lI.1.1 - The Reception and Expedition of Hydrocarbons and Chemical Products

At the entrance to the port, separate from other port facilities and approximately one kilometer away from the first inhabited areas, the Port of Le Havre has set up and dedicated a first oil facility, the oldest, allowing for the reception of ships up to 300,ooO tons.

The facility operated by the CIM (Compagnie lndustrielle Maritime - Industrial Maritime Company) has 9 specialized berths and storage tanks with a total capacity of more than 5,000,OOO square meters for crude oil and oil by-products.

In addition, the Port of Le Havre has constructed an oil terminal at Antifer, located 20 km to the north of Le Havre, which can receive the largest oil tankers (550,000 tons).

This terminal has particularly favourable access conditions as well as two berths in the shelter of a very imposing breakwater measuring more than three kilometers.

A storage yard located at the foot of the cliffs holds 4 150,000 square-meter tat&s which make it possible for the discharge and reloading of cargoes for Le Havre to take place in good commercial and safety conditions.

There are many facilities set up in the Port of Le Havre Industrial Zone. These are either specialized public facilities or private facilities directly serving production units in the industrial zone.

For chemical or gaseous products, specialized berths, located on the Le Havre Grand Canal, are accessible to ships of up to 70,000 tons. These make the reception and re-expedition of hydrocarbons and various chemical products as well as gases such as butane or propane possible. 13 specialized berths are set up in the Industrial Zone to ensure this traffic which directly supplies the important petro- chemical activity in the region of the Lower Seine.

II.1.2. - Facilities for Solid Bulks

The principle solid.bulk trades of the Port of Le Havre include coal, cement, fertilizers, grains...

Dry bulks are treated in specialized facilities, operated either by the Port Authority, licence-holders, or private companies.

The berths must be able to receive ships of various sixes, from 150,000 tons for coal to 30,000 tons for cement.

K1.3. - The Reception of Dangerous Goods in Non-Specialized Facilities : the Case of Container Terminals

The Port of Le Havre has installed five container terminals, three of which are located in the Tidal Basin. A considerable investment program has been undertaken in order to continue the development of facilities for the reception of container trades.

The various terminals are equipped with 19 40-ton gantry cranes allowing for the handling of all types of containerships.

This type of traffic makes the installation of vast storage yards (several hundred hectares) necessary for the reception of boxes.

Presently, the largest containerships can carry up to 4,000 boxes.

One can estimate that 20 to 30% of all containers contain goods which are more or less dangerous for the environment.

These goods are well-protected in the container, but it is difficult to identify the nature of the goods, and, consequently, the corresponding risks for each container, whose identification is too often limited to a simple number.

The computer systems used do, however, allow us to locate containers which may present a risk for the environment.
However, the containers remain, except in the case of particularly dangerous goods which have been idemified, dispersed on the ships and in the storage areas.

II2 - The Main Risks Linked to In-Port Transit of Dangerous Goods and Preventive and Curative Measures in Pollution Control and Disasters

It is not possible to do an exhaustive study here on possible risks and the means necessary for prevention and control.

Dangerous goods Nomenclatures have been set up and completed by specific recommendations according to the class of products and the products in each class.

The IMDG Code (International Maritime Dangerous Goods) published by the IMCO (Inter-Governmental Maritime Consultative Organisation) makes up the basic collection of safety measures applicable to the transport of dangerous goods on waterways.

Very briefly, it is possible to envisage three main types of risks applicable, for example, to certain goods:

- fk (hydrocarbon, coal, cotton)

- explosion (gas, hydrocarbons, grains, sugar, ammonia, nitrates...)

- water pollution (hydrocarbons, chemical products)

However there are other risks (radioactivity, toxicity, atmospheric pollution...).

In the same vein, it is possible to differentiate between means relevant to passive security and fixed means, on the one hand and those relevant to active security and mobile means, on the other hand

Retaining tanks, gas detectors, heating detectror~ . ..belong to the first category.

In the second category, we can cite classic fire-fighting means as well as tugs equipped for fire fighting and pollution control, booms, dispersal products, mobile storage tanks.

III - The Organization of Safety and Pollution Control

In the Port of LE HAVRE, a Managing Director, the Director of the Port Authority, is in charge of the management and operations of the port

His role is decisive in setting up and operating emergency means.

The port zone is a complex environment within which many professions and `participants`, often from outside the port, interact.

In addition, in the cycle from the fabrication to the use of dangerous goods, transport, and, more precisely, the rupture of port responsibiity, is a weak link.

Thus any accident in a port must, a priori, be considered important, or possibly important, as the first emergency decisions are often those which decide the future serious- ness of the pollution or accident.

It is thus necessary to have precise pollution and accident prevention and control plans which are capable of advancing easily through `progressive stages`, involving increasing responsibilities according to the seriousness of the problem.

III.1 - Pollution Prevention and Control

As for ship reception, prevention must be considered on two levels :

- the design of facilities and equipment, aiming at optimal safety,

- operating conditions in the port

International agreements, to which most of the large industrialized countries ate `parties, lay` out the conditions for ship passage in ports and, notably, specify the accommodations which must be available to them.

The "MARPOL" Agreement calls for the presence of `facilities` for the reception and treatment of polluted water (in particular, ballast water from tankers) as well as solid waste from ships.

Concerning the organization of pollution control measures, they are controlled by national regulations.

French regulations are based on a specific set of regulations called "POLMAR".

French territory is covered by plans called "POLMAR Land" and "POLMAR Sea" which envisage various scenarios and specify the means to be mobilized (public means and if neces- sary the requisition of private means).

POLMAR PLAN

message. POLREP

AF/MAR

PORT AUTONOME du HAVRE
- Capitainerie -
(Port du HAVRE - Port d'ANTIFER)

SAMU

(a)   (a)

Sous-Préfecture
LE HAVRE

Cie GEND
ou P. U.

C.S.P.

(a)

Gpt de GEND
ou D.D.P.U.

PREFECTURE

D.D.S.I.S.

- PREMAR 1 et CROSS/Ma
- Ministères concernés
  (si déclenchement Plan POLMAR)
- éventuellement, départements voisins (EURE-CALVADOS)

C O D I S C
(PARIS)
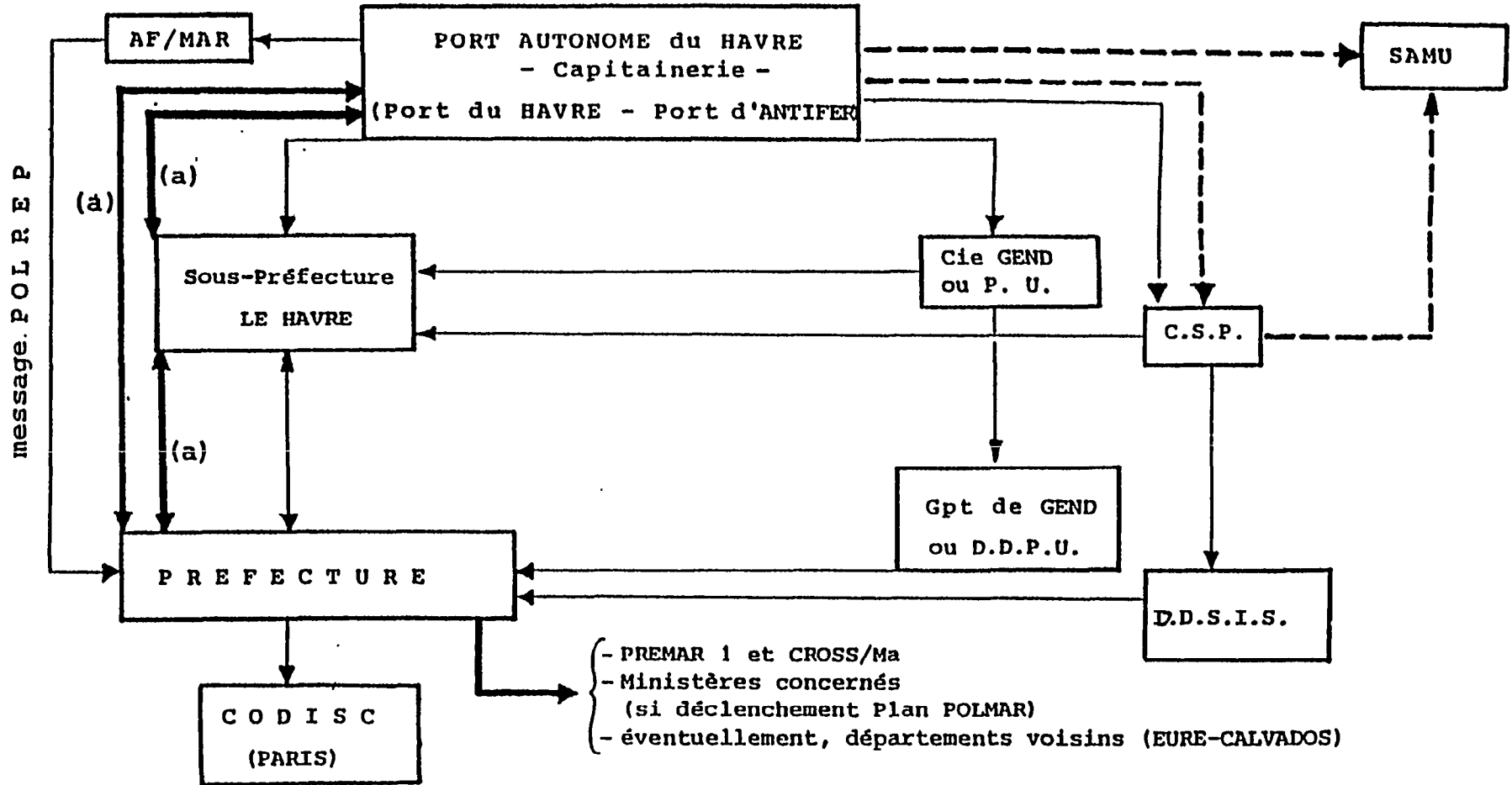
autorité à autorité
voie opérationnelle
pour sauvetage vies humaines (incendie ou explosion + pollution)

Equipment storage centers are set up along the coast and high-level training **exercises** are regularly organized by the State Maritime Services.

For small- and medium-scale pollution within the port, the Port Authority has its own means (equipment and personnel) which allow it to act with maximum flexibility (speed and efficiency). Agreements and treaties with port services (Pilots, river pilots and towage) provide for supplementary equipment to be put under the operational authority of the HarbourMaster.

<u>IIL2 - Prevention and Control of Accidents</u>

On a national level, for very large disasters of the ca- tastrophe type, the State and its local reprentatives, the prefects, put the emergency plan "ORSEC" into operation. This plan combines all functional and operational orders which provide for the organisation of emergency means and the management of the crisis.

We should note here that this aspect of the management of major crises, following the SEVESO catastrophe which caused a European order meant to prevent catastrophes, has taken on more and more importance.

The relation with the media, in order to be efficient, that is, objective, coherent and controlled must be correctly prepared

Jmprovised actions may in fact, have a negative effect which go largely against the public interest.

In applying the SEVESO Order, risky activities must have emergency plans (specialized emergency plans such as cordoning-off plans, internal operations plans for facilities at risk, particular plans covering the problems created outside facilities at risk).

Various plans are thus in place to manage all problems which may touch either the ship in the port, a port installation, or an industrial facility.

In particular, they provide for various alert levels and the mobilization of means, depending on potential risks and the manner in which situations develop.

The Port of Le Havre Harbour Master's Office, operational 24 hours a day, which ensures the direct surveillance of the entire zone and has the means necessary for transmitting information , is the mandatory point of passage for alerting the entire Le Havre area.

SAFETY PLAN

ETABLISSEMENT INDUSTRIEL
A L'ORIGINE DE L'ACCIDENT

VIGIE DU PORT

SAMU 6715	Pömpiers 6718 ou 18.	SAMU 6715 ou	Base hélico.
Autres CSP	Off. Sécu 7384 ou 8009 ou Astr.	Cdt de Port	Autres SAMU
Préfet - Dir. Cabinet	Service W	Dir. des Opéra-tions portuaires	Médecined'Urg. Secouristes
Préfet Dir.Séc.Civi.	S/Préf. 6617	Dir. Général	Hôpitaux
D.D.E.	Off. Sect. VHF ou télé.	D.R.I.R.	
D.D.P.U. ROUEN	POLICE 6717	S.N.C.F. 8734	
Cdt Gpt de gendarmerie	Gendarmerie		

IV - The Development Plan and the Charter for the Environment

The decision to set up a Port Industrial Zone in Le Havre was a national decision based on general development plans which may not be put into question, except by governmental decision.

On the local level, urbanism documents drawn up by local representatives reiterate the general provisions and confirm the port and industrial vocation of the entire zone (which covers 8,000 hectares).

The unity of the zone in terms of development is thus preserved. In addition, the responsability for its development is granted to a single organization, the Port of Le Havre Authority.

However, it appears more and more evident that industrial and port development must take the enviroment into account.

The Port of Le Havre Authority has thus been led to draw up a development plan notably describing the principle direc- tions of industrial and port development in the medium and long term.

Locally, this plan has been the result of a very wide cooperation associating public representatives, economic circles, associations, manufacturers, State Services.

The main objectives of the plan are :

- to provide for almost instantaneous decision-taking for a project of industrial construction or extension,

- to take into account the preservation of certain natural environments to be preserved (the central part of the Estuary),

- to incorporate, as early as possible, a consideration of the technological risks by examining, in particular, the compatibility between certain risky activities with areas where there is a high concentration of people (factories with large work forces, roads with heavy traffic...)

- to guarantee industrial and port development by simultaneously making the plan a reference document for the official city planning regulations which guarantee the control of urbanization and a communication tool for industrial and port promotion activities.

LEGENDE

Grandes et moyennes industries pouvant générer des risques *

Activités d'interface "à culture" compatible avec les grandes industries et à effectif sédentaire limité

Activités portuaires et ses annexes

Entreprises diverses ne générant pas de risque sans limitation d'effectif

Espaces d'accompagnement et naturels

Petites et moyennes industries pouvant générer des risques ou activités d'interface à culture compatible

Activités d'interface ou portuaires à effectif sédentaire limité

Entreprises diverses à effectif sédentaire limité

Entreprises d'interface à effectif sédentaire limité et présentant des aspects architecturaux et d'environnement de qualité

Zone de dépôt

Entreprises diverses ne générant pas de risque e nuisance présentant des aspects architecturaux e d'environnement de qualité

Accueil possible de grandes industries ou d'activités portuaires

Accueil possible d'entreprises PME-PMI diverses ou portuaires

Autoroutes

Routes principales

Limites de communes

A B Zones A et B : convention du 11/04/1985

ç, Zone des sources

· · · Périmètres (rapproché et éloigné) de protection à définir

Terrains occupés

Terrains disponibles

* Les zones à risques sont localisées et n'occupent en général qu'une partie réduite de la surface totale affectée à ce type d'industrie
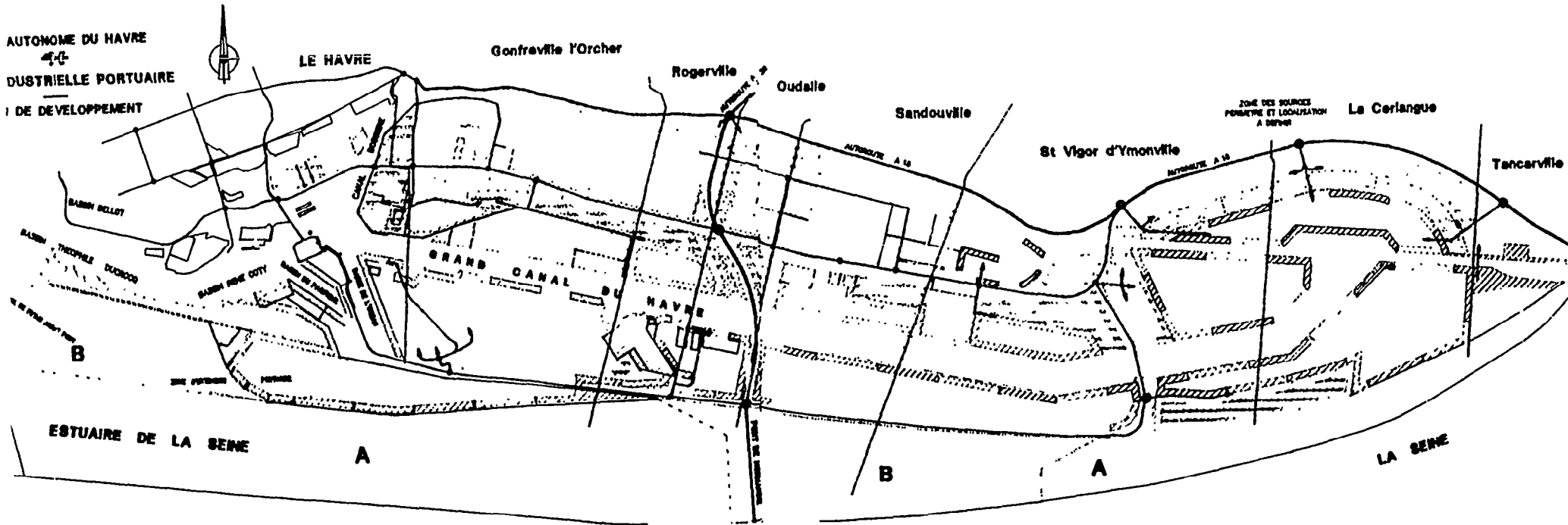
In order to complete the plan and to draw up guidelines for action and procedures, a charter has been drawn up. The charter describes the conditions under which the development plan is to be carried out. It deals extensively with concerns about the preservation of zones presently in their natural state which must either be upgraded or preserved in the expectation of their eventual conversion for industrial or port uses.

The charter also invites port personnel and the partners of the Port Authority to learn and think about the protection of nature and to participate in training programs designed to improve the relationship of the port with its environment.

Conclusion - The Stakes

The Port of Le Havre's goal is to confirm its position among the large European ports. Of course, this objective is reinforced by economic arguments.

However, it is becoming more and more obvious that safety and environmental protection will present important advantages.

Technological changes, both in ports and in industry, improve efficiency and reliability.

The development and the operation of a port, and even more so of an industrial zone, thus implies the implementation of complex systems, which ate not always easy to **interconnect**.

Data processing is an important tool in the creation of efficient organizational plans.

However, the concentration of large quantities of dangerous products on ships, in the port and in factories still presents, in particular in the two first cases where the environment is very variable and complex, a serious problem for present-day industrial societies.

In the eyes of public opinion, accidents are not very well tolerated and catastrophes are always inadmissible.

It is thus important to take preventive action as much as possible by offering facilities which provide the best safety guarantees, both in terms of developmment and current operation rules.

Emergency plans allowing for the mobilization of the necessary means, that is, both equipment and personnel, must be envisaged for all possible cases.

The prevention of accidents and the possibility of putting pre--existing plans for intervention into force in the case of problems guarantees the credibility of those in positions of economic and political responsability

They guarantee the quality of life for future generations.

CLEAN HARBOURS BY CLEANER PRODUCTION:
Reflections on Sustainable Port Operations in the Rijnmond area

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0   Abstract

Harbours all over the world have a long tradition as focal points in
distribution. In this paper attention will be given to the symbiosis
between economical and ecological aspects of harbour related activi-
ties and the societal need for Clean Living in the Rijnmond area. The
Rijnmond area is the geographical area between the city of Rotterdam
and the North Sea, on both sides of the river Rhine. In this area,
industrial activities, related to the Rotterdam port, are executed.
The industrial sector is dominated by oil refineries, chemical
companies, storage and transport operations, and, though declining as
an industrial sector, shipyards. The balance in the symbiosis as an
important aspect of Clean Living has been challenged in the strongly
growing harbour activities after 1945.

Three points of attention will be explored:

*   the environmental awareness by citizens of the Rijnmond area;
*   the environmental problems by harbour activities and toxic
       harbour sludge;
*   the reduction of pollution by Cleaner Production.

1   Introduction

In this paper, attention will be given to the symbiosis between
economical and ecological aspects of harbour related activities and
the societal need for Clean Living in the Rijnmond area. The Rijnmond
area is the geographical area between the city of Rotterdam and the
North Sea, on both sides of the river Rhine. In this area, industrial
activities, related to the Rotterdam port, are executed. The industri-
al sector is dominated by oil refineries, chemical companies, storage
and transport operations, and, though declining as an industrial
sector, shipyards. The balance in the symbiosis as an important aspect
of Clean Living has been challenged in the strongly growing harbour
activities after 1945. First, attention will be given to the develop-
ment of environmental awareness by citizens of the Rijnmond area.
Next, the environmental problems of harbour activities and the storage
of toxic harbour sludge are described. Finally, the possibilities of
the reduction of pollution at source by Cleaner Production will be
illustrated with case studies.

2   Environmental awareness of citizens in the Rijnmond area

The Rotterdam port has brought much prosperity to the Dutch economy in the 20th century. Both the transit function of the harbour and the bulk chemical industry were major parts in economic growth. But the prosperous growth had its dark sides too. In the second half of the 1960's, citizens in parts of the Rijnmond area were bothered by the increase of environmental pollution. Many citizen's protests against air pollution started. The protest movement became the base for a breakthrough of the environmental issues on the political agenda (Boender, 1985). In 1970 the National Government declared the Rijnmond area as an "Environmental Redevelopment Area". Many Pollution Control measures were taken, among others the development of high chimneys. By doing this, the environmental problems were not solved, but merely transferred to another area. The state of the art of meeting the requirements of the environmental regulations in 1990 have been reason for the National Government to remove the declaration of the Rijnmond area as an "Environmental Redevelopment Area". This will not say, that environmental problems do not exist anymore. Today, citizens in the Rijnmond area perceive as major industrial environmental problems, industrial risks, stench and noise, air pollution, dust and soot deposits. As the environmental awareness of citizens has been mobilized by the severe pollution in the late 1960's, the sanitation works in later periods restored the trust of many citizens in the Rijnmond area, that industry can control the environmental aspects.

The environmental awareness in The Netherlands *in* general has always been high. It has even increased in period 1988 - 1990; the percentage of Dutch citizens, involved with environmental problems, has increased from 40% in 1988 to 56% in 1990. In the Rijnmond area, environmental care is, next to health care, seen as the second most important societal issue (Province of South Holland, 1991). The Province of South-Holland is monotoring the citizen's judgements of environmental problems periodically. In relation to the increased involvement with environmental problems, the amount of impedement has increased too. The percentage of hindrance of several industrial environmental problems in the Rijnmond area in the category "often" are monitored in 1988 and 1990. Because "often" is a subjective qualification, the citizen's definition is asked too: 30% is saying 1 or 2 times a month, 70% are varying from *once* a week to each day.

Figure 1   Hindrance of industrial environmental problems: "Often" frequency (the first % is of Rijnmond-North, the second of Rijnmond-South)

Environmental aspect	% hindrance in 1988	% hindrance in 1990
Industrial stench	54 - 74	75 - 75
Industrial dust/soot	58 - 51	72 - 68
Air pollution	23 - 24	30 - 29
Industrial risk	5 - 12	8 - 7
Industrial noise	24 - 29	29 - 31

The data of the Rijnmond area are 2 to 4 times as high, compared with

a reference area. The data show, that the environmental problems in the Rijnmond area need continuous attention. The trend of the data in the last three years underscores this even more.

3   Environmental problems in the Rijnmond area

The sediments of the estuary of the rivers Meuse and Rhine have raised the present land, called Holland. That estuary is now developed into a thriving part of the country. The geographical situation as entrance of one of the most important trade routes into Europe has made the port of Rotterdam since 1962 the largest transit port in the world. This expansion was possible by the construction of artificial harbours, designed through innovative approaches of Rotterdam port authorities. These harbours need continuous dredging. The Rijnmond area is one of the trigger points in the Dutch economy. To keep the actual position, innovative approaches to economic development have to be sustainable. This means, that the port authorities have to cope with the environmental problems in the Rijnmond area. Three main sources of environmental pollution are detected:

a)   water pollution in the river Rhine;
b)   environmental problems of port activities;
c)   environmental problems of local industrial area.

__Ad)__
The river Rhine provided the area several functions in the recent past. The sediments of the dredging were used in agriculture as well as for preparations of foundations for new housing-estates. Another function was drinking-water supplier. More than 20 million people are dependent on this function in the total river basin. Due to severe pollution of the Rhine however, the river no longer meets the requirements of these last two functions in the region of Rotterdam. In the beginning of the 1970's the reduction of the Rhine water quality was reason for the city of Rotterdam to change the intake of drinking-water from the river Rhine to the river Meuse. 'A few years later the harbour sludge was found to be so contaminated with heavy metals and organic compounds that the application of this sediment for agricultural purposes was no longer safe.
As dredging is a continuing activity in order to keep the harbour open to the proper depth, Rotterdam had to find other ways of managing the sludge. The dumping of the sludge in the sea, one of the solutions, was no longer possible because of a ban by the Dutch administration. Furthermore, storage on land, another short term solution, became undesirable because the resistance of citizens and local authorities gave too much delay. Due to these developments the city of Rotterdam became obligated to store the sludge in several specially-made dump-sites. An example of this last 'solution' is a dumpsite made in the sea, called 'Slufter'. This dumpsite should provide for the storage of sludge of a certain qualification up till the year 2002. However, the 'Slufter-project' is an undesirable solution because of both ecological and financial reasons (as a matter of fact, this "end-of-river" solution is a specific example of an "end-of-pipe" solution). The actual costs of this project are estimated to be some DFl 200 million, a strong reason to look for more preventive ways of dealing with the pollution of the river Rhine.

In 1984 the Rotterdam-leaders have, therefore, formulated a Rhine Research Project. Based on the detection of the big polluters of the river Rhine and research into the possibilities of using civil law, a dialogue with chemical industries resulted in some covenants in 1991. In these covenants, goals were set for the reduction of certain emissions to the river Rhine in a certain timeframe. The preference of approaches to reach these goals has not been the subject in these covenants. Thus, a real opportunity was missed to implement reduction

of pollution at source, because some basic conditions for the process of Cleaner Production - goalsetting in a certain timeframe - are implicitly agreed in these covenants.

<u>ad b)</u>
The major environmental problems of port activities are related to the ships (used oil, maintenance) and the trans-shipment of resources and cargo.Based on Dutch environmental regulations, measures for polluti-on control have been taken, such as special roof constructions of storage tanks to reduce vapour emissions. For ships a harbour facility for the collection of used oil is available. There are many terminals for the trans-shipment of oil, coal, fertilizer, corn, cattlefeed and cargo in seacontainers. In the trans-shipment, still dust and noise problems occur. To promote further progress, the Rotterdam port authorities have developed a policy plan, "Clean Harbour 2000",

<u>ad c)</u>
The Rijnmond industrial area is rather monolithic with oil refineries, chemical companies and trans-shipment and storage facilities. The manifestating environmental problems in the 1960's and 1970's are managed by "Pollution Control" measures. In the 1980's, process integrated technologies were applied more and more. Though the big companies are developing "environmental care systems" within their plants,air and water pollution problems still need attention.

4   <u>Reflections to Cleaner Production</u>

In this paragraph the possibilities of Cleaner Production are described. Policies in existence are proving to be inefficient, too time consuming, and in some cases a hindrance to the reduction and prevention of pollution at source. The design and implementation of adequate policies needs much creativity and commitment to bring about the changes in practices necessary for cleaner waters in a reasonable time period. Two significant consequences of the application of the pollution prevention and waste reduction concepts are that the preven-tion of the production of industrial wastes increases company profits and improves the environment, simultaneously. Such an approach, in relation to water pollution, should focus upon both of the following types of emissions:

a)   reduction of emissions from industrial point-sources;
b)   reduction of emissions from non-point sources.

In contrast with the earlier "pollution control" approaches which manage produced pollutants, the concepts of Cleaner Production address both the technical as well as the attitudinal, motivational and other non-technical dimensions in an "anticipate and prevent" approach rather than in a "react and treat" approach (Baas et al, 1990, Hui-singh and Baas, 1991). Besides that, Cleaner Production is proving to be beneficial environmentally as well as economically. Cleaner Produc-tion is an on-going process towards a minimal waste and minimal risk status for the companies. Governmental policies to promote Cleaner Production and citizen commitment to making the necessary attitudinal and behavioural changes are integral components of Cleaner Production approaches, designed to help in ensuring sustainable societies. Under Cleaner Production is meant (Baas et al, 1990, Huisingh and Baas, 1991) :

CLEANER PRODUCTION, is the conceptual and procedural approach to production that demands that all phases of the life-cycle of a product or of a process should be addressed with the objective of the preven-tion or the minimization of short and long-term risks to humans and to the environment. A total societal commitment is required for effecting

this comprehensive approach to achieving the goal of sustainable societies.

Corporate leaders are challenged to address all aspects of the entire life-cycle of their products, including (Baas et al, 1992):

a) The evaluation of the societal relevance of a product;
b) The design of the product and the product development;
c) The selection of raw materials for the production of products;
d) The production of the product;
e) The consumption of the product;
f) The management of the product after usage.

Cleaner Production should be an ongoing process, that involves industrialists, governmental authorities, educators and citizens in helping to ensure sustainable societies.

5   Cleaner Production case illustrations

For reasons of competition, it became essential to not only start a dialogue with industries on the basis of the possible execution of legislative power, but also to find ways of stimulating companies to alter their work processes into a more environmentally friendly and economically rewarding way. After a pilot project Baas (1989), a research program based on the Pollution Prevention Principle was operationalized (Baas and Huisingh, Erasmus Centre for Environmental Studies, 1987 - 1992) in this way. Within this program, the issue is not only to indicate specific possibilities of changing production processes on the operational level, but also to find ways of implementing the philosophy of waste-reduction on the level of (strategic) industrial management. The underlying assumption is, that the attitude of people involved in production processes need to be changed in a more environmentally friendly way by innovations in the use of raw materials and substances in a more efficient way. However, this calls not only for a change in attitude with respect to the natural environment, but calls also for evaluation of production processes in a completely different way. In this respect, it is appropriate to speak in terms of the necessity for a new environmental industrial management approach. Hommes (1988) stresses the importance of periodically making environmental audits as the basis of action for industries, while Winter (1987) focuses on systematical ecological premises in every action of industrial management.

In the research program of the Erasmus Centre for Environmental Studies, the research started with a focus on industrial activities. But later also harbour related activities, like shipyards, transshipment companies and chemical industries were involved. Some case studies will be presented, based on the systematic approach of a Dutch Waste Prevention manual (de Hoo et al, 1990).
In this systematic approach, the introduction of the research in each company was followed by a visit of a research team for a special outsiders look. At the same time, the appropriate activities of the company were planned. The research-project continues with the inventarization of the environmental and economic aspects of the production process. Based on these activities, a growing awareness of involvement with the other dimensions of production usually develops. After that, feasibility studies for technical, environmental and economic aspects of priority options are performed, followed by the implementation of applicable options. The first features of a permanent Cleaner Production Management System will also be discussed. The research steps in this phase are to be visualized as follows:

Figure 2 Research steps in Cleaner Production research

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┌─────────────────────────────────────────────────┐
│ Introduction                                     │
│ * recognize need for Cleaner Production (1)      │
│ * questionnaire                                  │
│                                                  │
└─────────────────────────────────────────────────┘
                        │
                        v
┌─────────────────────────────────────────────────┐
│ Start meeting                                    │
│ * get management commitment                      │
│ * recognize need for Cleaner Production (2)      │
│                                                  │
└─────────────────────────────────────────────────┘
                        │
                        v
┌─────────────────────────────────────────────────┐
│ Company visit                                    │
│ * global inventarization                         │
│ * company tour                                   │
│ * selection of areas for                         │
│   priority attention                             │
│ * project-organization                           │
└─────────────────────────────────────────────────┘
                        │
                        v
┌─────────────────────────────────────────────────┐
│ Cleaner Production research                      │
│ * inventarization of production-activities       │
│   by the collection of data into worksheets      │
│ * identification of Cleaner Production options   │
└─────────────────────────────────────────────────┘
                        │
                        v
┌─────────────────────────────────────────────────┐
│ Cleaner Production Plan                          │
│ * prioritization of options                      │
│ * feasibility analysis:                          │
│   - economic feasibility                         │
│   - technical feasibility                        │
│   - environmental desirability                   │
│                                                  │
└─────────────────────────────────────────────────┘
                        │
                        v
┌─────────────────────────────────────────────────┐
│ Execution of Cleaner Production Plan             │
│ * elaboration of feasibility analysis            │
│ * implementation of selected options             │
│                                                  │
└─────────────────────────────────────────────────┘
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The impact of the implemented options need monitoring and evaluation.

The results of four case studies of Cleaner Production research will be given in the next paragraphs.

5.1   Chemical   company
The company, in the experiment (Dieleman et al, 1991), is a facility in the Rijnmond area within a large multinational chemical corporation. The test facility employees approximately 300 people and produces many types of resins. The process of filtering the resins was analyzed in detail and is presented here as illustrative of the opportunities for the preventive approach within this firm.

It was found that product losses due to the filtration process were 30 tonnes of resins per year. Additionally, 400 tonnes of filtration byproduct previously were reprocessed up to product specifications, each year. The rinsing of the filters between successive resin batches created another waste stream of 38 m^3 of organic solvent. Periodic cleaning of the system caused another 9 m^3 of organic solvent and 108 m^3 of alkaline wastewater. The wastewater was treated at a wastewater treatment facility. Other waste streams were burned.

Pollution   prevention   options
One promising process modification was the replacement of the old filter by a new type of filter. The new filter requires more precise attention to operating conditions, but its material efficiency is much greater. The stream of filtration 'byproduct' of 400 tonnes yearly, which previously had to be reworked up to product quality, is now totally eliminated. Furthermore, the wastestream of 30 tonnes is turned into product. Further advantages are that less solvent is necessary for rinsing between successive batches and the periodic cleaning is no longer necessary.

Environmental   and   financial   benefits
The environmental benefits are the reduction of raw material usage and the minimization or total elimination of several waste streams. The nearly 30 tonnes less product loss resulting from the filter change, represents a savings of about DFl 80,000. Another DFl 200,000 per year will be saved on operating costs by eliminating the need for reworking 400 tonnes of byproduct each year. The incineration costs of the new type of filter medium will be only DFl 20,000 compared to DFl 80,000 for the old type. The use of organic solvents will be reduced by at least 9 m^3 per year and the wastewater stream of 108 m^3 is completely eliminated. The savings on the purchase and recycling of solvents are not yet fully documented, but the potential annual savings are approximately DFl 50,000.
The investment costs for the new type of filters is DFl 360,000.

In summary, all process and procedural modifications will pay for themselves in one year and will provide net increases in annual profitability of almost DFl 400,000. Air emissions and water emissions will be substantially reduced or eliminated completely. Many similar changes in other portions of the facility are currently being implemented.

5.2   Shipyard
The small shipyard maintains small and medium-sized river-vessels (Olsthoorn and Baas, 1992). The main activities are: degreasing, ship's plating treatments, painting or coating, maintenance of ship-motors and propellor-shafts. The first step in the research, an inventarization of the ecological and economical aspects of the work activities, was recently finished. Though household and chemical waste and metal wastes were already collected, this was the first time in the company, that systematic attention to environmental aspects was operationalized.

Each year 2.5 tons of chemical waste, paint wastes and empty paint
containers were collected. The treatment costs were DFl 5,000; the
loss of resources was DFl 5,500. In the process of ships, put into
dock and after maintenance out of dock, 1,400 m3 water polluted with
paint wastes, rust and increments, come into the surface water. From
ship's plating conservation activities, 800 liters of organic solvents
are polluted. The preliminary analysis in a brainstorm session identi-
fied many options in the categories of source reduction (alternative
resources, good housekeeping, new technology) and internal reuse.

Figure 3   Prevention options in the shipyard in the different
             categories

Activity	Resource	Good hou-se-keeping	Technology	Internal reuse	In total
In/out dock		1	7		8
Cleaning of ship's plating	1	-	5	2	8
Conserving of ship's plating	4	1	7	1	13
Metal-working	2	6	1	3	12
In total	7	8	20	6	41

These options will be the base for feasiblity studies.

5.3   Seacontainer maintenance company
A small company, with twelve employees active in the maintenance of
seacontainers, was eager to join a pilot Cleaner Production project in
the Rijnmond area (Stimular project, 1992). The company-leader,
responsible for the collection of data in the inventarization, was
surprised by several findings, such as:
*   many data were not available;
*   the purchase of paint was too expensive;
*   the use of the paint was ineffective.

By doing the inventarization himself, the company-leader became
sensible to look at environmental aspects from a company perspective.
In this process of-sensibilization two illustrations were remarkable:
a)   each week eighty pairs of gloves were thrown away; only the
       right hand gloves were dirty. This finding led to the question,
       if the purchase of only right hand gloves is possible.
       After some time a company was found: a direct waste and cost
       saving!
b)   the spraying of paint with an organic solvent base was not so
       effective: the paint container consisted of organic solvents for
       about 50%, which was emitted in the air; about 20% of the
       content of the paint container was oversprayed, 5% was a residu
       in the paint container, so approximately only 25% of the paint
       container was used.

The primary emissions from the coating procedure were approximately 200 tons of volatile organic solvents (VOC's) per year and an inaccurately quantified amount of hazardous waste paint residues. The researchers discussed the possiblities of water based paints with the paint company, but the technical and economic development was perceived as too early. Half a year later, the paint company offered a water based paint with the same quality and price as the paint with an organic solvent base. After a period of experience, all the painting is done with water based paints. So less pollution to the air (VOC's), soil and water (overspray) was achieved by process modification. Another important aspect is the business relation between companies: through the demand of water based paints, the market dynamics were stimulated. Further advantages are:

*   The improvement of the worker's environment. They are not exposed to organic solvent vapours and the explosion risks are taken away;
*   A very high material efficiency results in less paint waste and a better energy efficiency decreases the energy use;
*   Financial benefits; the exact savings have still to be calculate.

5.4   Trans-shipment and storage company
This medium-sized company is trans-shipping and storing bulk products like phosphate ore, fertilizer, nepheline and general cargo like paper, cellulose and wood.
An important environmental disturbance to the surroundings is the dust development in transport activities. The product wastes in the transport system and storage compartments are major waste streams.
Each year, 270 tons of collected product wastes are sold as secundairy resources and 960 tons are transported to a dump site. The costs for collection of the product wastes, transport and deposit are
DFl 130,000 each year. The losses of nepheline in the several trans-shipment activities are inventarized:

Ship - ship: dust emission 2.6 ton;
Ship - shed: dust emission 5.8 ton, waste 88 ton;
Shed - truck: dust emission 4.8 ton, waste 73 ton.

Several "good housekeeping" possibilities and technology improvements are detected, such as:

* in the trans-shipment ship - ship, the height of opening the crane is a major variable in the amount of dust emission;
* the funnel, used for the loading of trucks, needs a better adjustment.

Figure 4 Prevention options in trans-shipment

Transshipment activity	Good housekeeping	Technology	Internal reuse	In total
Ship - ship	3	4		7
Ship - shed	6	18	2	26
Ship - truck	6	5		11
In total	15		2	44

The research project is now in the phase of feasibility studies.

6   Epilogue

In this paper, after the presentation of the environmental aspects and the environmnetal awareness of citizens in the Rijnmond area, the concepts of Cleaner Production have been illustrated by several case studies. There is a growing awareness, that treatment facilities have a function in the management of the environmental pollution, but are not able to solve all the problems. The prevention of the pollution at source is the best approach. The concepts of Cleaner Production give a promising perspective to this development, because all the phases of the life cycle of the product are addressed and integrated in business innovation.

It is clear that for the well-being of mankind a development to sustainable societies is needed. As there are many sources of pollution, it is not easy to foster integrated approaches to the reduction of pollution. Cleaner Production research is fostering this integrated economic and ecological sound approach, which is also applicable in port activities. The Cleaner Production approach will stimulate the integration of environmental aspects as part of sound port management, and will be the basic requirement for sustainable port operations.

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SAFETY OF TAILOR MADE VESSELS

J.M. Huisman
Nedlloyd Lines [1]

Summary

This paper deals with the safety of Owner designed vessels.An outline is given about the rule making procedures,are the basis of thesafety of a vessel. Some of the differences between Yard designs and Owners designs are pointed out.
In more detail, the design of the Ultimate Container carrier is explained.

Introduction

Safety on board of a vessel is a condition that is the result of people, hardware design),organisation and procedures.
This paper deals with the difference between "standard" ships (designed by yards) and "tailor made "vessels (designed by owners. The difference between those two shiptypes is the hardware. For that reason this paper discuss the h ardware part of safety only.
Safety hadware On board Of vessels is installed because it is mandatory by (inter)national rules and as a result of operational experience.

Rules and regulations

The majority of safety hardware is prescribed in (inter)national, rules. Most rules are made by the Internaional Maritime organisation (I.M.O.), a specialized agency of the United Nations, dealing with maritime affairs.
In Order to Understand the value of the mandatory safety hardware on board of ships it is necessary to understand the workingprocedures of IMO.

The governing body of IMO is the Assembly, which is assisted by a council,severalcommittees and many subcommittees, working groups and drafting paperwork is by a secretariat with some 300 international civil servants.
The most senior committees are the Maritime Safety Committee (M.S.C.)
the Marine Environmental Prtection Committee (M.E.P.C.)
In order to achieve its objections, IMD produces conventions, protocols, codes and recommendations.
After a procedure IMO instruments become mandatory most cases they areb implemented in domestic legislation.

The basic international convention related with matters of maritime
safety is the SOIAS 1974 convention (amended).
Although IMO describes itself as a organisation, the last 10
years politics have gained influence drastically. This means that
technicians propose or defend political issues in order to safeguard
domestic political aims.

In some submissions to IMO the improvement of maritime safety is of
minor importance; they are instruments to gain votes.

The INI bodies are formed by the delegations of National Maritim
Admimistrations, international governmental and non governmental
organisations. This represents a wide variety of people with different
background, culture and missions.
For that reason the result of all discussions is a COMPROMISE. In the
discussions with so many people, reality, facts and suitable solutions
are always loosing the battle against short term political gains, lack
of knowledge and "cold-water fear".
Sometimes this atmosphere and working procedures in unrealistic
rules and regulations.

Examples of IMO "bloopers:"
-The equatians in the damagest ability rules for passenger ships are
  violating proven mathemaical law's.
-MARPOL tries to reduce the oil spills by ships.
  Ships are restricted in pumping overboard oil; countries have to
  provide oil reception facilities.
  Countries that insisted most on environmental success have neglected
  to build reception facilities since.
  Twenty years after the enforcement- to equip tankers with ballast.
  monitoring sensors, it is not possible to fulfil the prescribed
  technical requirements.
-Herald of Free Enterprise
  For many years this vessel pops up in IMO discussions.
  Political pressure forced the Department of Transport to submit a
  lengthy List of proposals about lights, camera's, inclining tests,
  etc., irrespective the fact that not the hardware **but the procedures**
  caused the tragic loss of this vessel.
  Intemationally the IMO delegations are too polite to reject
  everything.
- **The many years of discussions about dangerous goods have not resulted
  in a one-to-one relation between a substance and an UN-number.
  Thirty years after the global introduction of computers, dangerous
  goods administration is still a lot of manual work, blood, sweat and
  tears.**
- **The Tonnage Convention
  The Tonnage Measurement Convention prescribes many complex rules and
  regulations in order to establish a figure to describe the seize of
  a vessel, while simple parameters such as length, depth, draught and
  beam are at hand.**

The above mentioned (questionable) rules and regulations are the basis
of the safety of a vessel.

Owners versus shipyards

Shipyard have to operate in a very competitive market. They optimize
their defsigns to minimum production costs.
s h i p y a r d s sail with ships and consequently do not receive
operational   feedback.
Although shipyards do their best,theyhavenoaccess to the right
information..

Shipowners have their own people sailing on vessels. Every vessel has a
safety committee.when safety is at stake the relevant information is
immediately available at the head office (design department). In order
to assure the safety of the employees in operational conditions
shipowners will add safety equipment and/or change shipyard designs.

Some examples of added safety features in "owners" ships:
-Additional fixe detection in spaces where it is not mandatory.
-No oil lines over engines.
-No fuel tanks and fuel drains in the vicinity of exhaust gas lines
-Special care for coupling method in fuel lines in order to prevent
 leakage.
-An extensive system to monitor engine room-and deck systems.Alarms
 are given when an parameter is out of range.
-Platforms to be made with closed anti-slipplating.
-Reduction of steps in decks and platforms.
- More navigation equipment than prescribed.
- Ergonomic design of wheelhouse, So all relevent information is

-No electric cable above engines.
-No steep stairs in engine roam,accommdation and on deck.
-No control rooms over engines.
-Thicker shell. plating at vulnerable positions (anchor, keelplating,
 rudderhorn, etc.).

Shipowners improve the safety of their ships by changing yard
standards and by adding equipment.

The Nedlloyd "Ultimate Container Carrier"

When designing a vessel of a novel kind,it becomes apparent that some
old fashioned rules and regulations cannot be incorporated in the
design. Nedlloyd faced this situation when designing the Ultimate
container carrier (U.C.C.).

The UCC design had problems with:
-Watertight integrity as prescribed in the International Load Line
 Convention, because the calculation of the freeboard (1890, amended)
 is based on the existence of a water tight upperdeck.
 The UCC has no watertight upperdeck, we had to find an alternative.

-Fire fight regulations,which stipulate that cargo holds should be equipped with a gas type fire fighting system,or equivalent.As gas can be blown away from an open cargohold, we had to find an equivalent.
-Dangerous goods regulatians,which make a distinctive difference between enclosed spaces and other spaces.
On UCC type vessels there are not so many enclosed spaces. In order to be flexible in the carriage of dangerous goods we had to find solutions.

Fortunately The Netherlands Shipping Inspectorate (N.S.I.) is a pragmatic and knowledgeable organisation. Nedlloyd and NSI together found sound and safe solutions.

watertight integrity

In order to as certain the safety of a vessel without a closed upperdeck Seakeeping model tests in extreme weather conditions are required. The importance of the model tests is to asses the freeboard at maximum draught.
An extensive model test program was established based on experience gained in the past during theimplementation of so called dock-ships. This means that reality prevailed old fashioned calculating methods.

Model tests have been carried out in long crested,irregular waves The Pierson-Moskowitz wave spectrum generated for the purpose of these experiments had a significant wave height of approx. 8.km and an average wave period of approx. 10.5 s, which corresponds 11, according to the scale of Beaufort.

The model experiments carried out with various headings and different ship speeds,including dead ship condition.

The loading condition during the tests corrresponded the maximum intended draught. The most unfavorable hold in terms of shipping of water was simulated to be empty,which means that no protection was provided by protruding containers.

In addition to the usual parameters (ship motions,ship speed, relative motions, rudder angles, etc.) the volume of water entering the holds was measured for each experiment. Moreover the accelerations were iizL.d asa~~ofthestrength~~~~ofthecellguides.

NSI has not stipulated the maximum quantity of shipped water, but a very small percentage of the volume of displacement (less than one percent) is considered as acceptable.
Nedlloyd was more stringent than the Administration. The Admihistration's prime objective is to cater for the safety of the crew and vessel, both allowed to become. Considerations based an "care for cargo" have led to an additional where the maximumm quantity of shipped water should be less than the quantity of water as a result of a rainshower.This ensures that the maximum "Water load" on the cargo does not exceed presently accepted levels.

Both the quantity of water shipped during the model tests and the water coming in the vessel during a tropical rain are taken into account in the determination of the bilge pump capacity.

The pump arrangement is as follows:
1. Two centrifugal bilge/ballast pump, one of which is placed in a separate space outside the engine room and connected to the emergency switchboard.
2. Each centrifugal pump is capable of pumping either:
    a. The maximum quantity of shipped water,measured during the seakeepingtestswithanat@esafetymrgin;or
    b. The quantity of water ingress into the exposed cargo holds owing to a tropical rainfall; whichever is the greater.
3. Additionally,two ejector pumps are installed to serve a fully automatic bilge pmp and stripping system. One ejector is placed outside the engine room and driven by emergency power

Thecarriageofdangemusgocds

On conventional vessels the cargo holds are considered to be an enclosed space. These spaces are separated from the deck by hatch covers. The deck area and the hold area are treated as separate spaces in relation to the carriage of dangerous goods.
The majority of the dangerous goods is carried on deck.

On a UCC-type vessel dangerous goods my leak into the cargo hold. For that reason all containers in and over the cargohold are considered to be loaded in the same compartment.
This situation reduces the flexibility to carry containers with dangerous goods.
In order to obtain sufficientv flexibility in the carriage of dangerous goods,the cargo holds No.1 and No.2 are constructed as conventional holds with hatch-.
These two cargo holds are especially equipped with appendages to carry all types of dangaous goods except explosives. These holds will be used to carry "special" cargo as well.

Fire detection and fire fighting

The usual ionization type sensors are not suitable in weather exposed areas. A system was chosen whereby air is sucked from each cross-over in the cargo hold. The air is analysed continuously.
Smoke in the air will activate the electronic monitoring system and a fire alarm will be given.   .

The best prevention against a blase in a container is the container itself. The steel container box will dump down a fire by its protection against incoming oxygen.However, the international rules do not count for containerized cargo. The authorities have never given any credit to this built-in fire protection device" on container vessels.

The closed cargo holds of a comential container vessel are normaly protected with a gas type (CO2)fire extinguishing system.The deletion of the hatch covers makes this method of extinguishing system very unreliable, as CO_2 may be blown out of the holds by the wind.

On the UCC-type vessels a water spray system was selected to protect both the vessel and the cargo. Each container bay can be isolated by a water curtain from the rest of the cargo and from the vessel's structure. This system was approved after several nozzle arrangements and nozzle types were tested in full scale on board the "Nedlloyd De jina".

The engine room and the conventional holds are protected by a CO_2 extinguisning system.

Conclusions

The Ultimate Container carrier, a typical ewqle of an owner's design, was carefully designed. ale vessel could not fulfil the requirements of the International Loadline convention. Practical and reliable solutions have been found to solve this problem.
The Netherlands Maritime Authorities have anticipated very welll during the design process in order to arrive at a sound and safe vessel.

HYDROMECHANIC ASPECTS OF MARINE SAFETY

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ABSTRACT

From all aspects of marine safety the hydromechanic issue is an important one. The criteria mostly considered and reviewed here, are those related to the still water condition such as transverse intact and damage stability, load lines and manoeuvring qualities. For all these topics criteria already exist or are under development.
Special attention is focused at the manoeuvring aspects of fast modern ships in certain environmental conditions such as ferry-boats in restricted water.
Another important issue considered here is the behaviour in a seaway especially for high speed advanced ships in high waves. Chaotic behaviour of the transvers stability in ultimate non-linear wave conditions appears to play an increasingly important role. Improved criteria concerning relative motions, accelerations, shipping and slamming should be developed. In this respect accurate and reliable calculation methods, together with aimed experiments and a probabilistic approach, are required to establish these criteria for future safety in marine transport.

INTRODUCTION

up to now the majority of the considerations related to ship safety is devoted to the still water condition with special emphasis on stability for the up-right situation against capsizing.
Another important criterium for the safety of ships is the determination of the load lines or the free board to achieve a certain amount of reserve buoyancy. A good historical review and state of the art about these subjects is presented by Kobilinski (1991) El]. For both above mentioned criteria general international conferences introduced recommendations and/or requirements [3,4,5,7,10,141.
One more important aspect with respect to damage stability is the required sub-division in a certain number of compartments by watertight bulkheads. With the increase of forward speed, criteria for manoeuvring will be more and more urgent especially related to the ship's condition i.e. trim and sinkage as well as related to the operation in shallow water. Formulation of manoeuvring criteria for designers by the IMO (International Maritime Organization) appears to be a difficult matter.

It might be clear that for considerations about ship safe-
ty the dynamic behaviour of a ship in a seaway should be
taken into account. At first related to ultimate situations
with respect to the safety of crew and passengers but sec-
ondly also in view of operational conditions to prevent too
much degradation of the performance of persons on board
 (sea-sickness) and danger for damage of cargo and local
ship areas.
For ultimate conditions knowledge about non-linear behav-
iour is required to simulate possible chaotic situations
and to improve the probabilistic approach in finding more
reliable criteria.
In the near future given the growing interest in fast ad-
vanced ship types such as catamarans, hydrofoils etc., it
may be expected that control foils are needed to maintain a
safe stable condition in still water and waves for both ho-
rizontal and vertical motions. Safety requirements for
these high speed craft hardly exist at present, but should
be developed.

STILL WATER CONDITION

<u>Intact stability</u>
From the beginning <u>intact stability</u> in still water has been
an important issue with respect to safety against capsiz-
ing. At the end of the nineteenth century the first at-
tempts were made to evaluate a safe minimum stability. In
this respect Rahola (1939) 121 should be mentioned who pro-
posed a set of stability criteria which after the second
World War were used in some countries as recommendations.
The different International Conferences on Safety of Life
at Sea (SOLAS) (1948, 1960) did not present requirements
concerning stability criteria.
The 1960 SOLAS Conference recommended the International
Maritime Organization. (IMO) to study intact stability of
ships in order to establish minimum criteria 131.
After collection of data on stability of ships, which ei-
ther capsized or operated safely, the IMO proposed stabili-
ty criteria for passenger, cargo and fishing vessels. These
proposals were accepted as IMO-recommendations [4,51, but
only as temporary ones because the statistical analysis was
considered to be based on an insufficient number of data as
signalized and specified by Bird and Odabassi (1975) 161.
The IMO continued her work with a programme aimed at the
development of so-called 'rational criteria'. These crite-
ria should be based on physical analysis of phenomena lead-
ing to capsizing. After some years of study by the IMO Sub-
committee little progress had been made because the physics
of capsizing are a very complicated problem. It became more
and more evident that ship motions generated by waves and
wind should be taken into consideration too. And so the IMO
Sub-committee expecting only results on the very long term

decided to adopt a more pragmatic approach and accepted a short term programme to improve the existing criteria.

In this way the weather criterion arose in which, on an approximate basis, the effects of wind and sea were taken into account E71. Extensive research over the last 20 years including four international Stabtility) Conferences, delivered a vast increase of knowledge about the physics of capsizing but up to now no reliable 'rational' stability criteria. Nevertheless, as a result of this continued research it has become evident that safety against capsizing should be considered as a system and dependent on several elements such as the ship, cargo, environment and operation as demonstrated in Fig.1 [l]. For this reason the IMO Subcommittee is trying to develop now an overall code of stability for all ship types considering the afore mentioned elements of the system. It remains questionable if such a solution may be expected in the foreseeable future. A pragmatic way with as its base the existing rules with differentation in ship types and elements is perhaps preferable or more likely a system with approval by recognized and authorized institutions or organizations. The historical development is remarkable: starting from the still water condition with static stability as the only element for determining criteria it followed from practice that such an approach is too simple. It appeared that the ship dynamic behaviour due to motions in a seaway should be regarded together with other elements of the system.

Fig.l:Elements of system influencing safety 111.

Load lines
Safety considerations for ships started in the second half of the eighteenth century with requirements related to freeboard. The name of Samuel Plimsoll (1824-1898) is connected to the wellknown freeboard mark which is being used up to the present time.

Determination of freeboard was based on the assumption that the ship should possess a certain amount of reserve buoyancy, characterized as the volume between the waterline and the uppermost deck exposed to weather. International requirements with respect to freeboard were presented by the first International Conference on Load Lines in 1930 followed by a second conference in 1966 organized by the IMO. At this conference it became already evident that determination of a required freeboard in a rational way is very difficult because of modern developments in seakeeping and because of the possibility of overruling by the recommendations concerning intact and damage stability.

With respect to seakeeping several papers were published such as from Bakenhus (1964) [81 and Krappinger (1964)[9] showing the possibility to determine freeboard based on the idea of using the probability of deck wetness in a prede- fined seaway.

The 1966 Conference accepted this method and delegated the execution to the technical coarnittee. The developments dur- ing the following 20 years were almost similar to those of stability: the problems appeared to be too complex for a sound physical and rational solution applicable for all ship types. So the technical committee decided to adhere to the old principles with re-adjustments of free-board ta- bles. The only exception worth mentioning is the determi- mination of minimum freeboard for fishing vessels based on deck wetness in a seaway. Because of easy controllability only the minimum distance from the deepest operating water- line to the lowest point of the top of the bulwark or to the edge of the working deck and the minimum bow height are considered.

At first formulae for minimum distance were developed based upon regression analysis of results of probability of ship- ping water on deck which are assumed to be 5 per cent in fully developed beam seas with significant wave heights of 5.4 and 4.0 meters. Formulae for minimum bow height were also developed based upon regression analysis of calculated results of the probability of bow submerging in head seas with a significant wave height of 11.75 meters. This severe condition was assumed in order to ensure survival of the vessel in heavy weather.

The Sub-Commnittee on Stability, Load Lines and on Fishing Vessels Safety (SLF) agreed in 1987 that deck wetness and reserve buoyancy studies should be conducted concurrently, using the following criteria for deck wetness. WI

Sea spectrum - ITTC, 2 parameter
Significant wave height - H, = 10,7,4 m
Directions of waves - Head seas only.

These studies should be restricted to monohull ships of all sizes. **The ships should be considered for H_S = 10 m at zero** speed, for H, = 7 m and 4 m at 60% and 90% of full speed respectively. For the static swell up of the bow wave Tasaki's formula 1111 should be used

$$\frac{h_S}{L} = 0.75 \frac{B}{L_E} Fn^2 \tag{1}$$

in which h, = static swell up of the bow wave
L_E = entrance length on the waterplane

Damaue stability and sub-division
Around 1850 compartmentalization of ships using watertight bulkheads was first applied in the UK. as a means to pro-

mote survival of the ship after damage of the hull and water inrush. These first limited requirements were applied to passengerships but did not include rules for residual damage stability. Mostly losses of passengerships accelerated the process of regulation in this respect.

The SOLAS convention of 1929 set international sub-division requirements for passengerships, still excluding regulations for damage stability.

However, it was not until the 1948 SOLAS convention that some residual damage stability requirements were included. The sub-division requirements utilizing floodable length concepts were based on vague assumptions involving several 'factors' intended to take account of ship characteristics in an approximate way.

More and more the need was felt to use another approach for the determination of sub-division. If damage is caused by a number of variable (stochastic) parameters which may be described by a probability density distribution it is possible to handle it with a mathematical model usually called the <u>probabilistic method.</u> Such a method was referred to by Comstock and Robertson (1961) [12] and Wendel (1968) 113]. A Working Group on Sub-division and Damage Stability, set up by the IMO, developed probabilistic sub-division standards for passengerships which were adopted by the IMO-Assembly in 1973 as Resolution A.265 [14] as an alternative to the usual deterministic method based on 'factorial' requirements.

In 1985 it was decided that requirements for watertight sub-division and damage stability of cargo ships also could be based on the probabilistic method. Recently draft requirements for cargo ships (for L > 100 m only) have been completed to propose them as SOLAS-amendments in 1992.

It is the intention that in the future only the probabilistic method for passenger- and cargo ships will be used and the deterministic method will become obsolete.

To improve safety after some serious casualties (eg, Herald of Free Enterprise in 1987) a series of amendments of SOLAS have been accepted. The most important one (SOLAS '90) is that related to residual damage stability enlarging considerably some parameters (Figure 2) 11]. These regulations are applicable for new ships only which means that existing ships are excluded. There is quite a discussion going on about how to find and apply temporary provisions for existing ships, also with respect to the expected regulations for passenger- and cargo ships based on the probabilistic method. For sub-division and damage stability it may be expected that the same developments will be seen as those for load lines and stability: ie. a necessarily growing emphasis on dynamic conditions for damaged ships. Research in pursuance of recent casualties by Vredeveldt and Journse . (1991) C15] shows that dynamic behaviour of a ship due to sudden ingress of water cannot be neglected.

Fig.2:Righting arm against
heeling angle for
flooding condition,[l]
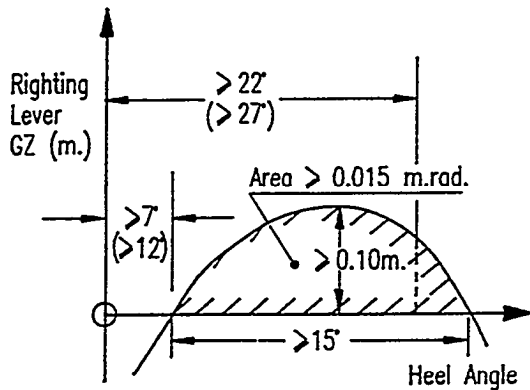
Note: ( ) are the criteria for
two-conpartment standard

Rol motion due to sudden water ingress.
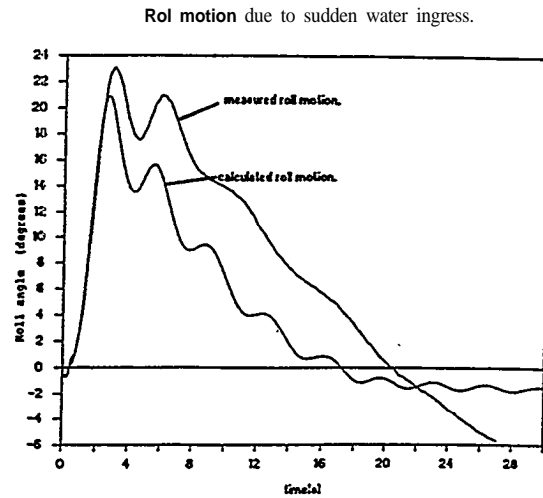
Fig.3:Roll motion as func-
tion of water ingress
time.[151

Rapid capsizing is caused by a drastic decrease of static
stability properties due to free surfaces, as well as by
inertia effects with regard to the rolling motion caused
by sudden inrush of water. See Figure 3 [151. A calculation
model was developed to determine this motion for a wing
tank crossduct configuration.
It should be kept in mind that the probabilistic method is
always based on the experience of the past only and should
follow new developments if possible, with whatever adjust-
ments become necessary.
For this reason it is again recommended for damage stabili-
ty and sub-division to start with authorization by recog-
nized institutes or organizations making use of experiments
and/or calculations taking into account the ship type con-
sidered.

MANOEUVRAB1L1TY

Up to now safety with respect to manoeuvrability has mainly
been considered in relation to actual collisions. This is
not amazing because recent statistics show that 1 vessel in
22 is involved in a collision each year. In 80% of these
cases other vessels were involved [16], However it is not
well known how many ships come into difficulties because of
bad manoeuvring characteristics or a lack of directional
stability. For a long time collision avoidance was consid-
ered to be purely a navigation problem, untill it was
recognized that safety against collision is also strongly
dependent on the manoeuvring properties of ships.

Present and proposed regulations

First formal regulations for collision avoidence were is-
sued by Trinity House in London in 1840. These regulations
were later included in the first SOLAS-convention in 1930.
Now they form a separate COLREG Convention which was ac-
cepted in 1972.
The first attempt to introduce some manoeuvrability crite-
ria was made in 1971 as a recommendation from the IMO ac-
cording to resolution A-209 (VII) about some data on ma-
noeuvring characteristics to be included in the Manoeuvring
Booklet on board of ships 1171.
A revision of this recommendation [181 followed in 1987 and
consisted of three parts:

1. Pilot Card
2. Wheelhouse Poster
3. Manoeuvring Booklet

The Pilot Card should provide the present condition of the
ship as information to the pilot.
The Wheelhouse Poster should be permanently displayed in
the Wheelhouse and provide information about the manoeu-
vring characteristics of the ship for easy use. The Manoeu-
vring Booklet on board should contain comprehensive details
of the ships manoeuvring characteristics. These data may be
obtained either from model tests or ship trials. The IMO
also described how to obtain these characteristics.
It should be clear that these recommendations may be help-
ful for safe ship handling, but criteria were not estab-
lished..
Different suggestions to formulate manoeuvrability stan-
dards have been proposed starting from Nomoto's (1966) 1191
first order equation:

$$T\ddot{\psi} + \dot{\psi} = K\delta_r \qquad\qquad (2)$$

with ψ = course angle
δ_r = rudder angle
K,T = manoeuvring coefficients

The coefficients K,T should be derived from manoeuvring
tests with existing ships and arranged on basis of ship
types. Establishing criteria for ship manoeuvring remains a
difficult matter for the IMO. The limit between safe and
unsafe is hard to determine even for the deep and still wa-
ter condition.
The problem becomes even more complicated if other impor-
tant elements are taken into account such as: human behav-
iour, operation and navigation, wind and waves, ship condi-
tion and restricted water.
To catch all these influences in one system appears to be

impossible, although planar motion model experiments and
manoeuvring simulation can strongly contribute to a respon-
sible judgment, in particular for individual ships or ships
of the same class.
Also for this aspect of safety authorization by recognized
institutes or organizations is almost inevitable on the
long term.

Shin condition and environment
The situation of- a ferry-boat leaving or entering the har-
bour is a rather complicated one to analyse. Many hydrome-
chanic elements are playing an important role such as: trim
and sinkage, the load condition (draught and trim), the in-
fluence of the bow wave, the effect of the bottom and/or
side walls of the channel and the presence of waves.
After the disaster with the 'Herald of Free Enterprise'
there was a heated discussion about the directional or
course stability related to the particular conditions of
the ship and environment at that time: with bow trim at
high forward speed on restricted waterdepth.
Bishop and Price (1988) published a study entitled 'On the
dangers of trim by the bow' 1201.
They put forward there that 'the vessels loss by hydrosta-
tic instability was preceded by loss of control. She
(Herald of Free Enterprise) became directionally unstable
at high speed in shallow water while trizuned by the bow'.
With the aid of linear equations of motion for the ship
motion in the horizontal plane the authors put forward as
condition for positive stability of the yawing, swaying and
rolling system:

$$\rho g \nabla GM \ [\ Y_v \ N_r \ + \ (mU - Y_r)N_v \ ] \ > \ 0 \qquad (3)$$

The first factor should be positive because the metacentric
height GM > 0.
The term between the brackets is the well-known criterium
of stability for the coupled yaw and sway motion for which
the manoeuvring coefficients Y_{vo} Nrr Yr and N_v only depend
on the underwater part of the hull form and consequently
also on trim and sinkage; m is the mass and U the forward
speed component of the ship. The stability criterion

$$[\ Y_v \ N_r \ + \ (mU - Yr{>}Nv \ 1 \ > \ 0 \qquad (4)$$

may be written as function of the trim

$$7 \ = \ \frac{T_{AP}p \ - \ TF_{pp}}{T_m} \qquad (5)$$

yielding

$$mU,(7) \ = \ 1 \ \frac{Yv(7) \ N2``(7)}{-N_v(r)}] \ + \ Yr(7) \qquad (6)$$

in which U_c = critical speed with respect to stability.

After some suppositions about the stability derivatives and their dependence on 7 analysis of condition (6), Bishop and Price (1988) came to the conclusion that trim by stern increases the critical speed above which instability appears. In the past, experimental research has been carried out to determine the hydrodynamic coefficients of the manoeuvring equations. Forced oscillation tests by a Planar Motion Mechanism (PMM) with a ship model have been used by Gerritsma (1979)[21] to determine these coefficients and the stability roots ϱ as a function of draught and trim by the stern. These experiments were carried out in deep water for two conditions viz. without rudder and propeller and with rudder and rotating propeller. For the last case a positive directional stability could generally be established. It also appears that the influence of forward speed on the directional stability is small compared to that of the draught variation and the trim. Without rudder and propeller directional instability was always present except for the condition of trim by stern.

The influence of trim on the hydrodynamic derivatives has also been investigated by Inoue et al (1981) as reported in WI . From these studies it appears that just as Gerritsma's (1979) study [Zl] showed the lateral drift force increases for trim by stern.

Also research carried out by Beukelman (1989) [231 shows that for trim by the stern the drift force indeed increases but the distribution over the ship's length is more symmetrical fore and aft resulting in a reduction of the drift force moment. The influence of waterdepth on the hydrodynamic derivatives for manoeuvring has been investigated by Hirano et al (1985)[24] and by Beukelman and Gerritsma (1983) 1251 .

These investigations showed an increase of the damping coefficients (drift force coefficient) Y_v and the added mass coefficient Y_{vf} with a decrease of the waterdepth. Measurements and strip theory calculations taking into account the influence of restricted waterdepth agree reasonably except for the damping coefficient Y,'in the aft part of the ship. To investigate the influence of waterdepth and trim on the directional stability of a Ro-Ro ferry ship PMM tests have been carried out with a model of the 'Herald of Free Enter-prise' at the Ship Hydromechanics Laboratory of Delft University [24]. See Figure 4 [26].

For all conditions considered a negative directional stability (positive root a) could be observed especially at high forward speeds-. See Figure 5 [26,27].

The influence of variation of waterdepth on the directional stability is generally small. However, the effect of the trim condition is more clear, showing an improvement for the case of trim by stern in deep water as shown in Fig. 5. Restriction of forward speed dependent on the waterdepth is strongly recommended.
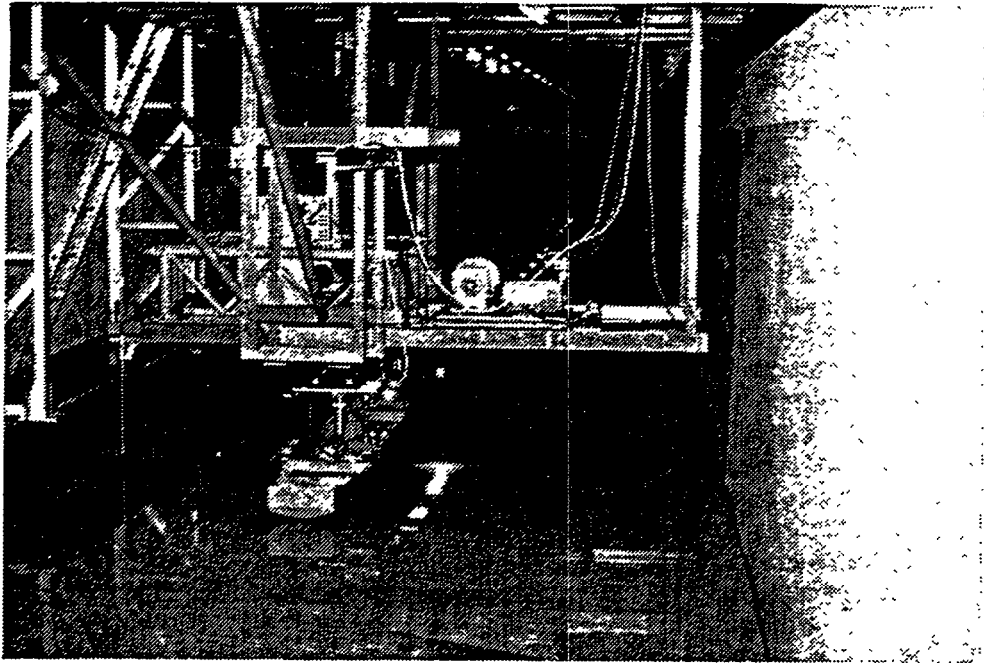
Fig.4:Experimental set up with PMM and ship model [26].

h = 12.5 m
L = 126.1 m
B = 22.7 m
T =   5.69 m
h/T = 2.2
o = Even keel
A = trim by the
    bow 0.75 m
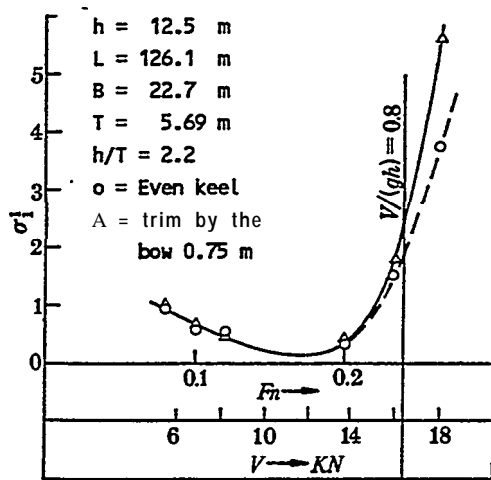
Fig.5:Stability roots of
     a roll-on-roll-off
     passenger ferry in
     shallow water.[26,27]

Calculation of the directional stability is up to now not possible in a satisfactory way because of the lack of knowledge about viscous influence. which is essential to determine the manoeuvring coefficients.
Further research is required in this respect.

Stabilitv and Control in waves
In the case of head and bow seas the frequency of encounter with waves causing yawing and swaying motion is rather high and since course or directional stability is usually large, serious difficulties seldom arise.
Quite different might be the situation of a ship travelling in quartering or following seas, especially if the frequencies of wave encounter are low so that large roll and yaw moments may build up.
The definition diagram for a ship operating in regular waves is shown in Figure 6 from C281.
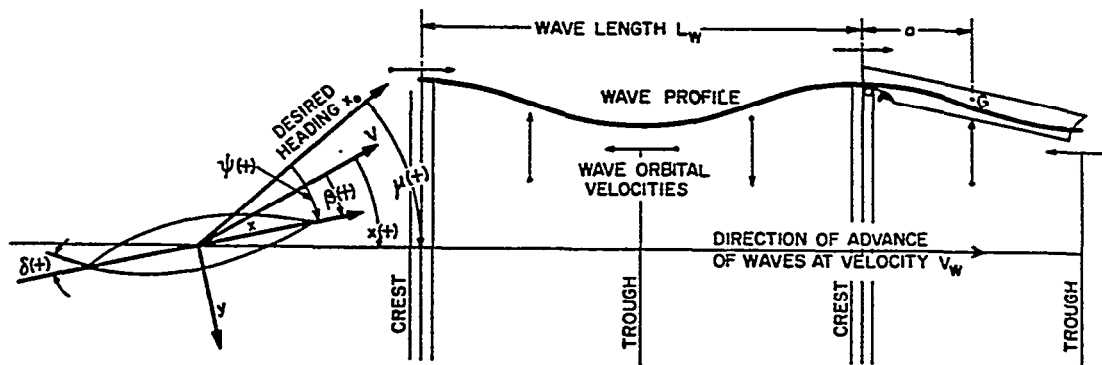
Fig.6: Definition diagram for a ship operating in regular
       waves. [281

The frequency of encounter between ship and wave is:

$$\omega_e = 2\pi \frac{(V_w - V\cos \chi)}{L_w}$$ (7)

where: ω_e = frequency of encounter with component waves
              = $2\pi/T_e$
          L_w = length of wave components
          ·· = ship velocity
          V_w = component wave velocity
          χ = angle from ship velocity vector to wave
              direction of advance.

The rolling motion may be introduced by the rudder motion
but also by the variation of the metacentre M dependent on
the position of the ship in the following or overtaking
wave and the frequency of encounter approaching the reso-
nance rolling frequency.
The characteristics of the course control system for such a
case are of critical importance. If the wave and ship speed
are almost equal a situation may arise with zero frequency
of encounter so that the wave crest may be present at the
midship section for a long time. The metacentric height GM
will be reduced because of this position but also due to
for example high forward speed influence in some cases
Such a semi-static situation can potentially lead to
capsizing. Another critical phenomenon in astern seas is
broaching (turning broadside to the waves). When a ship is
positioned as shown in Figure 6 with its stern at a crest
and its bow in-a trough, the orbital wave velocities induce
a destabilizing yaw moment on the ship unless x and p are
precisely zero. Extensive research on this subject has been
carried out by ie. Wahab and Swaan (1964) 1291.
Even with controls working there is a great danger of
broaching in the above mentioned situation, a danger in-
creasing with the wave height.

A reduction **of** the danger of broaching can be achieved by an increase of the fin area aft improving the smooth-water controls-fixed stability as shown by Eda (1972) C301 in Fig. 7 and by a right choice of the gain constants for steering control. For a more reliable judgment about the safety of the manoeuvrability of ships in waves, especially in following seas, experimental and theoretical research is required for the ship considered. The calculations should be carried out with a time domain model in six degrees of freedom including wind influence.
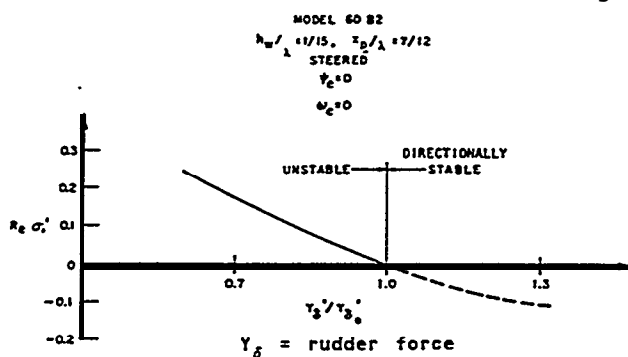
Fig.7:Effect of rudder size in
      following sea. [30]

SEAKEEPING CONDITIONS

Motions
Extensive research on seakeeping since the sixties delivered useful knowledge for the determination of ship motions in regular and irregular waves. Many reliable computerprograms were developed and may be used for optimization of the design or with respect to the operability of a ship in a seaway.
These computer-programs are most commonly based upon strip theory (2D) or diffraction theory (3D) both starting from linearized potential theory. So, viscous effects are not included but should be added from experiments in particular for the rolling motion. Calculation and experimental verification of hydrodynamic coefficients like hydrodynamic mass and wave damping as well as wave forces together with their distribution over the ship's length meant a valuable contribution to the development.
In this respect Gerritsma (1991) C271 should be mentioned who by means of forced oscillation technique determined the longitudinal distribution of the above mentioned parameters for a segmented ship model and found good agreement with calculated values, including shallow water conditions.
After determination of the response functions **of** ship motions the behaviour in an irregular sea is obtained as shown in Figure 8 from Karppinen (1987) in 1311.
This method may be used for all ship types and conditions with a restriction up to now for the following situations:

  1. at high forward speeds: the relative motions
  2. cases with viscous damping ie. barges, shallow water
  3. non-linear motions mostly introduced by high waves.
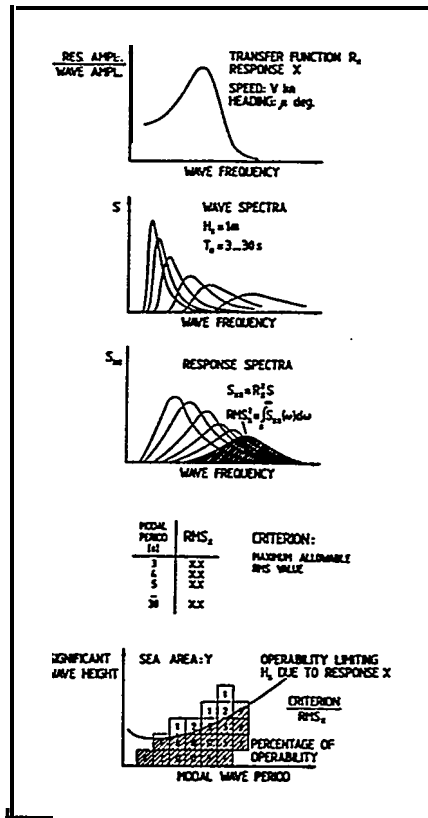
Fig.8:Prediction of the percentage of time of operation at a particular speed and heading. 1311

Strip theory (2D) may be applied for most ship forms even for simple semi-submersibles and catamarans in a moderate sea, but also for shallow water conditions. For more complicated underwater bodies at almost zero speed or with the presence of other objects and/or side walls it is preferred to use 3D diffraction programs. All these computerprograms are valid for linear conditions only which means that the response functions of the ship show a linear relation with the wave elevation. This also holds for the phenomena derived from the ship motions such as accelerations, relative motions, shipping (deck wetness) and slamming. It is of course worthwhile to investigate to what extent the linear theory may be used for real sea states. Generally spoken these programs may be applied to determine operability at sea but it is known that ie. capsizing in ultimate conditions is a non-linear phenomenon.

Chaos and caosizing
Danger of capsizing in bow or head waves is not of primary importance. Kaplan and Bentson (1986) provided a mathematical model in six degrees of freedom as basis for a computer simulation to predict capsizing in steep head seas 1321.
Non-linear large amplitude rolling in quartering and following narrow band seas is by far the most dangerous motion with respect to capsizing as already indicated before.
Considering a single degree of freedom system sub-harmonic, harmonic (synchronism) and ultra-harmonic oscillations may occur at resonance frequencies as shown in Figure 9 from Francescutto (1991) [33]. Because of non-linearity the roll response curve will show a bended character leading to multi-valued responses for one frequency. See Figure 10 from Soliman (1990) C341.
Trajectories which do not lead to capsizing will eventually settle down to a bounded stable motion, for example periodic or sub-harmonic oscillations. Such a stable steady state
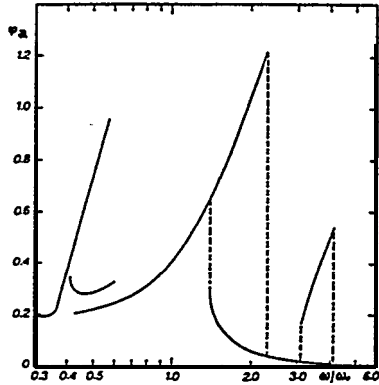
Fig.9:Rolling amplitude pa of the steady-state oscil-lations versus tuning ratio w/w, in all reso-nance regions. [33]

Here the solid lines represent stable steady state response; arrows indicate a jump to and from resonance. Dashed lines represent the unstable steady state response.
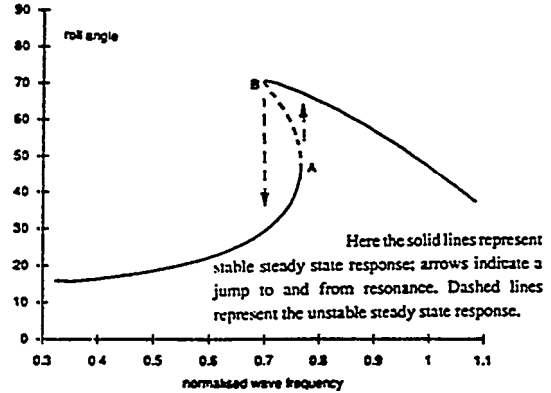
Fig.10:Typical response curve. 1341

motion is called an <u>attractor.</u> All starting conditions which generate trajectories that tend towards an attractor are defined as basin or domain of attraction.
The combination of the domains of all the safe attractors is termed the <u>safe basin.</u>
Near resonance frequencies there is a region representing the unstable steady state response with typical jumps to resonance at a cyclid fold <u>bifurcation</u> (saddle-node). The trajectories are usually presented in a phase space diagram showing the roll angle and the angular velocity as demon-strated by Rainey and Thompson (1991) C351 in Figure 11.
The shaded area is the domain of attraction or safe basin.
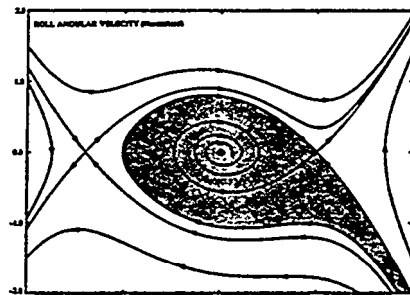
Fig.11:Trajectories in phase space for a ship in still water. Shaded area is the "domain- of attractrion or "safe basin".1351
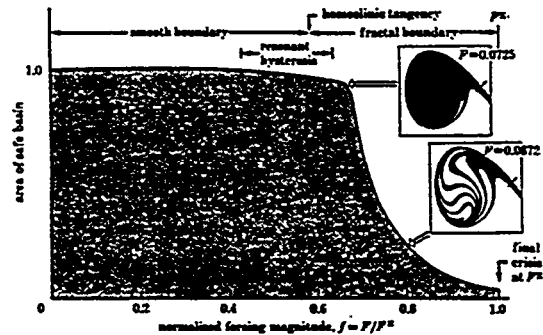
Fig.12:Safe basin area as a function of wave height. [351

Non-linearity may be introduced by variation of the right-ing arm, variation of roll damping and/or variation of wave exciting forces in a transient wave train as shown in Fig. 12 [35] where the safe basin is suddenly eroded leading to

chaos and finally to capsizing.
Such a dangerous situation may arise in sea conditions very
near synchronism with heave or pitch. In this case there is
even a strong sub-harmonic roll influence because the roll
period is about two times the heave period, so that phase
lag can play an important role.
It is therefore that Rainey and Thompson (1991) suggest in
[35] that a useful way to quantify the stability of a given
ship or ocean vehicle is to subject the model of it to a
train of regular transient waves with increasing wave
heights. The critical wave height or wave steepness can be
plotted against the wave period for various fixed values of
wave direction, heel angle and forward speed. This results
in the Transient Capsize Diagram as shown in Fig.13 [351.
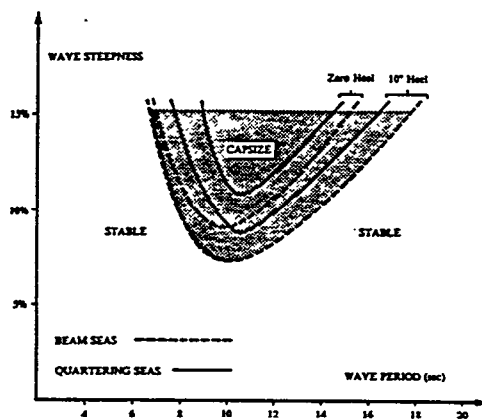
Fig.13:Transient Capsize
Diagram for a ty-
pical ship. 1353

It is presented as an attrac-
tive fast procedure although
it is only a first step in
analysing the possibility of
a capsize.
In further research other in-
fluences such as those of
current and waves should be
taken into account.
It is also possible to ob-
tain these Transient Capsize
Diagrams by computer simula-
tion taking advantage of re-
cent developments in non-li-
near influences on the behav-
iour of ships and marine
structures.

Motion induced Dhenomena

For the safety of marine vehicles ultimate conditions are
of primary importance, but sound operational conditions may
also contribute significantly to the safety of crew, pas-
sengers, ship and cargo. Violent motions and accelerations
may cause serious degradation of the performance of the
crew and less comfort or seasickness for the passengers.
For cargo and ship, accelerations, deck wetness and slam-
ming may lead to damage. If criteria for these phenomena
are known or accepted prediction of occurrence and opera-
bility is possible in the way as shown in Figure 7 1311.
Although these seakeeping criteria are a subjective matter
it appears useful to determine preliminarily such average
criteria from a large amount of full-scale seakeeping data
as was done by ie. Karppinen (1978) 1311.
Such root mean square criteria are presented in Table 1
[3l] for the roll angle and the vertical and lateral acce-
lerations as percentage of the acceleration of gravity g.
Even for high speed planing boats the root mean square va-

lues for vertical accelerations may be determined by linear strip theory as shown by Blok and Beukelman (1984) [36]. For prediction of peak values , however, a non-linear approach in the time domain is essential as shown by Keuning (1992)[37].

Table 1:Criteria with regard to accelerations and roll [31]

Root Mean Square Criterion			Description
Vert. acc.	Lat. acc.	Roll	
0.20 g	0.10 g	6.0°	Light manual work
0.15 g	0.07 g	4.0°	Heavy manual work
0.10 g	0.05 g	3.0°	Intellectual work
0.05 g	0.04 g	2.5°	Transit passengers
0.02 g	0.03 g	2.0°	Cruise liner

Depending on ship type or mission (merchant- or passenger ship) and place on board it is necessary to adapt the criteria of Table 1. For prediction of deck wetness the relative motion at a local position should be known which means a combination of the displacement because of ship motions, the wave elevation including the bow wave, and the dynamic swell up of the incoming waves due to the moving ship. In the operability predictions deck wetness is defined to take place when at a particular station the amplitude of the vertical relative motion exceeds the actual freeboard. To establish criteria, a permissible degree of deck wetness should be distinguished. Slamming (peak pressure due to impact) and deck wetness criteria have been defined in terms of critical probability (events per hundred wave encounters). The general operability limiting criteria often proposed are 0.03 for slamming and 0.05 for deck wetness. The critical number of slams per 100 wave encounters or the critical slamming probability against the length between perpendiculars for merchant ships is shown in Fig. 14 [31]. The restriction of this limit results mainly from fullscale

data. In most prediction methods Ochi's (1964) [37] definition of a slam has been used saying that slamming occurs if the foreship (at about 0.10L after FPP) emerges from the water and the vertical velocity relative to the water surface exceeds a critical value of
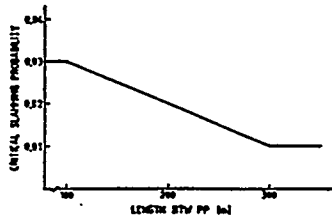
Fig.14:The slamming criterion for merchant ships. [31]

$$V_{cr} = 0.093 \sqrt{gL} \qquad (8)$$

with L = length between perpendiculars
     g = acceleration of gravity.

For some cases ie. modern high speed craft, this criterium
based on the vertical velocity only is not sufficient.
Recent research on wedges [39] hitting the water surface
shows that the forward velocity also has a strong influence
on the impact pressure while the highest pressures could
only be observed at angles of about 1 to 2 degree between
hull and water surface. Prediction of these pressures shows
proportionality to the squared vertical and forward speed.
Besides local high pressure loads on the hull slamming also
causes ship vibrations which in turn increase the total
ship load significantly.

INTACT STABILITY OF HIGH SPEED CRAFT

Various types of advanced high speed vehicles are achieving
their high speeds by means of special design features or
devices such as dynamic lift or fan-generated lift. The
most commonly used types are shown in Figure 15 [28].

ACV   = Air Cushion1 Vehicle
SES   = Surface Effect Ship
SWATH = Small Waterplane
        Area Twin Hull.

FIJWING I-wcfmaL Acv   s s   SWATH
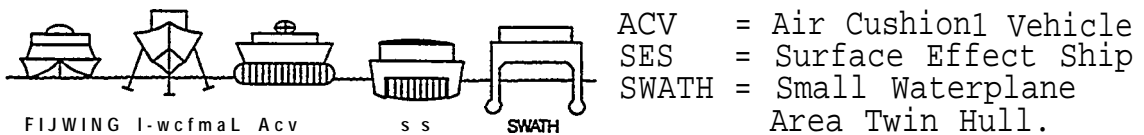
Fig.15:Types of Advanced Marine Vehicles. C281

For these types of vehicle separate treatment is required
when dealing with intact stability for displacement condi-
tion generally at low speed, and operation at high speeds.
When operating at low speeds in the hullborne or disDlace-
ment mode the stability problems are. almost similar to
those of conventional displacement ships. However, although
the requirements for adequate stability and buoyancy are
simular it holds that for the displacement mode these ship
types show peculiar qualities such as low freeboard, large
shifting of the centre of gravity, influence of entrapped
air pressure, etc. Specific intact stability criteria for
advanced marine vehicles in the displacement condition for
the U.S.Navy are presented by Goldberg & Tucker (1973)[40].
Planing boats, catamarans etc. have a large transverse me-
tacentric height GM in the displacement mode because of the
beamy condition. Capsizing of multihull vessels, especially
in high critical waves, is possible in spite of high initi-
al stability and righting moment curve. Transverse stabili-
ty and safety of most of the ship types are highly depen-
dent on the extension of the GZ-curve and the area under
the curve for heel angles greater than 50 degrees. At the
high speeds for which advanced marine vehicles are designed
the stability characteristics are quite different from the
displacement condition. In comparison to conventional ships
high speed vehicles are much more sensitive to the influ-
ence of lift forces and air pressures associated with

motions in waves. From these influences a sensitive behaviour follows with respect to transverse and longitudinal stability, which might be controlled by simple means as shifting ballast, wedges, reducing speed or by more complicated means like transom flaps or horizontal control surfaces. Longitudinal stability, expressed as deck diving probability, is a very serious problem in following and quartering seas as shown by Jullumstroe (1990) in C411. Reduced foil-lift due to wave particle velocity, out of water situations and pitch angle close to or larger than zero-lift angle may lead to bow-deck diving. This phenomenon occurs frequently for wave length ship length ratio's between 1.0 and 2.0 even in moderate wave heights if ship speed is equal or greater than wave speed.

Model tests and computer simulation of deck diving in waves show good agreement [40]. However, it will be clear that it is hardly possible to design safety rules for all those ship types in different situations.

The IMO-recommendation concerning stability of high speed craft is laid down in resolution A-373(x), *Code of Safety for Dynamically Supported Craft* [42]. Transverse stability other than for hydrofoils is not covered by these recommendations, while longitudinal stability has not been taken into consideration.

CONCLUSIONS AND RECOMMENDATIONS

Future hydrodynamic 'research related to safety should be aimed at:

1. directional stability of fast ships in restricted water
2. chaotic non-linear behaviour in following seas
3. phenomena derived from motions, especially slamming, to take into account the danger of damage to the ship and degradation of the performance of crew and passengers
4. ship behaviour due to sudden water inrush.

In view of the necessity to consider the dynamic behaviour for ship safety, which is even more stressed for modern high speed craft and the impossibility to design rules and criteria for all ship types in dangerous and dynamic situations, it is advised to require for each ship(type) a certificate from authorized institutes or organizations. These institutes or organizations should with respect to ship safety also consider, if possible using preliminary criteria:

- directional stability in defined conditions
- probability of shipping water and slamming in certain sea-states
- degree of degradation of the performance of crew and passengers based on accepted acceleration criteria

- motions and stability during water ingress
- behaviour in transient following waves with diffe-
  rent heights (Transient Capsize Diagram).

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THE EFFECT ON MARINE SAFETY OF MEN, MACHINE AND REGULATIONS

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ABSTRACT

There is quite a large range of measures available to improve marine safety, however, demands will not always be satisfied. Within this paper some weak areas within the man-machine-environment system, governed by rules and regulations, are hightlighted. A simple model for detecting system disturbances is presented and clues for improvement are given.

MARINE SAEETY

The significance of safety within ship operation, similar to probably most other fields of professional activities, can in some respects be compared to religion: everybody confesses verbally to be convinced of and to follow established rules at all times but only some really do so. Operators and workers often feel bothered by the restrictions caused by safety rules and owners and manageres regard safety mainly as a cost factor the benefits of which are very difficult to realize. Therefore the significance of safety is about that of law. Most people reluctantly accept its necessity but take every opportunity to bypass established rules.

This is certainly a provocative introduction but within a paper, which has to be brief and concise, provocation should present a permitted means to elucidade circumstances and to stimulate discussion.

The term marine safety is somewhat vague and will be understood within this paper as "all measures and conditions minimizing potential dangers and harm to men, objects and environment which might be caused by operating vessels". Safety measures can be established within different areas:

  technicalmeasures and provisions when manufacturing a system, or when operating a system,

  organizational measures within a working process and

  behavioural measures when operating a system.

Additionally passive measures, such as man protection by special clothes (hard hat etc.) are possible.

There are three groups of people to be protected by safety measures: the operators directly involved in the working process, the co-workers and company members only indirectly participating but having some chances to observe and influence the working process and hence safety and finally those third parties not being involved at all but who might become exposed to results of incidents. There might be important interactions between all three groups by either checking the working process or specifying requirements.

An important aspect of shipping is that vessels are necessarily moving around. Third parties might not even become aware of potential dangers, and that shipping is an international business under tough competition. Thus there is little access for improvements on a national basis only.

As a rule, only spectacular events draw the attention of the public to certain conditions. Such casualties as the grounding of the "EXXON VALDEZ", the capsizing of the HERALD OF FREE ENTERPRISE" and the fire aboard of the "SCANDINAVIAN STAR" have caused more doubts about shipping operation and performance than the large number of smaller incidents. One should make advantage of the increased willingness of owners, operators and administrations to improve marine safety resulting from such spectacular accidents.

LEGAL ASPECTS

The whole human life is accompanied by laws and regulations to obtain order and justice within society. Our modem society is considerably influenced by technique. Technical rules therefore have to be part of laws and regulations. However, this requirement leads to a contradiction. Whereas technique is a dynamic subject, experiencing fast changes, the legal system is rather static, it follows general developments only very slowly. This is mainly due to the time democratic processes require to establish and modify law. However, it is not only a disadvantage but also a benefit regarding legal security and citizens' confidence into law. As a result it can be said that law and regulations will never be able to precisely define all facts and circumstances arising in practice. Technique, however, must be specified in great detail.

Resides the preventive character of law and regulations clear and unambigious principles are needed to decide after an incident who has to be blamed and, more important within business life, which persons or parties are to be held liable for damages. Since the more general legal comments- seldom allow for a simple decision on who is to blame, a whole bundle of tools was developed to supplement laws and regulations.

The state of the art describes in detail how a technical system should be constructed and how it should function and be operated. Agreed standards worked out by privately organized bodies cover a large ara of details but are not always up to date. The performance of standarizing bodies is not very different from legislative bodies and therefore comparably slow. Thus a vast market was created for experts, the consultants. There is quite a number of private consultants offering their services but also institutions, normally dealing with a certain professional area, are willing to provide their knowledge if required. Therefore law and regulations only present the shell of the operational system, the real

content has to be added by mostly private efforts. If a case is brought to court, the legal procedure requires a lot of time and large budgets. Opponing parties both present their impressive staff of experts trying to convince the judge that the other party has to be blamed. The more the case goes into technical details the more the judge becomes dependent on experts. To remain provocative, this procedure well feeds a large number of people without guaranteeing justice.

MAN-MACHINE-ENVIRONMENT SYSTEM

To discuss improvements, a model of the process under consideration is required. Since ship operation is rather complex, i.e. complicated and dynamically changing, models, only presenting a static view of the process should be treated with care. On the other hand a model is an appropriate method to structure brain storming. But is must be emphazised that at the end a thorough validation is needed before putting the measures into practice.
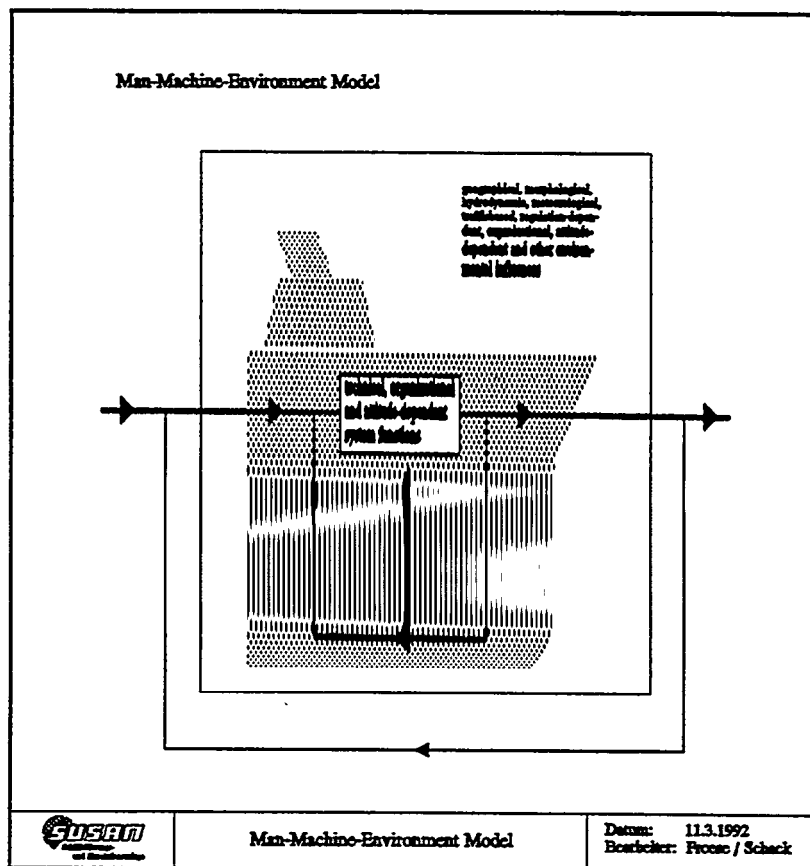
Figure 1: Man-Machine-Environment Model

Figure 1 shows a man-machine-environment model including two loons, the internal vessel's

must lead to emetic functions, Becausedif'ferentareas require different experts it is wise

to agree on an a "shell model" hosting other more detailed models. At the end of' every improvement process related to a special area one must come back to an overview for not neglecting undesired interactions between the area under consideration and others.

operational objectives	Level 6	
⇩ ⇩	Disturbance Level 5-6	
⇧ ⇧		
personnel	Level 5	
⇩ ⇩	Disturbance Level 4-5	
⇧ ⇧		
actual operation	Level 4	
⇩ ⇩	Disturbance Level 3-4	
⇧ ⇧		
required equipment functions	Level 3	
⇩ ⇩	Disturbance Level 2-3	
⇧ ⇧		
available equipment functions	Level 2	
⇩ ⇩	Disturbance Level 1-2	
⇧ ⇧		
available technical equipment	Level 1	

Figure 2

	Simple Layer Model	Datum: 7.4.1992
FUSAN		Bearbeiter: Fr / Sk
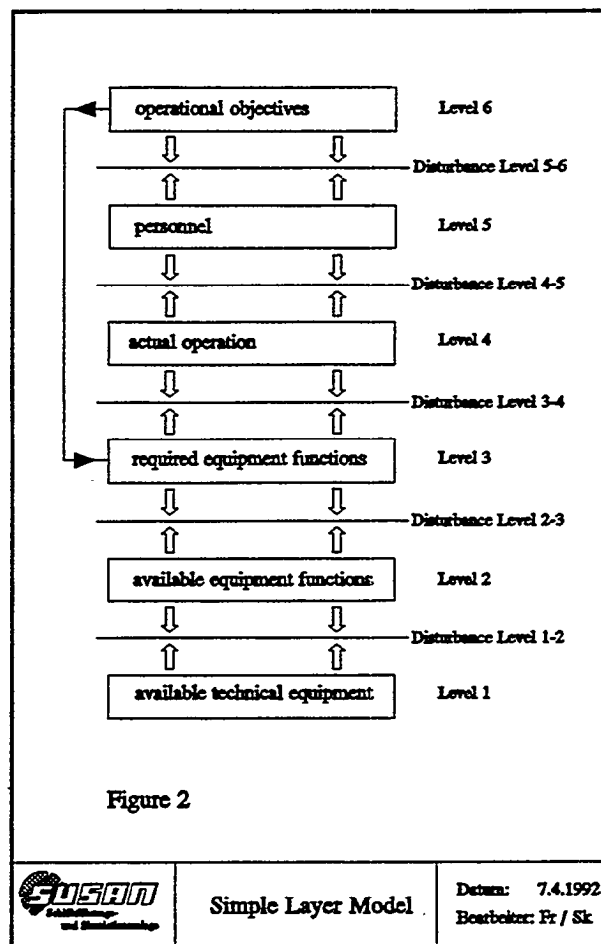
Figure 2: Simple Layer-Model

Figure 2 shows a layer model to be applied for a special area such as e.g. a ship's bridge. Such a simple layer model is quite appropriate to detect disturbances which might lead to an

Looking back then to level one it must be checked if all technical modules, required by planned functions are installed and properly working. If this is not the case, disturbance level l/2 can be specified.

On level three functions as required by tasks to be performed shall be described. Regulations, rules and recommendations having an impact on task performance must be taken into account.

If required functions do not absolutely match with available functions, disturbance level 2/3 can be specified. People not properly equipped for task solving act unsecure.

Level four describes the actual application and operation of said equipment observed in practice.

Often operators do not use technical devices according to operational rules or according to their assigned purposes. Thus, if level four does not properly fit onto level three, again possible causes for disturbances can be detected and described within disturbance level 3/4. On this level a concentration of causes for casualties will be found.

Level five contains details on staff, their formal qualification, experience and attitudes (behaviour).

Within an ideal working environment staff qualification should exactly fulfill operational requirements described within level four. Shortcomings may l%d to damages and incidents, overprovision to frustration and reduced job satisfaction, and as a consequence also result in incidents. Therefore both cases shall be documented within disturbance level 4/5. It is argued that attitudes present the main cause for accidents, thus behaviour must be carefully investigated and defiencies laid down within the same disturbance level, too. On this level another concentration of causes for casualties will be found.

Level six finally describes in detail objectives and tasks to fulfill these. The content of level three is derived from this level.

The described approach may already deliver desired results within a clearly limited area like a ship's bridge. If more complex areas have to be considered, additional levels resp. sub-levels reserved e.g. for regulations only might be required. The purpose of this example is to elucidade how models can be applied to determine interactions between different areas. A model is also an appropriate means to clarify desired systems performance and objective. Under ideal conditions the different levels of the layer model fit exactly upon each other. Although this never happens in reality the knowledge of disturbance levels helps to become alert in time and thus to avoid undesired events.

IMPROVEMENTS POSSIBLE?

An overall objective within marine safety is to improve conditons before they can lead to an incident. A well approved approach to obtain this goal is the analytical method based on

models as briefly explained the preceeding chapter. The disadvantage of this methods is that it requires considerable efforts and results are not always satifactory because not all circumstances encountered in reality can be forseen. Therefore the outcomes from casualty investigations play an important role to improve theoretical analyses. By studying incidents having occurred in reality one becomes sensitive for combinations of conditions and circumstances resulting in inherent potential dangers. This certainly sounds obvious but it is very difficult to do in practice.

There are the aspects of civil law, i.e. liability which the parties involved are mostly concerned about after a severe marine accident. And it is common procedure to hold back any information which could be used by counterparts, thus results of court cases much more demonstrate the ability of lawyers than elucidating causes and conditions of a casualty. If we really want to learn from marine incidents, to reduce the number and severeness of future ones, the marine casualty investigation system has to be changed. Probably a lot can be learnt from the aircraft industry where independent investigation offices immediately commence there search for causes and conditions after a crash or even in case of a near-desaster. Their most important source of information is the flight recorder providing all relevant data.

Some shipping countries, too, have qualified investigation bodies but in general they lack authority power and budgets. And there is hardly any other possibilitiy to obtain information than by interviewing people very reluctant to clarify circumstances. Other serious constrains are national responsibilities leading to quite different treatments of a cases and often enough national sovereignty is rated higher than common interest to avoid marine desasters. A severe pollution will disregard national borders and so should not casualty investigation offiCES.

However, competent investigation does not only caU for efficient administrations, access to scientific institutions dealing with relevant areas from computer science to psychology is a must. The ideal solution would be an investigation office operating jointly with a maritime rather than a marine research facility. Practice changes so fast nowadays that an investigation cannot be based on the experience of former seafarers, as it was common practice so far.

SIMULATION OF THE MAN-MACHINE-ENVIRONMENTSYSTEM

When applying an appropriate model of the man-machine-environment system or a relevant part of it, all physical facts can be calculated. If this is done by computer feeding the model with data and processing its algorithms this is called simulation. If this process can be performed faster than in reality because of the high processing speed of a computer, this kind of simulation is called fast-time simulation. There are several such tools available relieving us from the burden of endless calculations.

However, within the man-machine-environment system man plays a key role. To reliably assess this role, simulated processes must be run in real-time. Within an appropriately designed working process as e.g. navigating a vessel along a fairway, ideal routine workload

conditons result in perception, mental processing and decision sequences which require about 70% of the operator's capacity. Higher workloads would occupy remaining capacity which should be reserved for extraordinary situations or even overload the operator, i.e. he is liable to miss vitul information or actions. Considerably less workload may lead to boredom and fatigue and hence also to reduced perception of vital information. Real-time ship simulators provide an ideal environment to investigate the influence of technical, organizational and behavioural factors on performance of human operators. Figure 3 gives an overview over methods of ship simulation and figure 4 shows an example of a simulator allowing for full mission performance.
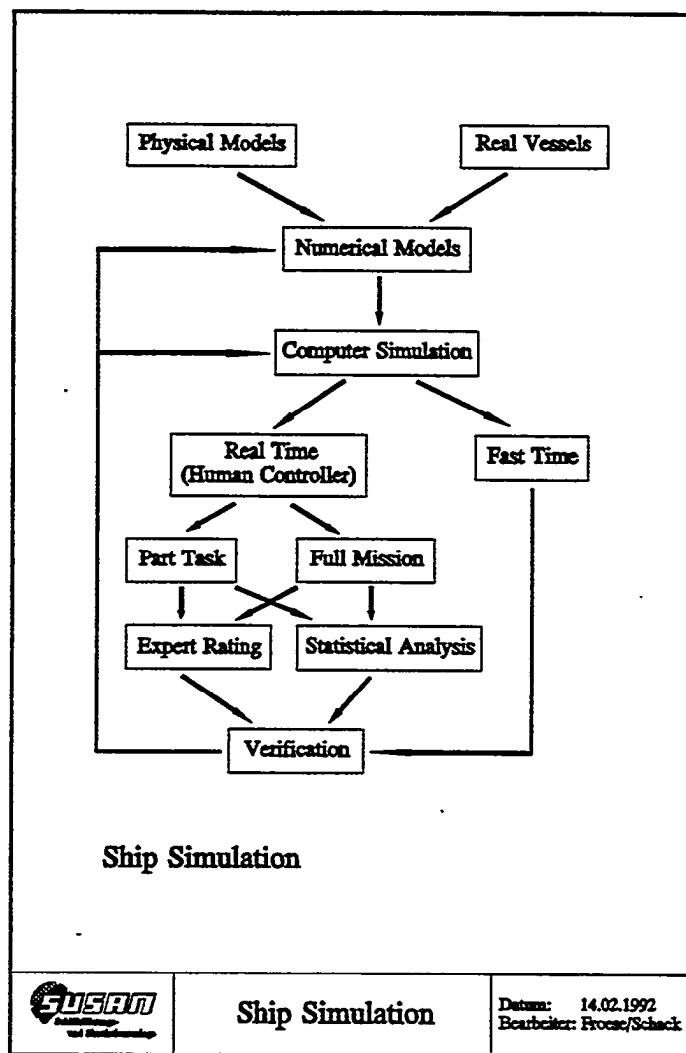
Figure 3: Methods of Ship Simulation
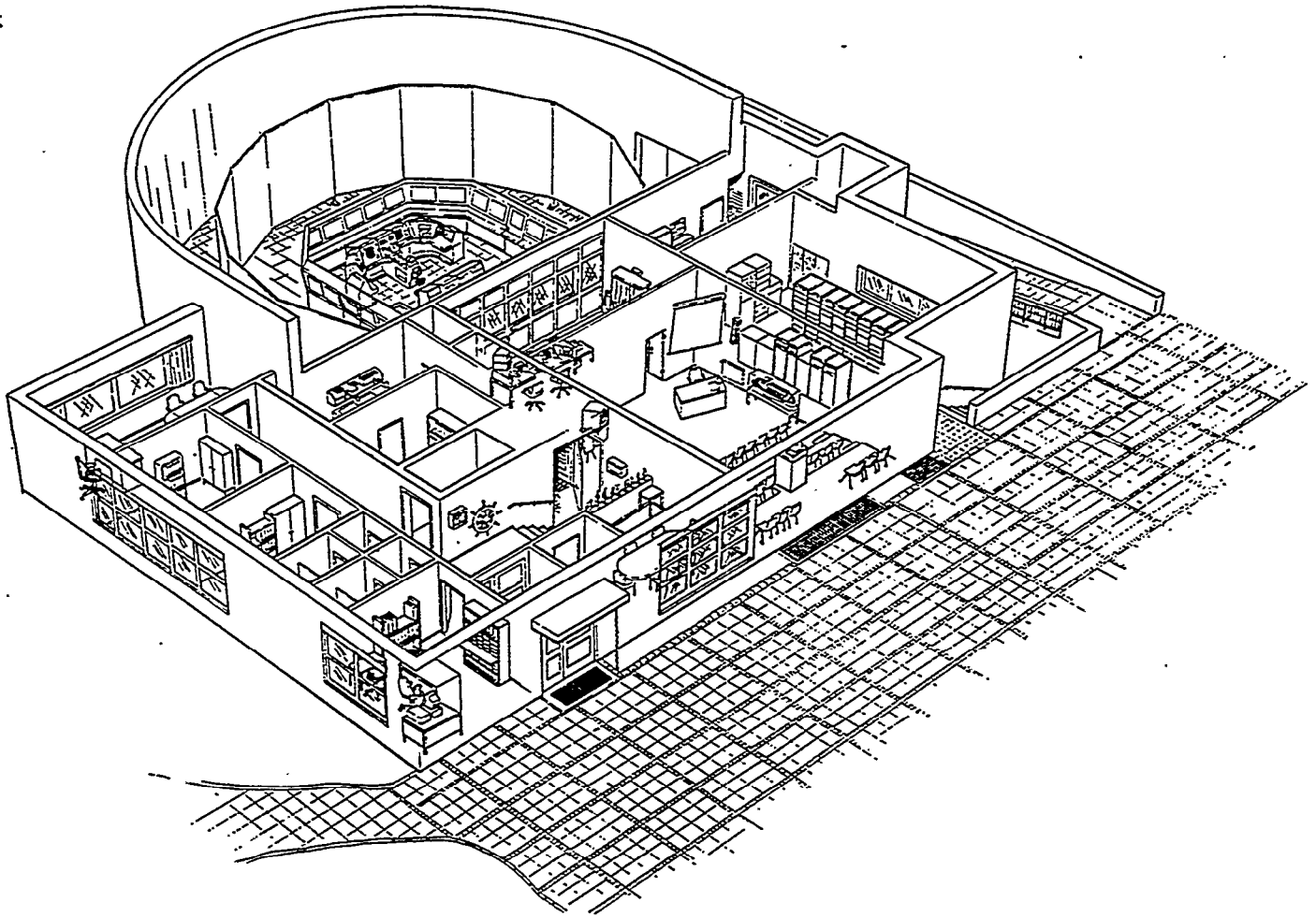
Figure 4: Full Mission Ship Simulator (SUSAN Hamburg)

The controlled conditions within simulation and the possibility to observe performance, to record all relevant data and interview operators provide good access to all operational processes. However, there is no guarantee that operators in simulation behave exactly in same way as they would in reality. There are some hints that e.g. rules will be less often violated in simulation because probands feel surveikd. Therefore all obtained results require verification.

There is an additional advantage of operating a ship simulator for training and research purposes, which should not be underestimated. Whereas seafaring normally takes place remote from investigating bodies and hence assessment projects are very time and budget consuming and will cover very limited areas, a simulator provides a constant discussion

platform with seafarers and other involved persons like pilots, tug masters, vessel traffic management system operators, administration people etc.. Acting persons change quite often, thus a broad spectrum of skills, knowledge, attitudes, experience and opinions is provided. From about 10 years of experience within such an environment some remarks on the effect on marine safety of men, machine and regulations can be made.

SOME REMARKS ON THE EFFECT ON MARINE SAFETY OF MEN, MACHINE AND REGULATIONS

It is argued that the safest ship operator is an appropriately educated and trained beginner! Such a person certainly lacks experience and se&confidence but is extremely alert and willing to ask for the master's assistance whenever uncertainities arise. The more experience without serious incidents is gained, the more people tend to become overconfident, resulting in unsafe attitudes. It was proven [l] that special training aiming at improvement of performance led to an increased number of accidents. The theory behind such surprising attitudes states [l), that men estimate actual risk and compare it to accepted maximum risk. Then e.g. a car driver after having participated in a special driving training programme will drive at higher speeds and accept more dangerous situations than before because he feels he can cope with these. The same applies to increased technical safety. Thus the invention of radar or later ARPA did not reduce collisions. To again apply an example from car driving, German car insurance companies allowed for a 10% premium bonus for cars equipped with automatic brake systems (ABS) but that was cancelled after 1 year because it clearly showed, that those cars were significantly more often involved in accidents. It therefore must be accepted that increased safety cannot directly be obtained from either better training or better equipment. This should not mislead to not investing into both areas. What we must learn from stated experience is that parallel to those investments both, individual overconfidence and risk acceptance level must become reduced by behavioural measures.   '

It seems that simulated reproduction of conditions which led to severe incidents results in improved awareness of potential dangers and hence safer attitudes. Practioners often are surprised when learning that most accidents are not preceeded by unambigious warning signals but are generating out of conditions experienced every day. It is, however, felt, that such improved attitudes may fall back very soon (compare behaviour of car drivers passing a serious road accident; they tend to drive slowly and carefully just beyond the site of the accident but get back to their original behaviour after some more kilometers).

The more complex technical systems become, the more difficulties will men face to build up a "mental model".of what happens within all those "black boxes". This is no problem as long as systems applications and output exactly fit to operational conditions. Technical disturbances or unexpected situations, however, require actions diverging from routine. The operator then will experience difficulties in estimating which system inputs will lead to which results. Whereas routine operations ask for a selection from known alternatives, he is suddenly confronted with a real problem solving task, difficult to be mastered if acting within a complex system, the functions of which are not well understood. It is therefore recommended to allow for cutting off automated interfaces between system components and modules to give the operator a chance to get right into the process and view processed

results from known inputs. It is further recommended to simplify systems. This will not only lead to an easier understanding of system's functions but also result in less malfunctions and allarmS.

Whenever searching for improvements of marine safety it must be understood that, different from most other operator tasks, within navigation it is impossible to foresee necessary actions. Internal systems interfere with outside conditions and a larger number of parallel actions concerning completely different areas and objectives might be urgently required. Furthermore most external information can only be perceived by man's visual or aural "input channels", i.e. eyes and ears. No technical sensors allow for automated perception. These circumstances shall support pleading for rigorous simplification of systems and abandonment of all "nice to have" features in favour of systems and functions covering just what is required.

Regulations, rules and recommendations from administrations, company owners and others seem to rather aim at having an excuse at hand if something goes wrong than supporting practice. The often cited "Standards of Training, Certification and Watchkeeping (STCW)", an IMO document adopted by most seafaring nations, presents a good example. All administrations feel happy about having established the standards believed to ensure sufficient qualified seafarers. In fact these standards are only guidelines giving a rough idea of rather the objectives than clear and unambiguous requirements. The minimum lmowledge requied for certification of masters and chief mates e.g. amongst many others reads: "Understanding fundamental principles of ship construction and the theories and factors affecting trim and stability and measures necessary to preserve safe trim and stability." [2] It becomes obvious that the terms "understanding", "fundamental principles", "factors" and "measures" will be interpreted fairly divergent and little "standard knowledge" will result from such guidelines.

The IMO Sub-Committee on Safety of Navigation within its report on 37th session from 4th October 1991 negotiated the toopic "bridge procedures". One member state proposed to standardize procedures and to promote procedure training and procedure handbooks,, check lists etc. on board.

There is certainly nothing wrong with that approach but from experience it is likely that finally the poor mariner will just receive an additional manual for his book shelf on the bridge already flowing over from piles of paper nobody can know by heart anymore. It is obvious that when suddenly confronted with extraordinary conditions no mariner is able to search for books showing how to cope with the situation. However, after having experienced a casualty he will find himself at the court of inquiry where the experts, after having studied the files for some days, will name him all the paragraphs he has neglected within that period of a few seconds he had available to decide. Within shipoperation we have reached a situation where we should have the courage to get rid of a big portion of regulations and find back to clear and unambigious rules. But that will remain wishful thinking as long as administrations even maintain rules they have already recognized as being superfluous. E.g. when navigating along fairways a number of nations do not allow for autopilot steering. Pilots, however, preferring a successful voyage to just following the rules, regularly apply autopilots. After an incident courts of inquiry then often, accepting this performance, just

autopilots. After an incident courts of inquiry then often, accepting this performance, just ignore that violation of the rules during the hearing.

But how to perform better? Just skipping all rules and regulations will certainly not lead to desired results. What is required most urgently are accepted standards of performance. The navigator must be told how to assess a situation and then to decide on "safe distance", "moderate speed" or "prudent seamanship". That is, however, much more difficult than it sounds. For years experts have been trying to work out such standards but the results obtained so far are not too convincing. Again simulation obviously provides a tool to improve the situation. By experiencing predefined situations and reproducing these as often as required applicable standards might be worked out, a task which really calls for cooperation amongst simulator operators and other experts.

CONCLUSION

Marine safety is a matter of public concern. Administrations and owners do not feel very comfortable facing potential disasters and therefore generate activities leading to additional technical features, organizational measures and regulations. One must doubt, however, if these activities will finally result in real improvements, i.e. fewer casualties. Improved marine safety requires meaSures generated within the system and really fitting to it not only trying to affect it from outside. Efforts must comprise the seafarers social and economic situation. As long as modem vessels worth far more than a hundred million US dollars and carrying cargo of about the same value are manned with crews receiving salaries hardly adequate for unskilled labour not too convincing results can be expected.

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SAFETY IN SHIP DESIGN

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Abstract

The goal of the paper is to provide a sound base for handling safety problems. Such problems exist with regard to the development of safety standards as well as to reactions of the public to ship accidents. The paper describes basic concepts available for the provision of safety in ship design. It further deals with concepts for answering the question "how safe is safe enough".

Introduction

With regard to the safety of ships we may notice several different and mostly contradictory points of view: For the head of the design department of a shipyard no safety problem exists; he just sticks to the safety regulations without compromise and nothing is left for him to bother about. For another designer the only problem with regard to safety is how to comply with the regulations (or rather how to satisfy supervisory bodies) at minimum costs.

For some people any accident is a proof that the safety requirements are deficient. Especially, when a major desaster is overplayed by the media, the public overreacts to it and polititians push regulatory to produce new safety regulations in order to appease the media. On the otherhand there are shipowners who claim that there are too many safety requirements or that they are exaggerated.

Many researchers are of the opinion that safety problems are caused by incomplete knowledge of physical relationships. This opinion is based - often unconsciously - on the idea, that perfect physical insight would lead to total safety. Since total safety does not exist in our world the actual question is "How safe is safe enough", and this question cannot be answered by physical reasoning. The situation is ably characterized by a word of the philosopher Churchman (1961): "Probably the most startling feature of twentieth-century culture is the fact that we have developed such elaborate ways of doing things and at the same time have developed no way of justifying any of the things we do." In other words, there is a discrepancy between the level at which we treat physical relationships on the one hand and the level at which safety per se is handled on the other hand.

In the following I will try to indicate some ideas for a methodology of ship safety. I shall start with the description of different concepts for the provision of safety.

Then I shall look at the question how to find the right level of safety.

Safety Concepts

Shipbuilding is one of the oldest technologies. Since the beginning the safety of the ships was the concern of seafarers and shipbuilders. The first and simplest concept to provide safety was to build the ships according to the experience-based description of the hardware. The oldest example is Noah's ark: It was built according to the given description with the result, that its stability, strength etc. were suffficient. Until the 19th century safety against capsizing was achieved by giving the ship proper proportions. Until not long ago the rules of Classification Societes provided sufficient ships strength by the description of structural elements in dependence of the main dimensions of the ship. The disadvantage of this hardware-based concept is, that progress was possible only in very small steps in order to omit risks.

The second concept to provide safety is not to describe the hardware but to require certain physical characteristics of it. As an example the requirement of minimum righting levers for providing safety against capsizing may be mentioned. Because the introduction of welding gave more freedom in designing the structural elements of ships the direct description of such elements in the classification rules was replaced by giving the section modules. This concept gives more freedom for the design than hardware requirements. But with respect to the safety philosophy the concept of requiring physical characteristics is not different from the hardware concept. Both concepts neither define safety nor do they allow the quantification of the achieved level of safety.

The necessity to deal explicitly with safety arose with the introduction of big electronic systems and with the development of spaceflight. Thereby safety is defined as the probability that a certain unwanted event does not occur during a given time. It is of interest that an - although simple - application of this concept has been proposed by a naval architect: Sir Wescott Abell (1919) showed how the "odds on" for surviving a damage can be calculated. At that time the professional community was not yet in the position to really understand and to appreciate this idea. More successful was a paper by Wendel(l960) which received worldwide interest and initiated the development of the first probability based safety regulations for ships, i.e. the Equivalent International Regulations on Subdivision and Stability of Passenger-ships adopted 1973 by the Assembly of the Intergovernmental Maritime Consultative Organisation. Now-the probabilistic concept of safety plays an increasing role in the design of ships and their equipment and machinery.

The three concepts of providing safety have been described in historical order. But one must not conclude that the older concepts have become totally obsolete and that only the probabilistic concept is still up to date. All concepts will keep their range of application. E.g. in order to build safe stairways it is completely sufficient to describe the hardware as hand rails, button plates for the steps etc. There will always remain cases in which the application of the probabilitistie concept is not

possible, either because of the lack of data or of too complicated relationships. Then the concept of requiring physical properties may solve the problem, especially when thereby the theoretical background of safety is kept in mind.

How Safe is Safe Enough?

Safety assessment by description of hardware is based on experience. Describing safe hardware includes the implicit provision of a certain safety level which has been reached during a trial and error process in the past. The same holds true for the concept of requiring certain physical properties in order to achieve safety. But this concept allows some extrapolation of the experience gathered in the past.

The probabilistic safety concept urges the use of explicitly stated safety levels. At first sight it seems logical to always choose the same level of safety, i.e. a level which has proved satisfactory in the past. But this would be justified only in cases, in which the risk source, the benefits of taking risks, the familarity with the risks etc. are similar, because for different situations the existence of different acceptable risk levels (or required safety levels) can be observed.

The explicit assessment of safety by probabilistic methods seems to be especially suited for situations where we meet new types of risks produced by new and un-familar technologies. These are situations in which the answer to the question "How safe is safe enough" would be of most interest. Unfortunately, up to now there exists no generally accepted method to find such an answer. In some cases it might be helpful to consider safety not as an end but as one of the means to reach a goal in a more comprehensive context. This procedure might be called system approach to the determination of the proper safety.

When the proper safety is to be determined for cases which do not involve loss of or damage to human life the problem can be solved by economic considerations. In order to achieve more safety one has in general to spend more money. At the same time the expected loss is reduced. The optimal safety level is that for which the present value of costs and expected losses is minimum. In order to get useful results the random time to the occurence of losses has to be taken in consideration. For a couple of redundancy problems methods for calculating expected present values have been developed by Krappinger (1986). When using this concept difficulties can arise when the failure probabilities are low and the losses in case of failure are high. In such cases the amounts of losses would have to be replaced by their von Neumann / Morgenstern utilities (Krappinger 1971). But the utility approach gives rather explanatory results than actual predictions of the optimum safety.

When human lifes are at risk there is no point in applying economic considerations. An example how to proceed in such a case has been given by Abrahamson (1962). His proceedure is now known under the name "Minimization of the total mortality". His concern was the optimal structural safety of ships. From statistics of fatal accidents in the Norwegian merchants fleet he estimatent that only 10 per cent of all accidental

deaths are caused by structural failures. In order to increase the strength of the ships their steelweight has to be increased. The increase of steelweight reduces the cargo capacity of that part of the fleet which consists of deadweight ships. From economic considerations it can be concluded that the reduction of the cargo capacity would be compensated by increasing the number of ships rather than by increasing the size of the ships. For the increased number of ships with higher structural safety the number of accidents due to structural failure would decrease. The number of fatalities in connection with cargo handling would remain the same and the number of fatalities from all other causes would increase corresponding the increased number of ships.

In addition to the above mentioned fatalities Abrahamson took into account the fact, that the production of steel claims its victims at all stages, from the time the ore and coal are mined until the steel is built into the ship. From statistics this number of fatalities can be estimated as function of the steelweight. If the sum of all numbers of fatalities is drawn vs. the ship weight (or the structural safety) one gets a curve with a pronounced minimum. This minimum indicates the optimal structural safety.

The merit of the above reasoning is rather the insight, that the requirement of exaggerated safety can lead to the contrary of what is aspired, than the numerical value of the optimum. This can be explained by the fact that neither **the** considered system is comprehensive enough nor that the goal is really the ultimate one. E.g. instead of varying the structural safety only one can think of the variation of other safety provisions additionally in order to influence the total mortality. As an ultimate goal the minimization of the total mortality is not suffient. The real end could perhaps be named "quality of life", but this can not explicitly or quantitatively be expressed. The idea that the minimisation of the total mortality has to be preferred to any other goal does not match the human nature.

Concluding Remarks

It is obvious that my paper contains **no** distinct prescription how to design ships with proper safety. But I hope that it exhibits a certain systematic of the safety problem which should be helpful to omit the confusion which is reflected by the points of view regarding safety mentioned in the Introduction.

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SAFETY OF CHEMICAL TANKERS

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ABSTRACT

A high level of safety onboard chemical tankers is necessary to ensure the best adequate protection for the cargo, the crew and the environment.

This safety is a complicated subject and is in fact a chain of single units acting together to achieve the common objective.

In this paper a number of these "units" are highlighted:

1. The Construction (design) of the Ship

    Is the double hull the only answer to reduce pollution or are there other designs which might offer an equivalent degree of environmental protection?

2. The Crew

    Adequate manning by qualified and competent crew is a key element in ship safety. Are these qualified crews available and what do we have to do to increase their standards and reduce the human factor in casualties?

The final conclusion of the paper is that ship-builders and ship operators jointly have provided the necessary' expertise and safety regime5 to transport chemicals safely and efficiently. However, the human factor in the safety chain is the weakest link.

THE SAEFTY OF CHEMICAL TANKERS

A.C. van Dorp
Technical Director - Gebr. Broere B.V.

A high level of safety onboard chemical tankers is necessary to ensure the best adequate protection for the cargo, the crew and the environment.

Given the subject of this conference .and the fact that environmental accidents, even the smallest accident, get and have the full attention of the media, I will restrict myself to the safety related to the environment and ask the question: "how safe are chemical tankers for the environment?".

This environment-related safety is a complicated subject and is in fact a chain of single units acting together to achieve the common objective.

The number of units differ widely from ship to ship and from company to company and perhaps also from flag to flag.
Our company, Gebr. Broere B.V., operates 15 seagoing chemical tankers and 15 inland chemical tankers, all ships sailing under Dutch flag.
It is obvious to answer the question "how safe are chemical tankers" I will base myself on experiences with our own ships.

Of course we are convinced that we have safe ships in our fleet, but what is a safe ship in general:

A ship is safe and efficient if being properly:

* designed
* built
* manned
* operated
* maintained
* surveyed

Especially for the environment we have to amplify these "units".

Design
Apart from the normal requirements which every ship has to meet, for example intact stability, the environment is especially protected by the type of the chemical tanker and the damage stability requirements.
In the International Code for the Construction and equipment of ships carrying dangerous chemicals in bulk (IBC code) for each product the type of ship is prescribed.

I presume we all know that there are 3 types of chemical tankers, namely type I, II and III (fig. 1).
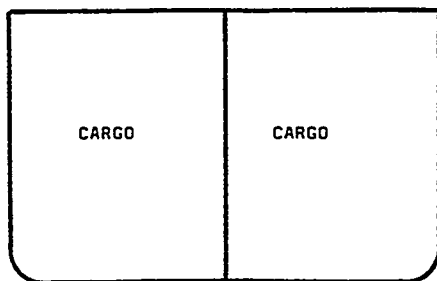
TYPE III
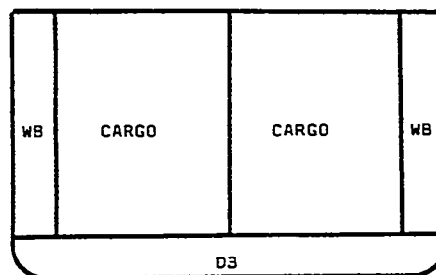
TYPE II
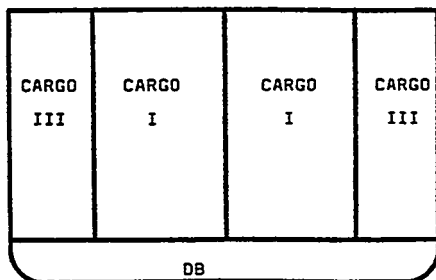
TYPE I

Fig. 1 Types of chemical tankers

Type II is the most common one in our fleet and almost for all chemical tankers. This type is also known as the "double hull" tanker.

Ever since the introduction of the IBC code, in the early seventies, the double hull has been recognized by all parties as the answer to reducing pollution in case of accidents with chemical tankers. Of course, there are arguments both for and against double hulls.

On the positive side:

* Most collisions and groundings involving tankers are low energy accidents, which are unlikely to penetrate the inner hull.

* The technology for building double hulls is well known, albeit applied to smaller ships.

* It has, as a design, a proven track record.

On the negative side:

* Increased building costs.
* Increased maintenance and repair costs.
* Reduced cubic capacity

In our company we have a 20 years experience with double hulls and I think we can confirm the above mentioned positive and negative arguments.

Unfortunately in these 20 years, we also had experience with collisions in the cargo area. However, as a bright spot in these dark events the double hull showed its importance and provided environmental protection. In two cases our ships, being anchored, were hit by another (bigger) ship in the cargo area. The collisions took place in heavy fog and they did not breach the cargo tank because of the double hull.
In these two cases it was a matter of a low energy accident, the third collision was clearly a high energy accident when our 2500 tons deadweight double hull tanker was hit by a 50.000 tons deadweight container vessel under an angle of about 30° at rather high speed. Unfortunately our ship did not survive this collision. During the salvage of the ship we could unload the cargo from the forward cargo tanks. Due to the double hull these cargo tanks were not damaged, although the outside hull had been pressed against the longitudinal outside bulkhead of the cargo tank.

During the grounding our ship, with about 800 tons "black frost" on deck, and with an angle of heel about 60° was blown on the sandy beach of Northern Poland. The double bottom was completely destroyed but also in this case we could unload the ship after the salvage operations because the bottom of the cargo tank was undamaged.

The American legislation decided in the wake of the EXXON VALDEZ accident that the double hull for oil tankers was the answer to prevent pollution.

On August 18th, 1990 a completely new piece of legislation, the Oil Pollution Act (OPA) came into effect, with the aim to provide an overall technical and legal response to the problem of marine conservation. This legislation reflects an all-encompassing approach to safety at sea on three levels.

1. Prevention of accidents.
2. Anti-pollution plan.
3. Removal of damage.

It provides a general strengthening of the safety of tankers in three ways.

1. Construction and equipment (double hulls).
2. Operation (crewing standards and rules on drug and alcohol abuse).
3. Navigation (compulsory piloting and towing, maritime traffic control system).

The Act gives provisions for existing tankers after January 1st 1995, all tankers after the year 2000, and newbuildings or those undergoing major conversions (of course all ships operating in American waters).

This is not the end of the story. In a recent paper the US National Research Council stated that "The OPA 90 - should be viewed as only an interim step to reducing oil spills" and has agreed that there are other designs which might offer an equivalent degree of environmental protection. IMO has already recognized that other designs can provide protection equivalent to double hulls.

There are two methods of minimizing pollution in the event of an accident. The first is to prevent the cargo tanks being breached, as double hulls are designed to, the second is to minimize the oil escaping from the tanks once the breach has occurred, the latter almost invariably involves the use of hydrostatic balance.

The IMO has set up a sub-committee under the auspices of the Marine Pollution Committee (MEPC) to study the questions raised.

A number of alternative designs has been proposed already.
The mid-deck tanker of Mitsubishi (fig. 2) has gained preliminary acceptance from the 1240 as an equivalent to double hulls. But also other designs are interesting such as the mid-deck tankers with rescue tanks, a design of Phillipe Embiricos (fig. 3).
The Polis design (see fig. 4) and the Polmis design developed by George Paraskevopoulos (fig. 5).
All designs promote hydrostatic balance as the answer to reducing pollution.
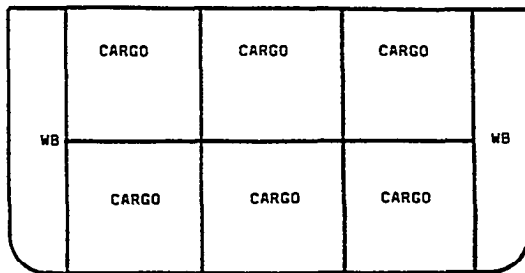
fig. 2 The mid-deck design of
       Mitsubishi
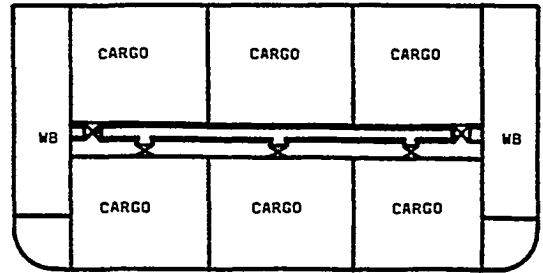
Fig. 3 The mid-decker with
       rescue tanks
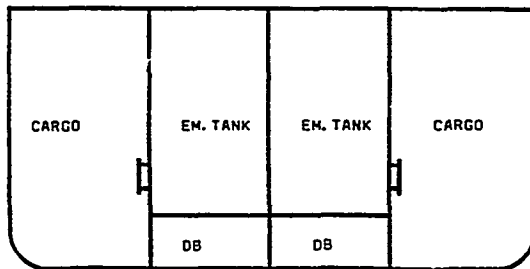
fig. 4 The Polis design
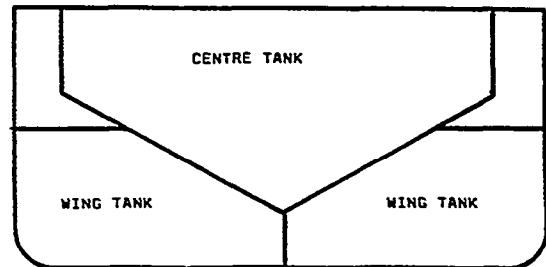
fig. 5 The Polmis design

During the thirty-second session in March 1992, the MBPC decided on the new Regulations 13F "design of new tankers" and 136 "treatment of existing tankers". These new regulations will come into force on the 6th of July 1993.

In these regulations also smaller oil tankers are mentioned (between 600 and 5000 DWT) and provisions were also made for alternative designs.
In the future all these new regulations, etc. will also have their influence on chemical tankers, even on the smaller ones. *For* example in our fleet the recently built ships have already a certificate for "oil- and chemical tanker" *in* order to transport the oil products zntioned in appendix I of ANNBX I. If we and other owners want to transport these products in the future, it is obvious that we have to follow these *new* rules for oil tankers in and after 1993. And perhaps at that time, even alternative designs have been developed for smaller chemical and oil tankers.

It was already mentioned that next to the design the environment is also protected by the damage stability requirements as mentioned in the IBC code, chapter 2.5 "damage assumptions" and 2.9. n5urvival requirements".

Although these requirements are very important in the design stage, especially for smaller ships it is a difficult demand to meet, I will restrict myself hereby saying that every chemical tanker has to comply with these rules, with or without a loading manual, because if not the national authorities do not hand out the Certificate of Fitness and without this certificate it is impossible to sail.

Building
A properly built and constructed ship is of great importance for the safety.

This was recently emphasized with a great *number* of bulkcarrier casualties experiencing extensive structural failure. Twelve of these vessels sank during 1990.

The Advanced Studies and Rule Development Group of Lloyd's Register and simular groups of other classification societies have investigated the causes of these incidents, as far as evidence was available.

The results of these investigations have been published and without doubt also during this conference we will hear something about the results and the theories as to why these casualties are occurring.
What is certain, however, is that these vessels were not structurally capable of safely fulfilling the task for which they were intended,

- whether because their designs have not ensured sufficient structural strength under all possible loading conditions,
- whether the ship had been loaded in a wrong order,
- whether the ship-had not been properly maintained
- or the captain was steaming too fast in heavy weather.
Any of these factors may have contributed to some greater or lesser extent.

There are valuable lessons to be learned from these investigations, valuable also for the safety of chemical tankers.
Especially the longitudinal strength is important and has to be calculated in the design stage for all possible loading conditions.
Norske Veritas advises to include these calculations in the contract specifications of newbuildings.

Also other recommendations have been made by the classification societies, but let us not forget that these societies are not responsible.
They are not accountable to anyone - neither the shipowner nor the insurers or national authorities, who rely on their ship monitoring procedures.

The shipowner is responsible, he has to supply the necessary money for maintenance and take the ship out of operations for inspections and/or survey. of course the shipowner wants to lengthening the time between two surveys as much as possible. Therefor intermediate inspections by the crew or inspectors of the Technical Department of the shipping company can help to discover excessive corrosion rates, cracking or structural damage. All in close cooperation with and the support of the classification societies,

Manning
Adequate manning by qualified and competent crew is a key element in ship safety.
However, in practice there are some difficulties with this statement.
First the demand for qualified maritime officers to work on board merchant ships is considerably greater than qualified personnel seeking employment at sea.
This situation is the complete reverse of the position as it was 8 or 10 years ago when substantial unemployment amongst merchant officers turned young people away from the profession.

According to the Royal Netherlands shipowners' Association (KNRV) one of the main causes for the ship manning and management problems facing shipowners is the continuous run of drastic changes experienced by shipping during the past century.

On board of today's ships which are packed with sophisticated state of the art electronic systems, many of the traditional positions have ceased to exist and some have been drastically stripped from their substance and glamour with the result that they lost much of their earlier fascination and attraction for young people seeking a career different from traditional jobs.

It is feared not only by the KNRV but also by the Short Sea Association of Shipowners (VNRR) that this will lead to a very serious shortage of higher educated and trained maritime officers.

There are some answers to these difficulties.
First the new maritime officer or the MAROF, according to the KNRV, a person who not only know5 his navigation and is familiar with ship propulsion but who also knows about automation, modern management and telecommunication.
The second answer that many shipowners are reducing the size of their crews, although this is for an other reason, namely to save money.

We stated already- that a well maintained ship is one of the safety units, good maintenance needs also practically trained people, but during the education on the secondary and higher institutes for nautical education there is hardly any time left for practical training, which means that professional skill is under pressure. Also the standard of the existing crew can be a problem when nothing is done to raise this standard in order to meet the developments in the technical field etc.

That a competent and well trained crew is very important for the safety is emphasized by the recently published study of claims experienced by United Kingdom Mutual Steam Ship Assurance Association, the largest in this field.

They found that human error is an identifiable cause of 58% of the claims but the true figure is probably higher as casualties caused by equipment failure arising from human errors would be categorized as having mechanical causes.

It is a very interesting report, too long for a review in this paper but the recommendations, to reduce this human factor in the future, are important enough to mention:

• Cargo knowledge, measures should be taken that ship officers are familiar with cargo characters.

* Safety audits and progranunes that reward accident free operations with a bonus should be considered.

* Adequate manning for the trade in which a ship is engaged in is necessary if flag state regulation5 permit lower level.

* Better training and motivation of both seafarers and shore personnel is of prime importance.

* There should be company operating manuals rather than random collection of circulars.

* Officers and crew should spend longer periods on familiarization before new ships are brought into service.

* All on board a ship should be able to use a common language.

To put it briefly, a lot has to be done to reduce the human factor in many accidents, not only for shipping in general but also for the owner of chemical tankers due to the high risk of polluting the environment when a casualty occurs.

Inland tankers
It is interesting to make a side-step to the inland barges.

At the end of last year the Department of Transport of Germany published a report of Mr Jungmann about the safety of inland shipping.

He investigated the shipping accidents on the river Rhine over the last 20 years and came up with the following accident causes:

- Human error   64%
- Technical causes   10%
- Technical problems with
  traffic routes and constructions   6%
- Weather conditions   4%
- Cargo problems during loading or
  unloading   4%
- Not identified   12%

Given the high factor of human error the recommendations for the crew of the seagoing ships can be the same for the crews of the inland tankers.

It will be obvious that the inland chemical tankers have many similarities with the seagoing chemical tankers.

The double hull ship has been introduced a couple of years ago (fig. 6) together with the corresponding damage stability requirements.

Fortunately we do not have a casualty record of the double hull inland tankers but still there are some doubts about the calculated damage after a collision.

In order to check the applied computer simulators full scale ship collision tests were held in December 1991.

In Session 8B of this conference the results of these tests will be announced.

The General Rhine Commission (CCNR), is now drafting a revision of the ADNR (The Rhine regulations for the transport of dangerous cargoes).
The ADNR revision will bring ADNR in line with the rules of ADR (dangerous goods by road) and RID (dangerous goods by rail), while CCNR also aims to harmonize its requirements with those of 1X0, which has strict codes for the sea transportation of chemicals, both in bulk and in packaged form.

The new regulations will become product dependent instead of shiptype dependent. They are designed to improve the safe handling of chemical cargoes and will also widen the range of chemical cargoes which inland vessels are permitted to carry.
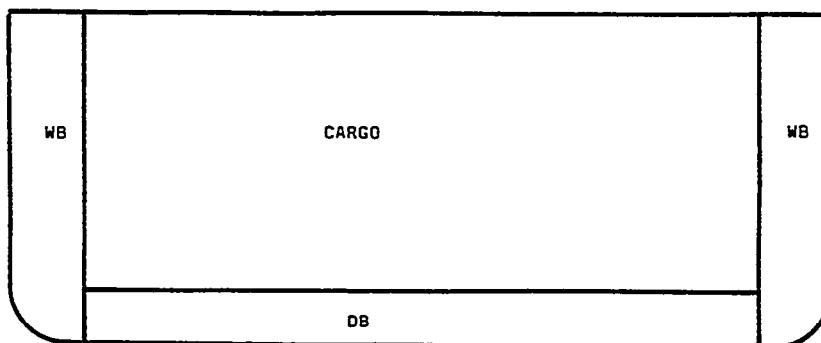
fig. 6 ADNR type IIA Tanker

Conclusion -
Summarizing we can say that a well-designed, well built, properly manned and sufficiently maintained chemical tanker is safe for the environment but that the responsibility to maintain this safety standard is not only a task for the ship and her crew.
The best way to express what I mean is to quote the words of Mr William A. O'Neil, Secretary-General of IMO in his annual message for World Maritime Day. Although he spoke in particular about the safety of passenger vessels I think his lesson is applicable to all types of ships.

The Secretary-General emphasized that:

"No single unit in the safety chain can act alone but, instead, all must work in concert to achieve the common objective. Shipbuilders, classification societies, shipowners, shipmanagers, charterers, insurers, seafarers, unions, government administrations and IMO must do all their part to bring about safer shipping".

List of references:

* The United Kingdom Mutual Steamship Assurance Association (Bermuda) Ltd. (1991).
  Analysis of major claims.

* Jungman, G. (1991)
  "Verkehrosicherheit in der Binnenschiffahrt".

* "Tanker Design: a question of equivalence".
  The Magazine of Lloyd's Register 100 AI, 1994-4.

* "Scanning the horizon".
  HSB International, November 1991

SAFETY OF BULK CARRIERS

J M Ferguson
Lloyd's Register of Shipping

Abstract

Safety of Bulk Carriers

Over the past year Lloyd's Register has endeavoured to provide the shipping community with an awareness of bulk carrier losses and the probable reasons for such. Single hull bulk carriers are ships which have developed in size to today's 'Cape' size ships, over a very short period of time, in association with the use of higher tensile steels and the optimisation of structural arrangements to suit both cargo handling and construction. Loadings on these almost open type ships are very complex and in addition to longitudinals bending and local cargo induced stresses the structural configurations employed result in significant torsional/ warping stresses. In addition the vertical cargo loading results in significant transverse stresses in the deck platings between the hatchways. These transverse loadings are particularly sensitive to overloading of cargo.

During the loading/unloading of cargo the ship can be subjected to physical abuse which can result in damage to the structure. Certain cargoes, such as high sulphur coals, can also create high levels of both localised and general corrosion in short periods of time. Awareness of the potential problems is therefore important by all parties concerned.

This paper addresses many of the problems and the actions to be taken.

SAFETY OF BULK CARRIERS

Introduction

During the year 1990, twelve ships carrying dry bulk cargoes, where structural failure may have been a factor, were lost with a consequent loss of life of a reported 200 seamen. Of the ships concerned eight were bulk carriers, two were ore carriers and two were ore or oil carriers. For ease of reference the structural cross section for each type is shown in Figure 1. A number of major structural failures to the primary hull girder members on bulk carriers which did not result in the loss of the ships also occurred during this period.

In the cases of the ships that were lost and also in the cases where major structural damage occurred without loss the ships concerned were generally carrying iron ore.

During 1991 thirteen ships with bulk carrier structural configuration have gone missing with additional loss of life. The majority of these ships were again carrying iron ore.

This year, to end of March, 1992, one ship has sunk and four others were reported as damaged, having leakages and fractures.

The purpose of this paper is to give an awareness of what LR has done, or is doing at this time with regard to addressing the situation regarding bulk carrier incidents as well as taking the opportunity to discuss the matter as a whole.

Bulk Carrier or
Ore Bulk Oil Carrier

Ore or
Oil Carrier
or Ore Carrier
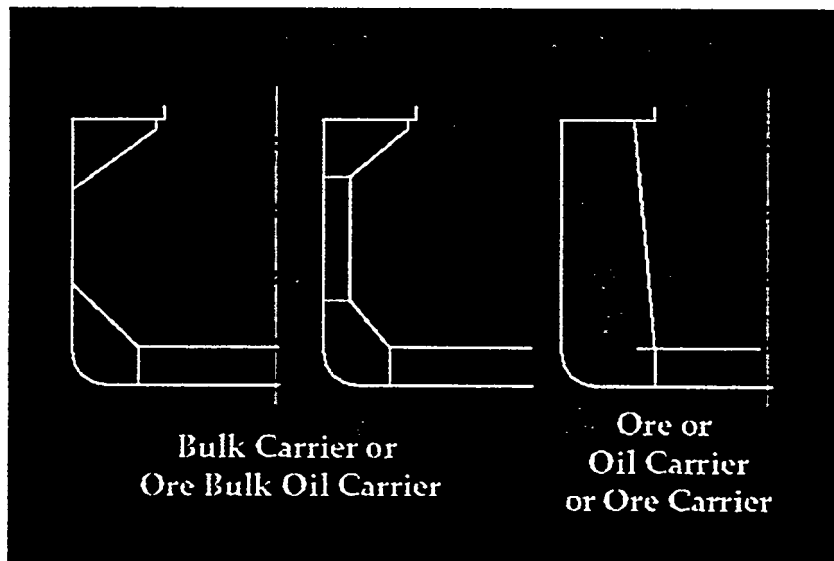
Figure1

Other aspects such as the greater usage of higher tensile steels in recently constructed ships also make this a time for deliberation with regard to this ship type.

It has become increasingly apparent that dry bulk carriers are the heavy workhorses of the world fleet and because of their cargoes could inadvertently experience loadings not normally catered for in their design. The growth in size of these ships and the proposals for the use of higher yield steels has necessitated that a more or less continual review of their scantlings takes place, taking account of both service experience and findings from theoretical investigations. Recent events, however, in the form of major damage to a number of bulk carriers some of which were constructed in the last decade led Lloyd's Register's Chief Ship Surveyor to giving priority to a study with a view to determining the probable causes of incidents to this ship type.

A brief chronology of events which illustrate Lloyd's Register's recent concern with regard to bulk carriers is given as follows:

February '89 - LR special instruction to surveyors on survey of topside tanks and holds.

November '90 - Commencement of bulk carrier investigation.

November ' 90 - LR special instructions to surveyors on survey of holds, in particular main frames and brackets.

December '90 - Press release by LR advising of corrosion and cracking problems.

January '91 - Additional guidance to surveyors on survey of bulk carriers.

January '91 - Letter to bulk carrier operators/owners portraying concern and requesting information.

February '91 - Further letter to owners of bulk carriers drawing attention to untypically high rate of casualties and advising of LR policy.

April '91 - Close up inspection requested on sample of bulk carriers as part of LR investigations.

May '91 to date - Lectures and Seminars worldwide advising
the shipping community about the problems
encountered on Bulk Carriers, as seen by
LR.

June '91 - Further guidance to Surveyors on the survey
of cargo hold spaces on Bulk Carriers.

October '91 - LR Brochure,
Bulk Carriers: guidance to operators on the
inspection of cargo holds.

November '91 - LR Technical Committee agreed new Rule
Requirements for enhanced scantlings of
Bulk Carrier's cargo holds, side frames and
transverse water tight bulk heads.

These actions can be summarised as both providing guidance to
LR surveyors and being a vehicle to provide the shipping
community with an awareness of potential problems with this
ship type. The letter to the shipowners dated January '91 as
well as indicating LR's concern also constituted a
questionnaire. This was sent out to a large sample of bulk
carrier owners and many have responded positively with
information. In addition to this a more general letter was
also sent out to bulk carrier owners worldwide during
February advising them of the study being carried out. This
letter also requested any information considered relevant to
be forwarded to LR's Technical Planning Department in the
Ship Division. A copy of these letters, together with the
Press release and the guidance brochure are included in
Appendix 1.

In investigating the various levels of the problem, from
design to operation, it appears that many operators believe
that cracking in the structure of these ships is inevitable,
possibly as a result of poor design or detail, and more
probably as a result of operational procedures.

This was the challenge that Lloyd's Register was addressing
with a view to making the occurrence of cracking and
unacceptable levels of structural depreciation a rare event
and thereby improving reliability of the ships concerned. To
do this it was recognised that a better appreciation of the
operators operational pressures was fundamental, together
with a reappraisal of structural arrangements and survey
requirements.

Initial Work

In the first instance, a five point plan was devised in order to produce a rational and measured short-term response to the main problem, if it could be identified. This plan, was also to define possible areas of work which, when completed, could have a positive effect on structural and operational safety of bulk carriers.

Five point plan: ,
1. Casualty and damage investigation.
2. Relevant information from operators.
3. Visits to ships during unloading/loading process.
4. Preparation of initial Rule proposals.
5. Commencement of relevant full scale measurements.

The first three points were essentially information gathering and were extremely important. The discussions with a limited number of extremely helpful operators and associated visits to their ships, particularly during the unloading process, were used to concentrate our thoughts and define the areas for further study.

It soon became clear that, whilst there are many factors which affect a bulk carriers' structural or operational capability, they are a well tried design and will perform satisfactorily provided the structure does not significantly deteriorate locally due to corrosion, physical damage or overloading.

Aspects which can influence the life of bulk carriers are shown in Figure 2 and include structural design, ship operation, cargo handling aspects, types of cargo and maintenance and repair policies. These topics are generally addressed in this paper although not necessarily under these specific headings.
A summary of aspects addressed is given as follows:

i) What is a bulk carrier, its cargoes and its environment.
ii) Age structure of the fleet
iii) Statistics of losses
iv) Focal points of damage
VI Development of damage
vi) Conclusions

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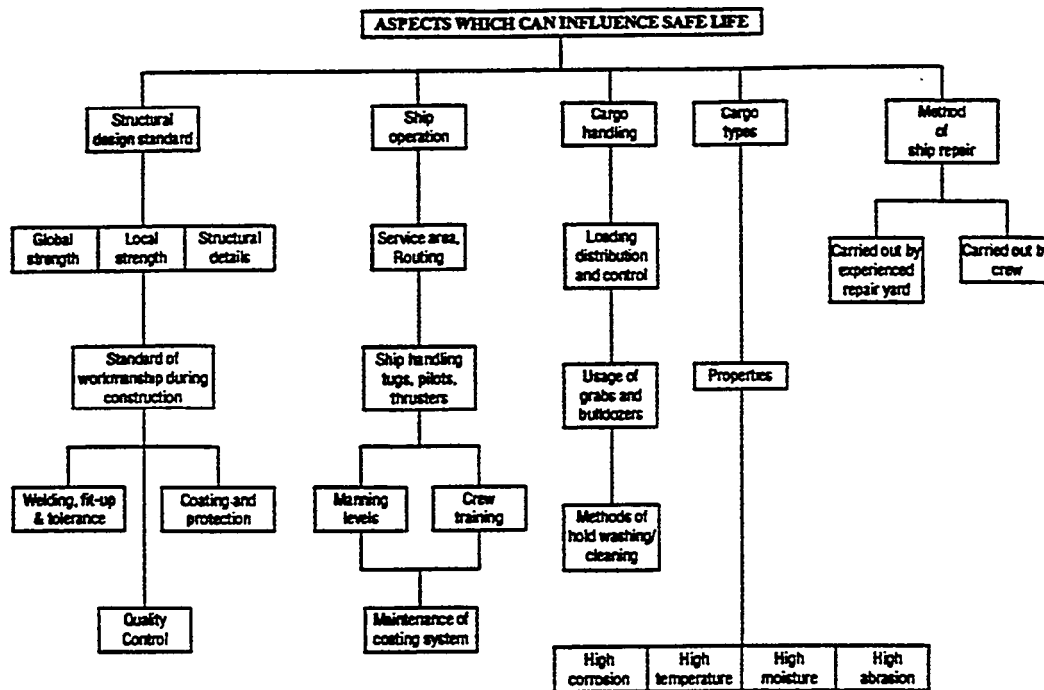
Figure 2

(i) **What is a** Bulk **Carrier, Its Cargoes and Its Environment?**

The most widely recognised structural concept identified with a bulk carrier is a single deck ship with a double bottom, hopper tanks, single transversely framed side shell, topside tanks and deck hatchways. This concept, as described, dates back to the early nineteen sixties when deadweights of up to about 20,000 tons were introduced. During the period until the early nineteen seventies this design configuration was extended to ships of about 170,000 tons deadweight. During the mid sixties the utility of the ship type was further developed when the O-B-0. (Ore, bulk, Oil.) ship was conceived. This development in operational capabilities came after considerable investigation which concluded that this ship type could carry liquid oil cargoes without destroying the basic simple structural concept. An outline structure arrangement for the cargo area of a bulk carrier is shown as Figure 3.

Cargoes carried by these ships are numerous, however, for the purpose of this paper, ,discussion will be on the carriage of ores and coals.

In .a practical sense the shipowner endeavours to minimise the empty ballast voyage legs of the operational cycle with these ships. With regard to the
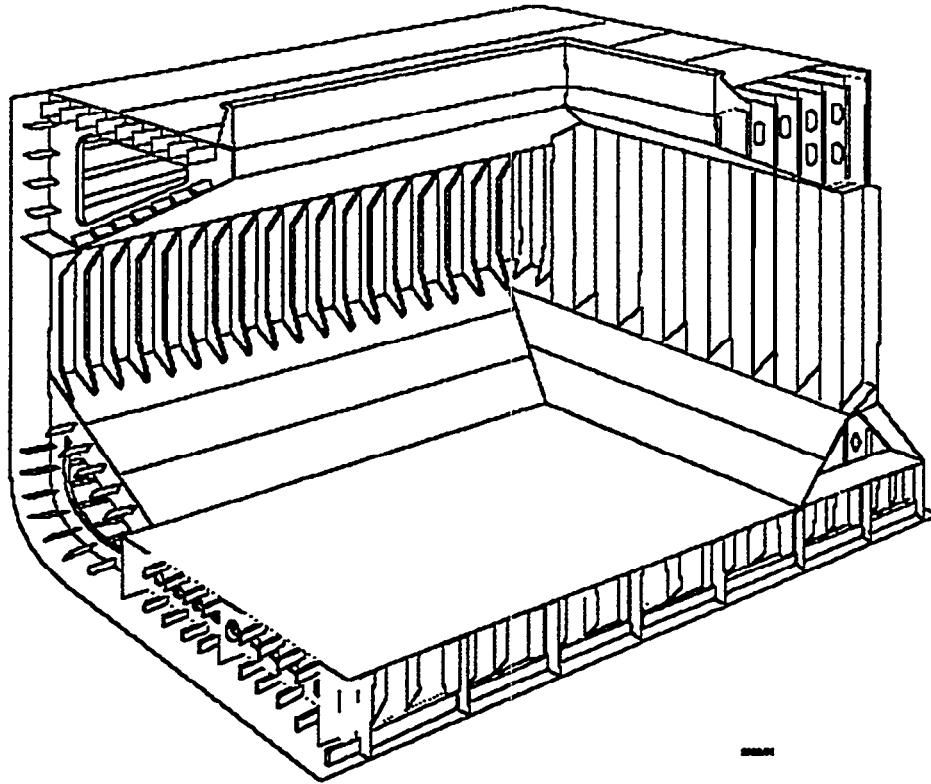
Figure 3

carriage of coal the major exporters and major consumers
dictate the trade plied by bulk carriers. Major
producers of coal for seaborne export include Australia,
United States and South Africa and the total coal
carried in ships is over 300 million tonnes per year.
Major importers of coal are Japan and Europe as well as
other industrial nations such as Korea and Taiwan. A
typical voyage route for a ship upon leaving Europe
could be a ballast trip to the United States for loading
of a particular coal cargo, followed possibly by loading
of another parcel of coal in South Africa and a voyage
to Japan. After discharge in Japan the ship could then
proceed to Australia for a cargo of coal or even ore for
delivery to Europe. During this service a wide variety
of coal cargoes, sea and environmental conditions as
well as port operational procedures will be experienced.

In the carriage of ore, which is the most severe cargo
carried in terms of loading on the ship, the ships ply
between the major exporters e.g. Brazil, Australia,
India, South Africa and Canada, and the major consumers
e.g. Japan, Europe, Korea etc.

Due to its high weight per unit volume, ore is normally carried in alternate holds within the ship. In general the holds loaded are the odd numbers i.e. nos. 1, 3, 5, 7 etc. The purpose of this alternate loading is to increase the height of the ships centre of gravity above the base so as to make the ship less stiff. i.e. the ships roll motions are more moderate. Even with the ore cargoes carried in alternate holds the cargo quantity does not occupy, in many occasions, a large proportion of the hold space.

In addition to commercial pressures dictating the growth in the ship size for the carriage of ore and coal they have also dictated that the cargoes can be loaded and unloaded from the ships holds as quickly as possible. In order that this can be attained ports have developed more efficient facilities in terms of grab size for discharge and conveyor systems for loading. In this respect grab sizes have greatly increased in capacity and in unloaded weight. Indeed it is now common for unloaded grabs to weigh as much as 35 tons. Examples of typical weights for unladen grabs are given as follows with their respective ports..Equipment to free coal or even ore from the ship structure can constitute hydraulic hammers fitted to the extending arms of tractors within the holds. In addition, the gathering of coal or ore in the holds can be the job of bulldozers which are, to say the least, ship unfriendly. A fundamental question to be addressed is; "can a ship be designed to withstand the repeated energy from 35 ton grabs or bulldozers when used with enthusiasm?" ... If traditional shipbuilding standards are to be employed probably not.

	Iron Ore	Coal
EmoMaasvlakte	20/36	18/28 (Tons)
Redcar	I0/15	20 (Tons)
Nagoya	20/30	20/30 (Tons)
Kure	20	20 (Tons)
Taiwan	19.4A9.9	19.409.9 (M)

It would be wrong and unfair to isolate the primary problem to the factor of stevedoring. Other aspects such as the corrosive nature of the cargo or even the environment can have a great effect on structural reliability and performance. In this respect certain coal cargoes can have a high sulphur content and this in association with the "sweating" of the steelwork, due to the environmental conditions experienced, can lead to very concentrated corrosion of the hull internal

steelwork. This phenomena, together with heavy sea conditions can lead to extremely rapid break down in the integrity of the structural components.

Other aspects, such as how the quantity of ore in each hold can be ascertained during loading are also fundamental consideration in terms of the hull girder loading. Cargo temperatures in the carriage of certain pelletised ores and also coal, while being less common is an aspect of load which cannot be ignored. In a paper to the Tasmanian Branch of the National Institute during 1988 Captain Davies, a marine surveyor, assumed the hypothesis that the loading and carriage of high temperature iron ore pellets excessively degrades ship structures. In this paper he commented that ores were being loaded at well above the recommended temperatures of 65 degrees centigrade, with temperatures of over 150 degrees centigrade being recorded. Ref. 1.

(ii) **Age Structure of the Fleet**

The age structure of the bulk carrier fleet is shown in Figure 4. From this figure it will be noted that the fleet is a reasonably balanced fleet in terms of size, up to about 100,000 t dwt, for ships built between the early seventies and mid eighties. During the early eighties there appears to be an upswing in newbuildings for ships above 125,000 t dwt.

By far the majority of the ships which form the bulk carrier fleet are the handy sized ships ranging in age up to over 30 years.

(iii) **Statistics of Losses**

Figures 5, 6 and 7 illustrate the loss of dry bulk carrying ships, where such losses can be attributed to structural failure, from the end of 1979 to date. i.e. ships which have had reported hull leakages or have simply gone missing. The ship types include single hull and double hull bulk carriers as well as ships with an ore carrier structural configuration. Over this time period the average rate per year is about 6 ships with the highest level being 13 ships during the year 1991.

Bulk Carriers World Fleet as at April 1992 (inc. OBOs, Ore Carriers and Ore/Oil Carriers)
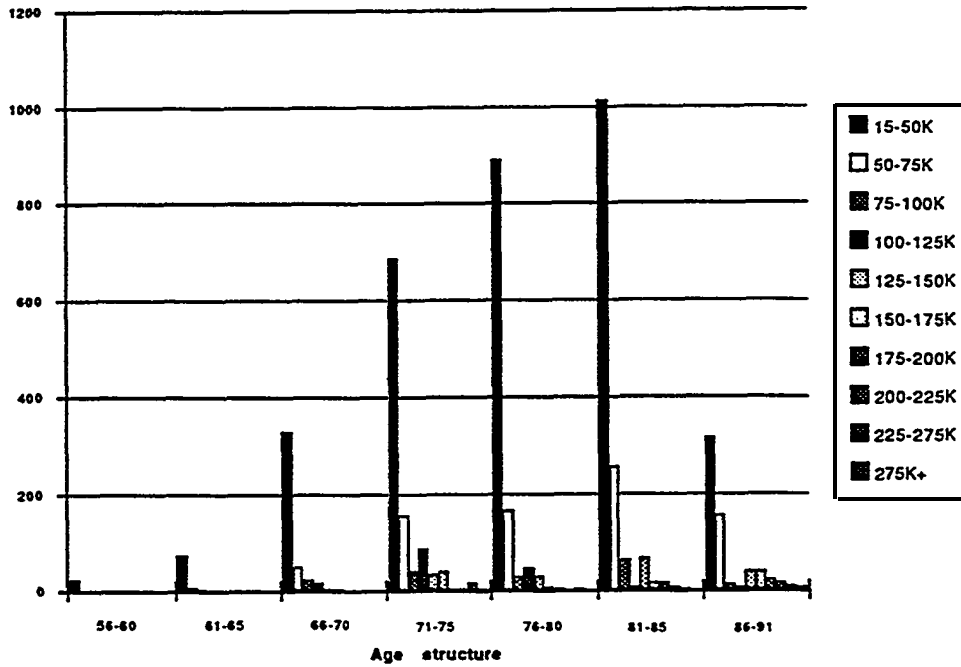
Figure 4

Bulk Carrier Losses Where Structural Failure May Have Been a Factor (inc. OBOs, Ore Carriers and Ore/Oil Carriers) (1980 - March 1992)
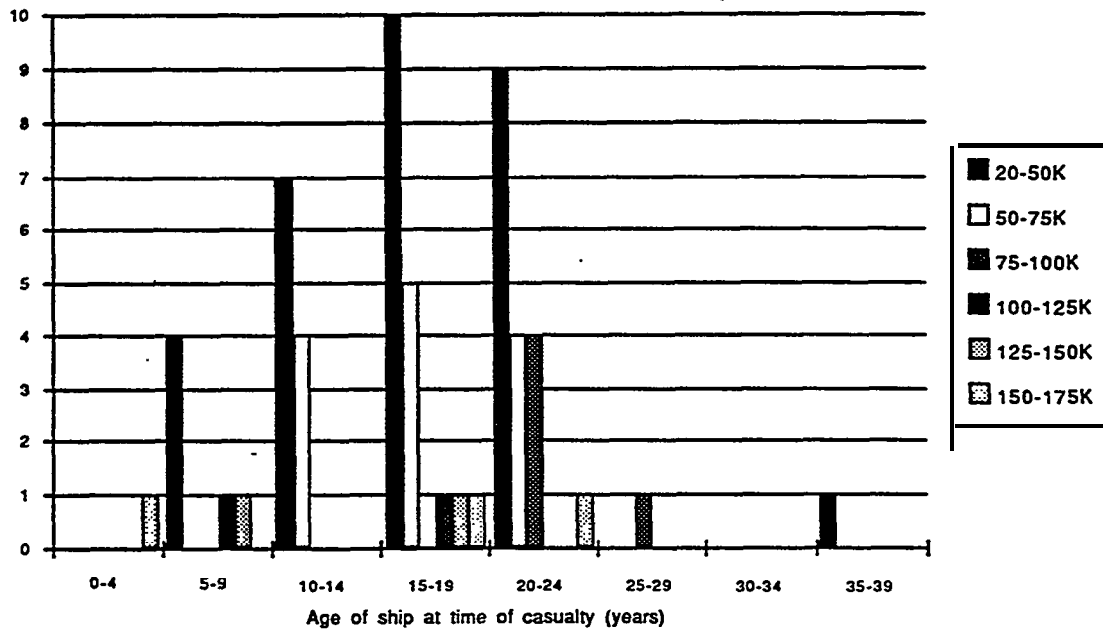
Figure 5

BulkCarrier Total Losses Where Structural Failure May Have Been a Factor (1990 - 91)
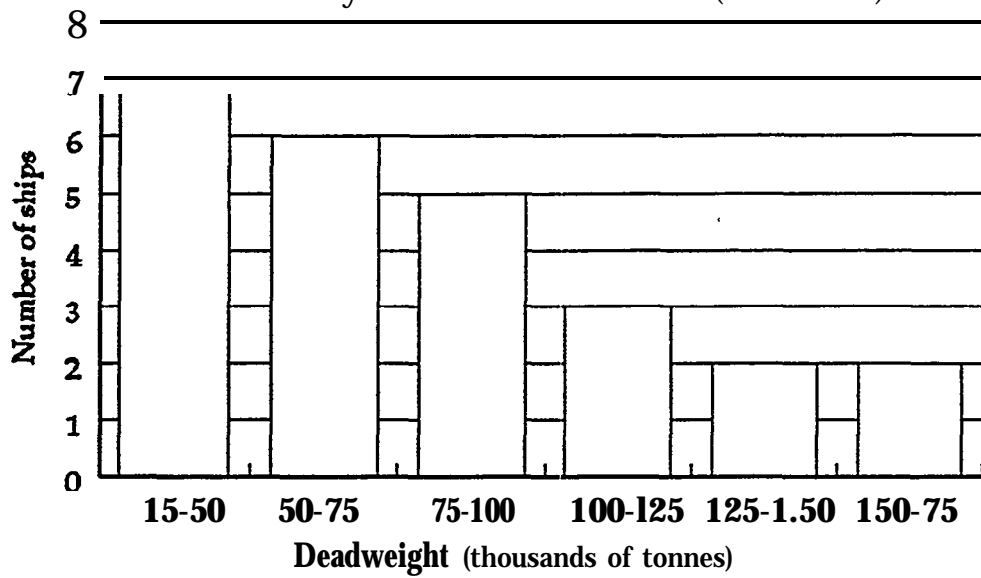
Figure 6

Bulk Carrier Total Losses Where Structural Failure May Have Been a Factor (1980 - 91) 15,000 T. DWT Upwards
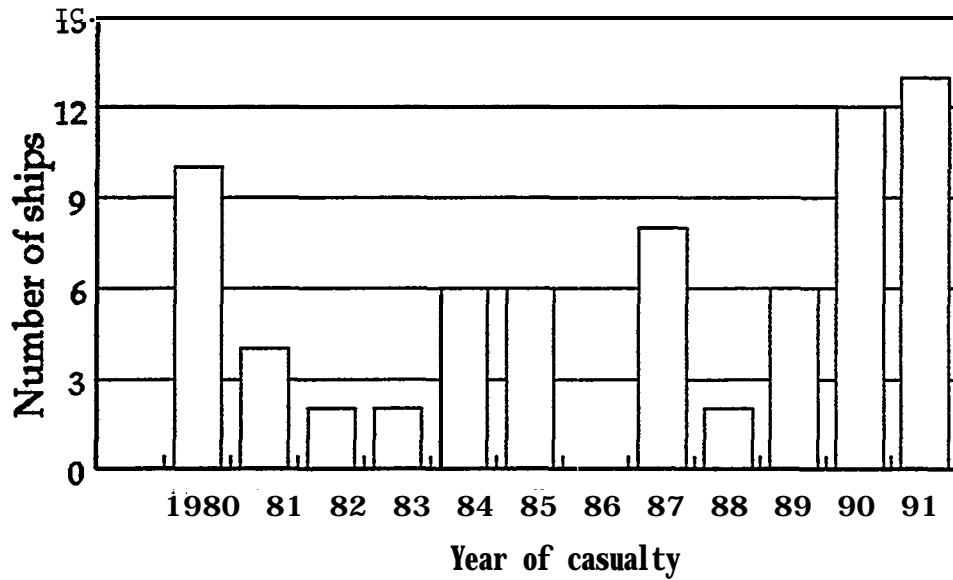
Figure 7

Ships which have been lost or have known to have suffered significant damage during the period from the beginning of 1990 to the time of writing are shown in Figure 8. From this information it can be deduced that the average age of the 25 ships which were lost during 1990 - 1991 was about 19 years, with the majority being over 20 years of age. The average age being influenced by the loss of the 'Mineral Diamond' which was only 9 years old. From this information it will also be noted that most were carrying iron ore. In nearly all of the cases (take off), except those where the ships have simply 'gone missing', it is understood that the loss was preceded by water being taken in one or more .hold spaces.

From the information available for the handy sized ships it is evident that the rate of sinkings increases with age. i.e. less than 1% for ships in the 5 to 9 age group ranging to 4% for the 20 to 24 year group. In the case of larger ships there are indications that this trend is still applicable with the 50,000 to 75,000 t dwt group being up to about 7.5% when the ships are in the 20 to 24 year age group. With regard to ships in the 100,000 to 125,000 t dwt the very much smaller sample is relatively consistent in performance at about 7%. It required to be appreciated when considering these magnitudes that as the sample group sizes vary to such a large degree that the actual percentages are not comparable in ship number terms. These percentages do, however, indicate a trend for the various deadweight ranges.

In view of the difficulty in establishing probable causes for ship losses, information available with regard to bulk carriers with significant damages within the same time frame have also been included in these statistics. The information available indicates that cracking of the main frames and their brackets is a consistent occurrence. In certain cases this cracking has led to a reduction in support for the side shell which in turn has resulted in cracking occurring in the side shell plating itself. In at least two prominent cases this phenomena actually led to the loss of the side shell plating over the affected hold lengths.

These statistics used also seem to indicate that there are two distinct problem areas. i.e. one with the older ships and the other on a smaller scale with middle aged tonnage.

Bulk, Ore/Oil, Ore C OBO Casualties - (Deadweight 20,000 tqnnes)
Missing, lost or serious Damage where structural failure
may have been a factor, Jan. - March '92

Name	Age	Type	Cargo	Cas date		Casualty Details
Ship 1	15	Bulk	Grain	Jan 90	.	Missing
Ship 2	17	Bulk	Coal	Jan 90		Side shell lost No 1 hold.
Ship 3	19	OBO	Iron Pellets	Jan 90		Heavyweatherdamage
Ship 4	9	Sulk	Iron Ore	Feb 90		No 8 side shell lost
Ship 5	24	Bulk	Phosphate	Feb 90	●	Damage in No 2 hold (flooded1
Ship 6	20	Bulk	Ballast	Eeb 90		Fracture No 1 hold
Ship 7	23	Ore	Iron Ore	Mar 90		Foundered
Ship 8	21	Ore	Iron Ore	Mar 90		Ballast tank leak
Ship 9	22	Bulk	Barytes	Apr 90		2 m fracture in No 6 hold
Ship 10	19	Bulk	Iron Ore?	May 90		Hull damage. Holds flooded
Ship 11	13	Bulk	Iron Ore	May 90		Hull damage. Flooded
Ship 12	12	Bulk	Iron Ore	May 90		Fractures in holds 2 L 3
Ship 13	23	Bulk	Iron Ore	Jul 90		No 3 hold flooded
Ship 14	18	Bulk	Cement	Jul 90		Bow lost ● keel fractured
Ship 15	9	Bulk	Coal	Aug 90		S shell damage
Ship 16	17	∞	Iron Ore	Sep 90		Missing
Ship 17	24	Bulk	Iron Ore	Ott 90		Fractured side shell
Ship 18	19	∞	Iron Ore	Oct 90		Presumed to have foundered
Ship 19	17	Bulk	Iron Ore	Ott 90		Wasted side shell framing in No 3 hold
Ship 20	21	Bulk	Bauxite	NOV 90		Fractures in holds 2, 3 L 6
Ship 21	19	Bulk	Ballast	Nov 90		12 m fracture in No 5 hold
Ship 22	18	Bulk	Iron Ore?	Dec 90		Bulkhead frames loosened
Ship 23	17	Bulk	Potash	Dec 90		Fractures in No 2 hold
Ship 24	18	Bulk	Iron Ore	Jan 91		Damage to frames in No 1 hold
Ship 25	24	Bulk	Iron Ore	Jan 91		Nos 2 c 4 holds flooded
Ship 26	19	Bulk	?	Jan 91		Fractures L detached frames in two holds
Ship 27	24	Bulk	Iron Ore	Jan 91		Fracture in No 5 hold. Flooded
Ship 28	21	OBCI	Iron Ore	Feb 91		Fracture in No 1 hold
Ship 29	14	Bulk	Ballast	Feb 91		Fractures in no 3 WB hold
Ship 30	24	Bulk	Pig Iron	Feb 91		Took water after striking object
Ship 31	17	Bulk	?	Mar 91		frames detached from No 6 hold
Ship 32	24	Bulk	Iron Ore	Apr 91		No 1 hold flooded
Ship 33	21	Bulk	Iron Ore	Apr 91		Fracture in No 4 hold. Flooded
Ship 34	9	Bulk	Iron Ore	Apr 91		Missing
Ship 35	16	Bulk	Iron Ore	May 91		Fracture in No 1 hold
Ship 36	16	∞	Iron Ore	May 91		Fracture in hull below waterline
Ship 37	15	Bulk	Iron Ore	July 91		No 3 hold flooded
Ship 38	21	Bulk	Steel	Aug 91		Grounded No 1 hold flooded
Ship 39	21	Bulk	Iron Ore	Aug 91		Severe crack No 7 hold
Ship 40	16	-Bulk	Iron Ore	Aug 91		Ingress of water No 1 or 2 hold
Ship 41	12	Bulk	1	Aug 91		Shell fracture frames detached No 3 hold
Ship 42	14	Bulk	?	Aug 91		Heavy weather frames cracked
Ship 43	23	Bulk	1	Aug 91		Disabled towed to safety
Ship 44	24	Bulk	7	Aug 91		No 5 hold frames fractured
Ship 45	18	∞	Oil	Aug 91		Hull fractures

Name	Age	Type	cargo	cas date	casualty Details
Ship 45	18	co	Oil	Aug 91	Hull fractures
Ship 46	18	03	Oil	Sept 91	Shell fracture oil leakage
Ship 47	23	Bulk	Phosphate	Ott 91	• hank in rrediterranion
Ship 48	18	Bulk	to load coal	Ott 91	Fractures in deck
Ship 49	14	Bulk	1	Nov 91	Extensive corrosion of shell plating
Ship 50	25	Ore	Iron Ore	Nov 91	• leakage in heavy weather
Ship 51	18	Bulk	Steel Machinery	Nov 91	No 2 hold flooded pip in side
shell					
Ship 52	18	Bulk	Iron Ore	Nov 91	• Cracks in side shell most holds
Ship 53	20	Bulk	Iron Ore	Dee 91	Side shell fracture
Ship 54	26	Bulk	1	Jan 92	Hull leaks when on voyage to breakers
Ship 55	25	Bulk	Calc Nitrate	Jan 92	Leakage into for peak and double bottom
Ship 56	21	Bulk	Coal	Jan 92	Detained for extensive repairs
Ship 57	18	Bulk	1	Feb 92	Upped deck fracture heavy weather
i Ship 58	23	OBO	Iron Ore	Mar92	• Engine room flooded

Figure 8   0 Denotesship **Loss**

(iv) Focal Points **for Structural Defects**

In a sense the particular ship configuration and service dictate the location and extent of damages on ships. In the case of bulk carriers the cargo containment space is bounded by the port and starboard side shells, the ships inner bottom and is normally subdivided along its length by corrugated transverse bulkheads which have supporting stools top and bottom. The presence of large hatchway openings over the cargo area also creates a hull with a reduced torsional resistance, as well as focal points for stress concentration at the corners of the hatchways. While seemingly not obvious the structural arrangements employed for transverse bulkheads can also create, under certain loading conditions, concentrations of load in the deck structure and in particular the cross deck strips between the hatchways. In addition to these aspects the handling of cargo can damage certain areas of the structure more than others by virtue of grab damage or even that created by bulldozers or hydraulic hammers. The cargoes themselves by virtue of their temperatures or their corrosive properties can also be fast acting and ruinous to the structure. Other aspects,

Such as structural discontinuities, can of course also be focal points for cracking.

A brief summary of types of defects and the locations where these can be found is given as follows:

i) Cracking at hatch corners.
ii) Plate panel buckling of cross deck strips and stiffening structure.
iii) Cracking of hatch coamings.
VI Cracking at the intersection of the inner bottom plating and the hopper plating.
vi) Grab and bulldozer damage to the main frames lower brackets.
vii) Grab damage to the inner bottom platings, hopper and lower stool platings.
viii) Cracking at main frame bracket toes.
ix) Both general and localised corrosion of main frames and brackets.
xl Cracking at fore and aft extremities of topside tank structures.
xi) Corrosion within topside tanks.
xii) General corrosion of transverse bulkheads.

While the above listed damages are typical of those found on bulk carriers they are not inevitable. Evidence would seem to indicate that even with sister ships significant differences in occurrence and extent do exist. This would seem to indicate that in addition to the importance of structural strength and detail design, that other factors, such as operational controls, come into play.

An aspect considered relevant with regard to loadings is the procedure and the number of loading passes made by the loaders on the individual holds of the ships. Again for commercial reasons it is in the ship operators' and port operators' interests the number of passes be kept to the minimum. In considering a group of very similar ships carrying very similar cargoes it becomes apparent that great variations in structural performance do occur. With the ships which incur minimum damage it would appear that the operators are particularly cautious with regard to loading ore cargoes and employ a large number of loading passes which will reduce the likelihood of overloading individual holds.

For the purpose of this paper it is not intended to discuss all of the items listed beforehand but to address only those aspects which are more likely to cause hold leakage and progressive flooding.

The remaining aspects have been, or are being, dealt with and will be reflected in rule reviews in the near future.

Grab and bulldozer damage to main frame lower brackets

As previously indicated it is normally expected that the lower region of the main frames at some time receive some level of damage during the- unloading of the ship. This can involve damage ranging from localised deformation of the frame bracket face plates to large physical deformations of a number of frames.

In the case of single hull bulk carriers the ships side main frames are individual pieces of structure, which, if rendered ineffective, will place additional load on the adjacent main frame or frames. Progressive failure by the domino effect is therefore a reality.

Cracking of main frame bracket toes

This type of cracking is initially created by detail discontinuities in the bracket toe regions. The type of bracket configuration used will to a large extent dictate the location and extent of cracking. Where separate brackets are employed the cracking location is more normally at the bracket toe position on the frames whereas with integral brackets the crack location is at the toe location on the hopper and topside tank. See Figures 10 and 11 respectively. Turning to the latter case first i.e., the contiguous bracket design, the cracking has been found to be almost self limiting with a very small propagation rate after the initial occurrence. In the case where separate brackets are fitted experience has shown that the fracture, once it has occurred, propagates very quickly to the side shell.

These experience-based conclusions have been confirmed by experimental and theoretical studies, carried out by Japanese shipbuilders, to determine the fatigue characteristics of various configurations of frame bracket. Ref. 2.

Loadings on the main frames and their brackets are complex and are generated by hydrostatic load and the rotation of the hopper and topside tanks. Cyclic loadings are induced from these load sources by the passage of waves and the motion of the ship in a seaway. See Figure-12.
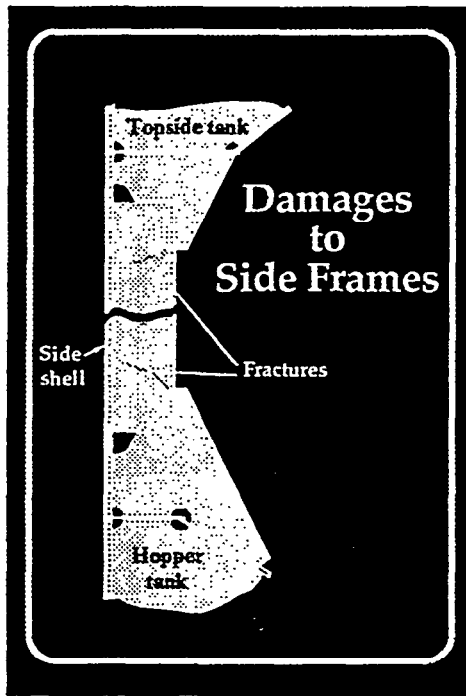
Figure 10
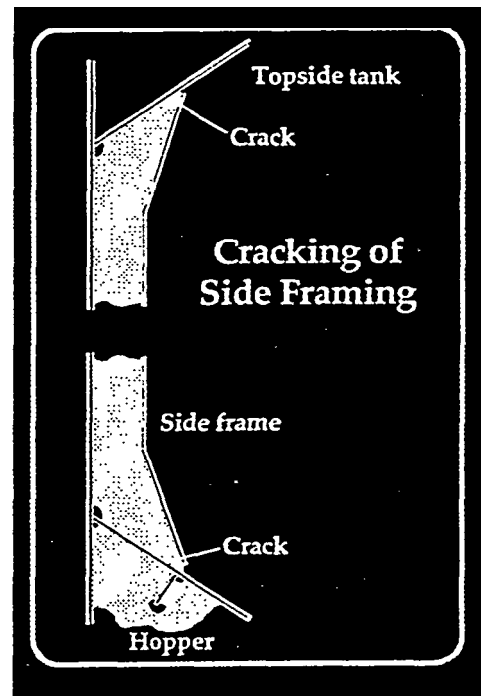
Figure 11
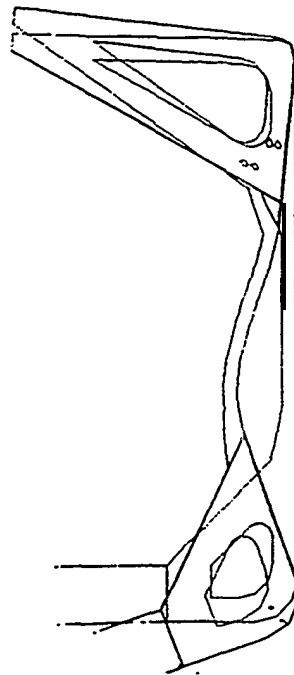
Frame/hopper deformation in Ore loading condition

Figure 12

Repair of Defects and Damage

Inspection of the ship by shipowners after cargo discharge on many occasions will reveal some level of damage. In many of the ports where unloading takes place there are no facilities for repair and therefore the owner can be faced with a decision as to whether to accept the damages as (i) being only a blemish, (ii) to carry out temporary repair and carry out permanent repairs later or (iii) to sail to a repair facility. It is emphasised that any significant damage should be advised to the classification society concerned. Commercial pressures will have inevitably influenced in the decisions taken in the past.

A fundamental question is; how can the internal structure of the holds be effectively examined in any case? The lower frame bracket areas can be accessed by means of ladders but how can the upper reaches of the cargo holds be accessed? To enable effective examination so as to assess corrosion or even cargo handling damage means to permit close up examination are fundamental. i.e. by the use of 'cherry picker' type equipment.

Both general and localised corrosion of main frames and brackets

The marine environment in association with the characteristics of certain cargoes can create a very severe situation in terms of corrosion. This has been very adequately demonstrated over recent years by the loss of ballast tank side shell structure on oil tankers due to differential temperatures between cargoes and the environment.

In the case of single hull bulk, or 'ore bulk oil' carriers the environment created within the hold spaces by a cargo, such as coal which is carried at temperatures of up to **38** degrees centigrade, can create, in association with the colder sea water outside, significant sweating at the interface of the side shell and topside tanks. In addition to this certain coal cargoes possess a high sulphur content which adds to the corrosive effect. By virtue of gravity the condensation is limited to the outboard portion of the main frame webs and the lower bracket connection to the hopper to which it gravitates.

It is not unusual therefore to find that bulk carrier main frames have suffered from highly localised corrosion on their webs adjacent to the side shell. In addition the bracket web connection to the hopper is similarly effected.

This corrosion, with some typical structure arrangements, would seem to be the trigger for fracturing which either propagates from the lower bracket toe outboard or up the web connection to the side shell (leaving the bracket intact).

Corrosion of Transverse Bulkheads

In the event that high sulphur bearing cargoes are being carried the (environmental conditions as previously mentioned) within the hold spaces also attacks the transverse bulkhead platings, if these are unprotected and this can create an increased rate of corrosion on these structures. As a principal failure mode for these members is the buckling of the corrugation flanger this can be very consequential, particularly in the event of hold flooding.

(v)   **Development of damage**

In the case where integral brackets are employed experience has shown that, in the absence of corrosion, any fatigue cracking will be contained in very localised areas at bracket toes, It has also been shown that where localised corrosion has occurred in association with localised fatigue cracking that this cracking propagated to the side shell along the bracket connection. In the absence of significant mechanical damage to the main frames this cracking, by virtue of its location, will be difficult to detect. In addition due to the consistency of structural arrangements, loads and the environment it is probable that the other frames in the same hold will be in a similar condition. If this situation goes unnoticed it is only a matter of time before the side shell cracks and tears thus permitting sea water into the hold space.

An obvious question to address would be: why does this damage more often occur when the ships are carrying ore as the evidence suggests? The obvious answer to this is that when carrying ore, particularly in the alternate hold loading condition, both the local components, such as the frames, and the hull girder are more highly stressed. In addition, because of the low fill rates of the ore cargoes the side frame deflection amplitudes and

panting are not restricted. Also the ship's very stiff rolling motions in the ore conditions can only exacerbate the loading situation.

With regard to the ships transverse bulkheads any hold overloading would create additional transverse forces and stresses as well as additional magnitudes of shear stresses, in the platings.

In the event that sea water entered the hold space the effect of sloshing, perhaps exacerbated by the excessively reduced scantlings of the platings could initiate failure.

An obvious question is "why do the ship sink"? The answer is not so obvious as any relevant evidence sinks with them. A number of hypothesis can of course be developed. In terms of probability these are two predominant possibilities which come to mind. The first of these is the flooding of a forward hold which results in the collapse of a bulkhead (for the reasons given beforehand) which then results in the ships bow becoming submerged and progressive flooding taking place. Another possibility is the flooding of centre holds and the ships ultimate strength being exceeded, resulting in the hull breaking in two. Both of these potential scenarios would be supported by the evidence available in terms of corrosion and the absence of any form of Mayday call from the ships concerned.

(vi) Conclusions

- If this portrayal of the situation is correct it would seem that there is a need to introduce a greater degree of structural reserve so as to improve the robustness of the hull thus making an allowance for a degree of human error. This is particularly true with regard to the side framing members.

- There is a need for an awareness in the ship operating community with regard to the possible consequence of damage to main frames, whether this is caused by cracking and corrosion or by the act of unloading the ships.

- There is a need to prevent corrosion occurring in these critical locations.

- Bearing in mind the age statistics of the ships concerned it would seem logical to require an increase in survey requirements, for hold areas.

- It would also seem logical to look to the future and ensure that new designs being constructed of higher tensile steels reflect the experience gained.

- While more a long term objective it would seem that positive means should be developed to gauge more accurately the ore filling levels and also to announce the ingress of water into hold spaces.

- It is considered that the lower frame brackets require to be increased in thickness because of their working environment. In addition it would also seem logical to consider the use of additional structure to provide an alternative load flowpath in the event of local failure.

Actions implemented with regard to Ship Structure

- Scantlings of main frame brackets increased.

- Scantlings of transverse bulkheads increased.

- IACS agreement to coating side shell and transverse bulkheads.

- Survey programme made more rigorous.

Work Still Ongoing

- Development of means to evaluate weight of cargo in holds during the loading process.

- Full scale measurements of stress magnitudes in side framing structure.

- Assessment of ships reserve ultimate strength in the flooded condition.

In conclusion I consider that the challenge for the classification societies is relatively clear but the effort of their actions will only be significant if an awareness of the consequences of damage is reflected in action by Industry.

There is still a degree of concern regarding the rapidity of the ship sinkings and the fact that the crew are apparently unaware of any structural failure or flooding.

In typhoon conditions the ship would behave differently and visibility may not be good and therefore experience and watchfulness may not be adequate. In this respect it is considered that a system of stress monitors on the ships deck could provide a level of warning that changes in the baseline stress were occurring. The adequacy of the warning would depend greatly on how quickly the ship was flooding and how many holds were effected.

Ref. 1   Arctic Carrier, 1985 - A contributory cause of loss? - Captain Davies, 1988

Ref. 2   Study on the fatigue strength of local parts ships structures 2nd report - Strength of side frame ends of Bulk Carriers - I H I, 1978

METHODS AND INSTRUMENTATION FOR ESTIMATION OF SHIP STABILITY AND SAIFETY IN DESIGN AND OPERATION

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Abstract
Presented methods of ship stability investigation and reliability estimation are based on developments of the stochastic theory stability of dynamical systems and the mathematical theory reliability. An application these methods to ship design and operation gives possibility to reflect the reality with higher order realizability in comparison with the exist methods and allows to reduce exist level of marine accidents. The foundation of this is sequential use of the probability theory techniques which links the problems under consideration at one series able to raise the level of ship safety in rough sea on the whole.

Introduction
The International Maritime Organization (IMO) and some national classification societies introduced the Weather Criterion which is widely used now to provide vessel stability. In fact this criterion reflects the ability of ship to withstand the wind squall impulse, assuming that initial state of applying this impulse is determined by parameters of ship motion in waves. It also assumed that after the moment of application the squall remains indefinitely constant. As a deterministic factor the Weather Criterion does not reflect real random external excitations and different phenomena causing the loss of ship stability in rough sea. This situation initiated in many countries the persistent search for more comprehensive and universal stability criteria.

Two approaches in this area are now evident. The first is linked to the class of deterministic factors affecting ship stability, the second - to the class of random functions.

Within the first approach the special attention should be played to the application of Liapunov functions ranging from simplest forms to vectorial representations. In this area the substantial progress was achieved by C.Kuo [I], A.Y.Odabaci [21, I.R.Ozkan [3] and others. But further

application of this method is limited due to the absence of universal methodology for forming Liapunov functions.

The first approach comprises also the techniques of time domain ship motion analysis facilitated by the modern computation means. These methods are based on the numerical solutions of nonlinear differential equations of ship motion which can describe the transition to ship capsizal under impulse action of deterministic wind-wave generations. The different initial dynamic conditions can be also taken into account. This approach can be used to determine the beginning of chaotic ship motion as a dynamic system familiar under the name strange attractor. The subsequent works in this area of J.M.T.Tompson 143, M.S.Soliman [5], A.W.Troesch and I.M.Falzarano 161 proved that numerical solutions in time domain significantly increase the understanding of capsizal phenomena.

At the same time there are some evidences that great variations of wind-wave parameters into the short time segments of realization, such as variations of the velocity of amplitude growth into wave pockets, their characteristic frequencies and initial conditions, increase the difficulties of obtaining the stability criteria for the whole space of possible deterministic disturbances. These complications become even more evident in connection with the general theorem of the mathematical theory of stability, which states that stability domain of nonlinear dynamic system is dependent not only on the particulars of the system itself but on the character of external excitation as well. So the variations of irregular wind and wave excitations into the separate short time segments of their realizations may be such considerable that for each segment the separate stability domain may be formed.

So the general stability criteria can be established only within the class of random functions and the second approach can be considered as the most perspective.

This approach was initially developed by l?.A.Firsov, I.K.Boroday t73, M.A.Shama CS] and others on the base of Weather Criterion. But the attempts to combine the random features of wind generations and initial conditions of ship motion at the beginning of short time segments of motion realization with the Weather Criterion transferred all negative moments of deterministic approach into the class of probabilistic solutions.

The application of the spectral theory for prediction of ship motion helped D.M.Ananjev [91 to introduce the criteria of stability based on the separate analysis of harmonic components of spectral representations of ship motion processes. But this method requires very laborious calculations. Also it is very difficult to provide the

physical background for stability loss of separate harmonic
components and for the ship motion as a whole.

More perspective for assessing the influence of random wind
and wave excitations on the ship stability domain is   the
approach of V.A.Nekrasov [lOI, who offered to analyse   the
statistical moments of ship motion and external disturbances
the latter of which are transformed by the method of shaping
filters in Sub-Gaussian random functions. The solution of
the problems under consideration in form of statistical
moments of random process helps to establish the connection
between the energy transformations of external disturbances
and ship motion processes. It is evident that disbalance
in the   energy   transformations and   breach of   the
phase correlations between considered processes which lead
to appearance of the chaos in ship motion are the main
indicators of possible ship capsizal. One-of-the advantages
is the' formation from the above statistical moments the
stochastic   analogues   Liapunov functions with the
following introduction of stochastic criteria of stability
in analytical form [lO, 11, 12]. Those general criteria can
be transformed into deterministic stability criteria [10,
133 in particular into Weather Criterion, using the method
of limit transitions.

!Phe described area of research covering the most   urgent
problem of safety at sea opening perspectives of development
of existing ideas.

Method of Stability Investigation
It is offered the method for the solution of the problem of
ship dynamic stability under sea and wind action.'Phe method
is based on the following assumptions   and algorithms
cm 13, 151.

  1. It is assumed that the ship, stabled in static balance
in a calm sea, is situated under action of the random wind-

wave excitations $\vec{X}$(t). The excitations $\vec{X}$(t) and   stable

ship motion $\vec{Y}$(t) are considered restricted Sub-Gaussian
random processes which ordinates do not exceed some finite
(extreme) values during the whole time of ship motion.
Distributions of such processes is determined by Pirson's
curves which- is in full presented with the help of
statistical moments of the first, second, third and fourth
orders [12]. The estimation of the extreme values of the
acting excitations and ship motion is effected on the basis
of the data of full-scale observations and the sense of the
problem solution.

  2. Non-linear differential equations of the ship motion
are given as the following

$$\frac{d\vec{Y}}{dt} = \vec{F}(\vec{Y}, \vec{X}, t), \tag{1}$$

and the processes of acting wind-sea excitations are assumed similar to the simplest Markovian processes (provided the filtration frequency band of the dynamic system under consideration is narrow) or are resulted from some transformations of the processes similar to Markov's ones with special pulse forming filters (provided it is necessary to take into account the spectral composition and other peculiarities of sea and wind pulsation load). In the first case such processes are close to white noise. For the second case the simplest equation of shaing**ng** filter, realizing a transformation of random processes and $\rho_z(t)$ close to white noises in the process of free surface evaluation of waving liquid $X,(t)$, may be presented as the following

$$\ddot{X}_1 + 2\delta_1[1+\psi_1(t)]\dot{X}_1 + 2\delta_3\dot{X}_1^3 + \omega_1^2[1+\psi_2(t)]X_1 + c_3 X_1^3 = 0, \tag{2}$$

where coefficients, δ_3, ω_1^2, c_3 are expressed with the help of spectral moments of wave spectrum **[15]**.

The use of the equation (2) in the system (1) allows to consider problems of ship motion probability characteristics determination and stochastic stability investigation when the ship is moved on free surface of sea with various courses in regard to wind and wave direction, because the changes of wave and wind spectrums conditioned by the ship speed is taken into account analogous changes of coefficients of the equations (2).

3. An investigation of the ship motion and the ship motion stability is realized with help probabilistic characteristics of the processes $x(t)$ and $y(t)$. Such characteristics are statistical moments. The system of equations for statistical moments is composed on the base of the equations (1) by the techniques seted forth into **[10]**. In general- case all statistical moments of the first-fourth orders are used. However, if we only consider the first and second order statistical moments and introduce the correlations between the higher order moments and moments of two first orders belonging to Sub-Gaussian random functions (or more approximately - to Gaussian functions) then the nonlinear system of equations for the probability characteristics will take the following form [10-13]

$$\frac{d\vec{\alpha}_1}{dt} = \vec{Q}_1(\vec{\alpha}_1, \vec{\mu}_2, \vec{G}_1, \vec{G}_2, t);$$

$$\frac{d\vec{\mu}_2}{dt} = \vec{Q}_2(\vec{\alpha}_1, \vec{\mu}_2, \vec{G}_1, \vec{G}_2, t).$$

(3)

In the system, $\vec{\alpha}_1(t)$ and $\vec{\mu}_2(t)$ are the first and second order moments of the processes $\vec{Y}(t)$; $\vec{G}_1(t)$ and $\vec{G}_2(t)$ are the coefficients of intensity of excitations $\vec{X}(t)$ defining their mean values and mean powers respectively.

4. A conventional, gradually rising storm is considered. At every stage of slow changes in storm (in comparison with ship time constants such as the period of free oscillations, their relaxation time, etc.) the processes of wind-sea excitations $\vec{X}(t)$ and ship motions $\vec{Y}(t)$ are assumed to be stationary random processes. Probability characteristics of stationary processes P(t) are determined by the solution of following nonlinear algebraic equations

$$\vec{Q}_1(\vec{\alpha}_1, \vec{\mu}_2, \vec{G}_1, \vec{G}_2) = 0;$$

$$\vec{Q}_2(\vec{\alpha}_1, \vec{\mu}_2, \vec{G}_1, \vec{G}_2) = 0.$$

(4)

5. A domain of existence of the physical solutions of the equations (4) is determined by a domain Q of real values of statistical moments as the complex values of mathematical expectations $\vec{\alpha}_1$ and dispersions $\vec{\mu}_2$ of steady-state real ship motion processes have no physical sense. Therefore, a' boundary R of the domain Q is caused by a transition of vector components s $\vec{\alpha}_1$ and d $\vec{\mu}_2$ f from real to complex values. It is showed in works **[10, 11]** that the boundary of domain Q determines the beginning of disbalance of power transformations in motion processes. It is due to the fact that the second order moments $\vec{\mu}_2$ are power characteristics of random processes.

6. Within domain of solution existence Q the stability of probabilistic characteristics $\vec{\alpha}_1^{(o)}$ and $\vec{\mu}_2^{(o)}$ of stationary processes $\vec{Y}^{(o)}(t)$ are studied. For this aim small perturbations $\Delta\vec{\alpha}_1$ and $\Delta\vec{\mu}_2$ are introduced and the equations of first approximation for small perturbations are composed

$$\frac{d\ \Delta\vec{\alpha}_1}{dt} = \left.\frac{\partial Q_1}{\partial \alpha_1}\right|_o \Delta\vec{\alpha}_1 + \left.\frac{\partial Q_1}{\partial \mu_2}\right|_o \Delta\vec{\mu}_2 \ ;$$

$$\frac{d\ \Delta\vec{\mu}_2}{dt} = \left.\frac{\partial Q_2}{\partial \alpha_1}\right|_o \Delta\vec{\alpha}_1 + \left.\frac{\partial Q_2}{\partial \mu_2}\right|_o \Delta\vec{\mu}_2 \ .$$

$$(5)$$

Hereat, the Routh-Hurwitz criteria are stability criteria of the solutions of the equations (4). It is known they are criteria of negativity of the real parts of roots of the following characteristic equation corresponding to the equation (5)

$$(\Delta\vec{\alpha}_1 , \ \Delta\vec{\mu}_2) = 0 \ .$$

$$(6)$$

A. determinant of the matrix of the first partial derivatives of the expressions (4) plays a main role here. It is the determinant of the matrix of the coefficients of the equations (5). This determinant equals a multiplication of the roots of the characteristic equation (6). Therefore equation

$$\begin{vmatrix} \dfrac{\partial Q_1}{\partial \alpha_1} & \dfrac{\partial Q_1}{\partial \mu_2} \\[2mm] \dfrac{\partial Q_2}{\partial \alpha_1} & \dfrac{\partial Q_2}{\partial \mu_2} \end{vmatrix} = 0,$$

$$(7)$$

in regard to such dynamic systems, as a ship, with the complete dissipation of oscillations energy, determines the boundary F of the domain S of stable solutions of the equations (4). For investigation a ship capsizing problem we shall called them local-stable solutions.

7. The boundary F of domain S is determined with the joint solution of the equations (4) and (7). This solution

determines also the ultimate values of the intensities $\vec{G}_{1max}$ and $\vec{G}_{2max}$ of the wind-sea actions which a ship withstands without any stability loss. Evidently, the set Q of having the physical sense real solutions of equations **(4)** includes the set S of local-stable (stable at little deviations from specified motion condition) solutions of these equations **(S ⊆ Q).**

The capsizing of ship is defined as the transition to the oscillations at overkeel position. It comes when the wind-sea excitation intensity slowly increases and a trajectory of the solution of the equations **(4)** intersects the boundary F of the domain S. In this time the point of local-unstable solution of the equations **(4)** will be between the boundaries of the domains S and Q or will came out from the domain Q when these domains coincide **[10, 11]**. However, in the both cases a ship capsizes once if an autocorrelative statistical moment , which is a power characteristic of ship motion, loses stability. In the first case ship does not capsize at once if a crosscorrelative statistical moment loses stability. In this case the ship begins to accomplish additional chaotic motions since the crosscorrelative moment only follows the phase synchronism between processes of external excitation and ship motion **[12, 13]** .

      , the system equations (4), following in process of increase of acting excitation intensities to stability loss of statistical moments, is become stochastic analogue of Liapunov function and the determinant **(7)** of a matrix of first partial derivatives of the equations **(4)** - stochastic analogue of Liapunov function derivative which can be used for research of the nonlocal stability (noncapsizing) of ships in rough seas.

The method under consideration is proximate analog of Bogolyubov **method** for **the** determulation of motion characteristics and stability of motion characteristics applied in the nonstochastic theory of dynamic systems. The latter is known to deal with such motion characteristics as mean value, amplitude and phase of oscillations. It was shown that ours results of the determination of motion characteristics and them stability are analogous to the results obtained with the application of Bogolyubov method for the nonlinear ship motion in regular waves [12,13].

On the basis of the considered method stability research a forming of stochastic stability criteria of the ship was carried out at first under assumption that wind-wave excitations are processes close to white noises [10,11]. An additional action of break' waves in beam sea position was taken into account **[16, 17]**. Results of this criteria

application for 28 small and medium fishing ships fulfilled by V.A. Nekrasov, G.G. Ampleyev and I.A.Alioshin in **1988** for Central Design Office "Leninskaya Kuznitsa" is given in Fig. **1.** Here the ships which was capsized in real sea conditions corresponding to the considered theoretical prognosis are marked by dark points. A capsizing other ships marked light points was not registered under operation.

Reliability Indexes of Ship in Heavy Weather Conditions

is assumed that a ship is operated in hydrometeorological situation of which is determined by long term distribution of mean wind velocity V_m, characteristic wave height $h_{3\%}$ and mean wave period τ_m.

General reliability index of ship characterizing probability of her noncapsizing is calculated by formula of total probability taking into account ship load variations and variations of ship position relatively to wind and wave directions **[18]**. Main role into this formula plays a partial reliability index which determines probability of ship noncapsizing at the given position and load. This partial reliability index are calculated as following **[10, 14, 18]**

$$ P_{NC} = \iiint_{\Omega_w} f(V_m , h_{3\%}, \tau_m) \, dV_m \, dh_{3\%} \, d\tau_m . $$

Where f (V_m, $h_{e}\%$, τ_m) is long time distribution and Ω_w is domain of wind and wave intensities withstood by ship.

Such domain for ship position beam on to the wind and wave **is given in** Fig. 2. It got up as solution of the equations for statistical moments (4) under the restriction of ultimate stability (7).

The calculations of partial reliability indexes for fishing vessels, operating into different regions under different loads, beam on to the sea, carried out by S.B.Prikhodko[19], show that values of these indexes can be change from 0.82 to 0.999. This means that some ships withstand without nonlocal stability loss (without capsizing) only 82 storms of a one hundred. Therefore such ships are especially needed to be equipped by onboard systems current control and prognosis of ship stability resources.

Instrumental Stability Control

The concept of applying various instrumental means to evaluate the level of ship stability is far from new. But capacity of existing devices such as Stalodicator, Wesmar's SC44 stability computer, etc., is restricted by load distribution and static stability control.

They are not intended to register and assess the ship motion
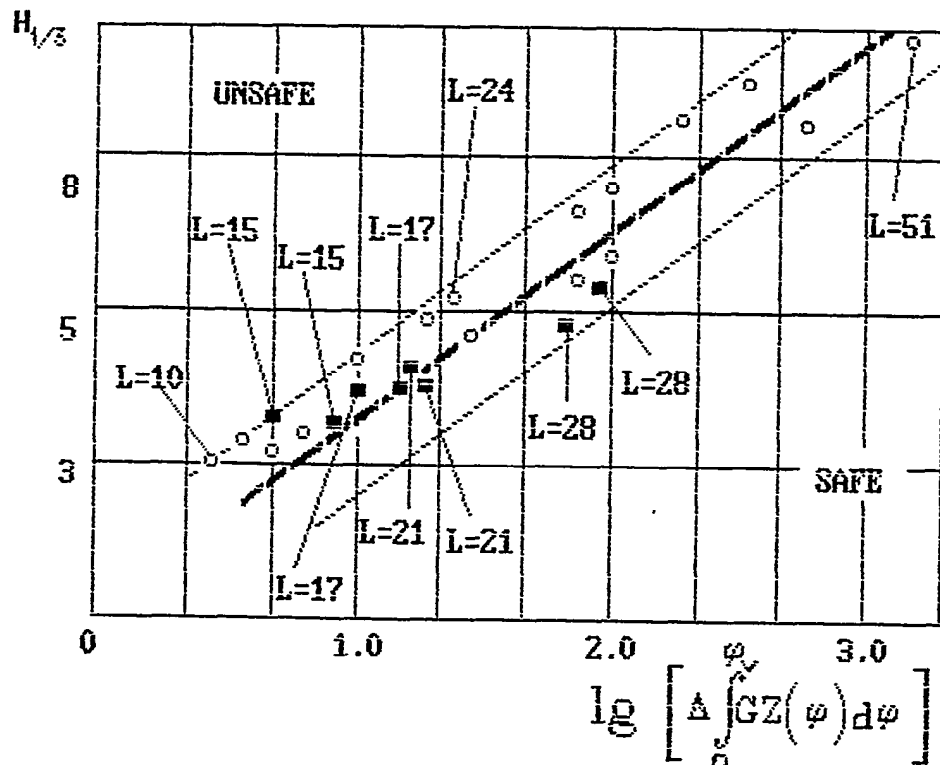
Fig. 1 Ultimate weather conditions withstood by fishing ships beam on to the wind and waves with breaking crests ($H_{1/3}$ - significant wave height, m; L - length of ship, m)
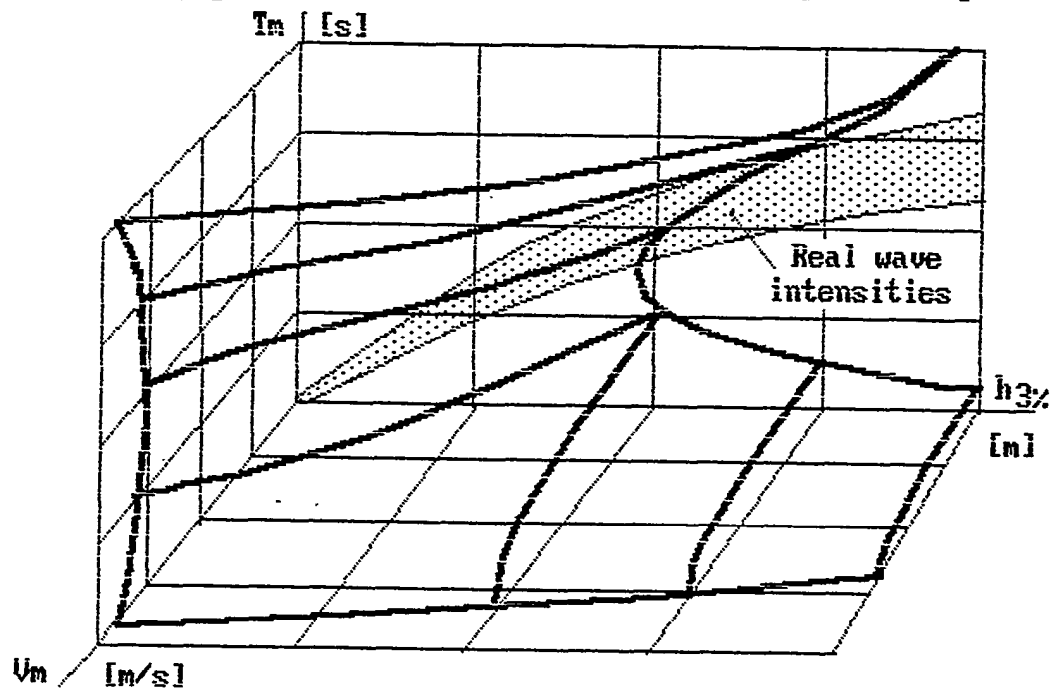
Fig. 2 Domain Ω_w of wind and wave intensities withstood by ship under restriction of ultimate stability

parameters and to provide continuous dynamic stability monitoring which is essential due to constant variations of ship loading conditions, sea state and wind force.

The new analytical tool including probabilistic stability criteria opens very promising perspectives of giving ship master the reliable information on current level of ship safety. Another area of application is the prognosis for safe speed and course combinations taking into account wind and wave data in the intended region of operation.

The instrumental systems developed at Ukrainian Maritime University have various sensors, hardware and software. The essential part is the dynamic sensors unit for collecting the data of ship's draft, heel and trim, as well as all components of linear and angular accelerations .

The automatic input of wind force and direction is provided, sea state should be evaluated by operator.

The subsequent estimation of safety level is based on comparison of measured parameters and precalculated critical values of stability criteria for current loading conditions. The variations of external conditions and loading will immediately result in size and position of zones with increased risk and critical zones giving the opportunity to take preventive measures.

Conclusion

The offered comprehensive solution of stability safety comprised the analytical methods, new probabilistic stability criteria and instrumentation for current onboard stability control.

The wide application of this technique may be performed in two directions:

- calculation analysis to establish the quantitative connections between parameters influencing the stability and probabilistic stability criteria as a measure of ship safety. The recommendations based on obtained information can be used for design purposes and to enhance the operational safety. In generalized form these recommendations will be a very useful addition to the IMO code of intact stability;

- development of -instrumentation for operational stability control which should include the wide programs of introducing these means to maritime community. Very important part of these programs are the demonstration training sessions and stability seminars. Besides the broader understanding of static and dynamic stability the attendees will obtain the practical experience of selecting safe speed-course combinations, voyage Planning load distribution control, etc. Stability control system can be a part of integrated bridge control as separate unit combined with radar or video plotter.

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1.   SAFETY AND TRANSSHIPMENT

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2.   The objectives of the Rotterdam Municipal Port Management

     The main objective of the Rotterdam Municipal Port Management (R.M.P.M.) is to promote activities in the port and industry of Rotterdam.

     In order to achieve this the R.M.P.M. has three key functions:
     - management of port infrastructure
     - provider of nautical services
     - co-designer of port innovations.

     In the organisation of the R.M.P.M. for each key function a directorate is responsible.

     The Directorate Shipping is responsible for the second key function: providing nautical services.

     The main objective of the Directorate Shipping is:
     Supporting the economical process by realisation of an efficient navigation in the port, under the conditions of a sufficient safety level and limited environmental effects.
     This objective is strived after by operating an optimalized nautical infrastructure and by means of an effective information process.

3.   THE ROLE OF SAFETY

3.1.   <u>Introduction</u>

Following our main device it is clear that safety is
no goal in itself but has to be evaluated together
with other interests.
This implies that a certain degree of risk has to be
accepted. The key question is: which level of risk is
acceptable.

The appropriate framework for answering this question
should be found in a safety policy.

Safety can be seen as divided into four aspects:
1.   Safety of the shipping traffic
2.   Safety in the transport of dangerous goods
3.   Safety of the (marine) environment
4.   Occupational safety.

As the R.M.P.M. has no authority in the last type of
safety - this is the working field of the Labour In-
spectorate - just the first three items will be
explored further.

3.2.   <u>General objectives of a safety policy</u>

In accordance with the overall objective of the
Rotterdam Municipal Port Management of promoting
activity in the port and in the industry, three
safety objectives are defined:

- to maintain a sufficient level of safety inside
  the port.
  This objective is aimed at the internal safety of
  the port and its industrial area. The intent of
  this objective is to ensure that all activities
  can take place unhindered by accidents, their
  effects or risks to public health:

- to maintain an acceptable level of risk to the pu-
  blic outside the port and industrial area.
  It is the responsibility of the authorities to
  protect the quality of life in the region from the
  hazards inherent to port activities. These activi-
  ties must be conducted in such a way that all
  reasonable precautions are taken to protect the
  safety and health of the public as well as the
  quality of the enviroment outside the port:

- to maintain such a water quality in the port that the sludge can dredged out of the harbour basins without any restrictions.
  If the water in the port is polluted due to shipping or industrial activities extra (costly) precautions have to be taken in order to handle the dredged materials.
  Polluted water and/or sludge threaten the long-term survival of the port. It is the responsibility of the authorities to ensure that (industrial) activities still will be possible in the future.

The safety in shipping traffic can be seen as the internal safety of the system, the transport of dangerous goods is determining the external safety. Protection of the environment means safety for the system in the long-term.

This paper we will further concentrate on the second type of safety. Especially the transport of dangerous goods is relevant in this respect.

4.   TRANSPORT OF DANGEROUS GOODS

4.1.   Seagoing

Approximately 45% of the total cargo in tonnes handled in the port of Rotterdam is classified as dangerous. 98% of this dangerous cargo consists of liquid bulk, of which crude oil is the main component.
Around 51% of the number of ships entering the port carry dangerous goods.
In 64% this implies the transport as packaged goods, like boxcontainers, tankcontainers, drums etc. Almost 95% of the notifications to the port authorities relates to this mode of transport.

For packaged goods and liquid bulk as well holds that the majority of the notifications deals with relatively small quantities. This also implies that a wide variety of chemicals is involved.

The transport of dangerous goods is concentrated in the Maasvlakte/Europoort area (84%) and into a smaller extent in the Botlek area (12%). At the Maasvlakte/Europoort this means in most cases crude oil, whereas in the Botlek a wide variety of chemical products is handled.

In the Waalhaven/Eemhaven\city area predominately packaged dangerous goods, containers included, are handled.

Approximately 60% of the packaged dangerous goods are transported in boxcontainers.

Around 40% of the in Rotterdam unloaded dangerous goods are carried by pipeline, around 25% by inland barge.

Table, Dangerous goods notifications in 1990

Type	Number	% of total no. of ships
Seagoing (according IMO)		
Gastanker	404	1.3
Crude tanker	746	2.3
Parcel tanker	3,995	12.4
Combination carrier	169	0.5
Total Tankers	5,314	16.5
General cargo (incl. containers)	11,201	34.8
Total	16,515	51.4
Inland Barges (according ADNR)		
Tankers	1,729	
General cargo (incl. containers)	1,681	
Total	3,410	

4.2. Inland barges

Per year approximately 23 million tonnes of dangerous goods are transported from Rotterdam by barge and around 7 million tonnes to Rotterdam. There are per year around 25,000 ship movements with dangerous goods to Rotterdam.

In the port of Rotterdam 40% of the ship movements of inland barges are related to the Botlek area and 30% to 1st and 2nd Petroleumharbour.

4.3. Safety policy

From the general objectives two main objectives for dangerous goods can be derived:
1.   Prevention of accidents in the port
2.   limitation of the effects should accidents occur.

For further specification accidents are categorized:
- 'daily' incidents, characterized by a high frequency ($> 10^{-4}$ yr^{-1}) and small effects $\leq 100m$)
- large scale accidents, characterized by a low frequency ($\_\_^{-4}$, $\geq 10^{-6}$ yr) and major effects (> 100 m, ≤ 500 m)
- catastrophes, characterized by a low frequency ($< 10^{-6}$ Yr $^{-1}$) and enormous effects m, ≤ 500 m)

These accident categories have their own prime instrument in the overall policy.
- catastrophes ---> prevention
- 'daily' incidents ----> physical planning (i.e. zoning as instrument of separating port activities and built-up areas)
- especially for- the accidents with major effects the incident fighting organisation and equipment is scaled.

4.4. RISK

It will be obvious that the word "dangerous" only refers to situations where substances have escaped their containment. Thus, risk is related to accidents in which dangerous goods escape from their containment Risk is considered as being a function of the effect Of an accident and the probability of this accident to happen.
Especially the transport of dangerous goods forms a risk to the public outside the port area. In special transport risk analyses this public risk is calculated and assessed according to standards that are derived from standards for the (process)industry.

This method- of assessing risk is applicable for general decisions on the acceptability of the transport of dangerous goods.

5.   An example: the transport of packaged dangerous goods

5.1.   Introduction

Studies have shown that the probality of an accident
with packaged dangerous goods during the transport
cycle is highest at the moment of loading or unloading.
The probability that, for example, a tankcontainer
aboard a ship is damaged such that the contents start
to flow out as result of a collision during sailing in
the port is practically neglectable.

Further, at the moment of transshipment the cargo is
lifted over a great height (12 to 15 meters), so a fall
might seriously damage the packing.

Due to the nature of (modern) general cargo the types
of packagings vary widely.
However, dangerous substances can be divided into two
categories: those able to cause effect restricted to
the transport area and those capable of causing effects
over a larger distance.

Looking especially at the latter category - excluding
explosives and radio-active material - it concerns the
gasses, either pressurized or liquified, and volatile
liquids. These substances are - in general - transpor-
ted in cylinders, tankcontainers and metal drums.

5.2.1.   Probability

Looking at probability first, a number of factors are
of influence:
- type of packaging
- procedures
- actual method of handling.

Some frecguencies of critical damage to several types
of packagings resulting in loss of dangerous substances
are presented *in* table . . .

Typically the accidents with drums can be considered as
daily incidents. And in a lot of accidents with drums
the complete contents are lost.

The reported accidents for tankcontainers referred only
to leaking valves. so, no accidents where the complete
contents of a tankcontainer were lost have been repor-
ted.

This point has given reasons to do some further investigations upon the damaging of tankcontainers as a result of a fall from great height.
Several dropping test were performed by the Bundesanstalt fur material prufung at a test site near Braunschweig.
In this test series a light type of gastankcontainer was dropped from a height of 12 meters, filled with water and pressurized up to 9 bars, onto a flat, rigid concrete platform.

This experiment did learn us that the maximum credible accident where tankcontainers are involved is a hole punched into it due to hitting an obstacle. This causes an outflow during maximally one hour till the moment that the contents are lost completely.
But, undoubtely transporting dangerous goods in tankcontainers is a very safe way of transport.

Looking at the types of packagings for dangerous goods, it means that the typical incident will comprise the release of the contents of a drum (250 1.) or tankcontainer (max. 28 m3) with a liquid or the escape of a gas from a cylinder (50, 150 or 1.000 1.) or tankcontainer (max. 20 m3).

For the most of the volatile liquids the distances over which dangerous concentrations could occur, will be restricted to ca. 100 m. and for most gases to ca. 500 m. Only for a few substances - mainly gases - the effects can reach farther.

Concerning BLEVE's, dangerous distances in the order of 500 m. occur for a tankcontainer with e.g. propane.
Contrary to poisonous substances, flammable substances can cause chain-reactions. So, for storage, maximum amounts of flammable substances have been decided upon as well as suitable segregation distances from each other and from poisonous substances.

When it comes to the possibilities of reducing the effect of incidents there are structural methods and curative methods.

One of the structural methods is the use of planology to separate activities with dangerous goods from residential areas.

And, finally, there are curative methods to limit the effects of an accident.
Accident fighting is primarily the responsibility of the partners involved: ship and terminal.
When the magnitude of the accident is beyond their capacity the authorities should step in.

So it is unavaidable to prepare emergency plans, make proper materials and equipment available and ensure that personnel is well trained.

A key factor is the speed at which dangerous substances can be identified in case of accidents.

A computer databank like Rotterdam's SISTER is a power-full tool in making these data readily available.

The proper application of and adherence to legal regulations have a reducing influence on the probability of accidents.

In addition to legal requirements ship owners, stevedores etc. set up their own procedures. These may aimed at higher efficiency but they usually lead to greater safety by consequently reducing accidents probability.

As a third factor the actual manner in which dangerous goods are handled is of substantial influence on the probability of accidents to occur.

It will be clear that the use of proper equipment, by trained people, strongly reduces the probability of accidents.

5.2.2. The effect

The second major factors is the effect of an accident.
This effect may be influenced by a number of factors, such as
- Properties of the released substances
- The quantity released
- Possibilities to reduce the effect
- Planology.

Dangerous substances vary widely in their properties.
They can be toxic, flammable, corrosive etc.
It is clear that the effect is very much dependent upon these properties.
Other conditions, in addition to the product's properties should also be taken into account: wind speed and

direction, temperature and atmospheric conditions
determine evaporation and dispersion and hence the area
which is endangered.

It goes without saying that the effects of an accident
with a dangerous substance is proportial to the relea-
sed amount.

SISTER stands for Substances Information for ship
Transport and Emergency Response and is a registered
trademark of the R.M.P.H.

The system containes 4 functional modules:
- Substance Identification and Properties;
- Bulk Transport Legislation:
- IMUG-code Transport Legislation:
- Accident Information.

SISTER is not only designed for use during accidents.
It is in the first place capable of providing ample
information to the R.M.P.M.'s dangerous goods inspec-
tors for their day-to-day job.

5.3.   <u>The zoning system for handling packaged dangerous good</u>

An example of following a policy where by means of
planology possibly dangerous activities are separated
from people living near the port is the zoning system
for handling packaged dangerous goods.

As the frequency of accidents with packaged dangerous
goods is relatively high it was the intention of the
policy makers to make use of separating port activities
and built-up areas in order to guarantee the safety of
people living close to those activities.

For all substances out of IMDG-code classes 2,3, 6.1
and 8 calculations were made. With hypothecial acci-
dents scenarios for the relevant, allowed packings
distances were found over which deadly concentrations
could occur.

Using a zoning system based on distances available be-
tween berthing location and living quarters, for each
zone the allowable maximum size of packagings and total
quantities for groups of dangerous goods are given in
tables in the Port Bye-laws. Activities are permitted
at such locations that in case of an accident the
distance to living quarters exceeds the calculated
effect distance.

In the A (O-100 meters), B (100-300 meters) and C (3009 500 meters) zones there are restrictions in maximum size and quantities as well. In the D (500-1.500 meters) zone all sizes are allowed but for some groups maximum quantities are given.
And finally where the distance is more than 1.500 meters there are no restrictions at all.

It is the intention of the policy of the Rotterdam Port Management to make rules that give forwarders at forehand insight into possibilities of handling dangerous goods in the Port of Rotterdam. So they can plan ahead and have no delay when a ship arrives in Rotterdam.

6.   Need for information

On of the major conditions to be met in order to garantee a good safety level via prevention is undoubtely the availability of reliable and up-to-date information upon the number, location and type of activities in the port.

By means of notification form, which is specified according to Dutch national legislation, the transport of dangerous goods by seagoing ship has to be declared at het competent local authority - in Rotterdam this means at the Harbour Coordination Center.

On this paper form the most important items are: name of the ship, berth, estimated time of arrival, correct technical name of the dangerous substance, the UN-number, quantity, activity (loading/unloading/transit), IMDG-class and flashpoint, and stowage location.

For practical reasons this form has two variants, one for liquid bulk and one for packaged goods and dry bulk.

Experience has shown that one of the problem is to have the right combination of UN-number and correct technical name. It is insufficient to use a trade name or just the proper shipping name.

The use of improper nomenclature is a well-known source of confusion when it comes to applying the proper rules or in case of incidents.

It was exactly this problem that made the R.P.M. decide to set up a database containing the necessary information: SISTER.

A study was set-up to see what the possibilities are to improve this notification process between the ship's agent and the Port Authority.
The study showed two points capable of improvement: the format of the notification and the quality of the contents of the declaration.
Another possibility to improvement would be the use of telematics.

Conclusion

In view fo the Rotterdam Municipal Port Management the real added value of an electronic notification would lie in a construction where the receiver (RPM) and sender of the Dangerous Goods Declaration could both use the same reference tables, i.e. SISTER, to fill in and check the combination of names, UN-number and IMDG-class.

In such a situation the advantages are:
- Uniformity in nomenclature
- Clear interpretation of legislation
- No unnecessary delay in incident fighting.

Transport of dangerous goods by ship in the port of Rotterdam in 1988

Sea-going vessels (IMDG notification)	
Type	Number
Gastanker	439
Crude tanker	748
Parcel tanker	3,676
Combination carrier	217
Tankers	5,080
General cargo	9,568
Total	14,648
Total (dangerous + no dangerous goods)	33,447
Barges (ADNR notification)	
Tankers	1,849
General cargo	969
Total	2,818

SCHIPPING TRAFFIC 1986
Nieuwe Maas / Nieuwe Waterweg

(Thousands)

NUMBER OF MOVEMENTS
(2 DIRECTIONS)

240
200
160
120
80
40
0

km raal →

1035 1030 1025 1020 1015 1010 1005 1000 995 990

INLAND VESSELS —————— SEA-GOING VESSELS – – – – – – TOTAL ············
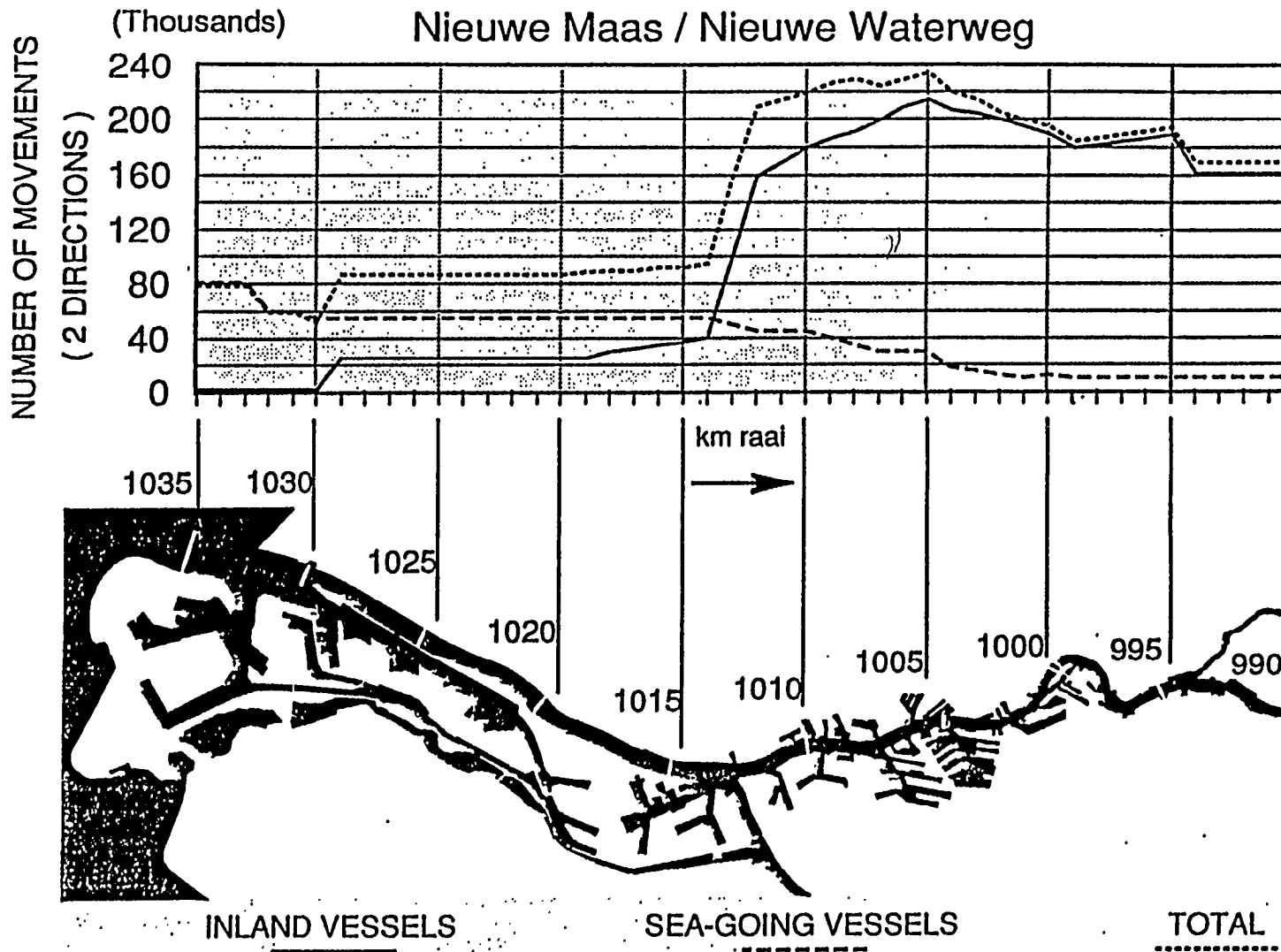
INCIDENT SENSITIVITY
Nieuwe Maas / Nieuwe Waterweg
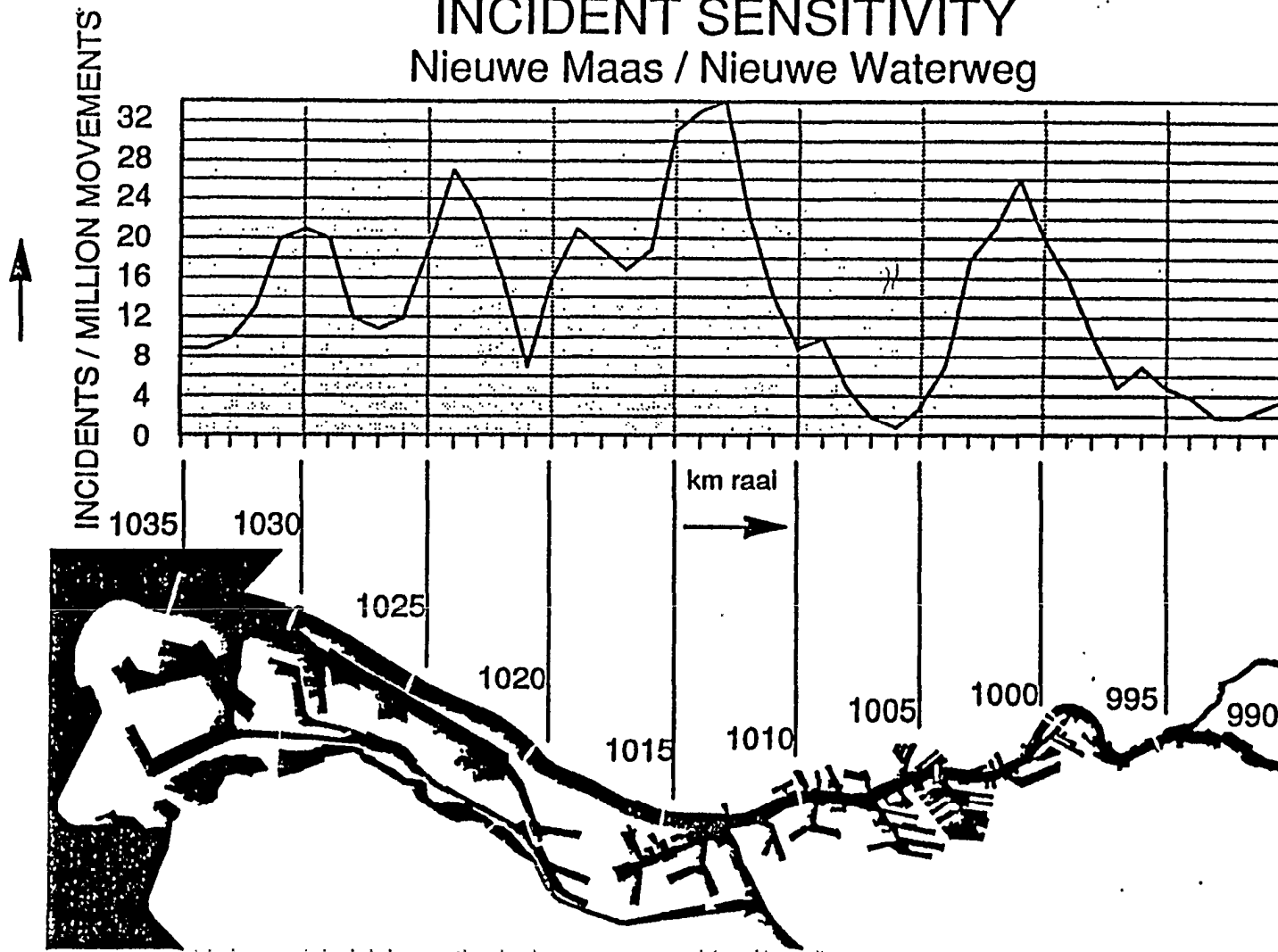
Frequencies of critical damage to several types of packing resulting in loss of dangbrous substances (basis 1985)

Type of packing	frequency (yr -1)
Boxcontainers	$2.7 \, 10^{-6}$
Tankcontainers*	$2.5 \, 10^{-4}$
Cylinders	$2.3 \, 10^{-5}$
Drums on pallets or skids	$1..8 \, 10^{-4}$
Drums	$1.1 \, 10^{-4}$

* For tankcontainers the reported incidents refer only to leaking valves

Traffic in 1987

32,624 incoming sea-going vessels

271.2 million tonnes

Transport in million tonnes

Crude oil	**82.0**
Mineral oil	**33.9**
Ore	**34.0**
Coal	**16.7**
Other dry bulk	**41.1**
General cargo	**47.2**

Port of Rotterdam

Transport of dangerous goods 1987

Number of sea-going vessels

(IMDG notification)

General cargo	9,623
Tankers	4,632
Gascarriers	713
Combination carriers	155

Number of   barges

(ADNR notification)

Tankers	1,832
General cargo	927

Port of Rotterdam

Notification 1987

Hulk

5345

average: 2 / form

total 112.2 million   tonnes

10 most shipped UN - numbers: 103.4 mill.   tonnes (92.2%)

10 most notified UN - numbers: 3635 (35.4%)

same UN - numbers:

conclusion 65 % notifications   for 8% cargo

Port of Rotterdam

Notification 1987

Packaged goods

9623

average: 20 / form

total 2.4 million tonnes

10 most shipped UN - numbers: 0.78 mill. tonnes (32.5%)

10 most notified UN - numbers: 28700 (15.5%)

no similarity

conclusion: some large shipments

frequently small quantities

Port of Rotterdam

SISTER

Substance Information for Ship

Wansport and Emergency Response

Port of Rotterdam

SISTER

Name

UN - number

CAS - number

↓

Systemname

Substance Identification and Properties	Bulk Transport Legislation	IMDG - code Transport Legislation	Incident Information
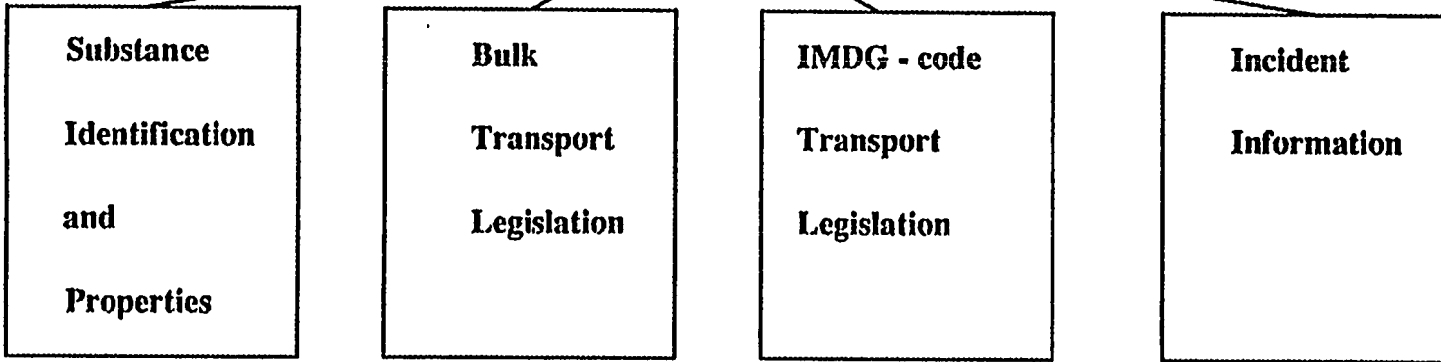
Functional modules

Port of Rotterdam

shipping agent → notification → RPM

RPM ↔ SISTER

shipping agent ⇠ SISTER
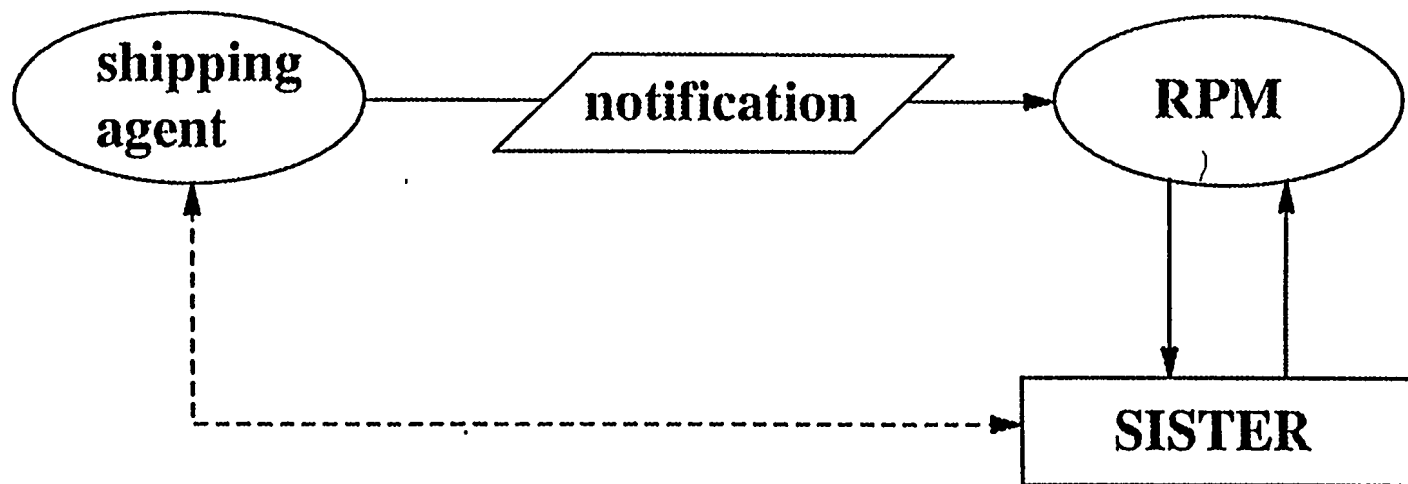
Port of Rotterdam

ACCEPTANCE OF INCIDENT SHIPS IN PORT

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Abstract: The paper briefly mentions the various bodies that are active on the international scene to promote safety of shipping. It then touches on Port State Control and its results. The various types of incident ships are mentioned, as well as the legal tools that are available to owners, underwriters and port authorities. It summarizes the parties involved in combatting the problems on the incident ships. The general sequence of countermeasures is highlighted and so is the role of the media. The conclusive remark stresses the need for a change in attitude of all parties involved in Shipping and Port Operations.
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1. INTRODUCTION

It is well known to most people who are actively engaged in shipping and port operations, that safety at sea and consequently in ports is largely governed by a host of Conventions and Resolutions of the International Maritime Organization (IMO), a vital part of the United Nations (UN).
Another international association that, amongst others, strives "to initiate measures designed to protect the legitimate interests and rights of Association-members within intergovernmental and other international organizations in order to improve conditions and efficiency in ports on a world wide basis" is the International Association of Ports and Harbors [l].
National Administrations implement most Conventions, Resolutions and Recommendations of the abovementioned international bodies in national laws. In this way common ground has been created for that very interesting part of the industry called "Shipping". And finally, not to be forgotten, the port authorities, with their Port By-Laws, give the finishing legal touch when ships operate in port areas and harbour basins.
The sum of all the abovementioned activities should result in a safe shipping industry and a clean environment. This is not the case however. Even in recent years we still had some tragic accidents.
But a disaster that really frightened the world community as a whole was the "Amoco Cadiz", that grounded on the coast of Brittany (France), causing an oil spill of 230.000 tons. This disaster was a major incentive for the Commission of the European Communi-

ties to start working on a Directive for the EC Member States concerning the enforcement, in respect of shipping using Community ports, of international standards for shipping safety and pollution prevention.

2. PORT STATE CONTROL

The Directive mentioned above found its final form in the "Memorandum of Understanding on Port State Control" (the MOU on PSC), an agreement between the maritime authorities of fourteen European countries, that took effect from the 1st July 1982. The objectives of the MOU are:
- to co-ordinate and harmonize the efforts of the maritime authorities in relation to port state control activities;
- to assist in securing the compliance of ships with international standards regarding:
  a) safety of life at sea,
  b) prevention of pollution of the marine environment,
  c) working and living conditions on board.

Fourteen European countries have accepted the MOU standards, as laid down in the so called "relevant instruments" (LOADLINE '66, SOLAS '74, PROTOCOL '78, MARPOL '73/'78, STCW '78, COLREG '72 and ILO 147), while Canada, the USA and the CIS-countries are associated as co-operating maritime authorities.

The sum of it all will eventually lead to an inspection rate of around 85% of all individual ships that use ports in the region of the states that accepted the MOU.

You may have wondered what the aforementioned text has to do with the subject of incident ships, because we still have none in sight. Well, this can change quickly now, because I would like to draw your attention to the 8th Annual Report of the Secretariat of the MOU on PSC [2], covering statistically the years 1988/1990.

Without Acts of God, Perils of the Sea or any other Act of a Higher Authority, the naked facts are shown of the deficiencies of every day shipping, the ships calling at our ports and the crews manning these vessels. While bearing in mind that, quote:
   care must be taken in interpreting and using the statistics .... accidents are not necessarily caused by a frequently occurring deficiency ....

a Port Authority can for its own purpose make some quick scans over the following devastating scene:

1. At least 15 (!) countries scored, with an average detention percentage of 4.48 for all ships involved, well over this figure with a percentage ranging from 4.59 up to and including 22.73! [2] This leads to the conclusion that exotic Morocco and St. Vincent & Grenadines for instance may well be beautiful countries to spend a holiday, but ships of these flag states have to be received in port with special interest, if not to say reluctance.

2. A combination of the annexes 4 and 5 to the Report [2] provides, after some additional calculations, the sickening impression shown in table **1:**

TABLE 1: MOST COMMON DEFICIENCIES DURING 1990 ON SHIPS CALLING AT THE FLAG STATES ADHERING TO THE MOU			
major categories of deficiencies	deficiencies in % of number of individual ships	in other words: one out of the number of ships - as indicated below - calling at a port has a problem with the subject mentioned against it	
		no's	subject
life saving appliances	60	9 8 7	rafts buoys life boat and/or inventory
fire fighting appliances	39	9 4	dampers/valves/quick closing devices/ remote control fixed installations, detection, inert gas, personal equipment, pumps
safety in general	27	4	safety plans, WT doors, hull damage impairing seaworthiness, stability/ strength
navigation	26	20 8	lights/shapes/sound signals nautical charts/publications
ships certificates	14	11	certificates for IOPP/NLS-, radio safety- and/or safety-equipment
loadlines	11	9	ventilators/air pipes/casing, freeboard marks, windows/scuttles/doors
MARPOL Annex I	10	50 25	oily water separator record book
crew	10	25 25	certificates number/composition of crew

Nobody would accept as a standard practice, when travelling by air, that one out of every 25 aircrafts had in the worst possible situation: faulty life rafts, malfunctioning fire extinguishing systems, a cabin door not properly locked, outdated route charts, broken windows and an uncertified pilot.

Nor is any port authority complacent about the list of deficiencies as shown in table 1. It is obvious that ports welcome the activities of the surveyors of the PSC and see adherance to the MOU as the largest contribution to the overall safety of shipping in ports.

It is here that the author wishes to make recommendation to the secretariat of the PSC. Port authorities would welcome two more annexes to the Annual Report, showing the overall performance of the different Classification Bureaus or Registers, as well as statistics about Underwriters and P & I Clubs. I think that the the sooner the port and shipping industry knows   performance   Register and Underwriters inspections aginst the impartial PSC surveys, the better it will be. In my opinion some improvements are urgently needed in these branches of private enterprise.

I want to conclude this chapter with a final remark. I should like to quote dr. J. van Tiel, representing the Minister of Transport, Public Works and Water Management of the Netherlands, on the occasion of the Fourth Ministerial Conference on Port State Control in Paris, 14th March 1991 [3]. Dr. Van Tiel stated in his speech:

> It is that the human element should be paid utmost attention . . . . the human element is a complex one, determined by various factors; operational matters is only one of them. Much more study remains to be done to eventually eliminate the human element as a main cause of shipping casualties. [n]

I think dr. Van Tiel raised a very important point there! It is not only meant for the crew on board, in my opinion. Shipowners should think twice before accepting any crew from some exotic country, just because wages are low; there is no justification for a situation as shown in table 1. Nor is it fair to have insurance companies or the port authority pay for the accidents caused by sub-standard ships.
In the meantime, the port and shipping industry should be on the alert and be prepared for the unexpected.

3. INCIDENT SHIPS CATEGORIES

If we bear in mind what has been said in chapter 2 of this paper, we come to the following possible division:

Category 1 incident ships

very often an incident ship is already in port without the harbour master knowing it. He thought that he had accepted a normal vessel, while he got stuck with a ship with a serious deficiency as mentioned in table 1. Once the ship is in port and the problem at hand, then the process of normalizing an incident is often accompanied by a lame duck situation, parties that want to downplay the seriousness of the problems, lawsuits and surveyors. From the port authorities' side the only tools directly at hand are the (Netherlands) Law and the Port By-Laws. very often a lot of time is involved in order to achieve an acceptable technical and financial solution.

Category 2 incident ships

Here we encounter from the start a more dynamic situation. In most cases the problems have already started at sea, and the owners, underwriters and salvors have already been in contact with each other. There is a strong tendancy to get things done as quickly as possible, but the trick is not to get carried away with too much enthusiasm. As Capt. A.D. Marshall, FNI states in his article "Salvage Services in Port Authority Areas" [4]:

> The owners' representative will assess the cost of salvage, repairs and disbursements and try to decide whether there is sufficient commercial value in the vessel to pay for these" (mostly as "General Average").

" The underwriters' surveyor will simply consider whether salvage and repairs, plus any necessary disbursements such as temporary repairs and towage, can be effected within the insured value. The salvor, in addition to assessing the technical risks in refloating or rescuing the vessel, will assess the sound market value of the vessel and deduct the estimated costs of repairs. The difference between the two -is normally the fund that is available to pay for the salvage operation."

A moment where the harbour master can get very upset is when the case at hand regards a vessel, poorly insured and in a bad shape, where the various parties disappear from the scene and the situation goes into limbo.

In most cases however an agreement is finally reached and liability will mostly be covered in a Letter of Guarantee from the P&1 Club.

I should like to conclude this chapter with a short list of incidents that in normal port operations has to be thought of beforehand:

TABLE 2: POSSIBLE INCIDENTS PER CATEGORY SHIP		
Incident	ship category	
	1	2
1) contact	X	
2) collision	X	
3) grounding	X	
4) foundering	X	
5) drifting	X	
6) shifting cargo	X	X
7) cargo handling deficiency	X	X
8) hull damage	X	X
9) machinery damage	X	X
LO) fire	X	X
11) explosion	X	
12) dangerous goods deficiency	X	X
13) personal injuries	X	
14) spills Annex I and II	X	X
15) miscellaneous	X	X

No problem is the same. Still a basic framework in which is indicated whom to contact, which party to mobilize, has to be at hand. The objective of this framework is to minimize injury and death and the risks when the unthinkable arrives unexpectedly, mostly in after-office hours, during local holidays or weekends.

4. LEGAL ASPECTS

Efforts, such as
    - the MOU, its relevant instruments and the PSC surveyors,
    - the use of the VTS monitoring aids around port areas and their approaches.
do not totally banish risks and accidents, as we have learned from chapters 2 and 3. It is therefore useful to look at the various international conventions which deal with the liability of the owners of vessels, under which an owner is liable for the compensation of victims for damage caused.

    1. Maritime Limitation of Liability Conventions.
        - the 1976 London Convention on Maritime Claims,
        - the 1969 and 1971 Conventions for Oil Pollution Damage,

- the draft "HNS" Convention (currently under
            examination of the IMO).
The satisfactory nature of these conventions is
diminished by the following facts as stated in the
Report of the CLPPI-Committee [5]:
"- the liability of the shipowner is established in
   association with a limitation of his financial
   scope, which, certainly, facilitates insurance
   coverage."
The limitation is the product of the Gross Tonnage
(GRT/GT) according to the Load Line Convention and
the maximum liability in SDR's/GT.
The Special Drawing Rights of the International
Monetary Fund (SDR of the IMF) is i.e. a basket of
currencies which follow the average erosion of the
various currencies in it.
"- the amounts of these limitations . . . . are
   greatly devalued by monetary erosions during the
   long delays before a convention comes into force,
   e.g. the 1976 Convention did not have a
   sufficient number of participants to enter into
   force, until 1986. And in certain countries the
   amounts of these original limitations had already
   eroded by 40 to 60% in terms of true purchasing
   power
 - thus, the USA preferred to draw-up, with its Oil
   Pollution Act of 1990, regulations, specific to
   them, which stipulate very high limitation
   amounts and facilitate regular updating of these
   sums, which, in counter party, this removes all
   possibility of the 1984 IMO Protocol to the
   1969/71 Oil Conventions coming into force. [n]

2. Salvage and the environment

The 1989 Salvage Convention merits highlighting
because of the concession that a salvor **may** increase
his remuneration, provided he has taken measures, in
addition to the normal salvage operations, to
protect or limit damage to the environment (marine,
coastal and port), whether by oil or other hazardous
substances. The fear in port circles was, however,
that the benefits of this convention would not be
felt for some time because of the usually lengthy
delay before the requisite number of contracting
states ratify a convention.
The Council of Lloyd's, supported by the shipping
community and IAPH, has attempted to overcome this
by incorporating a number of the provisions of the
1989 Salvage Convention into the Lloyd's Open Form
(LOF). Thus these provisions have been brought into

effect internationally as soon as possible, viz. upon introduction of the LOF 1990 [6), about one year after the 1989 Salvage Convention was signed (!]. LOF 1990 thus provides the port accepting a disabled or incident vessel all the latitude required for organizing such acceptance, so that the risks can be minimized and correctly covered.

In the introduction we touched on the Port By-Laws. The limitation of liabilities as mentioned above supports the need for some stronger and handier instruments when tackling the incident ship of either category. In Delfzijl/Eemshaven these aspects have been covered as follows:

3. Port by-law

The port by-law does have in its definitions a description of an "average vessel", which in short runs as follows:

> average vessel - a vessel directly inflicting serious danger, damage or hindrance, or being in such a state, through the nature of her cargo or the quality of her crew, that, according to the judgement of the harbour master, this is exceeding the acceptable risk levels in the requested berth and its adjacent port areas, or impairing the use of (a portion of) the port and her fairways by its presence."

In the relevant chapter on "Safety in the port" the harbour master has been authorized to issue a prohibition to the master of an average vessel to proceed to the port. This will of course only be done if and when precautionary measures have not been taken to minimize the risks, not only in the technical, but also in the financial aspects of the case. On top of this a rather liberal instruction has been issued from the Managing Board to the harbour master. It goes without saying that the essence of this instruction stresses the point that an evenhanded approach is paramount, that all relevant parties shall be heard and that the harbour master may avail himself of expertise where necessary. The. harbour master therefore has some leeway to act, but he should be constantly aware of not only the many pitfalls along the road to a succesful handling of the problem, but also of the interests that are at stake for the port and its users.
Based on International Conventions, National Law and the Port By-Law he is now in a position to

- issue a set of 'Port Acceptance Conditions",
- require. 'Power **of** Attorney" from owners/charterers (Appendix I)
  send a "Liability Message" mostly in combination with the requirement of
- a "Bank Guarantee" (Appendix II). In case the liability message accepted legal proceedings will be initiated including the possibility of eventual
- "Detention" of the vessel.

5. AUTHORITIES AND PARTIES INVOLVED WHEN HANDLING INCIDENT VESSELS

As soon as it is known that a meeting is convened regarding the unfortunate incident ship, then a stampede, it seems, starts for the harbour masters' office. Table 3 gives a good impression of the guests that, whether having been invited or not, scramble for his door.

TABLE 3: AUTHORITIES AND PARTIES INVOLVED WHEN HANDLING INCIDENT VESSELS	
parties	subject
authorities: - "Ministry of Shipping and Water Management, etcetera":	
* Directorate Northsea	- public interest
* Government Harbour Master	- VTS aspects
* Netherlands Shipping Inspectorate	- PSC aspects
* Local Representative Rijkswaterstaat	- water quality control
- Provincial Government	- public interest
- Municipality	- public interest
- Port Authority	- public and port interest
- (River) Police	- offical report
- Fire Brigade	- fire fighting
- Inspectorate of Labour	- safety aspects cargo handling
- Dangerous Goods Corps	- dangerous goods handling
- Committee of Inspection	- radio active substances
- Red Cross/Sanitary Services/Port Health	- medicare
- Constabulary	- immigration
- Customs	- im/export duties
- Experts (barristers/technicians)	.

TABLE 3: AUTHORITIES AND PARTIES INVOLVED WHEN HANDLING INCIDENT VESSELS		
	parties	subject

private enterprises:	- Classification Bureau
	- Underwriters
	
	- Bailiff
	
	- Ships' agent
	
	- Towage company
	- Salvor
	- Linesmen
	
	- Pilot Service
	- Shipyard
	- Stevedore/Terminal Representative
	- Port Reception Facilities
	- Specialized Firms
	- Experts (barristers/technicians)
		- class certificate
		- hull insurance
		- transport insur.
		- interests various
		  parties
		- owners/charterers
		  interests
		- port towage
		- salvage
		- (un)mooring and/
		  or crew assistance
		- nautical advisor
		- repair facilities
		- cargo handling
		- MARPOL I, II & V
		- special tasks
		- the case at hand

The trick here is to admit participants only then to the meeting after the business has been stated and the name, firm, telephone number and signature have been entered in a list.
In order to keep the meeting manageable, only one representative of each party shall in principle be accepted and very often some people have to be refused admittance. The result from this approach is usually a fruitful meeting with clear, concise agreements on a variety of subjects. The larger the group that is admitted, the greater the chance that the meeting will end in a bear garden.

6. SEQUENCE OF OPERATIONS

From a recent inquiry among several Dutch port authorities it appears that in general the following sequence of activities is adhered to before an incident ship is accepted in the port or one of the fairways leading to it:

- technical inspection

  This inspection is being held outside the port, mostly at sea or in the roads. On behalf of the harbour master, safety experts board the incident vessel. They act in close co-operation with the Government, the State Harbour Master and Shipping Inspectorate and occasionally with a salvage company participant.

- meeting in the Harbour Master's Office

   All relevant parties meet. The harbour master chairs the meeting. All aspects of the problem at hand will get attention, such as cargo particulars, ships' particulars, salvage aspects, financial consequences, etc. etc.
   This meeting leads to

- Port Acceptance Conditions

   All facts, including the results of the inspection, will be translated into a message (letter, fax, telex) with Port Acceptance Conditions. This message will be sent to the owner or his representative and his/their formal response will be awaited.

- Salvage Agreement

   Depending on the seriousness of the incident, a Salvage Agreement (LOF 1990 !) should be signed and/or accepted.

- acceptance of other third parties

   Third parties are for example the factory or installation the vessel is bound for, stevedores handling the cargo(port repair or dry-dock companies. The harbour master has to make certain that the participants will accept the incident vessel in their berth.

- power of attorney

   The power of attorney enables the harbour master to take any necessary precautionary measure against the incident vessel to make certain that the safety within the port boundaries will not be impaired (Appendix I).

- bank guarantee

   A bank guarantee is demanded from the owners by the harbour master to safeguard the port against claims or costs (keeping in mind the possibility of wrecking, sinking or pollution). The amount depends on the vessels' state and can be raised easily as a result of the inspection (Appendix II).

- liability

   In case of 'any occurrence of incident vessels already in port, the owners usually are held responsible for the consequences/damage/costs by sending them a liability message. It may include the demand for a bank guarantee.

If this demand is not met' there is the possibility of legal action including detention of the vessel.

When all the necessary precautionary steps have been taken, the ship will almost always enter the port and operations will start to get things back to normal. The point to stress here is to take care of a good and careful follow-up, to keep good communications with all parties involved and have a daily meeting where relevant parties shall report. Only then incident vessel handling can be brought safely to an end. The results will be most rewarding and a contribution to the interests of all parties concerned.

7. THE MEDIA

Some remarks have to be made about reporters of newspapers, radio and television. They have a job to do like everybody else. If insufficient attention is paid to their needs, then a severe setback can develop for the total operation.
In nautical terms "a press of sail has to be carried" to keep reporters regularly informed about the operations at hand. Ill-informed reporters try their luck on the scene and very often hamper operations.
The author furthermore has a very strong opinion on who should perform this task, viz. the Managing Director. In this way the harbour master can concentrate on the technical aspects of the problem, while the Managing Board, the Municipality and the media are being informed through the Managing Director. It is suggested to keep the information concise, clear, to the point and to operate with maximum credibility. Admit it if a prompt answer cannot be given, but come back on the subject at the next press conference. Remember that any mistake in giving correct information in general will be severely punished later.

8. CONCLUSIVE REMARK

The aim of the paper is to stimulate discussions and a better understanding of the problems and aspects for all parties concerned when handling incident ships. It is my most sincere wish that this paper, and the discussion during the Conference, will be beneficial for our common ship "PLANET EARTH and the crew that has signed the Articles.

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EXAMPLE "POWER OF ATTORNEY"

RE.: (name of vessel)   place/date

1.   Owners and Time Charterers accept the port acceptance conditions set
        by (name Port Authority) for their consent on the entry *of* the vessel
        into the port of (name port), as described in the message (letter,
        fax, telex), dated (date), from the Port Authority to (name Owners a/o
        Charterers).

2.   Owners and/or Time Charterers herewith authorize irrevocably the (name
        Port authority), in case abovementioned vessel and/or cargo and/or
        balances *of* cargo in the opinion of the Harbour Master of (name Port
        Authority) endangers **persons** and/or properties of third parties to
        perform or have performed for their account and risk all that is
        necessary to decrease the danger as much as possible and whatever may
        be in the interests of public order, public health and matters of
        public responsibility, such as to give first aid, discharge, make
        gasfree, clean, shift and do the necessary repairs, if any.

3.   Owners and Time Charterers, within the limits of the Rules **of**
        Limitation of the 1976 Convention and corresponding national
        legislations, agree to hold harmless the (name Port Authority) from
        any claims by third parties against the (name Port Authority) for
        personal injury **or** death or for damage to goods arising out of the
        consent given by the (name Port Authority) to the entry of the vessel
        and/or actions taken by or upon instructions of the (name Port
        Authority).

4.   Owners and Time Charterers undertake to pay all expenses and costs
        incurred by the (name Port Authority) with regard to the handling of
        the vessel and her cargo.

5.   This undertaking is subject to **the** Dutch Law with acceptance of
        (location of- Court, to be chosen by the Port Authority) jurisdiction.

SIGNED ON BEHALF OF   SIGNED ON BEHALF **OF**
(OWNERS)   (CHARTERERS)

EXAMPLE   GUARANTEE"

(Place/date)

We, the undersigned: (name Bank)

waiving and renouncing the benefits of eviction and **of** division of debt as well as of all other benefits and exceptions conferred **on** guarantors by Netherlands Law, including the right to invoke the provisions of articles 6:154 of the Netherlands Civil Code, hereby declare to bind ourselves jointly and severally as surety and co-principal debtor to and in favour of (name Port Authority), herinafter to be referred to as "the creditor", by way of security for the true and proper discharge by (name owners) and (name charterers), respectively owners and time charterers of the m/v (name vessel), hereinafter to be referred to as "the principal debtor", or whatever the principal debtor may be found to be indebted to the creditor by virtue of a judgement (which is not subject to appeal), rendered against the principal debtor - or jointly against the principal debtor and the undersigned guarantor - by a Dutch court of law, having jurisdiction in the matter hereinafter mentioned, or by virtue of a valid arbitration award or by virtue of an amicable settlement between the parties, in respect of the principal amount, interest and costs of suit relating to the port acceptance conditions for the vessel mentioned above, which are laid down in the message (letter, fax, telex) from the creditor to the principal debtor on (date).

This guarantee is hereby given without any prejudice whatever to the question of liability or to the amount involved or to any other matter in issue (including any question as to statutory limitation of liability) and for a maximum amount of Dfl. (to be filled in) (Dutch guilders in words).

This guarantee is given for the purpose of the prevention of an attachment in respect of the (name vessel).

This guarantee shall expire unless within 24 months from the date of signing hereof legal proceedings have been instituted with relation to the aforesaid issue in a court of law having jurisdiction in the matter, as referred to above, or a deed of compromise has been signed or an appointment of one or more arbitrators has been notified or requested or proposed in terms of an arbitration clause, or an amicable settlement has been concluded between the parties.

SIGNED ON BEHALF OF
(BANG

THE PROBABILISTIC APPROACH TO SHIP STRUCTURAL DESIGN AND MAINTENANCE --A REVIEW

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Abstract

This paper is a review of on-going research efforts in the international community to bring the application of probabilistic methods to fruition for ship structures. To date, probabilistic methods have not been accepted for the design and maintenance of ships to the same extent as they have for other types of structures. The very complex structural configurations and loadings of the ship structural engineering problem make the application of probabilistic methods both attractive and challenging, with much research work yet to be undertaken.

Introduction

Probabilistic or reliability methods have become a popular tool in the field of structural analysis. Unlike deterministic methods, probabilistic methods offer the opportunity to include directly the uncertainties associated with the statistical distributions of load and strength parameters. The engineer is given better insight and control over the factors which influence structural safety and can ultimately produce more rational efficient designs.The degree of acceptance of reliability methods has depended on the complexity of the structure and loading, the number of similar designs in existence, and the relative importance of safety for the structure. Ship structures do not benefit from well defined load or strength values, usually do not have many units of the same design, and in general, loss of safety from structural failure is not the overiding concern. As such, reliability methods have not had as significant an influence on ship structure design as they have had for other types of structures.

Despite the inherent difficulties associated with application to ship structures, reliability methods offer significant benefits in addressing the randomness and uncertainties associated with ship design. Many organizations throughout the world are addressing research efforts to this end. The author has had the fortunate opportunity to participate in three international working groups concerned with the application of probabilistic methods to ship structures. The U.S. based Ship Structures Committee (SSC), the International Ship Structures Committee (ISSC), and the Netherlands Ship Model Basin Cooperative Research on Ships (NSMB-CRS) whose work is only available to CRS members.

This paper does not present original work, but is a review of the current state of reliability methods for ship structural design and maintenance. It discusses probabilistic methods from the loads and strength aspects of ship structures and summarizes the most profitable areas of research in improving the application of reliability methods to ship structures.

Current Practice vs Probabilistic Methods

Current ship structural design and maintenance practice has evolved from years of experience in determining design loads, load effects, resistance models and safety factors. The method is one of working stress design where a characteristic value of design bending moment is derived from static balance on a design wave. The bending moment is transferred to a primary load effect (stress) by treating the ship cross-section as a uniform prismatic beam. This applied stress value is compared to a characteristic resistance stress value (such as yield), and a safety factor in the range of 1.6 to 1.8 [ISSC 1985] is used to separate the two. More advanced analysis methods such as finite element methods have been applied to ship structures but the underlying principles and faults of working stress design remain in place. A quote from Committee **V.1** on Design Philosophy [ISSC 1985] describes the general state of working stress ship structural design:

Even today, the techniques **for** *predicting all the loadings to which an oceanic structure is heir and its consequent structural response are not altogether reliable, and the quantitative analysis of risk of failure is still beyond reach, Yet such inadequacies have never deterred the naval architect, for, although he really has no rational basis for predicting failure, he continues to design with bold unconcern of such a drawback by selecting a hydrodynamic loading in a manner which, although claimed to be empiric, is essentially arbitrary, and by imposing criteria of allowable stress intensities which, although intended to ensure that the material of hull construction will never be strained beyond its elastic limit, are at best nominal, and he does this by candidly ignoring that ship hulls are of cellular construction and that the material of all oceanic structures, which is beset by an accumulation of locked-in stresses and strains, is always working in the plastic region beyond the yield point. If it were not for the precious quality of ductility by which-he selects the hull material (a quality which he never uses in his structural analysis), he would be a lost soul.*

Working stress design has the advantage of being relatively simple to use and easily incorporated into design codes. The fact that it has also provided good results for typical ship design increases resistance to move to a different design format. Chang [1990] argues that working stress or

'traditional' design of ships does have a probabilistic content in that characteristic values of load and strength and safety factors have been chosen to give an acceptably low probability of failure. He also points out that design codes based on probabilistic methods do not have to be more complicated than the traditional approach and that load and resistance factor design (LRFD) codes, which do not stray too far from the working stress approach but are calibrated by higher order probabilistic methods, have been successfully adopted by other agencies.

The main disadvantage of deterministic working stress design is that all uncertainties associated with defining the load effect and structural resistance are tied up in a single safety factor. The designer is not given any leeway to apply more accurate knowledge of the design process. The deterministic safety factor also does not reveal how or to what level safety is achieved in the design, as there is no consideration given to the likelihood that the ship will see its design condition. Reliability methods allow specific uncertainties to be defined for each step of the design and analysis process; therefore, they give the designer a more rational understanding of how safety is derived and may also provide a means to control some of the uncertainties to provide a more efficient and safer ship.

Design and Maintenance

The incorporation of inspection and maintenance in the design process has received considerable attention for producing more efficient, safer designs. A considerable amount of work has also been done in developing planned maintenance practices based on probabilistic assessment of the occurrence and growth of fatigue damage. Predicting when and where fatigue damage is likely to occur allows planned inspection and maintenance to be undertaken to maintain a minimum level of safety throughout the life of the structure. Being able to include this process as part of a design philosophy can produce more efficient 'fail-safe' structures in which damage expected to occur during life can be managed to achieve a known level of safety. Designing ships which are 'inspectable' is the first step in this process. The Ship Structures Committee is one of several US agencies involved in studying this process [Bea et al 1991].

Reliability Methods

Several texts such as Thoft-Christensen and Baker [1982] cover the basics of reliability methods extensively, and several computer codes are easily available to calculate safety indices. Because of the difficulties in defining the ship structure problem and its parameters, it became evident in the 1980s that reliability methods would not deliver true probabilities of failure and the term 'notional probabilities

of failure' was coined, indicating that reliability analysis was more of a comparative design process than an absolute one.

Most literature on structural reliability methods refers to three levels of reliability analysis, depending on the level of statistical information known about the parameters in the problem. These are well described in several texts and papers. Level 1 uses only one characteristic value of the problem parameters. This is the basis of working stress and load resistance factor (LRFD) design where a safety factor or load and resistance multipliers are used to separate a characteristic strength value from a characteristic load value. Level II methods use two characteristic values, the mean and coefficient of variation (COV), and also assume some type of distribution of the parameters (eg. normal, lognormal). There are various developments of Level II methods such as FORM (first order) and SORM (second order). These are the most commonly used methods for structural analysis and are available in commercial software. Level III methods require full joint probability descriptions of all of the parameters. This information rarely exists; hence, these methods have not generally been used in structural applications.

Level II reliability codes need two basic inputs which may be very difficult to obtain: limit state descriptions for all of the possible failure modes, whether structural failure is defined as collapse or unfunctionality; and, statistical characteristics in the form of means, COV matrices and distribution types of all of the parameters in the limit state.

The main output of level II methods is a safety index B, for the particular limit state of concern. A secondary product of reliability analysis, but one of probably equal importance, is the sensitivity of the safety index to the input parameters. While the safety index tells the analyst what the probability of failure is, the sensitivity factors tell him what parameters most influence the safety and where the most efficient design tradeoffs can be made.

To date, reliability methods have addressed probabilities of failure associated with physical parameters and have not included human error. Human error is by far the most significant cause-of ship loss even when the loss is a result of structural failure. Several researchers are trying to quantify and include human error in the reliability assessment process; this is a very difficult task which lies mainly outside the traditional fields of engineering study. True safety probability estimates of a structure must eventually include this aspect of failure analysis.

Loads and Load Effects

The random nature of the ocean environment has made ship and offshore structures natural targets for the application of probabilistic methods. The statistical description of sea state has probably received more attention than any other marine related topic in the past few decades. Still, according to ISSC [1991], the uncertainties associated with load prediction are an order of magnitude greater than those of strength assessment.

The limit states being considered in reliability analysis define the load or loads that need to be included in the analysis. The two basic categories of loading are the extreme and lifetime cumulative values for ultimate and fatigue failure limit states, respectively. The load development process begins with describing the ocean environment through a representative spectrum and associated wave property probabilities. Figure 1 shows six wave height probability distributions used in a parametric study of fatigue life for Canadian navy vessels in northern Atlantic operation: Ochi North Atlantic [Sikora et al 1983]; North Atlantic Annual and Winter [Bales et al 1981]; Norwegian Annual and Winter [Bales et al 1981]; and, one specifically derived from a history of Canadian warship operations (MABCOM).
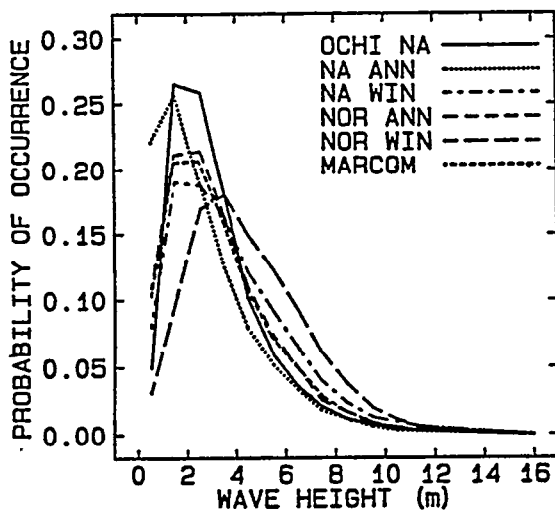
Figure 1: Wave Height Probabilities of Occurrence for Six Wave Climate
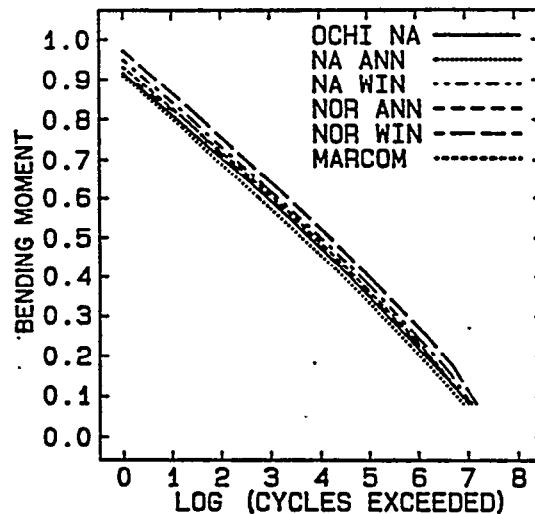
Figure 2 :Bending Moment Exceedance Curves for **Six** Wave Climates

Uncertainties arise in defining the load environment through (Nikolaidis and Kaplan [1991]): definition of wave spectra; the effects of short crestedness; sea directionality; use of visually assessed wave heights; and, the action of the captain against heavy weather.

The wave environment is translated to load effects through transfer functions (response amplitude operators - RAOs)

which are functions of ship speed and heading. These may be derived through linear 2D strip theory, higher order nonlinear strip theory, 3D panel methods or through, empirical methods. Upon defining probabilities of ship speed and heading and life at sea, a lifetime load effect distribution can be derived as in [Sikora et al 1983] who use generic empirically derived RAOs. This method was applied to the wave height probabilities of Figure 1 to derive midships vertical bending moment exceedance curves for fatigue life estimation as shown in Figure 2. Although these curves appear reasonably close together, those familiar with fatigue analysis will realize that the differences in these curves have a very significant effect on fatigue life prediction (in the order of 100 percent between the top and bottom curves).

Uncertainties which exist in translating the load environment to load effects are: evaluation of still water bending moment; development of transfer functions - RAOs; nonlinearities in transfer functions - hog/sag ratio; definition of ship operational profile; load combination models - wave and slamming; and, models to predict slamming loads. Dalzell [1991] presents an excellent review of the load requirements for probabilistic analysis. He argues that a combination of linear frequency domain, quasi-linear time domain and fully nonlinear time domain analyses is required to develop proper load history data from all relevent load components.

One of the most significant advances to be made in the application of reliability methods to ship structures is in quantifying the load related uncertainties. There has been surprisingly little effort in this area in comparison to other topics in reliability theory. Nikolaidis and Kaplan [1991] summarize some of this work, most of which comes from earlier efforts by Guedes Soares and Moan [1985]. They divide uncertainty into two categories, natural and model. Natural uncertainties are those arising from statistical natural scatter in the data and can be reduced with increased sample size. Model uncertainties arise from inaccuracy in describing a process and result in both scatter and a systematic bias. Modelling uncertainty is not a random quantity and is not reduced with increased sample size, but only through improved understanding and description of the physical process. Extreme load uncertainties have a significant natural uncertainty content while fatigue load uncertainty is a function primarily of model uncertainty. Model uncertainty factors can be estimated by comparison to experimental data or to more refined models.

Load uncertainties have been described in Nikolaidis and Kaplan [1991] in terms of a bias factor B, which multiplies the predicted quantity X_p to estimate the true quantity X, and a coefficient of variation, COV. Simplified versions of

the bias factors based on wave height, Hs are given and repeated here as follows:

- Spectral shape: B=1.O for H_s > 5m or ship length L < 250m and B=2.0-0.2 Hs for H_s< 5m or L > 250m and COV=O.l
- Shortcrestedness: B=1.O-0.0077Hs and COV=O.O5
- Directionality: B=0. 981+0.018 Hs and COV=O.l
- Visual Wave Height:B = (0.75 Hs)/(Hs-2.33) and COV=O.17
- Captain's Response to Heavy Weather: B=1.0 to 1.25

Still water bending moments may be relatively easy to derive from a known condition of a vessel but coefficients of variation can be very large depending on the type of vessel. COVs are reported [Nikolaidis and Kaplan 1991] to range from 0.29 for containerships to 0.99 for tankers in a ballast condition. Committee V.l of [ISSC 1991] uses a Rayleigh distribution for still water bending moment in their reliability assessment of an offshore production vessel. The COV used for still water model uncertainty is 0.10 for panel failure and 0.05 for hull girder ultimate strength. These values are lower than those reported by Nikolaidis and Kaplan [1991], which supports one of their underlying themes that model uncertainties used to date, even in design codes, are much too low. The approach used in the NSMB-CRS project [Gran and Loseth 1991] is to derive a spectral representation of still water moments based on the loading book using draft and trim as random variables. This model will serve as a subroutine input to the DnV reliability code, PROBAN.

Bias for vertical bending moment RAOs are reported in [Nikolaidis and Kaplan 1991] as B=1.22-.OO5Hs for all factors except hog/sag ratio which is given as a function of the block Coefficient as Bs=1.74-0.93C$_B$ and B$_H$=0.26+0.93c$_B$ for sag and hog respectively. A COV of 0.35 is reported for general bias of RAOs and 0.12 for the effects of hog/sag ratio. Committee V.l [ISSC 19911 used a nonlinear strip theory and time series approach to derive bias for linear strip theory results of Bs=1.l5 and B$_H$=0.85 for sag and and hog respectively, with a COV of 0.03. For sagging vertical bending moments, RAOs from linear strip theory are almost always unconservative.

The problem of load combination is one which has not been resolved satisfactorily. When combining loads from different time bases, it is particularly difficult to establish what and where the maximum combined value is. Still water, wave and slamming induced bending moments all occur within different time frames. Within the regular wave induced loads, vertical, horizontal and torsional components have to be combined; the effects of lateral pressure may also be important for the limit state of concern. Correlation coefficients for all of the loads of concern to the limit state being investigated are required, but are rarely

available. Monte Carlo simulation (MCS) can be used to generate statistical parameters for verification of combination models but is computationally intensive and currently computationally impossible for developing lifetime load profiles where statistically significant data would have to be generated for all of the ship operational permutations (>2000 [Dalzell 19911). Nikolaidis and Kaplan [1991] compared Turkstra's Rule, the summation of component peaks, and the square-root-of-the-sum-of-the-squares (SRSS) against MCS predictions for combined slamming and wave loads. They found that Turkstra underestimated the combined load with a bias of 1.17, the peak summation overestimated the load with a bias of 0.72 and the SRSS alternately over and underestimated the load with a bias of 1.01 with a slightly higher COV of 0.12, compared to 0.11 for the other two methods. The study of Committee V.l [ISSC 1991] used a combination parameter to multiply the still water loads in summation with the wave load with values ranging from 0.61 to 0.41 depending on the time span of the load input.

The NSMB-CRS project is primarily concerned with load combination models for probabilistic analysis and is combining theoretical development with full scale measurement data to predict the statistical parameters for combined still water, wave component, slamming and pressure loads. For some types of loads such as slamming and pressure, existing models to predict the load effects from the ocean environment and ship operational profile are inadequate.

Strength

The second part of the reliability equation is the statistical description of the structure's ability to resist the load effects. Three components make up this description: the geometry, the material, and the model describing the resistive capacity. Uncertainties for geometry and material data have been given in many published reliability studies [ISSC 1985, 1988, 1991, Mansour et al 1991] and will not be repeated here. These should be verified for the problem at hand but in general have COVs less than 0.05 for geometric parameters and less than 0.10 for material parameters. Biases are almost always greater than 1.0 indicating nominal values are conservative.

Reliability analysis of ship structures,which consist of complex welded stiffened shells should be undertaken by system reliability methods which allow assessment of the safety of the entire structure, not just component parts. To date, no sufficient methods of applying system reliability methods to ship type structure have been developed [Nikolaidis and Kapania 1990]. Computational requirements, simplifying assumptions which are not applicable to ship structure, and difficulties in measuring structural redundancy are cited as the main deficiencies. System

reliability is closely linked to structural optimization procedures, and it can be envisioned that eventually optimum ship structural designs can be developed using system reliability requirements as optimization constraints.

The most attractive method of analyzing the response of complex stiffened shells of which ships are constructed, is finite element analysis (FEA). Incorporating the statistical probabilities of the problem is not as straightforward when using FEA as it is for closed form limit states formulations. One approach to incorporating the randomness of the structural parameters in FEA is to use simulation techniques (for example, MCS) where the parameters are varied according to their distributions in a series of FEA runs to produce load effect statistics. This can be very CPU intensive, but methods for improving the efficiency of these simulations are appearing in the literature. Computational considerations become more severe when the limit state involves nonlinear behaviour, such as for ultimate strength assessment.

An area of current interest in the academic community, but of tremendous potential benefit in future application, is incorporating reliability methods directly into FEA codes [Moore 1988, Spanos and Brebbia 1991]. This eliminates the need to establish approximate limit state equations to describe failure, as FEA directly predicts (to the accuracy of the model) structural behaviour such as displacements, stresses, onset of plasticity, loss of stability, vibration, etc. The randomness of the structural parameters is used in the FEA calculation so that output load effects include the structural uncertainties.

Just as uncertainties for closed form equations of limit states need to be established, so must they be determined for FEA. This is in some respects much more difficult, as the uncertainty will depend partially on the actual modelling approach used, which may require a subjective evaluation. Typical FEA meshes usually overestimate the stiffness of the structure, particularly if relatively coarse models are being used to model global ship response. For the particular problem of determining twist angle for torsional response in an open hatch containership, Nikolaidis and Kaplan [1991] report a bias of 1.4 with a COV of 0.18 against model test results. They concluded that it is difficult to predict the warping torsion component with FEA. For the case of longitudinal deck-stresses in pure bending, FEA overpredicted the results to give a bias of 0.93 and COV of 0.17 compared to beam theory which gives values of 0.94 and 0.10, respectively. Committee V.l of [ISSC 19911 used FEA for ultimate strength calculations and used a bias value of 1.22.

No comprehensive studies on establishing uncertainties arising from FEA were found in the literature. Committee

II.1 of [ISSC 1991] undertook a comparative FEA study of
deflection and stress in a midship webframe bulkhead of a
large tanker [Zillioto et al 1991]. The extent and grid of
the model, boundary conditions and load representation were
all left up to each of the ten participants in the study,
with only the problem geometry via ship drawings and the
basic load condition being defined. Results for
displacements vary considerably, primarily from 2D and 3D
representations of the problem boundaries. In analyzing these
results the smallest COV for displacement was for prediction
of the bottom centerline deflection with a value of 0.4.
Stress results compare much better with a COV of 0.11 for
stress in a bracket flange. For this case, as for other
studies on FEA uncertainty, the sample size is really too
small to draw any hard conclusions. Commitee II.1 of ISSC is
continuing with its comparitive FEA studies to further
information on uncertainties. The current attempt will be
for a structure with experimental results so that a bias
value can be obtained as well as COVs.

Limit States for Ship Structures

Some of the limit states to be considered for ship structures
are: fatigue, defined by a certain length of crack growth;
fracture; local yielding of plates and stringers; excessive
displacements (permanent set) of plating or grillages;
excessive vibration; buckling of plates and stringers or
grillages; and ultimate strength of the hull girder.

Various limit state equations have been proposed for these
failure modes. These are usually of closed form but numerical
solutions have also been used [Ferro and Cervetto 1984].
Committee V.l of [ISSC 1991] gives limit state equations and
bias factors for local plate failure and ultimate hull girder
collapse. The work presented by this committee is a very
insightful consideration of practical application of
reliability theory.

Fatigue limit states have been given fairly extensive
treatment in the literature, especially for offshore
structures where the 'hot spot' fatigue crack initiation
points are reasonably well defined and have been modelled
extensively. A good discussion of crack initiation fatigue
failure mechanisms using the Palmgren Miner formulation and
SN curves, formulated in a reliability format, is given by
Wirsching and Chen- [1987]. The limit state is written as the
resistance to cumulative fatigue damage defined by
the dimensionless sum, A, usually equal to 1.0 but a random
variable, and the cumulative damage from some representation
of the lifetime applied stress.

$$g(x) = \Delta - \frac{TB^m}{K} \Omega$$

T is the time of exposure at the mean stress value, B is the

bias on the fatigue model, m and K are material fatigue parameters, and Q is defined by different methods for stress damage such as the deterministic, spectral and Weibull models given by Wirsching and Chen. B is derived from several uncertainty sources such as geometry, seastate description, wave load prediction, dynamic effects of structural analysis, and stress concentration factors [Nikolaidis and Kaplan 1991]. Bias values given by Wirshing and Chen range from 0.7 to 0.9 with COVs ranging from 0.14 to 0.5 from various sources. They also list COVs for material SN data which range from 0.43 to 1.36. COVs are summarized for all sources of bias by Nikolaidis and Kaplan [1991] with total COV values of 2.21 for ships and 3.42 for offshore structures with contributions from stress concentration and load description being the most significant, respectively. Although noted, no reason is given for offshore structures having a higher uncertainty than ships. In comparison with other limit states the uncertainties associated with fatigue prediction are very high. This is primarily due to the fact that fatigue models are very sensitive to the stress history input and material parameter definition. Load definition for fatigue requires input from all loads and hence the difficulties discussed in the previous section on load definition and load combination of still-water, wave, and slamming induced components are very relevant. A significant contribution to this uncertainty may be due to the fact that both the applied stress and material resistance parameters neglect the presence of residual stress. Efforts to include residual stress in the applied stress calculations and in the SN curves may result in considerable reduction in uncertainty.

Fail-safe design philosophy accepts the existence and growth of cracks and relies on being able to detect and repair cracks before they affect the structural integrity of the system. Cracks are considered to cause failure once they reach a critical length after which further propagation occurs quickly. As in the crack initiation SN model, a limit state giving a pass or fail criteria for the state of crack length in the structure is required. Madsen et al.[1987] describe a reliability model based on the Paris Crack Growth Law as:

$$g(x) = \int_{a0}^{ac} \frac{1}{Y(a)^m (\sqrt{\pi a})^m} da - CNS^m$$

where a is the crack length, C and m are the material parameters for crack growth, $a0$ is the initial crack length on build, a_c is the critical crack length, N is the number of cycles in addition to those that cause $a0$, S is the stress range in the far field and Y(a) is the geometric factor at the crack location.

The reliability of a structure can be continually maintained
through periodic inspection and repair of all detected cracks
above a certain limit. Madsen et a1.[1987] present two
formulae which can be applied in considering crack repair
effects. For a chosen size of crack to be repaired arep, the
number of cycles which are predicted to occur to cause this
size of crack is N_{rep}. The value of N_{rep} can be used to
estimate inspection intervals and can be determined by
replacing N and ao in the crack growth limit state equation
by N_rep and a_{rep} respectively.

After inspection and repair, the maximum crack size present
in the vessel becomes an and the material parameters C and,m
may also change due to the repair practice to become C_n and
mn. The crack growth limit state then becomes one of a
critical crack size occurring after the repair and can be
rewritten with the new initial crack size and material
parameters. Using this method, a minimum reliability index,
based on the crack size arep, can be maintained in the ship if
repair is made whenever a crack of size a_rep is detected.
Figure 3 shows this process schematically.
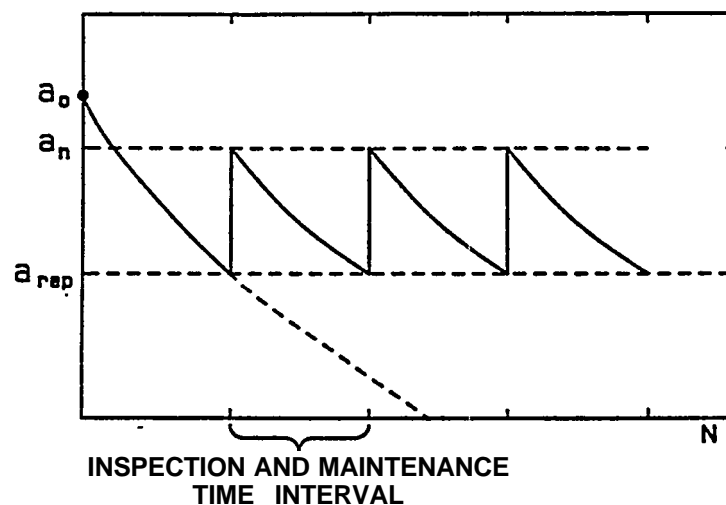
Figure 3: Reliability vs Time Including Updating for
Inspection and Maintenance

There are many uncertainties in crack growth prediction
models which still need further research. Distributions of
ao, a,, arePr.and an need to be established. Also
distributions of **C,-m, Cn** and mn need to be determined for the
details of interest. The geometry factor can be calculated
from FEA or formula but also needs probabilistic description.
Bias factors'for using the Paris Crack Growth Law also need
to be established. Inspection uncertainty, incorporated into
the COV of a, is probably the largest unknown in applying
this method to ship structures. The probability of detecting
cracks in a complex ship structure, often under very

difficult inspection conditions, is likely still too low to accept this method fully for ship inspection and maintenance planning.

Conclusions and Recommendations

Activity in applying probabilistic methods to ship structure design and maintenance is considerable and should be encouraging to proponents of these methods. The difficulties associated with establishing uncertainties in the load, strength and limit state models are still considerable, and it is difficult to imagine that a wholly reliability-based design code will be adopted for ship structures in the near future. However it is likely that components of reliability methods will be incorporated into design practice and allowed by design authorities as an alternative to traditional methods. The many areas in need of further development should keep researchers busy for some time. Some of these are:

- more accurate RAO models with associated bias and COVs to incorporate nonlinear and 3D effects;

- determine bias for specific wave spectral models;

- develop models for slamming and hydrodynamic pressure load;

- develop probabilistic load models for load components other than vertical bending moment;

- formulate and verify load combination procedures;

- develop reliability based FEA for large models develop bias and COVs for FEA

- develop system reliability methods for continuous stiffened shell structure;

- incorporate human error into the safety assessment process;

- develop improved methods for crack detection on ships to quantify probability of detection; and,

- determine target reliability values for design, maintenance and damage assessment.

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PROBABILISTIC EVALUATION OF OIL ODTFLOW FROM A TANKER FOLLOWING SIDE DAMAGE -REZATION TO CARGO TANKS CONFIGURATION

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ABSTRACT

The paper gives an outline on the potential capability of an improved risk analysis as an instrument to be used in a safety policy for shipping on a consistent and continuous basis. In this context a desirable version of a data base of casualty statistics and the interface with the associated source of information (i.e. casualty records) is discussed. In order to visualize an effect analysis based on probabilistic principles the results of a small scale parameter study on 'hypothetical' outflow of an oil tanker after sustaining collision damage are presented. In this way the design of the cargo tanks arrangement may be accomplished by an optimisation procedure in terms of protection of the marine environment.

INTRODUCTION

The appraisal of an arbitrary ship design in terms of safety can be dealt with by some form of system analysis. Such a methodology may require an extensive risk analysis. Generally speaking the concept of risk is defined as the following mathematical product:

Risk = [Probability of occurrence of an event]
*[Effect of this particular event]

Practical application of the concept requires statistical information on the occurrence of primary events and a sophisticated 'mathematical' model based on either deterministic or probabilistic principles in order to quantify the effect of the event considered.

The primary events which are of importance to the safety of a ship (and the persons on board) may be listed e.g. as:

    Collision/contact
    Grounding/stranding
    Fire/explosion
    Foundering/capsizal
    Structural failure
    Etc.

Note: Human failure may represent a significant contribution irrespective of the primary events under consideration.

If preventive measures are considered to be taken it is of utmost importance to have detailed information on the particular conditions and features affecting the incident rate in order to ensure that the provisions intended are effective indeed.

The vast majority of such provisions, generated to warrant a minimum safety level, are accomplished as mandatory (inter)national safety regulations and therefore casualty statistics shall be considered as an essential instrument for the purpose of pursuing a well-founded safety policy on a consistent and continuous basis.
Such a data base of casualty statistics should comply with the following requirements:

> The categories of primary events shall be defined in an unambiguous manner in order to avoid difficulties in interpretation.
> The sample shall be unbiased and as complete as possible which may be effected by the <u>obligation</u> of preparing a casualty record to be included in the data base.
> In order to enable trends to be identified additional information such as ship size, ship type, year of build, safety regulations (as applied), etc. shall be made available in a standardized form.
> For each primary event a record giving particulars which are relevant for the subject effect analysis shall be prepared.
> The casualty record shall preferably be a 'standard form' in order to facilitate access and up-dating of a computerized data base.

The effect analysis may be based on either deterministic or probabilistic principles. Bearing in mind that most input parameters, such as the environmental conditions and to a certain extent also the loading condition of the ship, are random in nature it may be concluded that most output parameters, such as ship motions and stresses, are stochastic processes represented by the associated probability distributions. In principle the probability distribution of an output parameter may be determined if the probability distribution of the input parameter and the response of the ship, either linear or non-linear, to all essential discrete values of the input parameter are known.
In general the response of the ship may be characterized as a stochastic process and there is a trend, which depends on

the state of the art and the acceptance by the parties involved, towards an increase of the application of 'probabilistic methods in the effect analysis.

This may be demonstrated with a topic of current interest i.e. the marine environmental protection of an oil tanker following collision damage.

CALCULATION PROCEDURE

The calculation procedure to assess the 'expected' outflow of an oil tanker sustaining collision damage may be based on probabilistic principles. The approach of this particular probabilistic method was introduced by Wendel (see ref.[1]) and has been developed along the lines of an effect analysis and is presently used for the subdivision and damage stability of some categories of both cargo ships and passenger ships. The most prominent feature of the Wendel-method is that the probability of flooding of an arbitrary compartment or group of adjacent compartments may be determined provided that the relevant (damage dimensions). statistics are available.
If the concept is applied than the contribution E_j of an arbitrary cargo oil tank to the expected oil outflow of the vessel is defined as the following (mathematical) product:

> E_J = [Maximum amount of cargo oil v_j to be carried in the
> cargo oil tank considered]
> *[Probability p_j that the cargo oil tank considered
> is involved in a collision damage]

where p_j (see also fig.1) can be expressed as:

> $\mathbf{P}_J$ = [probability of, a collision damage occurring anywhere
> along the length of the vessel with a
> penetration exceeding the value b_i]
> - [probability of a collision damage occurring
> anywhere along the length of the vessel aft of
> the cargo oil tank considered with a penetration
> exceeding the value b_i]
> - [probability of a collision damage occurring
> anywhere along the length of the vessel forward
> of the cargo oil tank considered with a
> penetration exceeding the value b_i]

The probability pj corresponds to the volume of the prism with the shaded area indicated in fig.1 as the base and the joint probability density distribution (of damage location and damage length) measured along the z-axis of the assumed orthogonal co-ordinate system.

The mathematical expression for the expected oil outflow of the vessel E_r is presented in fig. 1 where the variables p_i and have the following meaning:

p_i is the probability of opening <u>only</u> an arbitrarily assumed transverse compartment i
r_i is the conditional probability (reduction factor) that the damage penetration does not exceed the value b_i to account for local subdivision of compartment i

The mathematical formulae for p_i and r_i are presented in appendix 1 and are based on the IMO damage statistics.

The basic assumptions which are relevant for the application of the proposed mathematical model, having in mind that it is intended for a comparative study, are summarized as follows:

The damage is of a rectangular form.
The probability density of the centre of damage location is uniformly distributed over the ship's length.
The entire contents of a damaged oil cargo tank is spilled into the sea.
The effect of very large damages, with an inherent very low probability of occurrence, leading to the complete loss of ship and cargo is underestimated.

In this respect it may be observed that ref.[2] deals with an alternative approach leading to the same result and with a more comprehensive discussion of the inherent assumptions.

In order to show the capability of the suggested method a systematic parameter study has been carried out.

<u>PARAMETER STUDY</u>

For the purpose of this parameter study a 'reference' ship is defined. The basic data of the reference ship and the associated cargo tanks arrangement are shown in fig. 2.
The parameter study consists of a systematic variation of the following parameters:

non-dimensional cargo tank length
non-dimensional cargo tank width
non-dimensional double hull width

The calculations have been carried out on the basis of the mathematical model as given in appendix 1 and a summary of the results of these systematic calculations is given in appendix 2.

The results (expressed as a fraction of the cargo loading capacity V_c) have also been plotted in the figures 3-5 and give a clear picture of the effect of the systematic variation of the parameters on the expected oil outflow. The tendencies emerging from the figures 3-5 are not contrary to what could be expected.

Figure 3 shows that there is a linear relationship between the expected oil outflow and the cargo tank length.

Figure 4 shows the the relation between the expected oil outflow and the cargo tank width. The effect of the pragmatic assumption $r(b_1/B,=0.5)=1$ on the results is also indicated. Figure 5 shows that in the range of practical application there is approximately a linear relationship between the expected oil outflow and the width of the double hull.

The mathematical model and the way of presentation is such that the results may be generalized in such a way that the predictions for the expected outflow are valid for any ship size and cargo tank arrangement.
Quite recently other mathematical models (see e.g. ref.[3] and ref.[4]), also based on probabilistic principles but slightly different in the conceptual approach, have been developed.

REMARK/CONCLUSION

1. In order to warrant a consistent safety policy a reappraisal of gathering information on the basis of casualty records shall be considered. These casualty records shall be submitted on an obligatory basis and be in line with the needs of the associated effect analysis.

2. The expected oil outflow of a tanker after side damage may be estimated with an effect analysis based on probabilistic principles. This may lead to an optimum cargo tanks arrangement in terms of structural design and marine environmental protection assuming that the expected oil outflow is equal to the 'allowable' outflow.

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    presented at a meeting of the Northern California Section
    of the Society of Naval Architects and Marine Engineers

* * * * *

<u>APPENDIX 1</u>

Formulae for p_i and r, applied in the mathematical expression for the hypothetical-outflow E_T:

$$p_i = (l_i/L_s)^2/0.24 - (l_i/L_s)^3/0.1728 \qquad \text{if } l_i/L_s < 0.24$$
$$p_i = \{10.5(l_i/L_s)-1\}/9.5 \qquad\qquad\quad \text{if } l_i/L_s \geq 0.24$$

$$r_i = 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad \text{if } b_i/B_s = 0$$
$$r_i = c_1 + (1-c_1)\exp\{-c_2(l_i/L_s)^{c_3}/(b_i/B_s)\} \quad \text{if } 0 < b_i/B_s < 0.5$$
$$r_i = 1 \qquad\qquad\qquad\qquad\qquad\qquad\qquad \text{if } b_i/B_s \geq 0.5$$

$$c_1 = 2.662(b_i/B_s) + 0.027 \; ;$$
$$c_2 = 7.31(b_i/B_s) + 0.04 \text{ and}$$
$$c_3 = 1.488(b_i/B_s) + 0.52 \qquad\qquad\qquad \text{if } 0 < b_i/B_s \leq 0.2$$

$$c_1 = 10.579(b_i/B_s)^3 - 14.295(b_i/B_s)^2 + 7.111(b_i/B_s) - 0.376 \; ;$$
$$c_2 = -7.431(b_i/B_s)^2 + 10.2824(b_i/B_s) - 0.2572 \text{ and}$$
$$c_3 = -2.267(b_i/B_s)^2 + 2.395(b_i/B_s) + 0.429 \text{ if } 0.2 < b_i/B_s < 0.5$$

<u>APPENDIX 2</u>

Scheme of systematic variations

VARIATION OF L_c/l_c		VARIATION OF B_c/b_c		VARIATION OF B_c/B_s	
L_c/l_c	E_T/V_c	B_c/b_c	E_T/V_c	B_c/B_s	E_T/V_c
8	0.1504	5	0.1269	0.4	0.0703
5 *	0.1918	4	0.1304 ***	0.6	0.1229
3	0.2662	3	0.1613	0.8 *	0.1918
2	0.3594	2 *	0.1918 ***	0.9	0.2249
1	0.6396	1	0.3836	1 **	0.2622

*   Reference ship
**   Single hull concept
***   Effect of $r(b_i/B_s \geq 0.5) < 1$: $E_T/V_c = 0.1416$ for $B_c/b_c = 4$
                                           $E_T/V_c = 0.2150$ for $B_c/b_c = 2$

FIGURES

Figure 1: Diagram showing the principle of the computation of the contribution of an arbitrary oil cargo tank to the hypothetical outflow
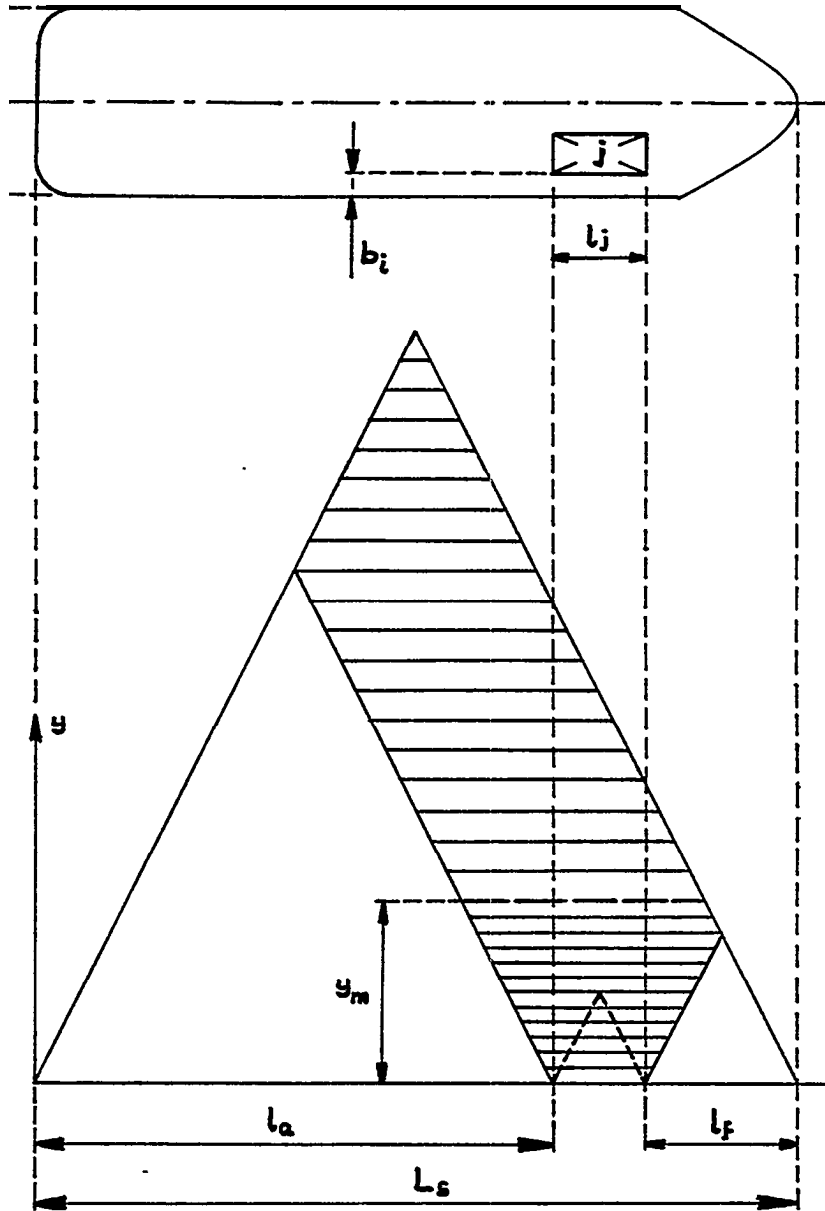
$$E_T = \sum_j v_j [\{1-r_i(l_i/L_s=1, \ b_i/B_s=b_i/B_s)\}$$
$$-p_i(l_i/L_s=l_a/L_s)\{1-r_i(l_i/L_s=l_a/L_s, \ b_i/B_s=b_i/B_s)\}$$
$$-p_i(l_i/L_s=l_f/L_s)\{1-r_i(l_i/L_s=l_f/L_s, \ b_i/B_s=b_i/B_s)\}]$$

$$V_C = \sum_j v_j$$

Figure 2: Basic data and schematic outline of reference ship

$$l_c/L_c = 0.20$$
$$L_a/L_s = 0.15$$
$$L_f/L_s = 0.10$$
$$b_c/B_c = 0.50$$
$$B_c/B_s = 0.80$$
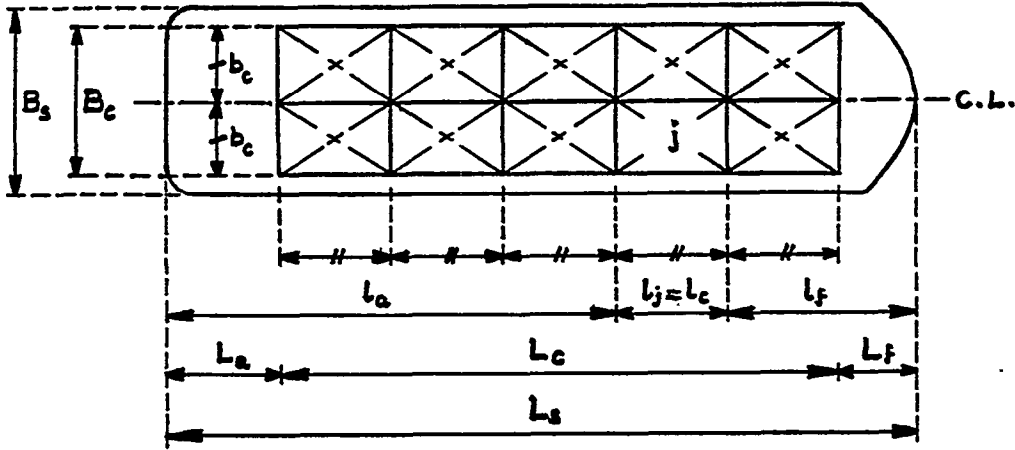
Figure 3: Graph showing the effect of a systematic variation
of the non-dimensional cargo tank length
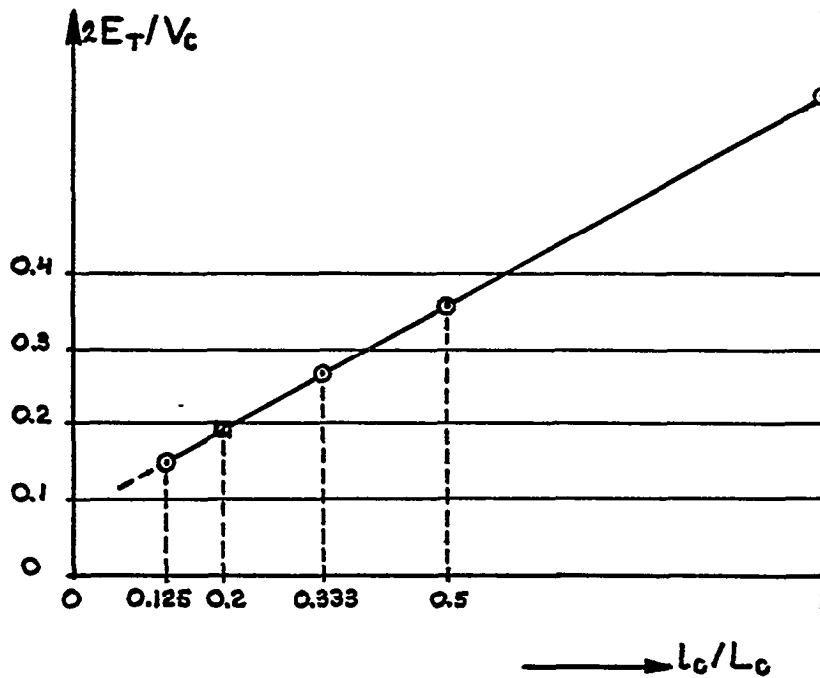
Figure 4: Graph showing the effect of a systematic variation
of the non-dimensional cargo tank width
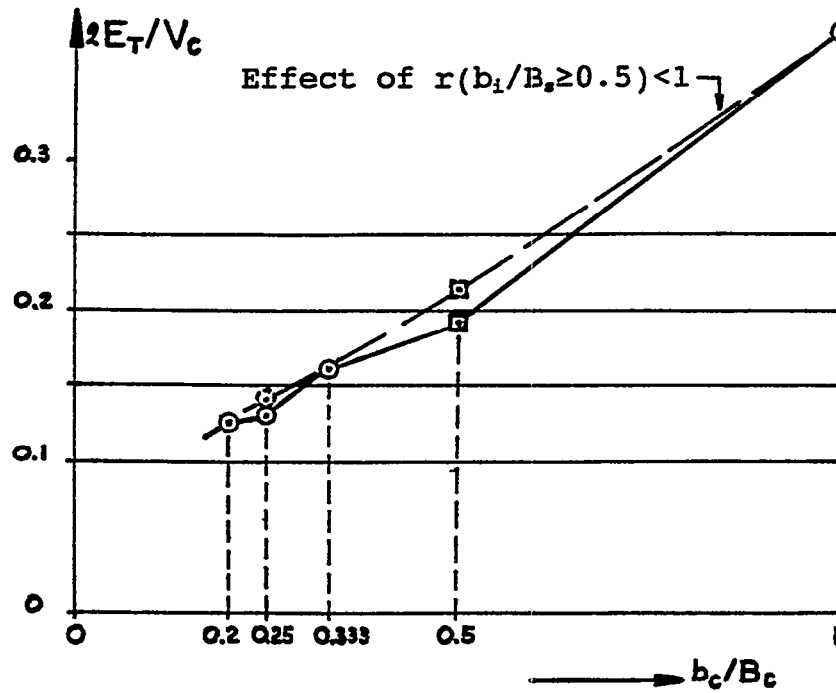
Figure 5: Graph showing the effect of a systematic variation
of the non-dimensional double hull width

Note: V_c is proportional to B_c
($Vc=L_cB_cH_c$)
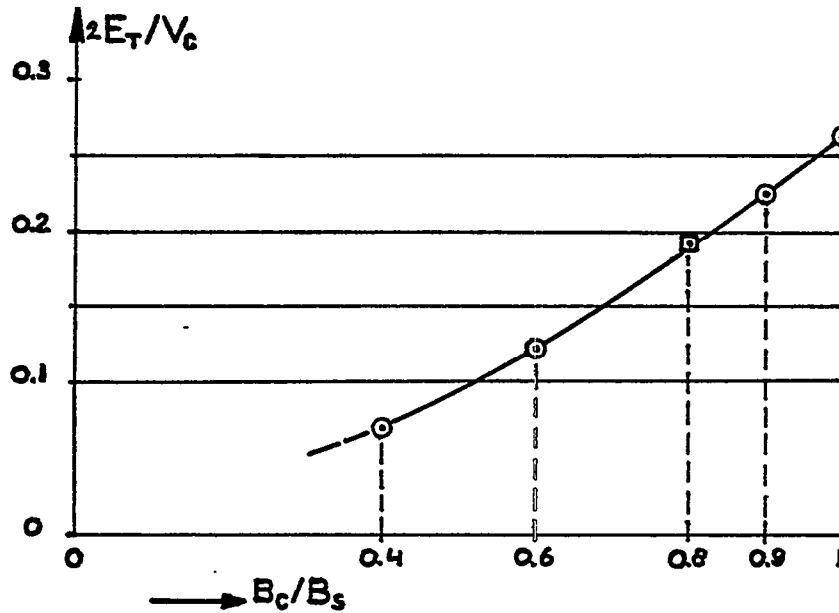
PROBABILISTIC DESIGN OF SHIPS: CALIBRATION OF SHIP RULES.

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ABSTRACT

During the recent years there has been a significant development in tools for probabilistic computations and the experience in use of these methods is growing. The probabilistic methods enables to quantify the effect of uncertainties in design of structures in a rational manner. Such methods may in practice be used for novel designs, but in most cases such analyses require an effort and a data background that is in excess of practical limitations.

On the other hand the rules for design of ship hulls are quite simple, efficient to use and gives easily controllable results. The rules shall reflect the state of the art methods that may be implemented through computer software and the gathered data on structural performance. The rules also reflect the accepted level of safety in design of traditional ship hulls.

Through a calibration scheme the results from probabilistic methods is used to narrow the gap between the two approaches. A reliability based formulation of the buckling capacity in deck panels have been applied to study the performance of the DnV rules against more advanced formulations.

INTRODUCTION

The ship designs are becoming more optimized often making local criteria such as panel buckling more critical than the overall strength, represented by the sectional modulus. This motivates to focus on the local criteria in the rules, such as the buckling criteria of stiffened panels studied herein.

The main reason for using probabilistic methods in rule calibration is to develop practical design rules which are based on state-of-the-art physical and statistical knowledge. Other considerations behind a probabilistic calibration of design rules are:

   Simple design rules are easier to use and more controllable than advanced reliability analyses. Probabilistic calibrated design rules will, however, contain an extract of the more advanced analyses.

   The uncertainty in each individual variable is assessed as part of the input preparation to the reliability computations.

   The choice of safety factors is documented and may be updated based on new based on new methods and improved data.

   The discrepancy between simple methods and advanced computations is reduced.

A probabilistic calibration is usually a costly process since an extensive data gathering, a complex reliability model and a large computational effort are needed. The calibration provides, however, a systematic rule development where each part of the calibration process can be documented and checked against physical observations.

Calibration of design rules may be performed with different goals in mind. The purpose of one calibration study may be to fit some strength formula to a number of test results in order to achieve a defined target reliability level for a range of designs. If the format of the limit state in the reliability computation is the same as that of the design rule, the

partial safety factors can in this case be derived from the most probable failure point and by specifying characteristic values for the design rule variables.

If the purpose of the calibration study is, however, to fit a simple design rule to an advanced reliability computation, the above procedure is not applicable. The reason is that the mathematical formulations in the advanced reliability analysis and the rule formula are different and the connection between stochastic variables in the limit state and characteristic values in the rules need not be unique. In this case the calibration procedure must reflect the difference in the formulations and the input data.

This is the case when deck panel reliability computations, based on FEM analyses or other numerical solutions for calculating the buckfing stresses is to be used in the calibration of analytical design rules. Different methods are hence applied in the reliability and the rule formulation and the most probable failure point does not necessarily correspond to any design rule value.

The link between the reliability formulation and the design rule is, however, present since the same panel is considered in both formulations. By assuming that the dimensions of the panel will be chosen on the limit of the design rule (by a clever design), the calibration procedure can cover for a set of such designs. The optimization procedure is outlined in Figure 4.

THE RELIABILITY FORMULATION

The Limit state

The buckling of deck elements are considered as the critical failure mode. This corresponds to a critical sagging condition that may lead to total collapse and loss of ship.

The limit state for hull girder collapse is generally written as

$$g < o \quad ; \text{failure domain}$$
$$g - 0 \quad ; \text{failure surface}$$
$$g > o \quad ; \text{safe domain}$$

where

$$g = u_u - \frac{M_s + M_s}{W_D}$$

M_s is the still water moment.

M, is the dynamic wave moment.

σ_u is the collapse strength of the stiffened deck panel.

W_D is the section modulus of the hull girder section in position of the deck panel.

Each of these entries in the limit state are described further in the following. The model is implemented as a limit state for use with the computer program PROBAN, Olesen and Tvedt (1989) .

Loads

A Tanker hull is usually a full form design with little nonlinear effects. Results from a linear strip theory is considered appropriate in this analysis. In this example some simplifications are made in the analysis:

Only zero speed head seas are considered.

The North Atlantic environment is assumed over the full time period.

The specified design still water condition for the vessel is combined with the computed wave bending moment.

A scaling related to world wide operation is included.

The above assumptions affects the loading only. This may here be reflected through the choice of the target reliability as determined from an ensabie of currently acceptable designs.

The specification of sea states, or wave conditions, is given in terms of *significant wave height H,* and *peak period T_p.* Based on data, a scatter diagram, a joint probability distribution $F(H,,T,)$ is determined as

$$F(H_s, T_P) = F(H_s)F(T_P \mid H_s)$$

where $F(H,,T,)$ is the joint probability distribution, $F(H,)$ is the marginal distribution of significant wave height and $F(T,,/ H,)$ is the conditional distribution of peak period given significant wave height.

The marginal probability distribution for significant wave height is represented by a three parameter Weibull distribution,

The sea state parameter for the worst S-hour storm is determined as the largest significant wave height with the corresponding period. By independence, the largest significant wave height, $HS,max,$ has the cumulative probability function

$$_{s,max}(H_s) = F(H_s)^N = \{1 - e^{-\frac{H_{s,max} - 0.594}{2.290}^{1.385}} \}^N$$

where N = 2920 is the number of sea states of 3 hours duration in one year. A transformation is performed describing H_{SJnu} by a standard normal variable X,, as:

$$H_{s,max} = 0.594 + 2.29\{-\ln(1 - \exp\{-\frac{1}{N}\ln\Phi(X_1)\}]^{0.722}$$

The conditional probability density function for $Tp,,$ by given $Hs,$ is chosen as the lognormal distribution, with distribution described as:

$$F(T_P \mid H_s) = \Phi(\frac{\ln T_P - \mu}{\sigma})$$

The parameters p and σ are:

$$\mu = 1.187 + 0.833 H_s^{0.242}$$
$$\sigma^2 = 0.1177 e^{-0.312 H_s} + 0.00541 e^{-0.041 H_s}$$

The conditional distribution of the peak period Tp for given H_{Smx}, is then given by a transformation of the conditioned variable T_p into a standard normal variable as:

$$T_P = e^{\mu(H_{s,max}) + \sigma(H_{s,max})X_2}$$

The above extreme value consideration on significant wave height $H,$ is only valid for problems dominated by wave induced forces.

To describe the response characteristics of the ship a 5[th] order polynomial has been fitted to the standard deviation of response, u,, as

$$\sigma_s = H_S (183.5 - 111.2 T_Z + 25.2 T_Z^2 - 2.54 T_Z^3 + 0.119 T_Z^4 - 2.14 \cdot 10^{-3} T_Z^5)/10.58$$

The average zero crossing period, T,, for the response as function of peak period, Tz, in the wave spectrum was found to be, see also Figure 2.:

$$T_r = 2.269 - 1.179 T_P - 0.0417 T_P^2 + 0.0005 T_P^3$$

The significant single amplitude stress is determined as 2u,, and the zero up-crossing period is determined from its relation to the peak period for the Pierson Moskowitz spectrum as $T,, = 1.41\ T,.$
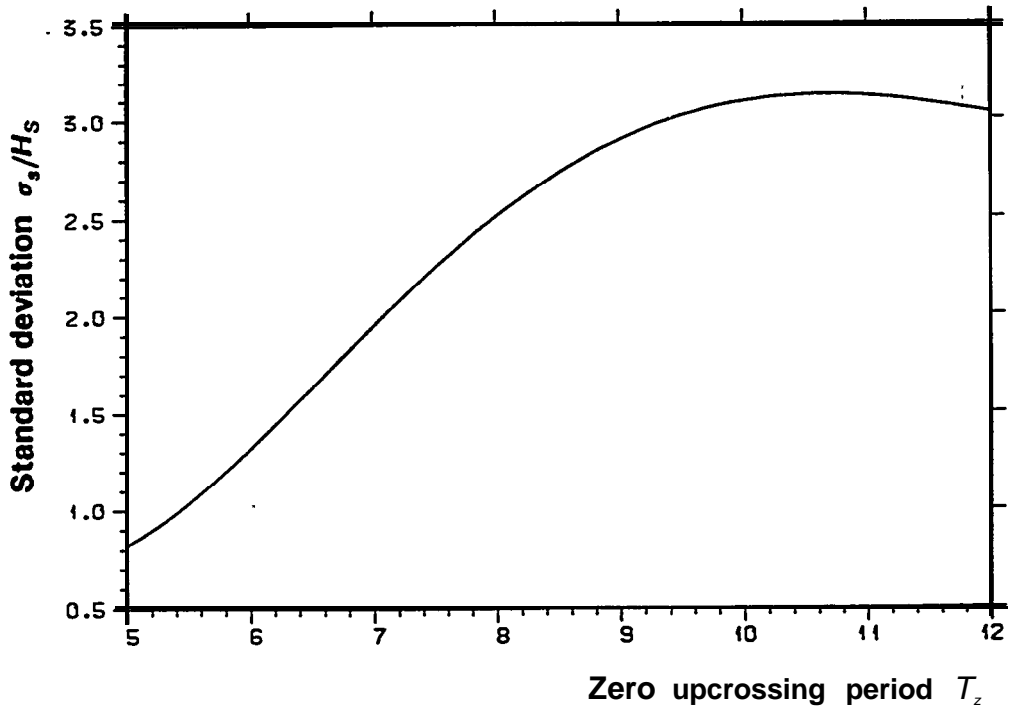
Figure 1. Basis axial stress In panel due to wave bending as function of T_z.
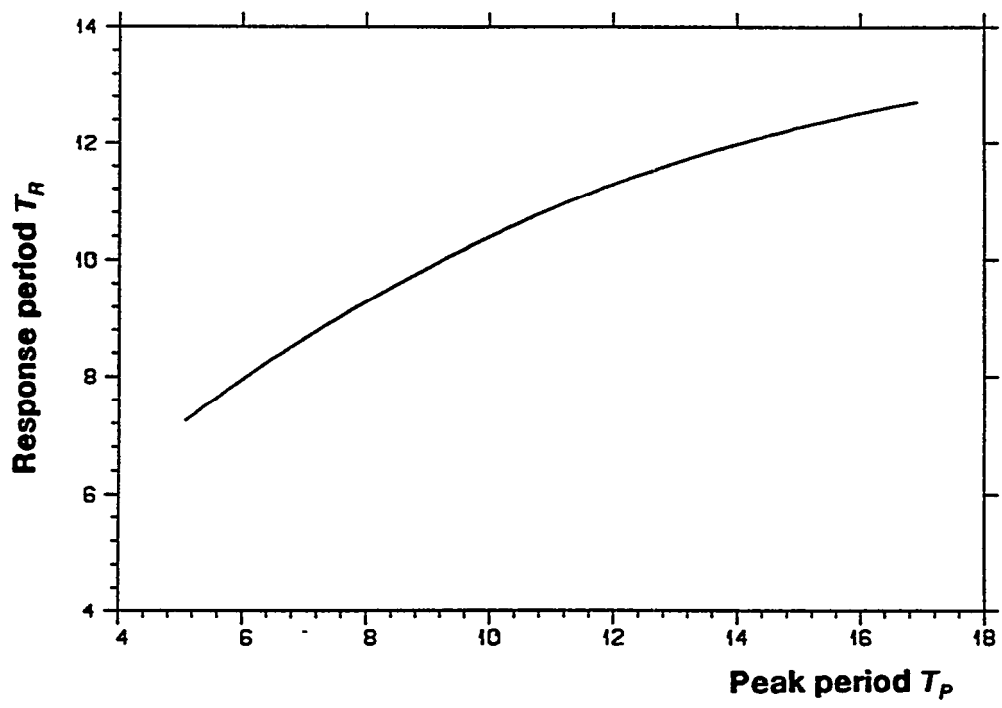
Figure 2. The period of response cycles, T_r, as function of T_p.

The extreme wave bending moment, $M_{w,}$, or X_4, is determined within the extreme sea-state with a one year period. The vertical bending moment in the hull girder may then be considered as a stationary Gaussian process. The distribution of the largest bending moment M_w can be obtained by assuming that crossings occur independently, i.e., they constitute a Poisson process, so that

$$F_{M_w}(m) = e^{-\nu_m(x)D}$$

where $\nu_m(x)$ is the mean up-crossing rate of the level m for the process $X(t)$, and D is the duration of the sea-state. The maximum wave bending moment within the seastate, M_w, is then expressed in terms of the standard normal variable X_4 by

$$M_w = [-2\sigma_s^2 \ln\{-\frac{T_r}{D}\ln\Phi(X_4)\}]^{\frac{1}{2}}$$

The duration of a specific sea state, D, is taken as 3 hours.

The mode/ uncertainty, X_6 includes a scaling from the North Atlantic climate to the world wide operation by a factor 0.8, as derived Bitner-Gregersen et. al. (1992). In CL30.6 (1991) a coefficient of variation of 10% on the standard deviation of response determined from strip theory analysis was derived by comparisons with measurements.

The uncertainty in non linear correction, X_7 is for a full form vessel like this tanker (large C_B) are not as important as for slender ships. This value is here included only as an additional model uncertainty.

The still water bending moment, m_{sw}. is the static contribution to the vertical bending moment caused by buoyancy and the static load distribution of the ship. Since cargo and ballast are being changed over time the still water bending moment will also change over time.

Based on all relevant loading conditions the mean sagging condition is determined (deck in compression). in this analysis it is taken as the specified still water condition for this vessel which is slightly less than the rule value. From Soares (1984) the COV. of 30%/6 was determined. in future analysis this COV. should be based on the possible variations of the still water moment for the considered vessel Gran (1991). The still water bending moment was included as an axial stress in the deck with a mean of 30 *MPa* and a C.O.V. of 0.3. it is assumed that a random still water load condition may be combined with the extreme wave bending moment.

Buckling Strength

A simplified model is adopted in which the ultimate buckling capacity u_u is given as a function of 13 physical parameters, i.e.

$$\sigma_u = \sigma_u(x_9, x_{10}, ..., x_{21})$$

The parameters are :

1) Geometry of plate and stiffener, depending on type of stiffener profile, $x_9, ...x_{16}$. See also Figure 3.

ii) Geometrical imperfections, $x_{17}, x_{18,} x_{19}$

    1. Global stiffener imperfection: x_1 or δ,.

    2. Sideways/torsional stiffener imperfection;   , or δ_2.

    3. Local plate imperfection: x_{19} or δ_3.

iii) Material description, x_{20} and x_2,

    1. Yield Stress, x_{20}

2. **Youngs Modulus, x_{21}**
   (strain hardening excluded, $E_T = 0$)

The basic assumptions behind the buckling model are described and discussed in Steen (1989) and Hauge et.ai (1992). By increasing the deflections the capacity is determined as the maximum axial force/stress of the panel.

The buckling model has been verified by comparing its deterministic strength assessments against some recent numerical studies presented by Smith et. al. (1991). It was found that the difference for the cases shown are generally of the order of 15% on the optimistic side. However, the present model shows extreme unstable behaviour for slenderness ratios X above say 0.8. (X is defined as the square root of the relation between elastic Euler buckling stress and yield stress). This is in qualitative agreement with the results given by Smith et. al. (1991).

The general strength difference of the order of 15% compared to the referred article seems to be high. However, the buckling stresses are very sensitive to sideways imperfections of the stiffeners for the geometrical ranges considered, making the strength assessments uncertain. Smith et.ai. (1991) do not give values for these sideways imperfections as used in their study. As a conclusion, it seems that the present model captures the basic physical behaviour of stiffened plate buckling and that it will be well suited for reliability studies.

The statistical data used in the reliability studies for the geometrical imperfections are determined by Steen (1992), see also Table 1, where the variables X_{17-19} are given.

THE RULES

According to DnV (1991) several buckling limit states are to be evaluated for the case of critical sagging conditions. These correspond to several buckling modes and they may be summarized as:

$$c_i \geq 0 \quad \text{acceptable DnV rule (I = 1,2,3,4)}$$

where

$$c_1 = \sigma_{c1} - \gamma_1 \frac{1}{W_D}(M_s + M_w); \qquad \text{plate buckling}$$

$$c_2 = \sigma_{c2} - \gamma_2 \frac{1}{0.85\, W_D}(M_s + M_w); \quad \text{lateral stiffener buckling (Euler)}$$

$$c_3 = \sigma_{c3} - \gamma_3 \frac{1}{0.80\, W_D}(M_s + M_w); \quad \text{torsional stiffener buckling}$$

$$c_4 = \sigma_{c4} - \gamma_4 \frac{1}{0.80\, W_D}(M_s + M_w); \quad \text{web stiffener buckling}$$

The factors 1.0, 0.85 and 0.8 are the allowable usage factors (partial safety factors) defined in the rules and the factors r_i represent changes in usage factors determined from the calibration. The buckling strength in the respective mode, u_{ci}. are taken according to DnV rules (1991). WD is the section modulus of the hull girder in the position of the deck panels. M, is the still water moment and M, is the dynamic wave moment defined in the rules corresponding to a return period of 20 years.

The section modulus WD is a pure geometrical constant and is treated as a fixed parameter in the present study. in the optimisation process of the code calibration study presented here, sectional parameters like plate thicknesses, stiffener heights of deck panels etc. are variable parameters that determine WD.

The DnV rules (1991) loads are summarized as follows :

Still water bending moment, in sagging, for a 20 year return period:

$$M_s = 0.065 C_W L_P^2 B (C_B + 0.7) \quad [KNm]$$

Wave induced moment bending, in sagging:

$$M_W = 0.11 \, C_W L_P^2 B (C_B + 0.7) \quad [KNm]$$

where the following notation is used:

L_P - ship length between perpendiculars

B - ship breadth

C_B - block coefficient

and C_w is a wave parameter depending on ship length.

PANEL DESIGNS

The rule criteria on buckling effectively limit the range of allowable designs with respect to the local dimensions of the stiffened panels. in this study some of the most important parameters as given below will be varied within practical limits. There are parameters that may be chosen by the designers, and the rules has to be checked for a range of such possible designs. To create a set of designs the parameters are here determined by use of a Monte Carlo simulation.
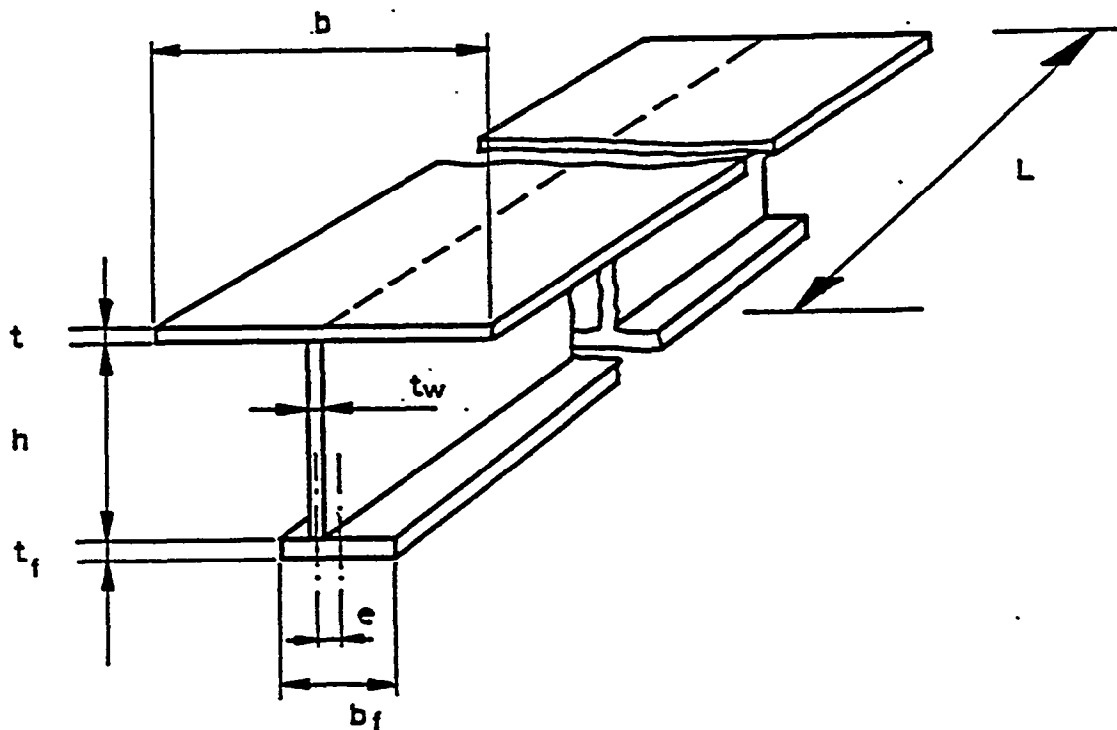

Figure 3. Definition of geometry variables.

Here the designer chosen parameters and the specified ranges are:

    the plate thickness, t, [14,26] mm

    the the height of the stiffener (the web height), h_w, [200,500] mm

    the thickness of the stiffener (the web thickness), t_w [12,30] mm

    the width of the flange of the stiffener, for Tee-profile, b_f [100,300] mm

the thickness of the flange, for Tee-profile, t_f, **[12,30] mm**

Normally the designer may also chose the transverse frame and stiffener spacing, but these dimensions are kept constant here. The yield stress is also kept constant at a high tensile steel grade, NV36. From the above range of parameters, designs that are on the limit of the rules are determined by iteration.

EXAMPLE OF CALIBRATION RESULTS

The optimization aims to determine possible improvements in terms of a reduced spread in the reliability indices computed from the more advanced probabilistic buckling model. Tee- and i-profiles have been studied. Other profiles and designs are currently being studied by DnV.

For the panels with Tee-profiles designed according to current ship buckling rules, the annual reliability index, βY, is estimated to be in the range 3.53-4.72. The lowest values are valid for the minimum weight designs. This lead to a choice of a target reliability index B-3.71, to be used in the calibration. For the applied reliability formulation and input data, this target reliability index is considered equivalent to accepted current practice. The target reliability is also in accordance with CL30.6 (1991) for serious failure in a redundant structure. Only one plate field and stiffener is considered, and adjacent panels may have a larger capacity by e.g. less imperfections. However, the redundancy is normally not large.

The objective of the calibration is to reduce the weighted deviation from the target reliability. This is evaluated according to the penalty function, see Figure 5, giving the weight on each reliability indices related to the chosen designs. The parameters to be used in the optimisation were the scaling factors r_i, or usage factors, on each failure mode.

When the scaling factors are equal to one this implies no change in the current rules. It turned out that it was not possible to reduce the spread in the reliability indices by changing these scaling factors for the Tee-profiles, for the considered ship and range of design parameters. Other changes in rule formulations and scaling parameters may improve the situation and this will be investigated further.

For the fiat bar profiles it is possible to improve the situation, according to this procedure, and a rule change may follow for this type of profiles. After the calibration some l-profile designs with low rliability were rejected without any significant increase in the steel weights. The implicit requirement to the stiffener strength is slightly increased to give comparable reliability to that of the Tee-profiles. The increased requirement come into play if the designer would chose to utilize increased plate thicknesses, that may be due to other requirements, to reduce the stiffener dimensions. in Table 3. the results for the low weight designs are shown after the calibration. it may be seen from the *wgt* column describing the weight of the deck panel relative the basis design, that the steel weight of the panel in this case may be reduced and still maintain a safety level close to that of the Tee-profiles.

It should be noted that the results of this investigation require further considerations on important topics such as e.g. corrosion and imperfections.

The aim of this calibration was mainly to study the performance of the buckling rules. It is seen that the analytic results for the buckling rules gives a band of reliability indices for the described reliability limit state. Such results may also be used to chose a target reliability level for direct use of reliability analyses in design.

CONCLUSIONS

The development towards more optimized ship design and the availability of more advanced methods requires attention from the classification societies. The local criteria in the rules must, be updated according to new information and advances in computational methods.

A reliability based formulation of the buckling capacity in deck panels have been applied to study the performance of the DnV rules against more advanced formulations. For Tee-profiles results show that the performance is excellent within the range of geometrical proportional typical for tankers.

The demonstrated reliability based calibration method developed by DnV enables to extract the state of the art knowledge from advanced methods into the rules.

The calibration also enables use of the applied reliability formulation as an equivalent requirement to the rules.

ACKNOWLEDGMENT

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REUABILITY FORMULATION	RULE FORMULATION
Collect data for input variables - strengths, loads, etc.	**Define type of structures covered by the rules and other explicit limitations (scope).**
I	I
Model the uncertainties and limit states.	**Decide the design rule format, fixed fractiles and parameters to be calibrated, e.g. the safety factors.**
Chose target values B_{rJ} for each type of failure, and possibly a minimum acceptable B_{minSi}	**Chose a range of design parameters to cover the scope of the design rule and estimate frequency of occurance.**

PROBAN-4:
1. Compute the structural design parameters according to the design rule and safety factors.

2. Compute the reliability index B_i for the limit states and calculated design parameters.
I
3. Compute the error according to the penalty function and decide improvements until convergence.

Figure 4. Scheme for optimikation of design rules.
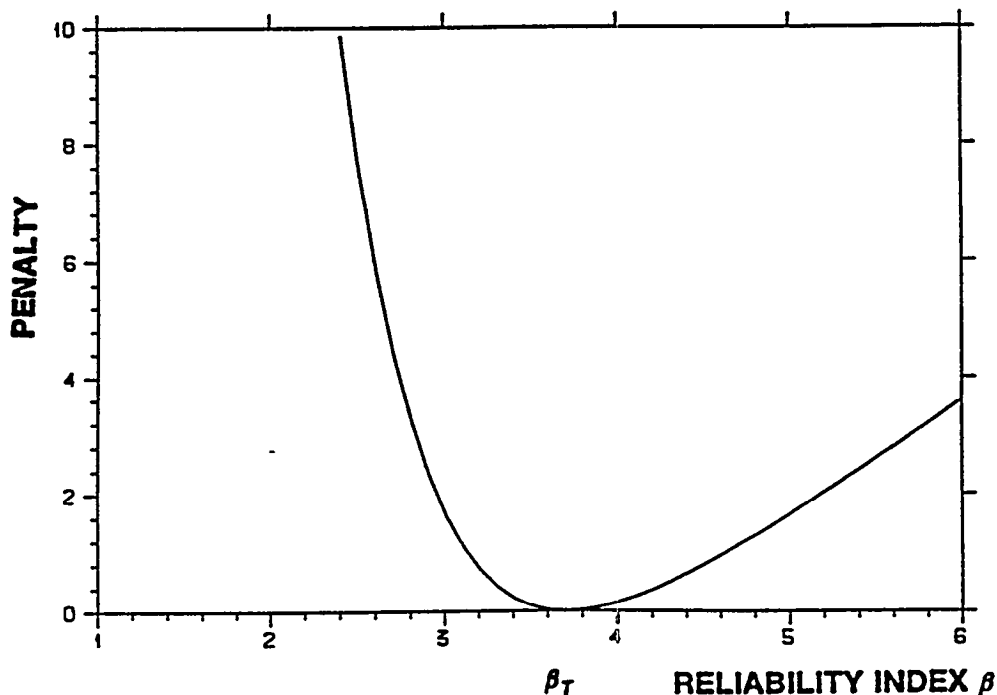
Figure 5. Penalty function applied in calibration.

Table 1. Input variables to the reliability analysis

No.	Description	Distr.	mean	st.dev.
1	Significant wave height	NORMAL	0.0	1.0
2	Peak-period	NORMAL	0.0	1.0
4	Extreme Wave Bend. in Seast.	NORMAL	0.0	1.0
6	Model uncert. short term	NORMAL	0.8	0.1
7	Nonlinear corr. model unc.	NORMAL	1.0	0.05
8	Still water bend stress(MPa)	NORMAL	30.0 *)	9.0
9	Thickness plate (mm)	FIXED	. *)	
10	Width plate bet. stiff.(mm)	FIXED	910. *)	
11	stiffener height (mm)	FIXED	. *)	
12	Web thickness (mm)	FIXED	. *)	
13	Width of stiff. flange(mm)	FIXED	. *)	
14	Stiff. flange thickn. (mm)	FIXED	. *)	
15	Eccent. of flange C.O.G.(mm)	FIXED	0.	
16	Length of stiff. panel (mm)	FIXED	4750.	
17	Global stiffener imperf.(mm)	LOGNO	10.	1.5
18	Side/tors. stiff. imp. (mm)	LOGNO	10.	1.5
19	Local plate imperf. (mm)	LOGNO	4.	1.79
20	Yield stress (N/mm2)	LOGNO	405.	32.4
21	Youngs modulus (N/mm2)	FIXED	2.1e5	

*) Chosen to simulate a number of designs, See Tables 2 and 3.

Table 2. Before and after calibration Tee-profile stiffeners

scaling factors	γ_1 1.00	γ_2 1.00	γ_3 1.00	γ_4 1.00				
des no	t	h	t_w	b_f	t_f	c_i	c_{val}	β
1	15.89	296.81	27.95	275.77	15.24	1	0.22	4.123
2	15.89	293.95	27.63	133.98	17.93	1	0.11	4.009
3*	16.03	280.10	22.76	103.44	15.17	1	0.00	3.542
4	16.56	448.96	15.13	149.19	23.38	3	0.00	4.629
5	16.19	393.92	18.07	137.30	15.79	3	0.00	4.374
6	15.89	500.00	12.00	252.80	29.96	1	0.28	4.569
7	15.89	488.29	29.37	122.47	13.92	1	0.35	4.597
8	15.89	355.99	21.38	186.09	16.66	1	0.12	4.268
9	16.58	492.74	14.33	180.36	20.84	3	0.00	4.758
10	15.89	394.17	30.00	299.99	14.52	1	0.356	4.475
11	15.89	205.82	17.50	272.66	19.75	1	0.01	3.531
12*	16.01	225.75	27.26	128.21	15.08	1	0.00	3.556

*) designs with the lowest weight

Table 3. Low weight flat bar panels using optimized scaling factors

des.no	t	h_w	t_w	c_i	c_{val}	wgt	β
3	17.46	303.74	21.54	3	0.0	0.9613	3.114
5	16.42	300.18	22.85	3	0.0	0.9342	3.381
7	16.11	296.50	25.40	1	0.0	0.9512	3.544

THE IMPACT OF MAINTENANCE ON SAFETY
A comparison with aircraft operations.

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SUMMARY

.A comparison will be made of safety in aviation and shipping
with respect to accidents and technical causes.
Legislative requirements and regulations are intended to
ensure a safe operation, by satisfying requirements with
respect to reliability and maintainability during design,
manufacturing and operation. An overview will be given and a
comparison will be made of the requirements with respect to
maintenance aspects in aviation and shipping.
Specific attention will be paid to the methods applied in
aviation, to develop a cost-effective preventive maintenance
concept in order to ensure a safe operation by adhering the
inherent reliability level of the aircraft and its systems. By
practical examples, it will be shown that these methods are
also applicable to ships and shipsystems.

SAFETY IN AVIATION AND SHIPPING

Safety can be expressed statistically in absolute and relative
figures of fatal accidents. In aviation these figures are
annually presented by international bodies as the Internatio-
nal Civil Aviation Organization (ICAO) by the ICAO-Bulletin
and by the Civil Aviation Authority (CAA) by the CAA World
Airline Accident Summary.
In regular civil aviation (exluding GOS and China) in absolute
terms about 20-30 fatal accidents per annum take place resul-
ting in 600-800 passengers killed, with about 10.000 aircraft
in service. In relative terms, flight safety is normally
expressed in the number of passenger deaths per 100 million
passengerkilometer or per 100.000 aircraftkilometer. In these
terms, flight safety has been increased considerably over the
years as is shown in fig. 1.
With respect to the causes of fatal accidents, some statistics
are available.

Human Factor HF	51%
Technical T-	14%
Combination HT and T	14%
Weather Conditions W	7%
Combination HF and W	8%
Sabotage and others	6%

The Human Factor is in aviation the major cause of accidents.
Technical causes account for about 20% of all fatal accidents
[I]. It is in this respect were maintenance has to make its
contribution to prevent failures of critical systems.

In shipping, accident statistics are published by Lloyd's Register of Shipping [2]. As is shown in fig. 2, the present level of fatal accidents amounts to about 30 per 10.000 ships per year by about 75.000 vessels and an annual figure of 600-4000 lives lost. This number of lives lost is of about the same order as in civil aviation. The relative number of accidents expressed as the annual accident rate, shows also in shipping a diminishing trend, as is shown in fig. 2.
An analysis of the (211) accidents in 1989, of which 32% recorded some loss of lives, reveals a figure of about 25% of the accidents caused by technical reasons.
This emphasizes the need to consider the reliability aspects during design and the establishment of an preventive maintenance program in order to keep the reliability at the required level.

LEGAL REGULATIONS AND ITS RELATION TO MAINTENANCE

Ensuring safety is a concern of the manufacturer, user and the government. The role of the govenment is to safeguard safety under commercial pressure. In aviation the governmental responsibilities in general and with respect to various aspects are laid down in the Convention of Chicago and its Annexes. E.g. in Annex 8 the Airworthiness of Aircraft. The actual legislation however, is a national responsibility, laid down in laws and regulations. In the Netherlands: the Aviation Law, Aviation Supervision Regulation, Airtransportation Regulation and Aviation Calamity Law.
The national regulations often refer to regulations of the authorities of the large aviation countries as the Federal Aviation Authority (FAA) of the USA and especially to the Federal Aviation Regulations (FAR) of which the FAR 25 lays down the airworthiness requirements for regular passenger aircraft.
Presently, the European countries have established their own regulations laid down in the Joint Airworthiness Regulations **(JAR)**.
These regulations are regularly updated as a result of new developments and of accident investigations.
The Aviation Authority is responsible for the supervision and certification of companies, products (aircraft), services (maintenance), persons (certification), training and operation.
The airwothiness regulations are estableshing requirements for the design, manufacturing and maintenance of aircraft, with respect to aircraft performance and characteristics, aircraft construction, aircraft equipment and propulsion and to maintenance.
In the design stage requirements are stated for aircraft structure and its resistance against load, fatigue and corrosion and the possibilities and requirements for structural inspection. For aircraft systems requirements are to be fulfilled with respect to reliability and fault indication.
During production requirements need to be satisfied regarding recording of process and productdata, inspection and (functional) testing. Each new aircrafttype will get a type certifi-

cate by which its airworthiness is proven by documented argumentation. Each individual aircraft will get its certificate of airworhiness, which need to be extended annually by showing that all required maintenance has been satisfactory performed. With respect to maintenance it is required "that the aircraft is maintained in accordance with an approved maintenance programme". "This maintenance programme must be reviewed annually for continued validity in the light of operating experience".
These two requirements will be subject of discussion in the next paragraph.

In shipping, legislative and other requirements are put by:
Classification Societies (class requirements)
National Authorities (flag requirements)
International Authorities (global requirements).
To be classed, a ship has to comply with Classification Societies' Rules and Regulations. The class is also required by Insurance Companies for insurance purposes. The ship must also comply with the laws of the country in which it is registered, to fly the national flag. Major International Conventions **(for** ships sailing international waters) are:
International Convention for the Safety of Life at Sea-SOLAS (safety)
International Regulations for Preventing Collosions at Sea (sailing)
International Load Line Convention (strength and sea-worthiness)
International Convention for the Prevention of Pollution from Ships
International Code for the Construction and Equipment of ships Carrying Dangerous Chemicals in Bulk.

The ship must also comply also with other, as for example, Panama or Suez Canal's requirements when sailing these waters. National Authorities require usually that the International conventions are met. Furthermore, any special requirements, exemptions or specific particular requirements are specified in national laws. For example, in the Netherlands these are:
Schepenwet, Schepenbesluit 1965
Richtlijnen van de scheepvaartinspectie
Uitwateringsverdrag 1966
Schepelingen besluit
Wet op de zeevaart-diploma's.
Classification is a representation by the Classification Society (e.g. Lloyds Register of Shipping, American Bureau of Shipping, Det Norske Veritas, Germanischer Lloyd) as to the structural and mechanical integrity for a particular use or service according to its Rrules and Regulations. The ship, if built according to these standards, receives a Classification Certificate, which ensures a definite standard of strength and quality. The ship's structure, machinery and equipment are during operation checked periodically for the attestation of the Class.

The Rules and Regulations are developed by the international

maritime community including naval architects, marine engineers, shipbuilders, engine builders and by other technical and scientific personnel associated with with the maritime industry.

Maintenance considerations during the design stage are implicite in the standards laid down for ship construction. The most explicit standards concerning maintenance, are reliability issues. These concern major ship functions and systems supporting these as the propulsion plant, the steering machine, the power (electricity) plant, boiler arrangements and safety systems (hazard prevention, detection and fighting). Major ship plans concerning these critical functions are Continuously reviewed during design.

During fabrication and outfitting, materials are tested and the construction of the vessel is supervised both by the Classification Society and the designer to meet the quality set in the Rules and Regulations, Before delivery the vessel is extensively tested (reliability demonstration). These trials prove the vessel is performing as stipulated in design documents, which comply with the Rules and Regulations.

When the ship is put into operation, the minimal maintenance requirements are laid down in the Survey Program, requested for the attestation for the Class. Surveys represent a periodical check of vessel's machinery"s and equipment's condition. However the ship operator is encouraged to implement a specific maintenance concept (preventive, condition based maintenance) if service experience or a systematic analysis, based on sound engineering principles, shows that overall safety and strength standards as specified in the Rules and Regulations, are met.

DEVELOPMENT OF AN INITIAL MAINTENANCE PROGRAM: ORGANIZATION

The organisation for the initial maintenance program for an aircraft is shown in fig. 3.
A Maintenance Steering Committee (MSC) is organized, consisting of engineering managers from the (original) manufacturer(s), from the "launching operators" and representatives of the regulatory authorities from the countries of the launching operators. In Maintenance Working Groups (MWG) for the different aircraft systems, the actual work is done, coordinated and reviewed by the MSC.
This results in a Maintenance Program Proposal (MPP). This MPP is subject of review in the Maintenance Review Board, chaired by the Regulatory Authority. The review by the MRB is especially directed towards safety items and the MRB recommendations are mandatory.
The result is the MRB document which is included in the MPP, resulting in the Maintenance Planning Data (MPD) document. The MPD form the basis for the Maintenance Manual, to be produced by the manufacturer. The MPD will be adjusted against the typical utilisation pattern of the aircraft by the operator, within the limits of the stated maintenance (interval) re-

quirements.
The motivation and assumptions for the adjustments are layed
down in the Maintenance Planning Substantiation (MPS) for
approval by the National Regulatory Authority and for future
reference purposes. The updated MPD is referred to as the
Engineering Specification Manual (ESM). From the ESM the
jobcards for the maintenance execution will be derived.

DEVELOPMENT OF AN INITIAL MAINTENANCE PROGRAM: MSG-3 METHOD

The method as developed in aviation for the development of an
initial maintenance program will now be described. The method
is applied by members of the maintenance working groups (MWG)
and will result in the maintenance program proposal (MPP). It
will also be used by the MRB review and for the maintenance
program substantiation by the operator. This method, as deve-
loped since the early seventies, is known as the Maintenance
Steering Group (MSG-3) method [4]. This method is sometimes
also referred to as Reliability Centered Maintenance (RCM).
The purpose of the maintenance program is to maintain the
inherent safety and reliability levels of the equipment. The
method will be described and illustrated by examples from a
shipsystem. This is to illustrate the use of this method in
the development of an initial maintenance concept for a ves-
sel.

The first step is to decompose the object into separate items,
normally components or in aircraft terms Line Replaceable
Units (LRU's). In aviation a standard system-breakdown is used
by distinction into systems, subsystems and components. For a
vessel, its functions will be broken down into systems as
indicated in fig. 4.
A system can be functionally decomposed into subsystems. As an
example in fig. 5, the Fuel Oil Service System 8.3 in fig. 4,
is broken down into its constituent components. A description
of this system by means of the SADT method [3] will show the
functional interdependancy of the components. This will be
helpful by the determination of the effects of functional
failures of component(s)(functions) on systemlevel. All inputs
and outputs may be quantified.

All components and its failure modes identified this way, need
to be classified into significance classes. They will be
called maintenance significant items (MSI's). An item is
indicated as significant if it:
-could affect safety
-is undetectable during operations
-could have significant impact on the operation
-could have significant economic impact.
For each item will be identified its:
-functions: the normal characteristic actions of an item
-failures: how an item fails to perform its function
-failure effects: what is the result of a functional failure
-failure causes: why the functional failure occurs.

The identification of the significance of each component will

be performed by means of a decision logic diagram, see fig. 6.
There are 4 subsequent questions which need to be answered for
each functional failure of the item being analyzed.
Question 1: "Is the occurrence of a functional failure evident
to the operating crew during the performance of their normal
duties?"
The intend of this question is to segregate the evident and
the hidden failures.
For each evident failure:
Question 2: "Does the functional failure or secundary damage
resulting from the functional failure have a direct adverse
effect on operating safety?"
A "YES" answer indicates a safety effect category. In this
case maintenance tasks are required to assure safe operation.
Question 3: "Does the combination of a hidden functional
failure and one additional failure of a system-related or back
UP function have a direct adverse effect on operating safety?"
The question takes into account failures in which the loss of
the one hidden function (whose failure is unknown to the
operating crew) alone does not affect safety;
combination with an additional functional failure (system-
related or intended- to serve as a back up) has an adverse
effect on operating safety.
A "YES" answer to question 3 classifies the failure into the
hidden safety effect. In case of a hidden safety effect,
maintenance tasks are required to assure the availability
necessary to avoid the safety effects of multiple failures.
A "NO" answer to question 3 classifies a failure into an
hidden economic effect. For these failures maintenance tasks
are desirable to assure the availability necessary to avoid
the economic effects of multiple failures.
Question 4: "Does a functional failure have a direct adverse
effect on operating capability?"
This question is asked for each evident, non-safety functional
failure. A "YES" answer classifies the failure as an operatio-
nal effect. For operational effects maintenance tasks are
desirable if the cost is less than the combined cost of the
operational loss and the cost of repair.
A "NO" answer to question 4 puts the failure into an economic
effect class. Tasks are desirable if the cost of the task is
less than the cost of repair.

The next phase in the development of an initial maintenance
concept is to identify effective and efficient maintenance
tasks. In fig. 7 are stated subsequent questions which need te
answered.
Question A: "Is -a LUBRICATION OR SERVICING TASK applicable and
effective?". Such a task is applicable if the replenishment of
the consumable reduces the rate of functional deterioration.
Question B: "Is the ability to detect degradation of the
function by normal OPERATING CREW MONITORING applicable and
effective?". Reduced resistance to failure must be detectable
and rate of reduction in failure resistance must be predic-
table.
Question C: "Is the ability to detect degradation of the
function by on-aircraft or off-aircraft INSPECTION OR FUNCTIO-

NAL CHECK applicable and effective?". Reduced resistance to failure must be detectable and the rate of reduction in failure resistance must be predictable.
Question D: "Is a restoration task to reduce failure rate applicable and effective?". It must be possible to restore the item to a specific standard of failure resistance.
Question E: "Is a discard task to avoid failures or to reduce the failure rate applicable and effective?".
The item must show functional degradation characteristics at an identifiable age and a large proportion of units must survive to that age.
Question F: "Is there a task or combination of tasks which is applicable and effective?".

For each identified task, frequencies and intervals have to established. These intervals may be derived from prior historical data from previous generation items which shows that a scheduled maintenance task has offered substantial evidence of being effective and economically worthwhile. It may also result from manufacturers testdata which indicate that a scheduled maintenance task will be effective for the item being evaluated. .
If there is no prior knowledge from other aircraftsystems/powerplants or if there is insufficient similarity between the previous and current systems, the taskinterval/frequency can only be established initially by experienced working group and steering committee personnel using good engineering judgement and operating experience in concert with accurate data (reliability, redundancy, etc.).
For this reason, an initial maintenance program therefore is of conservative character and needs to be adjusted on the basis of experience garthered during the operational phase.

PERIODIC ADJUSTMENT OF THE MAINTENANCE PROGRAM.

For reasons of periodic evaluation of the effectiveness of the preventive maintenance program, maintenance historical data have to be registered and analysed periodically. This means that all relevant failure data and inspection findings have to be recorded at component level. Especially in situations of a fleet of similar vessels, the time necessary to collect historical data which may become representative for the failure behaviour of the systems and components will not become too long.
For particular systems, Classification Societies are collecting allready failure data, which are being used to adjust the inspection rules.

In aviation, the operators are recording, as required by the regulatory authorities, maintenance and utilisation data. Larger operators will report these data periodically by means of a Reliability Monitoring Program. Monthly reports will be generated by which the Mean Time Between Failures per system and each significant component will be graphically recorded over longer periods. If a predefined alert level will be exceeded, investigation of the failurecauses will be carried

out and actions taken in order to reduce the failurerate. Possible action could be the adjustment of the maintenance concept.
Manufacturers play a role by providing operators with data of MTBF figures of their aircraft against the world fleet average* It means that for this purpose, operators need to provide the manufacturer with their failure data. An operator is therefore in the position to judge the reliability behaviour of his aircraft systems and components, against the world-fleet.

Another evaluation an airline will perform, is the evaluation of inspection findings. If nothing is found during a certain number of inspections, and the MTBF of the systems concerned are not decreasing, the inspection intervals may be extended by e.g. 10%. In case of safety-items, the manufacturer and the regulatory authorities have to be consulted and need to give approval. These interval escalation might be extended until experience shows that optimum intervals have been reached. In practical terms inspection intervals might be gradually extended 3-5 times the initial interval.

Also in shipping, maintenance plays not only a vital role in ensuring the operating safety by ensuring the reliability, maintenance costs are about 15-20% of total operating costs [5]. Investigations show that preventive maintenance costs are about 85% of these maintenance costs. In ship maintenance, lessons may be learned from civil aviation, by application of the MSG method in establishing an initial maintenance concept and the adjustment during the operational period by reliability monitoring and analysis and subsequent adjustment of the maintenance program and intervals.
May this lead to further increase of safety at sea and a reduction of maintenance costs by improving maintenance effectiveness.

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ACCIDENT RATES FOR PASSENGERS ON WORLD SCHEDULED SERVICES (ICAO CONTRACTING STATES, EXCLUDING USSR AND CHINA), 1950-1978
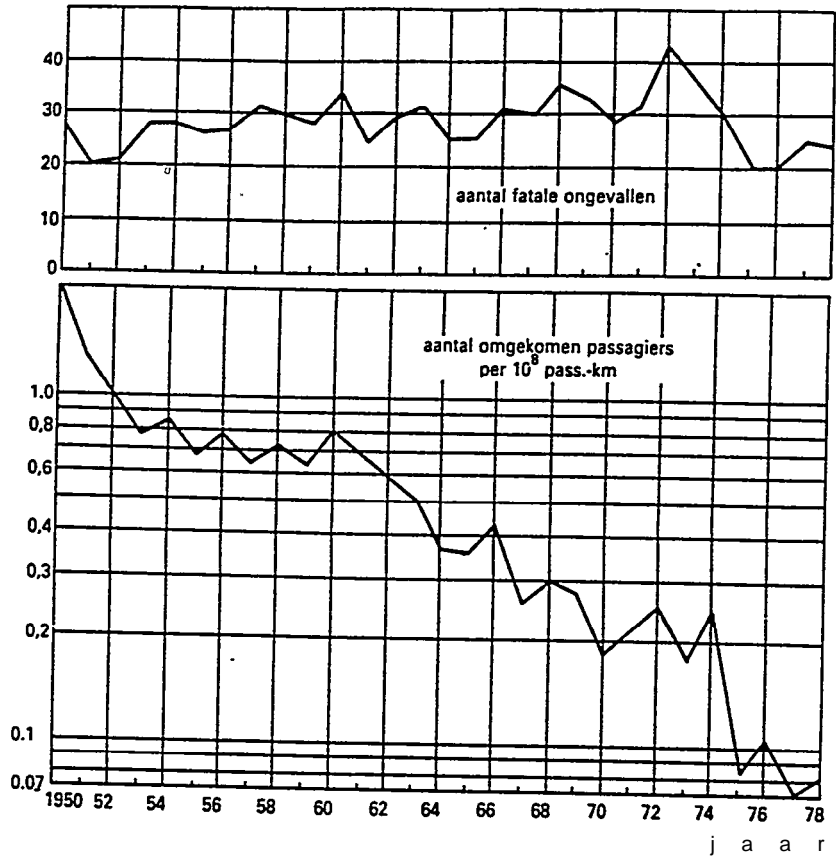
aantal fatale ongevallen

aantal omgekomen passagiers per 10^8 pass.-km

j a a r

ACCIDENT RATES FOR PASSENGERS ON WORLD SCHEDULED SERVICES (ICAO CONTRACTING STATES, EXCLUDING USSR), 1971-1990

Number of passengers killed on scheduled services

Passenger fatalities per 100 million pass.-km.

1971

1990
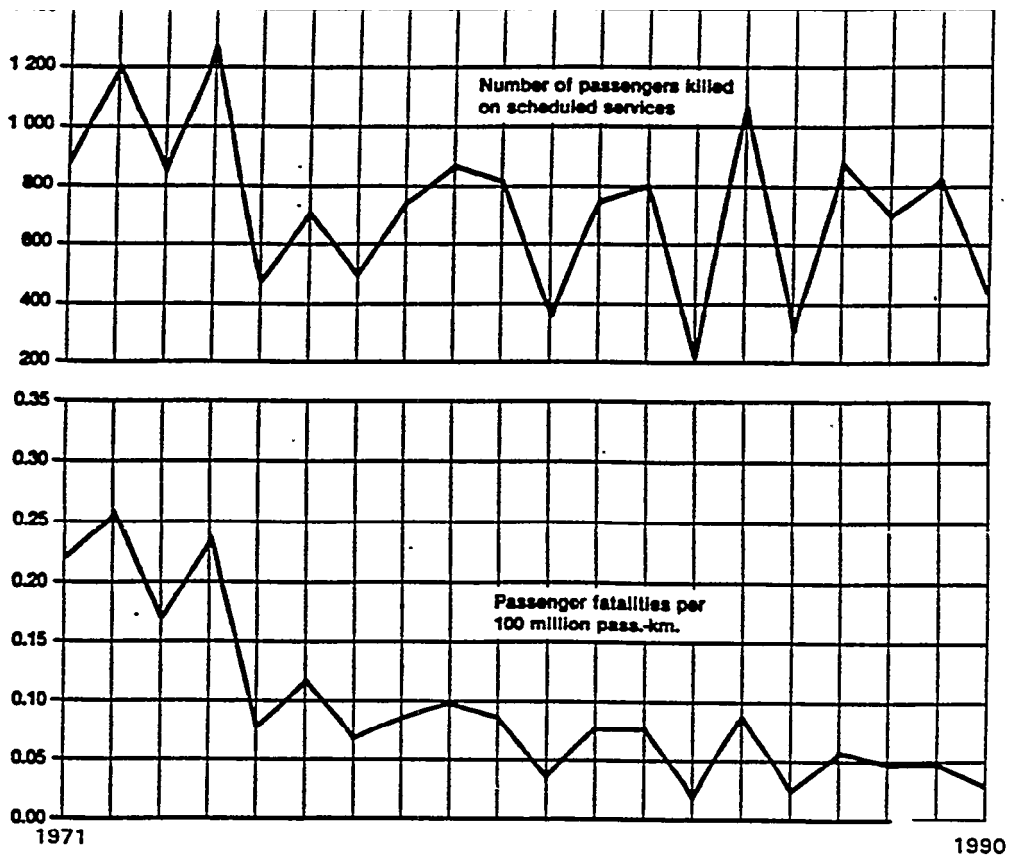
Historical ('48-'89) Overview of Accidents in Shipping

Historical Minimum (0.0027)

Legend: Missing — Lost — Collision — Fire/Explosion — Foundered — Wrecked/Stranded — Total
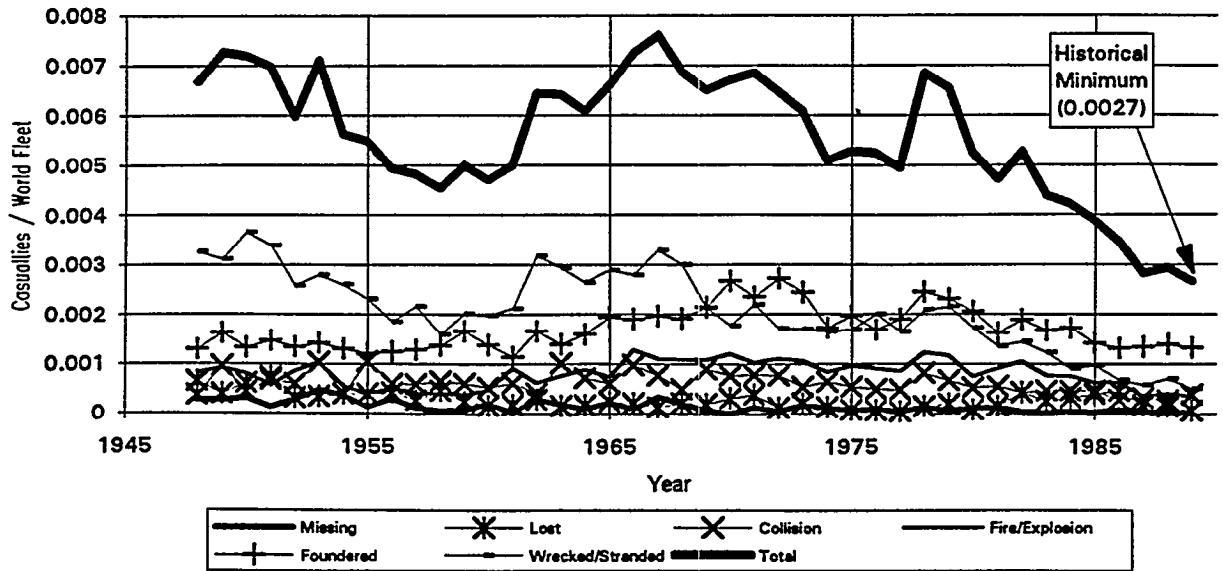
Lives Lost by Casualty Category ('84 - '89)

3841 Lives lost

688 Lives Lost

Legend: Foundered, Missing, Fire/Explosion, Collision, Wrecked/Stranded, Lost, Total
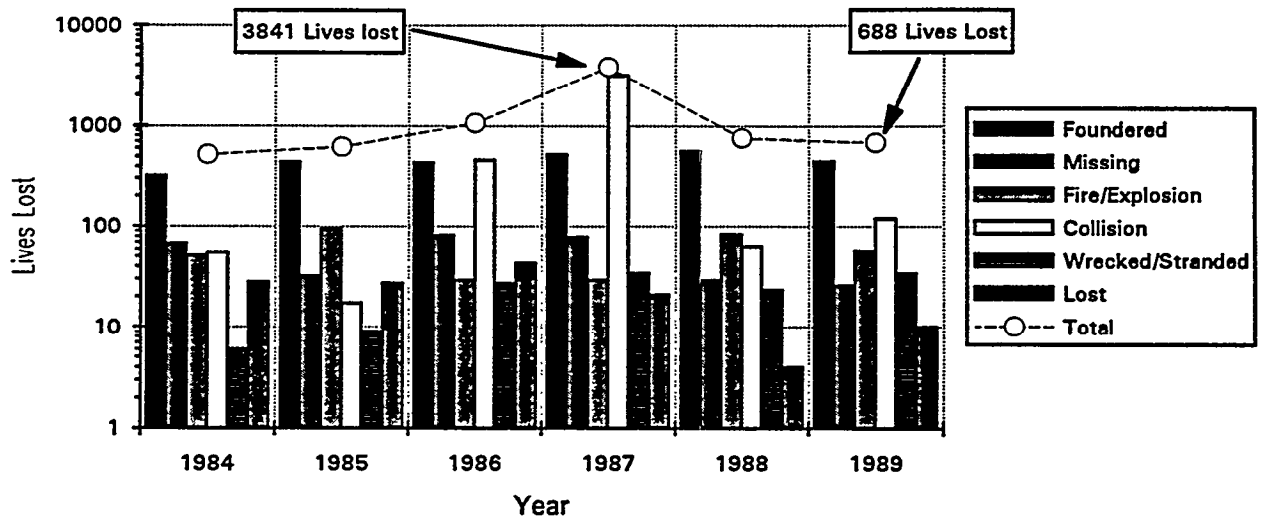
FIG. 2 ACCIDENT RATE AND LIVES LOST IN SHIPPING

ANUFACTURER REGULATORY
AUTHORITY

M S C

M W G¨s **M R B**

MPP → MRB DOC

MPD

OPERATOR

M M MPS

ESM

JOB CARDS
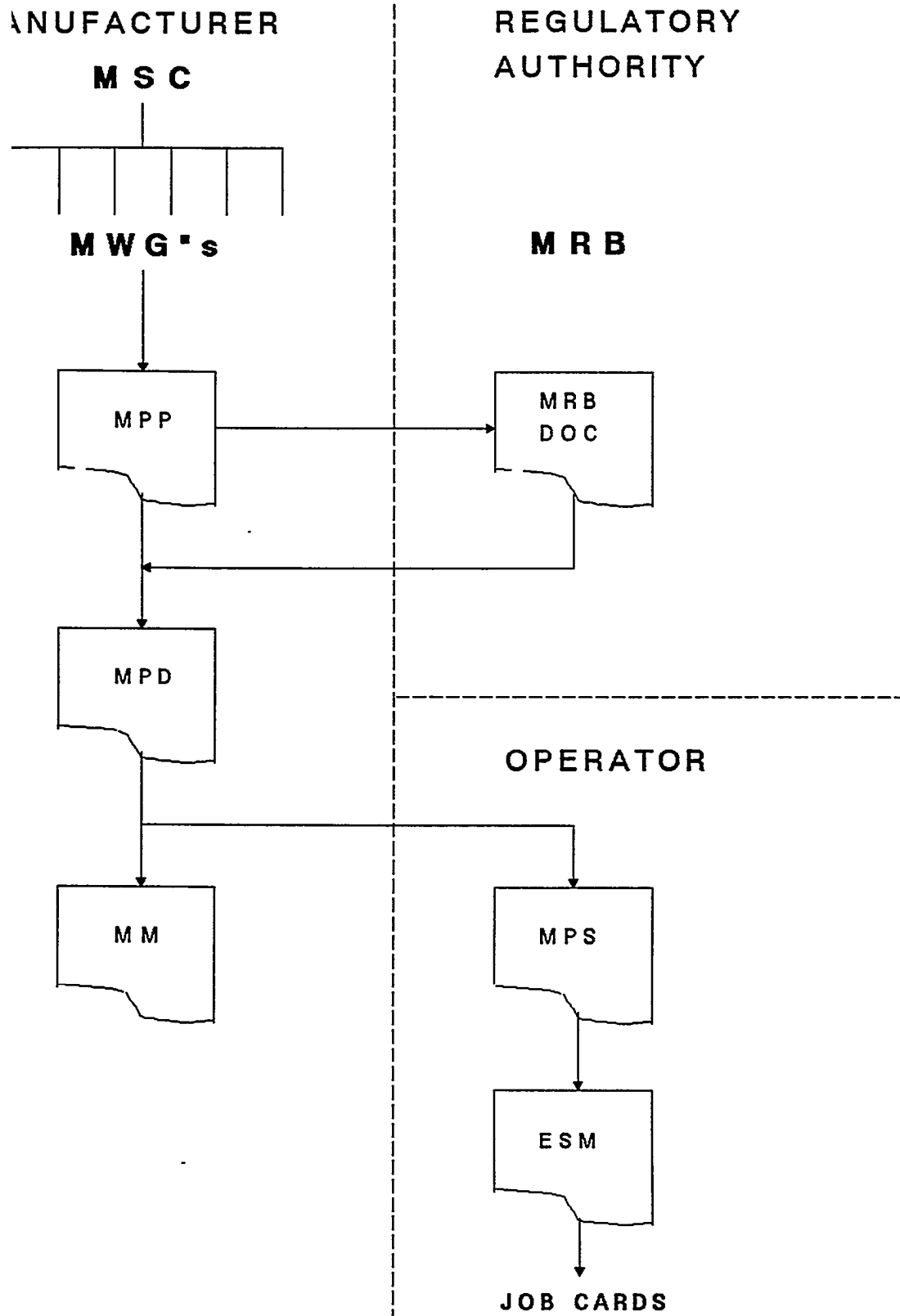
FIG. 3 ORGANISATION FOR THE DEVELOPMENT
OF AN INITIAL MAINTENANCE PROGRAM

FUNCTIONS:	SYSTEMS:
0. Containment, Protection, Accommodation	0.1 Shell 0.2 Decks 0.3 Bulkheads 0.4 Foundations 0.5 Superstructure
1. Ship Handling - Propulsion and Positioning	1.1 Engines 1.2 Transmission 1.3 Thrusters 1.4 Steering
2. Ship Handling - Deck Machinery	2.1 Mooring Equipment 2.2 Anchoring Equipment 2.3 Stores Stowage Equipment
3. Ship Handling - Navigation, Communication and Control	3.1 Navigation Equipment 3.2 Machinery Control Equipment 3.3 Communication Equipment
4. Ship Handling - Bilge & Ballast	4.1 Bilge System 4.2 Ballast System 4.3 Heeling System
5. Ship Support - Electricity Supply	5.1 Generation 5.2 Distribution 5.3 Consumers 5.4 Control
6. Ship Support - Air	6.1 Air Conditioning and Ventilation 6.2 Compressed Air Systems
7. Ship Support - Water & Steam	7.1 Sea Water System 7.2 Cooling and Fresh Water System 7.3 Feed Water System 7.4 Steam Generation and Transfer
8. Ship Support - Fuel Oil	8.1 Fuel Oil Transfer and Storage 8.2 Fuel Oil Treatment 8.3 Fuel Oil Service System
9. Ship Support - Lubricating Oil	9.1 Lubricating Oil Transfer and Storage 9.2 Lubricating Oil Treatment 9.3 Lubricating Oil Circulation
10. Ship Support - Stores	10.1 Stores 10.2 Workshops 10.3 Engine Room Tools 10.4 Other
11. Ship Safety	11.1 Fire Prevention 11.2 Fire Fighting 11.3 Fire Detection 11.4 Life Support 11.5 Emergency Electricity Set
12. Cargo Handling - Care	12.1 Loading and Unloading 12.2 Conservation 12.3 Processing
13. Life Support - Sewage	13.1 Sewage Treatment Plant 13.2 Sewage Collection System
14. Life Support - Crew Care	14.1 Food Storage and Preparation 14.2 Laundry 14.3 Medical Store 14.4 Inventory 14.5 Domestic Water System 14.6 Recreation and Leisure
15. Special Functions	15.1 Special Vessels' Systems

FIG. 4 FUNCTIONAL DECOMPOSITION
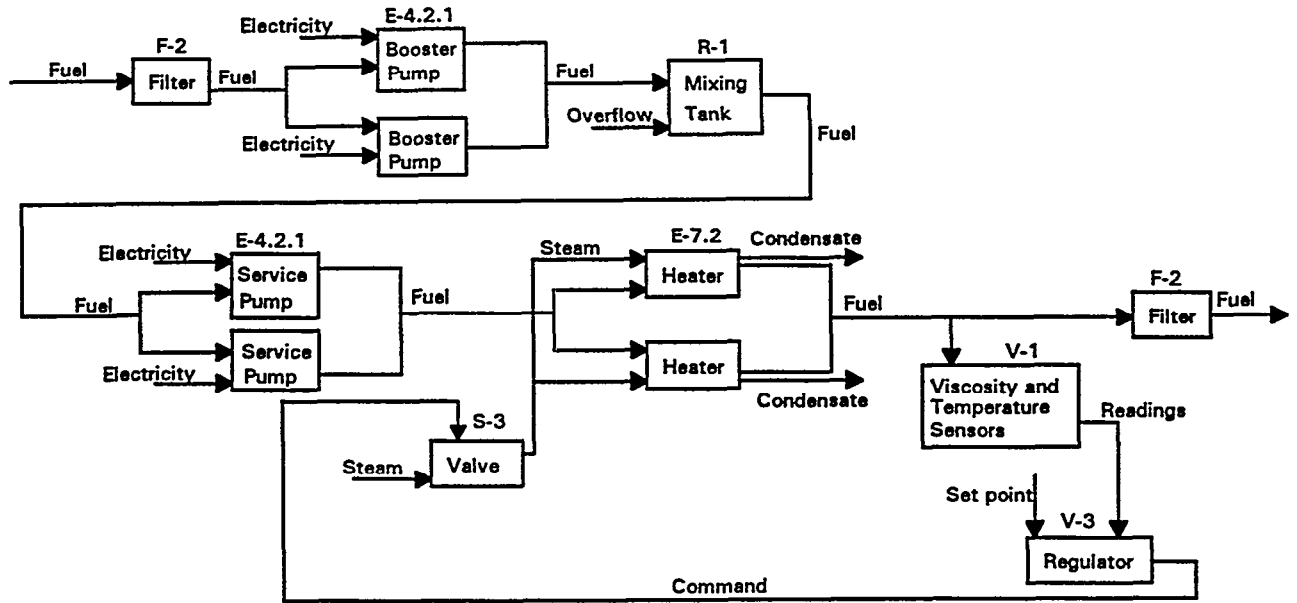
FIG. 5 SERVICE FUEL OIL SYSTEM

for each functional
failure

1.failure evident to
operating crew?

yes   n o

evident   hidden
failure   failure

2.effect on   3. effect on
oper. safety?   oper. safety?

yes   n o   yes   n o

4. effect on
operation?

yes   n o

safety   operational   economic   safety   economic
effects   effects   effects   effects   effects
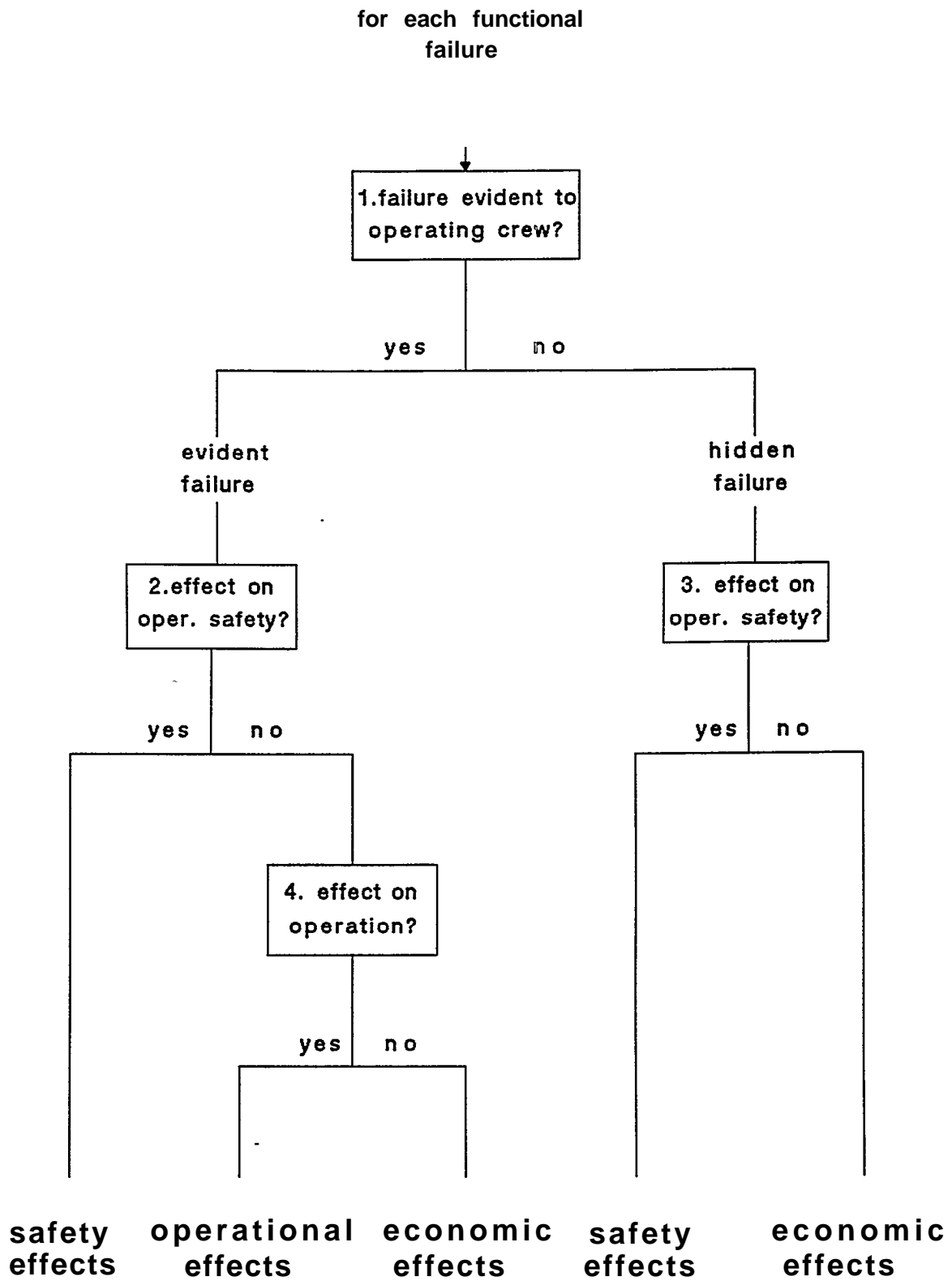
FIG. 6 DECISION DIAGRAM FOR COMPONENT
SIGNIFICANCE CLASSIFICATION

for each functional
failure

| LUBRICATION/SERVICING | ← yes | A:lubrication or service task applicable and effective? |

no

| OPER. CREW MONITORING | ← yes | B: degradation of function detectable by operating crew? |

no

| INSP/FUNCTIONAL CHECK | ← yes | C: degradation of function detectable by on/off aircraft tasks? |

no

| RESTORATION | ← yes | D: restoration task to reduce failure rate effective? |

no

| DISCARD | ← yes | E: discard task to avoid failures or to reduce failure rate? |

no

| TASK COMBINATION | ← | F: combination of tasks applicable and effective? |

redesign is mandatory
desirable

FIG. 7 SELECTION OF MAINTENANCE TASKS

SHIP MAINTENANCE AND ITS ROLE IN SAFETY

Douglas R. Stevens, Executive Vice-President
Life Cycle Engineering, Inc.

Underlying every successful marine maintenance system, the procedures, and training for personnel is one very important factor. That factor is a built in process to protect human lives and avoid environmental catastrophes-- in short, a factor of safety for people and the environment.   During the past decade, the world has witnessed agonizing tragedies involving massive fatalities and unequaled environmental pollution. For this reason, it is imperative that any marine maintenance system include what is referred to as "process safety management".

Technological infusion in our planned maintenance programs today provides an exciting challenge to effectively identify and apply what is most cost effective within accepted limits of reasonable risk. Specific applications such as artificial intelligence, expert systems, maintenance management, and monitoring programs are growing. We must not lose sight, however, that these are "tools."   They can be no better nor anymore effective than the fundamental logic, the engineering that makes up their development.

We within the industry will continue to see growth in the global sense of environmental restrictions. We continue to grow in our knowledge of the impact of hazardous materials and processes on machinery and personnel. It is likewise important that any applied maintenance program have within its logic base --the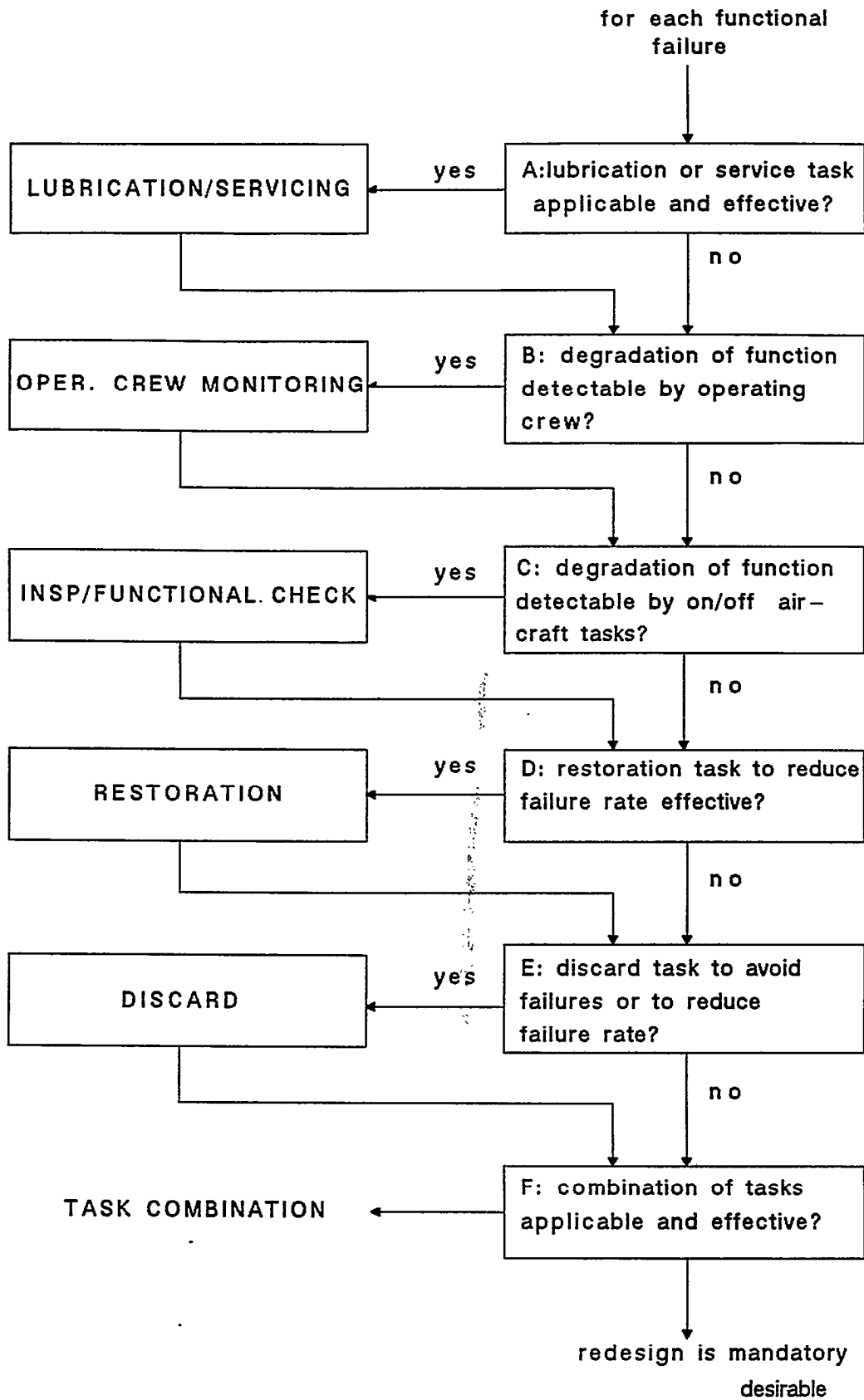 latest and most effective response to restrictions and engineered prevention of hazards.   It is equally important in this rapidly changing environment, that our maintenance program and/or systems be capable of sufficient upgrade as technology and litigation transpire.

The absolute key to assuring maintenance management application with assured safety and environmental responsiveness is to infuse our development logic at every level with the logic of process safety management.   This has been profoundly demonstrated by the on board maintenance management inspections and surveys conducted by Life Cycle Engineering in a joint effort with the United States Navy.   Our inspections focused exclusively on the daily, monthly, and annual planned maintenance procedures required for fixed machinery, calibration laboratories, ships monitoring systems, and also -- those functions supported by auxiliary ships. Having concluded our audit of maintenance requirements and their subsequent implementation on board ship, we then looked closely at the personnel and environmental protection procedures maintained by the ship. Our inspections, or more politely assessments, viewed the prevention of personnel hazards and environmental mishaps as a natural process meshed within the total planned maintenance system In so doing, we assessed system and process safety, personnel training,

safe work practices and procedures, the abatement of hazards, hazardous materials use and disposal, medical surveillance, personal protective equipment, and hazardous waste spill preparedness, plans and response capabilities on land and at sea. Our summary reports on each aspect of planned maintenance procedures, safety, and environmental protection provided documented evidence of improvement and a clear course of action for eliminating maintenance failures, personnel hazards, and environmental crises. The proof of success is always results --the bottom line - - the cost. In these instances the results were highlighted repeatedly by other inspections and surveys conducted by the Navy's own appointed team of experts. The ships efforts had rewarded them handsomely; maintenance procedures were on track and working; and, there were no incidences of personnel or environmental mishaps occurring on the worksite. Typical accomplishment no, but achievable by every maritime unit - - yes. The key again is the successful infusion of planned maintenance, safety, and preventive measures at every level, in every person, on a day to day basis.

Process safety management is a system for controlling the hazards to personnel and the environment by comprehensive forethought into all possible disaster sequences. In the development of planned maintenance procedures, it is important to ensure that the equipment is properly designed, installed, and operated; written procedures are established to maintain pressure vessels, piping systems, emergency shut-down systems and controls; evaluating processes within the maintenance arena are used to determine the hazards, the need for engineering controls, consequences of failure, and the effects and impact on shipboard personnel and the environment. Written safety information is provided to employees regarding safe work practices, the hazards of the maintenance processes; procedural steps for operation, emergency operations, shut-down and subsequent startup; employees are trained in these procedures and processes, emphasizing specific safety and environmental hazards, safe work practices, and supplemented by periodic refresher training. Lastly, process safety management is a team concept--backed by top management and infused into every employee in the maintenance organization. Compromising the loss of lives and the environment for profit or production is simply unacceptable; management at all levels is responsible not only for a successful marine maintenance system, but also for the elimination of hazards to employees and the environment.

An effective marine maintenance system is measured not only by the condition of the equipment but also by the costs required to maintain that condition, A well designed and integrated planned maintenance system, when compared to a system of merely corrective action, has been proven to increase equipment reliability, extend operating life, reduce the occurrence of in-service breakdowns, enhance personnel and environmental safety, and use scarce maintenance resources more effectively. The degree to which these benefits are realized will depend upon how well the maintenance requirements are defined and on the assigned frequencies for that maintenance.

Whether the maintenance system utilized is an automated monitoring or a manual recordkeeping system, an effective planned maintenance program must contain four essential elements: 1) identification of equipment and level of required maintenance, 2) development of detailed planned maintenance procedures incorporating safe work practices for each type of maintenance, 3) application of the maintenance and safe work practice procedures by trained personnel, and 4) a feedback mechanism to accommodate continuous evaluation, refinement and upgrading of the maintenance program

The identification of equipment and level of required maintenance and safety is a critical element in developing a planned maintenance system The selection of equipment should be based on the cost effectiveness to maintain the equipment in a high state of readiness, criticality to the operation, and the probable consequences of an unplanned failure. Personnel safety and environmental controls should also be considered in equipment selection. Examples of such controls include: the elimination of potential ignition sources, guarding of rotating belts and pinch points, exhaust ventilation systems, noise reduction, hazardous waste minimization, and in-place monitoring for dangerous vapors--all serve to minimize the potential for human or environmental tragedies. An accurate analysis of this information provides a clear definition of equipment which must be maintained.

The level of required maintenance focuses on the identification of failure modes and, more importantly, the types of monitoring needed to identify a degraded condition which leads to this failure mode with the consequences of disrupting plant availability, possible personnel injury, and property or environmental damage. Failure modes are best identified by reviewing previous historical records and an evaluation of equipment operating conditions. Analysis of these factors will lead to the type of monitoring required to identify the onset of a particular failure. This information is crucial in the next essential element of the planned maintenance which is procedure development. Many different types of equipment monitoring methods, many of which are nonintrusive, are currently being used successfully in shipboard maintenance. Those methods most prevalent include vibration monitoring, infrared monitoring, oil analysis, electric motor insulation testing and current signature analysis, ultrasonic flow and radiographic testing. Intrusive methods are also being used; however, the state of the art methods discussed here have proven to be cost effective and quite reliable. Therefore, once the failure mode has been identified, its signatures can be matched to the appropriate monitoring method.

Next, the development of detailed planned maintenance procedures is actually a series of stages in which these procedures become a fluid part of the system At a minimum, the initial procedures should contain the essential elements of maintenance required by the manufacturer as well as sound engineering judgment on equipment maintenance, operation and safety. The maintenance procedures developed to accomplish the planned maintenance tasks should include the following:

- resources required to accomplish the task, including skills, test equipment, reference materials, parts and supporting supplies

- identification of equipment location, operating conditions, component isolation, equipment line-up

- personnel safety precautions and safe work practices including hazard communication, lock-out/tag-out, required personal protective equipment, confined space entry, posting of specific hazards, engineering control devices, and procedures for emergency shutdown

- procedures should be technically valid, tailored to the specific component, comply with design specifications, and ensure quality assurance

- lastly, the procedures should be safe--short cuts are not allowed when there is any doubt concerning the safety of personnel or detrimental impact on the environment.

The language used in the maintenance procedures should be free of vague and ambiguous terms, using simple words and phrases that will convey the intended meaning. Consistency in terminology and organization of material is required for clarity. Procedural steps should be short, concise and written according to the skill level required and training provided to accomplish the task.

Limits on inspections and measurements should be specified so that a condition can be clearly judged as either acceptable or not acceptable. This information can be obtained from inspections and tests performed prior to or during disassembly; GO/NO GO acceptance criteria; requirements for cleaning, refurbishing, and replacement of parts; grooming criteria; and, post maintenance requirements which validate the item for reinstallation and service. In addition to time period - - fixed maintenance, routine inspections and tests should identify condition based maintenance requirements. This information must be merged into the system to lengthen or shorten fixed period maintenance. Information gained from maintenance personnel should also be added to this system so that valuable in-sight regarding equipment operation and safety is not lost.

Implementation of maintenance procedures requires corporate policy and unit procedures to be developed, issued, and implemented; however, it is also important to remember that this implementation requires highly trained personnel, skilled in planned maintenance program functions with the ability to execute changes which benefit the system Providing for maintenance, program effectiveness, and evaluating component material conditions require maintenance to be accomplished in accordance with standardized procedures, safe work practices, data recorded, and results analyzed to make informed judgment on subsequent maintenance strategies. Maintenance procedures should identify the logistics required to support such maintenance and performed with stand-alone, standardized procedures developed to specifications. This blending of the necessary logistics

and standardized procedures will ensure the successful accomplishment of the maintenance plan. Focused training and strict attention are required to ensure data recording requirements of the procedures are met. The maintenance plan identifies the planned work for the life of the component-- it is the driving force that identifies the skills required to accomplish the maintenance, promotes advanced training to ensure qualified personnel, and places the logistical elements within the plan to support the work. The execution of the planned maintenance system relies on the complete thoroughness in the development of maintenance procedures.

With the equipment identified, the maintenance procedures developed, and maintenance being performed, "the closing" of the loop is step four-- evaluation of the system. Without a feedback mechanism the planned maintenance system, the system itself can neither improve nor adapt to changing conditions and maintain optimal performance standards. The evaluation phase encompasses the elements necessary to measure and validate the effectiveness of the maintenance program, maintenance plan, and the material condition of the equipment. It requires implementing directives and procedures incorporating safe work practices at all levels to ensure critical maintenance data is collected, processed, stored, analyzed, and reported to the appropriate organizations with responsibil- ities for these functions. Comparison of observed conditions (e.g., during overhaul) with condition assessment parameters (performance monitoring data) must be made to ensure that monitored values are appropriate for determining equipment conditions. These items should be built in to the planned maintenance system or, in other words, implement- ed at the beginning, so that all involved are prepared to accomplish the necessary tasks for proper assessment.

An effective planned maintenance program must enhance equipment reliability, plant availability, while enhancing personnel safety and minimizing environmental impact. Most importantly--it must represent a sound financial investment. Factors to be considered in assessing program effectiveness are essentially maintenance cost benefits and equipment availability. Maintenance costs may encompass a myriad of individual factors, but for implementing revisions to an existing program -- cost benefits are more easily identified by comparing costs to future costs./. These costs should not additionally include injury to personnel, loss of life, and environmental pollution, damage, and liability. By instituting an effective planned maintenance program incorporating process safety management, cost benefits are ultimately enhanced and risks to personnel, equipment, operations, and the environment are minimized.

In summary, an effective ship maintenance plan provides the means to maintain equipment reliability for the operational life of the component and is based on the gathering of appropriate data which reflects the performance and condition of the component. It requires maintenance procedures and assessments; tracking and analyzing data to determine maintenance strategies; and trained personnel, with the knowledge of safety, the equipment, and maintenance procedures sufficient enough to

initiate appropriate actions.   The effforts of a successful ship maintenance plan serve to improve the overall maintenance program and permit planning for repairs and alterations which prevent catastrophic failures, disruption of plant availability, and endangerment of employees or the environment. An effective marine maintenance system incorporating process safety management is the deciding factor for long term reliability upon equipment, people, the environment, and prosperity.

TRENDS IN PORT QUALITY CONTROL: IT FOR Q?

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Abstract

Dutch ports are planning to improve their services by being safer, cleaner and offering better value for money than their competitors.

A vital element in this strategy is port quality control, which depends as much on government as on the officials in the port itself.

The possibilities opened up by information technology could mean great improvements in port quality control, making it much faster and more efficient. This is illustrated with a number of examples of projects dealing mainly with safety and environmental issues.

In the future, we can envisage even more new services we might offer using information technology. Vessel Traffic Services (VTS) are an important example. Setting up VTS systems is more a matter of cooperation and organisation than of funding, and ports that opt for VTS early are likely to enjoy a competitive advantage.

The magic word - quality

For at least the last three decades the world's largest port has been a Dutch port. But size is no guarantee of

continuing success. In common with other Dutch ports, therefore, Rotterdam has also joined the search for excellence.

There is a lot to be said for quantity, but in the end it is quality which says most about a port's competitive position. So what makes a port a quality port?

My unhesitating answer is:

    a safe port
    and a clean port
    which offers good service
    at reasonable cost

If I were a shipowner, such a port would be my preferred port of call.

A wide range of authorities, services and companies contribute to the quality of a port. Think, for example, of the tugmen; the pilot service; the mooring crews; the cargo handling, warehousing and forwarding agents; the engineering firms; the port authority; customs; and central government. And of course the shipping industry plays a major role. The ships themselves can determine whether a port has a reputation for cleanliness and safety, and the quality of service offered.

Port quality control - why bother?

In the Netherlands, ultimate responsibility for the safe and efficient management of vessel traffic routes lies with central government, This responsibility derives from the international conventions to which the Netherlands is a party, and is established in national legislation. The Netherlands has a long coastline with several significant ports. More than half of all shipping plying the North Sea off the Dutch coast is bound for a Dutch port.

Even the other 50 per cent of North Sea shipping sailing to and from other European ports comes under Dutch responsibility when it is off the Dutch coast. Authority is mainly exercised to prevent accidents, but extends of course to emergency services, and search and

rescue. As a maritime country with major ports, the Netherlands has every interest in proper safety and environmental regulations for ships and shipping.

An additional aspect is the protection of merchant shipping worldwide - and hence the Dutch merchant fleet - from unfair competition. Slapdash shipowners should not be able to derive any competitive advantage from their failure to invest in safety and environmental protection.

International regulations are laid down by the International Maritime Organisation (IMO) and the Central Commission for the Navigation of the Rhine. The Netherlands, of course, is a member of both. So the Netherlands promotes its interests in the international fora, in its capacities as a flag state, a coastal state and a port state.

Merchant shipping is international, and the international safety and environmental regulations apply in principle to any ship which sails into a Dutch port irrespective of the flag it is flying. The Netherlands government believes it has a duty to supervise compliance with the international rules. To perform this function, there are various bodies that enforce these rules, such as Port State Control and the Coastguard. The government also helps to set the context for the safety and efficiency of ships and shipping through its national legislation, by funding research and development, by offering incentives for new environmental technologies, and by providing the public with information.

Of course, the ports themselves have a strong interest in safe, environmentally sound and efficient shipping. Within harbour limits, the port authorities are indeed themselves responsible for these matters. So the interests of port authority and government coincide here to a large extent. Both are aiming for the same goals - no undue delays (preferably none at all) and service at reasonable cost.

International competition is so intense that only small differences in service or price are needed for a port to lose customers. With new logistical concepts, such as Just-in-Time and Door-to-Door, we need to be even more punctual and reliable.

Port authorities and government have several instruments for exercising port quality control. The most important of these are VTS for shipping, and Port State Control for ships.

Port State Control - PSC

International conventions explicitly permit the inspection of foreign ships. Inspections take place in port, since it is much more difficult to inspect ships on the open sea, and once moored a ship is under the jurisdiction of the port country. So, foreign ships can be prevented from sailing from Dutch ports if, say, they need urgent repairs to make them safe. This would happen if the Netherlands Shipping Inspectorate found serious deficiencies or breaches of the regulations.

The signatories to the port state control memorandum and their port authorities have a European organisation to coordinate their work. Here inspection procedures are agreed and information exchanged.

When Port State Control of foreign vessels was introduced ten years ago not all port authorities were happy with this new form of international cooperation. Many feared that it would make their ports less attractive, or that differences in enforcement policy between the contracting states would give some European ports an unfair competitive advantage.

Happily, this initial reluctance has since disappeared. Port State Control has not developed into the witch hunt predicted, and the results speak for themselves. If anything, the need for Port State Control has become even greater. Today, Port State Control focuses increasingly on environmental policing, through inspections of ships, equipment and operational checks to ensure that it is being used properly.

Port State Control has been so successful that it even has a following outside Europe. One reason for this is that other regions have often found their ships barred from European routes because they do not come up to standard.

The key words in this success story are unity of purpose and cooperation, both between countries and between port authorities. Without them, unfair competition could creep in at two levels: shipowners who ignored safety would go unchallenged, and slapdash ports would become their havens. There would, of course, still be ports which shunned the cowboys.

Now, if hannonisation and cooperation contribute to the success of Port State Control, they are also essential prerequisites for any forms of port quality control.

Vessel Traffic Services (VTS)

Shipping traffic from and to Dutch ports can be dense. This is one reason why VTS systems have been developed to further the safe and efficient mangement of shipping traffic. The VTS-systems that have been developed for the Rotterdam Waterway and the River Scheldt are highly sophisticated.
The heart of such a VTS system is its data processing system. All kinds of information, relevant for vessel traffic management (ship's positions, tides, cargoes etc.), is collected, processed, stored, or disseminated within or by VTS. As such, VTS has developed from what was seen as an "aid to navigation" into a basic instrument that, next to providing services to shipping, also improves the quality and effectiveness of other services concerned with safety, efficiency and protection of the environment.

PSC, VTS and IT - a new dimension

A great deal has changed since PSC and VTS were first devised. More dangerous substances are now carried. The environment has become more important. New logistics concepts have grown up - Just-in-Time and Door-to-Door. There is more international cooperation, particularly at European level. The world is literally getting smaller.

These developments create new problems for shipping inspectorates:

> inspections are more complex because more dangerous substances are carried;

> but, because of the demands of Just-in-Time and Door-to-Door, inspections must take less time, preferably without delaying the client;

> inspection reports have to be sent to other port authorities in other countries;

> and all this must cost no more than before.

There seems only one way to meet this challenge - with the help of information technology. Information technology is developing almost faster than the demands we make of it. New advances mean that we are able to collect, process and disseminate ever more data in shorter and shorter times. We can do much more, then, with exactly the same amount of information that we had before. Networking, data selection and automatic updating enable us to carry out inspections much more efficiently. The opportunities opened up by information technology are enormous.

The tools for port quality control - PSC and VTS - will have to be refined and improved in the future with the help of information technology and telematics. At the same time, we can expect to see many more applications geared to improving port services, such as automatic documentation and bills of lading.

Trends in the quality of port quality control

We firmly believe that by using information, information technology and telematics wisely, we can refine our existing quality control tools and produce a coherent package for port quality control. The Netherlands has therefore launched a number of port quality initiatives:

1. Selecting ships for PSC inspection

Let us go back to Port State Control. Every day, the shipping inspector has to decide which vessels to visit. To do this, he or she must be able to check the list of ships arriving against inspection reports from earlier ports of call. Has a ship recently been declared unfit at another port? Is there any suspicion of an illegal oil discharge?

From the outset, Port State Control has been Europe-wide. But few of the ports concerned have facilities for exchanging information on-line, although a suitable network would only take a few years to set up. An inspector would then have better information to decide which ships to visit. This is one area where good information exchange and selection would lead to a more effective and efficient Port State Control operation. The results would be an efficiency gain on the part of shipping inspectorates, and a reduction in needless delays and frustration for ships.

2. Broadening VTS objectives

Over the years, VTS has developed to a service that plays a central role in vessel traffic management. Within port, VTS may be used to coordinate traffic-related services, such as pilotage and tugboat-services. However, VTS may also coordinate in case of calamities and search and rescue operations. This supporting role of VTS towards "allied activities" is internationally acknowledged in the International Maritime Organization's "Guidelines for VTS" in 1985. To make full use of the coordinating potential of VTS it is essential to canalize the information flows through the VTS. Over the years, a great number of VTS systems has been developed. At present, most North West-European sea-ports operate such systems. This offers new opportunites for cooperation between

different VTS-centres. An exchange of information between those VTS-centres can reduce a ship's reporting requirements considerably, and it may speed up procedures related to cargo handling, customs and immigration as well. Information thus received may also be used to anticipate on entry clearances and to plan arrivals. As such, cooperation between VTS centres may enhance the efficiency of traffic flows.

3. Promoting MARPOL in ports: PMP

On arrival in port a ship is asked to report the quantity of slops in its tanks. The harbourmaster tells the captain where he can empty his tanks and the fee that will be charged for the use of a shore reception facility. If the ship then sails without discharging its slops while its tanks were reasonably full, it could be planning to discharge illegally at sea.

In these circumstances, a ship could be earmarked in the port's database with a note of its next port of call. Inspectors at the next port would look especially for empty tanks, as proof that the draincocks had been opened at sea.

This project is a Dutch initiative which is already being tested in Rotterdam. This kind of port quality control encourages the use of shore reception facilities in port, and enforces the environmental regulations more effectively. Slop tank data should be included in the information exchanged by European port authorities. So far, the response from other European countries has been positive.

4. Bonus malus

Information can be used as easily to reward good behaviour as to punish bad. You heard a lot about the green award in the last lecture. That is a good example of the bonus system. It is quite conceivable that the bonus malus system will be applied more widely in the future. But such a system is only feasible if enough information can be processed and exchanged by the authorities involved. And that is only possible if modem information technology is used. For the time being, the green award remains a Dutch - and specifically.a Rotterdam - initiative. It comes into force in 1993.

5. Reporting, Information and Monitoring (RIM) system

The carriage of dangerous substances by sea is on the increase in Western Europe. The chances of an accident are increasing too, with risks for the environment and for crews.

Technical standards covering the transport of dangerous goods are getting tougher all the time. But when an accident happens it is vital to know what is - or was - in a ship's hold. People involved in search and rescue or salvage operations need this information urgently. It might determine what action they need to take. An information network linking European ports could be the answer.

A ship carrying dangerous substances reports to the authorities in its next port-of-call 24 hours before it docks. Such information is required anyway for normal port planning purposes. If anything were to happen to the ship, there would then be a good chance that it had already reported its position and cargo to a European port. Its last known position could then be calculated by dead reckoning. In an emergency, these data would have to be directly accessible to, say, the coastguard coordinating search and rescue, the salvor, or others involved in the rescue.

The RIM system could therefore provide the information needed to decide on appropriate remedial action. All the North Sea states have agreed that such a system would be extremely useful. The Netherlands is pressing for an international RIM system, and is setting one up at national level.

European Waters Traffic Information System (EWTIS)

To achieve all this information exchange between port authorities and coastguard stations, we need a four-lane highway - in a communications sense - with everybody obeying the same rules. This means using harmonised and standardised messages (EDI) as much as possible. It also means using information which is already available as far as possible. The EC has already invested in this. The EWTIS Project (European Waters Traffic Information System) which started this year should produce a pilot network linking ports in participating countries by the end of 1993.

Initially, the network could be used to exchange information on ships sailing with full slop tanks, for search and rescue, salvage or disaster response, and to facilitate messages relating to Port State Control. In the long run, we hope the project will be expanded to cover much more information. The Netherlands is an active player in EWTIS, contributing both manpower and money.

Cooperation through information

The great advances made in information technology are helping port authorities and government to address the ever more complex issues of port quality control.

The beauty of IT is that it lets you handle the same amount of data you had before in a much more efficient way. You are not asking people to collect more data. All you have to do, as port authorities and governments, is to work together within well-defined objectives. And of course, this implies treating any commercially sensitive information with due respect.

But the benefits are enormous. After all, an efficient, safe, and environmentally responsible shipping industry has got to be in the best interests of both port authorities and governments. And the customer gets a better service for roughly the same price. This will inevitably bring in more customers - so there is a competitive advantage, too.

Information technology and rapid advances in telematics are forcing us to move into a higher gear than we envisaged a few years ago. We must grasp this opportunity and turn our paper ideas into the reality of port quality control as soon as we can. That is why the port authorities and the government sometimes encourage each other to embrace new applications, even before their full significance has been realised.

No doubt Dutch ports will have to face fresh challenges in the future. But as long as we regard these challenges as opportunities, we will remain masters of our own destiny.

ENVIRONMENTAL MANAGEMENT IN PORTS

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Summary

This paper generally deals with the environmental problems that could be expected to become future problems of the port and shipping industries. It also gives suggestions on how to solve some of these problems.

Three main areas are covered. They are:

1. Hydrocarbon emissions when loading petrol into tankers.

    Oil depots are often situated close to populated areas and as hydrocarbons are ventilated to the air when loading, more and more ports are required to collect and process these hydrocarbons.

2. Exhaust gas emissions to the air and noise from ships in the inner harbours of ports.

    Environmental authorities are requiring ships to connect to shore electricity while in port to reduce air pollution and noise from auxiliary engines of ships. The paper gives aspects on this and suggests better methods to reduce pollution.

3. The reception of ship generated wastes in ports.

    The MARPOL 73/78 Convention regarding reception of wastes is not effective in third world countries, not because ports can not build and run reception facilities, but because the ports can not get rid of the wastes they may collect. The most important reason for this being that these countries lack proper waste management systems.

The author sees the reception of garbage as the biggest future problem when it comes to the reception of ship generated wastes. Ports will require garbage to be separated onboard. The convention does not cover this, and ports are now setting up their own standards, which then will vary from one port to another. The paper offers a suggestion on a separation standard and the author pleads with naval architects to set ample space aside onboard ships when constructing new ships in order that garbage may be separated and retained onboard.

Background to the port environmental policies

Most ports were originally constructed in sheltered bays or riverbranches which-could give both weather protection to the ships and be fortified against those who wanted to lay their hands on the ships and their valuable cargoes. The ports gave job opportunities to people, attracted commerce and gave protection against malicious gangs of robbers or belligerent nations. Therefore, cities grew up around the ports.

Environmental aspects were neither thought of nor imposed any problems in those days. As ports expanded outside of their city boundaries the population followed, building their houses close to the new port areas. Industries took advantage of the proximity of the cargo handling facilities or were located there by the city counsellors who dedicated these new portareas as industrial sites. Roads and railroads were constructed to serve the new premises, etc.

Most of this expansion took placein our generation and is still going on. The environment was indeed thought of when the big liquid bulk cargo and container terminals were constructed, but the heavy expansion in the transportation of dangerous chemicals and other harmful substances was not anticipated. This traffic gave rise to safety and environmental problems in and around theports. Neither was the growth in the heavy truck-traffic and the problems it creates nor the problems associated with the bigger and bigger ships thought of.

Due to the change in packaging of general cargo from crates or palletized goods into containerized the traditional handling

andstorage areas in the inner harbours of the ports became too small. The ships also grew larger and their draft became too big for the old harbour basins. The goods was moved to the container harbours and many old parts of the ports became obsolete. Some of them could, however, be used for passenger vessels like cruising ships or large ferries. The draft of these is usually not as big as the draft of cargo ships. Other obsolete port areas in the middle of cities were, and currently are, being turned in to housing areas. One could think that this would solve the environmental problems of the inner harbours. But not so. Passenger ships need a lot of electricity also while in port. They therefore have to run their auxiliary engines and these produce exhaust gases and soot apart from creating noise.

The first generation of people who choose to live close to the port terminals often had some connection to the ports. They accepted noise and other troubles. The next generation, which had little or no connection with the ports at all would, however, not accept this. They demanded the ports to be clean, silent, nice and perhaps even picturesque.

In ports we will find almost all the environmental problem areas of our modern society. They will be: soil pollution, water pollution, air pollution and noise. However much I would like to talk about all this and what measures ports take or should take to solve the problems, time restricts me from doing so.

What often enough is not thought about is that safety and environmental protection in ports goes hand in hand. Most of the environmental problems are found in oil and chemical ports and terminals. If one wants to make an improvement to the environment in such a port or terminal it must never be done at the cost of the safety, because if safety is set aside one is very likely to end up with an environmental disaster. It may sometimes be very difficult to convince politicians and environmental authorities that some of their 'good" ideas could be dangerous. Haveing been working witht These matters for many years I have come across too many horrifying examples.

Hydrocarbon emissions to the air when loading tankers

The first of the three port environmental areas I intend to

address is hydrocarbon emissions when loading petrol into tankers. This will most probably be the future problem of those petrol loading ports who have not already come in to contact with it, which is the majority. As tankers are involved, it will also be a problem for shipowners, because tankers not complying with the demands ports and oil companies will raise in the future will probly have to seek business somewhere else.

When loading tankers they have to breathe out. If one does not allow that, they will take revenge by bursting, and that is indeed unpleasant. When loading petrol approximately half a kilogram hydrocarbons will escape per ton being loaded. As we don,t want to in hale these substances some thing has to be done. Cars run on hydrocarbons, people do not. So the hydrocarbon gases have to be taken care of in some way.

There are already quite a few ports around the world where the gases have to be brought ashore for processing and more will follow. But there are a lot of problems involved in doing that in a safe way. Petrol tankers must, of course, have connection points for the vapour return lines, like chemical carriers have, so the technique is there. The problem is more on the shore side, because shipowners do not want accidents ashore to affect their ships and terminal operators do not want accidents in their terminals.

Hydrocarbon mixtures in air maybe explosive if the concentration is the right one. The International Maritime Organization, which is the United Nation's organization for the safety and environmental protection of the *seas, is* currently discussing the safety problems. As always, there are several options. The tanks could be inerted before loading or flame arrestors and explosion traps could be inserted in the shore pipeline system, or both methods could be used. There are also talks about enrichment or dilution, but from a practical point of view I do not see them-as being feasible.

What do we do when we have brought the gases ashore? The simplest thing would be to burn them in flames like the ones you may see in petroleum refineries. But oil port people are a bit worried about flames, and besides, they are not the best for the environment, so that may not be such a good idea.

There are a lot of other ways to deal with the hydrocarbon gases. I will not try to cover all the methods but there is a Danish invention that is widely used not only in ship loading applications but also when loading rail and road tankers. It is called Cool-Sorption. The principle behind it is quite simple. The gases are sprayed with cold kerosene on which the hydrocarbons are adsorbed. The kerosene is then heated giving off the petrol hydrocarbons in a liquid form. The petrol is returned to a storage tank and the kerosene reused. Cool-Sorption even claims that after a couple of years, when the capital costs are paid, you will be able to make a profit on the petrol recovered. This method, it is said, has been shown to give a better result than refrigeration, compression, etc. At least 95 per cents of the hydrocarbons are recovered.

Let us now leave the oil,port problems and discuss other headaches ships give port authorities, still keeping air pollution in mind.

Exhaust gases from ships in ports

In my introduction I mentioned that passenger vessels in the inner harbours could create some problems as they have to run their auxiliary engines to produce the electricity needed for kitchens, air conditioning, lifts, illumination, etc. They create noise as well as pollutive exhaust gases and soot. People living in the neighbourhood of passenger terminals often complain about this. Ferries are usually not berthed for such a longtime, but when they load and unload cars and cargo over their ramps people are also disturbed by the noise from the ramps as well as the noise from the diesel engines of lorries and buses, especially if this takes place during the night.

What are we going to do about this? Well, politicians in the city where I come from had a solution to these problems: "Connect the ships to shore electricity while in port!" They went on by saying, that all ships staying more than two hours shouldbe connected. They probably made a comparison with cars who may not run their motors on idle for more than one minute, so two hours was generous!

An important drawback when ships are connected to shore

electricity is that, as the engines cool down when shut off emissions will be very high for a considerable amount of time after restart. It has been calculated that it takes about five hours for a modern large passenger ship to get emissions down to the same level as they were before the engines were shutoff. This, of course, means that shore connection even may be disadvantageous to the environment.

An emission source that shore connection will not affect is the main engines. They and the auxiliary engines have to be used when ships are at sea or maneuvring in port. The only way to cope with these problems is by dealing with the exhausts. One could either do something to the engines or to the fuel oils or to both.

The simplest way to-bring down emissions is to use a better quality of fuel. Almost all big passenger ferries calling at Swedish ports nowadays use a fuel oil for their auxiliary engines with a sulphur content of 0.5 per cent or less. Bunkering oils for main engines may have a sulphur content from 0.8 up to 6 per cents. The ferries I mentioned usually burn an oil with a sulphur content of about 1 per cent in their main engines.

When it comes to measures to the engines there are a number of ways to deal with them. Engines may be constructed in such a way that they become more efficient in relation to the quantity of oil they burn, cathalytic exhaust cleaning devices may be used or filtering devices may be fit to the exhaust outlets, etc.

Yes, we do use shore electricity in a couple of places in Sweden. In Stockholm the very big passenger ferries sailing to Finland connect to the city main and in Gothenburg equally as big ferries to Germany also connect.

The reason for shore connection in Stockholm was to reduce the noise from the auxiliary engines which disturbed patients of a nearby hospital.

In Gothenburgthe air is said to be extremely polluted, which is an exaggeration that some local environmental movements have succeeded to convince people of. However, I haveto admit that

a couple of days of the year Gothenburg suffers from inversion. This happens on cold winter days with low temperatures. During these cold days the ferries are not allowed to use the shore electricity, because the city can not supply enough. It has to be used for heating purposes.

One would think that these days should be the ones when it would be of the greatest importance to use shore electricity onboard ships. Well, it is not. The oil burnt in the city's electricity works is of a lower grade with a higher sulphur content than the one the ferries use for their auxiliary engines. The bizarre fact is, that when these ferries use electricity from the shore they add to the pollution of the air over the city. But the public does not know this, so the situation is now in a quite happy state.

There are a lot of obstacles that have to be overcome if one wants to connect a ship to the shore mains. First of all there is no place onboard to plug in the connection cables. Secondly, most ships use 60 cycle electricity while many countries only deliver50 cycles. The power reguirements for some type of ships are very high and the supply may not be enough. One will need big transformers close to the ships and they will obstractthe quays. Cables must be kept short to reduce losses and they are heavy and difficult to handle. Due to differences in ships, sizes there have to be numerous connection points in a big terminal. Connection must be done in phase by skilled electricians. If something goes wrong, computers and naviga-tional instruments onboard will get out of order.

My message is, if anyone should be dreaming about ships, connecting to shore electricity, stop doing so. There are much better and easier ways to cope with the problems.

Both the Baltic Marine Environment Protection Commission and the International Maritime Organization are currently dealing with the problem of air pollution from ships. The emissions have been found to be of a much bigger magnitude than earlier was anticipated. I think that in the future we will see standards for better marine fuel oils. It would be better to use high grade oils onboard ships and burnthe lower grades in power stations ashore where efficient exhaust gas filtering devices couldbe installed.

To finalize the point on problems associated with ferries in inner harbours, let me just say that the noise when heavy cars are passing the ramps of the ships can be much reduced. Rubber bushings could be introduced in the hinges of the ramps and the part of the quay where the ramps are landed could be covered with a soft material that will check the noise.

Reception of ship generated wastes in ports

My final item of this paper is problems related to the reception of wastes from ships.

You may have heard about the MARPOL convention or the International Convention for the Prevention of Pollution from Ships 1973 with Protocol of 1978, which is its proper name. The convention stipulates what kind and quantities of wastes ships may discharge into the sea taking into account the environmental sensitivity of different sea areas, how ships shall be equipped, etc. The convention also stipulates that reception facilities for wastes that are not allowed to be discharged into the sea shall be available in ports.

The reception is, however, not the problem. It lies in what to do after the wastes have been collected in the ports. It may sound fine to have reception facilities, and it works fairly well in ports in highly developed countries. But in the rest of the world the situation is somewhat different. Reception facilities are costly to build, people do not know how to run them and they are not aquainted with the special safety regimes governing the reception of wastes with regard to certain kind of ships and cargoes. But most important, ports can not just collect the wastes and store them. If they should do that they would very soon end up with an enormous environmental problem apart from a lack of cargo handling spaces. Subsequently, reception facilities are not built in these parts of the world. Ships have to keep their wastes onboard until they reach a port where they can get rid of them in a lawful way or discharge them overboard in an unlawful. This creates a very big problem to the ships.

To raise money for building receptionfacilities is, of course, quite a problem of its own. I will not address that one, but

there are ways. To produce guidelines and train personnel on how to use the facilities is another, but there are consultants like myself who would be very happy to help out. The third problem, how to deal with the wastes collected is the big one, and therefore I will elaborate a bit on that.

The countries we are talking about usually do not have any waste management systems. Garbage is often dumped outside the cities on big dumps where thousands of people are trying to find something useful. Sewage is let out into the sea and oily wastes may not be treated in any other way than draining away the water. They are then used for heating purposes and exhaust gas cleaning has probably never even been heard of.

What first of all is needed is to introduce an environmental consciousness among-the people in these countries and to convince their governments of the advantage of waste management. This is more easily said than done.

Now, let us assume that we have succeeded in these two tasks. I may then turn to the practical part of the reception of wastes from ships. Let me start with the oily ones. They can be diveded into ballast water, tank wash water and engine room wastes, the latter consisting of sludge from fuel and lubricating oils and oily bilge water.

As oil is usually loaded in refinery ports and ships then have to get rid of their dirty ballast or tank cleaning waters when they arrive at these ports the problem is really not so big. Refineries are usually equipped with oily water separators to clean their oil contaminated storm water. These separators can, of course, also handle oily water from ships. It is merely a task of conveying the oily water from the ship to a magazine where it is stored until it can be processed in the separator. The technique is simple and well known. I have often enough met the misconception that ship generated wastes are something mysterious that have to be dealt with in a very special way, but that must not be so.

To overcome the high costs of useing these facilities, the best way, in my mind, would be to let companies who are loading tankers be responsible for providing the reception facilities. That should even be done free of charge to the ships. The

shippers will in any way haveto pay for the discharged water, so why not let them do right from the start? They will then do what they canto keep costs at a minimum and hopefully also to be efficient. In this way port authorities will not be involved, which also will keep costs down and efficiency up.

Engine room wastes like sludge and oily bilge water have to be received by the port authorities as these kind of wastes arise in all kind of ships. Engine room wastes could also be processed in refinery separators, even if this is not the best way of doing it. Lube oils contain a lot of harmful substances that will pass an ordinary separator, but it all depends on what equipment one may afford to invest in. Due to economical restrictions one may not be able to go for the best possible solution at once. It would, however, be better to do it this way than not to do anything at all and end up with the engine room wastes going overboard.

Sludge and bilge water is quite easily received by the means of tank trucks or barges, so the reception facilities are not too expensive.

Chemical carriers should discharge their tank cleanings in the unloading ports. The consignees should provide the facilities as they may be able to use the residues in their industries or have the means to deal with the tank cleanings as they probably also would get the same wastes from their own operations.

Sewage may create a problem in ports where the municipality has not got any sewage treatment facility, which they usually don,t have in developing countries. Sewage may, however, be discharged to the sea in most sea areas of the world excepting in some so called" special areas". Modern passenger ships often have treatment plants onboard. In Sweden we have, however, seen that big ferries do not like to pump their sewage overboard even if they are allowed to do so, because environmental cleanliness nowadays is part of the ferry companies popular relations concept. They have found out that if they can show an environmental consciousness they will gain in business. The ferries connect to the municipal systems while in port and the sewage is pumped ashore. One problem is, however, that the shore systems often are not dimensioned for the high discharge rates of big passenger vessels only staying in port for a short period

of time. Sewage has been taking other ways than through the underground pipeline systems with some unpleasant consequences.

The waste that in the future will create most of the problems both to ships and to ports will be the garbage. Today almost all kinds of garbage except plastics, synthetic fishing nets, ropes made out of man made fibres and the like may be discharged into the sea under certain conditions.

I am quite sure, that discharges of garbage will become more restricted in the future. Governments will prohibit discharges in their territorial waters, more and more areas will become "special areas", etc. My guess is that discharges outside ʻspecial areas,, also will become more restricted. Apart from this, the coastal traffic already has to discharge most of its garbage to shore reception facilities according to the requirements of the convention.

Some ships, generated garbage like food wastes, some cargo associated wastes and infectious wastes from sick-bays should not be disposed of in dumps or landfills as diseases and foreign vermins may be spread. These wastes should preferably be incinerated. However, I do not think that the incinerators should be owned and run by the port authorities. They are costly to build and complicated to operate. They also need a constant flow of garbage to work well. The ports will probably not receive enough to feed them, so they should serve the community around the ports as well as the ports themselves and probably be operated by special companies.

Incinerators also need a lot of fuel, and some of this may consist of the sludge and other waste oils ports have received from ships. Exhausts from the incinerators should, of course, be cleaned.

The second best thing to do with garbage if incineration is not feasible is to deposit it in a safe place and spread lime stone over it.

Garbage that does not need incineration or other complicated means of processing may be dumped or used as landfill.

As different kind of garbage has to be handled and processed in different ways, ports will require the garbage to be separated prior to discharge. The problem is, however, that the convention does not say anything about separation. I have noticed that different ports often have different separation criteria. They depend very much on the different handling and processing techniques of the ports communities, processing plants.

If something is not done very quickly we may end up with a situation where ships are required to separate their garbage in a different way for almost every port of call. Of course, ships can not meet these requirements, and the garbage will subsequently be discharged into the sea.

What is needed is first of all an international regulation on garbage separation onboard ships. Shipowner and port associations should take part in the creation of this regulation. The processing plants shall then have to comply with it.

Secondly, ships need storage compartments for the garbage. When new ships are constructed this should be thought of in order that ample space can be set aside onboard.

The separation itself is a lesser problem. Different kind of wastes arise in different parts of the ships and this fact could be used. Garbage that has to be taken ashore should at least be separated into the following categories:
a) combustible garbage;
b) non-combustible garbage;
c) environmentally hazardous substances, like leftovers from solvents and paints, oily rags, batteries, accumulators and flourocent lamps; and
d) infectious materials and medicine residues.

There are, of course, a lot of other problems ports may encounter with regard to the environment. Various ports have also found good solutions to many of them. What I now have tried to outline are some of the major ones and the ones that can be envisaged to be problems for a great number of ports as well as for ships in the near future - if they are not already.

SAFETY INTEGRATED VESSEL DESIGN, THE BEAMER 2000

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Summary

This contribution describes significant developments in society and in the technology in the Dutch fishing industry which emphasize the need for major changes in the design of fishing vessels. By deploying a scientific approach, the safety integrated design method KINDUNOS, it is possible to integrate safety in an l early phase in the design process. Major improvements are possible in the conceptual phase of the design. A systematic approach is described in which safety is an explicit aspect in the design procedure, weighed against other design criteria. The beamer 2000, as a result of this design study, takes into account the safety, working conditions and the work load on the bridge, the fishing deck, the processing and storage of the catch, the engine room and noise and vibration in the accommodation. The potential for further improvements are indicated. The design is evaluated with respect to residual risks and the necessity of additional risk reduction strategies of a non-technical nature. Finally, the possibilities are discussed to apply the method more in general to the design of other types of vessels.

1. Ad hoc versus prevention

In the last three decades sea fishing in the Netherlands has developed from a craft to a modern industry. In this industry micro-electronics and information technology are widely applied for navigation and communication, fish detection and engine monitoring. Although technical developments and market demands have increasingly mechanized and controlled the process, the processing and storage of the catch on board and the selling of the catch at the auction are still organized traditionally. For many years the Dutch fishing industry has constructed vessels by adopting parent vessels and semi-serial building has been more the rule than the exception. Beam trawling, the most important Dutch fishing technique, is undergoing significant changes. After a period of growth and mechanization, the emphasis has shifted from scaling up and increased efficiency to improvement of the quality and the reduction of the costs gained by means of catch quota restrictions and fishing day limitations. The traditional practices of fish processing are being re-examined in the light of guality assurance standards for chilled flat fish. The processing of the catch both on board and ashore have become related by quality assurance and logistic requirements, Additionally, due to oncoming European guidelines, demands are put on better safety-and working conditions for the skipper and his crew and on a better marine environment.
The increased complexity, scaling up and interrelation of the various aspects requires a new approach. By deploying a scientific approach - the method KINDUNOS, which means 'hazard' in Greek - it is possible to integrate safety at an early phase of the design process. Major improvements are possible in the conceptual phase of the design. Instead of an ad-hoc approach, such a safety integrated design should result in a durable safe fishing process.

2. A safety integrated design process

2.1 A multi-disciplinary approach
Adesigner of fishing vessels is confronted with these developments because he has to fulfill the demands of his assignment within the constraints of the new regulations. In practice however, in the analysis of the safety problem, a maritime designer does not have the required accident data, noise and acceleration level data at his disposal: neither does he have the time and skills to analyze the accidents or to transform the results of the analysis into design specifications. During the evaluation of the design, he has limited possibilities to foresee future use or to formulate strategies of a non-technical nature which have to deal with residual risks and side effects. Therefore, the designer has to cooperate with safety experts and maritime researchers within a design team. The goal of this cooperation is to elaborate generically formulated 'soft' safety objectives into 'hard, specifically formulated design requirements which can be integrated into the overall Programme of Requirements for the designer and which may serve as the basis for the evaluation of the design (Stoop and Veenstra, 1992. 2).

2.2 Problem development
A generic description of safety on board does not lead to succesful design intervention. For a design intervention, safety problems must to be broken up into manageable sub-problems which contain satisfactory explanations of cause and effect relationships.
The basis for the safety analysis in the fishing industry was found in the Verdicts of the Dutch Admiralty Court. In the Verdicts, fishing vessels were overrepresented with respect to their number as well as to collisions and severe occupational accidents, especially those in which beam trawlers were involved.
Although the reports of the Shipping Inspectorate described the accidents in detail, additional information had to be collected in order to supply the research team with satisfactory explanations of the accidents and to formulate generally valid patterns beyond the level of individual case histories.
Additional accident material was found in the data of the Radio Medical Services of the Red Cross, the Labour Inspectorate and the Social Fund for the Partnership Fisheries. Observations on board and analysis of the normative tasks in the various work stations supplied the team with a good insight into the way these tasks were performed. Underlying causes of accidents and work load were revealed by further research in several fields on specific topics such as the application of human error theories, noise and acceleration level measurements and estimates of human energy consumption.
The analysis led to the definition of the following sub-problem areas in which different aspects and dominant problems occurred.
on the bridge, dominant problems were encountered with the mental load of the operator, the interfacing of the electronic equipment, the vision lines to and communication with the decks and the surrounding traffic and the layout of the bridge and the steering console (Buijs and Van der Sluis, 1991)
on the fishing deck, the physical load of the crew during the handling of the nets and the cod-end was dominant, together with the risk of severe accidents during handling of the gear at the fish processing station and during storage in the fish hold, much manual handling and lifting caused an exceptional heavy physical load, aggravated by high acceleration levels and climatic conditions (Hoefnagels et al, 1990)
in the engine room the layout of the main and auxiliaries systems are not matching quite well with regard to energy consumption, remote controlling, marine environment and maintenance.

Before a design team may proceed with the design, two points
have to be clear with regard to the setting of priorities and
the scope of the design improvements.
Firatly, the causes of accidents can be beyond the scope of the
redesign of the workstation where they occur. Problem areas are
interrelated. For example, the phenomenon of 'falling, on the
fishing deck must be divided into three types, because of their
different underlying causes. Falling can occur during the hand-
ling of heavy gear, where the crew has to operate the nets,
beams and chains and can be struck by the hoisting equipment.
Falling can be caused by violent movements of the vessel,
knocking the crew off their feet. Falling can be the result of
being hit by heavy stones, debris or other heavy material
caught in the nets and brought on deck during the hauling of
the cod-end. Each of these causes can have different solutions,
varying from gear redesign, or hull modification, to containers
on deck for undesirable by-catch storage. If such a solution is
beyond the scope of the design assignment, hazards will remain
and residual risks will have to be dealt with accordingly.
Secondly, the analysis will probably reveal a need for further
research into several different fields, without which the qual-
ity of the problem description could be inadequate, thereby
causing uncertainty about the adequacy of the design solutions.
The analysis of safety on board of beam trawlers, indicated the
necessity for research into:
the tasks of the man on the bridge with respect to the
modelling of human error, the need for an architecture in the
presentation of information including engine room control and
alarming and for an adequate programme for simulation and
training
Electra Magnetic Interference of the equipment, especially in
the light of future trends in automation and the restricted
space for the equipment available on the bridge
the dynamic modelling of the gear behaviour in interaction with
the vessel, especially under heavy sea-going conditions (Van
der Nat et al, 1992)
more detailed measurements of acceleration and noise levels,
especially with respect to noise transfer from the stern and
propeller to the accommodation area (Veenstra, 1988).

3. Analysis results

3.1 A systems model
   The analysis makes it possible to derive a systems model of the
   beam trawler, representing the safety problems on board. Such a
   model enables the design team to describe the sub-problems in
   relation to each other and to the vessel as a whole.
    (see figure 1)

   The model clarifies the boundaries which are chosen if sub-pro-
   blem areas are elaborated. Problems which are not selected for
   elaboration or have their underlying causes in other areas,
   will cause residual risks in the selected sub-problem area.
   During the evaluation these effects must be foreseen and coped
   with appropriately. Additionally, solutions in one area may
   have an effect in other areas; eg changing the working deck
   layout, changes the vision for the skipper on the bridge during
   his winch operation tasks and will alter the crossing routes
   for the crew from the accommodation area to the processing work
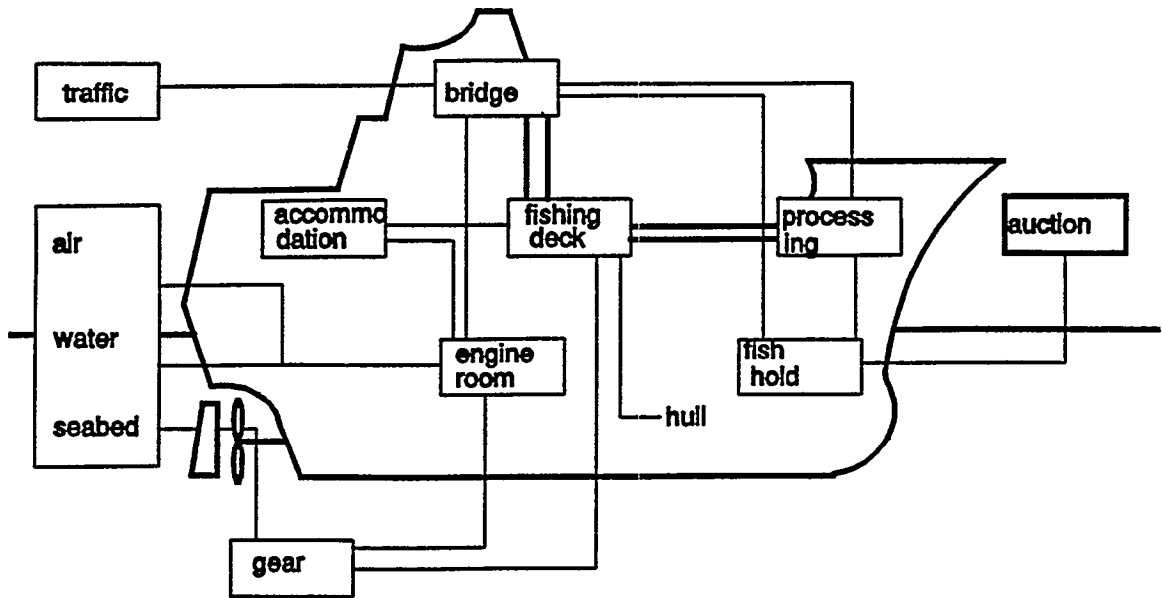   station.

Figure 1

3.2 Safety in the design requirements

The results of the analysis are translated into safety and
health requirements for the overall Programme of Requirements,
in a step by step procedure:
the safety and health demands are collated by workstation; i.e.
fish deck, bridge, engine room and accommodation
additional demands with respect to environmental issues and the
quality of the fish as a product are elaborated by workstation
all demands are brought together into a set of requirements,
specific to that workstation
these sets are arranged in a specific to type of vessel set of
requirements, suitable for integration into the overall Pro-
gramme of Requirements.
This overall Programme of Requirements is methodically devel-
oped through the various design phases by means of the, with
ship designers well known, Design Spiral until a satisfactory
result is produced. Safety and working conditions form a new
segment in the spiral and are elaborated parallel with the
other design requirements.
(see figure 2)

The final result of the problem analysis consists of three
items, which are of interest for the design team members:
a problem description in which safety case studies and research
findings are transformed into a complex model of the fishing
vessel. This model facilitates a systematic and coherent devel-
opment of the problem in which future effects are foreseeable
an integral Programme of Requirements in which safety and
health issues are weighed against other requirements
a research programme in which greater expertise of the
researchers is developed, giving a better insight into the pro-
blems and aiming at better assessment and control.

working conditions
(safety)

fishing method(s)
(shaft horse power)

propulsion
(engine room layout)

fishhandling
(decklayout)

ship's dimensions
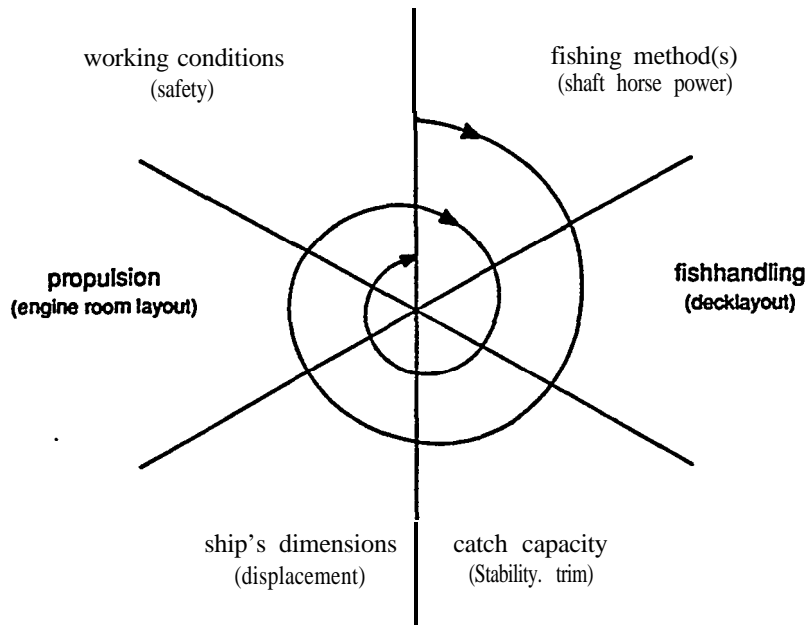(displacement)

catch capacity
(Stability. trim)

Figure 2

4. From Analysis to Synthesis

4.1 Principal decision points
In the transition from analysis to synthesis some crucial steps
are present in the design spiral, in which safety is a princi-
pal issue. The safety integrated design method KINDUNOS con-
tains 5 principal decisions with respect to safety (Stoop,
1990). In the conceptual phase of the design process, substan-
tial improvements are possible. The first decisions define the
attainable levels of safety for the later phases which only can
be influenced with great cost and additional measures. These
principal decisions run parallel with the design spiral and
should be processed in a-time sequence.
They focus respectively on:
the formulation of the design requirements. Safety aspects
should be explicitly present in the objectives and should spec-
ify the target group, the safety requirements and the hazards
to be dealt with. Until recently, the safety and health of the
skipper and his crew, the so-called 'Arbo law' working condi-
tions were not explicitly present in the design requirements of
a fishing vessel and therefore were not elaborated upon during
the design
the hazards inherent in the choice of a technology, energy sup-
ply and the overall layout applied to a design. The selection
of a mechanically driven winch and of warps for hoisting heavy
loads, introduces different hazards than those for a hydraulic
or electric crane. The position of the processing work station
under the foredeck instead of under the bridge in the middle of
the vessel introduces a different magnitude of acceleration
levels in the processing workstation and also creates different
transport routes around the vessel for the crew
the consequences of the decisions in the conceptual phases.
Hazards introduced in the early phases should be dealt with
during the detailing of the design. Once the hazards are intro-
duced, they should be mitigated or compensated for by effective
risk-reducing strategies. If warps are applied, they should not
run over a working deck at head height but should be confined
in warp runs or should be operated with self-tensioning winches
eguiped with emergency stops
interrelation between all previous design decisions may cause
unforeseen effects for other work stations on board. A redesign
of the fishing deck may cause vision problems for the skipper
on the bridge during winch operation. Alteration of the skip-
pers vision lines in order to deal with this problem, must take

into account his navigation and watch keeping tasks as well as his ability to operate and monitor the equipment on the bridge residual risks which are not dealt with in the design should be managed with measures of a non-technical nature once the design is finished. Additional measures may be necessary with respect to the certification of equipment, the training of the crew, legislation with respect to working time restrictions and the number of crew members or organization of the work on board.

4.2 The solution matrix scheme

The transition from analysis to synthesis is made by means of a solution matrix scheme.

This matrix scheme is developed as an instrument in order to structure and grade the various solutions by their nature and scope. On a horizontal axis, the solutions are classified into their relevance for the workstations, the design of the vessel and the organisation of the labour. On a vertical axis the solutions are graded by the impact which they have on the vessel, varying from minor alterations within the existing vessel layout, a partial adjustment of the layout, up to the redesign of the vessel layout.

concepts	workstation	vessel design	labour organisation
within existing layout	• warp containment • safe working zones • controlof objects • relocation of hoisting and control stations	0 communication bridge-fishing deck • vision lines to crew on deck • noise abatement • reduction of vessel movements	• education licenses • protective clothing • emergency brakes on winches • certification of hoisting equipment and gear components
partial adjustment	• cod-end containment • replacement gipsy heads by drums	• noise reduction at the source • hull optimization • exchange winch and processing station • elevation of bridges	• increase crew size • mechanization and automation increase • restricted working times
new concept Beamer 2000	• mast backwards • fishing pits to the side • hydraulic cranes for multifunctional purposes • quality control fish processing	• implementation of all noise abating measures • processing workstation amid ships • automated storage in the fish hold	• no waste overboard • watch and leave similar to merchant marine • optimired mechanization and automation

Figure 3: solution matrix fishing deck

This matrix scheme permits the design team to compose 'best technical solutions, for the overall vessel design as well as for local work station design. These 'best solutions' deal with several hazards at a time and eliminate or mitigate the hazards and not merely influence their effects. They often consist of multifunctional tools, such as hydraulic cranes on the fishing deck, or introduce new technical solutions, such as integrated visual displays on the bridge (De Vries, 1990).

The selection of solutions for further elaboration is done by a cost-benefit estimate of the different solutions. Several packages of solutions are produced, graded by their cost, so that each skipper-owner can select the package appropriate to his financial resources and personal preferences; quality of work, quality of fish and quality of marine environment.

The residual risks are estimated by consulting several experts. The acceptability of the residual risks is determined and the non-technical measures required to cope with these risks are estimated (Stoop and Veenstra, 1992.2).

To reach a durable solution in practice, all stakeholders must be involved in a further development of the solutions. The solutions must be discussed with shipyards, skipper-owners, governmental experts, research institutes and branch organisations through the medium of articles, talks, discussion sessions and of contacts during trade exhibitions.

The possibilities of developing implementation strategies in several problem areas may vary:

noise reduction was possible due to a governmental grant for implementation of several noise reduction packages on demonstration vessels

improvement of the safety and working conditions on the fishing deck and the processing and storage of the catch was made possible by the installation of a Safety Working Group, which formulates Guidelines for the design and construction of fishing vessels. This group included the Labour Inspectorate, Shiping Inspectorate, shipyards, branch organisation and the research institute,

improvement of the flatfish processing due to EC funding to optimize the fish routing procedure led to cooperative international research

cooperation with a manufacturer of electronic equipment resulted in a redesign of the bridge console. A full scale model of a Bridge 2000 was demonstrated on several trade exhibitions and can be used to perform simulation experiments

cooperation with a diesel engine manufacturer was possible to introduce the 'green and low-noise' diesel engine in the fisheries.

The solutions can be separated into two main classes. The first class consists of improvements at work station level on existing vessels, without costly alteration to the vessel layout. The second class comprises solutions which are only profitable for new build vessels because they change the overall layout of the vessel. The 'best technical solutions, are most profitable on new build vessels, due to the increase of safety levels with minimum costs. The implementation of the 'best technical solutions * combined with a 'change in beamer layout, resulted in a new beamer; the Beamer 2000 (Stoop, 1992).

This Beamer 2000 has the following overall characteristics:

application of noise-reducing packages resulting in a better communication with crew and maritime traffic, less stress and hearing loss, less fatigue and more attention to the quality of the catch and the environment

exchange of the winch under the bridge with the processing workstation under the foredeck eliminates warps running over the fishing deck, reduces the physical workload due to acceleration levels during processing, the fatigue of the crew and eliminates the crossing of the hazardous fishing deck when moving from accommodation to the processing workstation

elevation of the bridge and alteration of the layout gives the
skipper a better view of the decks and the maritime traffic,
reduce5 the mental load of the man on the bridge and reduces
the possibility of collision5
a better engine room layout regarding low energy consumption,
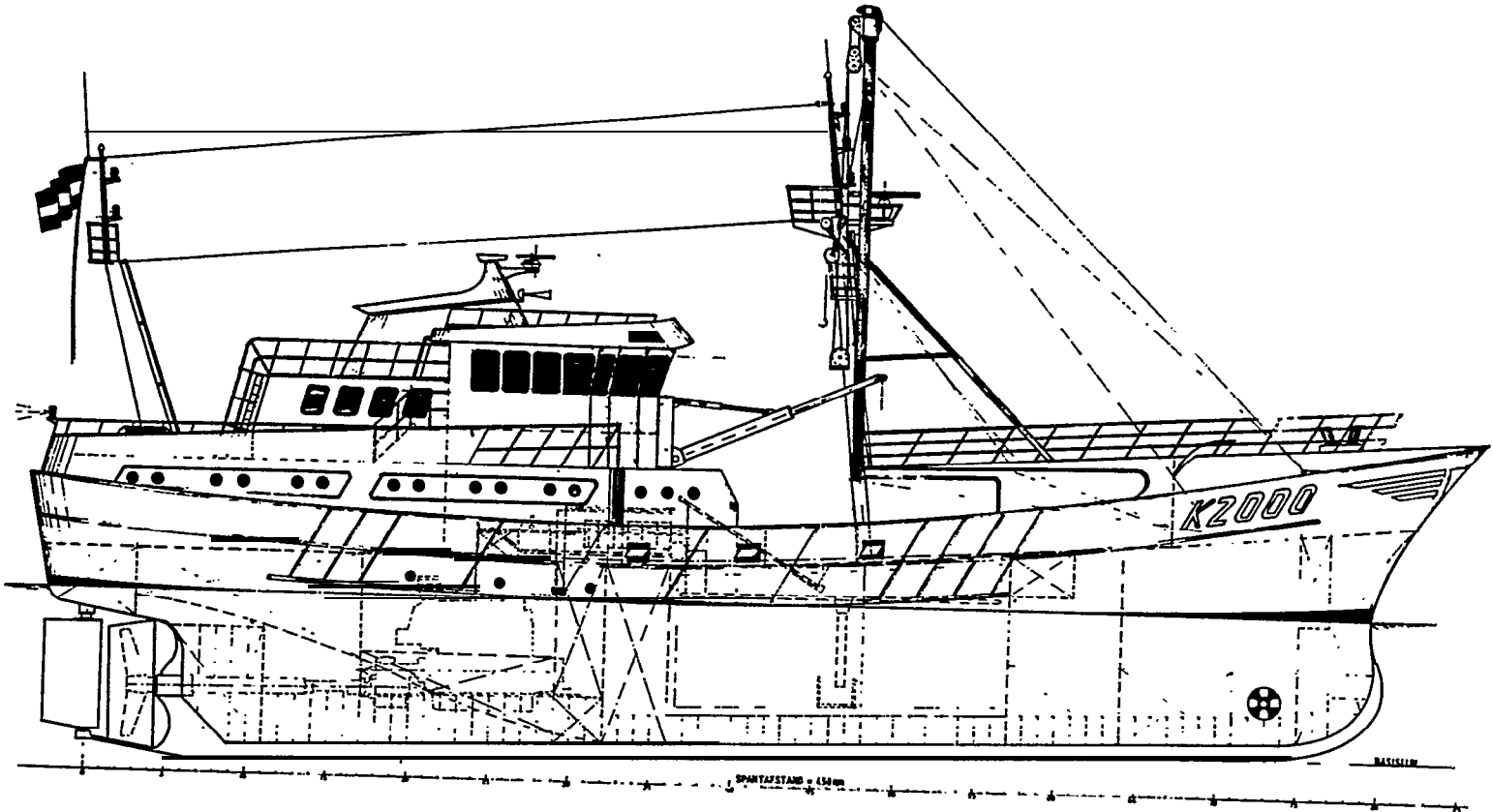an environmental impact and easier maintenance (see figure 4).

Figure 4

5.   The conceptual level

Although the beamer 2000 improves considerably the safety level on
board fiehing vessels, the overall concept of the present beamer
includes a number of shortcomings which can only be eliminated by
the development of a different vessel concept. The application of a
morphological chart demonstrates the variety of concepts for fish-
ing vessels. (see figure 5)

Different concepts can be elaborated and the requirements for an
optimized fishing process can be weighed againat each other.
Major modifications of the present beamers are possible with
respect to the overall layout of the vessels. A stern beam trawler
layout has advantages compared to the present beamers with respect
to the separation of noise sources and accommodation, better vision
lines, processing and gear handling amidships. Such a vessel
already exists and could serve as a parent vessel for a Beamer 2001
configuration. In such a Beamer 2001 application of new technol-
ogies is possible in order to cope with the logistic and quality
assurance requirements by the introduction of containers and tele-
auction (Stoop and Veenstra, 1992.1). Fishing techniques could also
change by the application of such techniques as electric flatfish
stimulation instead of tickler chains. A beamer 2001 concept could
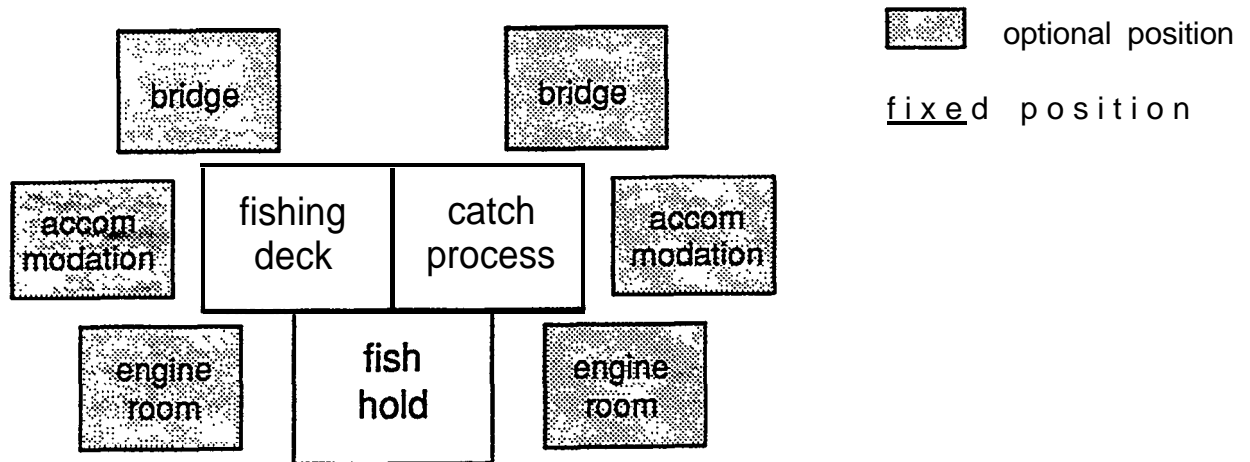serve to promote innovation in the Dutch fishing industry.

optional position

<u>fixe</u>d position

Figure 5

6. Evaluation

The safety integrated design method KINDUNOS, structure8 safety
problems, defines procedures and decision points in a time sequence
and improves the designer's ability to foresee future use. The
method is not restricted to fishing vessels but can easily be
extended to the design of other vessels and can be applied to other
projects, such as the Channel Tunnel (Eisner and Stoop, 1992).
The presentation of a Beamer 2000 concept served already as an
incentive in the discussion about safety and working conditions and
led to technical improvements on the vessels (Veenstra, 1990).
Besides, all Dutch beamer building shipyards are working out the
final specifications and have contract negotiations for actual
building. Several skipper-owners and shipyards have considered in-
novations in connection with noise reduction, the positioning of
the winch, the height and layout of the bridge and the application
of hydraulic cranes.
The analysis of safety and working conditions on the fishing deck
indicated its predictive potential. Unfortunately, during the last
2 years, several serious accidents occurred during gear handling,
as foreseen in the analysis, and led to verdicts of the Admiralty
Court (Raad voor de Scheepvaart, 1990-92).
From 1987 on, a remarkable decrease in collisions with fishing
vessels occurred. This decrease, with a magnitude of about 5, *is*
not the result of the redesign of the bridge or the equipment. Such
redesigns have still to be implemented in the near future. The
decrease is the result of the introduction in 1987 of the Sea days
Directive by the-Dutch government; a limitation of the days the
fishermen are allowed to be at sea. As a result of this directive,
it is no longer profitable to go out during aggravated circum-
stances. As a result, risk taking behaviour by the skipper is no
longer profitable and the *number* of collisions is subsequently
lower.
Although efforts on redesign may be promising, there is always a
higher order in the system which is likely to influence safety
levels far more drastically than any lower order.

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SOME OBSERVATIONS ON THE SAFETY OF SURFACE EFFECT SHIPS

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Abstract

The paper describes the IMO A373(X) requirements for high
speed craft and the proposed revision of the code. The code
shall be updated by IMO, to be in line with the actual
safety philosophy and developments in craft size and appli-
cation. The requirements with respect to safety effect
analysis and fire safety tend to get stricter. The require-
ments will shift towards the aviation type of approach with
respect to e.g. manuals, propulsion redundancy and crew
training.
The safety aspects of Surface Effect Ships are qualitatively
compared to other high speed craft, which leads to the
conclusion that Surface Effect Ships have the same level of
built-in safety as catamarans. The effect of the revised
code may be a higher lightweight, and as a result, the
economical benefits of high speed craft may strongly
deminish.

1.   Introduction

During the last decade we have seen a tremendous increase in
number of high speed craft, especially for ferry services.
The service speed of these vessels steadily increased, from
25 knots some years ago to 35 knots or more nowadays.
Looking at the application of high speed craft in congested
areas, such as major cities and inter island transportation,
the aspect of safety should be well cosidered. Untill now
this type of passenger transport has shown to be rather
safe, but with more and more craft, be it high or low speed,
the necessity for the Authorities to come up with stricter
rules and regulations is increasing.
In this paper some safety characteristics of Surface Effect
Ships are described and related to those of other high speed
craft.

2.   International RUles/IMo Rules

Special rules for high speed light craft were published by
IMO in 1977 as 'Code of Safety for Dynamically Supported
Craft' A373(X), to be applied instead of the more common
SOLAS rules and International Loadlines convention.
The SOLAS safety philosophy is based on the assumption that
the vessel is made of steel, which is normally not the case
for high speed light craft. The present A373(X) code is
based on the following premisses:

- The worst sea state for which operation will be permitted, is restricted;
- There will at all times be a reasonable proximity to a place of refuge;
- Adequate provisions will be made for communication so that any accident to the craft will be quickly known to the base port:
- Facilities are provided for rapid evacuation into survival craft;
- Rescue services will be rapidly available throughout the voyage:
- Reliable weather forecast for the area concerned will be available:
- Acceptable maintenance and inspection facilities together with adequate control arrangements are available;
- Strict control over operations will be enforced;
- All passengers are provided with a seat and no sleeping berths are provided.

The actual code was applicable to craft within the following boundaries:
- carrying more than 12 passengers but not over 450 passengers,
- Froude number in excess of 0.9,
- the maximum distance to a place of refuge is 100 nautical miles, and
- the ship's weight or a significant part thereof is balanced in the prevailing mode of operation by other than hydrostatic forces.

The Administrations shall check these requirements and issue a 'Dynamically Supported Craft Construction and Equipment Certificate' for the craft and a 'Permit to Operate' for each specific route.
Where any of the above does not apply, the Administration should consider whether equivalent safety can be achieved in another way. Quite some room for interpretation is left to the Administrations, which leaves it to the designer and owners to find out per case which additional requirements are to be met. Both for yards and owners it is of vital importance to have a craft that can be applied on routes all over the world without major modifications, and which complies with domestic legislations. We propose an international accepted code in the form of a handbook, comparable to the BHSR handbook.

This liberty of interpretation of the Administrations, together with the ongoing revision of SOLAS requirements, and the growth of passenger capacity of high speed craft, has urged the IMO to revise the A373(X) code in the near future. This revised code shall be read 'Code of Safety for High Speed Craft', and be applicable to all high speed

craft. The code shall allow the application of developments in technology and be applicable to new concepts aiming at safe and comfortable transport. The intention of the revised code will more than in the existing code be aiming at determining safety and operational standards by use of safety levels and performance criteria. Thereto verification methods shall be defined, more or less adapted for each type of craft.

The revised code will probably contain the following requirements:

- Craft speed shall be in excess of 25 knots.
- The craft shall be of lightweight construction. No
  definition is yet agreed upon.
- No dangerous goods are allowed, only special category
  spaces intended to carry motor vehicles with fuel in their
  tanks may be included.
- The shortest distance to a place of refuge shall be
  restricted by imposition of operational limits.
- A failure effect analysis (FEA) will be mandatory.
- The designer shall be obliged to supply sufficient
  information to enable the Administration to fully access
  the features of the design.
- Fire safety requirements shall be met, based on two
  alternative philosophies, as discussed below.
- The management of the company must ensure that only
  personnel qualified to operate the specific type of
  craft used on the intended route are employed. This will
  have impact on the educational requirements and updating
  courses for the crew.
- The management of the company operating the craft shall
  provide the craft with adequate information and guidance
  in form of manuals enabling the craft to be operated and
  maintained safely.

The revised code will not set limitation to the number of passengers carried.
Furthermore the existing and revised (draft) codes are applicable to passenger transport only. Other applications of high speed transport, such as transport of cargo by trucks, trailers, containerized products, are not (yet) covered. Meanwhile these type of vessels are already being marketed !

Proposals for the scope, philosophy and applications of a revised code as set up by representatives of Administration of several countries involved in high speed craft applications, shall in time be discussed by all interested parties, e.g. industry, shipping companies, classification societies and administrations.

The Royal Institution of Naval Architects has recently organized a seminar in order to stimulate a horizontal discussion, instead of the vertical discussion where shipowners, designers, builders and classification societies submit their comments to the national Administrations, before conferring it at international level.

Another attempt to structure the discussion was initiated by Det Norske Veritas Classification, to start an international committee on high speed and light craft in 1991, with participants of ship designers, shipyards and maritime authorities.

3.   Fire and Flooding Survivability

The revised code allows two philosophies regarding evacuation, as explained below.

The first is according to the existing code, which is based on the assumption of immediate evacuation of all passengers and crew, assisted by external rescue services, allowing an evacuation time of 7 minutes and 40 seconds maximum. Further more the code sets a requirement on the local infrastructure, e.g. communication and rescue services.
Looking at the new generation of high speed craft, this is not always realistic.

Figure 2 shows an escape slide arrangement according to the envisaged evacuation time of 7 minutes for 450 passengers onboard the SEASWIFT 60.

The requirements on the number and size of ordinary exits and emergency exits and the means of escape into survival craft shall be considered. Probably the means and arrangements for evacuation shall be tested in more realistic emergency training situations to measure the evacuation time, as already practised in a number of countries. Regular fire drills of the crew will be arranged. Figure 1 shows an evacuation trial onboard the SEASWIFT 23.

The second approach will be to determine the fire and floating survivability of (larger) craft so as not to immediately evacuate all passengers. In the choice of approach, the availability of rescue services on short notice is also considered.
This will imply a subdivision of the accommodation in such a way that the occupants of any compartment can escape to an alternative safe area or compartment in case of fire. In such case the craft shall be able to handle the situation by itself, by providing a safe accommodation of the persons onboard and by maintaining the operation of all main

functions on board even in case of fire in one major compartment. For larger vessels this might be no real problem.

Enclosed spaces such as galleys, shops, cinema's and restaurants are not permitted. However refreshment kiosks are allowed. In the revised code, again no enclosed passenger sleeping berths are allowed.

Special category spaces, such as car decks, will be treated as areas of major fire hazard, as a fire may be expected and will develop immediately. Furthermore areas of moderate fire hazard, such as crew accommodation and control stations are defined as spaces where a fire may develop from a local fire. Third, areas of minor fire hazard, such as accommodation spaces, are defined, where a fire is not expected to start or to develop.

Fire resisting bulkheads and ceilings shall be constructed to resist exposure to the standard fire test for a period of 30 minutes for areas of moderate fire hazard and 60 minutes for areas of major fire hazard. Passenger accommodation areas, including service spaces, shall be protected by a fixed sprinkler system (controlled from the navigating control station). At least two independent water fire pumps shall be arranged. Areas of major and moderate fire hazard shall be provided with an automatic smoke detection system. Main propulsion rooms shall in addition have a heat detection system.

In areas of major hazard, such as car decks, fixed quick acting fire extinguishing system and a TV monitoring system shall be provided.

This new subdivision in catergory spaces with stricter fire division requirements will be valid for both fire safety philosophies.

This revised code will impose a large influence on projects of larger high speed craft projects with respect to the internal arrangements and the ship's lightweight and as a consequence will drastically influence the payload. As the speed of a SES is even more sensible to displacement variations than a catamaran, this aspect needs careful consideration.

Looking at the number of accidents with high speed craft it can be noted that severe accidents, involved mainly navigation and system failures and not fire or flooding. Therefor to our opinion the existing code seems adequate for small high speed craft, operating in coastal waters.

4.   Failure Effect Analysis (FEA)

Looking at the latest designs of high speed craft and
considering the introduction of dynamically controlled
stabilization systems and sophisticated automation systems,
the Administrations feel the urge to outline a method
ensuring the vessel's safety, by the use of failure mode
analysis in the design process, while the final craft's
performance shall be verified. In the present code the
failure mode effect analysis is already mentioned for some
specific systems, i.e. machinery and steering.   In the
revised code the failure mode effect analysis will be
applied much stricter and be applicable to all main machin-
ery and components.

The focus will shift towards more and stricter operating and
safety procedures in order to prevent serious accidents in
the future.

With respect to reliability of the propulsion machinery,
experience has learned that the actual level is not accept-
able for the operators, especially for the main engines that
are a.0. too highly loaded. This will probably also have an
impact on the Classification Society's philosophy. The
failure of one propulsion system will however normally not
directly effect the vessel's safety.

This tendency to require stricter FEA is growing, a.o. due
to some accidents with high speed craft in the past year.
One accident with two passengers killed took place on
November 4th, 1991 in Bergen, Norway where a catamaran hit a
rock at full speed, because a lightbuoy was observed too
late: the occulting light frequency was not adequate for the
high craft speed. One important conclusion drawn will be the
development of performance standards for high speed craft
navigational equipment. Furthermore a requirement for two
navigators with two independent radar systems is considered.
Developments have started on ergonomical improvements of
bridge designs.

Another severe accident involving a high speed catamaran
concerned the 'Apollo Jet' in Hong Kong, which also resulted
in proposals for stricter operational procedures. In this
case the catamaran lost control of the engines and the
steering of the waterjets and collided with two moored
vessels and ran aground, killing four people and seriously
injuring another seven.

The Marine Court in Hong Kong notes: "Reliability of control
circuits for each and every dynamically supported craft
should be confirmed on a practical basis every year after
its annual survey - and prior to granting a speed exemption"

Stricter procedures will also imply the preparation of
operating and maintenance manuals, according to e.g. UK
Department of Transport requirements. The latter refers to
requirements formulated by the Civil Aviation Authorities as
the 'British Hovercraft Safety Requirements[1] for hovercraft
vehicles, and also, as a consequence of definition, appli-
cable to Surface Effect Ships.
One problem might be to keep the manuals user friendly, in
order to be adequately used by the crew themselves.

It seems that the requirements on FEA tend to some airline
industry type of operation. However opposite to aircraft
industry, the feedback of experience and information con-
cerning hazardous occurences from operators to designers and
regulatory bodies is not structured.

5.   Safety of Surface Effect Ships

The safety of a Surface Effect Ship is very much the same as
a comparable high speed catamaran. However with SES speeds,
of 40 to 50 knots, which are much higher than average
catamaran speeds, the necessity for strict safety analysis
is felt even more.
In comparison to high speed monohulls, the intact and
dynamic stability is better. Other safety aspect may be
comparable.

The advantages of a Surface Effect Ship are listed below:

- good intact stability : high metacentre, large stability
                          range
- high damage stability : 2 compartment type, with limited
                          heel and trim in asymmetric
                          damaged conditions.
- high redundancy   : two independent propulsion systems
                          and the craft can remain afloat
                          on-cushion with any compartment
                          damaged
- low crew fatigue   : relatively low level of vertical
                          accelerations
- failure effects   : a SES is intrinsically safe: no
                          active foils, flaps, skirts or
                          other stabilization system can
                          affect the vessel's safety
                          control. The loss of the air
                          cushion will only result in a
                          deceleration and a return to the
                          off-cushion (or catamaran) mode of
                          operation.

- good dynamic stability: The vertical centre of buoyancy is

within the critical limits. A
modern SES tends to heel inward in
high speed turns and gives
therefore a high degree of safety.

6. Conclusions

The number of accidents with high speed vessels involved
show that this kind of transportation is a very safe one.
The IMO requirements for dynamically supported craft dating
back to 1977 are being revised, and tend to be much strict-
er. The revised code will emphasize to the application of
failure mode analysis and operational procedures, more
comparable to aircraft industry.

As the speed of a Surface Effect Ship is very sensitive to
weight variations, the weight penalties of additional
requirements resulting from the revised draft code shall
impede the high speed potential of Surface Effect Ships.

In parallel to the development of high speed craft, the
supply industry shall be forced to develop equipment and
materials adapted to the IMO codes. This can only be en-
hanced by a flourishing high speed market.

The safety of Surface Effect Ship is not very different from
other high speed craft. The SES design is intrinsically
safe, but due to the very high speeds, the requirements on
navigational safety and system failures must be strict.

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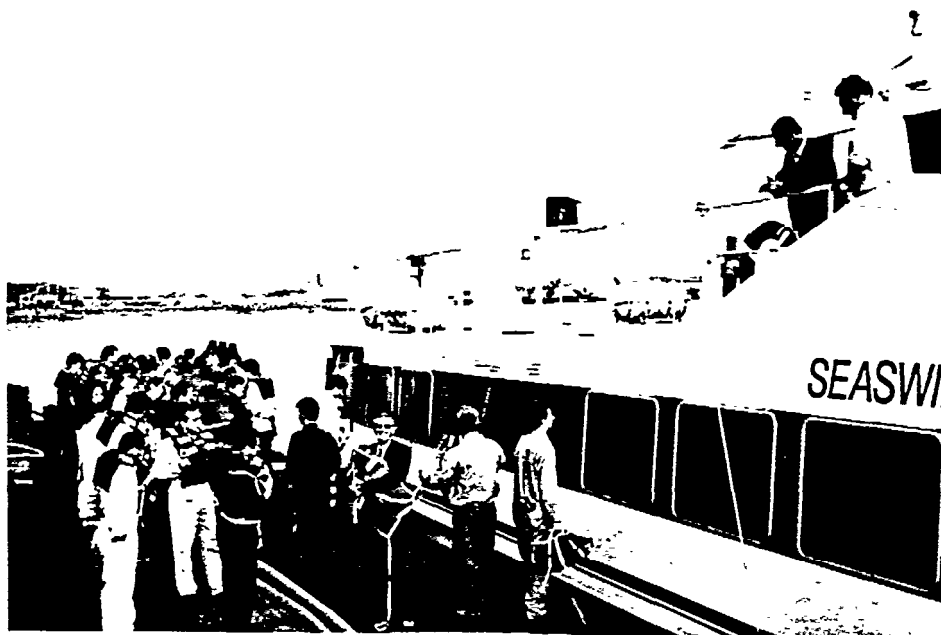
Figure 1.   Evacuation trials onboard the SEASWIFT 23 of Royal Schelde in Vlissingen.
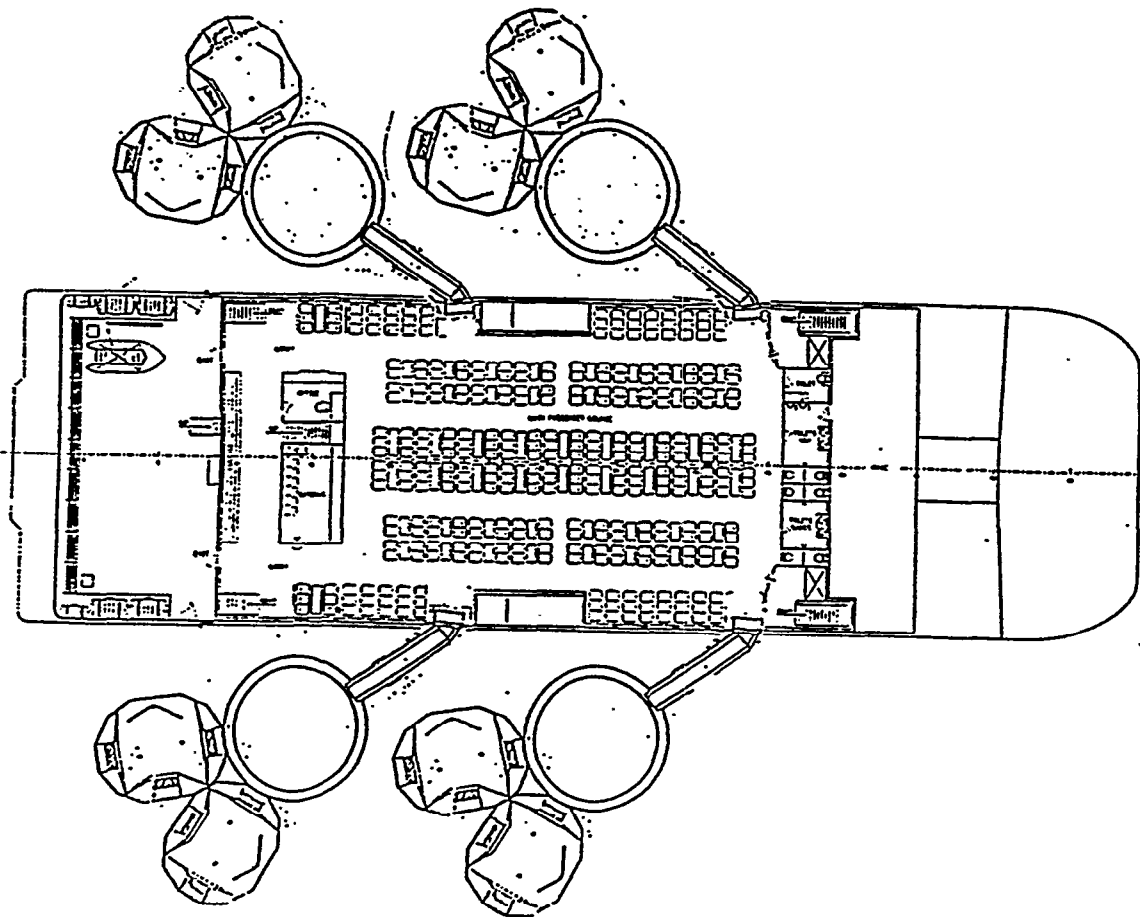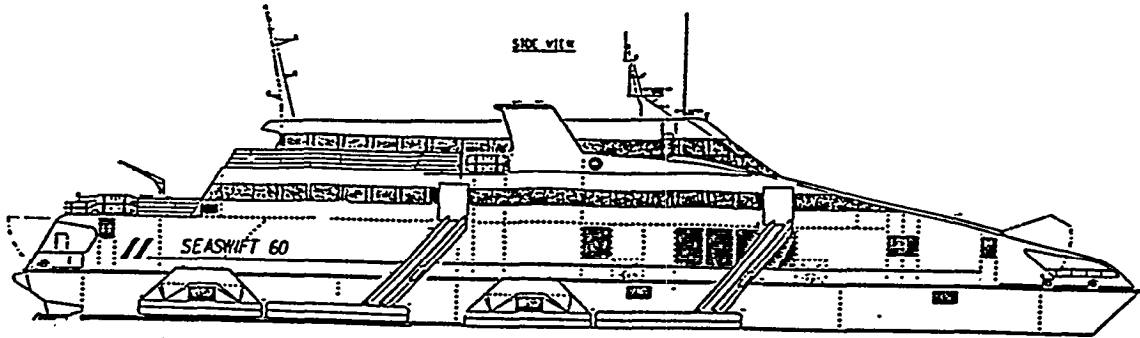
SEASWIFT 60

Figure 2. Escape slides arrangment onboard the
SEASWIFT 60 of Royal Schelde

ADVANCES IN SAFETY TECHNOLOGY APPLIED TO MARINE ENGINEERING SYSTEMS

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ABSTRACT - This paper is concerned with the problems associated with marine safety analysis and attempts to integrate design for safety into the practical marine product design process. Safety analysis techniques are used to identify risks and to evaluate system safety and reliability both qualitatively and quantitatively. Safety criteria, assumptions and the requirements for modelling safety systems for design analysis are addressed. With regard to industrial practice, the phases for marine engineering system design from a safety viewpoint are studied, and an illustrative example is used to demonstrate a design for safety framework. The analysis methods and modelling techniques used in this paper may be used for the design of complex marine engineering systems.

1. INTRODUCTION

1.1. Engineering design methodologies

Three design methodologies which may be used for the design of various marine and other made-to-order (MTO) products have been identified as 1. original, 2. adaptive and 3. variant. Original design is to produce an original solution for a system to carry out a new task Adaptive design involves adapting a known system to a changed task. Variant design is to vary the size and/or arrangement of certain aspects of a chosen system. Patterns within each of individual philosophies and engineering disciplines can be identified and analysed from a series of steps or frameworks for organising and guiding a design. Such a framework is referred to as a design methodology.

In relation to these methodologies, two distinct levels of design activity can be identified 1. a conceptual stage and 2. an embodiment stage. The conceptual design phase essentially requires design engineers to examine the problem statement and generate broad-based solutions to it. The embodiment design phase requires that the most promising candidate solutions are developed in greater detail with the final selection being based upon relevant technical, economic and safety criteria. Generally, a framework covering the design process can be expressed by stages such as clarifying objectives, establishing functions, setting requirements, generating solutions, evaluating alternatives and improving details.

The benefits of the methodology are obvious. These include rapid and direct generation of design solutions and the evaluation of these solutions. A rational and systematic framework can make the work of design engineers more efficient and effective.

1.2. Current status of design for safety methodology for mechanical/electrical (M/E) systems of marine products

The objective of system safety design is to provide assurance that the system will operate safely as intended by evaluating all aspects of the total system design from a safety viewpoint. System design for safety provides a systematic approach to the identification and control of high risk areas. Although design for safety methods were introduced in the aerospace, nuclear and chemical process industries many years ago, a series of standards, covering the general use of reliability throughout industry, were issued from 1980 (2, 3). The techniques described in these standards am applicable to M/E systems design of marine products.

Safety considerations have always been a matter for concern during marine design. However, research shows that design for safety of most M/E systems of marine products is usually based only on British standards and classification society requirements (or the equivalent), which incorporate the necessary factors of safety. Due to the complexity of safety analysis and lack of complete guidance for a design for safety methodology, design for safety has not been specifically integrated into the design process. It is worth noting that the deficiencies in many marine product designs are only corrected after accidents have occurred, and few organised safety design programs devoted to marine design have been devised and implemented. Many accidents, even those involving human error, could have been prevented if the design had been different. Therefore, there is a requirement for design for safety applied to marine products with a primary emphasis during the various design stages in order to obtain optimum safety.

For some years SERC (U.K. Science and Engineering Research Council) and U.K. industries have financed research projects in design for reliability and safety, the objectives of which were to develop practical procedures to quantify and incorporate safety as an integral part of the design process. Problems that have been identified include a lack of valid data and inadequate co-operation between industrial design engineers and safety programme researchers. Current research in design for safety at the University of Newcastle upon Tyne is focused on providing systematically derived information upon which rational decisions may be made. Analytical tools which can provide an insight into the problems involved and also extend the designers capabilities are being developed to provide a facility to design marine products safely, efficiently and economically.

1.3. Objectives, requirements and constraints of safety design methodologies for M/E systems

The objective of mechanical/electrical (M/E) system design for safety methodologies is to provide a framework for qualitative and quantitative safety analysis to be carried out. The general requirements of the M/E system design for safety methodologies are that they should not conflict with the general design process and its criteria, and therefore be consistent with a general products design methodology.

For M/E safety system design some simplifications and assumptions should be made to facilitate easier methods of analysis. The problem of a scarcity of mathematical methods for design for safety causes difficulties in applying the safety design techniques demanded by those concerned with marine accidents. However, it is generally agreed that proper appraisal methods for assessing safety and reliability of marine products are required in order to keep pace with the advance of technology.

2. DESIGN FOR SAFETY

2.1. Criteria

It is very difficult to judge the safety of a system as it is impossible to eliminate all risks but only to reduce them to an acceptable level. So, what is the acceptable safety level? One basis for judgement used in British law is that a product should be as safe as is reasonably practicable. However, that poses the question - what is reasonably practicable? It may bc assumed that the whole subject of design for safety criteria depends upon the answers to three basic questions.

1.   What can go wrong?
2.   What are the effects and consequences?
3.   How often will it happen?

The answers to these questions may change with time or the particular problem in hand. However, for M/E systems of marine products, design for safety would have the

general objectives of improvement in safety and reliability utilising technological advances. Modern methods of safety analysis enable the risks to be more easily identified and an estimation of the magnitudes to be determined more confidently. Control systems, sensors, alarm and protection systems provide the means to determine disturbance conditions and necessary actions. The criteria for M/E system design for safety of marine products can generally be described as follows:

1. Safety devices and protection systems are the principal contributors to system safety.
2. Safety devices, control systems and protection systems should be designed to have similar failure rates to the system being protected.
3. Safety devices, control systems and protection systems should be designed to fail safe with reference to the controlled system.

2.2. General framework

Design for safety should become an integral part of the design process. A model can be presented by an analysis phase, a synthesis phase and an evaluation phase. A design for safety framework based on this general methodology is proposed as shown in figure 1.
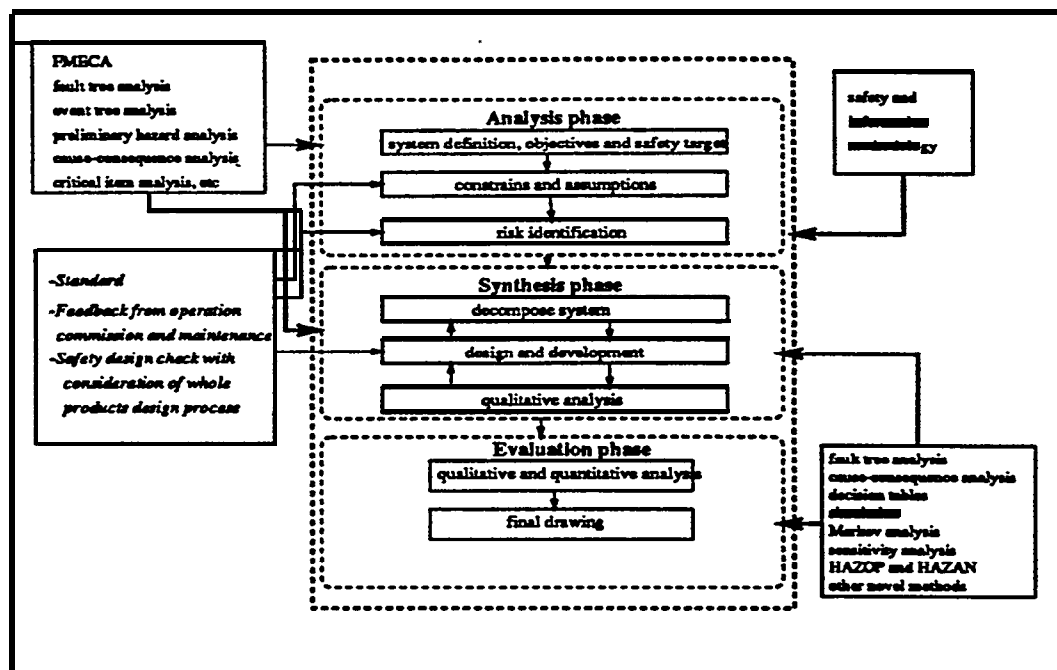
Figure 1 Design for safety framework

2.3. Detailed study of design for safety framework

Problem definition is very important in the analysis phase. This would include definition of objectives, identification of hazards and risks, definition of constraints and assumptions. Definition of objectives would define safety and reliability requirements and levels of maintainability and availability. Identification of hazards and risks would identify all of the possible hazards and associated reliability and safety data. Preliminary Hazard Analysis (PHA), Event Tree Analysis (ETA), Fault Hazard Analysis

(FHA), Failure Mode, Effect and Criticality Analysis (FMECA), Cause-Consequence Analysis (CCA), Fault Tree Analysis (ETA) and Safety Hazard Report (SHR) can all be used to identify possible hazards and risks. FMECA is popular with design engineers.

The synthesis phase may involve both qualitative and quantitative safety analysis. Weaknesses in design may be identified and redefined. Redundancies, protection systems and alarm systems may be used to improve the reliability and safety of a particular system Safety techniques that may be used include Boolean Representation Method (BRM), Fault Tree Method (FTM), Markov Model (MM), Monte Carlo Method (MCM), and Simulation, etc. It must also be remembered that safety is not only determined by design but is affected by operation, maintenance, installation, construction and commissioning.

In the evaluation phase, all aspects should be considered. Reliability and safety methods may be used for a detailed analysis of the maintenance requirements.

2.4. An expert system for safety design

Expert system technology could be usefully applied to design for safety as shown in figure 2.
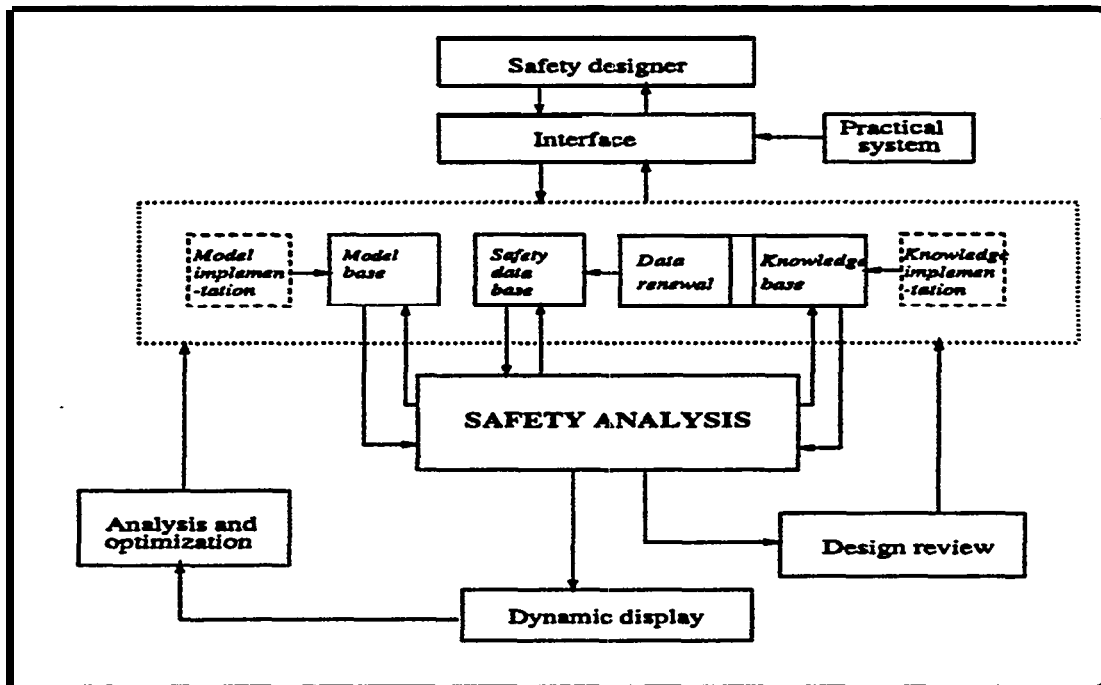

Figure 2 The structure of design for a safety expert system

3. SYSTEM SAFETY MODEL

3.1. Requirements for system modelling

A system safety model is an expression interrelating the logic and components that may be used to carry out qualitative analysis and numerical computation of the reliability and safety of a system. The requirements for modelling are as follows:

1. Must accommodate the level of system complexity required by design engineers,
2. Must allow reliability analysis to be carried out.
3. Be compatible with operational and logistical requirements.
4. Being compatible with other aspects of technical design.

33. Assumptions for modelling a safety system

Assumptions are necessary for modelling. Choosing assumptions depends on the practical requirements and analysis techniques to be used. For simplification of analysis, the following assumptions may be used

(1). Every component is considered independent. If a system is divided into several sub-systems, every sub-system is assumed to be independent.

(2). A continuous variable may be expressed by two states or multi-states such as high, too high, normal, low and too low one of which corresponds to a certain range of operation.

(3). There is no preventative maintenance during a mission, and failed components are assumed to be repaired to new condition.

(4). The probability distribution used in reliability and safety analysis is assumed to be exponential and the repair rate is assumed to be constant.

3.3. Modelling techniques

The purpose of safety system modelling is to provide a base for qualitative and quantitative safety analysis. Modelhng techniques could be BRM, ETA, simulation methods, etc. Various state-of-art techniques can be used to assist safety system modelling. Good definition and suitable assumptions are the key to the effective and efficient modelling of a system

4. QUALITATIVE SAFETY ANALYSIS

Qualitative safety analysis is used to locate possible failures and to identify proper precautions which will reduce the frequency or consequences of such failures. A qualitative reliability and safety analysis can be performed with one or more of the following objectives.

(1). To identify weak links in design.

(2). To assess the relative importance of all identified failures.

(3). To provide a systematic assessment of overall system and subsystem safety.

(4). To provide the essential knowledge for quantitative safety analysis.

The general steps in a qualitative system reliability analysis are to :

(1). Determine failures and identify consequences.

(2). Document safety and reliability knowledge in table, or other format,

(3). Evaluate overall system safety considering the above information.

4.1. Identification of hazards

Understanding design details is very important for identifying hazards. Corresponding to every failure mode, the failure rate, effect on system and method of failure detection can be determined by FMECA. Criticality analysis can also be carried out with regard to the corresponding risk criticality category.

4.2. Qualitative reliability and safety techniques

(1). FMECA

FMECA does not do the whole job, but does provide some early answers and a firm base for later study and analysis. Once the system and its intended use are defined and understood, the actual FMECA can be performed. The complexity of safety analysis using this technique depends on the system and the experience and knowledge of analyst.

(2). Boolean representation method.

Boolean representation is a method which can be used to automate construction of minimum cut sets of a system top event. Compared with the fault tree method this method is also more versatile. Further safety analysis can be referred to results obtained from this method. Information from a FWECA can be used to support safety analysis using this method.

(3). Fault tree

Fault tree analysis is a technique in which failures that can contribute to an undesired event are organised deductively and represented pictorially. Information developed in FMECA can be related to fault tree analysis. The use of this technique simulates the identification of possible failures and events, and fault trees can present all kinds of dependencies and common mode failures and events.

5. QUANTITATIVE ANALYSIS

The objective of quantitative analysis is to represent the system in a mathematical model, apportion the reliability and availability goals, and reconcile the calculated reliability and availability to the overall system goal. An intent of this analysis is to help the designer to minirnise system complexity, to be aware of the characteristics of the components selected, particularly their capabilities with the environment and other technical design. A quantitative analysis utilises a mathematical model for system success as a function of some or all of the following, failure rates, repair rates, test intervals, mission time, system logic, and surveillance test schedule. Data quality could affect the results of the analysis.

5.1. Definition of mission

Two ways in general use for expressing mission success are the reliability and availability of safety components, protection systems and whole systems.

(1). Reliability

Reliability is the characteristics of an item expressed by the probability that it will perform a required function under stated conditions for a stated period of time. Data may not be available to give a good description of hazard rate throughout a component's whole lifetime. During a period of middle life, the hazard rate is relatively constant Reliability for a mission time can be calculated by the following expression.

$$R(t) = \exp\left[-\lambda t\right]$$

(2) Availability

Availability may be considered as the fraction of the time the system is operational. It can be computed from the following formula.

$$\text{Mean availability } Q \quad = \frac{Up\ time}{Up\ time\ +\ Down\ time} \quad = \frac{t}{t + \lambda \mu t} = 1 - \mu_d$$

where μ = average repair time and μ_d = functional down time

5.2. Quantitative analysis

Once a mission is defined, the mathematical model generated and the input parameters prepared, the calculation is ready to start. Development of the model should anticipate the type of inputs required by a computer, and code should be suitable for the type of analysis required. The analysis can be carried out first to subsystem level, and then to system level.

5.3. Consistent check of results

After the results for safety and reliability are obtained, the following techniques are useful for reviewing a design proposal critically and credibly.

53.1. Sensitivity analysis

A sensitivity analysis **is** conducted for the purpose of determining the relative importance of the various component failure rates, test intervals or repair times on the system reliability and availability. The weak parts, weak subsystems or components can be identified and examined for credibility.

53.2. Comparison with prior analysis

If there are prior results available for similar designs, comparisons can be made. It should be checked whether the difference in results is credible in view of the design and input data., and whether the new design is consistent with experience or best judgement.

5.3.3. Modelling check

The errors in modelling a system cannot be eliminated but may be reduced to an acceptable level. It could be useful to make a list of model inadequacies and then evaluate them. If errors are significant and no conservative results are produced, designers should modify the model to accommodate the practical system.

6. M/E SYSTEM DATA COLLECTION PROGRAM

A brief survey of different field failure data collection systems reveals that most of the collected and analysed data seems to be inadequate. A reason for this may be that due considerations have not been given *to* the problem of determining the type of failure data required, and how to analyse and present the information. However, careful evaluation of available data for marine products may provide valuable information for the design and implementation of a more successful data collection system. Current data collecting programs tend to be of a specialised nature and are primarily concerned with military service, nuclear power station and space applications. Much of the data in these programs is applicable beyond these fields, and the use of these data sources will unquestionably benefit the analyst who has yet to establish a database of failure data. Actually, failure data is not static and should be collected dynamically. Powerful database and advanced data exchange techniques can also be utilised.

7. AN EXAMPLE

An hydraulic servo transmission system shown in figure 3 is studied as a test case to show how the design for safety methodology developed in this paper may be applied. This system is analysed on the basis of the process diagram supplied by the design engineer.
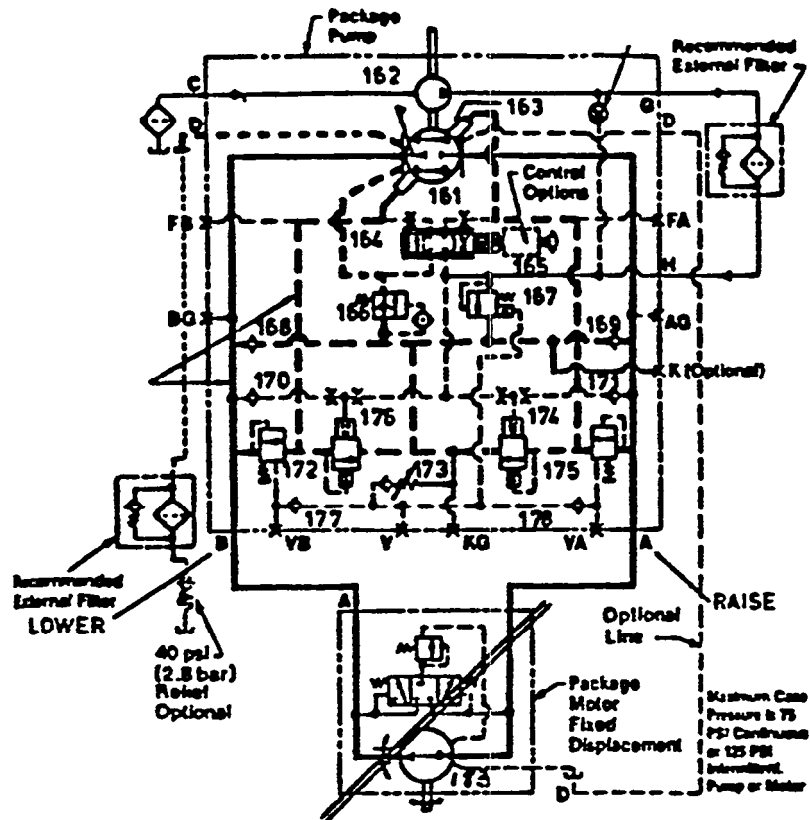
Figure 3 A hydraulic servo transmission system (process diagram)

7.1. Analysis phase

7.1.1. Objectives and system description

The objective of this analysis is to provide assurance that the hydraulic servo transmission system will perform its functions reliably and safely. This analysis is also aimed to establish priorities of the components for attention during the design stage and pro vide criteria for operation and maintenance of the system

This system is used to control the hydraulic power for the slewing, hoisting or luffing functions of a crane.

7.13. Constraints and assumptions

This hydraulic servo transmission system is assumed not to be operated above maximum rated pressures and capacities. A pipe or hose is not considered to be a component. No allowance for leaks from piping connections is made, and structural failure is considered as a possible failure mode of specific component. The oil used in this system is assumed compatible with all components. All maintenance activities are assumed to be expertly and properly carried out. Failure rate and repair rate are assumed to be constant. When a failure mode is defined as a major leak, this means a total leak of all fluid, All faults are assumed to be repaired immediately as soon as they are detected.

7.13. Risk identification

Risk identification is applied to identify potential failure modes of this hydraulic servo system and to define their effects and acquire reliability data at component level where a component is defined as a single hydraulic, electrical or electronic unit such as a pump, electric motor or servo control valve. The Reliability Block Diagram for this hydraulic servo system can be constructed and is shown in Appendix la. The criticality categories of risks can be identified as four types as follows :

1   A dangerous failure which could result in major damage to transmission system or crane.
2   Potential mission failure.
3   Failure resulting in loss of one or more motions.
4   A failure resulting in the erroneous activation of an audible or visual alarm.

The FMECA for these criticality categories of the hydraulic motor (component 183) is shown in Appendix lb.

7.2. Synthesis phase

7.2.1. Criticality analysis

The first step for criticality analysis is to classify all of the failure modes of this hydraulic servo system which have criticality category 1 or 2 obtained from the complete FMECA analysis and shown in Appendix 2a.

Criticality number C can be calculated using the following formula.

$$C = \sum_{n=1}^{N} \beta \, \alpha \, K_E \, K_A \, \lambda \, t$$

Where   p = conditional probability   a = failure mode ratio
        n = critical failure mode number   N = last critical fake mode
        λ = failure rate (failures per million) $K_{,,}$ = operational factor
        K_E = environmental factor

For simplicity of demonstration, K_A and K_E are taken as 1. The critical number for the critical failure modes can be calculated on the basis of the FMECA and is shown in Appendix 2b. The operating time (t) is taken as l0000 hours for this analysis. The analysis shows that 12 components in this servo hydraulic system are classified as having criticality 1 and 2. Criticality analysis shows that failure modes of components 161 (pump) and 183 (motor) with criticality category 2 have criticality number 0.175, and failure modes with criticality category 1 have criticality number 0.14. The failure modes with criticality category 1 for these two components are port plate separation, shaft failure and major leak. Comparing these failure modes port plate separation has a high probability of occurrence when compared to the other failure modes and therefore should be given more attention. During the design stage, the pump (161) and motor (183) should be considered in more detail from a safety viewpoint.

7.2.2. Qualitative analysis

The severe failure modes have been identified as follows considering the pump (161) and motor (183).

1. Shaft failure   2. Major leak

The first one can easily be identified and analysed. The possibility of this failure occurring can be reduced by good maintenance, installation and provision of a quality shaft. From the final critical transition table as shown in Appendix 3 based on major leaks as a top event, it can be seen that either pump 161 or motor 183 can cause a major leak. During design, these two components have priority consideration.

7.3. Evaluation phase

73.1. Quantitative analysis

<l> Reliability

Based on the critical transition table, the reliability for every cut set can be calculated for a time period of 10000 hours. The result is shown in Appendix 3.

<2>. Availability

Due to lack of relevant component repair data, it is assumed that the average repair time for every component is three hours. The availability of this system can be calculated as:

$$Q = 1 - \sum \mu_d = 0.9988$$

The components with high failure rates affect the magnitude of the mean availability of the system more than others. The reduction in repair time for those items with high criticality numbers would affect significantly the availability of the system.

73.2. Evaluation and discussion

Hydraulic systems are different to other systems because oil leakage and contaminated oil may cause many problems. Possibility of failures, caused by debris to component 161 and 183, can be reduced by fitting an oil filter. Port plate separation causing a major hydraulic leak could result in the crane load falling. This potential risk can be reduced by considering this component specifically and fitting suitable protection systems to the brake system. Other potential failures can be reduced by protection components such as 176, 166, 175 and 167 which are used for protecting against high pressure in this hydraulic system. The aspects of the maintenance can be viewed from the availability obtained. For this specific system, it would be difficult to change the design proposal. Nevertheless, engineering system design based on this proposed framework can be beneficial from a safety viewpoint.

8. CONCLUDING REMARKS

Attempts to improve the safety of marine products focus on safety components, and protection systems and the integration of design for safety into the design process. There are some strategies which can be applied in order to implement design for safety. The first is to concentrate on risk identification from a viewpoint of various potential hazards and their consequences. The second is to review all of the safety devices and the whole system, estimate all of the hazard paths and quantify them with the various available reliability techniques. The third is to reduce the possibility of risks to an acceptable level with regard to operation, installation, maintenance, etc.

Engineers designing marine products requite information to design for safety. A design for safety framework has been studied in this paper. This framework is very general and may be applied to various marine systems. Practically, a design engineer would still face a great deal of difficulty, and this may only be improved by design for safety training, development of flexible safety analysis techniques and use of information man-machine interfaces for the formulation of knowledge and information.

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APPENDIX 1 RBD AND FMECA

a.RBD
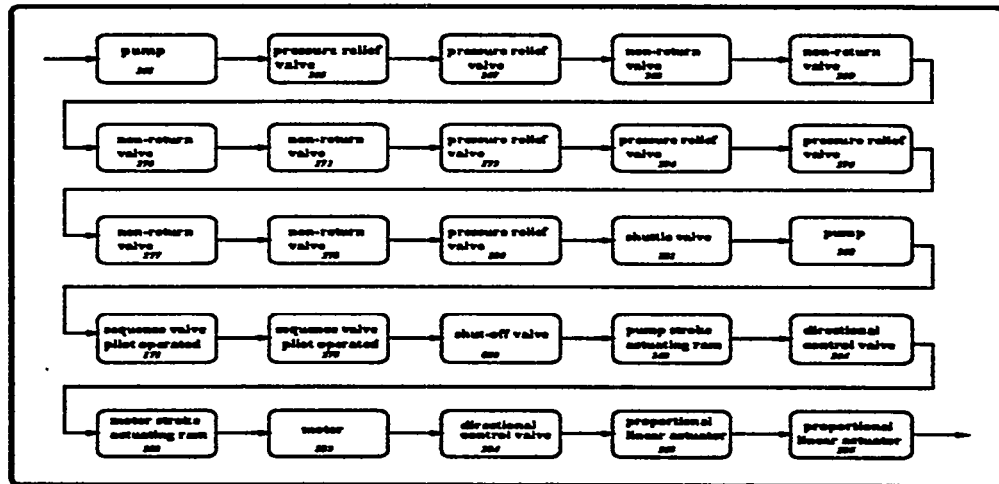
b. FMECA

Component name : variable displacement axial piston of motor (161)							
Failure rate 10.00 (failures per million hours) (λ)							
failure mode number	function	failure mode ratio	failure mode	effects on system	detecting method	criti-cality categories	remarks
1	change the displace-ment axially	0.25	fails to avoid debris to enter circuit.	may cause seizure of pump	by mainte-nance	2	
2		0.1	port plate separation causing hydraulic short circuit	In "lower" case, motor accelerates and load would fall	self-annunciating	1	
3		0.1	motor seizes	load holds	self-annunciating	3	
4		0.05	shaft fails	motor cannot apply torque. In "lower" case, load falls	self-annunciating	1	
5		0.45	minor leak	none	self-annunciating and by maintenance	4	
6		0.05	major leak	load falls	self-annunciating	1	

APPENDIX 2a Criticality analysis, hydraulic servo transmission system

CRITICAL FAILURE MODES FOR THE COMPONENTS IN RELIABILITY BLOCK DIAGRAM					
Component NO.	FM No.	Failure mode	Failure rate (Per million)	FM ratio	Criticality
161	1	failure to cause debris to enter circuit	70.00	0.25	2
	2	port plate separation causing hydraulic major leak		0.1	1
	3	shaft fails		0.05	1
	4	major leak		0.05	1
166					
167					
168					
169	1	fails to close	7.00	0.15	1
	2	major leak		0.08	1
170					
171	1	major leak	7.00	0.08	1
173	1	fails to close	7.00	0.16	1
174					
176					
177	1	fails to close	7.00	0.15	1
	2	major leak		0.08	1
178	1	fails to open	7.00	0.08	1
	2	major leak		0.08	1
180					
181	1	fails to switch in accordance with high pressure port	6.00	0.2	1
	2	major leak		0.08	1
162					
172					
175	1	fails to open	7.00	0.07	1
	2	fails to close		0.16	1
	3	major leak		0.08	1
080	1	fails to open	3.00	0.05	2
	2	fails to close		0.24	1
	3	major leak		0.07	1
163					
164					
182	1	major leak	10.00	0.04	1
184					
165					
185					
183	1	failure to cause debris to enter circuit	70.00	0.25	2
	2	port plate separation causing hydraulic short circuit		0.1	1
	3	shaft fails		0.05	1
	4	major leak		0.05	1

APPENDIX 2b Criticality number

CRITICALITY NUMBER		
Component	Classification category	Criticality number
161	1	0.14
	2	0.175
169	1	0.0161
171	1	0.0056
173	1	0.0012
177	1	0.0161
178	1	0.0112
181	1	0.0168
175	1	0.0248
080	1	0.0108
182	1	0.004
183	1	0.14
	2	0.175

APPENDIX 3 Reliability analysis

		161	173	177	178	169	175	182	181	180	171	183	major leak
Cut set	1	L	*	*	*	*	*	*	*	*	*	*	major leak
Cut set	2	B	*	*	*	*	*	*	*	*	*	*	major leak
Cut set	3	*	*	*	L	L	*	*	*	*	*	*	major leak
Cut set	4	*	L	L	*	*	*	L	L	L	*	*	major leak
Cut set	5	*	*	*	*	*	*	*	*	*	*	B	major leak
Cut set	6	*	*	*	*	*	*	*	*	*	*	L	major leak
Cut set	7	*	L	*	*	*	L	*	*	L	*	*	major leak

The reliability of this system at 10000 hours is 0.8998

SHIP DYNAMICS AND NAVIGATION SAPETY IN HARBOURS

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Abstract

The dynamic5 of ship propulsion are examined in this paper and, in
particular, the ship's backing ability and its enhancement through
various means. The most important aspects of ship backing are reviewed
and a number of alternative methods available for the improvement of
backing performance are evaluated by means of computer simulation, with
particular reference to a high-speed ferry application.
Results are presented for coasting stops under windmilling propeller or
locked shafting conditions and the improvements possible from the
application of both "soft" and "hard" brakes quantified in relation to
engine stall occurrences and subsequent starting requirements. Results
for CPP systems are given including potential improvements when
alternative control strategies are followed.
It is concluded that significant improvements in stopping time and head
reach are possible through careful consideration to design details in
propulsion systems hardware and control strategies.

1. Introduction

Although the stopping ability of every self-propelled ship is
considered essential and "emergency crash-stop maneuvers" are conducted
regularly during sea-trials, such tests are not mandatory and are mostly
used to demonstrate the adequacy of design of the propulsion systems.
No established criteria exist to judge the stopping ability of ships as
a mean5 of hazard-avoidance and "human factors" (such as crew
negligence, communication failure, inadequate training, etc.) are often
thought to be responsible for accidents. However, one must be aware of
the fact that under certain conditions (heavy traffic in crowded
harbours - packed with boats, barges, etc), navigation margins are
markedly reduced and a closer look at the ship's stopping ability, and
the means by which it can be improved is, therefore, warranted.

2. The Backing Requirements of Ships

For every self-propelled ship, the ability to stop and reverse is
considered essential. The "emergency crash-stop at full-ahead speed" is
common in all important ship trial codes (Landsburg,1983), although such
a test is not even considered mandatory (Coates, 1987), as it is
conducted under very specific conditions, rarely encountered during
pilotage (operation in restricted waters).

2.1 Backing as a Means *of* Maneuverability

The most obvious reason calling for a certain level of backing capacity
is the requirement to maneuver the ship into a desired position such as
during berthing or navigating in pilotage waters. Under such

circumstances, in the great majority of cases, the traveling speed of the ship is well below that of full ahead and the availability, therefore, of astern power is rarely a problem (as is the case during crash stop from full ahead; where the hydrodynamic windmilling effect of the propeller may lead to demands for substantial levels of power from the prime mover). Instead, as the ship has to respond to frequent changes of ordered speed, the time lags involved in the process of reversing propeller thrust and the rate at which reverse power can be built up are the predominant issues for consideration.

2.2 Backing as a Means of Accident Avoidance

It is possible for the ship to be running at full speed ahead when ship maneuvering is initiated (to avoid a potential collision, for example). Considering the directional instability of conventional single screw ships with the propeller producing reverse thrust (Crane, 1973), it is virtually impossible to avoid uncontrolled lateral path and heading deviations during a crash-stop maneuver, unless special means of heading control (such as use of bow or other thrusters) is provided. (In the case study, presented thereafter, such control possibilities-are assumed.) On the other hand, if sufficient sea room is available , turning is by far superior to stopping, for the purpose of hazard avoidance, for most types of ships. Advance in a turn is much less than stopping head reach, and directional control is maintained (Crane, 1973). Hence ship backing, as a means of accident avoidance, is most important for rather modest approach speeds, while navigating in restricted waters.

3. Systems Considerations in Relation to Ship Backing

In evaluating the backing performance of ships, it is instructive to use ideas and methods of systems engineering. The ship system, as a whole, can be represented as an (integrated) assembly of its various subsystems (Bakountouzis, 1991). For the purpose of the present study, it is sufficient to consider the ship-system consisting of: the hull, the propulsor, the transmission and the prime mover subsystems, interacting with each other and with additional inputs, as the case may be, resulting from the intervention of the human operator and/or the presence of the environment. Figure 1 shows, in a simplified way, the various subsystems and their interactions.

3.1 *Prime* Mover - Backing Power Availability.

In most ocean-going vessels, prime movers are directly coupled to the propeller. As a result, engine reversal is required for the production of reverse thrust.

3.1.1. Diesel Machinery

The turbocharged diesel engine is by far the most common type of prime mover, nowadays. It can in general be assumed that reversible diesel engines have nearly equal torque-speed characteristics when running in either direction, which implies that, in principle, full power can be made available for astern operation. At low approach speeds, the engine will have no problems in being reversed rapidly (Crane, 1973). However,

this is not the case when the approach speed and, in addition, the ship's inertia are high, due to the windmilling effect of the propeller; the reversing process can not not be started until the engine and the propeller have coasted nearly to a stop which, for the case of a 50,000 DWT cargo ship, for example, might be of the order of 4 minute5 (Schacht, 1979).

3.1.2 Turbine Machinery.

In contrast, to the diesel engine, merchant marine astern steam turbine8 are usually designed to provide 80% of normal ahead torque at an astern propeller speed of 50% of normal ahead speed (classification requirements). Under these conditions the stall (zero-speed) torque may be 100% of the full load torque (Clarke, 1971). [It can also be shown, theoretically, that the stall torque of a turbine is twice that at the design point (Woodward, 1975 - chapter 4).] Studies show that, for large ships, like VLCCs and ULCcs, stopping distance and time can be reduced by increasing available astern power (Crane, 1973). However, continuing increases in astern power provides diminishing returns, especially for high approach speeds (mainly duetothe significant contribution of ship resistance in slowing down the ship - which is independent of the available astern power). An additional disadvantage of increased astern power would be, of course, the increased losses incurred when going ahead, with possible serious repercussions to the overall efficiency. As far as gas turbine propulsion is concerned, it is noted that these are not made reversible and employ, instead, either CPP or reversible gearing. Effectively the whole of the installed power is available for astern operation.

3.2 Propulsor - Power Absorption

During backing the flow angles to propeller blade sections can vary widely, thus making the onset of cavitation inevitable. In fact, according to Harvald (1967), any screw in reversal is in a state of extreme cavitation and, as a result, 'no-cavitation propeller* may be impossible to attain, unless the ship speed has been reduced substantially and the propeller rotation rate is very low. Since duration times under such conditions are small, erosion problems can be disregarded and the aim should be to reverse and run the propeller as fast as possible and at as high reverse power as possible, in order to achieve minimum stopping times. (Other researchers had earlier suggested, (D'Arcangelo, 1957), that there may be a possible optimum rate at which the propeller should be reversed for optimum results.) Under conditions of limited draft power absorption can be reduced significantly; propeller characteristics (and also values of propulsion factors - discussed next) should be corrected for Froude No. effects (Bakountouzis, 1992).

3.3 Hull-Propeller Interaction

While it is generally true that if more backing power is available at a faster rate the ship can be stopped faster, the backing performance of the ship depends on the condition under which the backing power is converted into reverse thrust, ie on the propeller characteristics and the hull-propeller interaction. In general, the higher the wake factor, the lesser the hydrodynamics load on the propeller and this can have a

favourable effect on the reversing performance of the propulsion system (Schacht, 1979). This is particularly important in single-screw, full-formed ships, where the wake factor can be of the order of 0.4 or greater. It has been suggested, furthermore, that braking flaps can be fitted on the hull (and activated as necessary to increase hull friction). Such flaps, particularly if installed at the bow, can lead to widening of the boundary layer, thus increasing the wake and permitting earlier propeller reversal. When the propeller is reversed, the flow pattern at the stern of the ship is significantly disturbed and no stable flow pattern may emerge *over* a certain speed range (Harvald, 1967), with some energy being expended in altering the wake pattern, thus temporarily reducing that available to affect ship stopping (D'Arcangelo, 1957).

3.4 Hull-Bottom Interaction

As has already been mentioned, the stopping performance of large ocean-going vessel is, by and large, a hydrodlynamic problem. Therefore, when a vessel enters shallow or restricted waters, the stopping performance *is* likely to be affected. In fact, in the present context, the shallow water problem is in many ways a most relevant issue, since rapid stopping is mostly needed in ports or other areas with a restricted *sea* room. Unfortunately it is also a complicated situation to investigate. Stopping trials on VLCC had shown that the stopping *performance* is improved by the braking effect of the sea bed, although operators appear not to agree (Coates, 1987).

Theoretical studies are equally contentious. It is generally accepted that in shallow water the bare ship resistance increases (Harvald, 1983; pp. 76-78). Also, the wake and thrust deduction fractions vary considerably in different depths (Harvald, 1976). There is hardly any easily recognisable pattern in their variation, except that, in general, both increase as the depth of water decreases. Increased ship resistance, and wake fraction, tend to reduce the stopping time and head reach of a vessel while increased thrust deduction fraction tends to lead to opposite results. Different studies (Harvald, 1976; Fujino, 1990) have lead to different conclusions as to whether shallow water can improve or not ship stopping. It appears that the specific configurations of the vessels studied play an important role.

4. Evaluation of Potential Improvements in Ship's Backing Performance

For most ocean-going vessels equipped with the slow-speed, directly-coupled diesel engine, engine reversal (in conjunction with tug boat assistance in ports) has been almost universal. Controllable pitch propellers, electric transmissions, reversing gears (in conjunction with hydraulic, usually, couplings) and, more recently, reversible converter couplings have been developed in order to eliminate the need for engine reversal.

A number of alternative hydrodynamic aids (water parachutes, brake flaps, passive duct system etc.) have been proposed for emergency stop of large ships. It seems that none of these has yet been accepted as a viable commercial proposition.

4.1 A Case Study

Early work in estimating the ship's stopping ability, as expressed by head reach and time-to-stop ship, involved the derivation of simple formulae and the production of families of curves (D'Arcangelo, 1957). The aim was to determine the required astern power to be installed on steam turbine ships. With the wide availability of digital computers and the accumulation of experimental data over the years, ship dynamics during backing can now be predicted efficiently by means of computer simulation.

For the purpose of evaluating some of the means available for the betterment of stopping performance and, also, to quantify potential improvements, a high speed coastal ferry is selected as a case study. The vessel under consideration is a twin screw (CPP), with two engines (HSD) per shaft, each providing approximately 3 MW of power at the design maximum speed.

A mathematical representation of the complete system is formulated on a functional component basis typical of similar studies (Rubis, 1972, Thompson, 1984). The complete system is divided into its functional components, such as ship hull, propeller, diesel engines, etc. (Fig.1), with the relevant characteristics of each represented by mathematical formulae or tabulated values. The diesel engine is further broken up into its functional components such as turbocharger, manifold and cylinders (Fig. 2) and each represented by suitable formulae or tabulated values (Woodward, '1984).

4.1.1 Limiting Conditions

It is instructive to consider limiting conditions in backing performance first. Figure 3 shows results for ship speed and head reach under coasting (ie. ship stopping without the application of reverse power - which could also be taken as failure to start the engine), windmilling conditions. This, obviously, represents the worst possible scenario. Figure 4 shows results under coasting conditions again, but this time with the shaft arrested immediately after the fuel is cut- off. It is seen that a "locked' propeller contributes significantly to the total hydrodynamic drag of the ship. (In both cases, as can be seen in the figures, the ship is considered "stopped" when the speed is reduced to one knot.)

Figure 5 shows results for the other extreme condition; that of an idealised stop, where the full-load engine power is available at all times following the initiation of the maneuver. This, theoretical possibility, would only be possible for a CPP installation, where the pitch is constantly updated in order to ensure maximum power absorption. It is noted that for this (hypothetical) case, the value of the maximum thrust produced is more than three times that of the design speed.

4.1.2. Wake Effects

There is a pronounced lack of data for the values of the propulsion factors (and also propeller cavitation) under backing ship conditions. Some studies disregard their effect altogether (Miniovich, 1958),

whereas others have suggested the use of behind-the-hull propeller data (Rubis, 1978). In this study a number of different scenarios for the values of the wake during backing have been assumed, in order to evaluate its effect on the results obtained in the preceding section. These scenarios included constant values for the wake, plus combinations of constant and speed-depended terms, the relevant figures deduced from Harvald (1967, fig. 20). It was found that, for this particular, twin-screw application , the maximum variation in stopping time5 was no more than 4%, only. Wake effects were subsequently disregarded in all other calculations.

4.1.3 Shaft Brakes

Figure 6 shows simulation results from the application of a "soft" brake and figure 7 corresponding results from the use of "hard" brake. It is seen that the "hard" brake reduces the shaft speed to zero more quickly which leads to significant improvements in total time to stop and head reach. However, it can also be seen in figure 7 that repeated starting is needed in the case of the hard brake, as the engine is unable to provide the torque demanded and subsequently stall occurs. It *is* evident, therefore, that some sensing devices need to be incorporated in order to avoid unnecessary starts and *loss* of starting air. For-both simulations open-loop linear fuel rack control is assumed, at a rate of 3% per second (as can be seen in the figures). Faster fuel rates do not show any serious improvents due to limitations imposed by turbocharger surging.

4.1.4 Controllable Pitch Propeller

During a crash stop maneuver, the steady-state combinator control of the demanded pitch and speed are discarded (Forrest, 1972, Newmann, 1984, Fowler, 1987). A typical control strategy is shown in Fig. 8 (Forrest, 1972). As seen, the demanded speed *is* reduced to idling while the pitch decreases at a constant, maximum rate. Speed is increased to maximum when the pitch becomes negative. Figure 9 shows computer simulation results for some of the major system parameters for the case study ship. It can be seen that sudden load is imposed on the diesel engine after the pitch changeover from positive to negative; the engine is stalled and its speed (and power) can only recover slowly. The end effect is increased stopping time and head reach.

Figure 10 shows an alternative control strategy. To take advantage of the increased load acceptance ability of the diesel engine at higher speeds, the demanded speed is raised slightly ahead of the pitch changeover point. It can be seen (Figure 11) that the engine can now recover more quickly, as compared with the previous schedule. Stopping time and head reach are shown to be decreased by 21% and 11% respectively.

5. Conclusions

There are no established criteria to judge the adequacy of the ship's stopping ability. Backing as a means of maneuverability as well as a means of hazard avoidance needs to be considered.
The means and methods available for the improvement of the stopping

ability of ships have been examined by following a systems approach
with consideration being given to the major ship subsystems and their
interactions. Potential improvement5 have been evaluated through
computer simulation with reference to a particular ship application.
 Results indicate that significant improvements in stopping times and
heads reached are possible, although careful consideration to design
details in propulsion systems hardware and the control strategies
pursued might be required.

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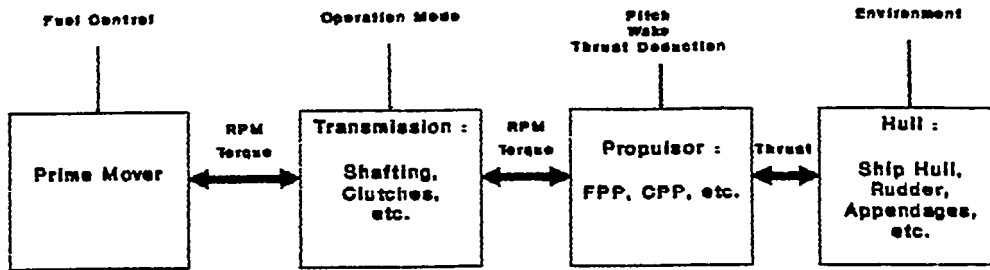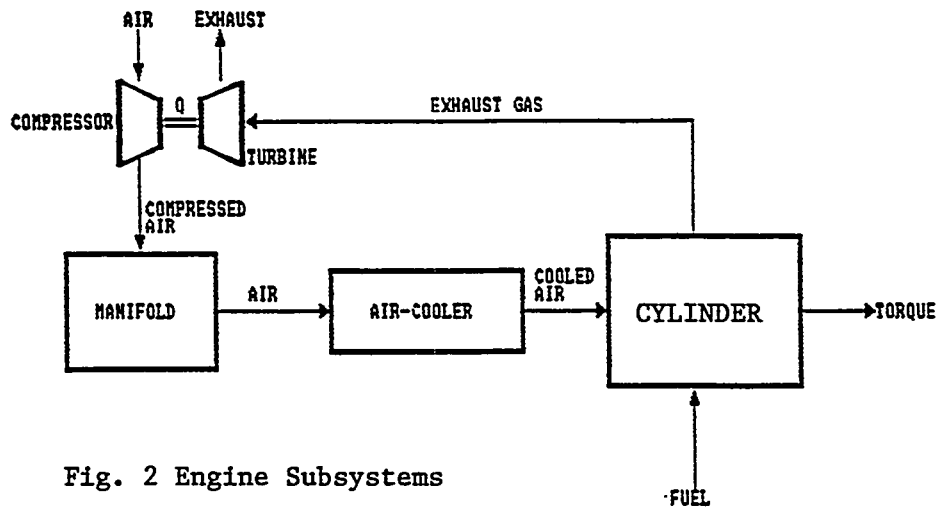analysis" Trans. SNAME, Vol. 92, pp. 33-49.

Fuel Control   Operation Mode   Pitch
Wake
Thrust Deduction   Environment

| Prime Mover | RPM Torque | Transmission : Shafting, Clutches, etc. | RPM Torque | Propulsor : FPP, CPP, etc. | Thrust | Hull : Ship Hull, Rudder, Appendages, etc. |

Fig. 1 Ship Subsystems

AIR   EXHAUST

COMPRESSOR   Q   TURBINE   EXHAUST GAS

COMPRESSED AIR

| MANIFOLD | AIR | AIR-COOLER | COOLED AIR | CYLINDER | →TORQUE |

·FUEL

Fig. 2 Engine Subsystems

—■— Engine RPM (x1000)
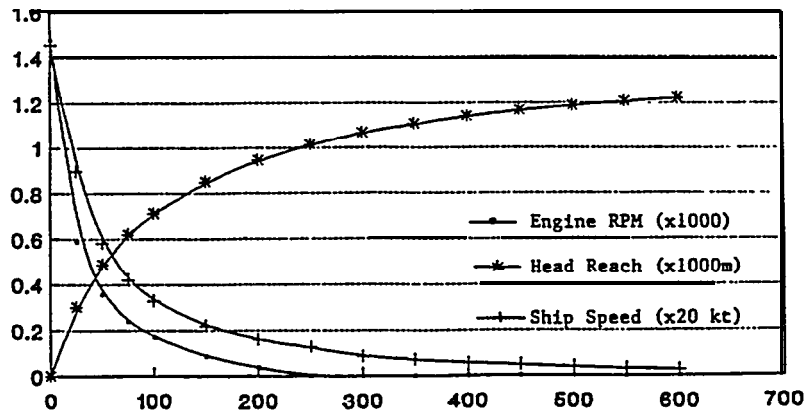—*— Head Reach (x1000m)
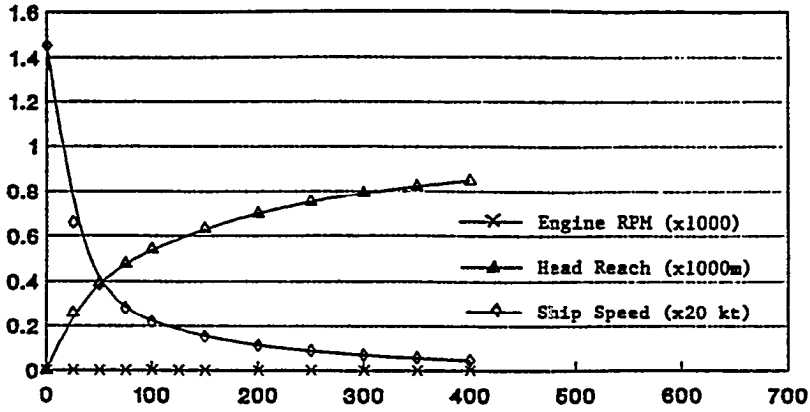—+— Ship Speed (x20 kt)

Fig. 3 Windmilling Stop
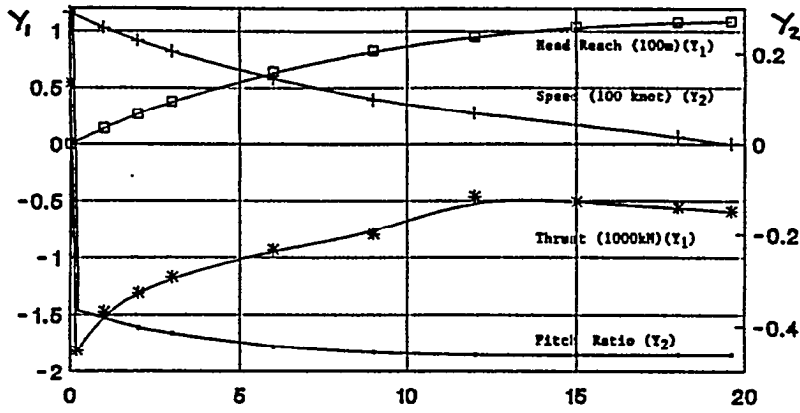
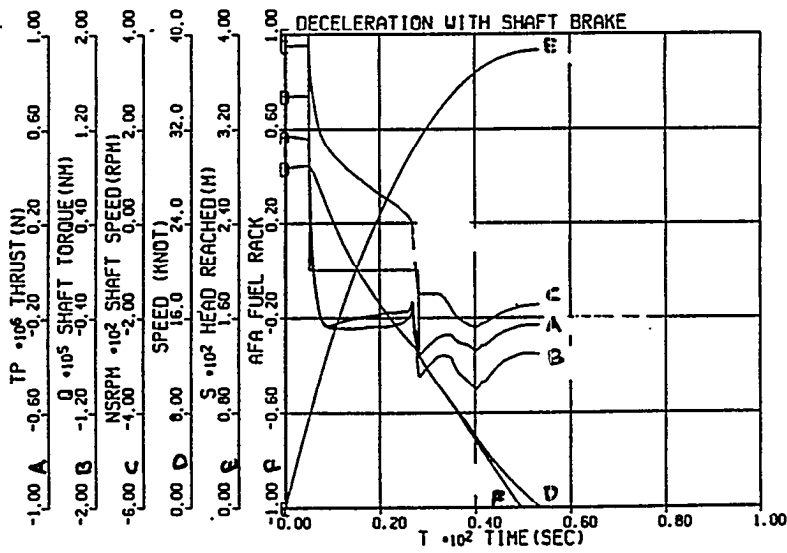Fig. 4 Arrested-Sheft Stop

Fig. 5 Idoalised Stop

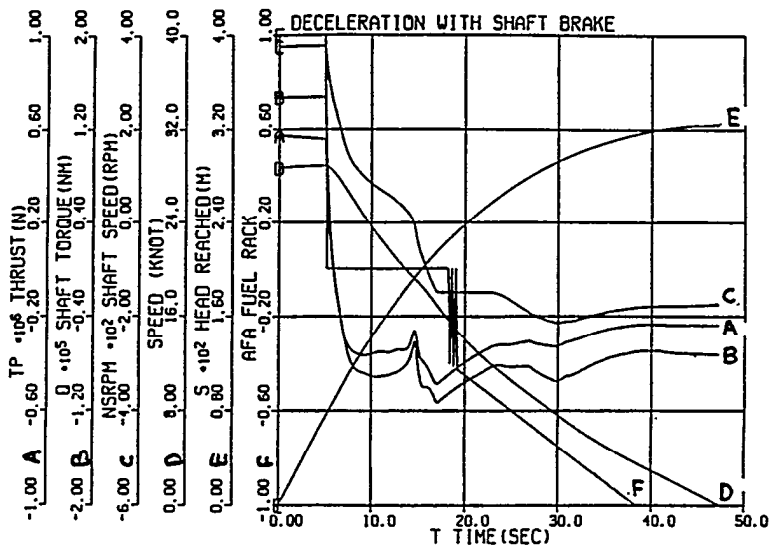Fig. 6 Soft Brake (Open Loop Fuel Control - 3%/see)

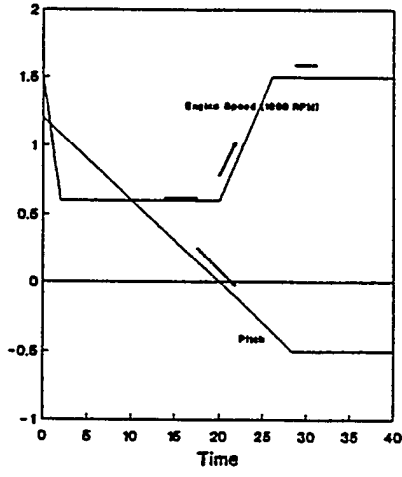Fig. 7 Hard Brake (Open Loop Fuel Control - 3%/see)
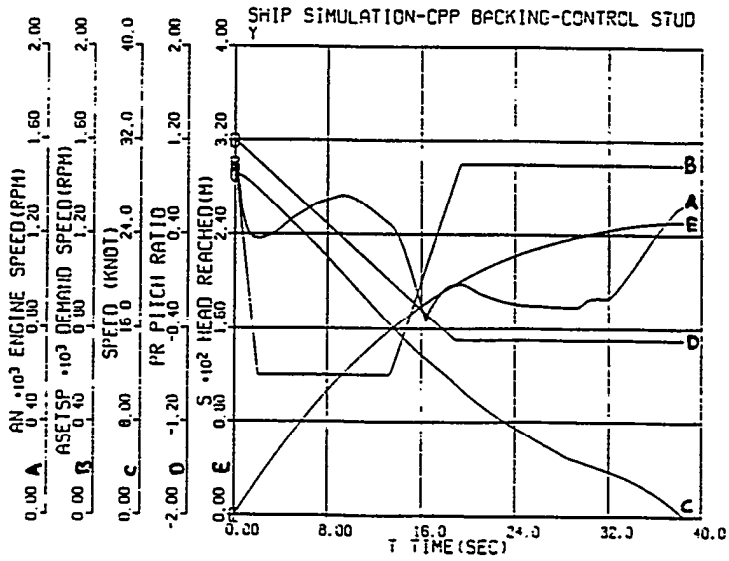

Fig. 8

Pitch/RPM Schedule
[Forrest, 1972]
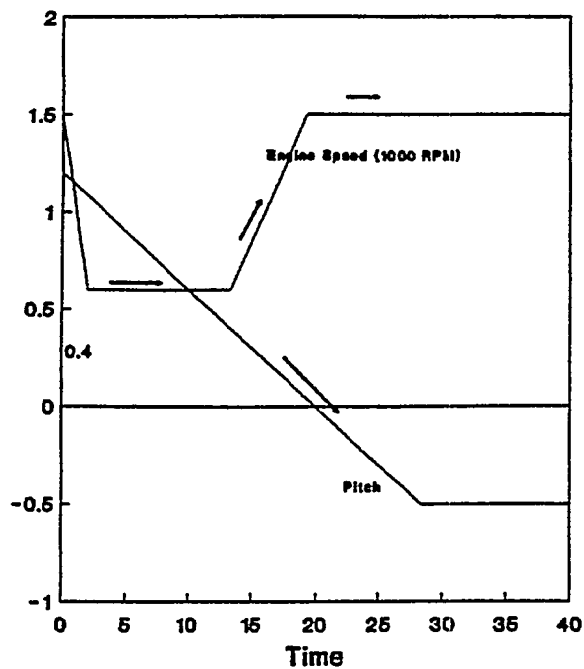

Fig. 9 Ship Simulation Results (Schedule Fig. 8)
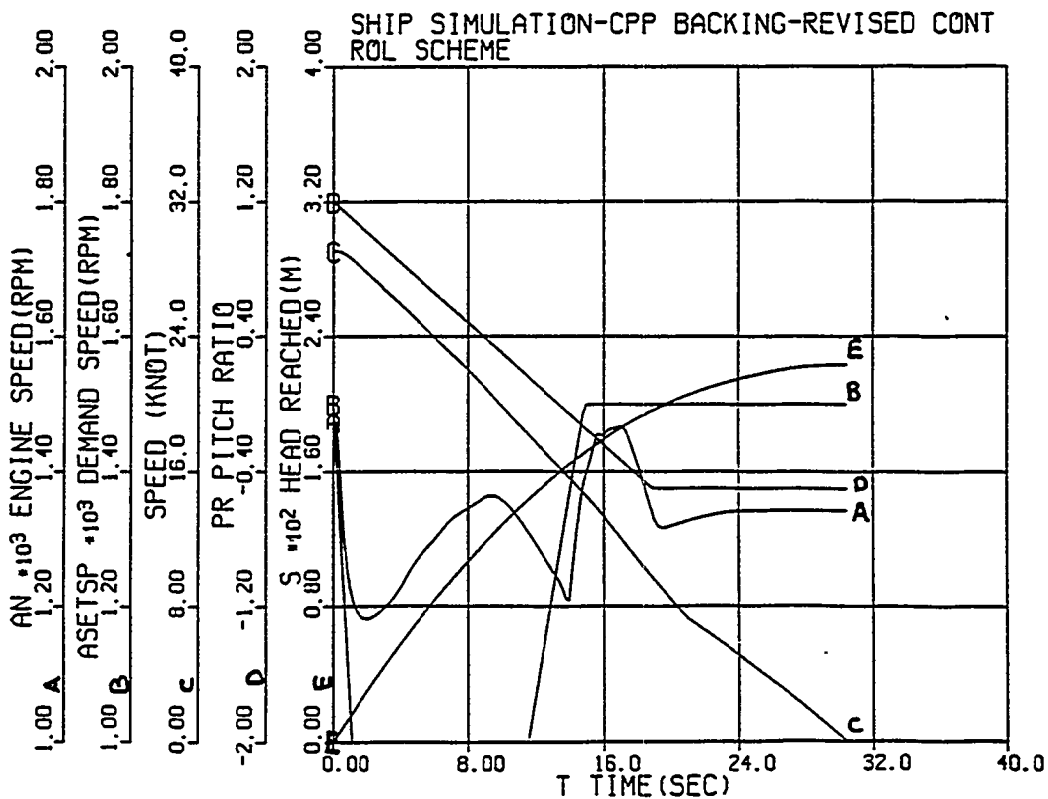
Fig. 10 Revised Pitch/RPM Schedule

Fig. 11 Ship Simulation Results (Schedule Fig. 10

Combined NO$_x$ and Soot removal *fror* diesel engine exhaust gases:

The DUT Approach

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Abstract

As environmental regulations are becoming more stringent, emissions of
(marine) diesel engines have to be dealt with. 80 far the use of primary
measures, engine modifications, can not meet the governmental reguirem-
ents. Therefore secondary measures, 'post combustion control' or 'end of
the pipe solutions', come into view.
At Delft University of Technology a catalytic process to remove soot and
NO$_x$ simultaneously is under development; soot will be oxidized to CO$_2$ and
NO$_x$ will be converted into N$_2$. A two stage process is used: a soot
oxidizing step with in series a NO$_x$ conversion system.
The first step consists of a catalytic soot converter. The emphasis of
the research in this field lies on the development of a suitable
catalytic material. To remove Nor from the exhaust gases an aqueous urea
solution is injected. The research focuses on the implications of using
urea as well as on catalyst improvement for the specific use in diesel
exhaust gases.

Introduction

Environmental issues are becoming increasingly important. Legislation is
pressing on to reduce any emission causing water, air or soil pollution.
In this case, the diesel engine, the primary concern is air pollution.
Reduction strategies can be divided in primary and secondary measures;
preventing and abating emissions. The first group can be subdivided in
engine and fuel modifications. This paper can be categorised in the
second group; the 'end of the pipe' solutions.
The kind of reduction strategy to be applied depends mainly on the kind
of pollution to be reduced. A summary of the relevant pollutants will
follow and subsequently the diesel engine emissions will be discussed:

Carbon dioxide (CO_2) is the main pollutant present in the diesel exhaust gas. This product is unavoidable when burning fossil fuels and the only reduction strategy is using as little fuel as possible; an efficient engine.

Sulfur oxide (SO_2) formation is proportionalto the sulfur content of the fuel used. The only sensible way to reduce this emission appears to be applying low sulphur fuels.

The main part of the nitrogen oxides (NO_x) emission is caused by thermal oxidation of nitrogen in the air. It is possible to reduce this NO_x emission by lowering the combustion temprature, generally causing a decrease in combustion efficiency. Moderate (50%) reductions can be obtained by engine modification at the cost of a considerable fuel penalty. It is expected that substantial reductions (>80%) can only be obtained by secondary measures.

Emission of unburned hydrocarbons (HC) results from low combustion efficiency and/or poor fuel quality. Carbon monoxide (CO) emission results from poor Combustion. A high combustion temperature will reduce both emissions.

The emission of ash, soot and sulphates etc, generally referred to as particulates completes the picture. This emission is caused by the fuel and lubricating oil (sulphates & inorganic materials), the engine itself (some metals) and a poor combustion (soot).

It is noted that some emissions are correlated; lowering NO_x emission by decreasing the combustion temperatures can cause a considerable increase in CO/HC & soot emission. This type of complications are giving engine manufacturers only a narrow margin for engine modifications.

Diesel & Otto engines

Compared with other type of engines (the Otto engine, figure 1) the diesel engine has a low CO/HC emission as a result of the high combustion efficiency, a moderate NO_x emission and a relatively high particulate emission. The goal of the research is to lower the Nor and particulate emission by post combustion control. The temperature of the exhaust gases is relatively low (200-600°C) , so a catalyst has to be applied. For otto engines three-way catalysts are extensively used. However these catalysts

can not be used for diesel
engines, the reason is obvio-
us:

According to the name of the
catalyst three reactions take
place. The unburned hydrocar-
bons and CO are oxidized to
CO_2 and water;

$$CO + 1/2 \ O_2 \ \longrightarrow \ CO_2 \qquad (1)$$

$$\overline{HC} + \overline{O}_2 \ \longrightarrow \ \overline{H}_2\overline{O} + \overline{CO}_2 \qquad (2)$$
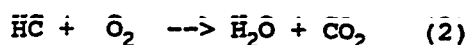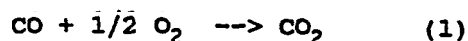
After almost complete oxygen
conversion the reduction of
NO_x can take place;

Figure 1 : Otto with/without catalyst vs
diesel engines.

$$NO + CO \longrightarrow 1/2 \ N_2 + CO_2 \qquad\qquad (3)$$

Because of these contradictionary requirements, oxidation and reduction,
the reactions depend strongly on the conditions of the exhaust gases.

This boils down to a
strict demand on the
air-fuel ratio, which
has to be about
stoichiometric (figure
2); this is controlled
by the so called λ-
sonde. However, a die-
sel engine operates
with an air excess;
the exhaust gases
always contain at
least a few percent of
oxygen. This prevents
reaction 3 taking
place because there
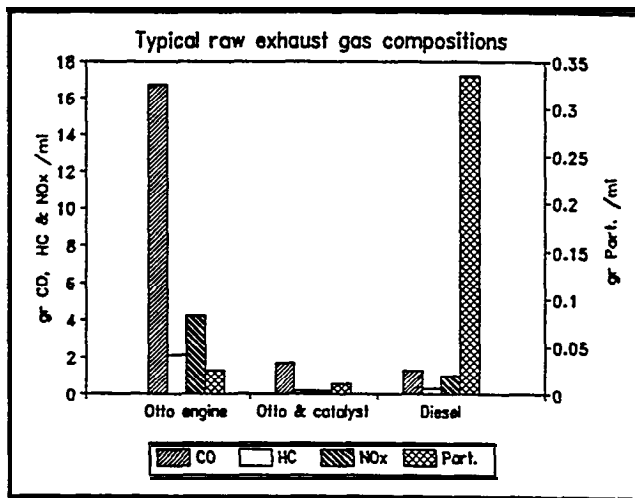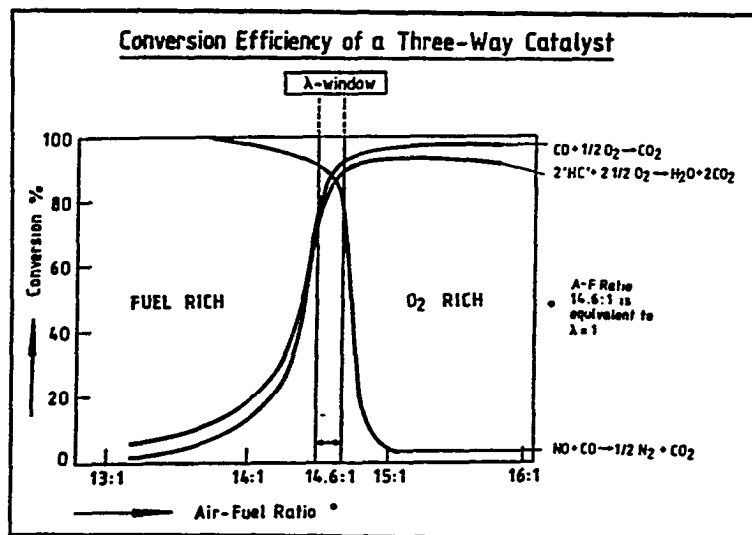are no reducing agents
present any more. Fur-

Figure 2 : Efficiency of a 3-way catalyst as a
function of the air-fuel ratio.

thermore some modern diesel engines produce not enough CO and HC for all the Nor to be reduced at all.

The DUT approach

Essentially the oxidizable part *of* the particulates have to be oxidized to H_2O and CO_2 and the NO_x converted to N_2 and H_2O. For the oxidation of the particulates a promising technique is catalytic oxidation because the temperature is too low for spontaneous oxidation to occur. The main focus of the research lies on developing a suitable catalytic active material. For the reduction of NO_x catalysts are available in similar applications (reduction of NO_x in electric power plants). A reducing agent has to be added; normally ammonia (NH_3) is used. Applying this technique on diesel engines (or other relative small scale O_2 rich gases like lean-burn gas engines) NH_3 is difficult to use for safety reason. Therefore an aqueous solution of urea is used. This type of process is already extensively investigated in the Delft group for the removal of NO_x from gas engine off-gases (Wypkema, 1991).Further catalysts, especially for diesel engine application, are under development.

Figure 3 : Schematic representation of particulate material.

Soot removal

The first step in developing soot oxidation catalysts is the characterization of soot (particulates). In figure 3 a schematic representation of a soot particle is given, using 0.3 wt % sulphur containing fuel. The composition *of* soot depends on the fuel composition, type of engine used, general engine conditions, sampling conditions, etc. The core of a soot particle is a carbon nucleus surrounded by adsorbed inorganic salts and hydrocarbons. The graphite like carbon nucleus is rather unreactive implying strong demands on the activity of the catalyst.
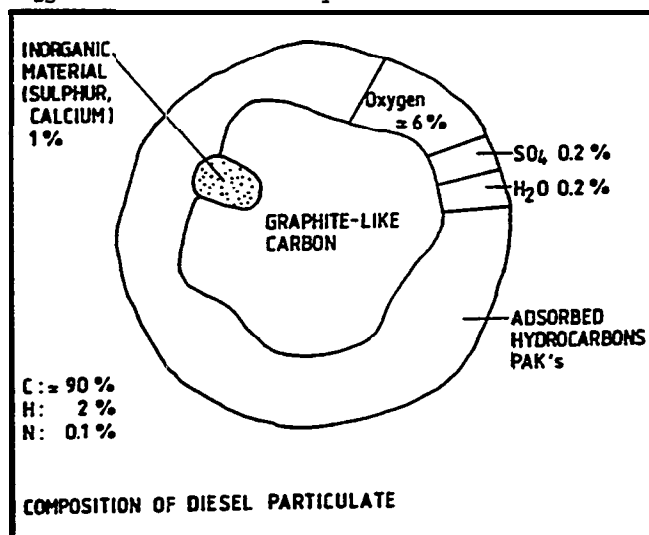
Present soot removal systems consist of (catalytic) filters which are periodically cleaned by externally heating. Since these systems have serious drawbacks, flow-through monoliths (figure 4), equipped with a good soot oxidation catalyst are considered to be a better choice (Saito, 1991). An important reason is that plugging due to incomplete or failed regeneration does not occur and a small pressure drop is maintained.

(A monolith consists out of a large number of parallel channels, coated with catalytic material. The main advantage of this configuration is the relative low pressure drop and the relatively high resistance to dust loading.)

Figure 4 : Monoliths

A suitable catalytic material has to be developed. One of the results is that, besides the chemical composition *of* the catalyst, the contact between soot and catalyst is crucial for the catalytic activity.

An extra demand of the catalyst is a relative low SO3 oxidation rate. Good oxidizing catalysts, such as Platina, tend to oxidize SO_2 to SO3 causing all kinds of corrosion and salt deposition problems to occur. The so formed sulphates will be leaving, at least partly, the system as particulate material. So using an oxidizing catalyst may increase the particulate emission, the carboneous structures replaced by sulphates.

Marine diesel engines

As already stated the particulate composition depends on the type of fuel used. Heavy fuel oil generally contains up to 3 wt % sulphur. The resulting particulates may contain over 50 wt % sulphates/inorganic oxides (GBtmalm, 1991). These compounds cannot be removed by oxidation. *As* a result, the theoretical particulate emission reduction for oxidation is limited to this 50 percent.

The only solution is using low sulphur fuel oils. The resulting particulates will contain mainly oxidizable structures and catalytic oxidation can achieve a considerable decrease in emission.
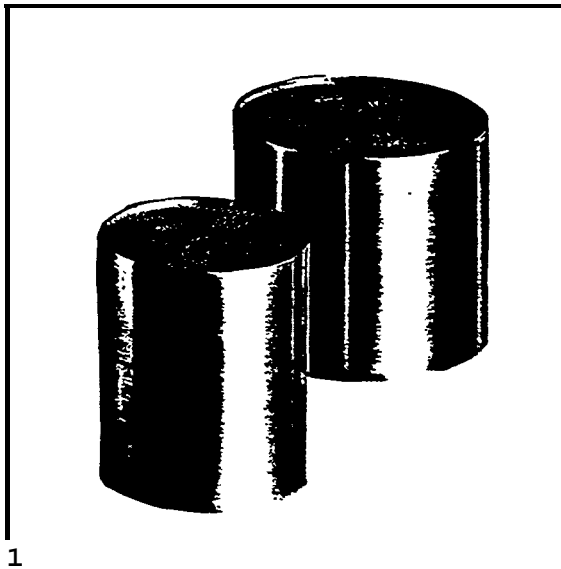
NO$_x$ removal

For the reduction of Nor in the presence of oxygen there is a sound technological basis available. Over 90 GW (Ribeiro, 1990) of coal-fired power plants (mainly in Japan and Germany) have been equipped with SCR technology. SCR stand5 for selective catalytic reduction of Nor. The point being that diesel operates with oxygen excess; 80 an agent has to be added which can selectively remove NO,. For this purpose ammonia (NH3) is used;

$$4 \ NO + 4 \ NH_3 + O_2 -3 \ 4 \ N_2 + 6 \ X_2O \tag{4}$$

$$6 \ NO_2 + 8 \ NH_3 \ --> \ 7 \ N_2 + 12 \ ?I_2O \tag{5}$$

Ideally, the only product5 are nitrogen and water. Ammonia is injected **into the exhaust gas at a temperature of 300-400°C and subsequently the** gas mixture is passed through a catalyst bed. The degree of Nor removal depends on the amount of ammonia added; however, an increase in added ammonia can result in higher levels of ammonia in the cleaned flue gas (NH3 slip). This concentration of NH3 should be as low as possible because $_{NH3}$ form5 salts with SC$_3$ which will condensate at lower temperatures, thereby deactivating the catalyst or causing problem8 in the exhaust gas system. For fuels containing large amounts of sulphur this means a lower temperature limit for the operation of the catalyst of about 3000C.
The upper temperature limit, 400°C, is determined by the catalyst stability, increased NH$_3$ oxidation and excess SO2 oxidation.
A serious drawback of applying this technique on a relative small scale is the use of NH$_3$. Ammonia is a poisonous and combustible gas which has to be stored as a pressurized liquid. So for safety reasons the use of NH$_3$ is not recommendable (and often even not allowed by unskilled persons). Therefore WEI$_3$ has been replaced by a harmless substituent; urea. In atead of ammonia a 40 wt % aqueous urea solution can be injected. This type of process is already extensively investigated in the Delft group for the removal of Nor from gas engine off-gases in order to use their C02-content in greenhouses for crop growth stimulation (Wypkema, 1991). -
This process has been tested with the exhaust gases of a real gas engine. The same type of process can be applied to the exhaust gases of diesel engine8 (demonstrated by Held, 1990). The research in this field can be divided in two areas, firstly the catalyst development and secondly the implication5 of using urea.

Catalyst development

The catalysts currently used are mostly of the flow-through-monolith type and consist of an extrudate of vanadium pentoxide on a titanium dioxide carrier. Several additives are used to improve the performance. Most of these catalyst8 are applied with (steady state) electric power installations. This meansthatthe catalyst condition (temperature) is essentially constant. The temperature range in which the catalysts are used is 250-4000C.

For diesel engines this temperature range is rather small; at low loads the minimal temperature will not be reached. The low temperature limit is determined by the lack of activity of the catalyst on the one hand but more important depends on the sulphur content of the fuel used. At **temperatures above 400°C the catalyst starts oxidizing SO_2 and NH_3 giving** rise to particulate8 and Nor emission. At still higher temperatures **(>500°C) the catalyst is not stable any more and will deactivate** irreversibly.

Therefore the catalyst development is aimed at searching for catalysts which can also be used at higher temperatures and do not oxidize NH_3 and SO_2. Furthermore improvement of the activity of the catalyst is of importance. At this moment the focus of attention is on metal exchanged zeolite type catalysts (silicium aluminates with a relatively high thermostability). These catalysts are being synthesized and tested in lab scale facilities.

Urea

Granular urea is widely used as a fertilizer. It dissolves rather good **in water, up to 50 wt % at 20°C, the solution being clear and odourless.** The solution, 40 wt % urea in water, is injected in the exhaust gas stream using an atomizer (preferentially a twin media nozzle with regard to plugging problems). Subsequently, urea decomposes, mainly and simplified, according to:

$$CO(NH_2)_2 + H_2O \longrightarrow 2\ NH_3 + CO_2 \tag{6}$$

A complication is that at low temperatures urea will not totally decompose but form condensation products. This means a low temperature limit for the use of urea. To be on the safe side the injection should **be started above 330°C according to the decomposition temperature of** cyanuric acid (one of the heaviest possible byproducts). This exceeds the

lower temperature limit of the catalyst (ammonium sulphate formation). Preliminary lab and pilot-scale experiment8 did not show any detectable byproduct formation above 300OC.

System configuration

The overall NO_x reduction to be obtained with a SCR system depends on the configuration. Using more catalyst gives a better NO_x reduction resulting in increased costs. using more urea give5 the same result, but the NH_3 emission (formed by reaction 6) will increase. The final NH_3 emission should be kept minimal (p.e. e 20 ppm). There are several solutions to deal with this problem;

Firstly one can inject a slight excess urea and subsequently oxidize all superfluous urea. The main drawback is that an extra oxidizing catalyst is needed. Furthermore most of the urea, or ammonia, will be converted to Nor. An advantage is oxidation of unburned HC, CO and some of the particulates. Secondly the outgoing NOr concentration can be measured subsequently using feedback control to regulate the urea dosage. Provided there is enough catalyst a high reduction level can be obtained. The main drawback is the difficult process control caused by the slow catalyst response. Further the mixing of urea with the exhaust gases should be rather good before entering the catalyst system.

The first system is somewhat more insensitive to the urea dosing rate. The amount of urea to be injected at a certain engine load can be obtained by mapping the engine during start-up/service. For the second system this is not sufficient to obtain a high reduction level, one needs to know what the outgoing NO_x concentration is. Until now NO_x measuring devices are expensive and difficult to use. At the Delft University research is being done on the development of Nernst-type NOr sensors (Ningling, 1991). These sensors are relative cheap and the principle of using them is analogous to the three-way catalyst control system. In the latter case one regulates the fuel injection with the oxygen concentration measured by an O_2 sensor. In the former case the urea injection can be controlled with the Nor concentration measured by a NOr sensor (when sufficiently developed).

Marine diesel engine

As already mentioned SCR is widely applied for NOr reduction. With respect to marine diesel engines two Danish engineering firms have already incorporated a SCR system using standard catalysts and ammonia

for NO_x reduction in two ships. A 90 % NO_x reduction is claimed cleaning the off-gases of an 8 MW two-stroke diesel engine (Gibson, 1991). A similar system using urea is proposed by Gotmalm (1991).

Conclusion

NO_x and particulates emission of diesel engines can be reduced using a combination of two reactors:

- flow through monolith coated with a suitable catalytic material
- monolith in which NO_x is selectively removed using urea

With respect to marine diesel engines the catalytic oxidation of particulates is seriously restricted by the high sulphur content of the fuel.

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INTEGRATED CONTROL AND AUTOMATION OF SHIPS, CONTRIBUTION TO SAFETY?

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Abstract

Over the last decade the Maritime Industry has gained vast
experience in the automation of advanced ships and offshore
work platforms, such as dredgers, naval vessels, and crane
and pipelay barges.

Up until five years ago dedicated computer hardware is
typically employed, but was often placed next to manual
controls as an extension. The industrial hardware now
available is becoming more and more advanced and is allow-
ing the creation of reliable "Integrated Control and Auto-
mation Systems" , which will, as costs decline with time,
also be applicable on less advanced ships.

This paper describes the development of ships' control sys-
tems, from manually operated, to integrated automation, and
the influence of this kind of automation on the reliability
of operations and safety on board.

Introduction

Integrated Control and Automation of ships is a logical
step beyond the more traditional control operations on
board. This mirrors a trend set in the industrial world of
automation. In industry it has been necessary to remain
competitive and meet the increasingly stringent legal stan-
dards on quality (liability) and safety (including environ-
mental aspects). This also applies to shipping. Much can
thus be learned and adopted from these-industrial trends.
The experiences described below took place at
Van Rietschoten en Houwens (Technology) B.V., a company
active in the fields of industrial and maritime automation.

Development of automation/computorisation capabilities

. Until 1970 automatic control was primarily accomplished using techniques current at the time, such as relay control and regulation with the help of analogue (electronic) amplifiers. As from 1970 the then recently available mini-computers (such as type PDP-8) were used for extremely difficult and complex automation problems. At the time these were very large and expensive computers. One application for which they were used in the "70s was the commonly seen Dynamically Positioned Drill Ships, which could remain in precise position without mooring while drilling for oil or gas. Because of the precision called for in holding the correct drill location, automatic control proved indispensable. This job was done by the then mini-computers, sometimes still provided with analogue back-up systems, built up from less sophisticated analogue controllers. [1].

Around 1975 the first micro-processors with a calculation capacity comparable to the mini-computers arrived. These micro-processors were much smaller and also much less expensive, which meant they could be used for simple measurement and control equipment or for more complex applications for which less money was available [23. Using these micro-processors many automatic control systems were developed that were placed in parallel with the manual controls 133 143.

Figure 1:   Task of different kinds of hardware.
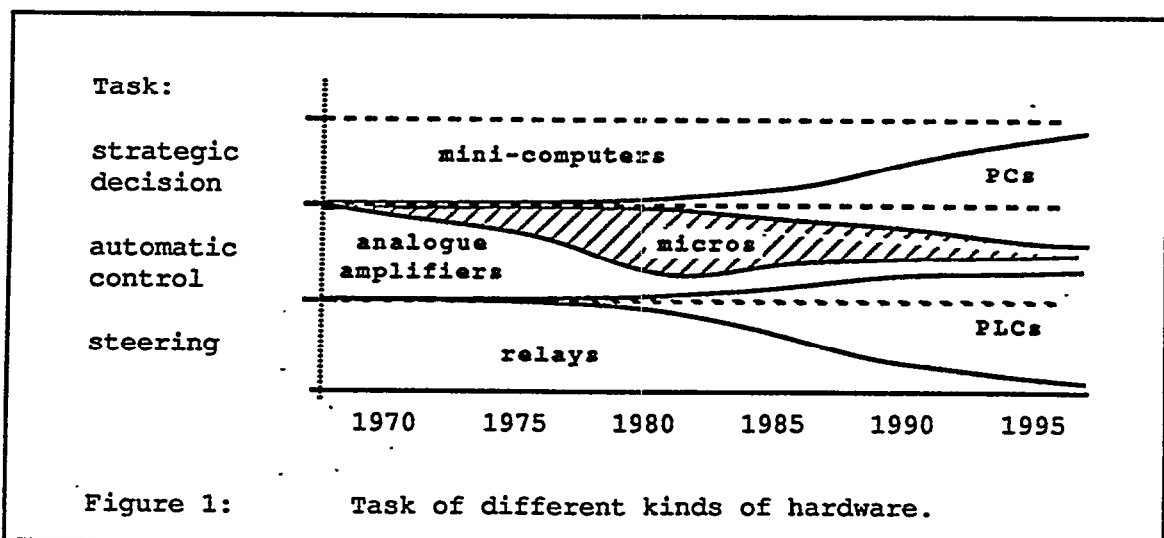
In 1980 came the PLCs (Programmable Logic Controllers) to replace relay controls. As from 1985 they could also execute analogue control functions. This made it possible to reduce a substantial part of the applications for micro-processors. In other words, the PLCs took over these applications. As from 1985 the PC (personal computer) arrived on the scene, even on board ships. They were often used to collect information (data logging), to aid in making strategic decisions, and to present information. These PCs took over some of the applications previously filled by micro and mini computers. The development described about is shown diagrammatically in figure 1.

The need for automation and motivational elements.

Automation is no goal in itself, but has to serve a clear function on board. The capabilities of automation depend on application needs. Automation is necessary for:

- required precision
    * position control   dynamic positioning
                            sailing on track
    * process efficiency   dredging
                            pipe-laying activities
                            loading/unloading activities
- complex coordinated tasks offshore activities
                            warships
- reduction of manpower   low manned operations
                            unmanned engine rooms
- trend analysis   for process optimisation
                            for maintenance
- integration with   navigation systems
- safety   loading/unloading activities
                            stability
                            damage control
- combinations of the above

An important proportion of these automation tasks are automatically stimulated by the economic benefits inherent to them. However, two aspects are not stimulated by economic advantage.They are:

- automation for purposes of safety and security,
- integration of the various control, monitoring and navigation systems.

Both elements offer less obvious economic.advantages; an advantage over the long term (safety) and an advantage for unambiguous and therefore safer operation (integration).

These elements should be stimulated by international regulations (incl. IHO and IMO). And the international regulations should be adapted such that any legal obstacles hinder new applications less than in the past. Consider the introduction of the Electronic Chart Display and Information System (ECDIS), for example.

Automation Concepts

The above shows that in many areas automation (i.e. the application of computer systems).is or will be applicable on board ships.

Table 1 : Importance of automation

	transport ships	ferries	naval ships	dred-gers	work-pontoon
Engine room	++++	++++	++++	++++	++++
Propulsion	++++	++++	++++	++++	+
Course control	++++	++++	++++	++++	++
Roll/list control	++	++++	++++	+	++
Position control	++	++	++	++++	++++
Navigation	++++	++++	++++	++++	++
Loading	+++	++++	+	++	+++
Safety/stability	+++	++++	++	+++	++
Damage control	+	+++	++++		+
Process control				++++	++++
Communication	+	++	++++	++	+

This table shows that on all vessels the engine facilities (engine room), propulsion,course setting and navigation are all equally important. This is not surprising as they are the basic tasks of the ship. For these functions there are many standard solutions also readily available:

```
engine room        engine room automation
propulsion         pitch control/load sharing
course control     auto pilots
navigation         radar, GPS, ARPA, (ECDIS)
```

A disadvantage of these standard solutions shown above is that each element has its own control and presentation system by which control and presentation is carried out in many different ways and at various locations.
In addition to this, the volume of information for presentation and operation on the bridge has increased in recent years for two main reasons:

- the volume of information has increased as a result of technical performance
- in endeavouring to limit the size of crews, more information has to be processed for, and decisions taken by each crew member (particularly on the bridge).

In the interests of safety the provision of information and control operations should be more uniform. This can be best accomplished through the integration of presentation and control functions. This integration will also achieve a reduction in the size of the control and presentation system (the so-called 'integrated bridge').
When this integration is not limited to the presentation and controls on the bridge but also automates functions, a completely integrated system is achieved with the following benefits:

- high degree of automation;
- optimal presentation of information (depending on process status);
- high degree of coupling and interlocking of separate automated functions;
- easily connected to other computer systems;
- easily adapted to new (future) circumstances;
- reduction in the number of individual measuring and control devices and in the amount of cabling required, leading to an increase in "Mean Time Between Failures" and a simplification of fault-finding procedures;
- standardisation of components;
- possibilities to achieve a"Decision Support System", by using an "expert system" for example.

In addition to the advantages mentioned the following negative points should be borne in mind:

- the added value per operator drops per control and, automation function,
- a higher level of operator training is required.
  In the same training time the "Multi-skill Officer" must learn more (concerning deck operations, navigation, engine room, radio etc.) by which this more general knowledge is frustrated by the dullness of work on board -
- operation and presentation will be different for each type of vessel by which the "exchangeability" of operators is reduced,
- increased dependence on sensors by which on breakdown difficult manual back up situations are created.

A number of the disadvantages mentioned above can be reduced by training (also with the use of simulators) and by the application of "Decision Support Systems[8]'.

Examples of 'Integrated Control and Automation'.

Warships
As shown in figure 1, up to five years ago automation was
carried out with the aid of mini or micro computers. This
was particularly the case for ships for which very complex
automation and decision functions are necessary.
An example of this is the on board automation of Dutch "M^8"
(multi-purpose) class frigates 163. In addition to the
general advantages of the integrated approach, this applic-
ation also affords a very high vessel availability. That is
why a Damage Control System [9] has been integrated into
the total concept by which damage control can be coordina-
ted from various locations (work stations) on board ship
(see figure 3). From these different work stations all
other control and monitoring functions can also be carried
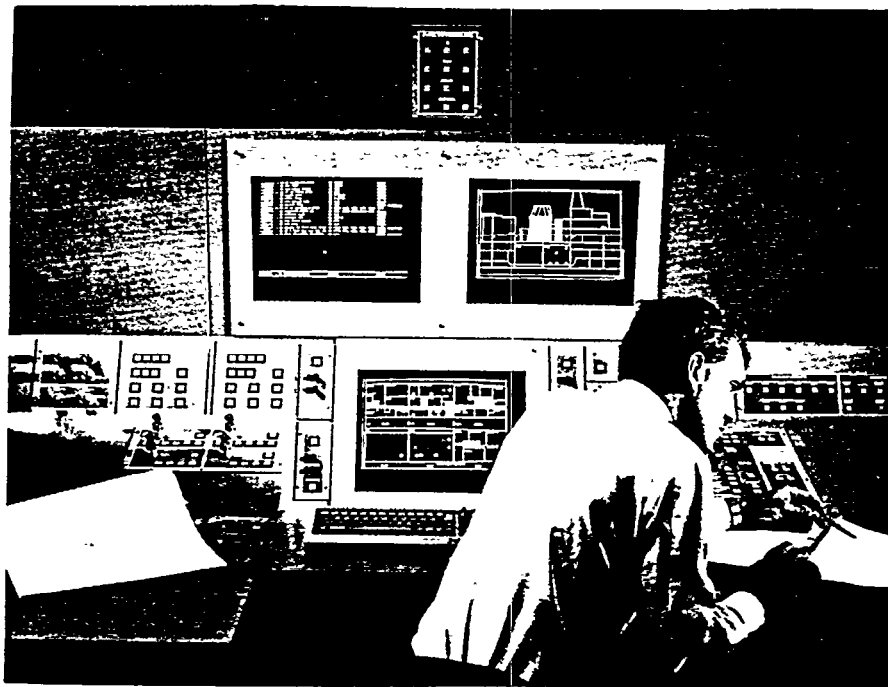out. Figures 2 provides an example of such a control
station.

fig.2. An operator work station in the ship's Control
Centre illustrates integrated capabilities.

It goes without saying that this approach is indispensable
for warships. But a similar approach has also been applied
to less advanced vessels. This technology is particularly
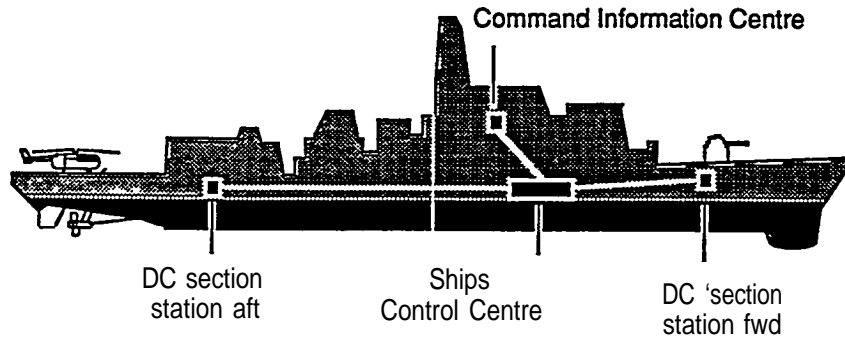used in the dredging and offshore industries.

fig. 3. Location of work stations

Dredgers
up to 1985 automation on board of dredgers was primarily
carried out with the aid of micro-processors, which were
installed separately next to the manual controls. Since
1985 it has been possible to combine (integrate) this type
of automation with manual controls by using standard
Programmable Logic Controllers (PLCs). These PLCs are prim-
arily used for industrial automation and the more advanced
PLCs are highly applicable for use on ships. Since 1985
more than 10 systems equipped with PLCs for integrated con-
trol and automation have been delivered to the dredging
industry.
Initially applications were limited to the so-called cutter
suction dredgers, non self-propelled pontoons which are
moved forward using anchor lines. The primary job of cutter
suction dredgers is to dredge waterways. In this area the
automation and control aspects primarily manage the dredg-
ing process itself. Since 1990 the integrated automation
and control concept has been used successfully for self-
propelled dredging vessels, the so-called trailing suction
hopper &edgers; into which, in addition to control of the
dredging process, the control of the engine room and pro-
pulsion are integrated (see figure 4) [S, 111.
Control of the completely automated processes is done via
keyboards and video displays (figure 5), through which
manual control and servicing can also be carried out. The
traditional manual controllers (handles and buttons for
several separate functions) have almost completely
disappeared.

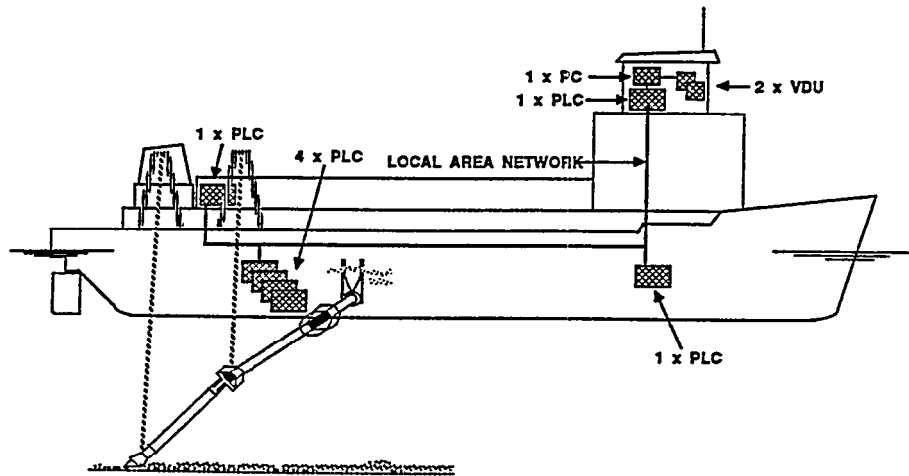fig. 4. Integrated Control and Automation on board
         trailer

The control of all actuators and the reading of sensors is
by the locally placed PLCs, which also carry out distribu-
ted control and regulation. The link between these local
PLCs and the man-machine interface (MMI) on the bridge is
secured via a network (with redundancy back-up or not).

fig. 5. Operator console on board dredger.

This network considerably reduces cabling costs and creates a large degree of versatility. The first such integrated system was delivered in the spring of 1990 and consists of 7 PSCs, 2 PCs with four monitors as MMI, and a 10 Mb/s network (figure 4). In 1992 two ships automated in this way will be delivered, including partially integrated navigation systems. This will require increased redundancy (e.g. for the network).

Transport Vessels

The application of the integrated concept for automation and control on board transport vessels is also feasible. An example of this is the "Auxiliary and Oil Replenishment (AOR) Ship" of the Dutch Navy which will be operational in 1994. Here also automation will be provided with the use of PLCs (8 units) and operation and presentation by means of 9 operator stations made up of 9 PCs fitted with 14 screens. Each PLC will offer local operation (also for back-up) and together with the operator stations will ensure:

- propulsion
- adaptive steering control [7]
- engine room control
- auxiliary systems
- cargo/load systems
- loadmaster
- nuclear biological chemical damage control (possible at three locations: aft, forward, central control station).

It will be clear that there are also benefits in the incorporation of this type of integrated system for other transport ships such as tankers and ferries.

Safety Aspects

Integrated Control and Automation influences safety on board ships in various ways:

- through the automation equipment directly (reliability of equipment);
- through the -functions carried out by the automation equipment (safety functions).

Reliability

The reliability of the equipment is expressed in availability (Mean Time Between Failures, MTBF), the speed with which failures in the system can be corrected (Mean Time To Repair, MTTR), and the influence of failures on the entire operation (incl. redundancy).

No general statement can be made about these aspects because the requirements and possibilities vary per application. In any event a very reliable system can be supplied technically by doubling the systems required. This possibility should be carefully considered for each subsystem to prevent unnecessary costs.

In any case, a reliable (perhaps even more reliable) subsystem can be achieved in an integrated system. Coupling of the various subsystems will in general take place over redundant networks, guaranteeing the transfer of information between the subsystems and the man-machine-interfaces. When compared to a traditional installation, a well-designed integrated system provides the following advantages:
- just as reliable, or more reliable control/automation per subsystem;
- more reliable presentation and control, because these are possible at several locations (back-up via other control consoles);
- quicker detection of defective subsystems via built-in diagnostic systems and a simpler hardware concept;
- quicker repair of defective parts by simple exchange of a limited number of different components (repair by replacement).

Safety
In addition to the greater reliability of the automation and control systems, safety is further increased by incorporating extra security systems (software modules) in the integrated systems:
- control over the operation of the individual sensors through trend analysis and comparing the sensors to one another (checking for possible contradictory sensor data);
- through (semi) automatic trend analysis of the performance of the individual ship's equipment better maintenance can be provided, increasing the availability of the total vessel;
- through built-in checks on operator inputs, mistakes or unsafe operation can be prevented;
- through a combination and presentation of relevant information-only, the operator gains better insight in the ship's operations (he is less confused by irrelevant information);
- during breakdowns or emergencies immediately relevant information can be provided which will aid in providing solutions (decision support system);
- through available calculation capacity, extra functionality can be added, such as stability calculations, load calculations, predicted behaviour etc.

The above summation shows that an integrated approach, in addition to operational advantages, also provides benefits in the area of safety, if the correct attention is given to this. A negative argument is that an integrated system can be somewhat more complex technologically, which requires the operator having extra training.

Future Developments

Until today the integrated system approach has been limited in two ways:

- an integrated approach from the automation suppliers by which automation and control form the most important area and navigational elements are being gradually included.
- an integrated approach from the suppliers of navigation equipment in which several monitoring elements of e.g. engine room control (alarms) are integrated, but whereby less attention is given to the real automation and control effects.

In the future navigation, automation and control should be further integrated. This will be easier to achieve with the availability of the Electronic Chart Display and Information System (ECDIS), because this navigation element is also included in a computer [10].

Conclusions

Integrated Control and Automation is already very profitable, especially for ships on which more complex operations are required (e.g. warships, ferries) or on which more complex process control is necessary (e.g. dredgers, offshore pontoons). Because today it is possible to carry out these functions with 'standard' industrial equipment, they are also more economically attractive to less advanced ships, especially if navigational controls can be further integrated into the system.

Special attention will have to be given to operator training including the use of simulators. At the same time standardisation will prevent an excess of operation and presentation concepts being developed and lead to trouble and risk-free transfer of operators. By means of unambiguous controls, the incorporation of security systems to prevent operator errors, on-line diagnostics and decision support systems a safer system will be made available.

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BRIDGE LILY-OUT, OPERATION AND SAFETY

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Abstract

Trends towards reducing costs of ship operation demand to
conceive the bridge as an operational centre for performing
both navigational and platform supervisory functions. An
automated bridge supports efficient ship operation and
makes single handed performance possible, but the need is
emphasized for experimental testing of lay-out, mental
workload and task performance with regard to safety. This
article addresses some design issues, such as function
allocation and the testing of performance in a series of
simulator experiments. After introducing the ergonomic
design process, particularly the process of allocating
functions to humans and automic devices, the testing of
ship's bridge lay-out is elaborated.
Results show that careful function allocation can lead to
an automated wheelhouse concept suitable for safe naviga-
tion in landfall conditions. The implementation of ergonom-
ic aspects in the design process is highly effective to
reduce human errors. The amount of human error-related
events might be reduced with 60%.
Questions concerning the effects of monotonous watch
periods on operator's alertness need further attention.

Introduction

The number of personnel on board merchant vessels amounts
today sometimes to about 16. In comparison with years ago
this is quite a reduction. Crew size reduction is a result
of the continuing search for efficient ship operation
through automation. These developments are based on studies
in various western countries to optimize design, opera-
tions, maintenance, investments and energy consumption
against the criteria of costs, safety and efficiency.
Human factors design methods and data contribute to effi-
cient and safe ship operation through adaptation of instru-
mentation and procedures to human capabilities. Human
factors research in particular is directed toward predic-
ting effects of crew size reduction on the quality of
system and human performance. The present study, under
contract to the Netherlands Foundation for the Coordination
of Maritime Research aims at the testing of the ship's

bridge as an operations centre suited for single handed performance.

National maritime authorities show increasing interest in the human factors on board ships because of accidents due to insufficient man-machine interactions. Other civilian and military organisations show for the same reasons interest in the improvement of the quality of work and safety of performance. Some shipping companies have developed surveys to check the performance of maintenance and operational tasks. Classification bureaus, for instance Det Norske Veritas, require training standards, particularly regarding emergency conditions. The US Defense Organisation conducts an extensive programme for the procurement and design of equipment emphasizing human-systems-integration. The policies of organisations is directed to the improvement of the match between human and equipment.

Ergonomic design process

To transform operational need into a system description, human factor design method follows a series of steps, involving mission analysis, function analysis, function allocation, task analysis and performance prediction. The analyses are repeated several times in the course of the synthesis phases of the design process. The analysis of system mission and system functions lead to functional requirements which are the basis of allocation the decomposed functions to men or machines. Finally the analysis of the operator tasks and machine processes give the data for interface and workstation design, to be tested in terms of operator workload and system performance.

The functions to be fulfilled on a bridge, conceived as an operational centre, might be: navigation, communication, propulsion, course control, electricity supply and ship's condition monitoring. In the present study, functions were decomposed to such a detailed level that performance by personnel or equipment could be allocated unambiguously.

Each decomposed function was analyzed (Schuffel, Dijkstra, Weeda and Tresfon, 1981) with regard to information source and information processing, control criteria and cations, statistics of accidents (Drager, 1981) and human factors data (Salvendy, 1987).

As shown in Table 1, the results of the allocation emphasized the Officer of the Watch's role as a look-out, decision maker and supervisor of automatons, whereas control functions are limited to set-point adjustment. At the planning level the master can be assisted by computers for optimizing the route with regard to minimal fuel usage, but decision support systems are not yet applicable and have to await further development. At the intermediate level the computer can support monitoring functions. For instance,

the Automated Radar Plotting Aid is superior in detecting and tracking targets on the radar display. The identification of targets however, need the human eye. At the control level the adaptive autopilot can replace the helmsman.

Table 1
Summary of a function allocation process for high workload conditions at congested navigational areas. A = automated functions. M = Manual functions.

activities	perception	functions information processing	motor control
planning	A M	A M	M
monitoring	A M	A	M
executing	A	A	A

The expansion of automatically controlled functions and the availability of electro-optical computer controlled displays make the design of workstations for single handed operation feasible. In Figure 1. the mock-up of a future bridge design concept is shown.
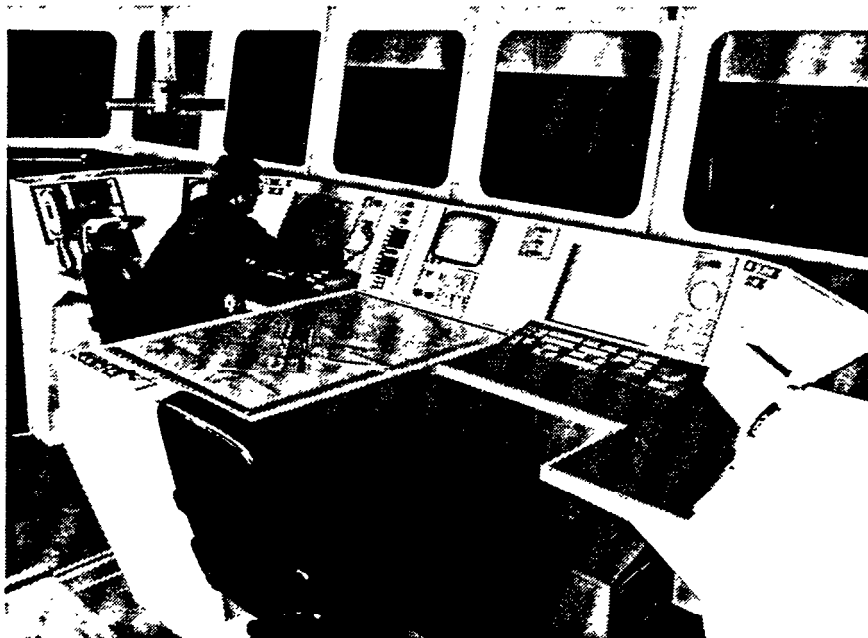

Figure 1. Picture of the mock-up of a future bridge design lay-out with a semi-automatic chart table and displays for monitoring navigation and platform functions.

In Figure 2, a sketch of the navigation display is presen-
ted. The three levels of information concerning planning,
monitoring and executing activities are presented in dif-
ferent colours to enhance overview and detailed information
at one glance (Baty and Watkins, 1979). The planning infor-
mation contains geographical, wave, wind and intended track
data. The monitoring information consists of the ship's
position and movement status, such as: heading, change of
heading, under keel clearance and its change, a ground
related velocity vector and echoes of ships, with velocity
vectors calculated by the Automatic Radar Plotting Aid
automaton. Information at the lowest level shows the rudder
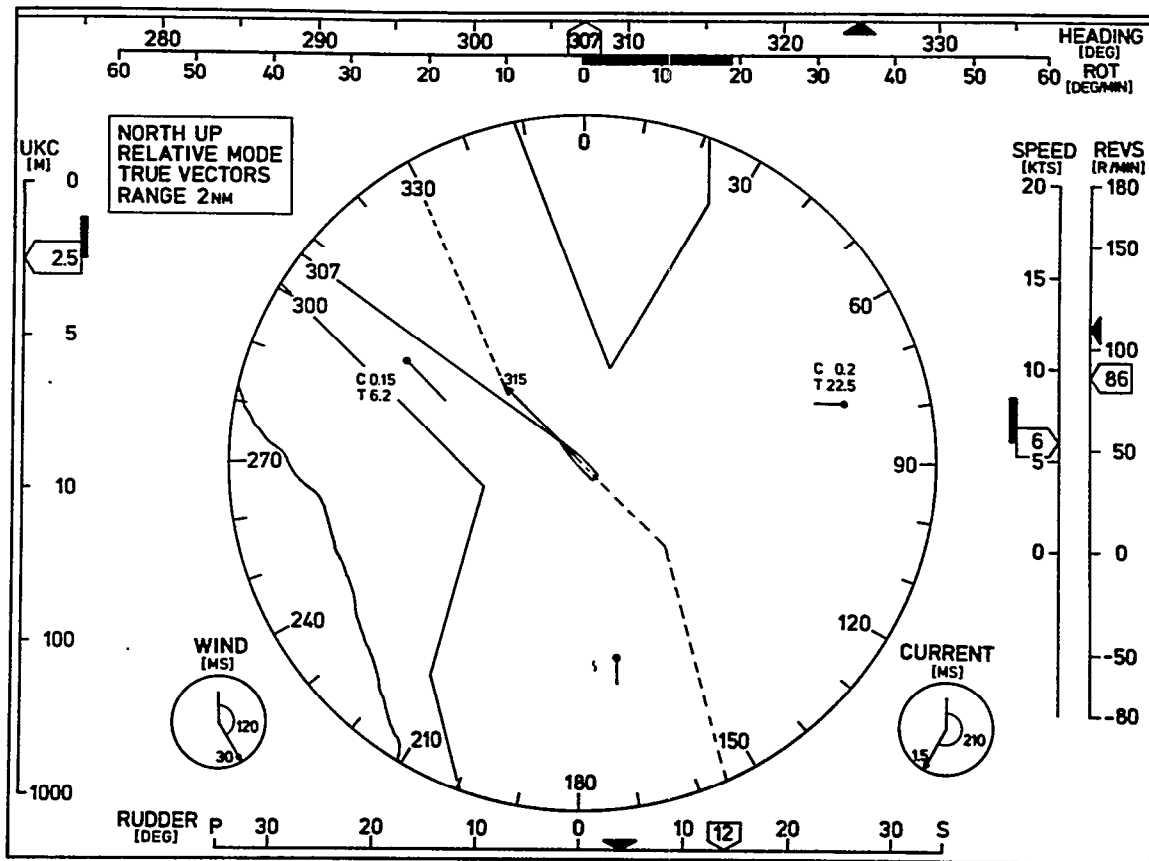deflection and shaft revolutions status.

Figure 2. Navigation display with integrated information
concerning planning, monitoring and executing activities.
The three levels of information ought to be presented in
different colours.

Testing operator's workload and system's performance

Method

The present study is focused on high workload conditions in coastal and congested areas. For these conditions, one of the relevant questions is whether one ship handler (the Officer of the Watch) can cope with the mental workload, maintaining the system performance at the actual average practice level. Mental load is defined here as the degree to which a task appeals to active processing of information; i.e. the number of conscious cognitive operations per unit of time.

The mental load of a primary task can be measured by using a standardized second task that requires active information processing continuously. The procedure is as follows: after training, the performance on the second task is measured separately; next, the second task has to be executed while navigating. The resulting performance reduction on the second task reflects the mental load of the navigation task.

To investigate the effects of automatic equipment on the mental workload of the Officer of the Watch and on the accuracy of navigation, performance of single-handed operation in an automated ship's bridge, the so-called "Bridge '90" has been tested against an average conventional bridge with two and one person control (Boer and Schuffel, 1985a, 1985b; Boer, Van Breda and Schuffel, 1986).

The mental load of the navigation task is expected to be larger in the one-officer-operated conventional bridge compared to a two-officer-operated conventional bridge and a one-officer-operated automated bridge. The main reason is that the design of Bridge '90 has been aimed at technical automation of routine tasks (e.g. position estimation) and optimizing information presentation by integrating relevant parameters on a navigation manoeuvring display (see Figure 2). Hence, as much attention as possible is free for planning and decision making as well as for a proper execution of additional tasks. In the conventional bridge, two officers are considered by maritime authorities to be quite capable of executing navigation and additional tasks. For one officer, however, it is believed that too much time is lost by sampling necessary information and too much attention is consumed by routine tasks to allow a proper execution of additional tasks.

In three simulator experiments, a total of 32 representative watch officers had to follow predetermined tracks in a coastal area with a 40,000 tons container vessel. The visibility range was 5 km, there was moderate traffic density and normal current and wind conditions. Deviations from the predetermined track were calculated as root mean

squared error to indicate accuracy of control. A continuous
aurally-presented memory task (CMT) was used to determine
the mental workload that the navigation task imposed on the
Officer of the Watch. Subjects were asked to memorize four
consonants in randomly presented letters of alphabet during
seven minutes. The sum of the absolute number of deviations
as a percentage of the total number of target consonants
was calculated to indicate workload. Three main conditions
were investigated.

> A conventional bridge with an Officer of the Watch
> charged with conning functions, assisted by a tracking
> officer (condition A):
> A conventional bridge with single-handed watch (condi-
> tion B);
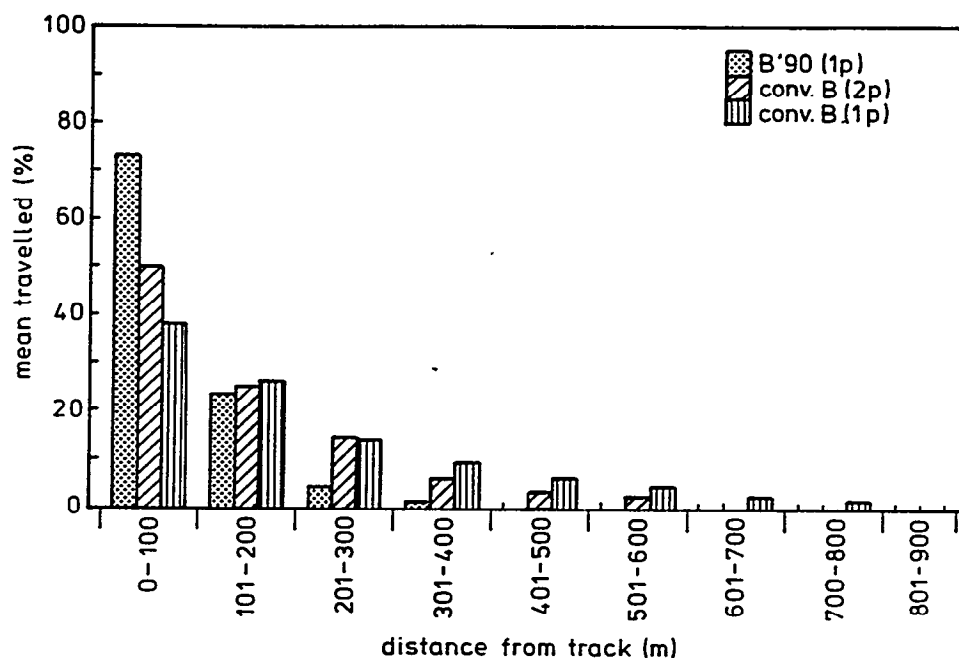> Bridge '90 with single-handed watch (condition C).

Figure 3. Mean percentages of the travelled time that the
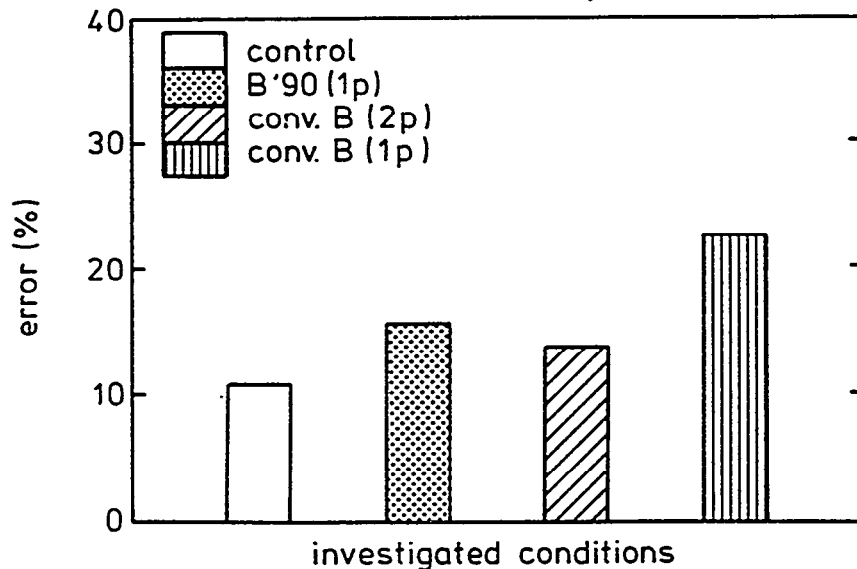ship remained within intervals of 100 m from the track.

Figure 4. CMT error percentages in the control and investigated conditions.

Results

Navigation accuracy. In Figure 3, percentages of the time
(averaged over tracks and subjects) that the ship travelled
within intervals of 100 m from the intended track *are* given
for the three conditions. In Table 2 the results of t-test
are presented.
From Figure 3 and a statistical analysis it becomes clear
that navigation accuracy differs significantly among the
three conditions. Navigation performance is superior in
Bridge '90. Path width remains within 400 m for 95 per cent
of the time. In contrast, two-officer operation in the
conventional bridge results in a comparable path width of
800 m, and one-officer operation even in 1200 m.
Mental load. In Figure 4, mean error percentages of the CMT
of the control and experimental conditions are presented.
The results of a statistical analysis show no significant
differences between the mental load of the navigation task
in the two-officer-operated conventional bridge as compared
to Bridge '90. Perhaps even more surprising is that for
these conditions (A and C), only a slight, and not sig-
nificant, deviation from the control condition can be
observed. This reflects that the mental load of the naviga-
tion task is quite low. In contrast, the mental load of the
navigation task in the one-officer- operated conventional
bridge (B) is significantly higher as compared to the
control, A and C condition. This difference suggests the
presence of attention-demanding task components (notably
position estimation).

Discussion

Observed differences in navigation performance and mental load of the navigation task can directly be attributed to bridge design on the one hand and number of officers on the other hand. As mentioned before, the two-officer-operated conventional bridge served as standard against which other conditions were tested. As far as Bridge '90 is concerned, it may be observed that due to accurately and continuously presented position feedback, navigation performance is superior as compared to the other conditions. As a consequence, navigation accuracy is improved.

The more accurate navigation in Bridge '90 does not seem to increase the mental load of the navigation task. Apparently, the greater frequency at which actual position is monitored as well as decisions on control actions resulting from these observations do hardly require attention. This conclusion is supported by the fact that CMT error percentage in Bridge '90 does not differ from the error percentage in the control condition.

Possible reduction of shipping accidents

Method

The causes of 100 Netherlands shipping accidents (1982-1985) were analyzed with regard to the question whether an automated wheelhouse concept could have prevented these accidents (Schuffel, 1987). Events necessarily contributing to the 100 accidents were categorized in an activity/system element matrix and in an activity-function matrix. In this exploratory study, three experts (an ergonomist, a nautical officer and a psychologist) estimated on the base of fault-tree analysis, whether the automated wheelhouse concept would have affected the occurrence of the events. It was expected that differences between the number of events related to accidents with conventional ship bridges and to supposed accidents with the advanced automated bridge, would reveal advantages and disadvantages of the function allocation process and the inferred automated wheelhouse concept.

Results

The results showed that 276 events were involved in the 100 shipping accidents. This number of events consisted of 209 events related to human errors, 24 related to hardware errors, 9 related to procedural errors and 34 related to environmental errors.

The automated wheelhouse concept would have reduced the amount of 276 events to 88; a reduction of 68%.

Regarding the reduction of the number of events related to human error only, Table 2 provides an overview. The

209 human error-related events were reduced by the auto-
mated bridge with the number of 162 to a remnant of
47 events.

Table 2
**Reduction of the number of human error-related events due
to the automated wheelhouse concept.**

activities	perception	info processing	functions info storage	handling	rest	total
voyage planning		27	2	0	0	30
voyage execution	1	65	4	0	0	88
communication		4	0	0	0	6
monitoring tasks	0	28	9	0	1	38
total	22	124	15	0	1	162

Discussion
**The results showed that the automated wheelhouse concept
might be highly effective to reduce human errors. Hardware
and procedural errors might be affected to a lesser degree.
Environmental factors, including communication and informa-
tion exchange between ship and shore seem to be nearly
affected. This emphasized that the effectiveness of the
automated wheelhouse concept is, of course, also dependent
on the organization of the shipping company and the mari-
time authority.
The distribution of the events over activities and func-
tions shows that in particular errors could be prevented in
the performance of the information processing functions.
With regard to the simulator experiment results, these
improvements are interpreted as the improvements of
navigational performance supported by the semi-automatic
chart table, the integrated APRA-manoeuvring display and
the availability of navigational an auxiliary systems
information at one position.**

Conclusions and recommendations
**It has to be emphasized that the investigations concerned a
feasibility study, primarily concentrated on human per-
formance and mental workload of the Officer of the Watch.
It is obvious that a number of other important items have
not been addressed. On the one hand, the effects of monoto-
nous watch conditions on the operators' alertness and the
effects of the change in the task structure - from active
manual control to passive monitoring activities - on the
operators' skill and interest in the job, need more**

research. On the other hand, the progress of technological development and the reliability of automatons and human beings is assumed on the basis of similar developments in aviation. Although the suggested technology is not extremely advanced, applications of electro-optical computer-controlled displays and the related chain of sensors, as well as data preprocessing and data transmission is not widely spread in the maritime field. Currently undertaken projects, such as the development of the electronic chart, indicate that progress may be expected here.

It is speculated that the annual number of accidents will decrease when an automated, ergonomicaly, designed, bridge concept is put into practice. The costs of studies and the investment due to new equipment are negligible (presumably 1 per cent of the design costs), in comparison with the estimated prevention of injury, loss of live, and the saving of environment and capital.

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QUALITY ASSURANCE IN THE SHIPPING INDUSTRY

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Abstract
The paper reviews the growth of quality system implementation in the shipping industry since the early 1970's. The initial interest was focused on the new build aspect. This was developed successfully in Japan and later adopted by some European yards to improve their competitive position.

In the mid 1980's repair establishments started to show interest in quality systems although they faced different problems than those experienced in new construction. The most recent adoption of QA has emerged from the ship management sector of the industry.

Adoption of ISO 9000 requires in some instances supporting guidelines which assist in interpretation of the standard for a specific industry. Lack of uniformity in the guidelines produced by certification bodies has created a problem in itself. Some of the difficulties encountered during assessments are described although common problems across new build, repair and ship management are communication and document control, training and commitment.

Introduction
Within the shipping industry, the principles of quality assurance have gradually gained acceptance over a period of some twenty years. The initial interest commenced with the new construction sector in the early 1970's and much later spread into those organizations offering repair capabilities.

Certain recent events in the shipping world focused attention on the actual management of vessels particularly with respect to safety and pollution. This has created a further opportunity to use the management controls afforded by the implementation of the quality system standards in the ISO 9000 series.

QA in New Construction

Perhaps the most notable attempt to implement a quality management system approach to new build came in Japan in the early 1970's. With the introduction of the Very Large and Ultra Large Crude Carriers (VLCC's and ULCC's) the need to closely control and monitor the work flow became a critical aspect if delivery deadlines and product quality were to be achieved.

The problem facing those Japanese yards who were producing such vessels, many of which were 2.5 million tonnes dwt and larger, was the fabrication of some 135,000 tonnes of steel in a timescale of 40 to 50 working days.

Traditional inspection techniques had to be coordinated and precise build and inspection programmes had to be integrated into a closely controlled quality system. With the volume of material to be handled, the control of suppliers assumed a major importance as delays or late rejections would seriously influence the defined programmes. Supplier control coupled to Just In Time delivery was therefore essential.

The early quality programmes did not have the advantage of using ISO 9000 for their structure. However they effectively covered all the essential elements which are now taken for granted in any comprehensive quality system. There was still a heavy bias towards inspection, with three stage inspection being the general approach.

A number of the major Ship Classification Societies had recognized that they could take advantage of the quality systems being implemented by the shipyards to streamline their traditional inspection approach. By employing a blend of inspection and system audit the Classification Societies could still exercise their control over the process and at the same time obtain a greater insight into the company's operation.

Lloyd's Register of Shipping, the oldest Classification Society introduced its Hull Construction Scheme in 1973. Although the scheme did not cover all of the system elements now embodied in ISO 9001 requirements, it did have all the important features which would be expected in a comprehensive system, eg:

    process control
    calibration control
    design
    inspection and testing
    records

incoming material control
identification and traceability
fabrication control
sampling procedures
corrective action
control of nonconforming products

The first shipyard granted Lloyd's Register approval was NKK Tsurumi Shipyard in Japan followed quickly by 9 further Japanese yards. The move towards certification in yards outside of Japan was limited. In order to survive as international builders of merchant ship, a number of European yards progressively realigned their production controls and successfully implemented the requirements of the various Classification Societies with respect to quality systems. Under the Lloyd's Registers scheme, the first European yard to gain their approval was Odense Staalskibsvaerft A/S followed by yards in France, UK and Belgium.

With regard to the UK scene, those yards which had dealings with the Ministry of Defence warship programmes already had experience with management system evaluations. The MOD had introduced its own assessment standards - the 05 series -in the 1970's to control all of their suppliers. The standards were later to form the basis of the UK national standard BS 5750. This in turn was taken as the basic document for the development of the International Standard IS0 9000 series for the evaluation of management systems.

With the publication of the IS0 9000 standard in 1987, this generated in its wake a renewed surge of interest in system certification from shipbuilders. In the UK, LRQA acting in its capacity of a third party certification body was contracted to evaluate most of the major shipyards supplying to the merchant fleet.

The IS0 9000 requirements extended beyond those previously covered in the Classification Society schemes with stronger emphasis on written procedures, training, internal auditing etc.

Assessments undertaken by LRQA showed that almost one third of the requirements in IS0 9001 were cause for raising deficiency reports (non-compliance notes). -In relationship to the clauses in IS0 9001, the following illustrates some of the problems encountered:

Quality System (4.2): This particular clause requires written procedures and work instructions throughout the organization. These have been lacking in many instances with a reluctance to commit working practices to paper.

Document Control (4.4): Generally there are a high number of documents in circulation eg. drawings, often with a short life expectancy. Control is recognized as being vital but difficult to implement. Work package systems, distributed and maintained at key work areas have gone a long way to improving the situation.

Purchasing (4.5): Many items are only purchased to satisfy a single contract and the control exercised over suppliers is often difficult. Past contract reviews are one means of establishing future supplier selection.

Process Control (4.6): Many shipyards and also manufacturers fail to realise that the following processes require qualification, testing of equipment and personnel evaluation.

Welding
Galvanizing
Heat line bending
Plating
Painting, etc.

Inspection Equipment (4.10): The significance of calibration is not well understood. An effective system should strive to reduce the amount of calibration to the minimum yet stiJl ensure that measuring equipment is suitable for the tasks performed. In some cases the cost of calibration may exceed the equipment cost and replacement may well be the most economic solution.

Internal Quality Audits (4.16): This feature is new to many yards where traditionally any form of audit or surveillance has been undertaken by the foreman. The findings are rarely formally reported and instant rectification on verbal instruction is the general practice with little chance of establishing the root cause of quality problems.

QA in Ship Repair

Unlike the new build environment where long term planning and programming is possible, the repair aspect presents a different set of circumstances. Speed of response can be of the essence if the trading capability of vessels and hence financial viability is to be maximized. Accommodating the element of speed to satisfy an owner creates difficulties when operating within a quality system designed to comply to the ISO 9000 series. Some of the problems facing repair yards are as follows:-

Contract Review (4.3): This represents a main problem as contract review is generally done from verbal instructions or at best very limited written instructions ie. "recondition" "service" etc.

Process Control (4.9): There is often a lack of details available ie. no original drawings, specifications etc. Because of the need for rapid turn-round standard procedures are ignored.

Purchaser Supplied Product (4.7): It is generally overlooked that items provided for repair are customer supplied products. Items should not be scrapped without prior agreement.

Many of the problems associated with the repair aspect can be resolved by introducing a relatively simple documentation system. The question of contract review and process control can be handled by the yard giving confirmation to the customer as to their understanding and extent of repair. This can be transmitted to the process planning. Irrespective of the repair, certain tasks can be covered by general standing instructions, eg.

      weld repair
      cutting procedures
      line heating

Specific equipment strip down and maintenance can probably be handled by using manufacturers maintenance manuals.

Ship Management and QA

Although the principles of quality management systems have been readily adopted into the manufacturing industries, including the shipbuilding industry, the concept has now spread into the service sectors. Within the context of QA in service industries, the transport and distribution sector has certainly taken a positive move. This has been mainly orientated towards road transport, however over the last 18 months a great deal of interest has been created in the use of IS0 9000 in the activity of managing vessels.

The intention of using IS0 9000 in the service industry and particularly in the field of ship management has caused some organization to question its applicability. The general impression from certain quarters is that the standard was developed by engineers, for engineers and is applicable only to engineering activities.

The standard can be used over a very diverse spectrum of industry and this extends to the service sector. However what is required is a guidance document which interpretates the IS0 9000 requirements in terms of the specific industry. This is the case with Ship Management if IS0 9002 is to be accepted as the appropriate assessment standard.

A complication which has arisen in the Ship Management sector has been the publication by the International Maritime Organization fIM0) of draft requirements IMO A647/16 relating to safety and pollution prevention. (This document has recently been revised to edition IMO A680/17). The document has many features which would be expected within any comprehensive quality system and has resulted in some certification bodies merging the requirements of IS0 9002 and IMO A647/16.

The ship management industry is now being confronted with a bewildering number of options with schemes ranging from IS0 9002 hybrids to those which are more strongly biased to the IMO draft requirements. Some of the options now available are:

- International Ship Managers Association Code (ISMA)
- Dnv
- BVQI
- ABS
- LRQA Ltd

International Ship Managers Association Code:	**This can be regarded as the starting point of Ship Management schemes although it should be mentioned that a number of major operators already had implemented their own in-house systems. The code is extensive in ik requirements and covers both shipboard and shore based activities. Certain demands of the code are outside of the ISO 9002 requirements eg. cost efficiency, insurance, accountancy. The actual process of auditing is undertaken as a joint arrangement between the three Ship Classification Societies who have been associated with the development of the Scheme.**
Det Norske Veritas:	**The scheme was issued as DnV tentative rules for the "management of safe ship operation and pollution prevention". As with the ISMA code, the scheme covers both ship and shore activities and encompasses IMO 647/16 together with elements of ISO 9002.**
Bureau Veritas:	**The BV Scheme makes provision for shore/ship based activities and incorporates IMO 647/16 requirements and ISO 9002.**
American Bureau of Shipping:	**The ABS document on ship management issued in ApriI 1991 requires compliance with ISO 9000 series and IMO 647/16.**
Lloyd's Register Quality Assurance Ltd:	**The scheme developed by LRQA follows each clause of ISO 9002 and incorporates into the appropriate clauses the requirements of IMO 647/16.**

In the early days of QA certification in the manufacturing industries, each certification body produced its own guideline to the assessment standard. This caused confusion because the final certification was to the appropriate National Standard eg. NEN 2642, BS B7!50 yet the guidelines had differences of approach.

This situation has now been repeated in the Ship Management field with equally confusing results. The solution which has gained ground in the manufacturing industry has been for the industry to develop suitable guidelines together with interested Certification Bodies. A good example of such an approach has been achieved in the Chemical Industry in UK. The time may come when the shipping industry, ie. the Ship Management element develop a similar approach. However because of the sensitive nature of preparing a unified guideline ie. it may influence the eventual classing of a fleet, then this may be a long term hope.

An important feature of the various ship management schemes is that they are voluntary and this has always been the case with third party QA certification. However there appears to be a mounting pressure to have mandatory certification regarding the ship management aspect and this is causing concern to certain operators, especially the smaller operators.

From the assessments undertaken by LRQA, certain features have consistently emerged regarding problem areas.

Resources (4.1.2):	Shore based office staff are usually quite limited in numbers and there is little resources remaining to take on the additional duties of the "quality/safety representatives. Invariably the appoint of such personnel leads to higher loading on the individual and the quality/safety aspect assume secondary priority. Similarly the resources available to develop and maintain the scheme are limited.
Calibration (4.10):	The calibration requirements of ISO 9002 cause grave problems. The degree of control used in manufacturing industry is misplaced in ship management. What has to be determined is precisely what instruments or equipment require to be calibrated eg. length, volume and weight measurements, navigation equipment, cargo monitoring instruments are typical. It is easy to impose extensive bureaucratic systems which have no positive and practical significance.

Internal Auditing (4.16)
h Management Review (4.1.3): Although surveillance of the system may be undertaken it is often sporadic. There is no defined programme and little evidence available of it being undertaken. The management review often only consists of reviewing deficiency notes issued on the system without understanding the full extent of what the review should consider, eg.

changes in trading conditions.
manning requirements.
suitability of the system to current operating needs.
analysis of complaints.
changes to company structure which have been or should be implemented.
defining quality improvement targets.
establishing and agreeing internal audit programmes.

Documentation (4.4): Because of the traditional nature of the industry, the documentation aspect as required by the IS0 9002 standard is usually quite vague or non-existent. Controlling the issue of documents has not been a strong feature in many of the systems examined.

Conclusion
The adoption and implementation of quality assurance techniques together with formal certification has been rather a slow process in the shipping industry. Logically the starting point was focused on new build although even in this area the adoption has not been widespread or particularly rapid.

Moving into the service sector of the industry has brought with it a degree of controversy with feelings running high amongst some of the shipping c o m m u n i t y .

Although it is possible to highlight specific problems under each category of the industry, ie. new construction, repair and ship management there are two problems common to all aspects:

Documentation: The most significant deficiency has been that related to documentation as this impacts on so many of the elements in the system.

A fundamental aspect of a quality system is good communication and a concise communication network must be established if the system is to be successful. The written word is a key feature and virtually every element of the assessment standard requires "written procedures" as it is recognized that verbal instructions can so easily be misunderstood or forgotten.

To be effective, instructions and procedures must be up to date and there must be a defined system to update documentation otherwise unauthorized practices quickly develop, product/service quality and productivity suffer.

Training: Throughout an organization problems can often be attributed to lack of knowledge as to what is expected. This indicates that one of the single most important factors in actually improving quality is training.

Often non compliance reports raised on the training clause of the standard relate to records. However without adequate training in procedures, work instructions etc then the documented quality system FIN never produce the anticipated benefits.

Training is essential to create the desired atitude change towards quality and it must cover all levels of the company. The implementation of sound training programmes can achieve the desired attitude towards quality awareness and provides a base from which Total Quality Management becomes a reality.

The continued adoption of quality management systems in all sectors of industry as a mechanism of improving product and service quality indicates the usefulness of well documented and implemented systems.

Certification of the system by an independent third party organization such as LRQA is not a requirement of the assessment standard. However, in the current commercial climate, many end users are demanding evidence of such certification and this is driving the market awareness for formal certification.

Systems implemented solely to satisfy end user demands seldom have outstanding success. The desire and belief in quality and quality systems must come from inside the company if really success is to be achieved.

Basically there are no real barriers to the shipping industry in adopting quality management systems - it rests with the commitment of the company and their desire to provide a quality product or service.

QUALITY ASSURANCE IN NAVAL SHIPBUILDING.

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Abstract.

Contracts for the building of Naval ships - and for the
greater part of Merchant ships as well - include
requirements on Quality Assurance according to the
international standards, for instance AQAP-1 or ISO-9001.
Elaborating these requirements into an efficient and
company-oriented quality system demands a high level of
engagement of the company's employees on all organization
levels.
Insufficient engagement on the part of the employees will
often lead to a large amount of written manuals,
procedures and instructions, experienced by those involved
as a non-integrated part of the organization and therefore
considered as an extra workload.

For some years Royal Schelde developed and introduced a
company information system in which the requirements of
AQAP-1 and ISO- have been integrated.
The set-up of the system is process-oriented with
llinformationn as a basic concept.
The system has been laid down in process diagrams and
information-instruction-descriptions.
The managers on all organization levels were and are still
held responsible for their share of the information
records as part of the system as well as for the
implementation and observations thereof.
In this way the organization, the procedures and the
quality aspects during all the phases of the production
process, have been laid down in a clear and compact **way**,
while the production process itself is carried out under
controlled conditions.

The goal of this presentation is to present examples of
to-day's practice in relation to the realization and
implementation of Quality Assurance in Shipbuilding.

1.   INTRODUCTION.

This presentation will also be based upon the experience gained during the early seventies and up till now by extended implementation and maintenance of the quality assurance system for Royal Schelde's Business Unit Shipbuilding.

Royal Schelde was established at 'Vlissingen in 1875 under the name of Koninklijke Maatschappij "de Schelde", mainly focussing its attention on shipbuilding and marine engineering.
Under the influence of the industrial revolution its activities expanded to various other branches.
Through the years the business has developed into a company which now employs about 3600 people.
It yearly sales value amounts to more than NLG 800 million.
In 1992 the organisation started to convert into a more market oriented structure.
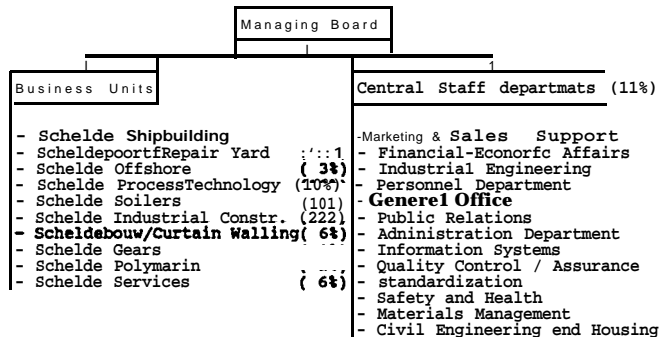The name of the group of companies was changed into "Koninklijke Schelde Groep", however the English version remained the same: Royal Schelde.
The core of the new organisation structure consists of ten business units, each working with a high degree of autonomy.
Maintaining individual responsibility *for* their results, these business units are covering Royal Schelde's activities in the field of marine constiructions, energy conversion, process and environmental technology, curtain walling, industrial services and the design and development of products composed of exotic metals and/or advanced composites.

A number of central staff departments supports the business units and the Board of Management.
Each Business Unit includes its own quality department.
Structural deliberation remains between the head of the central staff department for l[t]Quality Control/Assurance[11] and the heads of the Business Units quality departments.
A brief summary of Royal Schelde's organisation is given in figure 1.

Managing Board

Business Units

Central Staff departmats (11%)

- **Schelde Shipbuilding**
- ScheldepoortfRepair Yard   :':::1
- Schelde Offshore   (3%)
- Schelde ProcessTechnology (10%)
- Schelde Soilers   (101)
- Schelde Industrial Constr. (222)
- **Scheldebouw/Curtain Walling**(6%)
- Schelde Gears
- Schelde Polymarin
- Schelde Services   (6%)

-Marketing & Sales Support
- Financial-Econorfc Affairs
- Industrial Engineering
- Personnel Department
- **Genere1 Office**
- Public Relations
- Adninistration Department
- Information Systems
- Quality Control / Assurance
- standardization
- Safety and Health
- Materials Management
- Civil Engineering end Housing

( ) Breakdown of personnel mid. 1991.

Figure- 1 Royal Schelde organisation structure.

2.   <u>SCBELDE SHIPBUILDING.</u>

The core business of Schelde Shipbuilding mainly consists
of:

Naval Vessels
- design and construction of surface naval vessels,
  including vessels for coast-guard duties and other
  para-military application.
- service life-extension programmes

Merchant Vessels
- design and construction of sophisticated vessels

High Speed Ferries
- design and construction of WES" (Surface Effect
  Ship)

A summary of secured orders from 1975 up till now, is:

10 Standard Frigates
 2 Air Defence Frigates
 1 Diver and Hydrographic Training School Vessel
 1 Torpedo Recovery Vessel
 8 Multi-Purpose Frigates
 1 Surface Effect Ship
 1 Auxiliary Oiler and Replenishment Ship
 1 Ro-Ro Passenger Ferry

3.   <u>QUALITY SYSTEM SHIPBUILDING.</u>

The contract for building the Standard Frigates implied
that during the execution of this contract a quality
system had to be applied meeting the requirements of the
AQAP-1.
It then was for the first time that Schelde Shipbuilding
got a contractual obligation to apply and to perform
according a quality system.
The quality system developed and implemented at that time
was completely department-oriented and it was laid down in
department manuals.
Although that quality system was meeting the requirements
of the AQAP-1, an increasing number of disadvantages was
met in the course of years when practising and maintaining
the system.
Those disadvantages concern among others:
- the large number of written manuals;
- the process-oriented activities had been
  described in different manuals;
- the same general information was given in
  each manual;

- the junctions of activities from different
  departments were badly regulated in many
  cases;
- the top-down structure was not clearly visible;
- the llquality-looplt aspects had been insufficiently
  described;
- the responsibilities and competences had been
  insufficiently described.

For a.o- the above mentioned reasons, the top-management
of Royal Schelde decided in 1986 to establish a
process-oriented quality system which should be laid down
by means of a different methodology.
The basis of this system is the following:
For an effective and efficient functioning of an
organization, it is of importance for quite a number of
activities to be performed in a regulated and always
identical way.
In order to realize such a functioning and because all
activities are controlled by means of <u>information</u>, a
<u>company information system</u> has been chosen in which:
- <u>company processes</u> (activities) and <u>information flows</u>
  are shown by diagrams and
- <u>information-instruction descriptions</u> are prepared in
  which the relative staff employees are mentioned.

The development and subsequent elaboration of this company
information system has been executed in accordance with a
plan of improvement, prescribed by the Royal Schelde's
management.
An important aspect of this matter was the formation of
working-teams, consisting of managers and executives /
staff-members from the various line-functions.
Those teams were responsible to the top-management and
were co-ordinated by a control panel.
The advantage there-of is, that the executives were
directly involved in the development of the system from
the very beginning, bringing them the experience the
system is an integrated part of the organisation.
Moreover, because of that fact the implementation of the
system was simplified considerably.

4.   <u>THE COMPANY INEQRHATION SYSTEM</u>.

<u>General.</u>

The system is process-oriented and contains the following
company processes:
- Managing the enterprise.
- Managing primary processes.
- Marketing and sales.

- Managing of projects.
- Development, design and engineering.
- Purchasing goods and services.
- Materials management.
- Production.
- Setting to work, Testing and delivery.
- Servicing the product in the field.
- Providing support.

These company processes are shown in diagrams by means of
the IDEF-0 methodology and focussing on the "information
flow".
(IDEF = Integrated DEfinition Function modeling method).
This means that in the diagrams function boxes are shown
which are connected by information channels.
A box, together with its input and output arrows can be
considered as an element of the diagram.

A general impression of such a function-box is shown in
figure 2.

```
                              │CONTROL
                              │(Requirement, regulation etc.)
                              │
                              ▼
                    ┌─────────────────────┐
INPUT               │      FUNCTION       │              OUTPUT
                    │  (proces/activity)  │
  ──────────────▶   │  described by a verb│     ──────────────▶
                    │  and possibly a noun│
                    └─────────────────────┘
                         ▲         │
                         │         ▼
MECHANISM                            CALL
 (human resources/means)             (process described elsewhere)
```
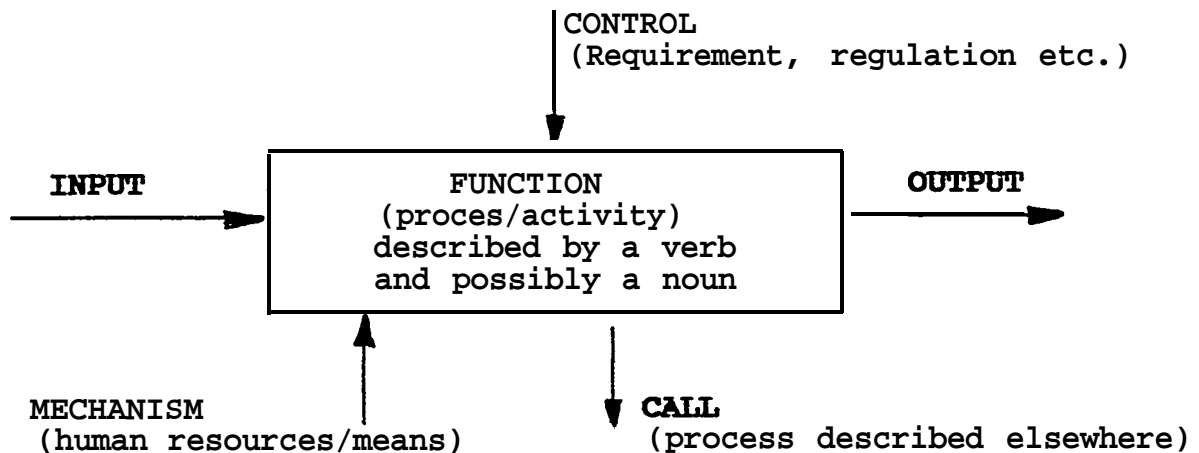
Figure 2 Typical IDEF-0 element.

The function (process/activity) transforms input into
output.
However, this process of transformation is subjected to
controls, which keep the transformation between certain
limits.

Mechanisms as human resources (professional skill and experience) and means (technology, buildings, equipment, tools etc.), which help to bring about a function but which are not changed as a result of the activity, are necessary.

Finally, a different function can be called from the function in the box concerned through call.

A call is an arrow pointing downwards in a diagram which refers to a process specified elsewhere and as such brings that process into the diagram.

Near the llcalln-arrow the number of the diagram is given which provides further information about the function called.

Diagram Structure.

The first box of a complete set of diagrams represents the system one wishes to show.

This box is only shown in the top diagram, the so-called A-O (A minus zero) diagram.

In the next more specified diagram the structure of the functions within the system is shown, resulting in the A0 (A zero) diagram.

So the A0 diagram is created by zooming in on the A-O diagram.

By zooming in on the functions of the A0 diagram, a new diagram can develop from every box.

In this way a top-down hierarchy of the diagrams is formed, the first ones representing the structure of the total and the last ones the structure of the specified activities.
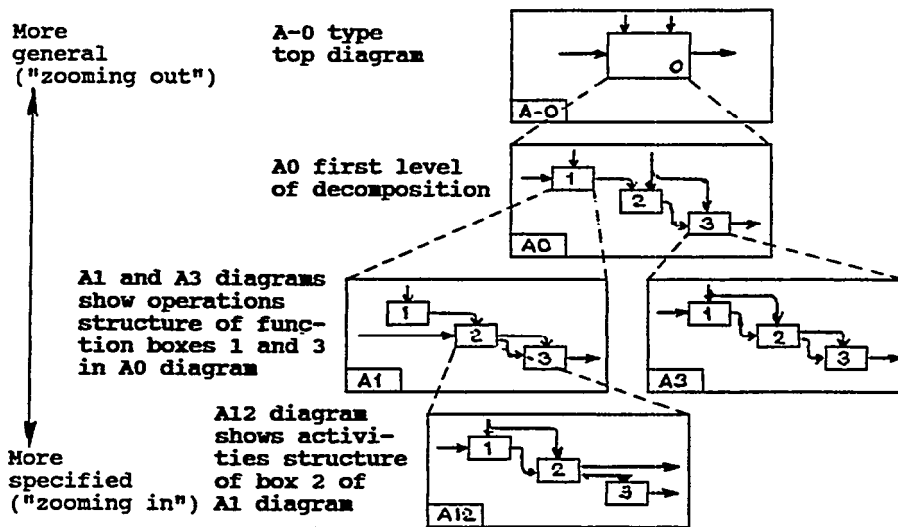
Such a structure is shown in figure 3:

Figure 3 Typical IDEF-0 structure,

This composition clearly shows that the diagram numbers
represent the relations between the functions.
Each time when a figure is added one arrives at a lower
composition level.
This is a so called the parent/child relation.
In case of two consecutive diagrams, the highest diagram
is regarded as the parent of the lowest diagram.

The diagrams are linked together by the numbers!
With the help of these numbers an index can be made of all
diagram boxes, the so called "node-index".
The "A" before the numbers means "Activity".

<u>Arrows.</u>

In *this* method it is possible to findback the arrows
crossing the bounderies of the scheme in the child-diagram
in the parent-diagram on the box originating the
child-diagram.
As shown in the Al2 diagram in the previous figure, for
exemple, four arrows pass the lines of the scheme and four
arrows are connected to box 2 of diagram Al.

The arrows can be regarded as channels along which the
information flows.
In the direction from left to right, they indicate
feedforward flows.
Arrows going from right to left are considered feedback
flows.

Status reports (indicated in the diagrams as status) and
problem definitions (indicated in the diagrams as
problems) represent important feedback information.
Such feedback information is shown in nearly every
diagram.

As explained before, the arrows in the diagrams shall
serve as information channels.
These information channels operate by means of several
kinds of "data carriers", like reports, drawings, computer
printouts, monitor information, even verbal information,
etc.
In order to obtain an overview of all the information
playing a role in the diagram structure, an information-
instruction description is made for each carrier or group
of carriers together.

Information-instruction descriptions.

In the information-instruction descriptions all important documents and all duties and responsibilities of the involved executives are laid down.
The information-instruction descriptions are laid down in a standard form consisting of two parts.
In the first part the function, contents and use of the data carrier is given together with possible references to connected procedures and/or instructions.
In the second part those who are responsible for the preparation, review and authorization of the carrier are mentioned as well as those who have to take actions as a result of the contents of the carrier.
This second part of information-instruction descriptions combine the company's organization with its structure of functions.

An example of such an information-instruction description is given on page 10, figure 6 and page 11, figure 7.

Documentation of the company information system.

These documentation comprises the following:

- ROYAL SCHELDE MANUAL, containing:
  - the organization of Royal Schelde;
  - diagrams (functions, processes-activities):
  - information-instruction descriptions;
  - general information, such as the explanation of the system and control-aspects.

- BUSINESS UNIT MANUAL, containing:
  - the organization of the business unit and the business unit's departments;
  - duties, responsibilities and competences. of the managing employees.

- PROCEDURES, in which a coherent description is given of the working-method within a certain process as a furter specification of the diagrams and information-instruction descriptions.

- INSTRUCTIONS, that (only if necessary) are prepared by the department's management, and which also control the distribution and performance.

The advantages connected to the above mentioned company information system are among others:
- based on the flows of information in the company processes, the usual working-methods have been fixed;

- the requirements of ISO- and AQAP-1 have been
  integrated in these working-methods:
- the system contains a minimum of documents and it
  provides a clear insight into its structure.(top-down);
- the necessary data carriers as well as the involved
  duties and competences have been laid down in a
  uniform way; -
- the principles of the "quality loop" have been
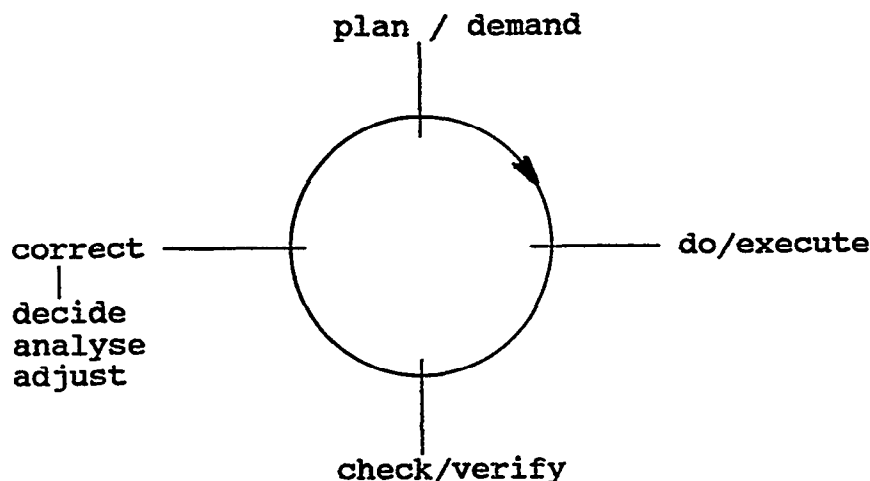 completely integrated into the system.

Figure 4 Quality Loop.

5.   ORDER-ORIENTED APPLICATION OF THE COMPANY INFORMATION
      SYSTEM.

For the execution of each contract a project-manager is
appointed by the director of the business unit.
Since the company information system describes all
company's processes and where at the same time all
requirements of both the ISO- and AQAP-1 are
integrated into those processes, it is necessary to
determine for each project which parts of the system are
applicable.
This is to be based on the Royal Schelde's policy as well
as on the contract-requirements.
The above will be triggered by process A21301 "manage
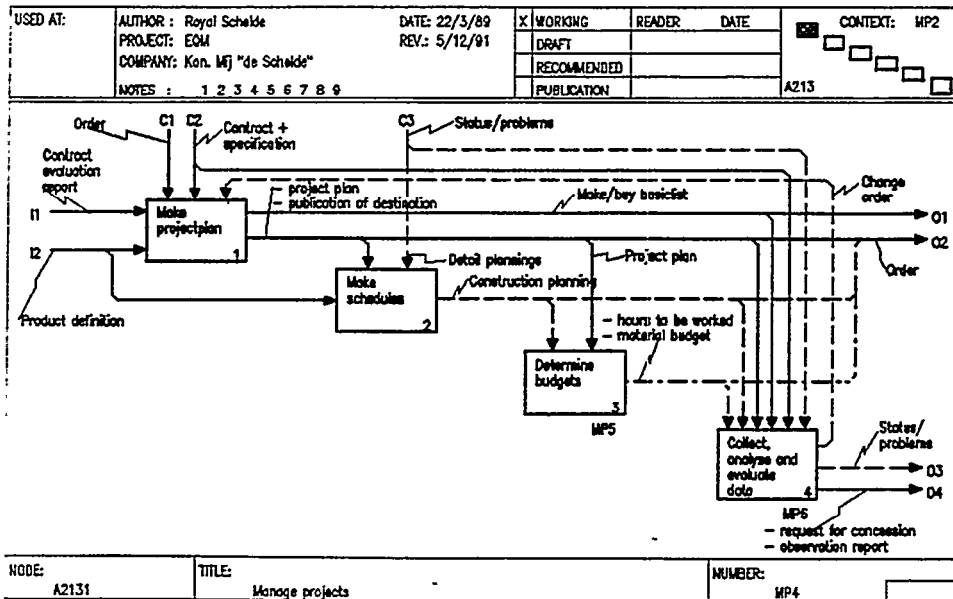projects", as shown in figure 5.

USED AT:	AUTHOR : Royal Schelde	DATE: 22/3/89	X	WORKING	READER	DATE	CONTEXT: MP2
	PROJECT: EQM	REV.: 5/12/91		DRAFT			
	COMPANY: Kon. Mij "de Schelde"			RECOMMENDED			
	NOTES : 1 2 3 4 5 6 7 8 9			PUBLICATION		A213	

NODE: A2131	TITLE: Manage projects	NUMBER: MP4

Figure 5 Proces "Manage Projects".

This diagram shows the data carrier: "Project plan" as one
of the outputs from the constituent process A213-11 "Make
projectplan".
To this data carrier is connected the information-
instruction description A213-1/A-"Project plan" as shown
in figure 6.

* This means a
  statement of
  applicable parts
  of the company
  information
  system in rela-
  tion to the order
  concerned, and is
  based on:
  - company's policy
  - contract re-
    quirements

Figure 6 "Project Plan".

According to the above shown information- instruction description, the specific project organisation and the control aspects for quality, progress and costs will be laid down in the project plan.

An information-instruction carrier that must be prepared for each order, is the "Inspection plan".
This carrier is initiated in the process: "Production" and it is an output of the constituent process: "Manage production".
The description of this carrier is contained in the information-instruction description A213.51/A - Inspection plan as shown in figure 7.

As can be concluded from this description, the inspection plan is of essential importance to initiate and schedule necessary inspection activities, registrations as well as the involvements of both the quality department and the client before starting the production.

Figure 7 "Inspection Plan".

As mentioned before, the principles of the "quality loop" have been completely integrated in the company information system.
With the assistance of registrations, analyses and reports of status and problems it will be determined whether and in which way measurements for improvements shall be taken. This information can also be used by project-teams or quality-circles in case a further investigation appears to be necessary according to Royal Schelde Continuous Improvement.

6.   **CERTIFICATION OF THE COMPANY INFORMATION SYSTEM.**

Royal Schelde's company information system (used as the quality system documentation) has been certificated in April 1990 by the Dutch Ministry of Defence and it meets the NATO quality assurance requirements specified in STANAG 4108, AQAP-l/edit.3.
The certificate was valid till May 1 st. 1992 and is being renewed.

However, company evaluations for the certification of quality systems will no longer be carried out by the Ministry of Defence.
For that reason Royal Schelde demanded the services of Det norske Veritas, who started to evaluate the present company information system in comparison with the requirements of ISO- and AQAP-1, in order to issue a certificate.

The Business Unit Schelde Boilers was, based on the same company information system, certificated in October 1991 by Det norske Veritas.
The system met the requirements of ISO-9001.

7.   **FINALLY.**

One remark has to be made:
People have to work with the means described in this paper.
Having a quality system or a certificate does not assure quality, people-have to do so by their continuous attention and the system is just a helpful1 tool.

COMPANY-WIDE QUALITY ASSURANCE AT A NAVAL SHIPBUILDING YARD

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Abstract

Complying to stringent naval shipbuilding standard demands a comprehensive quality assurance system which the shipyard lacked in the early years. As more ship types were designed and constructed, this deficiency manifested and has brought negative impact on reputation to the shipyard. To ensure compliance with quality standard, cut warranty costs and to protect long term business strategy, the shipyard embarked on an aggressive drive to promote quality achievement. From an inspection-oriented type of simple quality control, the shipyard developed and implemented an effective system coined by the shipyard as Company-Wide Quality Assurance (CWQA), which encompassed the involvement of all departments towards quality achievement. The capability of building desired quality ships and satisfying customers' specifications was due to the success in making quality attainment accepted as every employee's responsibility, and the more organised and systematic documentation of quality matters. Outside the shipyard, vendors and contractors were required to comply with the shipyard's quality requirements before their sales or services were contracted. The shipyard's CWQA has been adopted by a few companies to which the shipyard was then a consultant. This paper presents the overview of the shipyard's quality assurance activities in which development the author was the lead contributor.

Introduction

The shipyard has established a long history and experience in naval shipbuilding. Complimented by the lack of fierce competition in the early years, the business of the shipyard was good, despite the absence of a comprehensive quality assurance system, which recently, is almost a mandatory requirement especially in the manufacturing industry. The shipyard survived because it was not a norm to require shipyards to operate in accordance with a quality standard, such as what is a household name today, the IS0 9000 series

or the BS 5750 series.   The lack of a quality system did raise customers' dissatisfaction which very often could adequately be compensated by re-work without costs and providing more spare parts, and sometimes by extending the warranty period.   This did not mean that the shipyard was not concerned about the expenditure in fault-finding to discover malfunctioning, design change brought about by bad quality and warranty.

As more ship types were designed and constructed, the lack of a quality system manifested itself in rising failure costs and receipt of more customers' complaints. To safeguard its reputation which was declining and to fight the ever increasing competition in the later years, the shipyard was compelled to re-examine its shipbuilding activities. In this endeavour, the   shipyard discovered   the   many factors contributed to poor quality.   It believed that the solution was to make strategic changes.   This marked the beginning of company-wide quality assurance for the shipyard.

Company-wide quality assurance

Having suffered much from failure costs and lost of reputation, the shipyard admitted the significance of quality in shipbuilding.   It adopted the philosophy that quality was the responsibility of every employee who must contribute towards quality achievement.   Based on this slogan, the shipyard embarked on a quality drive in an attempt to make quality an integral part of every employee's work.   For organisational convenience, the responsibility for quality management was assigned to the quality assurance (QA) department.   Soon after top management has established the company policy, the race towards company-wide quality assurance (CWQA) began.   It was the shipyard's firm believe that CWQA was the tool to re-gain and sustain customers' confidence, and to remain competitively strong in naval shipbuilding.

Quality assurance department as the managing agent for CWQA

Before CWQA implementation, the level of quality as defined by the shipyard was that to be achieved by inspection by the QA department.   The principal role of the QA department then was inspection to verify that construction and installations conformed to the requirements of pre-declared acceptance documents such as the ship specification.

After the QA department has been assigned the additional
responsibility for quality management, it carried out its
duties more than just inspections. Being the spokesman on
CWQA matters, it co-ordinated the company-wide quality
development activities, while at the same time, like in all
other divisions, has to re-shaped its internal organisational
structure so that it was oriented towards CWQA. To fulfil
the multiple roles, the immediate requirement for the QA
department was the teaming of quality personnel. This was
done by recruitment and engagement of a quality consultant.
Where specialised knowledge was required and not justifiable
to employ a permanent staff, expertise from other divisions
was incorporated to the QA department. With the total
knowledge required satisfied as shown in Fig. 1, the QA
department was transformed from an inspection department to
a department performing the advisory role on CWQA, the
challenge the QA department has overcome.

Quality Assurance Department for CWQA			Other Divisions
Total Knowledge			Supporting Knowledge/ Input
Basic	Others	New Assignments	
Inspection Testing Trial	Marine/Mechanical engineering Shipbuilding Electrical engineering Other trades •Welding •Painting •Corrosion •Woodworking •Costing •Metrology •Instrumentation	Quality engineering Quality administration Quality development	Weapon systems Electronics Control engineering Input from equipment suppliers Union supports

Fig. 1 - Knowledge requirement of QA department for CWQA

The activities for CWQA development of the QA department
became interactive. Although not solely responsible for
CWQA, it however, oversaw and co-ordinated the company-wide
development. In this centralised role, the QA department,
supported by divisional quality representatives, provided

assistance to help implementing, maintaining and reviewing quality systems. To fulfil this respect, the QA department was always involved in all phases from marketing to after sales. The crossover of the quality assurance activities into other disciplines is shown in Fig. 2.
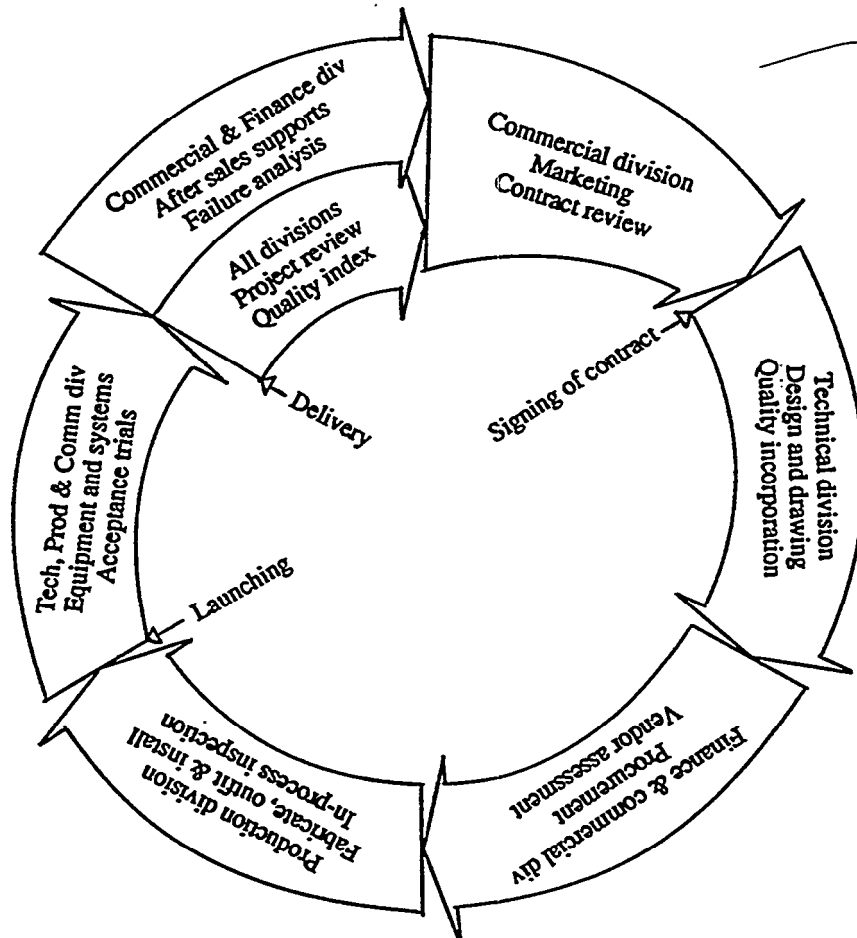
Fig. 2 - Quality assurance activity loop

Quality organisation

All divisional directors reported to the managing director on all matters pertaining to quality policies. The directors were required to state their divisional quality policies and establish the quality objectives, and were responsible for instituting an internal quality system to ensure that policies were carried out and the objectives achieved.

For the reason that the technical division was first identified to require a quality system, it was considered most appropriate to organise the QA department within the technical division which housed the design departments and drawing offices. All paper work for specifications, purchasing, production, testing and trials were generated from the technical division. Being under the same roof, the QA department has immediate contact with the technical personnel to ensure that all quality commitments were discharged so that the paper work, based on which procurement and production were planned and executed, was in order before issuing. Although the QA manager reported to the technical director, the former carried out his duties and responsibilities independently of the technical activities. This was possible as the director's quality role was well defined and he has to place his priority right. In fact, as the shipyard has discovered, it was effective to implement and resolve quality matters in the technical division with the director entrusted with the responsibility for quality commitment. The notable changes in the division were the requirement for design review, systematic vetting of production drawings and incorporation of quality parameters in drawings and contractual documents.

The implementation of a quality system in the technical division was seen as the first success in CWQA. Based on the experience gained from the technical division, each director was assigned the additional role for quality management in his division.

CWQA development

The success in implementing a quality system in the technical division boosted the shipyard's confidence in continuing CWQA development in other divisions. The implementation in the technical division was used as a model. Some of the eventual quality activities implementated in other divisions were:

Production - Production review to ensure quality achievement
            Project management to include quality
               activities
            Quality control planning and management

Commercial - Vendor assessment and rating
            Enforcement of quality compliance on vendors
            Contract review

```
Personnel    - Quality induction and refresher courses
               Liaison with union to seek supports for quality
               Paid time off to participate quality functions

Finance      - Quality cost analysis
               Payment procedure to ensure quality services
               Financial catagorisation of vendors' capability
                  to supply
```

It was for about four years and not without much difficulty
that CWQA finally became a reality in the shipyard. What
the shipyard has learned about the success in CWQA
implementation was the creation of an atmosphere of quality
awareness and commitment of all employees, and not
authoritatively assigning quality responsibility to every
employee which would only be short lived. The overall progress
from the initial production quality control to CWQA is
illustrated in Fig. 3. The system that the shipyard has
developed is summarised in Fig. 4.
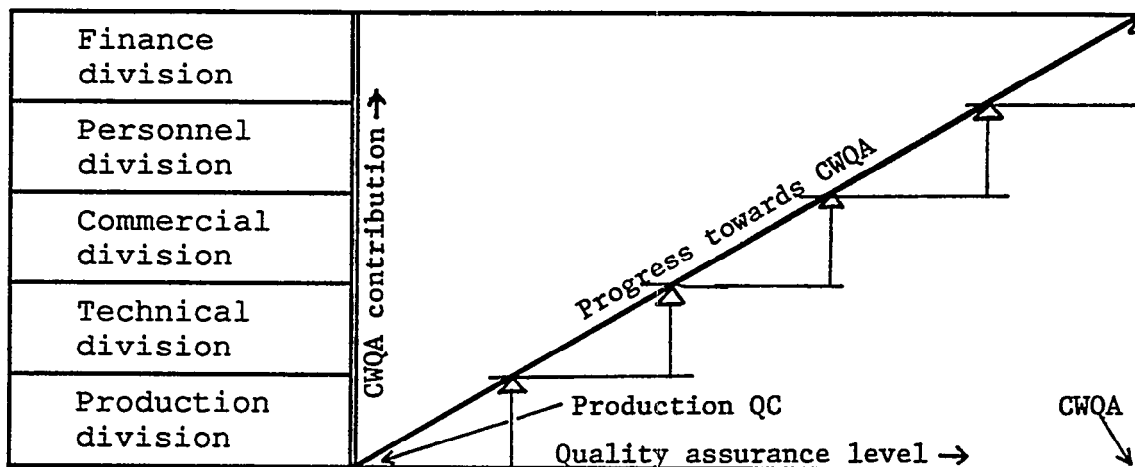
Fig. 3 - Progress from production quality control to CWQA

Documentation for CWQA

As a permanent reference for CWQA implementation and
maintenance, a quality manual was produced for use by all
employees. It described the company policy, organisation
and management system for quality attainment, functions and
responsibilities of each divisions for quality commitment.
The quality manual was a very essential document to customers.
Although it was usually not a contractual document, it has

certainly given customers the assurance of a systematic quality management and the confidence to receive a quality ship.

Complementally to the quality manual, procedures for procurement, production, quality control and other quality related operations were written for systematic execution. In-house quality standards were established for verification of workmanship and conformance to pre-declared acceptance documents. Being the shipyard's managing agent for CWQA, many of the documents were produced by the QA department in consultation with all concerned departments.

Quality assurance documents

Amongst the many documents implemented, the following were the most essential ones:

(a) Company quality standards
(b) Manufacturing procedures
(c) Technical information sheets
(d) Inspection check lists

Company quality standards (CQS) were in-house standards developed based on experience and adaptation from military and other shipbuilding standards. They were purposefully used to ensure that compliance of workmanship and other quality parameters with acceptance documents has reached the minimum level as stipulated in the standards.

Manufacturing procedures (MP) described how a task should be systematically executed. As shipbuilding processes are multi-disciplinary trades, the implementation of manufacturing procedures has proven to be very productive. The specific benefits of their use were as follows:

(i) Pre-requisites for a task could be identified for advanced preparation of resources, and liaison to resolve pptential problems to avoid causing delay in starting.

(ii) Work sequence for a task could be defined so that little pre-planning and minimum supervision would be required during operation.

(iii) Quality requirements could be specified so that an inspection plan could be incorporated.

(iv)   Interaction with owner's representative and classification surveyors could be established in advances for the purpose of inspection and acceptance in order to avoid unnecessary interruption to the progress of production.

Manufacturing procedures have been particularly useful for newprocesses, critical installations andmulti-disciplinary tasks. To protect confidentiality some procedures such as those used for weapon systems installations were restricted to designated users only. Manufacturing procedures were standard documents applicable to many ship types. Where additional or different quality parameters were imposed, they were reflected in technical information sheets which served as addenda to the affected manufacturing procedures. This has saved the need to write new manufacturing procedures and to have them approved procedurally each time there was a difference in quality requirements.

Inspection check lists (ICL) enumerated the quality parameters to be verified in sequence. This has ensured systematic and complete inspection. Inspection check lists were important documents as they were permanent records of evidence of quality attainment. Inspection check lists were used throughout the shipbuilding operation for inspections, testing and trials as stipulated in inspection plans.

Quality planning

Soon after the award of a contract and prior to commencement of fabrication, quality planning was one of the major quality activities. The planning activities not limited to the following involved:

(i)   Review of inspection facilities
(ii)   Certification of process, welders and vendors
(iii) Identification of quality parameters and processes to be inspected or verified, and formulation of an inspection plan
(iv)   Identification of inspection system requirements
(VI   Formulation of test and trial procedures for contractual acceptance

Quality plan which was another important quality documents gave customers the overview of the shipyards quality system and hence the level of quality attainment.

Inspection plan

Inspection plans detailed the job sequence, specified where and what inspections was to be carried out to verify quality compliance and the documents to be used for records and as the appropriate manufacturing procedure. The inspection plan written for the installation of main engine and gearbox is shown in Fig. 5. As could be seen, its usefulness is obviously apparent.

Inspection system

The system concerned the planned inspections and did not include other inspections such as random inspections.

(i)   In-coming inspection
(ii)   In-process inspection
(iii) Shop/harbour testing or trial
(iv)   Sea trial

The need for an inspection system is summarised in Fig. 6. The system defined the objective, responsibility, method, documentation, level and class, and treatment of non-conformance. A typical inspection system for in-coming and in-process inspections is shown in Fig. 7.

Conclusion

The shipyard has developed a quality assurance system which required the involvement and contribution of all employees. The implementation of the system was successful as every departments accepted the responsibility for quality. Since then, production quality control was displaced and quality assurance activities became company-wide. Comprehensive documentation was used for systematic execution of shipbuilding operations and recording of quality matters. In two of its technology-transfer projects, the agreement to help set up the shipyard's quality assurance system in two companies was a specific partial requirement of the contracts.
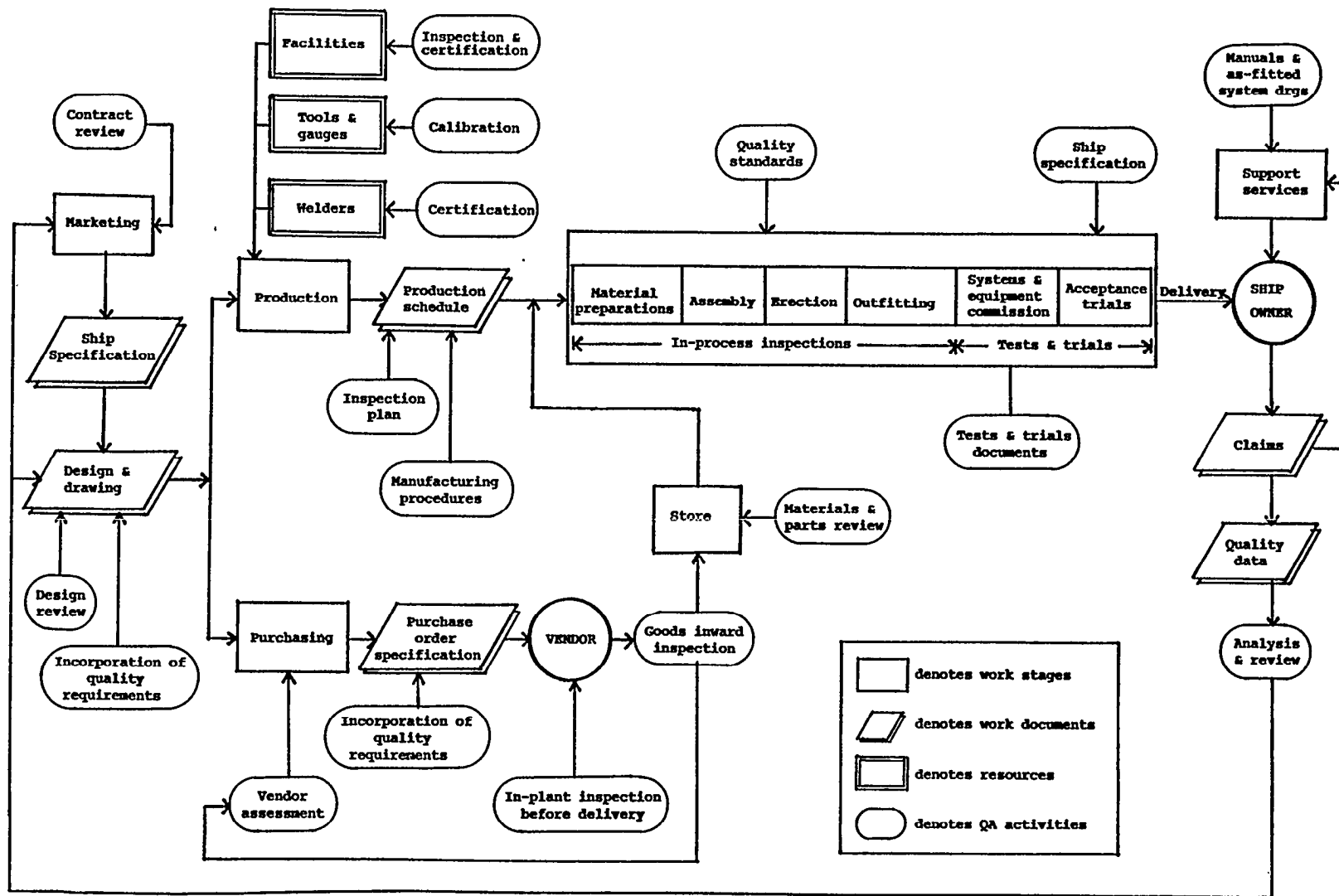
Fig. 4 — Company-wide quality assurance system

Sequence		Operations to be carried out	Documents to be used
INSPECTION PLAN FOR THE INSTALLATION OF MAIN ENGINE AND GEARBOX (Shipyard)	(Document no) — Sheet no. / (Effective date) — of no.		

(Shipyard)		INSPECTION PLAN FOR THE INSTALLATION OF MAIN ENGINE AND GEARBOX	(Document no) — Sheet no. (Effective date) — of no.
Sequence		Operations to be carried out	Documents to be used
(P/Q)	00	Weigh main engine and gearbox	Weighs to be recorded in Form WE/2 and submit to Design Department.
(P)	05	Establish shaft lines	Ref drg no. 5/1 sht 1 & 2/6 sht 1.
(P/Q)	10	Align shaft alignment supports	Ref drg no. 5/6 sht 1.
(P/Q)	15	Dimensional check on main engine and gearbox seatings	Ref MP2-07 and use ICL 035.
(P)	20	Shafting alignment	Ref MP3-05A and use ICL074
(P/Q)	25	Check acceptance of shafting alignment by measuring the radial tolerance and skewness	Ref document CQS 17/79 Part 1 and use ICL 076
(P)	30	Install propeller shaft correct to shafting arrangment drawing	Ref drg no. 5/1 sht 1.
(P)	35	Main engine and gearbox loading	
(P/Q)	40	Completion of hull and underwater fittings	Use ICL 080/2.
(P)	45	Launching	Check water tightness
(P)	50	Align gearbox to shaft coupling	Ref gearbox manufacturer's alignment procedure and/or MP3-08.
(P/Q)	55	Check acceptance of alignment by measuring the eccentricity and breakage simultaneously using two dial gauges	Where tolerances are not specified CQS 17/79 Part 2 is applicable.
(P)	60	Drill and ream holes on seating in conjunction with gearbox (or main engine) mounting feet for holding down bolts	Ref drg no. 5/5 sht 1.
(P/Q)	65	Fit holding down bolts. Where fitted bolts are present, fitting force is to be verified and alignment readings to be rechecked for possible runout after fitting	Ref drg no. 5/5 sht 1.
(P)	70	Prepare and pour chockfast compound as per manufacturer's Technical Bulletin No. 654	Ref manufacturer's Technical Bulletin no. 654.
(P/Q)	75	Submit test pieces of chockfast from the same pour for hardness and crushing tests	Technical data given by PRC as follows: Crushing 13.3 kg/mm^2 Hardness 35-40 Barcol
(P)	80	Release jacking bolts and alignment gear after curing	Minimum curing time at ambient temperature is 18 hours.
(P/Q)	85	Tighten holding down bolts to the respective torque	Ref manufacturer's Technical Bulletin No. 652A and use ICL 075
(P/Q)	90	Recheck alignment readings for possible runout	
(P)	95	Couple gearbox output flange to shaft coupling	Use ICL 075
(P/Q)	100	Turn shaft assembly manually to check if it rotates with minimum torque applied	Nominal torque should be 30-40 kg-m
(P)	105	Align main engine to gearbox	Verification of alignment tolerances by engine manufacturer for warranty purposes
(P/Q)	110	Perform steps 55 to 90	
(P)	115	Fit Flexible coupling between main engine and gearbox	
(P)	120	Couple flexible coupling to main engine and gearbox	
(END)	125	Installation complete	Certification of alignment by inspection party

P   -   Operations by Production Division
P/Q   -   Inspections by Production Division and Quality Assurance Department

Fig. 5 – Inspection plan for the installation of main engine and gearbox

To ensure that customers are delivered with the ship that perform to the declared specifications

To evaluate performance of existing labour, machines and quality control system

To compare actual quality level with designed level for quality evaluation

To minimise waste and scraps

To determine optimum quality level for available machines and processes

To check consistency of manufactured quality

To enable diagnosis of processes and machines

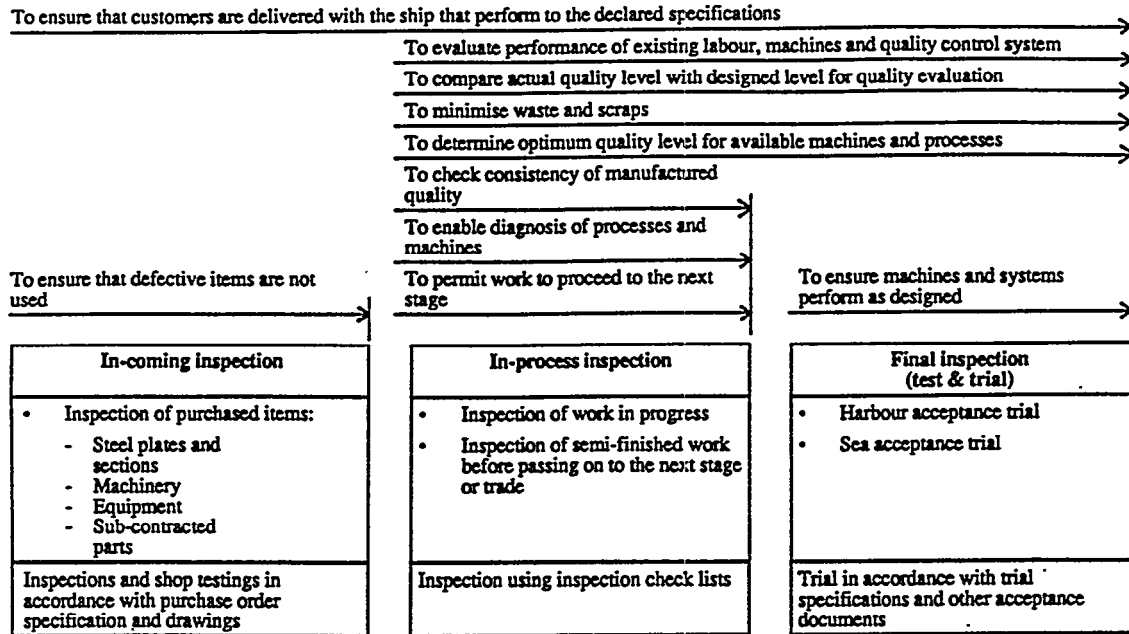| To ensure that defective items are not used	To permit work to proceed to the next stage	To ensure machines and systems perform as designed
In-coming inspection	**In-process inspection**	**Final inspection (test & trial)**

• Inspection of purchased items:
  - Steel plates and sections
  - Machinery
  - Equipment
  - Sub-contracted parts
	• Inspection of work in progress
	• Inspection of semi-finished work before passing on to the next stage or trade
		• Harbour acceptance trial
		• Sea acceptance trial

Inspections and shop testings in accordance with purchase order specification and drawings	Inspection using inspection check lists	Trial in accordance with trial specifications and other acceptance documents

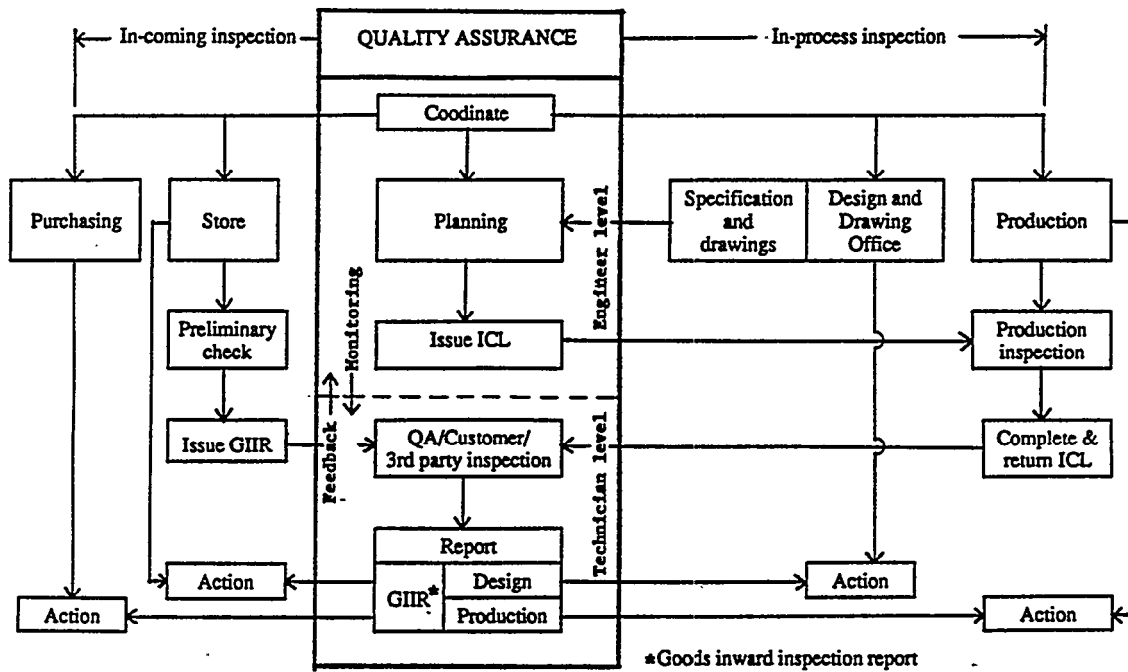Fig. 6 - Inspection system

Fig. 7 - Inspection system for in-coming and in-process inspections

`STRUCTURAL SAFETY AND FATIGUE OF SHIPS.

J.J.W,Nibbering,
University of Ghent Belgium.

Abstract:
The high stress level in ships - largely due to the use of
higher strength steels- has made fatigue a major problem for
shipowners and classification societies.
It will be discussed that fatigue-cracks are not merely a
nuisance .(leakage and repairs), but that they constitute a
and probably the main danger for the safety of ships
against (brittle) fracture.
It is doubtful whether sophisticated fatigue and reliability
calculations are of much use in this respect.
Rather they may give a false feeling of safety.
Better design of details and especially improved workmanship
(welding), are more valuable.
Examples will be given.

Introduction:

Reliability theories and procedures have developed spectacu-
larly in recent years.
Applications in structural design are coming in use. But the
reliability of the outcome of these activities for individu-
al cases is not (yet) large.
The problem is that the experts in reliability are seldom
sufficiently expert in the various specialities involved in
structural design.
Perhaps the aspect of 'loads" is the best treated link of
the structural design chain, thanks to the fact that relia-
bility-theorists and load-experts are on good statistical
terms.
But often several of other links, like fatigue, corrosion
fatigue, weld-parameters and their consequences(defects,
heat-affected zones, residual stresses and deformations)
inspection methods and detection possibilities(N,D.T.)
acceptance testing, fabrication of structural
details(tolerances, distortions, misfits, poor painting,}
may be more or less outside their scope.
But let us be optimistic.
For off-shore structures balanced integration of all aspects
of structural design is so important - and the money so
available- that sooner or later shipbuilders may simply buy
commercially available programs for making estimates of
structural capability.
But even then they should be aware that the reliability of
the outcome is determined by the accuracy and soundness of
the input(f.i. shipyard parameters in the widest sence.)

Fatigue damage in ships.

It should be realised that fracture problems of ships differ from those of off-shore structures in many respects.
Ships have an all-covering skin as a most important structural item; they are severely longitudinally loaded, can easily be inspected and repaired and can escape from or adapt to bad weather conditions.
Ships which are UsimpleYfrom the structural point of view like tankers, hardly need thorough fatigue-calculations because the feed-back from exsisting ships is sufficient(and probably _more_ reliable). Of course also these suffer from cracking but often this is partly due to the urge from shipyards and shipowners to build ships at low cost per ton deadweight.
This had led to the wide use of the higher strength steel F e 510.
In general this only helps in cases of ships in with still water loads differ largely from one trip to another,overall or more locally.(loaded ballast)
The normal loss of fatigue-strength due to the higher stresslevel when using Fe 510 should be compensated for by better design and fabrication of structural details.
Unfortunately this may reduce greatly the benefits of economising on material (and welding?.)
Protection against corrosion is of utmost importance and certainly in order to avoid corrosion fatigue.
Expensive methods to protect ballast tanks do often not succeed in avoiding cracking of paints in corners and at structural discontinuities.
Precisely where the protection is badly needed, it does' not work.
This is another argument for smoothing welds at these spots by grinding, T-I-G-welding and such in order to keep the new paint intact in service.
how can anybody believe that even the best paint will do its job in flame-cut edges of holes in stiffeners through which dirty, perhaps sandy water may pass at high velocity.
In a paper by Ferguson and Osborne [l] and Lloyd's Reg.[Z] on cracking due to grabs, bull-dozers,ore etc. the accompanying loss of paint {very soon} corrosion, {wet ore, condensation,and coal} and bulging of brackets make the structures very vulnerable to corrosion-fatigue.
Double hulls may pay!
Both papers are very informative and practical and are of greater use for shipbuilders and owners than the beforementioned papers on- reliability. This may not sound sympathetic to those working in that field, but that is not the intention-It is more a plea for doing first things first. To that belongs insight in and knowledge of basic items of fatigue and fracture. The best start is buying the Fatigue Handbook [3]- For those who have already come thus far, papers in which _applications_ of reliability methods for ships are given can be very instructive.

They show the overall complexity of the problems and often give data of which the value can be judged by own research and common sense.
Examples are papers appeared in Marine Structures 141 by Akita {informative}, Guedes Soares and Moan (most practical), Pittaluga et al (shows many uncertainties   in design), Juncher Jensen (loads). Also the U-S-Ship Structure Committee has been active in the field for years. See for instance the proceedings of the 1984 Symposium 151.

In the present paper it is only possible to mention a few primary aspects which are poorly or even wrongly treated in several of the beforementioned papers.
It has to do with overall strength and critical crack lengths - Connected to it are practical hints which may greatly simplify fatigue analysises for designers coping with time limitations.

Cracking impairing longitudinal strength.

Perhaps the weakest item in papers on reliability   in connection to fatigue is critical crack length.
This may be connected to the fact that often fatigue experts and brittle fracture specialists seem to live in separate worlds.
The origin is probably that brittle fracture is mainly a material problem and fatigue more a "mechanics" one.
In hardly any of the beforementioned papers temperature appears as one of the parameters in the whole analysis.
Yet it is the most crucial one for welded structures.
One might say that when a crack has become unstable,it is of little interest to know whether it was a brittle or a shear one. But the difference is large and has serious consequences for the safety of a ship. A brittle fracture, once started , very soon propagates at a speed of 1 to 2 Km/set. This means ultra high-speed loading of the material ahead of the crack. Because steel is very sensitive to such loading, its fracture toughness drops to values of 1/100 to 1/1000 of that for low speed loading. Due to that it can hardly stop.
In case of shear fracturing the drop in fracture toughness is an order of magnitude smaller and often negligible.
Due to that the speed of propagation is small. Both factors make that when a shear fracture starts in a ship f.i. due to a combination of a high wave load and a severe slam. (see fig. 2) the fracture cannot come far because the part of the load due to the- slam drops quickly. After l/4-1/2 sec. the dangerous situation is over.
The arrested shear fracture may have a length of centimeters but will not easily start again, unless a similar extreme load accurs. Even then,the phenomenon of a jumping and hal- ting shear crack may be repeated several times.

It would be wise to test the shearing strenght of steel in
presence of fatigue cracks as a routine-check, because this
property can differ largely between steels and also depends
on thickness.
Shear fractures and fatigue cracks can be arrested-or at
least largely retarded-by several simple measures like hole
drilling, hammering around the tip, and forcing a wedge in
the crack. It is something ship officers should be familiar
with.

What are the main types of brittle fractures which start at
fatigue cracks.
The first one is a pop-in at a local brittle zone (L-B-2.)
in a weld or heat-affected zone.
In fact it is mostly a rather low stress fracture.
Many people think that pop-ins hardly occur in ships because
they are seldom found. But this does not mean that they do
not exist. Mostly they <u>start</u> at small fatigue cracks in
the welded region and are arrested inmediately outside that
region. Crucial is that that region is generally so small
that the energy set free at crack extension (proportional
to the root of cracklength) is still little when the
crack-tip arrives in the sound parent material. Fig 1
illustrates the situation.
It may be surprising that <u>small</u> fatigue-cracks (mm's) can
be , and often are more dangerous than larger ones (cm's),
The unsympathetic aspect of a fatigue-crack in welded
structures is that it patiently ªseeks″ the worst place in
its weld region.
When at that time the weather is stormy and the tempera-
ture is low a brittle fracture may start
The risk that it does not only "pop-in' but propagates far
{and too far) is significant.
High Charpy-values do not guarantee arresting. High C,0-D.
values say nothing about crack-arrest properties.
A C.O.D.-test is a static one and for arresting is dynamic
fracture toughness relevant.
One of the first investigations in the Ship Structurs
Laboratory concerned a brittle fracture started at a fatigue
crack in a bilge keel.161 The crack was only 3 mm deep.
There is no need to show it here because a few years ago
numerous pop-ins were found at draining holes in bottom
stiffeners. It is not so much a miracle but certainly very
fortunate that not any pop-in lead to <u>a large</u> brittle
fracture (fig. 3). But it is obvious that such local brittle
cracks might once start again at greater lengths when they
have grown due to cyclic loading,
Normally ship's steel is good enough to tolerate such cracks
and that is the reason that few ships fracture in two.
But these cracks will inevitably develop in large (complete)
fractures when the longitudinal stresses exceed yield point.
It is curious that still many people do not realize why this
is so dangerous. Imagine a plate with a central through-
crack in it.

Below yield point (in the net-section) the nominal
deformation is in the order of 0.15%.
At yielding it grows to about 1%.
The consecuence is that also the crack-tip material has to
deform suddenly 7-fold. It means that the crack-tip opening
displacement (C.T.O.D.) may grow from for instance 0,2mm to
about 1,5mm. and that is too much.
When temperature is close to 00 a brittle fracture is highly
probable. It wil not easily be arrested in Dor E/quality
plates because the energy set free per unit crack
propagation is high: high stress, long crack.
It will be clear that in this respect a high-yield point of
the steel is of great advantage. (see next   section}
Returning now to the pop-ins at local brittle zones it is
obvious that a large number of C.O.D. tests are required for
finding the worst spot in a weld of H.A.Z.
Far more realistic, reliable! (and cheap) is fatigue loading
at low temperature 171. The growing of the crack acts a s
"screening" of the zone.

The joint probability of extremely high wave loads and low temperatures.

The situation in the field of loading is similar to that in
the field of testing. Above it has been emphasized that
fatigue and brittle fracture experiments should not b e
separated but combined. When we look to loading there is an
enormous amount of literature on wave-induced loads and
their extremes, and also on temperatures of air and water,
but nothing about the probability of occurence of extreme
loads at low temperatures.
We have repeatedly brought this aspect to the notice of
relevant ISSC-committees, but the situation is still bad.
Therefore it was tried to find something in the (scarce!)
literature on ships'fractures. Among these was " A study of
extreme waves and their effects on ship structure. by
W-H-Buckley 181. As the title says, the paper was focussed
on extreme sea-states. Consequently nowhere in the text
relations with temperature appear. But fortunately in the
appendix a table of data is given with particulars of
ships,the weather conditions and the damages. The following
information could be drawn.
38 Heavy-weather cases;in 31(1) cases the temperature was
between +lOOC and +25OC. The rest was as follows:

Ship no.	Sea temp.	Air temp.
11	+3	+1
12		+7
15	+l	+l
19	+4	+2
31	0	- 3
33	+3	+7
38	+7	+2

As a matter of fact the sea temperature is the most characteristic one. There were two cases where the damage consisted of cracking. Ship 31 was the SL7 container ship Sealand Market. There was a "hairline crack in the main deck at the forward end of no. 2 hatch with a length of 14 inches"-
A crack of that length may be a fatugue crack, but it is equally possible that it was an arrested brittle fracture, started at a small fatigue crack.

Ship 15 was a 16000 ts dw dry-cargo ship, built in 1969:
"There was a sharp loud crack heard throughout the vessel. A fracture in the main deck at hatch no. 4 was sighted from the bridge deck with a length of 16 feet'.

From the foregoing it may be deduced that brittle fracture (only?) occur due to combinations of extreme loads and low temperatures. Perhaps the most convincing fact is that the other 36 ships did not get brittle fractures. The probability of occurence might be taken as the product of the probabilities of for instance loads higher than the one year extreme and temperatures lower than the one year minimum. In that case both phenomena are thought to be independent variables, When some correlation exists it may be as well positive as negative. What we ideally should dispose of are joint probability functions for loads and temperatures. For ships and floating offshore strlntures this could be restricted to sea temperatures {winter and spring). For jack-ups and jackets also air temperatures are of concern, and eventually the temperature of that part of the structure with is above sea level. The latter may be different from air temperature in case of high waves. A dramatic disaster supports the need of data. In January 1977 a ship fractured completely near Cape Ann, Mass. The water there is cold at that time. The wave was 90 m long and 14 m high, with means an extreme steepness of 1:7. The ship had a length of 85 m.

So the wave height was nearly three times as large as that of a conventional standard wave (L/20).
Again a combination of a high load an a low tempereture occured.

In [9] the case of the Sealand Market has been further analysed. It came out that at hatch corners fatigue cracks must develop after two or three years service. Futhermore it was shown that it is highly probable that the ship once survived in extreme stormy conditions (fig. 2,), thanks to the use of Fe 510 in the deck-box girders, When the ship had been made totally of Fe 410, as was the original wish of the shipowner, a plastic hinge midships would *have* developed. This would have led to nominal strains in the deck of about *1%,* which normally cannot be tolerated in the presence of fatigue cracks at the temperature concerned.

How well fatigue loading at low temperature simulates service behaviour is illustrated in [IO].
In the Delft Ship Structures Laboratory high stress fatigue loading was applied at -1OOC with a full-scale cross connection of tubes of 368x20 mm. The yield point of the steel was 850 N/mm^2. A complete fracture occured when fatigue cracks at the fusion line had a depth of only 2mm. The realism of this alarming result was demonstrated in January 1985 when the 10 years old Beryl SPMl broke in two. It was evident that fatigue cracks were present in the lattice structure made of tubes [11] .

"On the safe side" design procedures.

A   Fitness for purpose.
Fatigue and fracture analysises for maritime strutures largely tend to be on the safe side. For instance for S-N-curves (Wohler) for welded connections, lower regions of scatterbands are used.Welding stress are always taken tensile and equal to yield point. Crack closure is neglected. The beneficial influence of tensile overloads, both in connection to welding residual stresses as from the pure fatigue point of view, is not taken into account.
Also it is seldom realised that in brittle fracture control the existing (Charpy) specifications have emerged from practical experience and consequently are not "averages" but "safe. values. On the other hand there are also approaches with are too optimistic. Post-weld heat treatments are not always as beneficial as is hoped. It may give rise to cracking, destroy compressive residual stresses at critical points or- in case of heating parts of existing structures- bring forward new stresses and deformations. Furthermore it can (and will) be shown that the generally held idea that high-stress fatigue strength is not impaired by corrosive environment, is not justified. The influence of neglection of changes of mean stress has been discussed earlier[12].
In the following a case will be discussed, in with every possible aspect of fracture analysis was on the safe side. The whole story is no fantasy, but reflects an actual stage in the design of an exsisting offshore structure!
The problem started when it was observed that in a multi-run X-weld in a thick plate the specified C.O.D.-values could not be met in the as-welded condition. The critical crack lengths calculated from the measured C.O.D.-values were in the order of magnitude of only a few mm's. The crack lengths calculated on the basis of the expected loads in 20 years, hot-spot stresses, N-D-T.-defect lengths, Miner's rule and B.S.153 S-N-curves, were about ten times as large as the critical ones. The situation seemed to be hopeless. The decision was taken to replace several meters of welds, and heat-treat others on the spot.
In the autor's opinion, the outcome would have been different, when not everypart of the analysis had been unduly conservative.

The main point was a complete neglection (or misunderstanding) of the role of the residual welding stresses.
When a multi-run X-weld is made by alternatively laying beads on both sides of the plate, the residual stresses are tensile at the surfaces and compressive at the root of the X. Important defects are mostly only present in the root (slag inclusions, lack of penetration, root cracks), where the state of stress is highly triaxial (plane strain). Consequently crack growth, if any, can start at the root.
Now the fatigue calculations were made according to a standard procedure. In it it was stated (as usual!) that tensile residual welding stresses are present around defects and should be taken into account. Yet in the case considered (root) the welding stresses were compressive! (Most unrealistic was that even for structural parts which were loaded in compression, fatigue calculations had to be made, because of the presumed presence of tensile welding stresses in the X-roots!).
A calculation procedure in with residual stresses were simply neglected resulted in zero crack growth!
But this is not yet the whole story. The C.O.D.-testing it self for estimating critical crack lengths had been carried out in a way which also suppresses the beneficialeffect of compressive welding stresses in the centre, where toughness is worst. It is well-known that in order to be able to supply a C.O.D.-specimen with a straight fatigue-crack, precompression in the thickness direction of the notched zone is applied. This has two effects: elimination of the welding stresses, and strain hardening of the material. This may reduce substantially the C.O.D. of the weld metal. Consequently the corresponding critical crack lengths will certainly be smaller than what is justified.

B   Residual welding stresses.

Welding stresses have a clear influence on the fatigue-strength for constant amplitude/constant mean stress loading.
The smaller the cyclic stresses the larger the influence. However, in actual structures welding stresses diappear quickly when incidental high loads occur. The first storm will do the job. It is often thought that this is only true in case the nominal stresses approach yield point. But figure 4 demonstrates that for a mild discontinuity being a circular hole, a nominal stress of only one third of yield point eliminates the welding stresses completely.
In ships much higher stress {strain) concentrations are present. Precisely at these points where the danger of cracking is greatest, the residual stresses are soon relieved.
In the absence of residual stresses the phenomena of crack closure and the Elber-effect can occur. This may cause increases in fatigue-life in the order of magnitude of a factor 5.

For when a crack of a few mm's has foried, the compressive part of a load cycle (in alternating loading) becomes insignificant. Also in repeated axial loading on a centrally notched 500 mm wide plate of 19 mm thickness, crack closure was manifest. The effective load was only about 75% of the real load (Elber effect).

c   Ultra low cycle- corrosion fatigue.

This section will start with a quotation from a paper of Det Norske Veritas /18/ on corrosion fatigue: " In the low cycle fatigue range, normally defined to be less than 100.000 cycles, the deterioration promoted by seawater is less". This is a generally held opinion. The arguments are in the sense that the crack growth is faster than the penetration rate of the corrosive environment. The cyclic frequency of the high loads is apparently taken equal to that of the lower loads (0.1 Hz for ships). Fig. 2 allows another look into the situation. The "built up" stress-change of 370 N/mm2 occurs about once a year. Changes of some 300 N/mm2 will be more frequent, but the frequency remains (very) low. Severe slamming may occur two to three times per hour. Still waterloads are also very low frequent.

In order to get an idea about the corrosion fatigue damage caused by ultra-low frequent extreme stress cycles, experiments were carried out [14]. One typical result for 0.0003 Hz is that after about 1500 cycles the crack in the seawater specimen was nearly 10 mm in length. In the accompanying air-specimen it was only O.5mm!
In conclusion it may be said that extremes occuring at large intervals contribute effectively to crack growth in seawater. A few thousand changes of hot-spot stress between 0 and σ_y at places where weld defects are present may lead to some 10 mm crack extension.

Final observations.

In view of the scepticism expressed about the actual, practical value of reliability calculations in connection to safety for fracture the desinger may take benefit from the following observations.
Shipfatigue is essentially corrosion fatigue. For that, sequence effects and load peaks have far less influence on lifetime than in case of cyclic loading in air.
Also relief of residual stresses is less important. For 3-dimensional structural details crack growth calculations have many pitfalls. Of course finite element calculations are indispensable. For those details where full scale experimental results are available the application of Miner's rule is obvious. The Miner's sum should be taken 0,3 in stead of 1, when the experiments had been carried out in air. Make preferably use of experiments for repeated loading (R=O) or R= -l/2.

It is on the safe side and allows for residual stresses.
Steel strength and quality do not matter: results for Fe 410
differ little from those for Fe 510. (But for critical crack
length quality has an enormous influence}. The Delft Ship
Structures Laboratory has largely contributed to the
literature on fatigue of ship structural components. These
may be used for Miner calculations [12].
Kathodic protection improves fatigue properties greatly
[13]. It may be cheaper than painting! Fig. 5 summarises a
lot of corrosion fatigue results. The new item is results
for longer lives. In [13] the same figures can be compared
for equal thicknesses. Thickness has an important adverse
effect on fatigue-strength.

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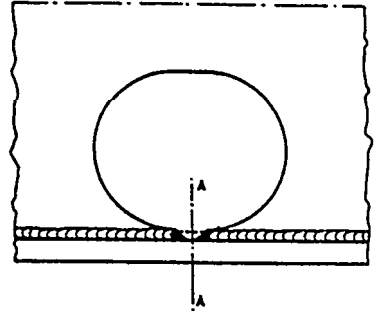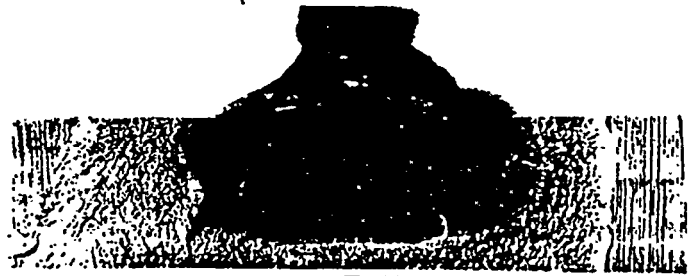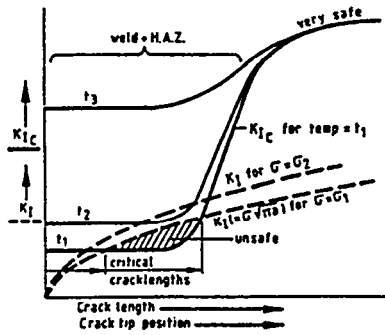
Figure 1: Relative importance of crack length and crack tip position in a welded region.

Wave Induced Longitudinal Vertical Midship Bending Stress (average of Port and Starboard)

Expanded Time Scale Showing Combined Wave and Slam-Induced Stresses

Figure 2: Extreme bending stresses of the Sealand-McLean recorded during a winterstorm.
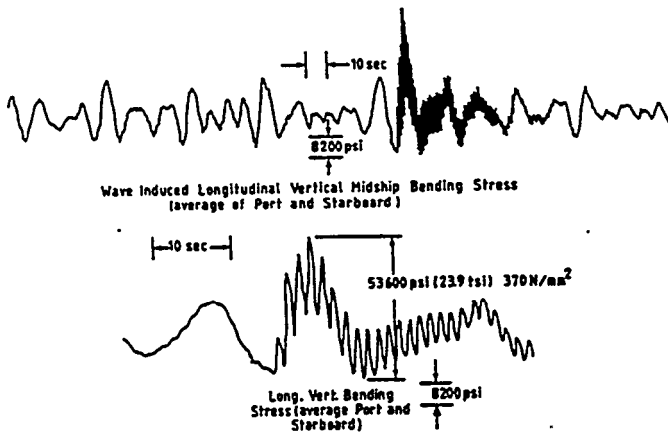
Figure 3: Pop-in from tiny fatigue crack.

Stresses and deformations at discontinuities with stresses/strin concentration = 3
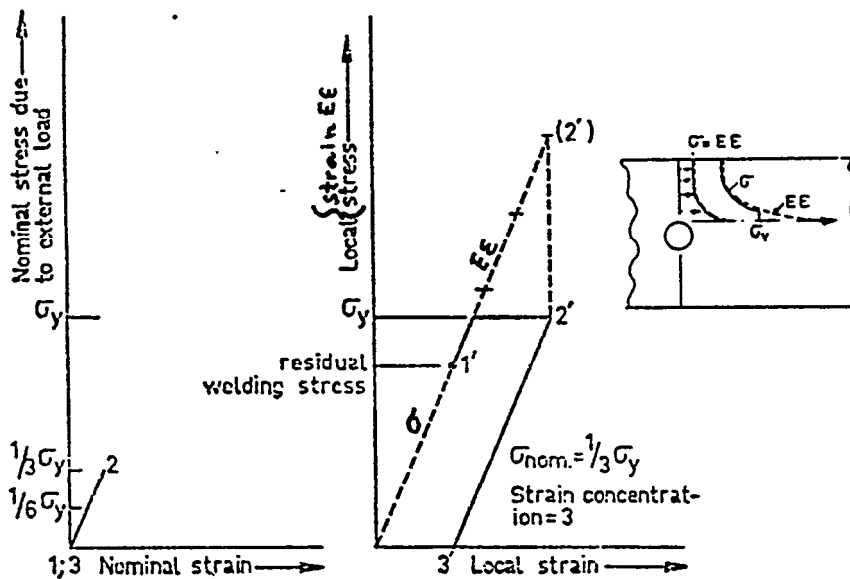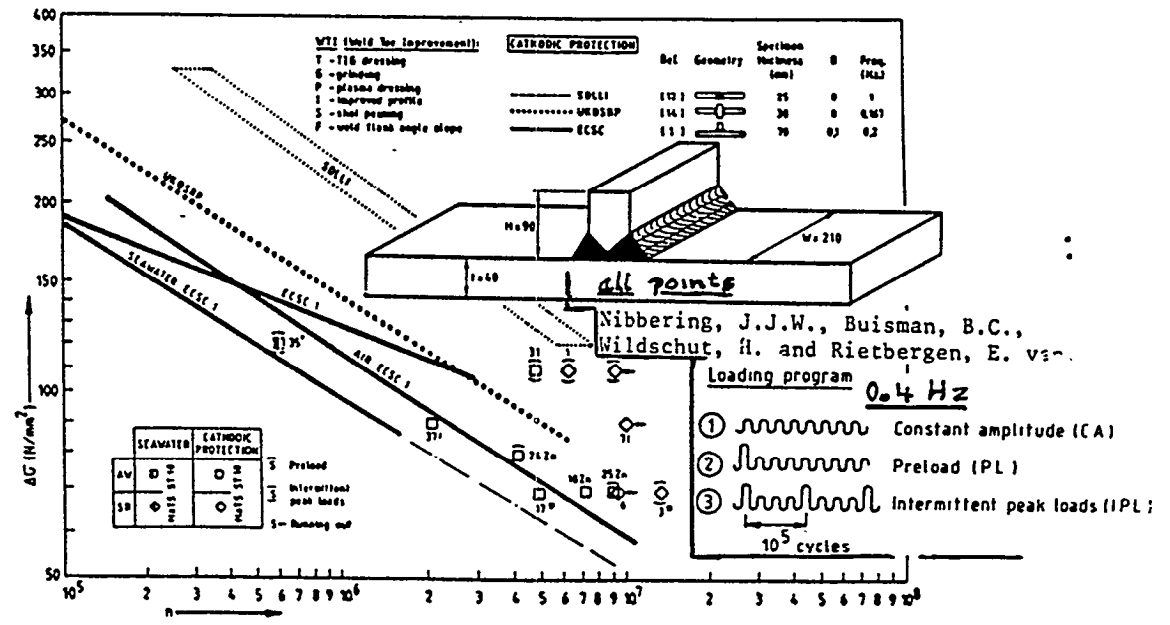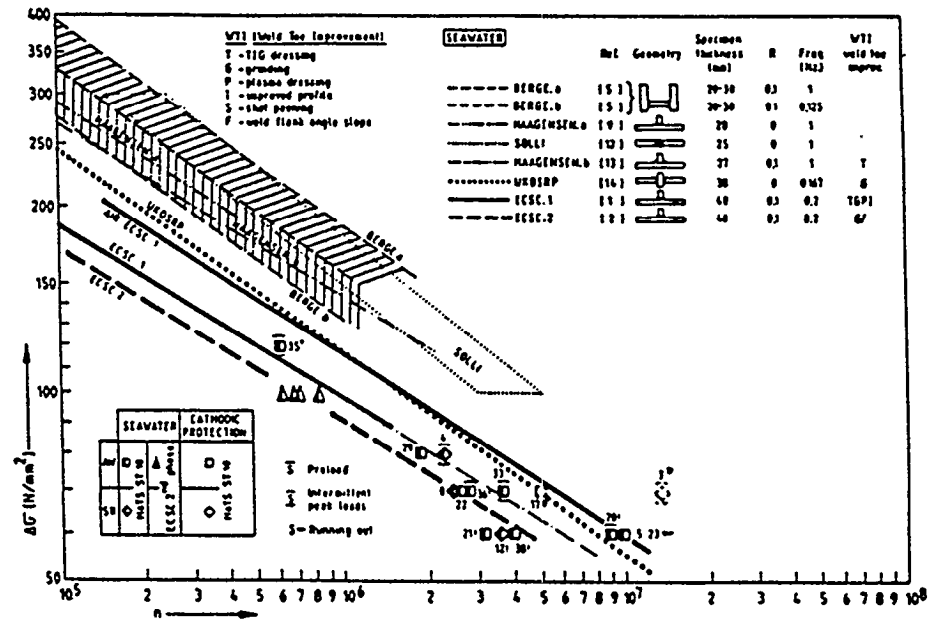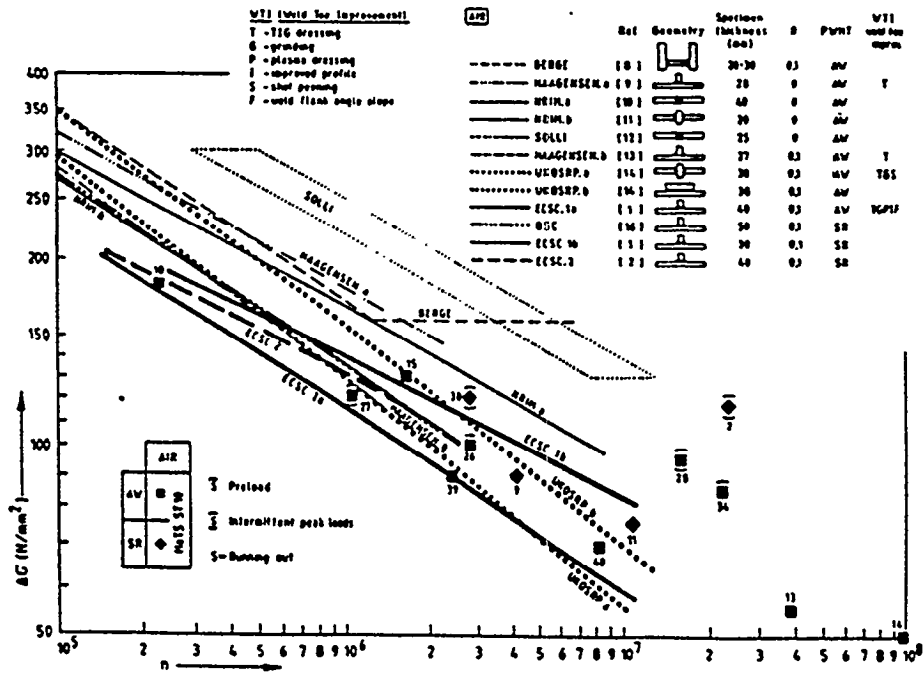
Nibbering, J.J.W., Buisman, B.C., Wildschut, H. and Rietbergen, E. v...

Loading program 0.4 Hz

① Constant amplitude (CA)

② Preload (PL)

③ Intermittent peak loads (IPL)

10^5 cycles

all points

COST EFFECTIVE LIFE-CYCLE DESIGN OF FATIGUE SENSITIVE STRUCTURAL COMPONENTS

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Abstract

The paper describes the theoretical backgrounds and presents the preliminary results of a numerical tool for cost effective design of fatigue sensitive structural components for their total or remaining life-cycle.

The method is similar that proposed by Madsen et al and is based on a reliability analysis of crack growth for which the Paris-Erdogan relation is assumed. The planned inspections with their qualities and a repair strategy are accounted for. This is done by applying a system reliability analysis on an imaginary system which represents all logically connected events leading to the failure.

The cost associated with the risk of failure is estimated by the product of the probability of failure and the cost due to failure. The maintenance cost consists of the inspection cost being a function of the inspection quality, and the cost associated with the repair which is estimated by the product of the probability of repair and the cost of repair.

1. Introduction

Ships and offshore structures represent very large capital investments, have large variety of types and are usually one-off designs. They are subjected to severe environmental actions which are predictable with a high degree of uncertainty. They are difficult and expensive to maintain, have extremely high downtime costs of about 20,000 $/day for ships and one order higher for offshore structures. Furthermore, they are prompt to human errors and are subjected to the public's hypersensitivity to their accidental events. In addition, the average age of the world fleet is increasing and is now 17 years. It is reasonable to forecast that the market will require the services of the existing world fleet for a number of years to come. For offshore structures extended lifetime seems to be the challenge of the present decade. It is becoming clear that for instance North Sea platforms designed for a lifetime of about 25 years, may have to continue to serve for considerably longer periods. Hence the operation of marine structures, especially above their design lifetime, posses a

significant challenge with respect to Inspection, Repair and Maintenance (IRM).

The goal of IRM is not to increase the reliability of structure, but to guarantee that the defined safety level is maintained. In this respect, standard IRM procedures, carried out at fixed intervals as required by present design codes, can increase the reliability of the structure over the required level. It may also happen that the standard procedures do not guarantee the defined safety level, and that a special IRM procedure has to be followed.

Terotechnology, as an interdiscipline which is a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life cycle cost, i.e.: design, construction, service and demolition costs, emphasizes that IRM should be defined already at the design stage where important system properties are determined. One of these properties is the resistance to ageing, i.e.: the resistance to technical deterioration.

Fatigue as the main reason of ageing is treated as the most crucial consideration in the strength design of a welded steel offshore structure. This can be found back in service experience in offshore, which indicates that serious accidents are caused by fire, explosions and blowouts and not by structural collapse. As far as fatigue damage is concerned, with the exception of a few 'nasties", fatigue performance is generally very good. The other reasons, beside 'fatigue-phobia" in the design stage, are thought to be related to a general overestimate of design loads in current practice and to the generally high standards of design, construction and maintenance adopted by the offshore industry itself and/or in response to regulations of governmental bodies.

Learning about serious accidents of ships from service experience is limited. This because ships in contrary to offshore structures often disappear after serious accidents. Nevertheless, ship's disappearances are thought to be attributed to a combination of brittle fracture and fatigue and additionally to explosions in case of tankers. In general, ship industry adopts less stringent standards of design, construction, maintenance and verification, but this is to some extent compensated by the fact that ships are more redundant than offshore structures..

In spite of substantial experimental research, a designer still has to do with a large scatter of fatigue data. However, even in the case of exactly predictable fatigue behaviour, a design which assures a certain safety level during a whole life of structure may lead to impractical

solutions. Therefore, fatigue is sometimes treated as an inherent property.

All the above implies that in order to keep a certain safety level, the structure has to be inspected and if necessary repaired during its life. Inspection, repair and risk of failure of a structure involve substantial costs which interact with the initial cost of design and production. An optimum design may be defined as a design which minimizes the total life-cost of a structure.

Hereafter, a method is outlined which makes cost effective life-cycle design of fatigue sensitive structural components possible. The method is similar that proposed by Madsen et al, and in general, is based on a reliability analysis of a crack growth for which the Paris-Erdogan relation is assumed. The inspections and a repair strategy are accounted for by applying a system reliability analysis on an imaginary system which represents all logically connected events leading to the failure.

Before that, let consider briefly the notions "safety", "accident" and 'failure". Safety is 'control of accidental loss". This includes both preventing accidents and keeping losses to a minimum when accidents do occur. An accident is "an undesired event that results in harm to people, damage to property or environment and loss of production or transport capability". An accident may be caused by failure which is lack of the performance. Fatigue, ductile collapse or corrosion may for instance lead to failure. This consideration is crucial for selecting the mathematical definition of failure and costs which contribute to the cost of failure. Both elements should be compatible.

2. Life-cost model

The following costs are assumed to contribute to the total life-cycle cost C_T. First, the initial cost C_o, which consists of the design, construction, transportation and installation costs. Then, the maintenance cost which consists of all inspection costs C_{Ii}, and all repair costs C_{Ri}. Finally, the cost associated with the risk of failure. It is also possible to include positive or negative demolition cost and the rate of interest.

The initial cost is assumed to be a function of component scantlings Z_i and the production quality q_p. The production quality is assumed to be a product of the assemblage quality q_e, the welding quality q_w, and the post-welding treatment quality q_t. The assemblage quality is measured by the inverse of appropriate tolerance, for instance the allowable misalignment, and the welding quality is measured by the

inverse of the allowable crack size. The post-welding treatment quality is quantified based on judgement. The inspection cost is assumed to be a function of the inspection quality. The inspection quality is measured by the inverse of the mean detectable crack size including the smallest detectable crack size. The repair cost is estimated by the product of the probability of repair and the cost of repair. The cost associated with the risk of failure is estimated by a time integral of the product of the probability of failure pF and the annual cost of failure C_F.

In general, the total life-cycle cost is calculated by a formula of the following type:

$$C_T = C_0 + \sum_{i=1}^{n} (C_{I_i} + C_{R_i} p_{R_i}) + \int_{T_0}^{T_{life}} C_F p_F \, dt$$

(1)

where: n is the number of inspections, To is the initial time and T_{life} is the design or the extended life time.

It can be seen that in order to calculate the total cost it is necessary to calculate the probability of failure and repair. The probability of failure has to be calculated for a sufficient number of time intervals in order to make the integration possible.

How to calculate the probabilities of failure and repair, which are functions of many, in general, random variables, is described below.

The most crucial consideration for using (1) is the appropriate selection of costs which contribute to the cost of failure. When a failure causes a serious accident, for instance, total loss then the cost of failure may include: the cost of new investment, loss of benefit and costs of environmental pollution. If a failure causes loss of structural integrity then the cost of failure may include: the downtime cost, transportation costs, docking costs and repair costs. In general, the mathematical definition of failure, or its parameters, used in the above two examples will differ.

3. Crack growth model

The crack initiation and growth are the main reasons for technical deterioration of structures. The crack initiation is left out of the scope of the present work. The argument for that is that initial cracks in welded structures are always present and it is assumed for the time being that

only such cracks can grow and may consequentially lead to a failure and then possibly to an accident. Of course, cracks can also initiate at places where stress concentration are high. After that, these cracks can easily become dominant.

The conventional S-N approach is not suitable for reliability analysis of fatigue in combination with IRM because the governing information being the crack length is hidden in this approach. The fracture mechanics is well suitable.

In the present work the simple, one-dimensional and linear model of the crack growth defined by the Paris-Erdogan relation is assumed:

$$\frac{da}{dN} = C\left(\Delta K\right)^m, \qquad \Delta K > \Delta K_{thr}, \qquad a_{N=0} = a_0$$

(2)

The left hand side gives the crack length increment in one stress cycle with stress intensity factor range at the crack tip ΔK. C and m are material factors. ΔK is expressed as:

$$\Delta K = Y(a)\sqrt{\pi a}\; S$$

(3)

where Y(a) is the geometry function depending on the overall geometry of the joint including the presence of the weld, and S is the range of a far-field reference stress.

The discussion of associated assumptions and transformation of relations (2) and (3) into the integral form is omitted here, because it is well established and can be found in literature. The integral form of (2) is as follows:

$$\int_{a_{beg}}^{a_{end}} \frac{da}{\left(Y(a)\sqrt{\pi a}\right)^m G(a)} = C\,v\,(T_{end} - T_{beg})\,A^m\,\Gamma\left(1 + \frac{m}{B}\right)$$

(4)

G(a) is the auxiliary function:

$$G(a) = 1 - \frac{\Gamma\left(1 + \frac{m}{B}\,;\left(\dfrac{\Delta K_{thr}}{A\,Y(a)\sqrt{\pi a}}\right)^B\right)}{\Gamma\left(1 + \frac{m}{B}\right)}$$

(5)

which allows for the threshold effect (stress range intensities at the crack tip lower than ΔK_{thr} do not contribute to the crack growth, for steel $\Delta K_{thr} \approx 300$ $Nmm^{-3/2}$). $\Gamma(x)$ is the gamma function, and $r(\overline{x};p)$ in the numerator of (5) is the incomplete gamma function $r(x;p)=\int_0^P(e-ttx-1)dt$. v is the number of stress cycles per unit time. A and B are parameters of the Weibull distribution, which is assumed to describe the long term far-field stress range distribution:

$$F_S(s) = 1 - e^{-\left(\frac{s}{A}\right)^B}, \qquad s>0$$

(7)

The left hand side of relation (4) represents the resistance R of a joint against crack growth from the crack length a_{beg} at the beginning of the loading till a given crack length a_{end}. The right hand side represents the loading L imposed on the joint between the time T_{beg} and a given time T_{end}.

4. State function

The state function is defined as:

$$g = R - L$$

(8)

and is a function of the set of variables:

$$g = g \{ a_{beg}, a_{end}, T_{beg}, T_{end}, V \}$$

(9)

where V contains, in general, the following variables:

$$V = \{ A, B, m, C, v, \Delta K_{thr}, Y_i, ... \}$$

(10)

The set of variables in the state function can be subdivided into two sub-sets: deterministic D and stochastic X:

$$g = g \{ X, D \}$$

(11)

This subdivision is arbitrary. In general:

$$X = \{ a_{beg}, a_{end}, A, B, m, C, Y_i \}$$

(12)

$$D = \{ T_{beg}, T_{end}, v, \Delta K_{thr} \}$$

(13)

The state function is universal. Its physical interpretation depends on of the first four variables in (9).

Hereafter, it is outlined how to use the state function (9) for calculation of the probability of failure including inspection and repair. For the sake of simplicity, two inspections are assumed and the repair strategy is such that all detected cracks are repaired.

5. Probability of failure

One physical component with one state function (9) is considered. The first four variables in (9) are as follows: the initial crack size, the critical crack size, the initial time, and the time. At each time there is a certain probability that the component will fail. This is because some variables in (9) are uncertain. The probability of failure can be calculated by the componental reliability software, e.g.: COMREL (a part of STRUREL).

The act of inspection complicates the situation. -First of all, when during the inspection no crack is detected it does not necessarily mean that no crack is present. A crack may be in fact only detected by a certain probability depending on the size of the crack and on the inspection method, while cracks shorter than a certain size are not detectable at all by ordinary methods. For crack detection under water, it is claimed that there is a 90% probability of detecting a 45 mm long crack with the use of MPI (Magnetic Particle Inspection). However, to detect a crack with the same probability with VI (Visual Inspection) requires a crack length of 225 mm. The probability of crack detection is calculated in the same way as the probability of failure before the first inspection. Namely, by calculating the probability that the crack has grown longer than the detectable crack size. This is made using the same state function (9). But in this case a_{end} is the detectable crack size and not the critical crack size as it was in the case of calculation of the probability of failure.

A second complication caused by the act of inspection is that there are more possibilities leading to a failure (at least 2_n). Therefore, a systematic approach is necessary. This is done by creation of an imaginary system which is shown on figure 1, and which consists of components which are defined in table 1.

Now, the problem of calculating of the probability of failure is as follows. The state of a system is defined by a set of state functions describing the components or failure modes of the system Aj. In the present problem the limit functions of all components have the same form (9). The difference between the limit functions of the various components is the different meaning of the first four

variables in (9). The components are arranged in a logical representation which connect the components by "And-gates" and "Or-gates" in a fault tree (figure 1) with system failure as its top event. All state functions in the system are a function of common set of variables some of which are uncertain. These uncertain variables X (12) called basic variables are random with joint distribution function $F_X(x) = P(\cap^n_{i=1}\{X_i \leq x_i\})$ defining the stochastic model. The individual state function, denoted by $gj(X)$, is defined such that $gj(X)>0$ corresponds to favourable states of the j-component in the system. $gj(X)=0$ denotes the so-called limit state or the failure boundary, and $gj(X)<0$ defines the failure domain of the j-component. The logical connection of the system components has an equivalent representation in the connection of the failure domains F-j. An "Or-gate" defines the union of componental failure domain (series system): $F_{ser}=\cup^n_{i=1}(F_i)$. An "And-gate" defines the intersection union of failure domain (parallel *system): $F_{par}=\cap^n_{i=1}(F_i)$. An arbitrary logical arrangement of components in a coherent fault tree can always be represented in terms of a minimal cut-set system, which is the union of intersections of failure domains $F_{sys}=\cup_i\cap_j(F_{ji})=\cup_i\cap_j(g_{ji}\leq 0)$. This represen-tation should be minimal in the sense that no combined set contains another as a genuine subset. The formation of such a set can always be achieved by the systematic application of the distributive and the absorption rules of set algebra (figure -,. The probability of failure is defined as:

$$P_f = P(X \in \{F_{sys}\}) = \int_{\{F_{sys}\}} dF_X(x)$$

(14)

SYSREL which is a part of structural reliability software STRUREL provides an approximate solution for pf.

The fault trees which appear in the present problem contain the complementary events, i.e.: A_i and $\tilde{A}_i$ such that $A_i \cup \tilde{A}_i = I$ and $A_i \cap \tilde{A}_i = 0$. CUTALG (an utility of STRUREL) can not reduce such fault trees into minimal cut-sets. Such systems can be reduced by hand by the application of the rule: $A \cup (\tilde{A} \cap B) = A \cup B$. The result of such reduction is shown on figure 1.

6. Example

The numerical tool is under development, and is not yet fully operational. The author hopes to show during the presentation results of an example which includes costs calculation.
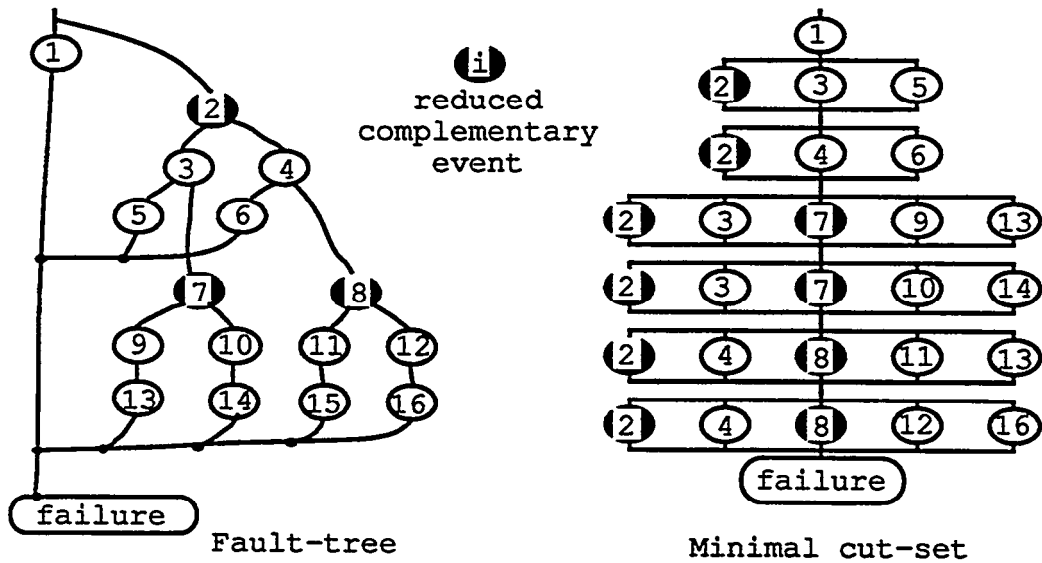
Figure 1. Fault-tree and minimal cut-set.

Table 1. Definition of components

j	State function	$A_j=$ ($g_j<0$)	Description
1	$g_1=g(a_o,a_c,T_o,T_1)$	$g_1<0$	failure before 1st insp
2	$g_2=-g_1$	$A_2=\tilde{A}_1$	complementary to 1
3	$g_3(a_o,a_{d1},T_o,T_1)$	$g_3<0$	detection at 1st insp
4	$g_4=-g_3$	$A_4=\tilde{A}_3$	complementary to 3
5	$g_5(a_{r1},a_c,T_1,T_2)$	$g_5<0$	failure after 3
6	$g_6(a_o,a_c,T_o,T_2)$	$g_6<0$	failure after 4
7	$g_7=-g_5$	$A_7=\tilde{A}_5$	complementary to 5
8	$g_8=-g_6$	$A_8=\tilde{A}_6$	complementary to 6
9	$g_9(a_{r2},a_{d2},T_1,T_2)$	$g_9<0$	detection at 2nd insp after 7
10	$g_{10}=-g_9$	$A_{10}=\tilde{A}_9$	complementary to 9
11	$g_{11}(a_o,a_{d2},T_1,T_2)$	$g_{11}<0$	detection at 2nd insp after 8
12	$g_{12}=-g_{11}$	$A_{12}=\tilde{A}_{11}$	complementary to 11
13	$g_{13}(a_{r2},a_c,T_2,T_3)$	$g_{13}<0$	failure after 9
14	$g_{14}(a_{r1},a_c,T_1,T_3)$	$g_{14}<0$	failure after 10
15	$g_{15}(a_{r2},a_c,T_2,T_3)$	$g_{15}<0$	failure after 11
16	$g_{16}(a_o,a_c,T_0,T_3)$	$g_{16}<0$	failure after 12

The present example illustrates the capability of the tool in reliability calculation of a fatigue sensitive joint including inspections and repairs.

The physical problem is a centrally cracked panel. The panel is made of steel, which has stochastic constants of crack growth lnC and m. The effect of corrosion on fatigue is modelled by assuming $\Delta K_{thr}=0$. The panel is cyclically loaded

from an initial time T_o till a final time T, with v cycles per year. The amplitude of the loading is a stochastic value defined by the Weibull distribution of two parameters lnA and 1/B, which are also stochastic. In the panel at time T_o there exists an initial crack which has an uncertain length a_0. The failure is defined when the crack length reaches the critical crack length a_c, which is also uncertain. The geometry function is assumed constant. The stochastic model is summarized in Table 2.

Two cases are calculated. Case I - two visual inspections, with the same quality q_I=0.23, at T1=10 and T2=20 years. Case II - one MPI inspection with the quality qI=1.3, at Tl=10 years. In both cases all detected cracks are repaired.

Table 2.   The stochastic model

Sym.	Variable name	Unit	Distribution	Mean	Dev.
T_0	initial time	year	fixed	0	–
T	lifetime	year	fixed	30	–
T_1	first inspection	year	fixed	10	–
T_2	second inspection	year	fixed	20	–
a_0	initial crack size	mm	exponential	1	1
a_r	repair crack size	mm	exponential	0.5	0.5
a_c	critical crack size	mm	normal	10	1
q_I	quality of VI	mm^{-1}	fixed	0.23	–
q_I	quality of MPI	mm^{-1}	fixed	1.3	–
a_{min}	minimal smallest detectable crack size	mm	fixed	0	–
lnA	Weibull parameter of stress distribution	MPa	normal*	1.6	0.22
1/B	Weibull parameter of stress distribution	–	normal*	1.2	0.15
v	upcrossing rate	cycles /year	fixed	$1 \bullet 10^6$	–
m	material parameter	–	normal**	3	0.15
lnC	material parameter	...	normal**	-29.9	0.5
Y	geometrical function	–	fixed	1.12	–
correlated values: *– ρ=-0.79, **– ρ=-0.9					

Results which are self explaining are shown on figure 3.

7.   Conclusions

A procedure for cost effective life-cycle design of fatigue sensitive structural component and in particular reliability calculation of such component including inspections and repairs has been outlined. The reliability calculation has been illustrated by an example.

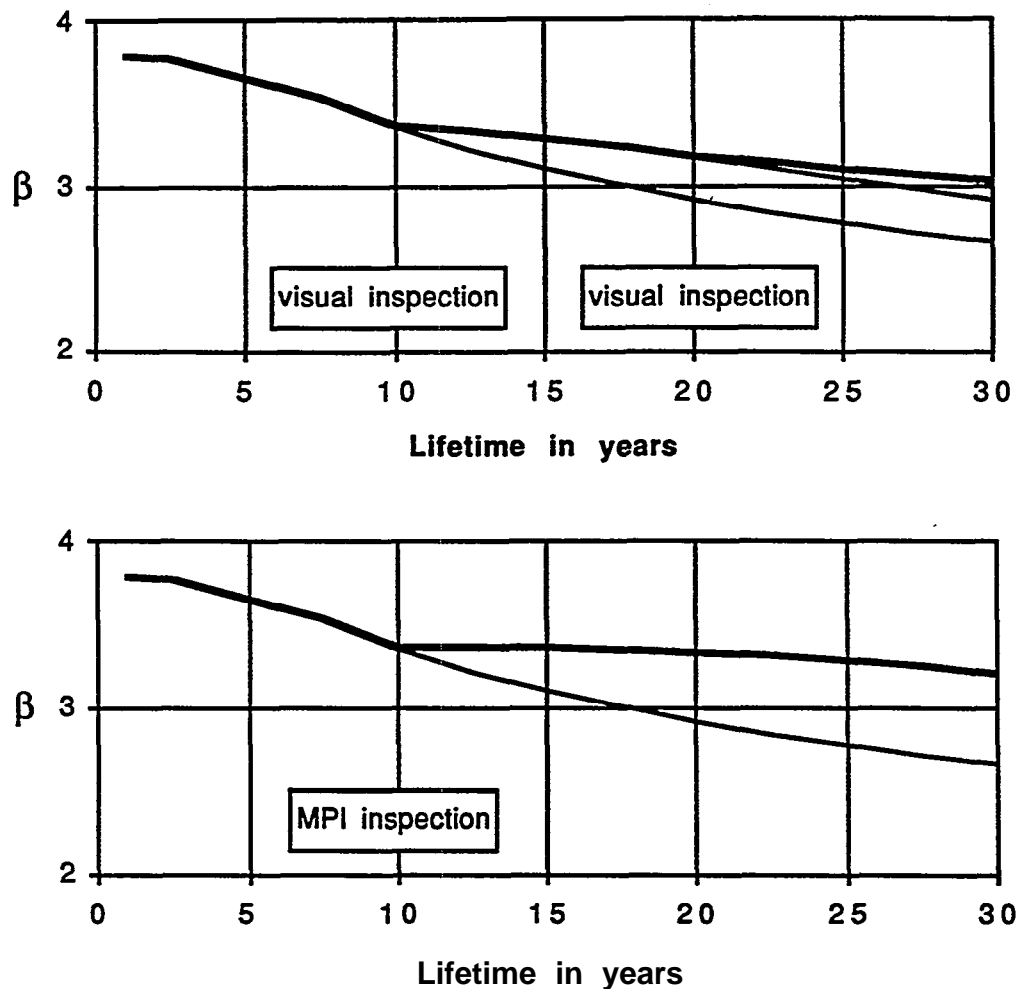Figure 3.   Results of reliability calculation including
            inspection and maintenance

Acknowledgements

The 150 anniversary note
On behalf of the Nevesbu wherein 90% of all graduates come from the Delft University of Technology, the author would

like to congratulate the University and especially the Division of Naval Architecture, which contributes significantly to the Dutch and the international shipbuilding. Furthermore, on behalf of all those who find a friendly working or studying place at the University during the wind-storms of the history in their home-countries, the author would like to acknowledges the University for its helpful attitude.

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WELDING INDUCED IMPERFECTIONS AND COLLAPSE OF SHIP PLATING IN COMPRESSION

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Abstract

Analysis of the load-carrying capacity of plates under uniaxial compression was carried out in elastic-plastic range with due allowance for large plate deflections. The calculations were performed with finite element method (FEM) computer code PANFEM, developed at the Ship and Offshore Structures Mechanics Department, Technical University Szczecin.

Plates were analyzed having dimensions which mostly appear in ship structures. Results of measurement of post-welding deflections of plates are presented and their influence on the load-carrying capacity of ship shell plating is discussed.

Combined effects of post-welding deflections and stresses are also examined.

Introduction

Plates constitute basic structural elements of all ship structures. Uniaxial compression dominates in many parts of these structures therefore the performance of plates under this loading condition is of considerable importance for practice. This particularly is the case when the load-carrying capacity of the ship hull girder is to be determined.

The phenomenon of shrinkage which accompanies the welding process is the reason why structures which have been fabricated by means of welding are always to a greater or lesser extend deformed and contain balanced internal stresses. At present, welding is the dominant process in the joining of steel elements and thus is the main source of fabrication distortion of the stiffened plates of the ship shell-plating and the residual stresses occurring there. Results of measurements of these imperfections are presented below and their effect on the ultimate strength (collapse load) of plates under uniaxial compression is examined.

Characteristics of ship's hull plating

Ship's plates dimensions proportions differ from those encounter in other metal structures. Figures 1 and 2 contain histograms of plate aspect ratio (a/b) and of plate slenderness (b/t) of ship's hull plating. In the figures values of means and variances of these quantities are also given together with the number of the plates which dimensions were examined. The examined plates were of general cargo ships, bulk carriers, OBO carriers, chemical carriers, refrigerated vessels, tankers as well as passenger/car ferries. The deadweight of the ships investigated was within 1,900 and 116,280 tons.

Plates boundary conditions

Plate ultimate strength is associated with large deflection what in turn results in considerable displacements of its middle plane. Plates with simple and clamped supports were analyzed and with boundary conditions for the edges of their middle planes that, like simple and clamped supports, also constitute two extremes, namely:

-the edges unrestrained; unloaded edges of the middle planes of plates unrestrained (free to pull in, v # 0, av/ax # 0, Fig.6) while loaded edges remain parallel both before and after plate deflection (au/ay = 0, Fig.6),

-the edges restrained; the plate deflection is not accompanied by the displacements of the unloaded edges of its middle plane while the loaded edges remain parallel both before and after the deflection $(au/ay = 0, v = 0,$ **Fig.6**).
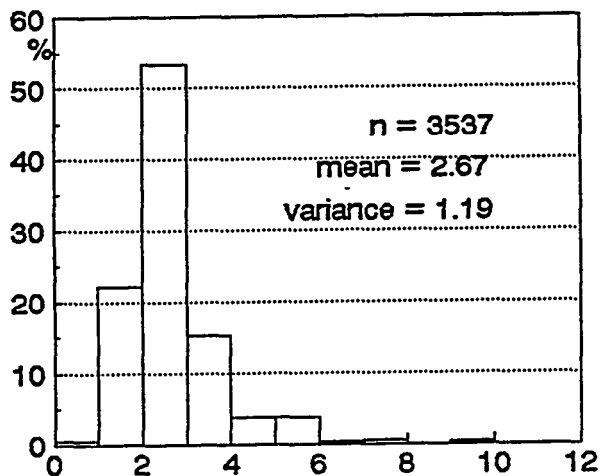

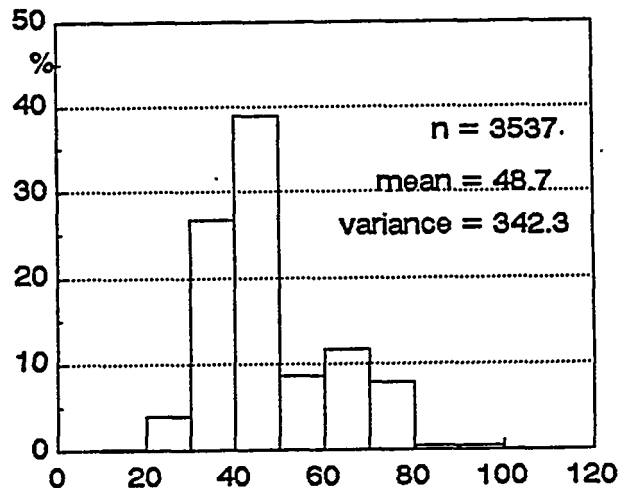Fig. 1. Histogram of plate aspect ratio, a/b

n = 3537
mean = 2.67
variance = 1.19

Fig. 2. Histogram of plate slenderness, b/t

n = 3537
mean = 48.7
variance = 342.3

FEM computer code PANFEM
The numerical study was performed with the computer program PANFEM, developed by the Ship and Offshore Structures Mechanics Department, Technical University Szczecin. This is nonlinear finite element code for flat plates and flat stiffened panels with imperfections (initial deflections and stresses) under lateral and/ or in plane loads. Large displacement effects are handled using total Lagrangian formulation. Isotropic hardening of material is assumed and Huber - von Mises yield criterion together with associated Prandl - Reuss flow rule are applied. The Newton - Raphson and the Modified Newton - Raphson methods are utilized combined with the Powell and Simons (1981) or the Crisfield arc length procedure (1981) to handle both pre - and post collapse behaviour of plates and stiffened plates. PANFEM was calibrated with well documented experimental recordings published in the world literature. Very good agreement was obtained between PANFEM and experimental results (Kmiecik 1992).

Ship plating imperfections
Post welding stresses and distortions are highly varied. Structures with the same geometrical characteristics exhibit significant differences in the magnitude and geometry of their distortions and in the magnitude and distributions of stresses. These differences are the result of deviations in the welding parameters and depend on many uncontrolled factors in the production process as well as on the conditions accompanying the welding process, such as the initial distortion of plates and stiffening sections, the boundary conditions and the state of loading of the structure during welding, etc. As a result of this, welding stresses and distortions are treated as random variables whose magnitude can only be estimated on the basis of the appropriate statistical data.
Fig. 3 contains examples of post-welding bending distortions of three ship plates of varying aspect ratios, *a/b (Kmiecik et al. 1990)*. The distortions were approximated by means of a double trigonometric series of the form:

$$w_o/t = \sum_{i=1}^{m} \sum_{j=1}^{n} w_{o(ij)}/t \ \sin \frac{i\Pi x}{a} \sin \frac{j\Pi x}{b} \qquad (1)$$

In the figure the values of the coefficients of the series are also given. The coefficients of the series were defined on the

b (mm)	t (mm)	$w_{o\,max}$ (mm)	a/b	b/t	$\frac{w_{o\,max}}{t}$
834	7	3.421	0.96	119.14	0.489

a (mm)	b (mm)	t (mm)	$w_{o\,max}$ (mm)	a/b	b/t	$\frac{w_{o\,max}}{t}$
2,500	700	8	19.840	3.57	87.50	2.480

$w_{o\,i,j}/t$			
i\j	1	2	3
1	0.9972	−0.4873	0.2176
2	0.2999	0.0395	0.0028
3	−0.7242	0.0729	0.1174
4	0.3353	−0.0795	−0.0117
5	0.0756	−0.0066	−0.0593
6	−0.3990	0.0995	0.0799
7	0.3256	−0.0908	−0.0674
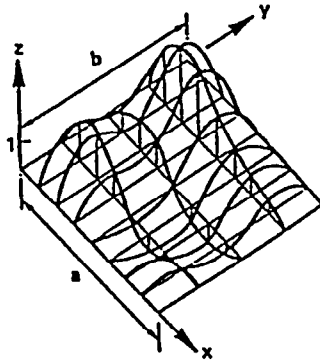
$w_{o\,i,j}/t$			
i\j	1	2	3
1	1.0104	0.9443	0.7758
2	−1.3318	−0.0715	−0.3253
3	0.4473	−0.1134	0.4158
4	−0.4259	0.0129	−0.0270
5	0.4216	−0.0994	−0.1943
6	−0.3556	0.2896	0.0733
7	0.2557	−0.3731	0.0054
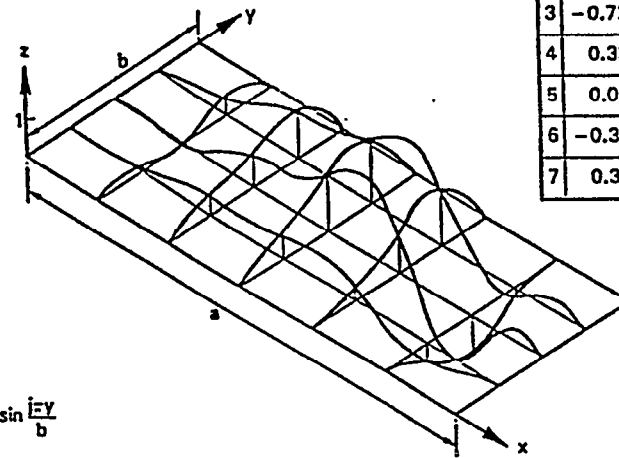
b (mm)	t (mm)	$w_{o\,max}$ (mm)	a/b	b/t	$\frac{w_{o\,max}}{t}$
600	8	2.384	2.33	75.00	0.298

$$\frac{w_o}{t} = \sum_i \sum_j \frac{w_{oij}}{t}\, \sin\frac{i\pi x}{a}\, \sin\frac{j\pi y}{b}$$
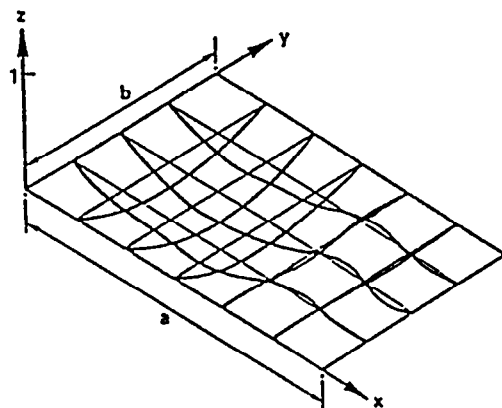
$w_{o\,i,j}/t$			
i\j	1	2	3
1	−0.2048	−0.0219	0.0017
2	−0.1371	0.0059	−0.0079
3	−0.0135	0.0178	0.0048
4	0.0190	−0.0127	0.0028
5	−0.0327	−0.0055	−0.0085
6	0.0140	−0.0097	−0.0103
7	0.0019	−0.0081	0.0062

Longitudinal stiffeners
Transverse stiffeners
Y
LVDT gauge heads
Measuring jig
Paths of measurements
X
Plate

Fig. 3. Examples of measured post-welding distortions of plates

basis of the recorded deviations from the base plane Of twenty or twenty five point on each of the five measurement paths Of a plate. The measurement paths are shown in Fig. 3. Report by Kmiecik et al (1990) contains a summary of results of almost fifteen years measurements carried out mainly in Polish shipyards in the process of construction of ships. In total about 2000 plates were examined. Results of statistical and regression analysis of the measurements are also given in the reference together with a short description of the measurement technic applied. The measurements confirm the random nature of ship shell plating bending distortions and their complicated geometric shapes.

In Fig. 4a an example of histogram of some of the recordings is given. The figure shows that the plate deviation from flatness is not normally distributed. The Weibull's distribution provides the best fit to the results of the measurements. No correlation between relative maximum plate deflection, w_{omax}/t, and the plate aspect ratio, a/b, could be established while practically linear relationship exists between w_{omax}/t and the plate slenderness, b/t (Fig. 4c). Also linear relationship holds between the buckling mode componen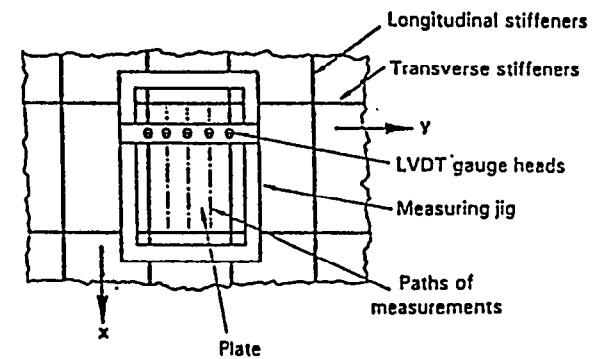t w_{ob}/t and the plate slenderness, b/t, and the plate aspect ratio, a/b, (Figs. 4e,f). Comparison of Figs. 4c i 4d shows that $w_{o(11)}/t$ component dominates in plate initial deflections which constitutes the buckling mode component for plates with aspect ratio of 1 - 1.41 (Table b in Fig. 4). Figs 4e and 4f also indicate that magnitudes of buckling mode components of initial deflections increase with plate slenderness, b/t, but decrease with plate aspect ratio, a/b. As can be seen in the figures initial deflections increase with plate slenderness and on average for plates with b/t between 30 and 100 one can reckon with w_{omax}/t between 0.05 and 0.50.

A typical distribution of post-welding stresses in a plate to which stiffeners have been welded is shown in Fig. 5. To Simplify the analysis straight lines were substituted for this distribution in *FEM* calculations.

Post-welding stresses as internal stresses are balanced, and in the tensile region their magnitude is equal to the yield stress of the material (Fig. 5):

$$2\sigma_y \eta t = (b - 2\eta t)\sigma_r$$

b)

a/b	Wob/t
1 - 1.41	Wo(11)/t
1.41 - 2.45	Wo(21)/t
2.45 - 3.46	Wo(31)/t
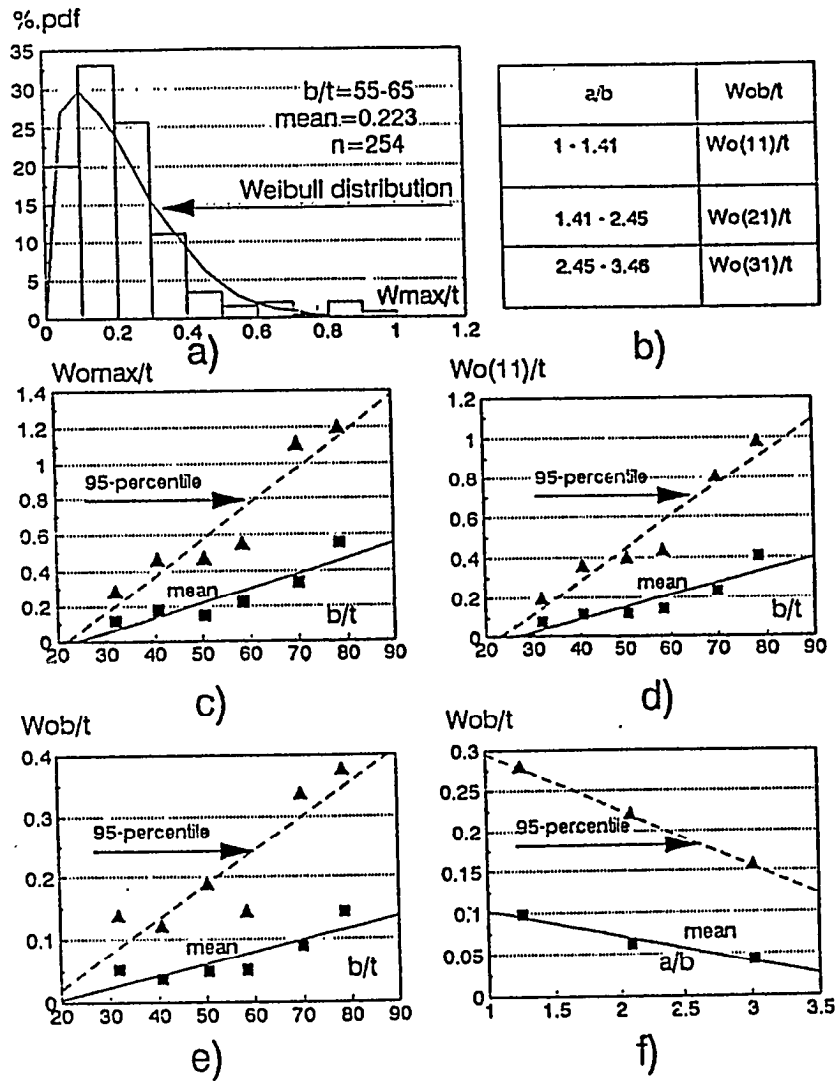
Fig. 4. Statistical data and regression analysis of measured post-welding plate deflections

• Measurement results

b = 600 mm; $t_t/t = 1.0$; $\sigma_y = 250$ MPa
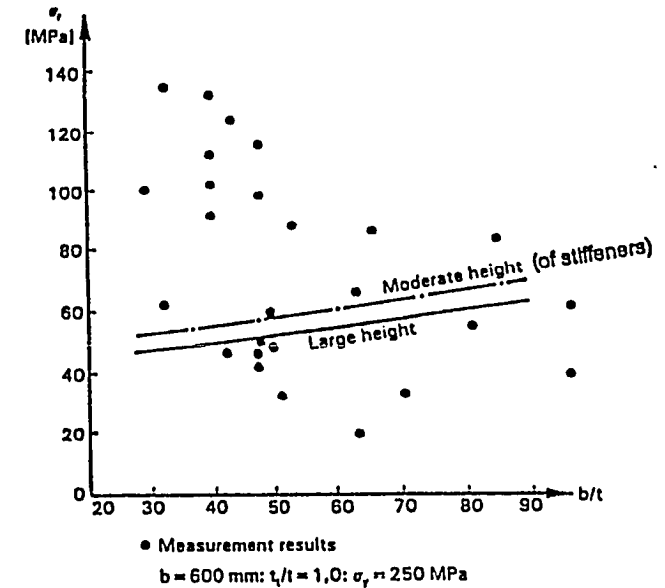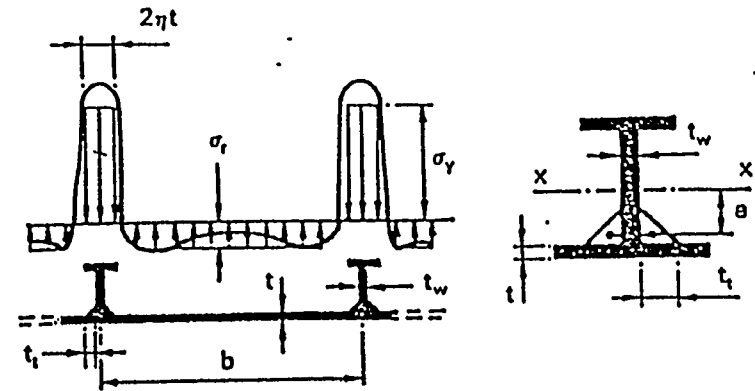
$$\sigma_t = \frac{\sigma_y}{\dfrac{b/t}{2\eta} - 1} \qquad \eta = \frac{1}{t(t_w + 2t)\left(\dfrac{1}{F} + \dfrac{e^2}{J} - \dfrac{\sigma_y}{E\mu q_t}\right)}$$

F plate cross section area

J plate cross section moment of inertia

$\mu = -3.13 \cdot 10^{-6} cm^2/cal$, $q_t = 7250 t_t \sim 2 cal/cm$

Fig. 5. Post-welding stresses in longitudinally stiffened panels

of plate during compression:

$$\sigma_r/\sigma_y = \cfrac{1}{\cfrac{b/t}{2\eta} - 1}$$
(2)

In Fig.5 the values of σ_r in relation to the slenderness ratio
b/t of the plates which have been measured and calculated by
various authors are also given (Carlsen 1976, Kmiecik 1986). As
might have been expected, in practice one has to deal with a
considerable variation in the magnitude of σ_r and thus also of
the values of η for the same slenderness b/t. As indicated by
Guedes Soares (1988) in ship structures the mean of $\bar{\eta}$ = 5.25
and the coefficient of variation of n, V_n = 0.07. In accordance
with Fig. 1 the average slenderness of ship plating b/t ≃ 50
what together with the above numbers (after their substitution
into (2)) results in average σ_r/σ_y ≃ 0.25.

Effect of imperfections and boundary conditions
Figure 6 contain calculation results of the load-carrying
capacity (relation: axial compressive stress – axial
compressive strain) of simply supported and clamped square
plates with two different and extreme – in terms of
displacements – boundary conditions of the edges of their
middle planes: the edges unrestrained (completely free to pull
in) and restrained (no displacement at all in the middle
planes). Initial deflection of the plates is in the form of
regular half – wave:

$$w_o/t = w_{o(11)}/t \; sin \; \frac{\Pi x}{a} \; sin \; \frac{\Pi x}{b}$$
(3)

Calculations were carried out for initial deflections
constituting 50 and only 0.5 per cent of plate thickness.
The collapse loads obtained for the latter magnitude of the
initial deflections, because of their very small values, are
treated as the capabilities of perfectly flat plates.
In Fig. 6 critical loads are also given but only for plates
with slenderness b/t = 100. Plates of this slenderness buckle
in elastic range and in this range only exact expression for
critical loads can be found in world literature.
As can be seen in Fig. 6 restraining the plate middle plane
against displacement increases its load – carrying capacity
considerably. This positive effect depends on the plate
slenderness, b/t, and on the plate support (simple, clamped).
Most affected are simply supported plates and plates with high
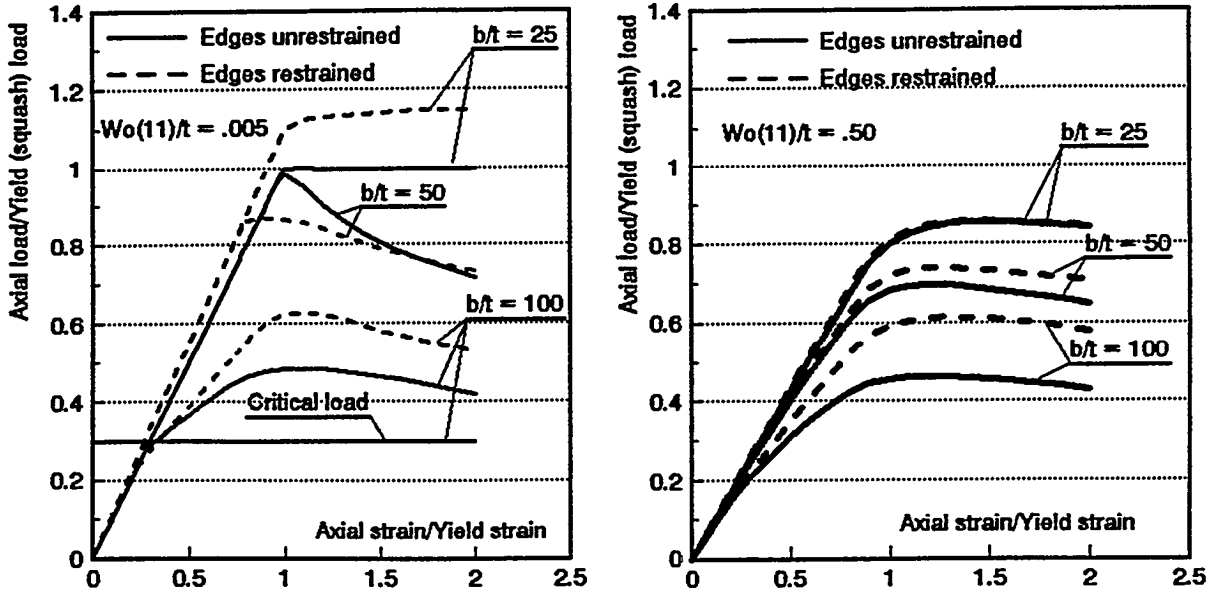
a) Simply supported
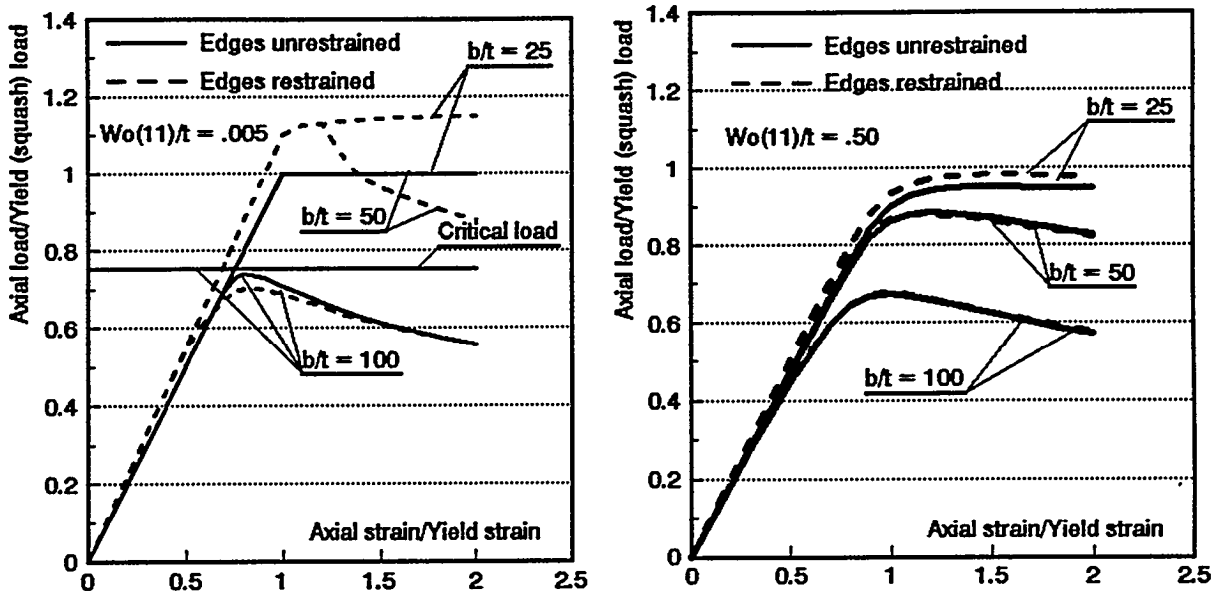
b) Clamped

Axial strain = u/a

Yield strain = σ_y/E

E = 206 kN/mm^2

σ_y = 248 N/mm^2

γ = .3
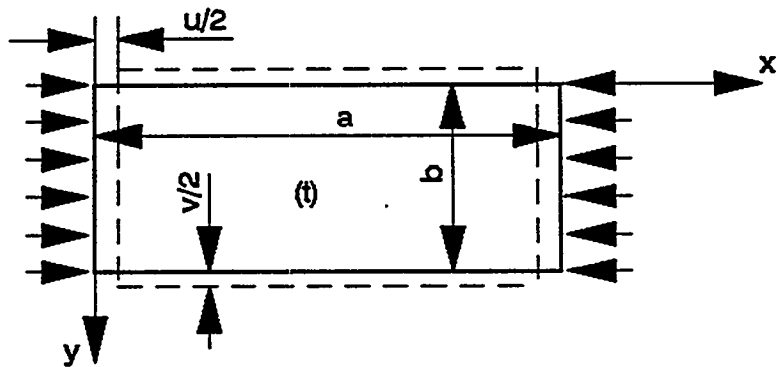
Fig.6. Square plates under uniaxial compression

slenderness. Simply supported plates are also much more sensitive to initial deflection than the clamped once. The initial deflection decreases plate ultimate strength; his effect is stronger for larger initial deflection and larger plate slenderness.

Fig 7 demonstrates the dependence of the load-carrying capacity on plate aspect ratio a/b and initial deflect $w_{o(11)}/t$. Increase of initial deflection in the form of a regular half - wave decreases ultimate strength of square plates considerably (Plate 2 in Fig.7) while the strength of rectangular once increases (Plate 3 in Fig.7). This is due to well known shell effect as deflection in the form of half - wave is not sympathetic with buckling mode deflections of rectangular plates. Fig. 7 also indicates that the maximum deviation from plate flatness w_{omax}/t is not a rational measure for the detrimental effect of initial deflection on plate ultimate strength. Rectangular plate 3, 4, 5 and 6 in Fig. 7 have in fact the same (≈ 0.5) but their ultimate strength is distinctly different. It is not the maximum deviation from plate flatness w_{omax}/t b but the geometric shape of the imperfection on which the ultimate strength of the plates depend and which also decisively effects the behaviour of the plates both before and after their collapse.

Fig 8 shows the effect of initial stresses on ultimate strength of plates. Practically no effect of the residual stresses on the ultimate strength of plates is observed at axial strain exceeding 1.5 yield strain'. This result can be explained by the analysis of the behaviour of the plate shown in Fig.9 on the assumption that it will not buckle. Compression or tension of a plate without residual stresses will not change the elastic - plastic nature of the plate material. The existence of the residual tensile stresses at the plate edges equal to the yield stress decreases the plate stiffness under tension as the width of the plate is reduced to $(b - 2nt)$ already on onset of the tensile load. The ultimate strength of the plate is, however, not affected and is equal to the yield stress of the material. In case of compression, the existence of the residual compressive stresses σ accelerates the yielding of the material in the region (b - 2nt) causing a sudden drop in the stiffness of the plate in the ratio of $2nt/b$ at the axial load equal to (σ_r) but the load - carrying capacity of the
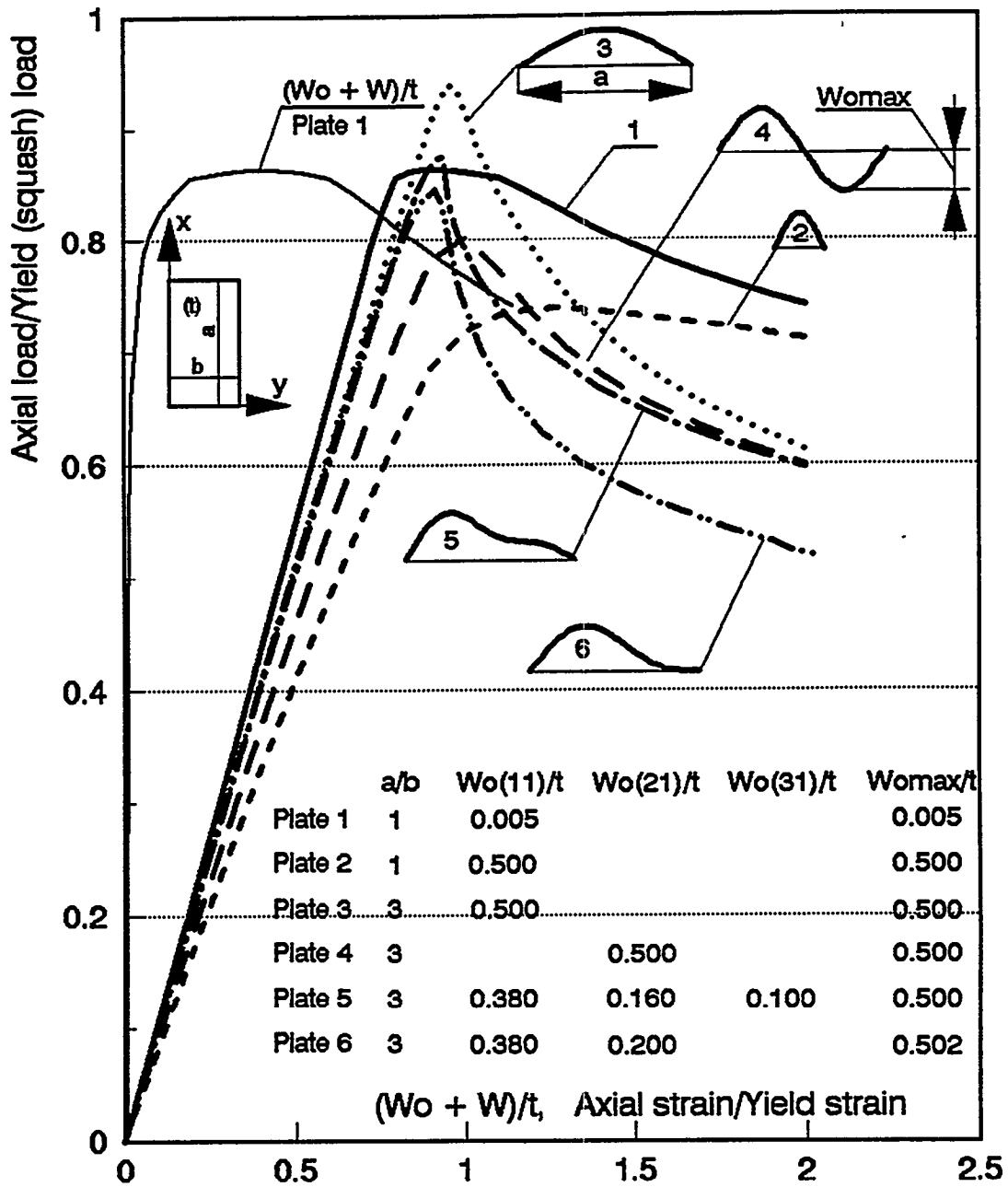
Fig.7. Simply supported plates with initial deflections,
edges restrained, under longitudinal compression,
effect of initial deflection shape on plate behaviour,
W - plate central deflection
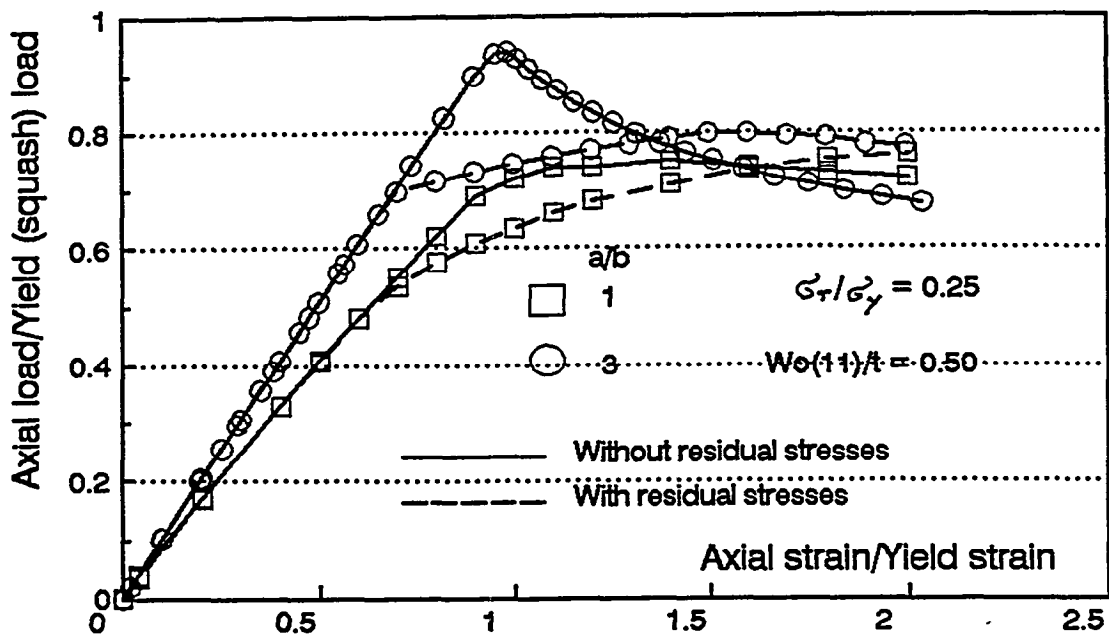
Fig.8. Simply supported plates, edges restrained, with initial deflections and residual stresses, under logitudinal compression
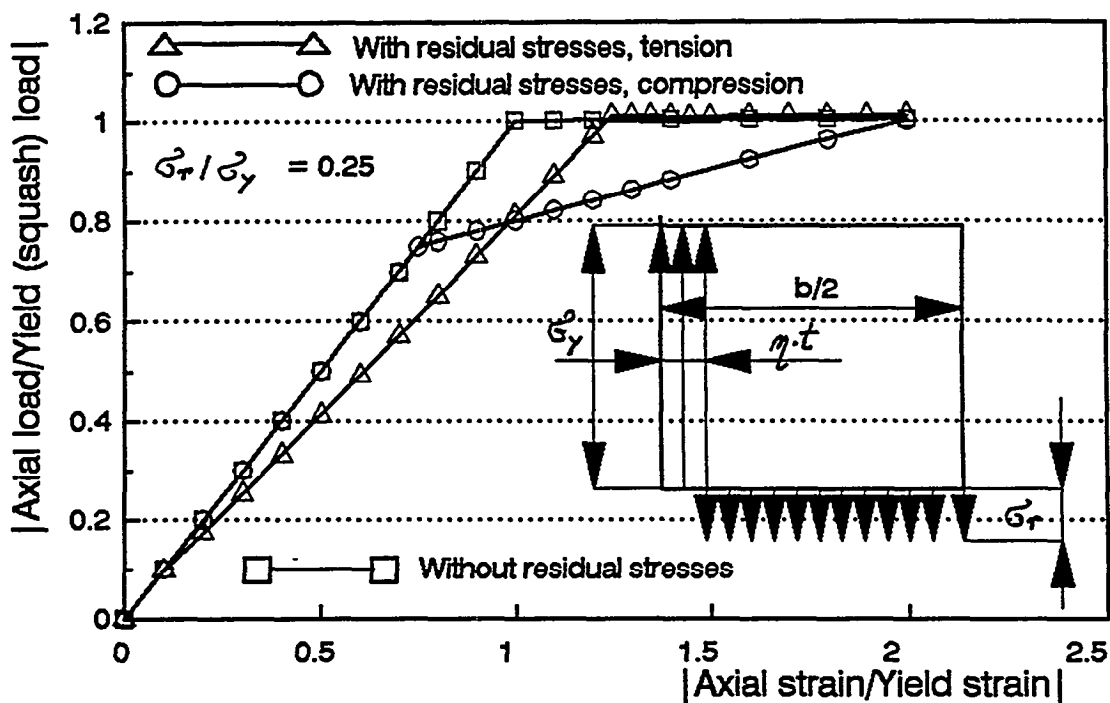
Fig.9. Plate with residual stresses under tensile or compressive loads, σ_r residual compressive stress, σ_y yield stress

plate is again the same when the axial strain is sufficiently large (twice the yield strain). The same phenomenon occurs in plates having both initial deflections and stresses. The sudden drop of the stiffness is now expressed by a "cutting off" of the extreme part of the plates equilibrium paths, especially in plates which have clearly marked extreme points. This particularly pertains to plates having initial deflections which are not sympathetic with buckling mode deflections what is the case with the rectangular plate whose equilibrium path is given in Fig. 8.

Conclusions

Simply supported and clamped square and rectangular plates were analyzed to study the effect of in-plane boundary conditions and imperfections (initial deflections and stresses) on their load - carrying capacity under uniaxial compression. Restrained displacements of edges of plates middle planes (no possibility to move in after plate deflection) increase considerably plates ultimate strength. Most affected are simply supported and slender plates. Initial deflections' only then decrease ultimate strength of plates when their geometric shape is sympathetic with the shape of the buckling mode. Initial compressive stresses decrease ultimate strength of plates considerably only if the plates have clearly marked extreme points. This pertains to plates having initial deflections which are not sympathetic with their buckling mode deflections.

Initial plate deflections are not normally distributed and have very complicated geometric shapes. In the shape dominates the first harmonic term $w_{o(11)}/t$. The average of the maximum relative deviation from plate flatness w_{omax}/t as well as of the first harmonic $w_{o(11)}/t$ and the buckling mode components w_{ob}/t increase linearly with the slenderness b/t. Also linear relationship holds between the mean of the buckling mode components and the plate aspect ratio a/b but w_{ob}/t decreases with the increase of a/b.

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EDUCATION, TRAINING AND SIMULATION

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Training and Simulation

The STCW Convention which came into force in 1978 is by today
recognized world wide as a common standard for training and education
of seafarers.

The Convention was prepared during the 1970' to establish a training
and education régime for seafarers serving in ships built to a design
developed during the Second World War.

Since the Convention came into beeing and until the late 1980' we
experienced one of the worst recession in shipping ever. During years
of recession the development of a high tech, low manned ship design
gained ground, and today more and more ships are build in accordance.

Training Standard in the STCW Convention has to a large degree been
outdated by the high tech ship and seafarer. New training methods and
means - of which simulation seems to be the most significant single
one - are urging for implementation.

This paper are defining what separates the training needs of today
from the needs of the future.

The total crew concept is described and areas in which the use of
simulation can assist and improve training efforts are defined.

EDUCATION, TRAINING AND SIMULATION

Education and training of todays seafarers are in most seafaring
countries regulated by the International Maritime Organization's
(IMO) Standards of Training, Certificate and Watchkeeping Convention
(STCW) which was adopted by the Organization in 1978.

Before the finalization of the convention, work within it had gone on
for almost 10 years.

The convention has without doubt played a tremendous role in raising
standards of training and education of seafarers. With more than 80%
of the world fleet being contractors to the STCW convention it might
be assumed, that seafarers plying the oceans do have the necessary
skills to do so in a safe way!

Casualty and accident reports and statistics are giving another
picture which questions the assumption just mentioned. It is widely
acknowledge, that around 80% of all accident or casualties at sea are
caused by the human element.

That this percentage is not just anecdotal is revealed by more and
morestudies of which on e.g. concludes, that human element was found
present in over 90% of collisions and groundings, and in over 75% of
contacts and fires/explosions.

Exactly the types of casualties which most presumable could be
aworded by having the correct training and education system and
regulation on watchkeeping on both navigation bridge and in engineroom
present. Precisely the intentions of the convention.

A variety of questions are frequently raised on that background.
These questions can be categorised in 3 main groups as follows:

1. Standards set up in the STCW convention are too low.
2. Standards set up in the STCW convention are sufficient, but
    contracting governments do not comply with them.
3. Standards described are desirable, but not achievable with the
    means of todays STCWC convention.

Before addressing questions 1 - 3 it might be appropriate to look at
the convention in details, and more particularly to look at the
education and training philosophy on which the convention is based.

The STCW convention is built on a traditional English system of
training where young persons are indentured to become master
craftsmen in 4-5 years. This system was adopted in shipping in late
19th century.

The system proved successful due to the slow pace of evolution of
ships design and long periods spent at sea onboard the same vessel

which ensured that apprenticies were indentured to the same master for the whole training period.

Seafaring and seafarers encountered many unexpected problems, and solutions were often based on intuition and experience.

Training people to such an environment was well suited by the indentured system which was carried along without being questioned all the way into the 1978 STCW convention.

Education system in the convention is based on an academic approach where competence is achieved at college and is directly related to time spent in college.

The traditional departmental division is furthermore laid down in the convention, in such a way that competence and training are divided into separate herarchical systems.

The convention itself does not only describe how to train and educate seafarers. It also regulates working and watchkeeping arrangements. It is, when discussing the convention, essential to draw a distinction between standards of training and education and standards of carrying out onboard duties regulated by the convention.

Standards of training and education are presumed to be the means by which the standards of working and watchkeeping are secured. By the intention of the convention it is understood that the aim of the standards in supporting one another is to establish a faultless operation..

More than anything else casualty statistics demonstrate that the convention has not been successful in that respect.

Before returning to question 1-3 formulated in a former section, it is appropriate to elaborate on the meaning of standards within the convention, in preparing answers to the questions standards are being discussed as well.

Are standards to low as indicated by Question 1?

It is hard to give any firm answers to this suggestion, as the necessary standards are changing with the technical development. The main problem seems to be that the convention is covering education, training and operational standards in ships which only have ARCHIMEDES' PRINCIPLES in common.

Standards are for a traditional ships design with a traditional complement of crew in many ways acceptable with the current convention, but out of place for high tech ships as the Germans "shiff der zukunft" and the Danish "projekt skib" which is a design rapidly gaining ground throughout Western Europe.

In *some* areas, both traditional and futuristic ships design are profiting of todays technology which was not foreseen at the time of setting up the convention.

For instance a lot of emphasis is placed on navigation officers ability to establish their position on the globe and their ability to find their way. All this is today carried out by pressing buttons. These developments are not reflected in the way navigators and oprators of navigation systems are trained and educated by today. This is more highlighted particularly in discussing question 3.

Question 2 is the most simple to deal with as it is not only commonly agreed but also well documented that some governments are all to lenient in interpretation of the convention and in issuing certificates to their seafarers.

The answer to this problem is, on the other hand, not to establish a new examination board within the auspices of the port state control which could be the implication of the proposals of having operational checks carried out by port state control inspectors.

Question number 3 is far the most complex one, but also the one which is addressing most of the problems faced by the convention. As mentioned the intention is not in this paper to describe or redescribe standards, but to look at how they are presently achieved and assessed, and most imporatantly to give consideration to change.

Assess technics as proposed *in* a coming *section* will apply to both the standards of todays convention and a revised convention.

Mr Juan Kelly is in session 7 B dealing with the training of tomorrow and the need for revision of the convention, and with it the need for reestablishing the standards.

3 different kinds of standards are described in the existing convention, namely

Standard of experience - *experience* mostly gained by training.
Standard of education - education as an academic learning process.
Standard of duties.

Experience is gained by seatime. The convention states that so and so many months have to be spent in a specific capacity either to obtain a higher certificate or to gain experience to get access to an education.

In gaining experience to qualify for an education some possibility of equivalating seatime with programmed training are allowed, but the convention *is* by and large trapped in the old snare of equaling time spent with experience.

Furthermore it is appropriate to question if the old tradition of working ones way up the hawse pipe is justifiable in todays shipping. As described in a former section, this way of training seafarers are reminiscent of the old training system well suited to ships of sails and paddles.

With todays ships and ships of the future, training efforts should be concentrated on subjects important to work carried out by the single individual.

Education is gained by classroom instruction and the final product is assessed by sitting an examination where the candidates' performance is measured by the ability to reproduce the syllabus.

Standards of duty are supposed to be fulfilled, if people trained and/or educated by the convention framework are carrying out the duties.

This is a well organized, but wholly academic approach which at its best is outdated and at its worst directly dangerous.

Even within the framework of todays convention, new ways of training, education and duties must be implemented.

In doing so we have first of all to realize, that todays seafarer is more and more becoming an expert operator of more and more complex systems. Training and education have to be focused on that fact.

For other reasons it might be desirable to train seafarers in academic disciplines e.g. to have the right number of administrators with a seafaring background available at any time, but it should not be dealt with by the convention.

The result of changing focus from academic education to training of operators could very well be a shortening of time spent in training and education, and at the same time an improvement of standards.

Training of operators requires simulators, and time has come to abolish the view of simulators being sophisticated tools for training captains and chief officers in delicate manoeuvring technics.

Simulators will for two reasons become one of the main tools for training seafarers:

First because they can replace todays accidental gaining of experience, and second because they are the most natural tool for training operators of complex systems.

Navigation, colreg, shiphandling and watchkeeping duties can be trained in a simulator in one sequence with an increasing amount of stress laid on the operator/trainee achievement which can never be

reached in classroom instructions with textbooks and wooden models.

The same applies to engineering, engine controlroom, operations, cargohandling and communications.

Instead of sitting examinations, the candidates' ability can now be assessed in the simulator giving a much broader picture of his or her behavior as an operator.

As mentioned before there are a very wide gap between the traditional ships design and the high tech ship design. Where the traditional design can be seen as the final stage of a long evolution in developing designs, the high tech ships must be seen as revolutions.

A revolution has also happened regarding the crew, but unfortunately it remains a well kept secret.

The high tech ships are referred to as low manned ships. It is thereby understood to many or most one could argue, that they are manned by a traditional complement of crew cut off in numbers from the bottom so to speak, but with the traditional division between officers and ratings and departments.

Sailing the worlds largest reefer with a total of 7 as is done by the Danish Lauritzen Group demands a team instead of a complement of crew. Within the team you have to take full advantage of single individuals' experience and competence when delegating the work load onboard, doing it in a traditional hierachial way department by department, would in days moor these ships up alongside quays.

The team onboard is being backed up by a team and other experts ashore, together forming the total crew.

In summing up there is a need for within the existing convention to review how competence and experience are assessed, understanding that paper qualifications do not necessarily confirm that a person is competent. Furthermore it has to be realized that competence and experience can not be counted on a day by day basis, accumulating to exellence.

Simulators have to become a main tool for training, and education must be directed towards the training needs.

Shipboared duties as watchkeeping should be allowed to be carried out in accordance with the level of automation onboard.

Instead of focusing on bits and piece5 in the industrial system, a review of tasks should be carried out to establish the need of training and education to ensure that seafarers are capable for carrying out the tasks in a safe manner.

It is, so to speak, necessary to turn things upside down, assessing the demand to the output, and from that point work your way down in a training and education scheme taking advantage of todays high tech media to ensure the highest level of competence.

With the new regulation I/5 of the STCW convention an opening has been made, and it is now actually possible to establish the before mentioned changes with the existing convention.

One could on the other hand fear, that changes as has happened with the sole look out could be twisted and turned for so long in the drone of the IMO machinery that the convention could end as not just outdated, but as an museum piece.

THE ROLE OF SIMULATORS IN NAUTICAL TRAINING AND RESEARCH

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This paper provides an overview of the role of simulators in nautical training and research.
Several developments in the shipping industry lead to an increased need for training. In the present paper a distinction is made between technical and non-technical training. Both types of training are required to meet the present and future demands of the shipping industry.
Research, in which simulation models play a dominant role, is needed to guide technological developments, like the concentration of information and various tasks on the ship's bridge.
The concern with the environment in relation to the transport of dangerous goods and the risk of pollution requires careful planning and monitoring of traffic flows.
The design and modification of ports determine the need for research and evaluation instruments in which nautical safety and efficiency are key concepts.
These factors lead to design criteria for nautical simulators and simulation models which are indispensable tools and cannot be missed anymore to solve the various research and training problems faced by the shipping industry.

1. Introduction

Bridges of modern ships tend to be equipped with more instruments and information systems. The following distinctive parts are of importance:

*   Navigation instruments;
*   Communication, including information on weather and waves;
*   Propulsion systems;
*   Manoeuvring devices such as bow thrusters and steering engines;

* Cargo handling and monitoring systems;
* Monitoring systems of engine performance and hull.

The reasons for this increase in functions on the bridge are the present requirements for efficiency and safety. To reduce the cost of exploitation the number of crew members has been decreasing steadily and serious attempts were and are made to reduce the cost of maintenance and to minimize the working expenses, however, without reducing the safety of crew, ship and cargo.

Examples to the above are the availability of good navigation instruments to avoid unwanted deviations from the required track, to create the possibility of efficient weather routing and the introduction of sufficient manoeuvring capacity to reduce tug assistance. Moreover, there is a tendency to transfer information of the engineroom to the bridge so that watch keeping during the nights in the engine room can be avoided. The cargo has to be loaded and unloaded efficiently and, in many cases, is monitored during the voyage to guarantee that the cargo is in good shape upon arrival. Hull monitoring can be of utmost importance as recent history with bulk carriers shows.

The introduction of these functions on the bridge generates new categories of problems. For instance, given the fact that a lot of different information is presented on the bridge, this information should not only be processed during normal operational conditions but also during stress situations. This implies that the information should be presented such that in a very short time a good impression of the whole situation can be obtained followed by the right sequence of actions.

In addition bridges are getting more and more complex, hence the familiarization time for new officers on board does increases considerably.

Now, because of the decrease in operational sailing time of the crews, the possibility of getting training on board, the fact that more and more of the crews are composed of seaman of different nationalities as well as the increase of bridge functions, simulator training provides a good instrument to keep up the required safety and efficiency level. This simulator training can be supported by PC oriented courseware to train specific tasks of the ship's operation or specific aspects for instance to reduce the familiarization time.
By means of simulator training the skill to manoeuvre ships safely given the specific environmental conditions can be improved and maintained. In this respect procedures are essential. Moreover, the way in which the information is presented and subsequently processed can be trained.

Partly away from the simulator, attention can be paid to bridge management training to deal with team building of the bridge officers in which the role of the pilot may be included.

Except for the shipping companies also the authorities responsible for the infrastructure have a thorough interest in safety and efficiency of navigation.
On the one hand a well designed and efficient infrastructure contributes to the economy of a country and is therefore of great importance. On the other hand a keen eye has to be kept on the environment. Risks of polluting the environment and disturbing existing ecosystems should be kept as small as possible.

Looking at the infrastructure first, the dimensions should be such that all ship manoeuvres involved can be executed safely. The definition of admission criteria deserves special attention. Also motivated answers are required when shipping companies ask permission to enter and leave ports without assistance of pilots.

When designing new ports or improving existing ones a nautical check on a simulator is usually carried out to determine whether the design meets the required safety level or to provide answers on other relevant questions such as the contribution of aids to navigation to safety.

When more shipping operations and other water related activities take place, for instance offshore activities, the interaction of traffic and traffic with structures is becoming relevant.
In the first place the vessel traffic operations should be mentioned. Along the coast and rivers of the Netherlands the nautical Vessel Traffic Service (VTS) operators are active. They highly contribute to the safety of navigation. Training of these VTS-operators takes place at a dedicated simulator.

To study the traffic process, the related safety level and to be able to predict the safety level of future situations use is made of traffic models. These models are becoming powerful tools for the authorities for planning purposes regarding the development of future infrastructure and for improving the existing safety level. To calibrate these traffic models use is made of extensive accident databases.
Based on these database studies are carried out to assess e.g. the effect of traffic separation schemes and the effects of planned offshore operations.

Training and research impose conditions on both the architecture and layout of nautical simulators. Flexibility both in hard and software as well as in efficient maintenance are key words in this respect.

At MSCN in Wageningen attention is paid to many aspects related to efficient and safe navigation. The company is a joint venture of MARIN (Wageningen) and Delft Hydraulics and has become operational early 1992. In the following chapters a state-of-the-art of the MSCN activities is presented.

2. Training

2.1. Introduction

In the Introduction, several reasons for training are indicated. Although the nautical industry knows the phenomenon of training on simulators for quite a long time, systematic and structured simulator training design is a relatively new development. Looking at simulator training with educational technological "glasses", one of the first questions that must be answered is:

Are training simulators effectively being used?

This is a very interesting question which often must be answered with "no". MSCN has started the design and development of new training programmes aiming at using the simulator as effectively as possible.

2.2. A structured approach to training design

The field of simulation has attained a sophisticated state as a result of the capability to reproduce high-quality, realistic visual, aural and tactile phenomena. However, this capability has given many individuals in the training profession a false sense of security because it has been assumed that by merely exposing the trainee to a group of high fidelity simulator events and conditions from the real world, effective training will take place. Such an assumption, however, does not always hold.

Very often, too little emphasis is placed on specific <u>training</u> criteria. Little is known about what specific demands a training simulator imposes on training and training design. The effectiveness of training is much depending to a large extent on the skills of the instructor. What is missing is a systematic, structured approach to training.

MSCN has based its systematic training design and development on "Designing Instructional Systems" (ISD) of A.J. Romiszowski [1].

One of the first steps in this approach is a thorough task analysis which must map the tasks, subtasks and the underlying knowledge and skills to be trained. On basis of the results of this analysis, the following aspects can be determined:

> what exactly must be trained on the simulator;
> the operational sequence of the tasks;
> the evaluation criteria;
> the kind of knowledge and skills;
> the applicable instructional tactics.

This information, resulting in detailed learning objectives form the foundation of further training development.

The next steps deal with the design of the training scenarios. Together with these scenario's, MSCN is developing:

> especially designed instructional tactics (in cooperation with the Department of Education of the University of Twente);
> a training evaluation system which must be able to determine if and how the training programme has contributed to the improvement of the knowledge and skills of the trainee. From the results derived from this system, it will be possible to determine where improvements of the training programme are required;
> entrance level and exit level tests.

2.3. Training modules

The above mentioned facts must result in several series of training modules (see figure 1). In these modules, the established basis formed by the results of the task analysis, is clear. From this basis one or more standard training scenarios are developed. However, it is possible to adapt these standard scenarios according to specific wishes of the customer, the target group characteristics or events during the training session itself.

Anticipating on possible variations, the training module gives some indications and directives. The simulator must be easily adaptable to new situations, so that possible customer demands of the client can be quickly incorporated into the system.

The training evaluation instrument controls all aspects of the modules checking for possible improvements.

MSCN is using training materials of the flight crew training centre of KLM Royal Dutch Airlines thereby benefitting from their large experience in simulator training.
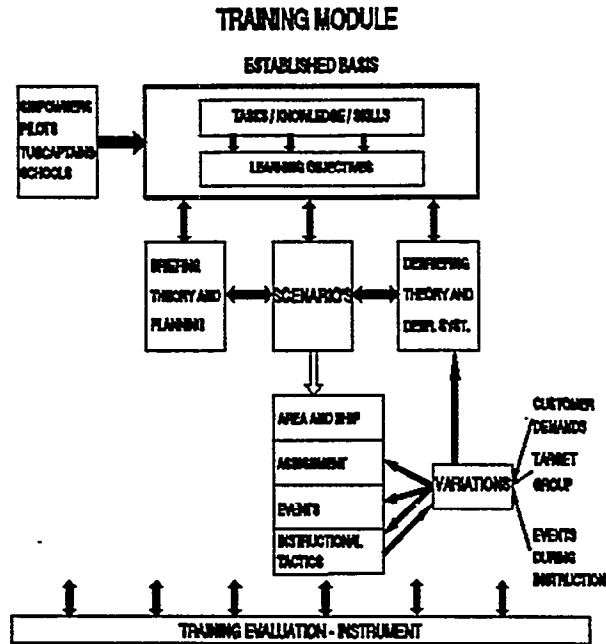
Figure 1: A training module

2.4. "Technical" training
MSCN is currently developing the following three
types of "technical" training:

1.   skill training aiming at specific skills
       like the mooring of a ferry in various
       difficult situations. Within this kind of
       training also part task simulators will *or*
       can be used for example to practice the
       engine room monitoring or cargo handling
       tasks before going to the full mission
       simulator. It is also possible to inte-
       grate Computer Assisted Instruction (CAI)
       in these part task simulators so it will
       be possible for one instructor to indi-
       vidualize and differentiate individual
       training.
2.   *Procedure training* aiming at required
       bridge procedures for various situations;
3.   *Familiarisation training* aiming at the
       transition to another type of ship and/or
       modified part.

2.5. "Non technical" training
Except for the above mentioned types of train-
ing, MSCN will also develop two "non technical"
training courses:
       1.   *Instructor* training;
       2.   *Bridge management training.*
MSCN is of the opinion that simulator instruc-
tors must have a close relation to practice.
They have up to date information available which
they can pass to the trainees and this will make
the level of acceptance of the instructor by the
trainees higher. But a good pilot or bridge
officer is not necessarily a good instructor.
For that reason selected pilots and bridge
officer5 are given a course on instruction
methods after which they can be employed by MSCN
when necessary. Because of the fact that these
"MSCN instructors" will not use the simulator
frequently, the instructor facilities of the
simulator must be user friendly. Training scen-
arios must be easily adaptable before and during
the training so that the instructors will have
total control over the training.

Also the total simulator system must be robust enough to tolerate input mistakes both from the instructor and the trainees.

The development of the bridge management training is due to the need for more management skills by bridge officers because of the increasing "mixing" of the bridge teams in culture and level of education. The training will aim at for example: decision making, giving and handling of feedback and information processing and leadership styles. In the airliner industry, the significance of this type of training is growing rapidly.

3. Research with manoeuvring simulators

3.1 Introduction
Research with the aid of manoeuvring simulators can be performed for two totally different purposes, namely:
- Ship design;
- Harbour and fairway design.

Each purpose has its own requirements, but the starting points are the same. Both purposes will be discussed in this paper.

3.2 Simulator research for ship design
As already mentioned in the introduction two items are of interest within ship design. The first item is related to the performance of the vessel that is it's capability to perform a certain mission. The second item is directly related to the information transfer between the vessel control system and the navigator. These items will be discussed separately bearing in mind that they are interacting.

For certain types of vessels the importance of manoeuvring performance is steadily growing. For instance, the increase in size of luxury cruise vessels in combination with the requirement to call at small pittoresgue harbours in the Caribbean puts more stress on the manoeuvring performance.

The size of ferries is often increased without increasing the size of the harbour facilities.
Offshore operations require vessels with good station keeping performances.
Special rudders, bow thrusters and controllable pitch propellers in combination with an integrating controller must result in an optimal controllability of the vessel. But before the actual vessel is built simulator studies should prove that the proposed tools are sufficient.
Vessel operations are simulated under various environmental conditions. Limiting conditions are determined up to which safe operations are possible. When these conditions are exceeded procedures have to be defined such as which measures have to be taken to cope with these extreme conditions.

An example of a study which combined both channel design and ship design is the study executed by *MARIN* for the, Carnival Cruise Lines ship owner. Problem here was the entrance and departure manoeuvre of Freeport with the huge newly-built cruise liner 'Fantasy'. The entrance and turning basin at *Freeport* was regarded as 'narrow' by the master5 of visiting cruise liners.
It was expected to become crucial for the *Fantasy'.

Full mission simulation was carried out with this vessel. Several environmental conditions were investigated and a separate programme was executed with an integrated joystick manoeuvring device in order to compare the performance of this system with that of manual control of main propulsion, rudders, bow and stern thrusters.

The project resulted in recommendations (which are implemented now) for widening the approach channel and the modification of manoeuvring strategies.
The joystick control appeared to improve the manoeuvre, especially within the turning basin.

A completely different aspect of ship design is the bridge layout and the presentation of all sorts of information to the navigator.

The amount of information available on the ship's bridge is still increasing. Among other thing5 information is provided on position, weather forecasts, route planning, cargo handling, stability and engine performance. Furthermore there is more communication i.e. with other vessels, with the shipping company and with traffic control centres. In principle this increase in information and communication reduces the risks of navigation and is therefore also often an argument to reduce fairway dimensions, to reduce the crew and even to allow an increase in traffic intensity while maintaining the same safety level. But there is still one man on the bridge who is actually sailing the vessel. He has to interpret all available information and must take decisions.

An optimal bridge layout with an optimal positioning of controls, radar screens and computer screens is a first step to make the information better available to the navigator. But this is not considered sufficient.

The amount of data available on the bridge is still increasing and new tools are required to monitor the available information and select and display what is really required. A decision support system should select the critical information for the navigator and present it logically. The next step is that such a system interprets the incoming information and advices the navigator. For some matters like weather routing, optimising fuel consumption or stability these systems are available but they are not yet integrated into one system. For navigation in confined waters, including the effect of other traffic, such a system is even far more complicated.

Such a decision support system will be one of the most important topics in nautical research for the nest few years.

For the design, implementation and verification of such a system nautical simulators are an indispensable tool.

3.3 Simulator research for harbour and fairway design

In most harbours and waterways there is still an increase in cargo flow. This also implies that the density of traffic and also the average ship size is increasing. Furthermore it is a well known fact that the amount of hazardous cargo being transported is also still increasing. In general one can say that the safety level per ton cargo is high compared with other means of transportation like rail and road. But still, if something happens the consequences may be disastrous.

Within the development of ports and fairways main questions are:

   what is the maximum ship size?
   under which condition is safe passage possible?
   what is the determinative traffic situation?
   what is the safety level of the harbour?

Nowadays we see that larger ships and more ships are allowed in relatively narrow fairways. The argumentation to allow this is the availability of more electronic equipment like:

   Vessel traffic systems;
   Better positioning systems (GPS);
   More knowledge about the actual environmental conditions during transit.

All this information offers the opportunity to schedule more exactly entry and departure manoeuvres. Despite all this information, the actual manoeuvring in busy areas or confined waters is still performed by the navigator. He has to absorb all available information, draw conclusions and take decisions.

Much more stress is put on the man on the bridge. More and more he becomes a critical factor in the navigation process. Consequently a failure or accident is often caused by the "human navigator".

To determine the risk of "failure", simulation is the only tool which can be used to estimate the potential risk of certain manoeuvres. Such a simulation should have the possibility to include other traffic and a vessel traffic system.

For the statistical analysis of simulated manoeuvres various methods are available, each with its own potential and drawbacks.
Some methods have proven to be useful for the comparison of conditions, like the method proposed by Van der Beek [2]. New promising statistical methods are still under development, for instance the method proposed by Kok and Burgers [3].

Another approach of the problem how to determine the safety of channel passages is the method of pairwise comparison (Cook [4]). This method compares the results of simulator runs with existing situations with a known safety level. After a simulator run the pilots are confronted with questions like:
"Is passage under condition "i" more difficult than under condition "j"? The results of these questions are analyzed such that inconsistencies are detected. Furthermore, a coefficient of agreement is determined which is a measure of agreement between the experts within the experiment, and a so named "goodness of fit" which, in practice, indicates whether the modelling assumptions are valid.

To obtain balanced conclusions from simulator research information from different sources e.g. statistical information and expert opinions, have to be combined into a unifying framework.

4. Nautical Safety Assessment

Safety and Efficiency must be kept in balance with each other in the strategic and operational evaluation of nautical problems.

This balance is continuously changing by governmental decisions and hence classification societies by putting heavier weights on the safety side of this balance.
All this makes the accurate assessment of safety in a wider range of areas necessary and more important every day. The mutual effects of safety on efficiency adds to the necessity of an accurate assessment as well.

4.1 Safety assessment methods

The existing methods are all based to a certain level on the modelling of aspects of the nautical problem area under investigation.
The choice of the level of modelling is firstly determined by the state of the art of the available techniques where Albert Einstein, although not being a nautical expert in particular, gave us our leading principle: "As simple as possible . . . . . but not simpler".
Secondly, the type of the problem under investigation determines the choice of the method. For example, if the number of ships involved is substantial then the traffic density parameter enters the scene and will change the applied method completely.

The differences in approach then, can be distinguished by the measure of modelling used in the safety assessment method. On the one end of the scale we have the full mission simulator used in multi-ship situations and on the other end of the scale the mere registration of accidents in the form of casuistries and statistics in case that fleets of ships are involved. In the last case statistical data help5 us where modelling of the total process would be cumbersome. However if predictions on the safety level of future traffic situations have to be supplied, based on this historical data some modelling assumptions have to be introduced.
In between these two extremes, traffic simulation further helps to relate the historical accidents data to traffic density and fairway dimensions by relating the traffic and its manoeuvring characteristics to probabilities of accidents.

In the refinement of the traffic simulation models, aiming at a better description of the behaviour of the individual ship in the fleet, again the full mission simulator is used. It contributes by showing nautical experts typical traffic situations on which they give comment, which is used for setting rules governing traffic flows in the traffic simulation models. The usage of this model for determining safety of the design of an inland waterway is currently in progress.

Traffic simulation or assumptions on traffic densities are used for the determination of probabilities of accidents in relation to offshore installations as well by using historical accident data.

4.2 Vessel Traffic Services

Risk assessment methods based on historical data or on traffic simulation can also be used in the evaluation of newly designed VTS scenarios for sea areas under consideration. A cost benefit analysis should determine the appropriate level of VTS support in terms of safety and efficiency.
Such a cost benefit analysis has to include both costs of the VTS system and the reduction in risks and waiting time.

5. Development of nautical simulators

5.1 Introduction

The Ship Manoeuvring Simulator System of MSCN is designed to meet the requirements of ship officers, pilots and nautical students to gain or to augment their understanding of the behaviour of ships, the effect of external conditions such as wind, waves, current and shallow water, how to deal with tugs, how to control the computerized systems and how to act in case of emergency situations. Furthermore the Simulator System is designed for application in consultancy projects where design of ports and fairways and nautical safety play an important role.

The Simulator System is capable of simulating up to 10 fully controllable ships, each equipped with a sophisticated CGI (Computer Generated Image) system with a 360 degrees horizontal angle of view.

Due to the modular set-up and the scalability of the system it can be adapted to any specific training- or research project requirements and available budget. Future upgrades are always possible by simply adding components, hardware or software without major adaptions to the original system

5.2 Requirements

In designing the Simulator System the following design requirements have been followed:
- modularity;
- scalability;
- flexibility;
- robustness;
- real world bridge;
- high performance outside view;
- part task possibilities;

These requirements are reflected in the set-up of the Ship Simulator System.

5.3 Set-up of simulator system

5.3.1 General

The Simulator System consists of a real time Part, the Simulator part, and three non real time parts namely, Preparation, Debriefing and Analysis. It can be regarded as a collection of different functional components, referred to as sub-systems. Each sub-system, in turn, can be considered as a logical unit that fulfils a number of functionally related tasks. Sub-systems can be built up from hardware, from software or from a combination of the two. Sub-systems are connected via LAN communication networks. The software has been developed in an Ada Programming Language environment making use of Object-Oriented Design techniques.

The latter technique allows a reflecting of real world objects into recognisable objects in the software and hardware.

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┌─────────────┐   ┌─────────────┐   ┌─────────────┐
│ PREPARATION │   │ INSTRUCTOR  │   │ DEBRIEFING  │
└──────┬──────┘   └──────┬──────┘   └──────┬──────┘
┌──────┴─────────────────┴─────────────────┴──────┐
│                LOCAL AREA NETWORK                │
└──┬───────┬────────┬──────────┬──────────┬────────┘
┌──┴───┐┌──┴─────┐┌──┴────┐┌────┴───┐┌─────┴────┐
│ SHIP ││OUTSIDE ││BRIDGE ││ RADAR  ││ SPECIAL  │
│MODELS││ VIEW   ││       ││        ││ OBJECTS  │
└──────┘└────────┘└───────┘└────────┘└──────────┘
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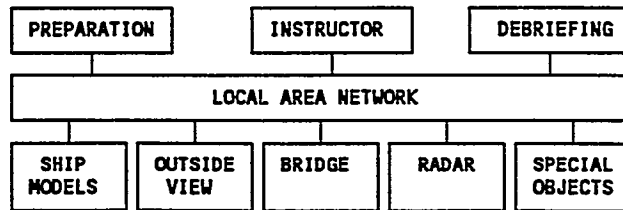
Figure 2 Simulator set-up

5.3.2 Sub-systems
The Instructor Sub-system
The Instructor Sub-system enables the controlling of the simulation process by an instructor. Once a specific project and condition have been selected, the instructor can for instance start and halt the simulation process and re-position and playback a previous carried out simulation run.

The Ship Sub-system
Within the Simulator Systems ships are defined into three different classes: Own ships, Targets and Tugs. The main objective of a Simulator System is to simulate the behaviour of the Own Ship which must be identical to that of a comparable real ship. This is achieved by the use of extensive mathematical models which describe the ship's behaviour. The more accurate the mathematical models are, the more realistic the simulated ships behaviour is in the Simulator System. Own Ships are extensively modelled and are being controlled by humans.

Own Ships are ships with extensive sub component modelling and always consist of the following major sub components: AUTCON which models the functions of the various autopilots, ENGINEROOM which delivers the actual control settings and MATMOD (mathematical model) which generates positions, orientation angles and velocities;

The modularity of Own ship is very clearly reflected in the software. Each force acting on the ship is modelled as a separate Ada package. An Ada package consists of a specification part and a body. The specification part is always resident.

The Bridge Sub-systsm

The Bridge Sub-system resembles the bridge of a real ship and provides the manual control functions. It consists of a number of consoles with instruments which are connected through a front-end computer, with the other parts of the system.

As a consequence of the modular set-up the bridge of the Simulator System can represent a wide variety of ships. It is possible to rearrange the consoles as well a5 the instruments in the consoles in a very short time. Instruments are mounted in sub-panels with standard dimensions and can be plugged in anywhere in the console. A software configuration file keeps track of the position of the instruments and sends the right data to the right port.

The Outside View Sub-systsm

Together with the Bridge Sub-system the Outside View Sub-system is very much responsible for the realistic feeling the simulator system evokes. The Outside View Sub-system presents the scenery in which the ship, controlled by the crew or a single person sails. It generate5 in real-time the actual visual image, covering a total viewing angle of 360 degrees.

The scenery is generated by dedicated high-performance graphical computers with special three-dimensional visualisation software components. The image is built up of different sectors of about 36 degrees. Each sector consists of one graphical computer and one projector. The size of the image is scalable between 1 and 10 sectors.

Radar Sub-system
On bridges of modern ships rasterscan radars are most commonly used. The Simulator System is equipped with one or two rasterscan radars which were built by MSCN.

The Radar Sub system includes ARPA functions and is in accordance with the requirements imposed by IMO.

Special Effects Sub-system
The Special Effects Sub-system offers a wide range of utilities which support the main functions of the Simulator System and increase the real world effect. Some of the utilities, presently available are: sound generation, special dynamic effects and NAVLAB to train the use of navigation instruments.

5.4 MSCN Simulator Systems Series
MSCN offers a wide range of Simulator Systems which may vary both in size and application; for instance the MERMAID 100, MERMAID 500 and MERMAID 900 series. The MERMAID 100 is a relatively small simulator setup with a small bridge mock-up and a reduced set of available operations whereas, the MERMAID 500 is a full-mission ship manoeuvring simulator with extended outside view capabilities and all possible bridge features. In addition to the MERMAID 500 the MERMAID 900 series offers a fully integrated Engine room simulator, capable of training of Engineroom Staff.

Furthermore, MSCN has developed part-task simulator systems which allow stand-alone operations of specific tasks. These part task simulators run on relatively small computer systems such as work stations and top of the line PC-stations.

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THE HUMAN FACTOR IN SHIP HANDLING AND ITS EFFECTS ON MARINE SAFETY AND THE ENVIRONMENT

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Abstract.

Shipowners and shipmasters are under a great pressure to avoid casualties in general and particularly accidents that affect the marine environment. Much is done in the way of prevention to reduce the risks of casualties and claims. Shipping is an international activity and therefore national and international organizations are involved in marine safety.

In spite of all efforts, including the availability of high quality ships, equipment and modern training systems, collisions and groundings take place worldwide nearly every day. The daily casualty report in Lloyd's List contains all maritime casualties of any significance. These accidents may cause pollution and they are often the result of poor navigation and shiphandling practices. In order to avoid maritime disasters as they have occurred in the past few years, it is essential to improve the proficiency in navigation and shiphandling of certain navigators with emphasis on the planning aspects and a proper control of the execution of various actions.

International standards.

International safety standards have been set by the IMO, the agency of the United Nations in charge of marine safety. Consultative to IMO are a number of maritime organizations such as the Shipowners Association of Latin America, ALAMAR, and IMPA, the International Maritime Pilots' Association. Recommendations made by the IMO are often incorporated in the national law and regulations of its member states. However, these IMO standards should be considered as minimum standards. National maritime authorities and organizations have their own responsabilities in this respect. This also applies to shipowners and pilot services. Each particular coastal area, fairway and port presents its own degree of risk to navigation

and safety standards should be in accordance with the requirements for such an area open to navigation. With respect to the navigational and shiphandling skills of navigators, shipmasters and pilots alike, the safety factor not only depends on the knowledge and experience of the navigator but also on the application of that skill at the right moment in a particular situation.

Skill, ignorance and negligence in shiphandling.

Skill in navigation and shiphandling commonly includes knowledge and experience. The degree of knowledge depends on the level of education, training and the results of proficiency tests. Basic knowledge of shiphandling may be learned from texbooks and from simulator courses even before any shipboard practice has been gathered. Experience in navigational matters and shiphandling is gained on board of ships. This process is different in the various trades and types of ships. There is a clear distinction between deepsea navigation and coastal navigation with ocean going vessels, coasters and ferries. Ocean navigation and shiphandlingis outside the scope of this survey, which is limited to coastal areas, fairways and port areas.

A person on a ship in charge of navigation and shiphandling should not only have sufficient skill to control a ship in a certain situation, he should also have enough initiative to apply his skill whenever needed. It implies to be alert and prepared for the unexpected and to act with determination, confident that a certain action or manoeuvre will have the desired result. Such competence is certainly required for the persons who are manoeuvring ships in restricted areas including anchorages and inland waters. Usually the shipmaster or pilot is in charge of navigation and shiphandling in those circumstances. Marine accidents, particularly collisions and groundings, may be the result of bad luck or misunderstandings, but other reasons could be ignorance, negligence or criminal behaviour. Ignorance in shiphandling may include a lack of knowledge in the proper use and interpretation of nautical instruments or poor communication practices. Negligence, a lack of proper care, maybe a temporary or permanent attitude of certain navigators. It could be related to their educational, social or cultural background or poor management as a whole. Some examples of negligent behaviour: omission of testing

procedures of navigational instruments, omission of the testing of astern power of ship's diesel engine if doubtful before entering a sensitive manoeuvring area, unattended anchors while proceeding in port areas. Criminal behaviour will be evident in those situations when navigators and shiphandlers are not capable any more to operate properly because of their physical condition which may range from fatigue to drunkenness and the influence of medicines and drugs. These are social and management problems which may remain unknown until a serious accident has happened.

Critical situations that may arise in coastal areas, port approaches and anchorages.

Serious accidents with ships and consequent oil spills have taken place in the approach areas to certain ports, often as a result of a grounding or touching of the seabed by ship's hull. Usually these casualties occur when there is no pilot on board of the ship in question. Therefore a report of the accident to the authorities will be delayed or omitted. The necessary rescue and cleaning operations would start then much later which is a great disadvantage. The causes of such accidents, including collisions, are various. A number of those cases have been the result of poor shiphandling and anchoring practices. Some notorious casualties in the past were the loss of the large low-powered bulkcarrier "Hyundai New World" in Ponta da Madeira, Brazil in 1985 and a few years later the catastrophe with the tanker "Exxon Valdez" in Alaska. Both ships were fully loaded. Misjudgement of the turning capacity of the vessels, a common human error, resulted in a total loss of the bulkcarrier and her cargo and an enormous oil spill caused by the tanker. Bulkcarrier groundings have been reported in different parts of the world until this very year. In February 1992 the capesize bulkcarrier "Arisan", 20 years old, grounded on the rocky coast of Norway after she had left the port of Narvik loaded with iron ore. The result of this was a serious oil spill and pollution of the coast through the damaged fuel tanks. The probable cause of this accident was engine trouble in connection with risky anchoring practice. Engine problems with older ships are a threat to marine safety. Following this accident with the "Arisan" the Norwegian government has increased surveillance along the coast and also extended compulsory pilotage for certain ships. The nature of the coast, rock or sand and mud, certainly determines to some extent the degree of risk in case

of a grounding.

Surveillance systems and pilotage.

Loss prevention is a major task of shipowners, shipmasters, pilots and the maritime authorities. Independent observers and expert shiphandlers like marine pilots are important tools in the field of loss prevention. VTS-systems to guide the flow of marine traffic have also a controlling and informative task, in the way of safety and prevention. Marine pilots, operating on board of ships in coastal and inland waters are of great importance with regard to marine safety for a number of reasons. Marine pilotage can be divided in different specialities such as deep sea and coastal pilotage, port approach and river pilotage and also harbour and dock pilotage. A pilot may operate in one or all of these areas, depending on his abilities and flexibility in view of the needs for flexible pilots in certain pilotage areas. Whatever their working area may be, all pilots serve a common-purpose which is safety. Another advantage for shipowners, charterers and the ports is timesaving when ships are guided by pilots because of their professional skills, including expert shiphandling and local knowledge. A main advantage of a pilot on a bridge of a ship is merely his presence as an independent observer and informant of what is good or wrong with the ship, her equipment, operational condition, command, crew, etc. In case of serious problems or risks he is the first representative of the port or national authority to inform shore stations immediately of his findings so that early and adequate measures can be taken to avoid accidents. A pilot is all eyes and ears when guiding a ship from A to B, positioned on ship's bridge as a spider in a web, also as an important link in communication between ship and shore, to other ships in the area and assisting tugs. Safety requires from pilots an excellent command of navigation and shiphandling of various types of ships including the use of anchors and tugboats, communication and procedures, and local regulations. Pilots often serve as interpreters in order to get things organized on board or to obtain the necessary information because of poor language skills of shipmasters and crew. Compulsory pilotage is also related to the vulnerability of certain areas open to navigation and the amount of risk that certain ships and ship's personnel cause to those areas.

Shiphandling training and the use of simulators.

The introduction of Simulators for training in marine navigation started with the application of radar simulators. For over twenty years shiphandling simulators have now been used to train shipmasters, deck officers and pilots to improve their knowledge in ship manoeuvring, to refine or maintain the required skill and practice in the art of shiphandling. The shiphandling simulator has proven to be an excellent instrument to make navigators aware of the limitations of ships in the way of turning, stopping and control in general. It also gives the opportunity to navigators to rehearse emergency situations with ships like sudden engine problems. These training objectives are of great importance to prevent marine accidents and environmental damages.

Conclusion.

Marine casualties take place regularly and damages are sustained because of such accidents. Serious accident are certainly those that involve loss of life and those that affect the environment, the marine environment in particular. Human errors are often the cause of such accidents. Much is done to reduce the amount of serious accidents like groundings and collisions. In spite of all safety support measures in the way of the construction of efficient ships, the introduction of modern equipment and VTS-systems, adequate education and training, it is still the navigator on the bridge of a ship who, with his qualities and shortcomings, determines to a great extent the degree of safety that his ship carries along while proceeding in a certain navigational area. It is undeniable that good ships, modern equipment, surveillance systems and training facilities are indispensable to improve marine safety. However, these means are often not sufficient to avoid serious accidents with ships. Navigational errors and harmful conduct are also related to commitment, attitude, management, pay, addiction and fatigue of persons in charge of navigation and shiphandling. Particularly ships that are a potential risk because of cargo, fuel, ownerships and casualty records should be treated with great care by the maritime authorities in charge of navigation and safety. Additional expert manpower by skilled pilots and tug assistance when needed may avoid such disasters as reported on certain occasions in Lloyd's List. Mare liberum, the free sea, is for obvious reasons not so free anymore as it

was for centuries. Independent surveillance onboard of certain ships in coastal waters and from shore stations will remain of interest for years to come. Marine pilots and VTS-operators have an important task in this respect. The contents of this account is a summary of the own experience of the author as a merchant officer, marine pilot and consultant, with assignments in various countries, in addition to publications in Lloyd's List the past few years.

COSY: A COMPUTER AIDED SYSTEM FOR INTEGRATED CARE, QUALITY, ENVIRONMENT, SAFETY

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ABSTRACT

In recent years growing industrialization and trade have been matched by increasing awareness and demands for product quality and safety, better and safer working conditions and protection of the environment. At the present time there is also general agreement that enterprises within industry and trade must demonstrate ability to meet all statutory and other requirements on these matters. The earlier -introduction of quality systems and quality standards (ISO- series) has set an example for organizational and other measures by which enterprises seek to manage and control own activities with regard to external and internal requirements, the so-called care management systems. In this paper an integrated approach to the development of care systems for quality, working environment and environmental protection is presented, along with an innovative supporting documentation system and a computer aided tool.

1. INTRODUCTION

In the past years industry and trade have been facing increasing expectations and demands from markets and society with regard to product or service quality, safety of human life and preservation of the environment.
This development can be seen in relation with increasing public awareness about the risks associated with the intensification of the exploitation and processing of natural resources and of industrialization and trade. This has resulted in a number of initiatives for new national and international legislation.

While new proposals are being debated, processed through parliaments and legal procedures or already adopted and implemented, there is an increasing agreement that the primary responsibility for quality, safe working conditions and preservation of the environment lies at the "source". In this respect, enterprises from industry and trade are expected to demonstrate their ability to satisfy market needs and their commitment to social and legislative requirements.

2. FROM PRODUCT QUALITY TO INTEGRATED CARE

Quality can be defined as the capacity of an enterprise to comply with internal and external requirements regarding the control and assurance of product and service quality at the lowest possible costs. External requirements can originate from principals, statutory bodies and authorities.

The traditional way to ascertain compliance with requirements was based on supervision, inspection and control by own personnel, on behalf of principals and authorities. This practice has been gradually replaced by an ordered set of management measures which aim to obtain control of organizational and technical processes, to effective handling of nonconformities, to avoid repetition of errors and to strive for continuous improvements.

An important development in this respect was initiated by the introduction of quality assurance standards which finally evolved into the ISO- series. When the above mentioned measures are set up according to these standards and qualified or certified by accredited bodies, sufficient confidence will be established with regard to organizations' ability to comply with contractual and statutory requirements.

A similar development can already be observed with regard to the care for (human) working environment and environmental preservation. A particular problem here is that legislation requirements are not presented in a form which allows direct "conversion" into easily to be taken measures. A reference model is not available and for this reason attempts have been made to use the ISO-standard as a basis for developing and implementing systems to assure safety, health, environment preservation, etc.

In principle all care systems aim to obtain control of processes, to handle nonconformities, etc., each one being directed at a particular area of interest; it stands to reason that an integrated approach should be followed.

The question is whether legislation can be treated in such a way that "conversion" into an ordered set of measures can be included or integrated within a general care system, while preserving the possibility to highlight specific aspects related to specific requirements.

This matter has been addressed within the frame of the "Shipyard Development Programme", a collective R&D effort initiated and carried out by the Netherlands Shipbuilding Industry Association VNSI. While the shipbuilding industry did not belong to the van of enterprises adopting quality measures and implementing quality systems, shipyards were confronted from the very beginning with legislation on working environment and preservation of the environment.

Most technical processes in shipbuilding and shiprepair produce waste material and emissions which polute the environment (air, water, ground); this is especially the case with surface cleaning, blasting and conservation.

The above relate directly with the working environment
in workshops and on board. Shipbuilding and shiprepair
are labour intensive and combine significant physical
effort with work in confined spaces and emission of
smoke, gases, dust and spray.

The restructuring of the Netherlands Shipbuilding
Industry in the seventies and eighties has not only
diminished the labour force but has also raised its
average age. For to attract young and well trained
employees, the industry had to compete against other
industries with greater appeal. Improvement of working
conditions was necessary as well as the development of
an approach which will help safeguard the improvements
and support the efforts to comply with new (Dutch)
legislation on working environment and environment
preservation.

Within the "Shipyard Development Programme" a project
was initiated which aimed to:
- develop an integrated approach to the care for qua-
  lity, working conditions and protection of environ-
  ment
- develop the necessary supporting documentation in the
  form of a computer aided system
- set up and execute a pilot implementation

The above computer aided system will be further refer-
red by its (Dutch) acronym COSY.

3. FROM LEGISLATION TO MEASURES: THE CONVERSION PROCESS

The process of converting legislative and other requi-
rements into ordered and documented measures was analy-
sed following a top-down approach. In total, eight
different steps were identified (fig. 1):

1. Company programme
   This involves the definition of company goals and
   the determination of all organizational functions,
   technical processes and activities which must be
   performed in order to achieve these goals.

2. Control programme
   This is the framework for the execution of the pro-
   gramme which is defined by company policy, relevant
   legislation and other requirements. In other words,
   the governing conditions for executing the company
   programme.

3. Requirements programme
   This is a detailed specification of the control
   programme in terms of quantitative criteria, norms,
   standards, etc. which have to be met by the company
   involved in the execution of its own programme.

4. Programme of measures
   This refers to the ordered set of measures which must be implemented in order to meet the requirements programme. Such measures can adress policy, organization, personnel, procedures, work instructions, etc.

5. Programme of documents (documentation)
   This is a set of ordered documents (system) which "reflects" the programme of measures and, likewise, can address policy, organization, etc. The system of documents must be defined, realized and implemented in correspondence with the measures.

6. Programme of changes
   It is common experience that during the process of implementation measures and documents may have to be adjusted or changed. The programme aims to assure change control.

7. Acceptance or approval
   In this step the effect of measures and documents is being investigated with respect to the established control programme. In other words, the ordered set of measures and documents, the care system, is being examinated (audited) on the basis of criteria relevant to the control programme.

8. Evaluation
   Changes in markets, legislation, technology, etc. can lead to changes in company programme and control programme; in this step, the relation between both programmes is being evaluated.

4. DOCUMENTATION SYSTEM

A key element in any system is the supporting documentation. ISO-standards address the matters of establishing, maintaining and controlling documentation in several of its articles (ref. 1).

In general, documents can be seen as information carriers to be used in communication, recording, reporting, prescription, description, instruction, authorization, etc. The functioning of an organization can be followed through registration and analysis of documents and document flow.

The ISO-standard refer in principle to two types of documents:
1. Documents which contain information related to resources, organizational functions, management activities, technical processes, etc.
2. Control documents.

The first type of documents is usually being used to support decisions which must be taken within any kind of process; decisions usually refer to acceptance of results (intermediate, final).

The second type of documents must assure the relevance, validity, quality and proper use of documents of the first type.

The framework for a documentation system can be represented by a pyramid structure consisting of four layers:

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layer                                    document type
top    : policy documents                1
second: organization description         1
third  : operational procedures and      1 and 2
         control
fourth: instructions, norms, specs       1
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(see also fig. 2)

The very "heart" of the documentation system lies at the third level, where the organizational functions are described by means of operational procedures. When the system is to provide a reliable representation of company functioning, the relations between documents of various layers and within one layer must be unambiguous .

The commonly used descriptive style (prose) for operational procedures proves to be a rather limited instrument when it comes to portray the functioning of organizations. Reference to other procedures, documents, tasks, etc. must all be deduced from texts which are occasionally supported by flow diagrams. The relation with control documents is not always clear and a lot of time is spent riffling through the pages of procedure manuals and the like.

A second difficulty arises when the system and its documents must be adjusted or changed. The impact of changes on the system must be traced through the relations between documents in order to maintain and assure system unambiguity.

5. COSY-DECISION MODEL

The poor operational efficiency of prose-style documentation systems has led to the development of a new approach which was used in the COSY-project. Based on a concept developed in the eighties (ref. 2) the description of organizational functions relies on a so-called standard decision model (STADBM), derived from the DRMING-circle (fig. 3).

According to the STADBM concept, control of organizational functions can be obtained by controlling decision making at crucial points within the functions. Decision making implicates acceptance of some sort of results following any kind of technical, intelectual or other activity.

By providing relevant, complete and correct information on time, conditions are created for good decision making provided that the decision maker is competent and possesses adequate authority.

The STADEM model includes the following eight decisions based on acceptance:
1. General requirements regarding final result.
2. Programme/plan regarding parts/components.
3. Specific requirements regarding parts/components.
4. Instructions regarding execution of parts/components.
5. Acceptance of intermediate results (parts/components).
6. Acceptance of changes to parts/components.
7. Acceptance of final results.
8. Evaluation.

(see fig. 4).

Each decision must be supported by at least one document (or input), which is called main decision carrier (MDC); thus, one MDC per decision. If necessary, more decision carriers (DC) can be used.

The quality of the decision is significantly determined by (M)DC quality and its use; control of organizational functions can therefore be obtained through control of (M)DC quality and the quality of (M)DC use.

By introducing MIX-documents in the STADEM-model a standard description of organizational functions is obtained (STADOF, fig. 5 and 6). By introducing suitable terminology in the definition of decisions and MDC-documents, a model for a particular organizational function is obtained.

To assure proper control of organizational functions, the following elements are necessary:
1. Authority to take decisions.
2. Resposibility to prepare or provide all (M)DC and other documents necessary to the decision making process.
3. Assurance of (M)DC quality and proper use.

Elements (1) and (2) are covered by task allocation. Element (3) is provided by means of a so-called IID-document (information-instruction-description) which:
· includes information regarding (M)DC content;
· includes instructions regarding (M)DC routing.

IID-documents are in principle control documents. By specifying (M)DC content the following is obtained:
. the full extent of information required for decision making is determined;
. the specified information will always be available, regardless of the identity of the document maker.

(M)DC routing specifies the critical milestones through-out the making and using of the document as well as the department *or* person responsible for each particular milestone. A total of 10 milestones are identified:

1.   Initiation of document making.
2. The actual making.
3.   Check.
4.   Authorization for document use.
5.   Distribution.
6.   Copy.
7.   Action (triggered by document).
8.   Inspection.
9.   Verification.
10. Archives.

The milestones describe the document lifecycle which is divided in two periods:
. milestones 1 to 5 relate to the making of the document (doc-period);
. milestones 6 to 10 relate to the execution of instructions laid down in the document (do-period).

Both periods form the so-called doc-do cycle (fig. 7).

It should be clear that by establishing IID-routing the tasks and resposibilities of departments and persons within the framework of organizational functions are unambiguously determined. The scheme of departments (persons) and related tasks is called Information-Instruction-Organization (110) matrix.

STADOF, IID and IIO are the principal models by which the functioning of organizations can be described within the COSY-structure. The location of these models within the pyramid structure of the COSY-documentation system is shown in fig. 8.

6. COSY PROGRAM

The COSY program was developed with the aim to "house" and manage integrated and/or dedicated care systems for quality, working environment, safety, environment protection, etc. Main system functions are (ref. 3):
• authorization; the program can be used by either:
  a. system managers (M), authorization unlimited
  b. system viewers (V), authorization limited
• insert and delete documents (M)
• fill in documentens (M)
• view documents (M/V)
• search for documents (M/V)
• draw up a list of catchwords (M)
• draw up a set consisting of various documents (M/V)
• help screens (M/V)

An overview of main and secondary menu's is given in fig. 9. The pyramid structure of COSY-documents is shown in fig. 10.

The main tasks of system managers is to fill in all
COSY data bases and maintain (manage) the system accor-
ding to the needs of the organization. To support these
tasks a number of standard data bases have been provi-
ded:
- database organizational functions
- database IID-documents which are named "procedures"
  within the COSY-documentation structure.

The first data base includes a list of about 15, most
common organizational functions within organizations
involved in manufacturing of goods and rendering of
services.

The second data base consists of an ordered set of
procedures (IID's) which cover most activities within
any type of organization. The procedures are divided
into 10 groups:

group nr.	title
000	management and administration
100	marketing and sales
200	finance
300	design and development
400	testing
500	purchasing
600	production
700	inspection, audits and acceptance
800	material management
900	(after sale) services

The first 8 procedures within each group are MDC-orien-
ted, hereby assuring the quality of basic information
for decision making. The system manager can use this
database to fill in STADEF models for important organi-
zational functions.

For specific sectors of industry and trade as well as
for individual enterprises, additional standard data
bases can be provided (norms, instructions, checklists,
etc.). Hereby, the effort required to fill in COSY data
bases can be significantly reduced. In principle, the
number of documents housed in COSY should be limited to
those which address critical or important issues in the
functioning of the organization and/or require formal
authorization, proof, etc.

7. STATUS AND FUTURE DEVELOPMENTS

The main COSY-models (STADOF, IID, 110) are for some
time being used in various configurations within QA/QC
systems (processing industry, suppliers, shipbuilding).
The complete COSy package for QA/QC applications has
recently been purchased by various enterprises from
trade and industry.

A pilot project regarding a limited implementation of
the integrated care approach on a shipyard (Scheepswerf
Visser B.V.) was started in January 1992 under the
auspices of three Dutch ministries (Economic af-

fairs/Social affairs and Employment/Housing, Physical Planning and Environment).

Project monitoring and control is provided by a work group which includes specialists on care systems, QA/QC, safety, environment protection and information systems from:
. Industry (Netherlands Shipbuilding Industry Association, the Royal Flushing Group, Lloyd's Register).
. Delft University of Technology (Safety Science Group, Information Systems Group).
. Consultancy (Bureau ir. J. Leupen).

Based on intermediate results and conclusions (pilot project) several subjects for future developments have been identified; these are:
. extension of the number of standard data bases for specific sectors of industry and trade
• extension of help functions
• development of functions and data bases to support identification of statutory and other requirements, or the basis of a specified company program
• coupling of COSY with computer aided systems for project and/or production management and control.

8. CONCLUSIONS

Growing industrialization, trade and the resulting statutory and other requirements for quality, working conditions and environment protection have initiated a need (and a duty!) for implementing so-called care (management) systems within enterprises.

Care systems consist of a set of ordered organizational and other measures which must assure that enterprises comply with requirements and demonstrate this ability in a convincing way.

To bridge the gap between requirements and the daily running of enterprises, a step by step conversion process was developed which matches company program (functions, processes, activities) with relevant legislation, market demands, etc. (control program). To obtain maximum efficiency, an integrated approach is used which finally leads to a likewise integrated set of measures and supporting documentation system.

The integrated set of measures is based on the principle of control of organizational functions. This is obtained by controlling and assuring the quality of decision making within principal organizational functions by means of supporting documentation.

The standard models for decision making (STADEM), organizational functions (STADOF), task allocation (IIO-matrix) and control documents (IID) for main decision carriers (MDC) are efficient means for developing and implementing supporting documentation for care systems. Hereby, a better operational efficiency with respect to

prose-style documentation systems is obtained.

Development, implementation, operational efficiency and overall management and control of the documentation system are further improved by using the COSY computer **program.** Program functions provide effective means for search, viewing, change control and program management whereas standard data bases for STADOF, IID and other documents support and reduce the effort required to fill in the system.

Considering the already demonstrated potential and the interest shown by industry and authorities, an increasing contribution by COSY to the development and implementation of integrated care systems is expected.

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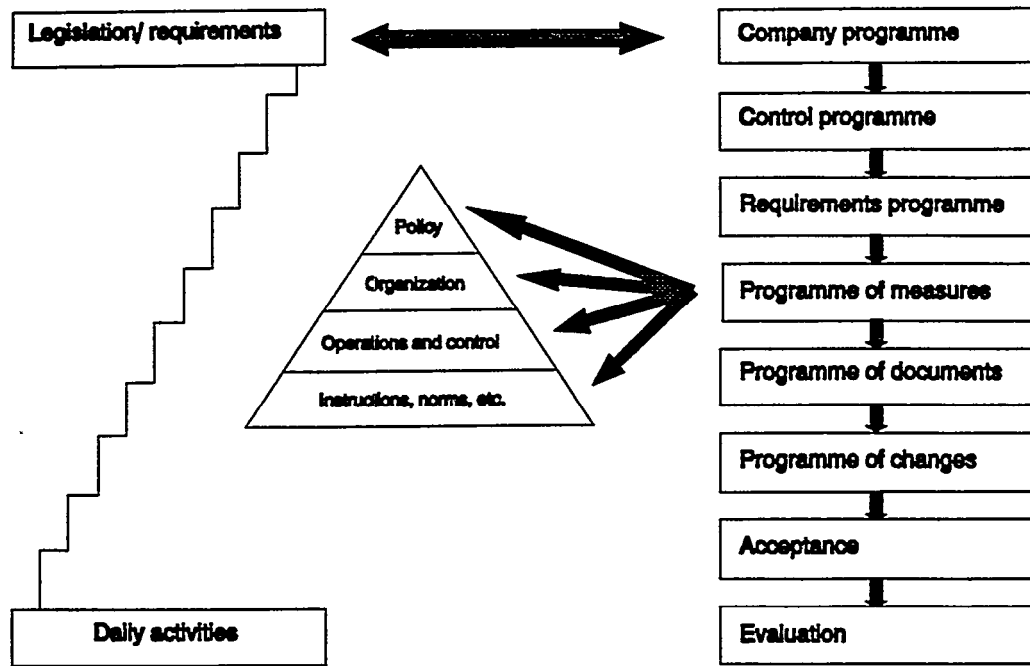
Fig 1: From legislation to measures, an eight-step conversion process.
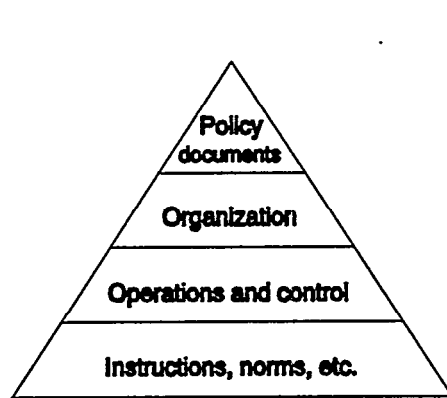
Fig 2: Pyramid structure of documentation systems.
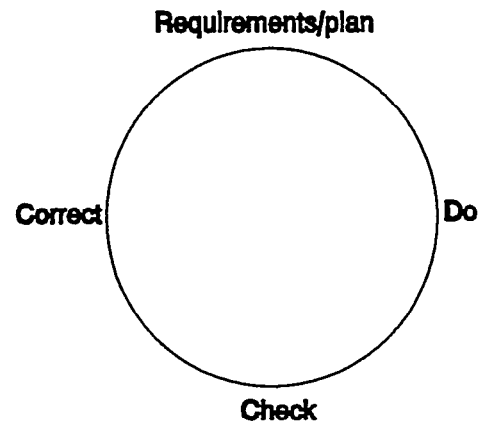
Fig 3: Deming circle.
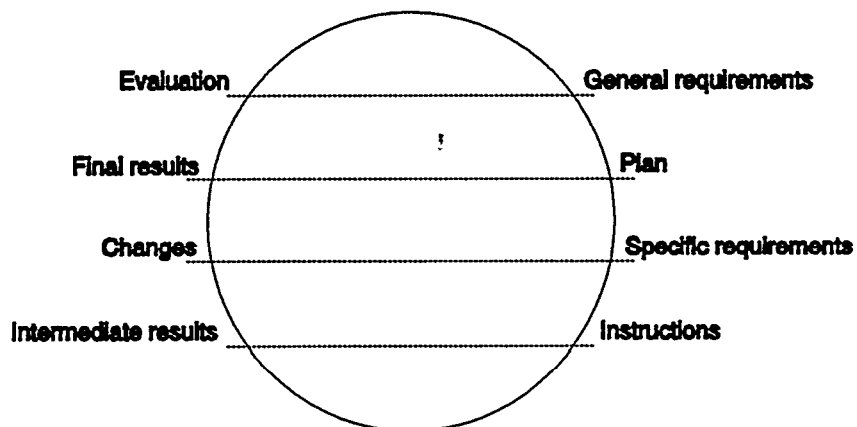
Fig4: STADEM standard decision model.
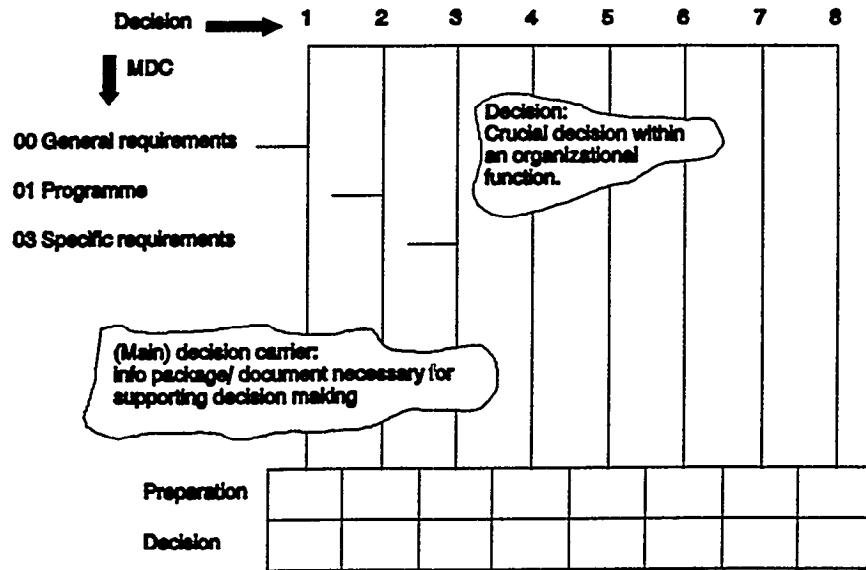
Fig 5: STADEF: Standard organizational function model (principles).
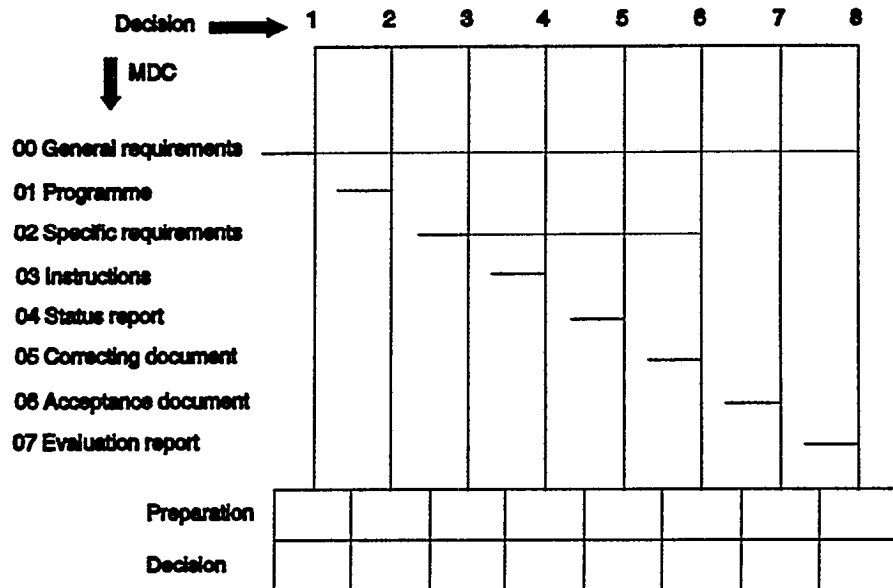
Fig 6: STADEF: Standard organizational function model (complete).
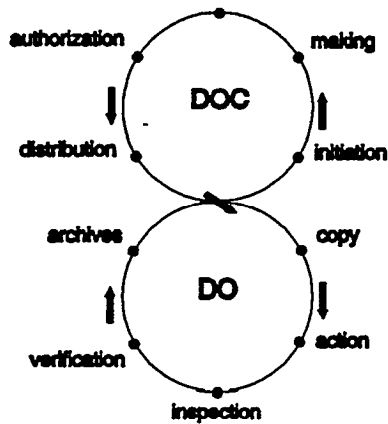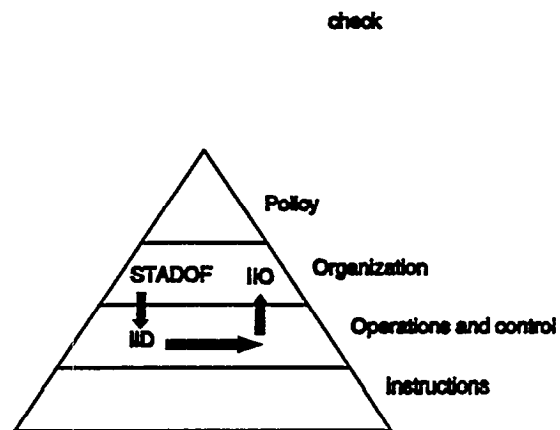
Fig 7: DOC-DO cycle.   Fig 8: Location COSY-models in the pyramid structure.

Main menu:

	Document:
Policy documents ⟹⟹	Policy document
Organizational functions ⟹⟹	Organ. function
Organization data	⇓
Procedures ⟹⟹	Procedure ⟹⟹
Monitored lists ⟹⟹	Monitored list
Instructions ⟹⟹	Instructions ⟸
Norms ⟹⟹	Norms ⟸
Catchwords	
Sets ⟹⟹	Each document
Maintenance	
Logout	Checklist ⟸

Information Instruction Description (IID)

Submenu:

Org. chart ⟹⟹	Org. chart
Regular meetings ⟹⟹	List regular meetings
Department tasks ⟹⟹	Dept. task description ⟹
Task description ⟹⟹	Pers. task description ⟹
IIO matrix department ⟹⟹	IIO matrix departments ⟹
IIO matrix tasks ⟹⟹	IIO matrix tasks ⟹

Fig 9: Main and secondary menu's.

Fig 10: Pyramid structure of COSY documentation system.

MONITORING AND CONTROL OF AUTOMATIC WELDING

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SUMMARY.

In large fabrications subject to complex stressing in service (e.g. ships), the existence of planar defects in welds could prove disastrous. Defects such as lack of penetration, interrun fusion and cracks must be avoided. Prior knowledge of the size and location of these defects are essential if predictions on fatigue crack initiation and propagation lives are to be determined. Relatively simple techniques used to predict reductions in life show the importance of detecting defects during manufacture.

Ultrasonic monitoring of the weld pool has been demonstrated and has been used to control the arc welding current and thus penetration. This task utilises the 100% sound pressure region of a divergent transverse wave ultrasound beam. Control is via a fully closed loop using a computer to monitor U.S. signals and to adjust the welding current. This technique has resulted in penetration control accuracies of +/- 0.3 mm in plates greater than 10mm thick. A wide range of materials have been employed, as have an equally wide range of welding processes. These systematic studies have shown that the accuracy of the results remain unaffected.

Ultrasound beam spread creates the conditions where the leading edge signal interrogates the weld seam immediately in front of the weld pool whilst the trailing edge signal examines the freshly solidified weld metal. Both of these signals have been utilised. Seam tracking has been demonstrated to accuracies of +/- 0.3 mm (about the same as the reproducibility of an industrial robot), whilst work on defect identification is still on going. Currently both planar and porosity defects can be identified in real time at about the 1mm size.

A simple reference system, comprising of welding code and acceptable defects will be programmed into the control computer. This will enable the system to decide whether to continue welding, or to stop, if it detects solidification defects.

INTRODUCTION.

The concept of in-process inspection and monitoring has been addressed as the act of interrogating and characterising weldments during the weld cycle. When a control system measures the workpiece and uses the measurement information to compare and correct in line with design data this is termed "in-process". In-process controls rely on the sensing of variables directly at the point of welding. Very few other production processes permit such in-process control.

Automatic process control and rapid inspection techniques must be used to keep production errors from generating large numbers of faulty products. Welds must be inspected along the joint to be sure that welding defects will not weaken the final product. Ultrasonic methods are the most promising of the possible non-destructive evaluation techniques for these inspections because they can interrogate internal structures at production line speeds.

One of the most important characteristics of a fusion weld is that it should show complete and uniform penetration[1]. Lack of root or side penetration can either statically or dynamically result in failure due to the formation of notch-like defects becoming the site for crack propagation. Due to the high cost of down time and destructive testing, many welded structures are not inspected as often as they should be. For an efficient application of the methods of weld quality and in-process control in welding, it is necessary to develop sensors providing accurate information of the condition of the weld, especially data on the depth of undercut, the extent of penetration, the height and shape of the underbead of the weld, the structure of the weld metal, and other parameters of weld quality. Such a system of sensors combined with controlling computers ensures the formation of welded joints with the required geometrical characteristics and service properties[2].

Workpieces that have flaws in them present two major problems for industry. The first, of course is the existence of the flaw itself, how it was created and the potential adverse effect on the finished product. The second part of the problem is detecting the flaw on a production basis and qualifying it accurately. Typically, skilled inspectors are used to check workpieces periodically, comparing them with masters that exhibit acceptable or rejectable flaws. This type of quality control is usually very expensive and inconsistent to some degree since it is dependant upon personal option. Fatigue, boredom, human error, or borderline decisions all take their toll on the accuracy during the workday. In answer to these problems, the paper presented will firstly evaluate the effect of defects on the fatigue life of a structure and then introduce a flaw detection system which automatically performs consistent high speed, high accuracy inspection of defects through the use of ultrasonic transducers.

EFFECT OF DEFECTS ON FATIGUE.

Welding has been commonly used in the joining of ships for several decades- and it has been stated that the weldment constitutes ca. 1% of the total mass of the ship. Thus it is reasonable to assume that a number of weld defects will be present within the structure. Rogerson[3] investigated the occurrence of defects within ship hulls and reported their population in comparison with other major welded constructions. His results, shown in table 1, reveal that the hulls contain about 4.9 defects per metre of weldment. These defects can be categorised into a number of groups, viz a) cracks b) cavities (porosity and shrinkage) c) solid inclusion (slag and oxides) d)

lack of penetration and fusion e) imperfect shape and f)
miscellaneous (eg spatter, arc strikes etc.) [4].

Table 1 : Defects in welded constructions (after Rogerson)

Structure Type	Average number of defects per metre of weld
Aluminium pressure Vessel (MIG welded)	1.6
Steel site welded Tankage (MMA Welded)	0.7 - 4.9
Steel site welded Tankage (Sub arc welded)	3.4
Ships hulls (MMA welded)	4.9
Low alloy steel pressure vessel (MMA welded)	0.7 - 1.0
Low alloy steel pressure vessel (Sub arc welded)	0.3 - 0.5
Nodes in tubular offshore platform jacket (MMA welded)	5.9

The technique for welding presented in this paper describes a
method for controlling weld penetration. Lack of penetration is
usually considered as a planar defect and its importance needs
to be explained briefly to validate the welding technology
research.

A ship, such as a large bulk carrier, may be described as a
flexible beam which operates in a seaway. The seaway itself is
of a sufficient nature to excite resonance within the structure.
These low frequency loads are the main driving force behind the
global fluctuating stresses which cause fatigue cracks to grow
within the main hull girder[5].

Fatigue failures consist of three distinct phases. Firstly there
is the initiation, followed by propagation until the crack
reaches a critical length before brittle or ductile failure
occurs. In welded constructions, however, it has been shown that
the neglect of the time for the initiation period has little
effect on the total failure time[6]. Thus it is sufficient to
consider only the fatigue crack propagation period. Experimental
work on the effect of lack of penetration on fatigue life has
been available for several years [7]. Alternatively simple models
may be used to quantify the reduction in fatigue life. One such
approach based upon fracture mechanics is outlined below.

Assuming the fatigue crack growth rate is given by[8].

$$\frac{da}{dN} = B(\Delta K - \Delta K_{th})^2 \qquad (1)$$

where B is a material constant related to the tensile properties
and the cracking mechanism present. For specific applications

this equation can be given in the form

$$\frac{da}{dN} = 3.75 \; x \; 10^{-10} (\Delta K - 7.4(1-R))^2 \quad for \; R \leq 0.6 \qquad (2)$$

where R is the stress ratio.
The stress intensity factor AK is given by[9]

$$\Delta K = F_s F_c F_w F_g \Delta \sigma \sqrt{\pi a} \qquad (3)$$

where $\Delta\sigma$ is the nominal stress range
F_S accounts for the free front range
F_E for the elliptical crack shape
F_W for the finite width
F_G for the stress gradient due to stress concentration.
Various relationships may be found for these within the open
literature[10],

Simple integration of equation 2 can be used to calculate the
numbers of cycles to failure. The limits being the initial defect
length and the critical crack length to avoid yielding or to
brittle fracture. For the purpose of our calculations it is
sufficient to assume that the crack may grow until the stress on
the remaining ligament is equal to the ultimate tensile strength
of the material, ie.

$$a_{cr} = \frac{t(\sigma_{UTS} - \sigma)}{\sigma_{UTS}} \qquad (4)$$

For the sack of illustration, a typical situation is considered.
If a nominal tensile stress across a weld is 100 MPa and a
fluctuating stress of 80 MPa. The material properties are assumed
to be of an equivalent to LR grade A and has a thickness of 15mm.
By varying the allowable crack size and integrating equation 2
the following fatigue lives were obtained.

Table 2 : Fatigue crack propagation lives.

Initial Defect Depth (mm)	Remaining Life
0.3	3.996×10^6
0.5	2.302×10^6
1.0	1.113×10^6
2.0	5.687×10^5
3.0	3.996×10^5
4.0	3.140×10^5

Thus significant improvements in the fatigue propagation lives
can be achieved provided the lack of penetration can be
controlled or reduced to low levels.

ULTRASONIC INSPECTION.

The purpose of an inspection system is to detect defects in products to maintain established quality levels in them. Inspection of product quality for defects both in manufacturing and in-service, is an important, common and general requirement. Human inspection is, to a large and increasing extent, being replaced by automatic instrumental methods. Fully automatic methods have important advantages as outlined below:

1) Automatic methods have great potential for consistency, while the performance of the human operator is variable with respect to both recognition and judgement.
2) The speed of the human operator is limited and his capability is inadequate for many applications, while automatic inspection methods are potentially capable of very high speeds.
3) Many inspection tasks are highly monotonous while demanding continuous high concentration. Such tasks are prime candidates for automation.

The main tasks of ultrasonic inspection are:

a) Reliable detection of all defects with a large safety margin to relevance.
b) Location and classification, whether further analysis is necessary.
c) Sizing and characterisation of these defects.

These criteria and characterisation are valid for manual as well as mechanical ultrasonic inspections. It is a testing system that does not involve potential health hazards and work disruption. Weld inspection may be divided broadly into two classes:

a) Inspection for the purpose of ensuring that products comply with given specifications.
b) Inspection on a fitness-for-service basis.

The goal is effective process control for economy, for failure prevention and for operational safety of the finished product. It should be emphasised that inspection is concerned not only with the test welds but also with the materials that they represent and intelligent inspection can help enormously in mundane production routines if its energy is directed more towards the fabricated components rather than languishing over post-mortems on test-pieces. Certainly, if it were possible commercially to apply a single NDT technique conclusively to a production weld to prevent failure in service, there would be no need at all for much of the testing and certification done at present. Even so, some failures are inevitable owing to operational causes or inadequate design. The tragedy is that many service failures bear no relationship to the quality of the welder's test, hence the latitude which should be allowed in their assessment is quite different from that accorded to actual production work.

The ideal control of weld quality is to perform such control functions whilst welding. With the present "state of the art" in measurement and control, certain combinations of the parameters create conditions which raise the question "can in-process measurement ever be applied?". Control applied to a manually controlled inspection is relatively simple. The welding operations can be stopped and the operator can use the conventional flaw detector equipment to inspect the weldment. With the particular large volume fabrication, measurement during the welding cycle can be difficult. However, the benefits which can be achieved if measurements can be made automatically during the welding cycle are considerable and would be well worth any investment in equipment. The last two decades have seen enormous changes in both manufacturing and inspection technology. These developments can fulfil four-fold requirements for inspection, viz.

1) improved ease and speed of measurement
2) improved accuracy of measurement
3) reduction in the time taken to record results
4) reduction in the time taken to analyse results

The principal contributory factor in the inspection has been the development of two orthogonal linear tables carrying the probes with motorised drives. This leads to the computer assisted inspection and thence to automatic co-ordinated inspection.

Development of automation of technological processes and development of inspection methods influence and compliment each other thus becoming an integral part of automated production.

Techniques using ultrasonic waves for the detection of defects in materials are now well established in industry and have proved themselves invaluable assets in both production and laboratory. Ultrasonic flaw detection is particularly successful in the metallurgical industries where it is used for the inspection of semi-fabricated products and many finished metal components. In most cases in the past all that has been expected of ultrasonic inspection has been the detection and location of defects, but more detailed descriptions of discovered faults are increasingly demanded as engineering design advances to cope with greater speed and power. In many industries today safety factors are such that even small flaws in highly stressed components can cause catastrophic failure. Obvious examples are to be found in aircraft, ships, atomic energy equipment and turbines, where extreme care must- be taken to prevent such failure.

Designers would naturally prefer to have no defects in their materials, but in the general run of production it is difficult to produce metals completely from defects or discontinuities. The problem of inspection therefore becomes one of deciding which defects or discontinuities will have an effect on the behaviour of the material in service. Before this can be done it is necessary to have information not only about their location but also their size, shape, type and orientation. Defects which are large compared with the cross-section of the ultrasonic beam

present little difficulty since their boundaries can be traced out to determine size and orientation. Furthermore, with the critical type of work mentioned, defects of such magnitude will usually cause rejection of the material. When it is required to obtain information other than location, it is the small defects which present problems and the principal method at present in use is one where a pulse-echo technique is employed. In this technique the amplitude of the echo from the defect is compared with that from a standard known defect. The cost of locating and preparing these defects constitutes a significant portion of the total weld fabrication costs. The welding process is capital intensive, prone to quality control difficulties and unpleasant for human operators.

The current work in-process weld monitoring and adaptive control forms the basis for intelligent welding systems. An expert data base using information acquired will make intelligent decisions concerning process control without human intervention. Two major areas are addressed. Firstly, the ability to select the correct solution to a welding problem must be developed. That is, the sensors must not only be able to detect an out of limits event, the expert system must also be able to diagnose the cause and correct the situation, or determine that human operator must be alerted. Secondly, a fitness for purpose criterion must be included. Thus, when a potentially defective length of weld is formed, the significance of the defect may be assessed based upon the ultimate service conditions so that an appropriate reaction (continue welding, record defect location, stop welding etc.) occurs. Utilisation of machine intelligence (expert systems) is feasible because of the ultrasonic sensors which form a computer cognition system.

THE ULTRASONIC SYSTEM.

A conceptual model of an ultrasonic system to monitor the formation of the weld pool, was constructed in 1979 and was attempted with manual arc welding"". It was shown possible to determine both penetration and weld symmetry, the programme was thus extended. Submerged arc welding was investigated on plates of > 10mm thickness. Two ultrasonic probes were carried by the welding head to ensure that the relationship between them and the weld pool did not vary (see figure 1). In submerged arc welding the occurrence of maximum penetration lags the centre-line position of the electrode (by about l-2 mm) and the beam centre-line has to reflect the point of maximum penetration([2]). Equally, due to the heat-flow considerations, the US transducers remain cool as, by the time the heat reaches the probe location, the welding heat has moved forward, as have the transducers. Thus, the sensors are always in contact with cold/cool plate material.

With this approach a series of reference lines was established which, later, simplified the task of automating the welding process and making it responsive to the measurement from the ultrasonic transducers. Control of the weld pool size was exercised by direct control of the welding current (this is because the weld electrode melting rates is controlled by the

forth power of the welding current : I'), also this was immediately accessible for control purposes. Even, as crude as the initial system was, weld penetration was controlled to +/- 0.5mm on a regular and reproducible basis (see figure 2).

Figure 3 shows a schematic diagram of the arrangement as well as the control algorithm utilised. From this figure it may also be seen that the natural beam spread covers the whole of the weld zone. This phenomena has been utilised to control the weld pool position relative to the seam and to interrogate the solidifying weld metal (these functions will be discussed later)[13]. Lack of penetration accuracies in the weld zone triggered a maximum surge response from the power source which increased the size of the weld pool in all directions and frequently re-melting the area which caused the response.

The above behaviour became a much more regular occurrence once a very high response power source became available, but the control of the current surge became much more easy, resulting in a much more consistent weld bead shape. Using this equipment brought the control of weld penetration to +/- 0.3mm[14].

Work then diverged to cover other welding processes, materials and joint profiles other than simple butt welds. Lap joints in aluminium, welded by M.I.G. (G.M.A.W.) was also investigated, This joint format being selected because it required only a marginally different probe placement than the butt welds[15]. Using joints of this format required a weld seam following strategy to undertake this task with only one viable signal path. There were no differences in the overall technique when other metals or processes were involved which demonstrates that this control process exploits basic and fundamental materials behaviour. If a weld pool exists, -then this control logic will be available because ultrasonic shear waves are ideally reflected by the liquid/solid interface. Weld pools were created by T.I.G. (G.T.A.W.) welding and the growth of these pools monitored ultrasonically, once more showed that all the ultrasonic responses were from the weld pool and not from any other arc/work-piece interactions[16].

Fillet welds, as a type of joint, are probably the most common form of joints, and once the fundamentals of the process were understood then joints of this format were investigated. Beam paths available for control and monitoring of these joints is illustrated in figure 4. This shows that the joint following is really only on the vertical member (in this figure), the continuous member not being available, having no reflection surfaces on the leading edge signal[17]. A second order approximation was possible based on the position of the weld pool, but this pre-supposed that the weld pool would be regularly positioned relative to the joint[18]. Despite this, seam following ability to +/-0.31nm was shown to be regularly available. A small, crawler robot was designed, accommodated and demonstrated to follow the joints in an internal box section, (as typified in lower hull section designs[9])'. This robot sought the joint, back-tracked to an end point (i.e. where the fillet joint ended) and

would have commenced welding. (Work ceased before welding was attempted due to financial constraints, however it was believed that the weld control and accuracies (pool size, penetration) would have matched that already determined.) After some difficulties in finding a strategy for this robot to negotiate tight corners, it was shown that this robot could carry over 100 kg and yet still follow the seam to accuracies of +/- 0.3mm.

Ultrasonic control of welding was attempted on thinner materials (i.e. < 10mm thickness) with considerable success. Materials as thin as 0.25mm, were welded , using plate surface waves instead of shear waves. Both fillet and butt welds were investigated, as was seam following. Penetration could be controlled to 0.05% of plate thickness, whilst seam following was still +/- 0.3mm (20'.

To offer completely automatic welding, two further aspects were deemed necessary, these were i) defect detection in real time and ii) incorporation of an expert system for total system control. Defect detection (in real time) is possible and at the current time being investigated. Defects such as cracks and lack of fusion can be readily monitored and identified at fusion welding speeds, with porosity of < 1.0 mm in diameter being readily identified with cracks, lack of fusion and other planar defects of about 0.3mm also determined[21]'. The establishment of an expert system for control welding by ultrasonic means was initiated at the same time as seam following was investigated[22]. This expert system was initially one which compared the achieved weld pool shape and position with a desired (pre-programmed) sizes and locations. Simple logics were programmed into the control computer memory and operated as a series of "pull down" charts with very simple decision points. Some success was achieved, certainly on a demonstration basis Currently work is continuing to develop further this system to control laser welding in the ship-building industry (BRITE/EURAM project BE4331).

This European project ultimately seeks to control the process by neural networks, there is however, one very fundamental philosophical point which must be answered. This question is "once defects are located and identified what controls are available? How does the system react?" Once the defect(s) are determined and sized the expert system will decide if these defects are acceptable to the (desired) standards, if they are acceptable, welding continues, but if these defects are unacceptable, what does the system do? Does it stop the process, does it mark a defective area, does it sound (operate) alarms? This problem, not a technological/scientific difficulty, is the current block on progress.

CONCLUSIONS.

In-process welding has been described and satisfactorily used in a variety of welding processes, utilizing ultrasonic sensing techniques. Accuracies to +/- 0.3mm have been achieved for lack of penetration as well as real time defect assessment.

Future developments of the system will need to include evaluation

of defects sizes via the method described to accept/reject welds based upon a pre-defined in-service requirement. Once this stage has been achieved then the burden of post-weld inspection and assessment will be an extinct skill and best estimates suggest fabrication cost savings approaching 30% may be achieved. Increased security should also result from much enhanced control of the welding process and decreased chances of undetected defects existing in crucial situations.

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Figure 1: Schematic Diagram of U.S. Beam
Spread and three sensing signals

U.S. Transducer

Penetration Sensing signal

Arc

Seam

Leading edge signal

Trailing edge signal
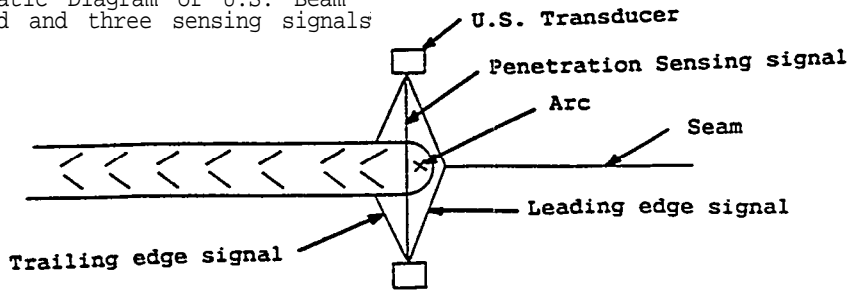
Figure 2: Schematic diagram **of** relative position **of**
electrode and point of maximum penetration

Delay about 0.5 secs

Point of maximum penetration

₵ of electrode
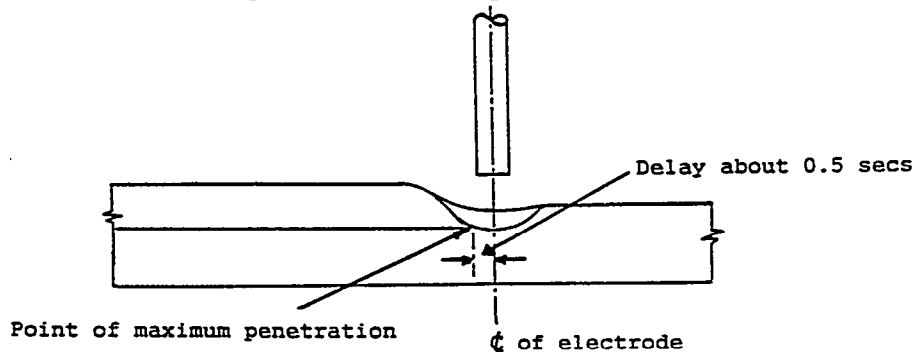
Figure 3: Signals associated with under/over penetration

T D R

Amplitude

Time

Incomplete
Penetration

U.S. Recorder

T R D

Over
Penetration

T = Transmission
R = Received signal
D = Desired path

Figure 4: Beam paths in fillet welds

IMPROVING SHIPYARD PERFORMANCE THROUGH SPECIALIZATION IN PRODUCTION

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april 15, 1992

INTRODUCTION

The business of shipbuilding is influenced by many factors which can't be controlled by the management of a yard. Market conditions and (national) administrations influence the objectives and hence the strategy to operate and develop the enterprise. The volume and conditions of the shipbuilding market are subject to considerable changes in few years periods. The role of national administrations, unions and e.g. systems for social care differ substantially from one country to another. Management has to organize, structure and finance the production process, considering these external factors. Specific skills and tools are under such circumstances required to manage a shipyard operating in the world market.

Literature and standard handbooks do not offer much help to formulate a strategy and to develop a competitive marketing, sales and production organization for a shipyard.

A fundamental problem is that the forces driving the competition between shipyards, as e.g. described by Porter (l), cannot be compared on world scale:

> Cultures, labor conditions, industrial infrastructure and environmental ruling differ from continent to continent or country to country, and even from region to region.
> For substitute products the same remark can be made.
> The development of the industrial infrastructure depends on national policies and the relevance given by a government to the maritime industry as well as the priority given by the administrations to create favorable industrial conditions in a specific region.

Shipping and shipbuilding are *cost-driven* businesses:

> New entrants, i.e.low (labor)cost builders will continue to influence international competition.
> In a well developed second hand market shipowners with relative low capital investments are competing with "first class shipowners" operating with efficient, high-tech vessels.

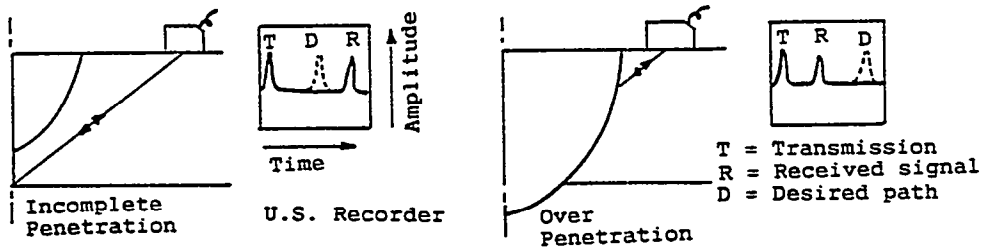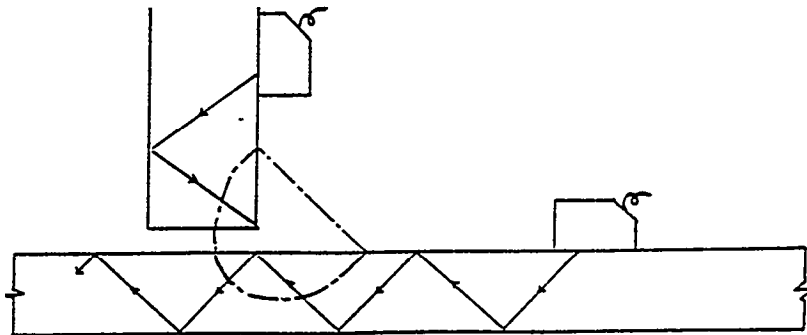Shipbuilding calls, under these circumstances, for the capability to meet individual commercial and technical wishes of a client in combination with a flexible organization able to respond to the demand.

The external factors should motivate shipyards to a continuous evaluation of the production methods and -facilities. The research on ship production should have as first aim cost reduction. Reducing building time means reducing costs for the shipowner. Quality is controlled by the classification societies.

The operating conditions for a shipyard should be considered simultaneously e.g.:

> The pressure to realize shorter lead times is increasing.
> Capital is difficult to raise if returns on investment are unstable or difficult to predict.
> The increasing complexity of ships requires higher and better educated people on ships and in shipyards.
> The importance of organizational and social values grows. A result of the demand for flexibility and well trained people.
> The pressure to decrease manpower with the aim to minimize

risks in an unstable market.
Emphasize is put on governmental ruling to improve the working conditions.

The conditions are in some cases conflicting.
Shorter lead times usually require an increase in manpower-capacity of the shipyard. This is in conflict with a policy aiming at a decrease in manpower to reduce the risk of overcapacity during periods of a cut back in demand. Reduced delivery times are of prime importance for the shipowner, but are a problem for the traditional shipbuilder with a limited capacity (fig. 1).
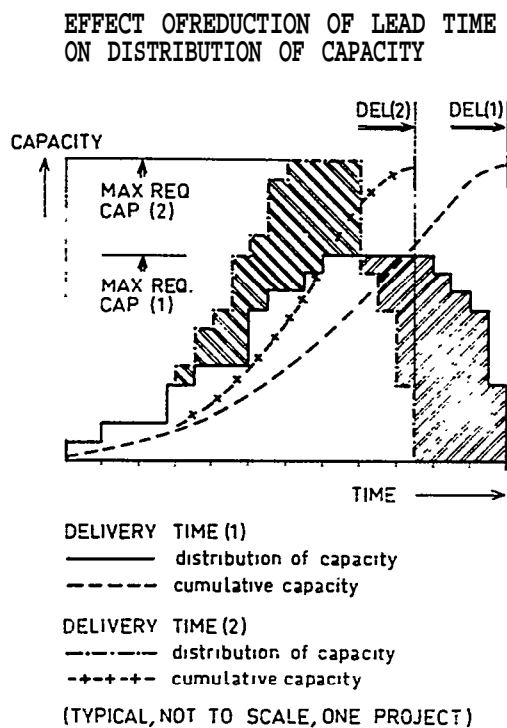
Reduction in lead times are attainable through e.g.:

increasing the production capacity of a single yard,

maximizing flexibility of labor between departments,

subcontracting production capacity with other yards,

sharing specialized production capacity with other companies,

increasing the productivity of the organization,

simplifying the product etc.

EFFECT OF REDUCTION OF LEAD TIME ON DISTRIBUTION OF CAPACITY

DEL(2) DEL(1)

CAPACITY

MAX REQ CAP (2)

MAX REQ. CAP (1)

TIME

DELIVERY TIME (1)
———— distribution of capacity
— — — — cumulative capacity

DELIVERY TIME (2)
—·—·—·— distribution of capacity
-+-+-+- cumulative capacity

(TYPICAL, NOT TO SCALE, ONE PROJECT)

FIG 1

In order to be able to judge advantages and constraints of the (combination of) solutions, detailed look into the Production system of a shipyard is desirable.

Incentives are suggested to develop new technologies, improve products and productivity, change the structure of the industry. Programmes are proposed to explore reductions in cost ameliorate quality and generate new solutions with the objective to run a business more competitively.
However, the validation of an idea requires a preferably simple tool enabling an individual shipyard to evaluate changes in a production system. It demands the availability of a reliable prediction and evaluation method, considering the effects on:
cost, lead-time and quality of the product and
profitability of production process
to assist the management with a decision support tool.
The effects of specialization in combination with an autonomous operation of parts of the production facilities may be an answer to improve the performance of a production system and are discussed in

this paper.

The paper observes the following features:
*   A review of the opportunities described in the literature to improve the market position of a business in general terms.
*   A description of distinct production systems which can be defined in shipyards. The systems are reviewed indicating limits, opportunities and requirements associated with the key functions of a shipyard.
*   A method to predict and measure performance in terms of cost, delivery time and quality.

THE COMPETITIVE POSITION

Methods to reduce cost and improve productivity or quality differ considerable and are amongst others depending on the market position, the structure of the industry and the production system. Areas which are usually indicated for further investigation to improve competitiveness are:
>   Relations and communications of the management with labor.
>   The search for possibilities to create entry barriers for the competition.
>   The evaluation of the structure of the industry i.e. the relationship between shipyards and suppliers or subcontractors.
>   The organization of the production.

Frankel (2) gives some guidelines and recommendations to improve the competitiveness and productivity of the shipyards in the United States. These views are of particular interest when the present position of the shipbuilding industry in the U.S. in the market of the merchant marine is taken into consideration.

Porter (1) describes some sources to create barriers for entry to an industry.
*   *Economies of scale.*
Economies of scale can be found in any functional area or part of a business. The goal of economy of scale is to reduce the unit cost of a product or a part of a product.
Examples are R & D, manufacturing, industrialization of production processes (prefabrication or panel-line fabrications), combining capacities to increase output, improve quality, implementation of new technologies and the reduction of joint costs.
*   *Vertical integration,* the successive stages of production or distribution are in one hand or combined. This refers to the association with subcontractors and equipment suppliers.   Apart from technical and organizational cooperation techniques and means to reduce cost could be part of the teamwork. However, in practice, it is nearly impossible for a shipyard to restrict the supplier or sub-contractor to use the jointly developed know-how elsewhere.
*   *Capital requirements.*
An entry barrier to the market is the need for capital requirements. This can be cost for research and development, but also investments for new technological developments.
*   *Cost advantages independent of scale.*
Some factors are:
>   Favorable access to raw materials.
>   Convenient geographical locations.
>   Proprietary product technology. In shipbuilding and shipping

it is difficult to protect product know-how by patents or proprietary agreements.
Learning or experience curves
the development of standards are leading to cost reductions.
*   ***Government* policy.**
A government may limit the competition and initiate entry barriers by supporting the industry, implementing rules for environmental standards, product safety etc.

Benefits of specializing parts of the production system are generally resulting in decreased cost per unit, cost advantages independent of scale and capital cost.
The classic learning curve is the result of experience through specialization. Improved working methods, a refined lay-out and use of equipment, increased performances of labor, better dimensional control with appertaining measuring techniques are resulting in declining costs per unit and improved quality (3).
The general view is up till now that for the type of heavy construction work as shipbuilding not much can be expected from dimensional control in the assembly stages. The dimensions of large assemblies are difficult to control due to the deformations during welding and assembly, resulting from heat-input, transportation, insufficient homogeneity of the material, lack of repetitive work etc..

INTEGRATION OR DIVERSIFICATION

The traditional shipyard is based on *vertical integration* i.e. the fabrication of as much equipment as possible: castings, turbines, main-engines, foundries, machine-shops, pipe-shops, carpenter work. It includes nearly any type of work required to build a ship and adding value to shipyard production.
Advantages of vertical integration are found in the reduction of joint costs, resulting from economy of scale. Overhead costs are spread. The production proces is in one hand. Delivery times can be controlled by employing (own) spare capacity and subcontracting when capacity is short.
This diversification puts also constraints on the effectiveness of the proces. The balancing of the capacities of the departments in the flow of the proces is difficult to achieve. Efficient use of investments in production facilities in a single department, e.g. through an increase of the production volume to maximum available capacity, may not be possible. The opportunity to obtain reductions in cost per unit remains unused in case capacities cannot be balanced. Particularly in case of process-type or batch type production systems, cost reductions are not realized when the production of a unit is limited to the demand of one shipyard. The total production system does usually not allow for levelling the production capacities of single departments. Moreover the degree of utilization of equipment and machinery will vary as a consequence of different types and sizes of ships which are subsequently under construction. The production system is under these conditions faced with additional costs which have to be accepted.
Specialization of subcontractors and suppliers initiated a change in the industry and made it possible to buy an increasing amount of equipment and installations from outside suppliers.

A process of *specialization and horizontal diversification* took place in the industry, without effecting the position of shipyards. The result was a different industrial infrastructure. "Make or buy" decisions became a relevant topic for a shipyard to be able to reduce costs (6).

The shipyards concentrated on what can be considered their core production activity. Production capacity became a matter of the combination of available manpower and physical capacities, building any type of ship and trying to cover new markets. At the same time some yards specialized in specific markets and types of ships.

In the Netherlands the advantages of product specialization were successfully exploited by a number of yards.

The process of specialization and horizontal diversification is continuing. To explore where further progress can be achieved, the effects of improving the quality in the up-stream stages of the production process (engineering, purchasing, material handling, prefabrication) will have to included in the evaluation and weighed with regard to the impact on the production stages down-stream the process, e.g. the assembly.

The required capital demand up-streams, as sophisticated computer applications, could be limited when combined purchase and shared operation are envisaged. The same applies for costly up-front R&D and software development. A decrease of the cost per unit is than feasible. The problem of inter-dependability is not necessarily a commercial but often a psychological factor. The assurance of the persistent competitive attitude of a combined "service tool" needs attention.

The advantages of horizontal diversification are: spreading of capacity and increased flexibility, maintaining the capability to realize short lead times.

The attitude, bargaining power and the strengths and weaknesses of the suppliers to the shipbuilding industry deserves attention. The shipbuilding industry is usually not an important customer for the suppliers because the market volume is limited compared to the total sales volume. The relationship between equipment Suppliers and shipowners is creating switching cost for both shipyards and shipowners (e.g. paint, navigation equipment or propulsion systems). The position of the shipyard can be weakened and the yard may investigate the possibility of vertical (backward) integration. On the other hand the cost of the product of the supplier often represents a small part of the total costs of a ship and the penalty for failure or late delivery may be high in relation to its cost.

The building of the steel hull, which represents approximately 75 % of the added value of a shipyard to the cost of a ship for the merchant marine, is one of the core manufacturing activities of the shipbuilding industry. The aim of some (e.g. Japanese) yards is to reduce the added value of the yard from 30 - 35 % of the total cost of the ship to 10 - 15 % in the coming years. Most of the cost related to the production of the steel hull are in assembly. It means that much attention should be given to this part of the production flow. The well organized assembly is another major area to be investigated.

PRODUCTION SYSTEMS AND SHIPYARD ORGANIZATION.

The objectives for a business in terms of profitability, market share and the operating conditions for the company under the prevailing market circumstances shall be well-defined.
Christensen and Andrews (5) formulated and investigated the concept of an explicit strategy for a company. The combination of targets, means and people defines the relationship between the strategy and the operational attitude of the management.

The tools to realize the objectives are, according to Andrews and Christensen:
    target-markets for products and product development,
    products which the company will have to develop or actually is producing,
    research and development for product- and production development,
    marketing (as one of the major preparatory functions) for product development,
    sales,
    manufacturing,
    labor,
    purchasing,
    finance and control.
The specific articulation of the operational instruments by the management depends on the nature of the business. As remarked earlier not much is published about the shipbuilding industry.
Generally it is said that "the organization will depend on the nature of the business[11] and that management may be more or less specific in defining the operating policies for the key functions and from thereon shape the organization to the purposes of the company.
Each activity of an organization involves cost. Cost that must be financed from the profit generated by that activity.
Any activity in a diversified production process, which is subject to changes, entails the risk of potential losses. Insight in the key functions of the proces is needed to be able to minimize risk and generate profits utilizing the required human-, physical- and capital resource.
"Production is not the application of tools to materials." It is the application of logic to work. The more clearly and rationally the right logic is applied, the less of a limitation and the more of an opportunity production becomes", according to Drucker who developed some principles of production based on distinct rules, requirements and features (4).

Differentiation in production systems

Unique product manufacturing can be recognized by the organization of the work by homogeneous stages. The production organization is dependent on
- the type of product
- the application of standardized tools,
- the use of standardized materials.
Unique product manufacturing demands a relatively low capital investment compared to the cost of labor. Cost per unit are high

but break even points low. The organization must be flexible in order to make it competitive.

The characteristics of *series* or *batch production* are close to unique manufacturing. Sometimes the organization of the work is arranged as line production. The use of standardized parts is introduced, next to the application of standardized tools and materials.
Series production is less labor-, but more capital intensive per product than unique product manufacturing.

Process production can probably be described the best by "producing in an integrated system, sometimes starting with one basic material, in one single process, different end products".
Examples are process industries and transportation or distribution systems which are based on the same principle. The process is rigidly fixed and can hardly be changed: The production process is the integration of process and product, the production volume is high. Compared to unique product manufacturing and batch production the process industry is not labor intensive.

For each production system the organizational -, capital -, labor - and requirements for the key functions, as described by Andrews and Christensen, seem to be different This is relevant for the qualifications for personnel, the requirements for the physical resources, marketing and sales as well as the style of management.
Although the key functions are the same for different businesses, the qualifications for the functions vary with the production system. Recognizing the type of process is apparently an important factor in organizing the production system which is defined as the total process i.e. marketing, sales, manufacturing, purchasing, finance and control etc. By organizing (parts of) production according to the principals of each system and learning how to apply and harmonize those systems within a production process, it becomes possible to advance the whole process.
The principles to improve production performance and pushing back certain limitations of the production systems are:
* Consistent and thorough application of the principals of the system in use.
* Awareness of different degrees of complexity of the systems; Unique-product production is usually called the least complex and process (flow) production the most complex.

The traditional building of the steel hull -as unique product manufacturing- is described as a labor intensive activity. The production process has certainly been improved by introducing new manufacturing technologies. Cost savings have been mostly realized by improving the up-stream stages in the production process such as numerically controlled processing of the prefabrication, panel-line assembly, pre-outfitting of blocs etc., without however changing the basic structure of the shipyard.
The possibility that there might be different types of processes within the overall proces of ship production was not investigated.
Moreover the development on the application of new technologies or processes for production equipment for the shipbuilding industry is primarily done by equipment suppliers, e.g. welding, cutting,

numerically controlled machine applications, etc.. In shipbuilding this part of the production technology is available to the world market. Under these conditions, one of the core activities of the industry relies, to a great extent, on the results of Research & Development which are available to every shipyard in the world. On the other hand history proves that advanced technology is not the prime mover for competitiveness and insufficient to be competitive in the market. Neither is the cost of labor, as is being proved by the current developments. This is another reason to consider the process of ship-production in relation to the infrastructure of the industry and the different types of processes.

Research for production at the Delft University of Technology

The goal of research in ship production carried out by the Technical University of Delft is defined as
> "find potential for reduction in cost and lead time and improved quality by studying the changes in the industrial infrastructure, production methods and organization of the shipyards as well as the construction of ships".

The systems explored -on a limited scale- as a part of the overall production system, in cooperation with some shipyards are:
> unique product manufacturing,
> batch and series manufacturing and
> process production.

The identification of the different types of processes is used as a starting point to study parts of the production process. The total cycle design-engineering-fabrication is explored.
The research is related to:
> The development -learning to know- of the specific possibilities, requirements and limitations of each system.
> The organization of the production according to the principles of each system.
> Learning how to apply and harmonize the systems within a total production process.

Different parts of the shipbuilding process are being studied with the aim to verify the features of the production systems and to establish if, and under which conditions,- the principles of production outlined above are applicable and could serve as a tool to advance the total system.
The purpose is not to make studies or to measure the individual performance of welders, steel workers or other trades. The various stages of the process are divided in storage, transportation and manufacturing. Production flow and "product" are analyzed. Process analysis includes-the evaluation of time spent on searching for materials or available information, set-up and preparation, the effective working time and time lost for reasons beyond the control of the worker. The "product", is in this case not the ship, neither a distinct component or piece of equipment, but that part of the construction or assembly that can be identified and observed during the work. It may be the fitting, installation and welding of **a** penetration, the fitting and preparation of a part of a bulkhead for welding, the welding of a part of the structure. The purpose is to identify families of jobs, types of processes etc. to enable identification and comparison.

Why this approach?

The structure of the shipbuilding industry in the Netherlands makes it possible to explore different types and sizes of shipyards and organizations. Shipyards covering the entire production process having all the above mentioned operational instruments on one location up to enterprises which combine various specialized companies and jointly represent the -conventional- shipyard. Small and medium size yards with varying markets, from yachts to naval vessels, sometimes combining repair and newbuilding, provide for a versatile shipbuilding industry in the Netherlands, covering the international market.

When companies are grouped in a holding or similar organizations, independent operating businesses as well centralized organizations can be found. When it is considered useful from a business point of view and economically attractive key functions of an organizations may be combined. The aim is to link the effects of economies of scale and cost advantages independent of scale originating from experience and shared operations.

Some shipyards generate, very successfully, new technologies. The technology is marketed and sold to the industry independent from the shipyard.

Simultaneously this situation entails limitations for the research. To mention some:

It is not possible to study repetitive identical "tests" or processes. The effects of e.g. a change of one parameter of a in the process cannot be measured.

The variation in "products", offer a limited possibility to study identical products under identical conditions.

The differentiation in departments and trades increases the above mentioned effects.

The methods and equipment in use differ (size, capacity, type) from yard to yard.

Production flows vary with the lay out of the yard.

The ships under construction are not the same.

The organizations of the yards, including the method of subcontracting are not comparable,

Observations are limited in time, for practical reasons.

Although also apparently similar shipyards are involved, the organizations appear to be different. The conclusion must be that this type of research cannot be made under ideal laboratory conditions.

These considerations are leading to the present approach. By identifying:

similar types of production systems and

families of similar products,

in combination with labor and equipment involved, an attempt is made to come to a systematic analysis of different processes.

Aspects to be taken in consideration are:

planning and material distribution,

administrative systems,

comparison and evaluation of working methods,

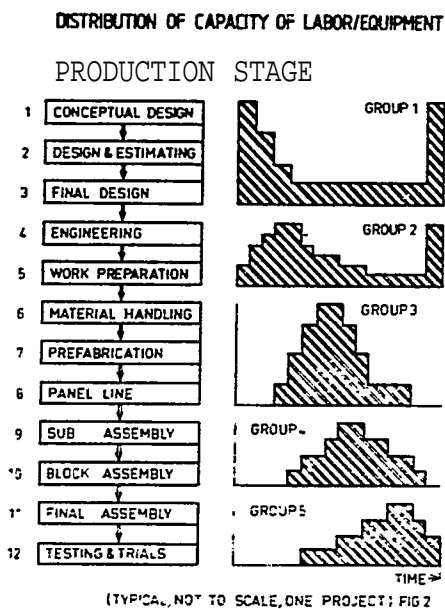manhours in relation to the use of materials

the involvement of subcontractors and sub-suppliers,

methods used to increase capacity etc..

Quality and safety.

To be able to measure quality and safety industry-wide, norms and standards are required as well as references to determine the "value" of quality and safety in terms of money. There is no purpose in promoting quality in cost-driven industries if there is no relation to a financial reward. The well developed second hand market is prohibiting the introduction of quality in transportation when safety is not an immediate concern. Safety is the result of commercial evaluations and only in a few cases related to public appreciation. Safety is in the first place related to performance of people and in the second place to performance of equipment. The quality of the product and the quality of the worker are interrelated and cannot be separated. Without suitable norms and standards which make it possible to measure and compare, quality can only be measured by using administrative procedures determining the performance of the product. Again, the role of the classification societies as well as the insurance companies is crucial when performance of ship and crew are to be measured. Complicating factors are the life time of a ship (up to thirty year or more), changing ownership during the life time of the ship, the different modes of operation and exploitation, varying environmental conditions, different modes and attitudes towards maintenance etc. These conditions make that tangible results of projects as NEUTRABAS (9) and ROCOCO (10) remain to be seen. Particularly when the "life cycle" of the ship and process modelling for CIM appear to be leading reasons to develop complex and costly computer software where simple and cheap tools are required and available. The question is under which conditions this type of supporting tools is indeed reducing cost or lead time.

The quality of shipyard production is depending on two main factors throughout the total organization. Knowledge and people are the assets in design and engineering, but even more on the shop floor. Experience, training and education are the crucial factors.

Some results.

DISTRIBUTION OF CAPACITY OF LABOR/EQUIPMENT

PRODUCTION STAGE

(TYPICAL, NOT TO SCALE, ONE PROJECT) FIG 2

The different production stages are shown in fig. 2. The twelve stages are combined in five groups. Engineering (stage 4) includes purchasing and is, with work preparation, considered as a supporting activity for production. So far only the stages in group 3 and group 4 have been the subject of observations. The targets for engineering and work preparation are usually the result from planning for production. The activities of the production departments depend on the master planning of the yard. The parameters controlling the lead time for the work of each group are different.

Groups 1 and 2 are primarily controlled by the availability of (external) information, the lead

times of group 3 are governed by the production capacities of equipment while the lead times for group 4 and 5 are depending on the delivery times of the (long lead) equipment, the manpower capacity and the equipment capacity in terms of transportation.

The observations made so far indicate that the manufacturing activities in group 3, i.e. material handling and pre-fabrication as well as panel line production have the characteristics of process-production, while assembling can be considered as unique product manufacturing, with the particularity that the activities of certain trades show aspects of batch or series production. The operations of group 3 are part of the manufacturing of the (steel) hull and are totally different from the unique production process. This indicates that there is a chance for specialization if the preparatory activities of group 2 are able to meet the demands from this part of the process. This includes not only the ordering of steel and the preparation of the numerically controlled fabrication of plates and profiles but also the timely and precise grouping of all materials required for sub-assembly.
Assembly (group 4) and fabrication (group 3) are putting different requirements on engineering and work preparation. The organization for assembly demands a specific approach for grouping and handling of materials, partly resulting from the previous stages in group 3 and simultaneously directly depending on engineering and purchasing actions. The observations show that there is considerable room for improvement compared to the activities in group 3.

The observations confirm the views of Schonberger (3) that the lead time is the governing factor for costs. Progress can be measured, according to Schonberger, by controlling two conditions:
> All materials for a product going to the shop floor.
> The finished product leaving the shop floor.

BLOCK ASSEMBLY + PRE OUTFITTING (TYPICAL)
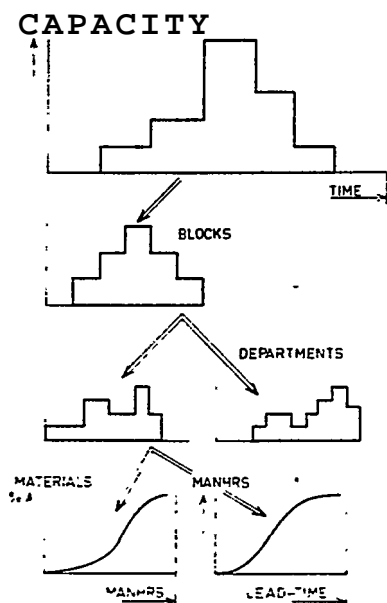
FIG 3

This type of control is only feasible if the lead time for production is a few days. The administrative and supervisory procedures are simplified. For a shipyard this is not a realistic condition for all the production activities. A simple method for longer lead times was developed in cooperation with a shipyard in the Netherlands. The method is also based on the material flow registered from the warehouse. Materials, manhours and lead times are estimated and combined, based on manhours, materials used in trades and departments for previous ships. The analysis indicates that the various activities of a shipyard can be characterized by curves having different shapes (fig. 3). By breaking down the ship into blocks and installations, it becomes possible to control progress,

CHARACTERISTICS OF CUMULATIVE
MANPOWER CURVES (TYPICAL)

MANPOWER

(1)
(2)
(3)

LEAD-TIME OF ACTIVITY →
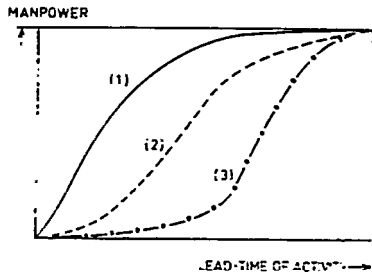
(1) ENGINEERING
(2) SUE ASSEMBLY
(3) FINAL ASSEMBLY

indicate where certain delays in production can be expected which require corrective measures and assess at any time the actual materials and manhours spent in relation to the progress of work and the original estimates.

From the distribution of manhours and materials different types of curves can be established which are characteristic for certain trades and departments. (fig. 4)

Strategic selection of production development.

The selection of production activities for a shipyard - i.e. a make or buy decision - shall be based on an analysis considering the aspects of cost, lead time and quality simultaneously. A shipyard has to decide which parts of the production are to be considered as core activities of production, essential for the continuity of the company. The preparation of such decisions requires tools for the management to be able to evaluate and compare different options and develop solid financial and economical policies.
The basics for such decisions are depending on conditions which will vary for each individual shipyard. Some of the variables to be considered are shown in fig. 5.

POTENTIAL TO REDUCE
COST OF PROJECT

EFFECT OF CHEAP LABOUR ON COST

CAPITAL REQUIREMENTS
FOR NEW TECHNOLOGY

STRATEGIC RISK OF
SUB-CONTRACTING

POSSIBILITIES TO
SUB-CONTRACT WORK

POTENTIAL FOR INNOVATIONS
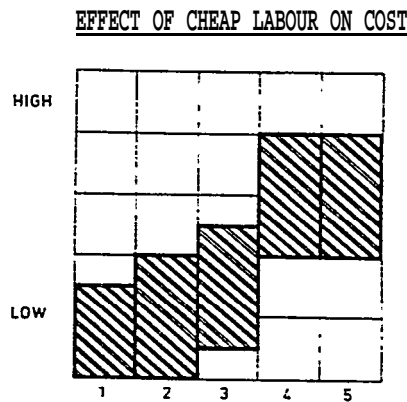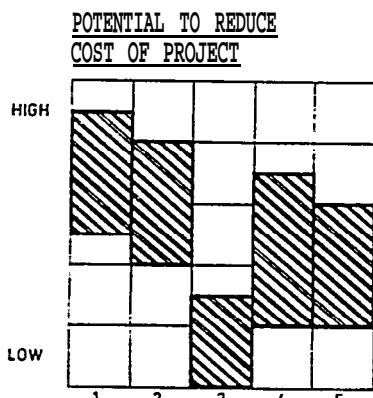
FIG5a   FIG5b   FIG5c

The numbers 1 through 5 in the figure refer to the groups mentioned in fig. 2. Although the variables displayed in fig. 5a show the same trend, only the potent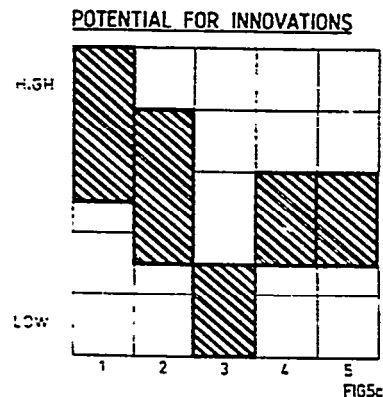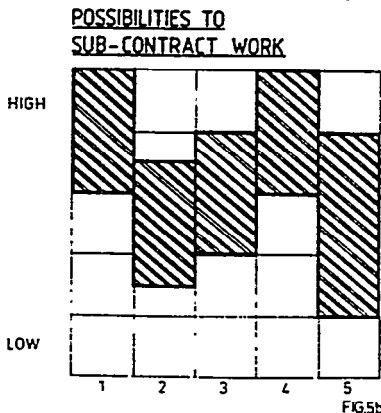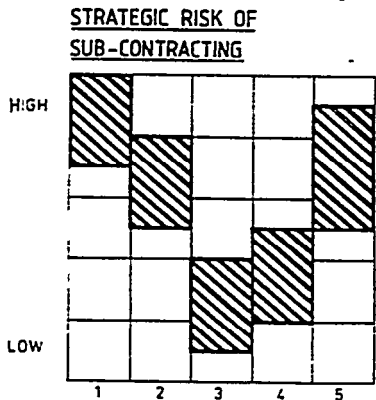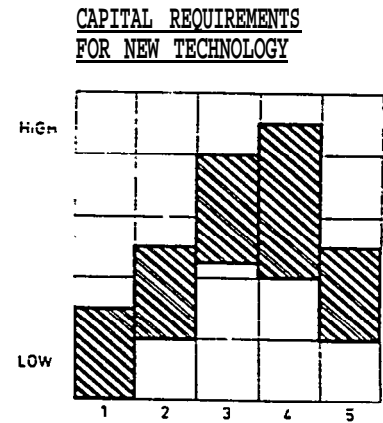ial to reduce cost can be estimated in terms of money. The effects of sub-contracting and cheap labour are easier to verify. Fig. 5c indicates that capital requirements for new technologies and potential for innovation have different effects. Capital requirements can be reasonably well estimated. The potential for innovation is much more difficult to measure. The effects shown are related to the total shipyard operation. Groups 1 and 2 seem to include essential operations for a shipyard as well as groups 3 and 4. The in depth evaluation of a shipyard operation requires a tool enabling management to weigh the effects of any change into expected profits for the company and improve the competitive position. With the help of the type of variables as shown in fig. 5, financial modeling can support these evaluations and translate actions into a long term financial perspective.

Final remarks.

1.   Design and engineering are crucial activities for a shipyard. The data base for production information is prepared during the engineering stage (including purchasing). The tools to support production can be simple, cheap and easy to maintain as long as the information required for production and accumulated during the engineering phase is limited to the needs of production, no more no less.

2.   For the shipyards it is worthwhile to pay more attention to the R&D in manufacturing and assembly technologies which means:
logistics,
material handling,
development of logically composed, system oriented, packages which are suitable for easy subcontracting, development of standards for engineering,
more "containerization" of installation work,
the development of "user friendly" software, for data bases containing the information from engineering for production.

3.   It is recommendable to analyze the competitive position of the shipbuilding industry in Europe in the same way as has been done for the automotive and airplane industries. Studies of the automotive industry revealed unexpected high differences between e.g. the Japanese and European costlevels. Similar studies, on a smaller scale however, indicate that the shipbuilding industry in certain European countries i.e. Denmark and The Netherlands is much more competitive on worldscale than the automotive industry (6). The remarks made by Sverdrup (7) deserve attention.

4.   The dangers of an unbalanced industrial infrastructure are becoming visible when economical performances are compared for existing industries considering a multi-dimensional industrial structure as described by Porter, Apparently the statistics of economists do not have the possibility to produce information on e.g. a three or four level deep client-supplier relationship without disbanding the present statistical structure.

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ABSTRACT "IMPROVING PRODUCTIVITY IN SHIPYARDS"

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On the expectation of major improvements in productivity, shipyards
tend to invest in new equipment, new facilities and machinery.
Indeed these investments generally contribute to the expected higher
productivity.
Very often, however, the results are not in conformity with what was
calculated and expected.
In most cases it has appeared that insufficient attention has been
paid to the organization, the preparation and the implementation.
In other words people form the organization.
They have to organize the process in such a way that the objectives
aimed at by the investments can be realised.
There are other important elements than investments in equipment and
facilities that can contribute to a major productivity raise.
These important elements are "culture" and the "way we work together".
Explanation will be given how organizations can be changed and delega-
tion of responsibilities can be achieved in such a way that a major
improvement on production can be realised.

PRODUCTIVITY IN SHIPYARDS

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Statement: Labour productivity is less important than one thinks

I notice you think, this can not be meant seriously.
It is, and I hope to explain to you why.
When a shipyard meets problems one of the first remarks made by the
management is: "Productivity should be increased and the costs should
be decreased".

In relation to "Productivity should be increased" the first thought
generally is: "Everybody has to work harder".
The second thought will be "Management has to organize the work much
better, more in detail".
The third thought will be: "We have to invest in machines, we have to
mechanize, we have to automatize, we have to robotize.

Working out the first thought: "Everybody should work harder", means
in many cases that management will hold speeches in canteens to
motivate personnel to work harder as well as personal talks.
I can assure you, based on experiences, that this does not help at
all.
Maybe only for a short period.

The second thought "Management has to organize the work much better"
means in many cases, at least in the past, that management decided to
prepare more information in offices, to prepare more in detail and to
give more detailed orders, having the idea that by doing that on paper
the organization will improve.
You know what I mean, line production, precisely written down in pro-
cedures, division of labour activity, bureaucracy, very very detailed
planning, in other words an organization in accordance with the Taylor
model.

If this is realised and a number of years later management looks back
to the past years because of the fact that their competitors are still
doing very well, perhaps better, management realizes that the result
is much less than expected and in some cases the measures did not even
help at all to improve the results of the yard.

What might be the reason?
The disappointing situation is in many cases declared by management by
saying that people are not doing their utmost, not willing to work
properly, the organization of the work is poor.

Disappointed in "people" (remember this because of the second part of my lecture).

The second remark: "The cost should be decreased."
Of course this makes sense and to my opinion this belongs to the daily responsibility of the management.
But when this remark means:

     saving costs of maintenance
     saving costs of education and schooling
     saving costs of research and development

then management is making wrong decisions in the long term.

Why did I start this lecture so strange bearing in mind that it is a lecture about productivity in shipbuilding.
Mainly because many managers think that productivity only means making less man-hours in production.

I assume that managers know or feel that productivity has a wider meaning and has more than one meaning.

Maybe I should give a more justified academic explanation about productivity, but then my lecture will definitely be dull.
I will try to avoid this, that's why my attempt to simplicity.

Productivity is not the same as efficiency or in other words effectiveness.
Productivity free translated means 'fruitfulness'.

or

$$\text{Productivity} = \frac{\text{result}}{\text{efforts put in}}$$

We have to distinguish from the meaning of productivity:

$$\text{labour productivity is} \quad \frac{\text{result}}{\text{efforts put in (in labourcapacity or tonnes)}}$$

$$\text{capital productivity is} \quad \frac{\text{result in money or similar}}{\text{capital per year}}$$

Naturally numerator and denominator should be a relation to work with to refer to because what is it all about in a company:

A)   used man-hours
B)   costs

In fact the most important for a company is the question: 'How can we achieve the lowest production costs?"
More recognisable for us shipbuilders is:
the sum of man-hours x man-hours tariff + materials and services + a percentage for general costs and sales costs.

The graphics (enclosure 1) show how this is related to each other.

This subdivision differs, on one hand shipyards with more simple ships, particularly small series, in general man-hour related shipyards and on the other hand shipyards that are highly specialised or also a mixture of both which very often is the situation in the shipbuilding industry.

Also we can see from the graphics that from the total 'production costs the number of man-hours as part of man-hours x tariff is restricted (limited percentage).

So it shows that when we try to improve the man-hours amount with 5% and the other aspects like materials and services are not under control the result is very limited.

I know it is a cliche, but I hope that with my presentation I can make clear that it is much more important for companies to take not only notice of the man-hours situation but also to decrease the tariff of man-hours as much as possible, to lower as much as possible general costs and sales costs and trying to get the best result by buying materials, components and services.

Again back to the subject of the lecture.

Of course, labour productivity has a direct relation to man-hours.

Discussing minimizing the amount of direct man-hours as part of labour productivity, the most important aspects are:

good facilities	(a)
good tools and machines	(a)
mechanizing	(a)
automatizing	(a) + (b)
robotizing	(a) + (b)
CAD/CAM	(a) + (b)
planning and work preparation	(c)
just in time approach	(c)
production friendly construction of structures	(c)
pre-outfit of ship sections	(c)
building of units	(c)
good organization	(c)
qualified and motivated personnel	(c)

We can define the above mentioned aspects in 3 major groups:
a) hard-ware aspects
b) hard-ware aspects in combination with soft-ware aspects
c) soft-ware aspects

Group a) are investments in facilities, machines, tools and mechanization, in other words hard-ware.

That the yard should achieve the most optimal situation goes without saying.

One can speak of bad management if there is not taken care of these elementary aspects.

Group b) means automatizing, robotizing and CAD/CAM in other words the combination of soft-ware and hard-ware.

Buying and implementation of these subjects to decrease the amount of man-hours means very objective and careful judgement in respect of costs of the investments with regard to the profits.
These investments do not always mean cost savings or in other words no <u>capital</u> productivity improvement, despite less man-hours for production.
Also this group of aspects belongs in my vision to the normal activities, judgements and policy of the management.
Also here applies that when a shipyard is not regularly busy with these aspects, one can speak of insufficient management.
Unfortunately it is amazing that these aspects get very often less attention than necessary.

Of great importance in this group b) is the involvement of the personnel.
When these investments with great influence on the way of working of the employees and the way the work is organized, are not well prepared and not sufficiently discussed with employees involved and as a consequence not properly implemented the expected results and advantages will definitely not be achieved.

Group c) are mainly aspects in relation to the organization of the departments and the way the work is organized as well as a relation to human involvement (software).
If employees and managers
    see importance of these aspects
    do completely agree with this policy and the way the
    organization has to be realized
    are willing to accept the implementation, the changes of the
    organization and the change in the way of working
    are willing to discuss organizational and work matters on equal
    basis and make good appointments about that
great improvements can and will be realised without major extra costs.
A good organization together with qualified, motivated and involved employees are essential for a shipyard.

Everything said sofar makes clear that success is highly depending on people.
Fortunately more and more managers realize that employees do not dismount their head at the entrance of the yard and mount their head at their body again when leaving the yard.
The majority is able to do much more and complicated work than one thinks.
Why do managers hesitate to delegate, to give more responsibility to the employees?
Why are managers not willing to change their organization in such a way that responsibility and work are delegated into the organization as far as possible?

The answer to this is that it often lacks of courage and it also lacks of managers that are capable to implement this way of working together and to work in an organization with far delegated responsibilities, because the management should be ready and willing to change the organization from a functional production organization into a flexible product-orientated organization and way of working, giving the employees the possibility to be involved with the ins and outs of the yard in such a way making optimal use of knowledge of all people in the organization.

At IHC Holland we decided in the mid eighties after careful detailed investigations in relation to modem management to change from the said existing functional production organization to a flexible product related organization.
We named this process: Andere Werkvormen (free translated: other working method).

We as managing directors were completely aware and conscious of the deep intervention of this change in management style and the influence on the functioning of almost everybody in the yard.

The most important aspects of this approach are:
     as less organisational levels as possible in the organization
     delegation of responsibilities to the lowest possible level in the organization
     forming of production groups responsible for all aspects of the work that has to be carried out by the group
     bringing into the group all activities of importance to perform the given task
     more than one professional discipline in the group
     increased communication between departments not only horizontal but also vertical

The organization based on above mentioned aspects is realised and operational since 1987.
On the organization chart (encl. 2 and 3) you see the difference between the old and the new organization.
Into the group are brought together several- professional disciplines including some detailed management disciplines (encl. 4, 5 and 6).
A few examples:
A group in the ships section assembly.
The ship section assembly consists of steel assembly, welding, grinding etc.
The group members- execute all the activities for assembly of ship sections, fabrication assembly, welding, grinding, mounting of piping, units, cable trays etc.
Also the group is given the opportunity to determine the working methods in building these ship sections and to make a detailed planning.
The group is also responsible for the quality of the final ship section.

If quality is not according to specification and the 'next step is assembly of ship sections on the slipway, the employees at the slipway having problems, address their problems to the group responsible for assembly of the ship sections.
In the group the ironworkers also weld and grind and welders do assembly work or grind etc.

Another example is a group that has the responsibility for outfitting a pumproom.
The group consists of the next professions: pipefitters, welders, mechanical fitters, structural fitters, who, after discussion with each other based on rough planning and ,working methods, determine their working method and they also have the task to discuss with subcontractors to fit them in their activities.
Also in these groups fitters do weldingwork or the other way around.
The work of the groups are coordinated by a group coordinator.
In many cases these group coordinators circulate, for project A mr. X and for project B mister Y.

Also in the drawing office the organization set up is based on products/orders (encl. 7 and 8)
There is no mechanical drawing office and no shipbuilding drawing office.
In the drawing office only a few people have a fixed desk.
Depending on the work, groups of different disciplines are formed and located in such a way that they are in each others vicinity.
The coordination as a result of this type of organization set-up is considerably improved and almost optimal.

Because of the fact that information necessary for the production based on this new organization set-up can not be too detailed the amount of paperwork is decreased significantly as well as the number of employees in these offices.
In other words less indirect employees as the production does not need detailed planning.

Maybe you think, this can not be completely true, this is too nice and this can not be arranged just like that.
Also it probably is a bunch of discussion groups and no working groups.

To start with the last remark, this is not the case at all.
Shipbuilders do not like to talk much, are very practical and our experience learns-us that discussions every now and then about the backgrounds, about things happening in the company, about the work situation etc. cost less time than to correct the situations where information was not available or not sufficient.

Indeed it was not easy to change the organization in the way as it is nowadays:
        Before implementation we made a very well detailed scenario what
        to do.

Our employees were informed as good as possible.
We discussed as much as possible the alterations with our employees.
A very important part of this change in management style and working together is schooling.
Approximately 80% of our production employees are capable to perform another profession.
Approximately 40% followed an internal course in elementary knowledge of planning, work preparation, organization etc.
Approximately 15% followed an internal course about elementary aspects in how a company is managed.
That means financial, economical and organizational matters and also how orders are handled (calculations, planning, work preparation etc.).

This approach appeared possible and indeed it is remarkable that the majority of our employees do a lot more than thought and are willing to bear more responsibility, are capable to work in this environment and are motivated, having more knowledge what is going on in the company.
Because of that there is more understanding nowadays among each other and between departments in a horizontal as well as vertical way and the communication improved.

About the remark: 'this is too good to be true, such a happy family.
Of course it is not so beautiful or complete yet.
In 1985 we allowed ourselves time till 1990.
Now in 1992 we are even not half way of what we wanted to achieve.
Not all groups work as described in this lecture.
Not every employee is completely convinced of this way of working together.
Every two steps forward means one step backwards.

But what we have achieved is very important:
the organization is formed in conformity what I showed you
the organization works, according to what I told you, despite a lot of limitations
an important part of our employees is indeed capable to cope with the delegated responsibilities.
the motivation has improved.
the 'pikorde' has gone.
multi-skill working has been improved and is not any more an item to discuss
and last but not least there is a major increase in productivity and costs are brought back to a level belonging to a yard that specialised itself in a certain market segment (enclosure 9).

FOR IHC HOLLAND THE POINT OF NO RETURN IS PASSED

Our employees do not accept any more that management tells them in detail what to do.
Cur employees do not accept the hierarchical situation as before.

We are very pleased notwithstanding that what we want to achieve is still far away.
Is it chaos, is everybody doing what he likes to do?
Quite the contrary.
Motivated employees and involved employees do not waist their time, so playing policeman as before is not the case any more which is of great importance for management.

One of the most difficult aspects of this other way of working has been the cut off of some hierarchic levels like foreman etc.
I have to confess that this operation has been a little easier because of changing the company to a lower level because of the shipbuilding crisis in the seventies and eighties.

But even nowadays there is a lot of attention necessary from our managers to keep the proces of changing to a style of management as we implemented on the right path.
It is worth to give so many man-hours and attention in the interest of the employees of the company.

Finally:
Of course labour productivity is important, but if you allow me to remind you once again to the formula in relation to "production costs" meaning:

man-hours x man-hour tariff + materials and services + percentage general and sales costs

that general costs and sales costs are kept to a minimum (naturally!?)
that purchasing materials, components and services is done at the lowest possible price against good quality (naturally!?)
that the man-hour tariff consists mainly out of direct personnel costs, indirect personnel costs and maintenance costs
that man-hour tariff is highly related to the way the company is organized especially in relation to the number of indirect employees
that decreasing the number of man-hours by facilities, machines, mechanization, automatization, CAD/CAM is part of the normal aspects of policy of a yard and in fact not too difficult (naturally!?)
that people and the way they are organized the way they work together and the way they are motivated are very, very important (naturally!?)

Means that only an integral approach of "means" and "mean" leads the company to the lowest possible 'production costs', of which decreasing the amount of man-hours per unit as part of decreasing labour productivity is less important not taking into consideration the "self-evident" aspects.

So my statement: "Labour productivity is less important than one thinks' has quite a bit of truth.

Do not think we are a bunch of sociologists.

For managing directors it is important for the existence of a company that the company makes profit.

Therefore you have to invest in means and in people.

Do not forget to invest in "people".

We IHC Holland do.

IHC HOLLAND NV

9 %

31 %

60 %
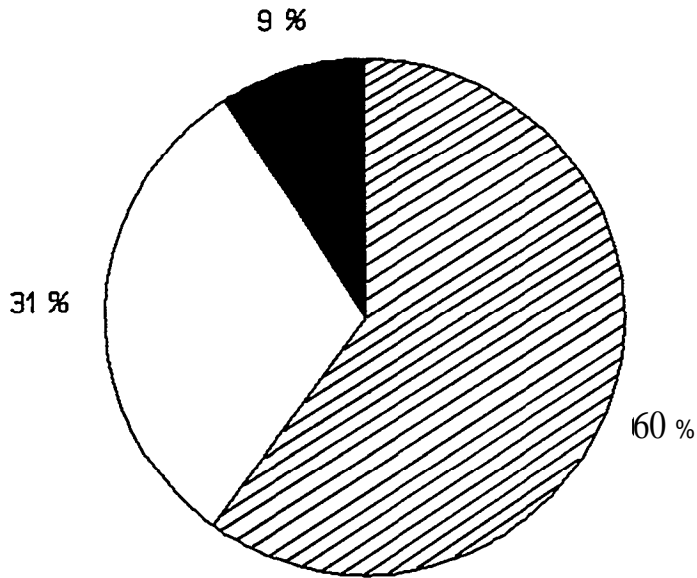
**YARD ORGANIZED FOR
BUILDING OF
"SPECIAL SHIPS"**

4 %

43 %

53 %
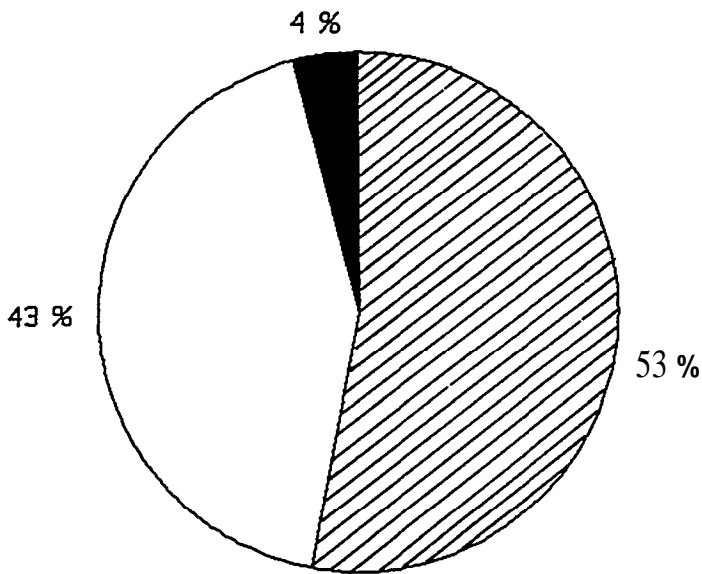
**YARD ORGANIZED FOR
BUILDING OF
"LESS COMPLICATED SHIPS"
(PRODUCTION FACILITY)**

7 %

38 %

5
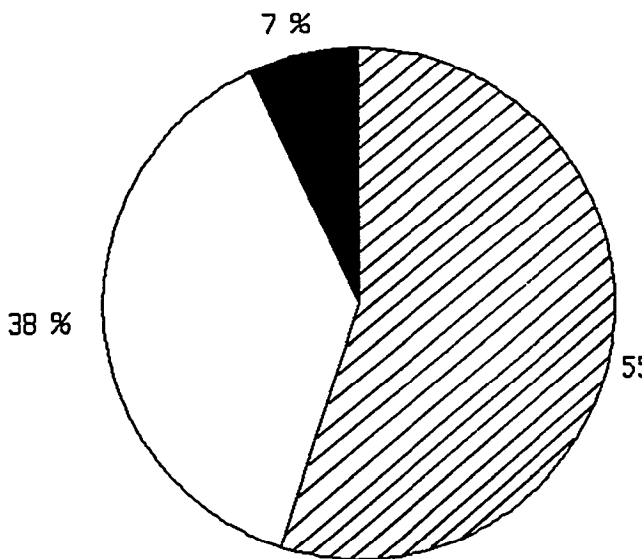
**MIX OF
"SPECIALIZED" AND "PRODUCTION"
YARD**

MATERIALS, COMPONENTS
SERVICES

GENERAL COSTS, SALES COST

PRODUCTION COSTS

IHC HOLLAND NV

(FORMER   ORGANIZATION   STRUCTURE)

```
                        ┌─────────────────┐
                        │   MANAGING      │
                        │   DIRECTOR      │
                        └─────────────────┘
                                 │
                   ┌─────────────────────────────┐
                   │   GENERAL MANAGER           │
                   │   PRODUCTION DEPARTMENT      │
                   └─────────────────────────────┘
                                 │
       ┌─────────────────────────┼─────────────────────────────┐
       │                         │                             │
┌──────────────┐                 │              ┌──────────────────────────┐
│ SECRETARIAT  │                 │              │ WORK PREPERATION         │
│              │                 │              │ PLANNING "A"             │
└──────────────┘                 │              └──────────────────────────┘
                                 │
          ┌──────────────────────┴───────────────────────────┐
          │                                                  │
   ┌──────────────┐                                  ┌──────────────────┐
   │ MANAGER      │                                  │ MANAGER          │
   │ SHIP         │                                  │ SHIPBUILDING     │
   │ BUILDING     │                                  │ MECHANICAL       │
   └──────────────┘                                  └──────────────────┘
```

| WORK PREP. CUTTING MAT.HANDL. | SHIPS SECTION IRONWORK | SHIPS SECTION WELDING | SLIPWAY FITTERS | SLIPWAY WELDERS | | FITTERS | CARPENTERS | MACHINING |
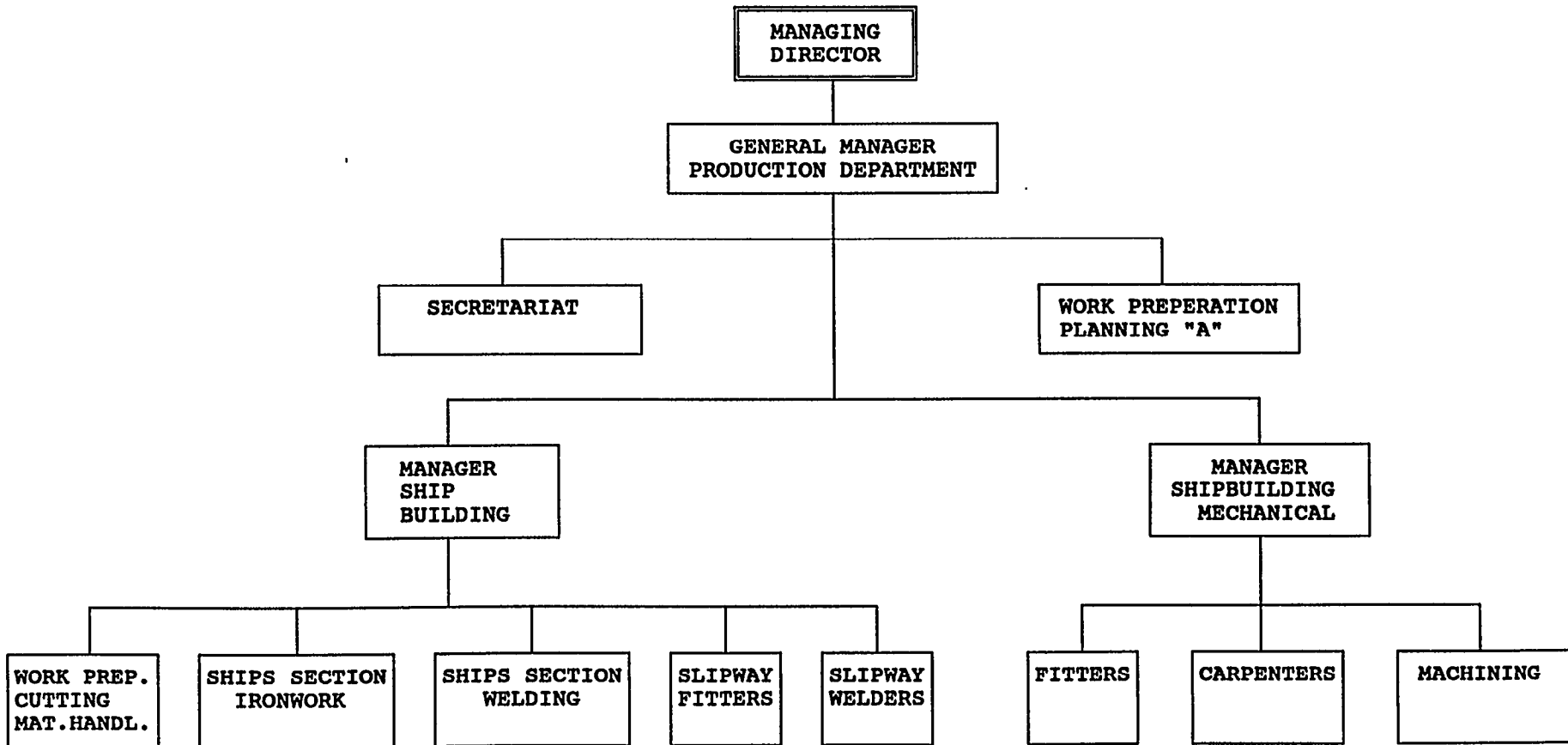
FUNCTIONAL   STRUCTURE
"PRODUCTION"

IHC HOLLAND NV

(PRESENT ORGANIZATION STRUCTURE)

```
                          ┌─────────────────┐
                          │    MANAGING     │
                          │    DIRECTOR     │
                          └────────┬────────┘
                                   │
                          ┌────────┴──────────────┐
                          │   GENERAL MANAGER     │
                          │ PRODUCTION DEPARTMENT  │
                          └────────┬──────────────┘
                                   │
         ┌─────────────────┐       │       ┌──────────────────┐
         │   SECRETARIAT   ├───────┼───────┤ WORK PREPARATION  │
         └─────────────────┘       │       │     PLANNING      │
                                   │       └──────────────────┘
```

| MANAGER | MANAGER | MANAGER |

| PREPERATION ING RIAL HANDL. TRANSPORT. | THIN PLATE SHOP | MECHANICAL WORKS | CARPENTERS | PANEL FLOWLINE | BEAVER BUILDING HALL | SHIP BUILDING HALL |

- Productiongroup
) Profile/plate Cutting

- Productiongroup
) Plate/profile bending machine

-) Internal Transport

(I)(II) Productiongroup

(III) Productiongroup

(IV) Productiongroup

(I) Productiongroup

(II) Productiongroup

(III) Productiongroup

(IV) Several Treatments

Carpenters

(I) Productiongroup

(I) Productiongroup B250 - B1000

(II) Productiongroup B1500

(III) Productiongroup B3300

(IV) Productiongroup Custom Built

(I) Productiongroup Ships Section Building

(II) Productiongroup Ships Assembly

(III) Productiongroup Ships Outfitting

PRODUCT STRUCTURE "PRODUCTION"

IHC HOLLAND NV

FORMER ORGANIZATIONAL
STRUCTURE

PRESENT ORGANIZATIONAL
STRUCTURE

IHC HOLLAND NV

IHC HOLLAND NV

THE NEW SITUATION IN HER MOST SIMPLE SCHEMATIC FORM

DEPARTMENT
IRONWORK

OUTPUT

DISTURBANCE

INPUT WORK PREP.

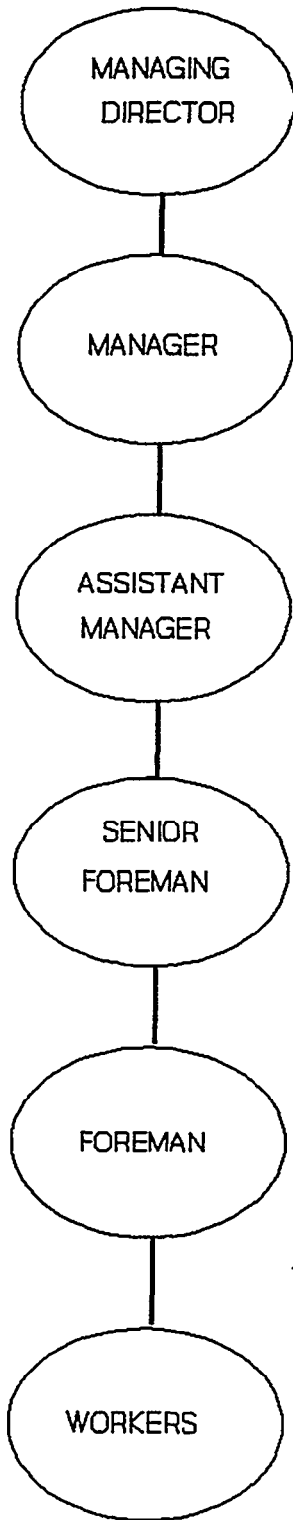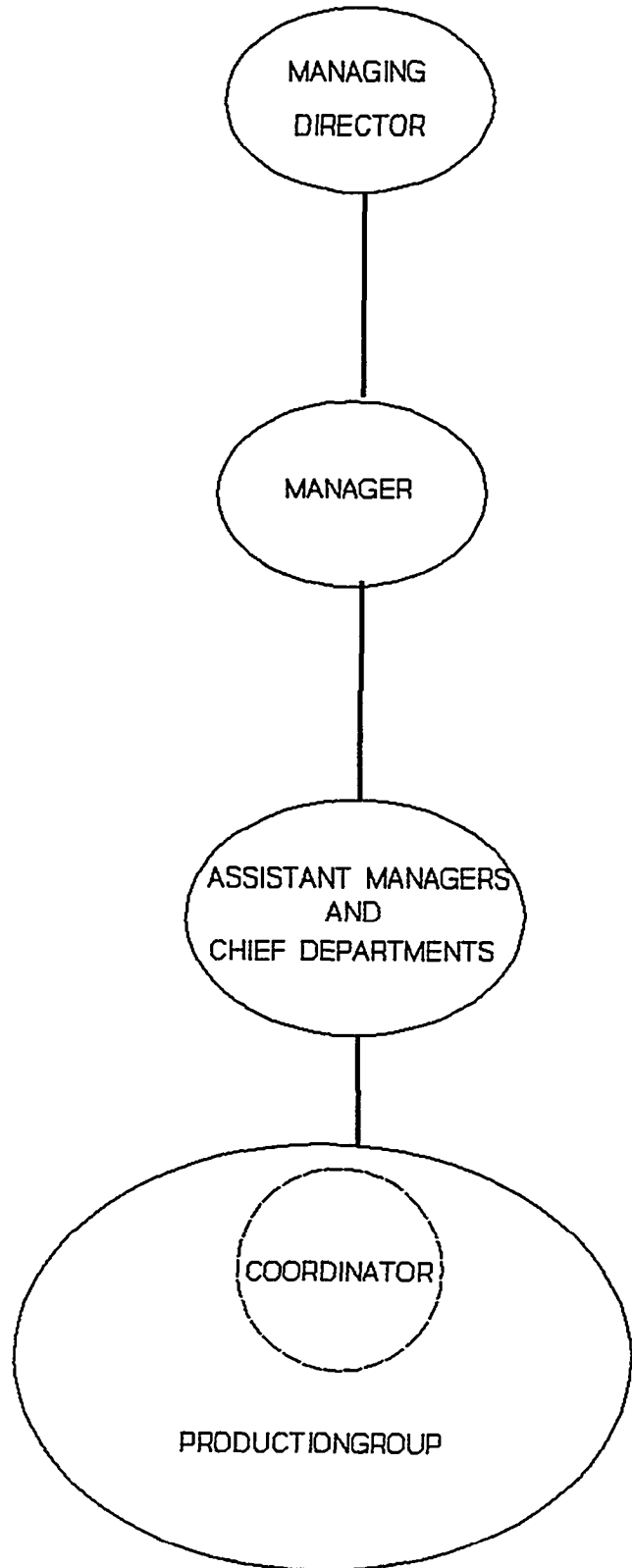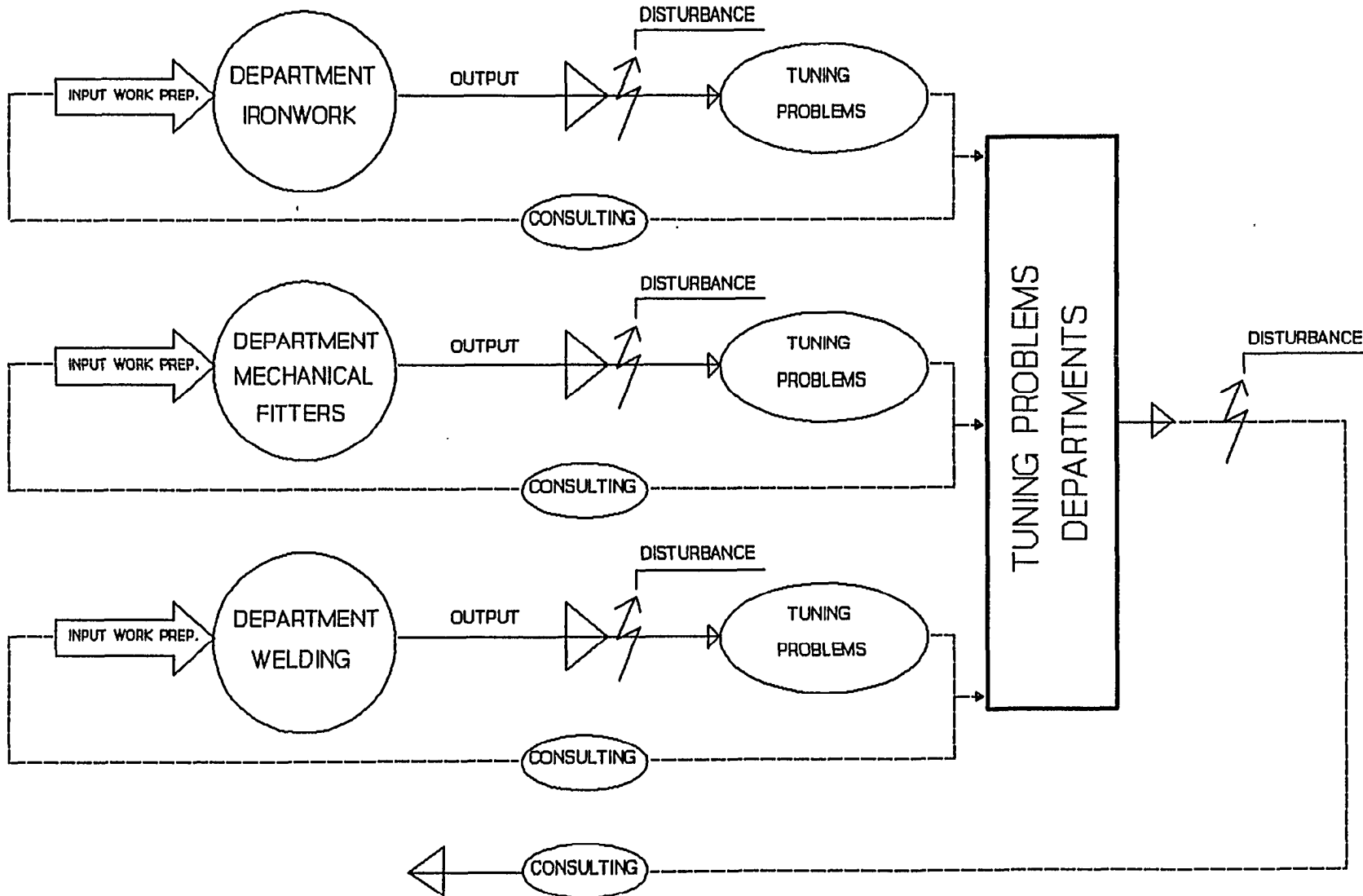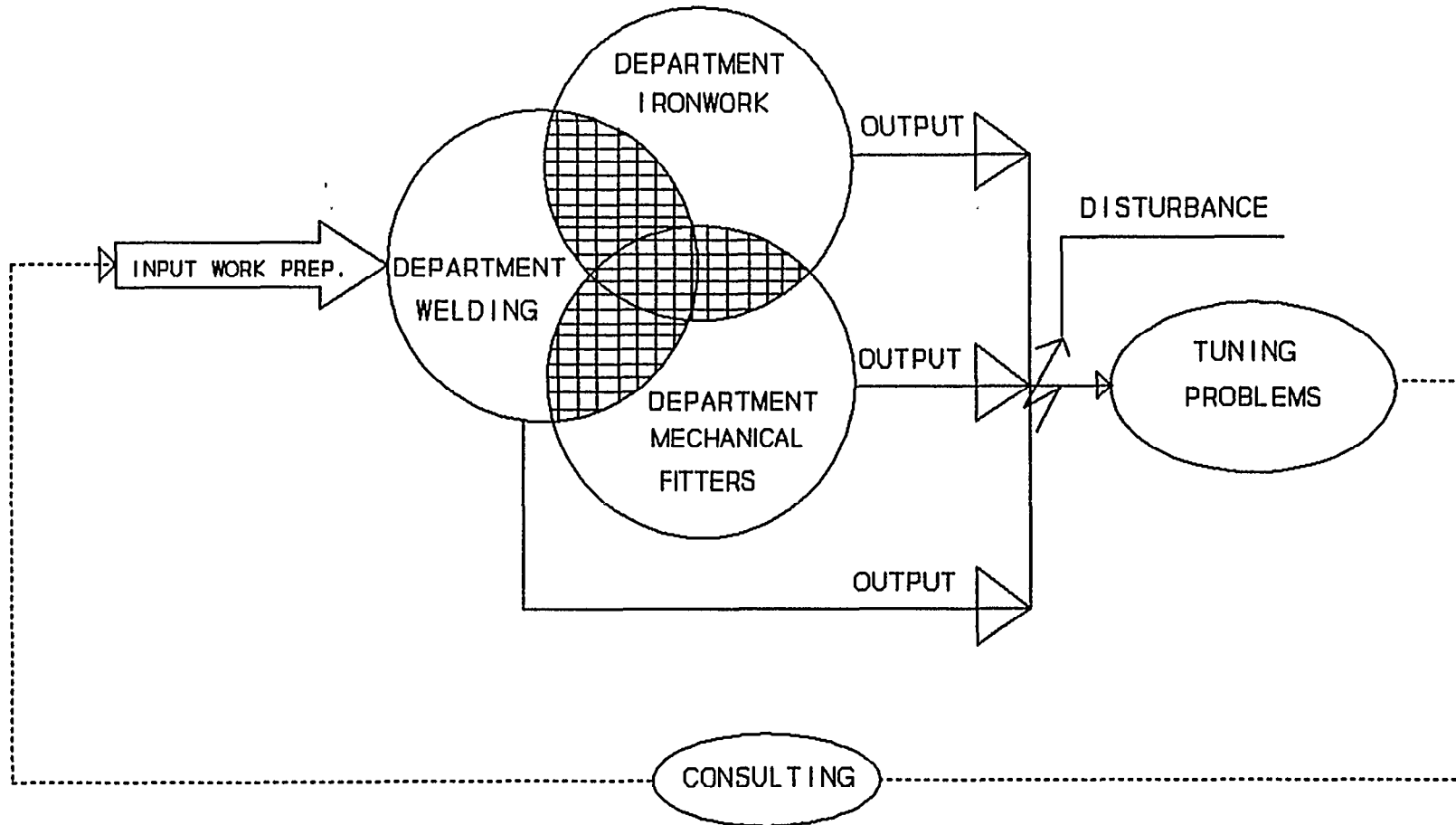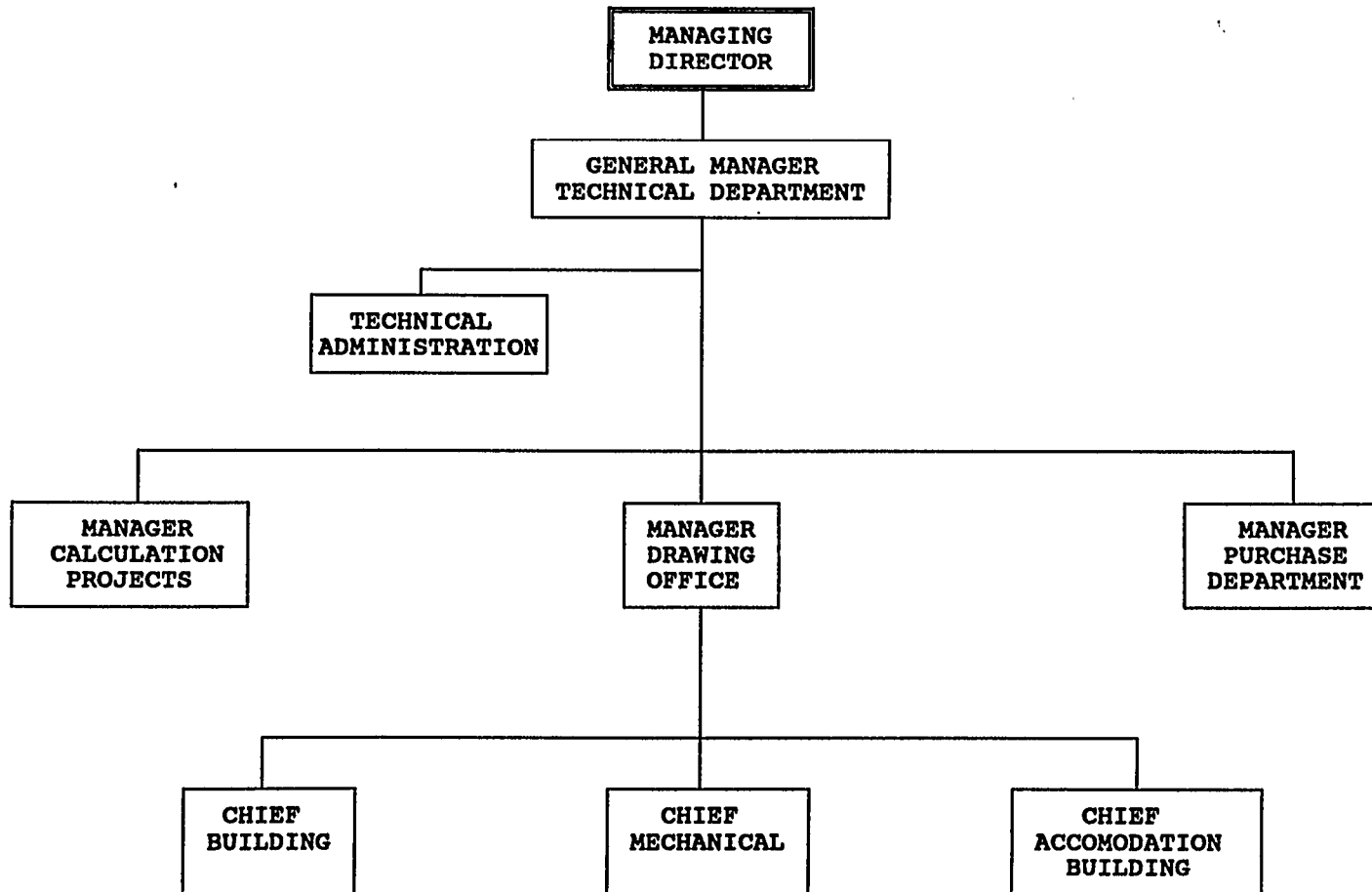DEPARTMENT
WELDING

OUTPUT

TUNING
PROBLEMS

DEPARTMENT
MECHANICAL
FITTERS

OUTPUT

CONSULTING
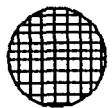
MULTI - SKILL ACTIVITIES

IHC HOLLAND NV

(FORMER ORGANIZATIONAL STRUCTURE)

```
                        ┌──────────────────┐
                        │    MANAGING      │
                        │    DIRECTOR      │
                        └──────────────────┘
                                 │
                   ┌──────────────────────────────┐
                   │      GENERAL MANAGER         │
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   │ CALCULATION  │      │   DRAWING    │      │   PURCHASE   │
   │  PROJECTS    │      │   OFFICE     │      │  DEPARTMENT  │
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FUNCTIONAL STRUCTURE
" T E C H N I C S "

IHC HOLLAND NV

(PRESENT ORGANIZATIONAL STRUCTURE)

```
                      ┌─────────────────┐
                      │    MANAGING     │
                      │    DIRECTOR     │
                      └────────┬────────┘
                               │
                   ┌───────────┴───────────┐
                   │    GENERAL MANAGER     │
                   │ TECHNICAL DEPARTMENT   │
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 │CUSTOM BUILT│ │CUSTOM BUILT │ │ STANDARD │
 │ PROJECT A  │ │ PROJECT B   │ │ PRODUCT  │
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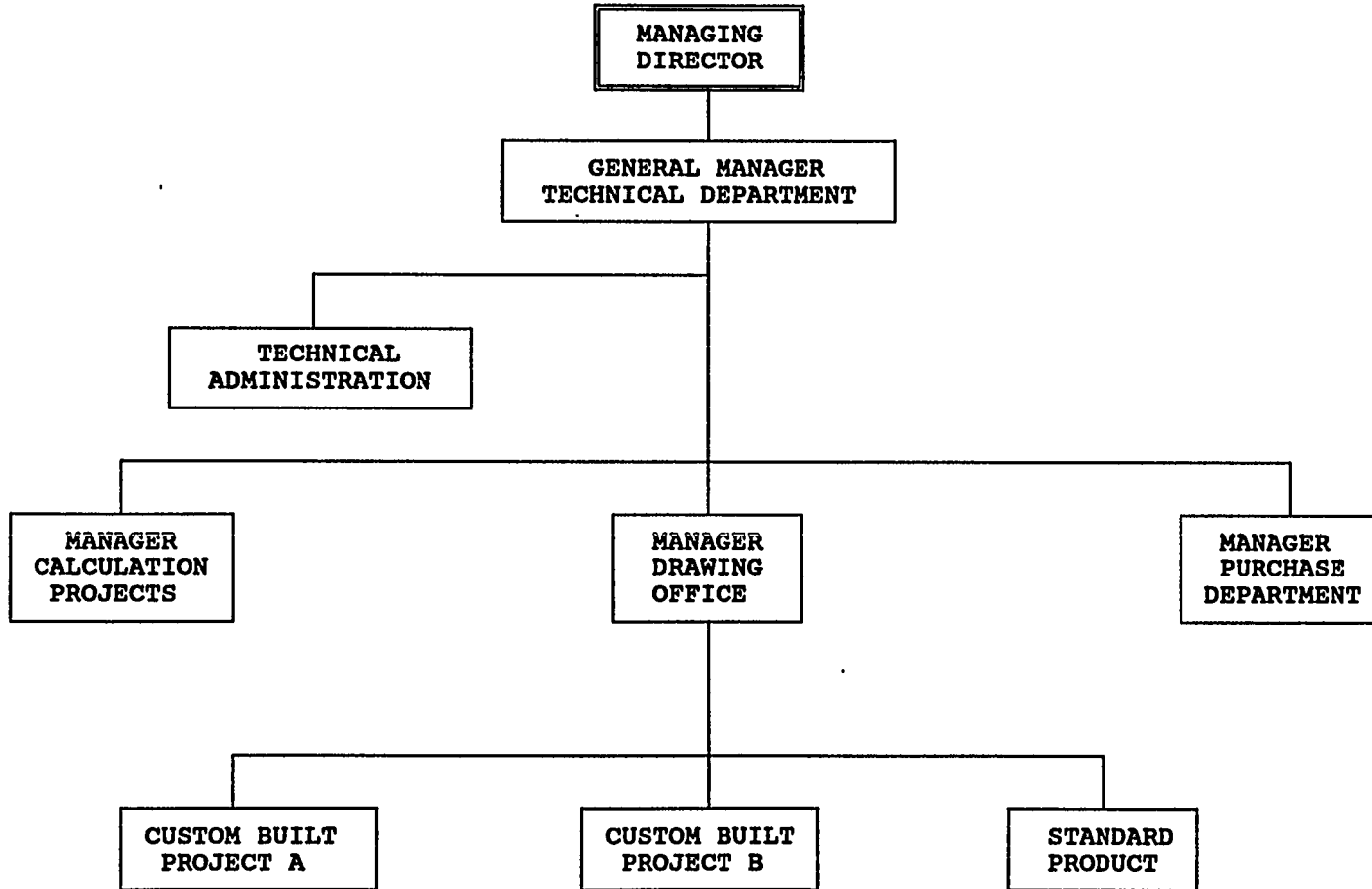
PRODUCT   STRUCTURE
"TECHNICS"

IHC HOLLAND NV

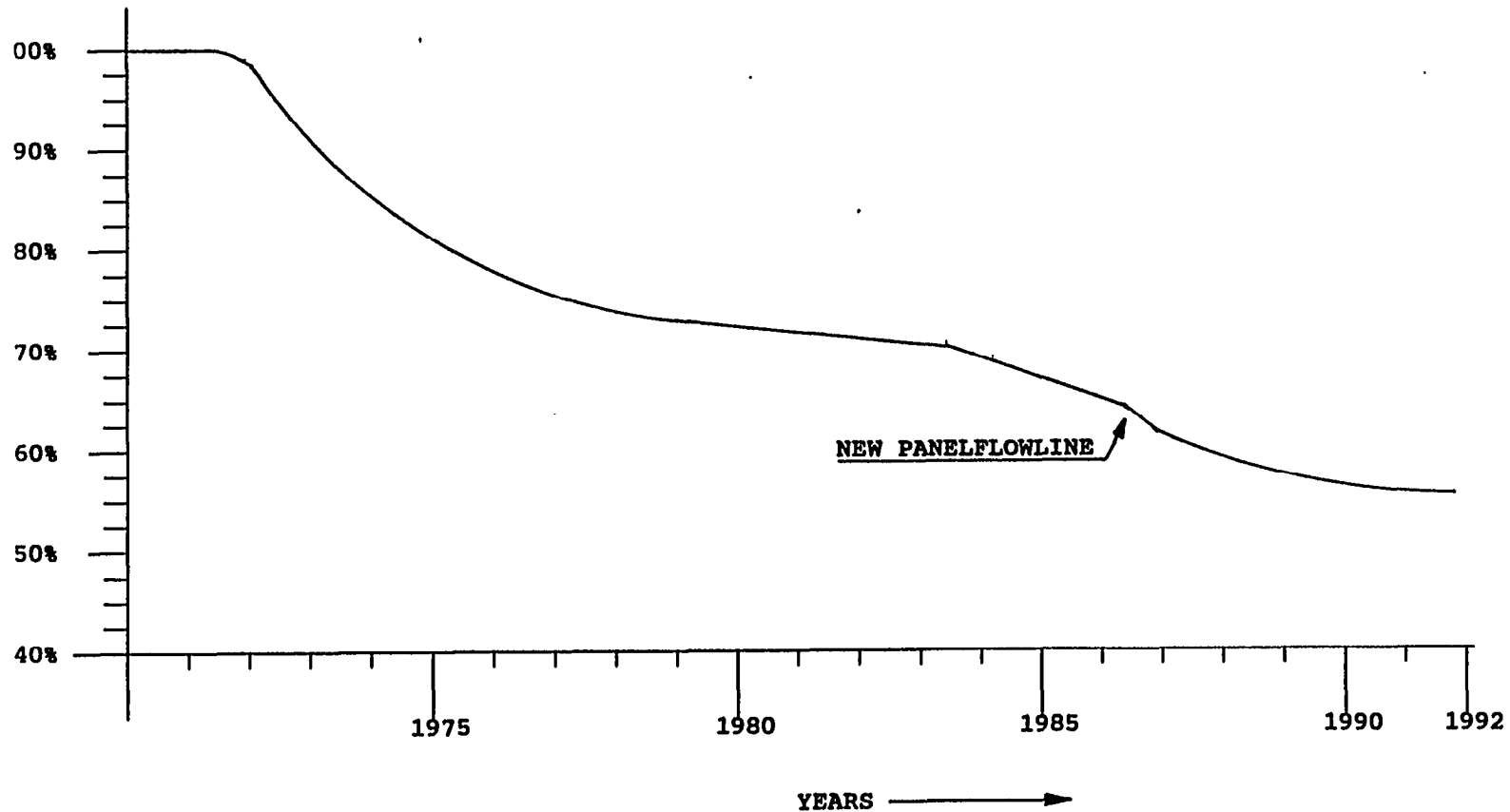## PERIODS OF IMPROVEMENTS DUE TO:

ACILITIES :
CUTTING
ED SLIPWAY
HIP SECTION
BLY

| NEW FACILITIES | PREFAB UNITS, PRE-OUTFIT | 'ANDERE WERKVORMEN' MAINLY MULTI-SKILL | 'ANDERE WERKVORMEN' MAINLY ORGANIZATION OF GROUPS ETC. |

NEW PANELFLOWLINE

00%
90%
80%
70%
60%
50%
40%

1975   1980   1985   1990 1992

YEARS ⟶

EXAMPLES FROM THE AUTOMOTIVE INDUSTRY FOR SHIP PRODUCTION

Ir. R.W.F. Kortenhorst
managing director, Consultancy Centrum Groningen B.V.

<u>Summary</u>

Many western industries suffer severe competition from their
far east collegues. The being so competative of far east
companies is oftenly caused by their way to manage their
industrial processes.
That is why many western industries have tried to implement
the management principles of the far east in their own
companies: 'If these principles prove succesful over there,
why shouldn't they over here ?'
Unfortunately these attempts of tenly didn't bring the
improvements expected. An oftenly used explanation for this
failure is: 'their culture is different....'

In the recent years many far east industries start companies
succesfully in the western world. Western people are
employed in these companies. Especially the automotive
industry can show many succesful examples.

Why can people, workers and managers with a 'western'
culture; be more succesful in companies set up by far east
managers ?
In this paper an analysis is presented on how Japanese/ far
east managers recognize the difference of culture between
 'western' and 'far east' people as the basis for choosing a
management approach.
This analysis is based on experiences with Japanese car-
manufacturers in western-Europe. The analysis is
 'constructed' by making use of a conceptual model of the
phenomeon 'project'.

As shipbuilding-is a profession of projectmanagement, the
author, who has been a shipyard-manager, uses the analysis
to derive some conclusions for projectmanagement in ship
production.

EXAMPLES FROM THE AUTOMOTIVE INDUSTRY FOR SHIP PRODUCTION

Ir R.W.F. Kortenhorst
managing director, Consultancy Centrum Groningen B.V.

0. Introduction

0.1 The far east cultures: better for industry than the western?

Industries like the automotive, the optical/ photography,
the electronic and the shipbuilding can hardly be compared
to eachother.
Yet, in the western world, one thing can be mentioned as
very comparable for each of them: all these industrie suffer
a severe competition from their far east colleques.
In quality, industrial performance and in keeping their
technology up to date, the winners are nowadays mostly found
in the far east areas.

Industries in the West, of course, didn't keep passive. Many
study-tours have been organized, and many consultants have
earned lots off money while dealing with the magic question
 'How do they do it that good ?'
Lots of 'eastern' business sciences and management tools
have been introduced into the western industries, many
experiments took place. Unfortunately they did not yet
result in again our companies becoming the world's most
modern and most competative ones.
An oftenly heared explanation for this failure to introduce
here the far east 'business tools' is that 'their culture is
different'. If you listen to many western managers, they
oftenly explain the far east success-story as being a result
of a culture that:
 - is typically suited for performing well in industrial
   activities and developments
 - unfortunately is difficult to adapt by our West-European/
   American cultures.

0.2 West-European people: succesful in far east companies

In the industrial expansion of the Far East nowadays we see
that they start-up many industrial acitivities in the U.S.A.

and in West-Europe. Many examples can be given: Honda in the USA, FUJI in Tilburg the Netherlands, Mitsubishi now owning a one-third part in the former Dutch company 'Volvo-car', Hyundai opening companies in Europe, and last but not least: Nissan Motors United Kingdom (NMUK).

If the exaplanations given by the West-European and American managers are right, these new companies can't get as successfull as their far east mother-companies. In our world these companies will deal with our people, having our culture and not theirs.
Yet, what we see is nothing else than.....success.

Let us focus on NMUK: the company that launched the new NISSAN PRIMERA as 'a new European Car'. A company located in an area where only a few years before the largest tragedies took place that was ever seen in the automotive industrie. And a company working with the same British people as did the former British factories.
Yet a company that has really shown how 'success' in the European automotive industry looks alike.

The British in NMUK: did they become the far east minded people from the western world ? Did they dramatically change their own culture ?
No, these people still are as British as British can be. They haven't been brainwashed, and they haven't been selected by the fer east managers on their talents in taking over other cultures.

The thing is: the Japanese managers recognized and accepted the strengths and the weaknesses of the Western culture, and adapted their management system accordingly. This, instead of trying to change Westerns into Easterns.

After having worked in the shipbuilding industry, during some recent years the author has worked in various management positions in the automotive industry. In closely cooperating with far east carbuilders he was teached how far east car companies deal with projects in the 'Euro/ Asian' automotive industry in an effective way.

In this paper we herefrom try to derive some lessons for our own industry: ship engineering and ship production.

This paper therefore will cover the following subjects:
1. A conceptual model on 'projects'.
2. Some comparison between various ways of project

management, and amongst them: the way Japanese companies deal with projects that have to be carried out in a West-European cultural setting

3. What can the shipbuilding industry learn from this ?

1. A conceptual characterization of projects

1.1 Why 'projects' as the backbone of this paper ?

If we analyse the process of shipbuilding industry we recognize two main items:
- the processing of steel: from pre-processing of plates and profiles, until processes as welding, section manipulation etc.
- the process of controlling a project, starting from initial engineering, ending with the commisioning and delivery of a complete ship.

The first item, in many aspects, can be bought: equipment that improve productivity like CNC-cutting machines, modern welding equipment, panel lines etc. are available from many professional suppliers.
The second item however cannot be bought: it concerns mainly a management task, a way of approaching the profession.

This last item contains lots of potential 'winning' or 'loosing'.
It is the projectmanagement that defines the projects' lead time. It is the project- (and engineering-) management that enables a manhour saving pre-outfitting of sections. It is proper project-management that enables a yard to foresee production problems and, by foreseeing, enables to prevent them.

It is our own practical shipyard experience that tells us that the majority of lead-time and manhours that is experienced as 'lost' and 'unnecessary' is caused by bad projectmanagement.
It is the projectmanagement where we feel that the biggest improvement in shipbuilding performance can be gained.
And, probably the most important thing: shipbuilding is nothing more and nothing less than dealing with projects. Projects in which a ship has to be developed and to be built within a limited time and a (mostly very....) limited budget. And in this job: it is projectmanagement that shows

how yard- and engineering- managers deal with their profession. This paper is written for these managers.

Therefore: we choose projectmanagement as the subject to illustrate the way far east companies implement succesful business-operations in a western culture. As an example for the shipbuilding industry.

## 1.2 Projects: the art of scheduling and controlling of decisions

Technical projects can be defined as an integrated process of:
 - getting through a huge amount of decisions to be taken.
 - doing a lot of engineering, purchasing and building actions.

And all this where:
 - many decisions are dependent on many others and on many of the actions to be done
 - it is mixed up in a way you oftenly don't know in advance.

In other words: while managing your project, a scope of uncertainty needs to be eliminated. Only during the final phases of your projects no questions should exist anymore. See also picture 1.
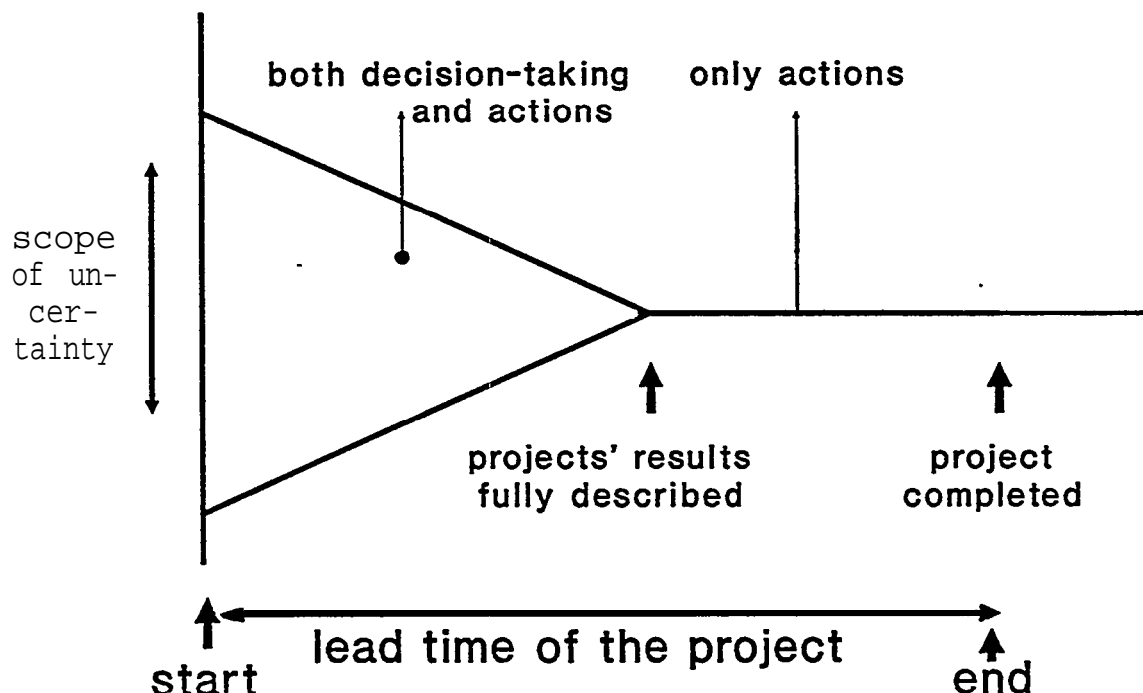
For example: a part of the engineering process of a ship.

hull construction:
a decision needs to be taken: longitudinal or transversal
framing. Then an action needs to be done: the drawing a
construction plan.
Then a decision needs to be taken on...... etc.

engine room installation:
a decision needs to be taken: propulsion system.
Then an action needs to be carried out: select main engine
alternatives.
A decision needs to de taken: what main engine will we
choose ?
An action needs to be carried out: further 'power train' to
be engineered.

hull construction and engine room installation meet each
other:
A decision needs to de taken: where and what kind of
fundations ?
An action needs to be carried out: further engineering to
be done.
Once this engineering is ready: a good basis is available
for many further decisions on the (detailed) engineroom lay-
out.

Dear reader: please notice how many times the one decision/
action is depending on the other decision/action !! (and
please notice as well that if the integration of all these
is not done right, that many corrective actions will be
necessary in later building phases !)

italics: decisions to be taken
underlined: actions to be carried out

framing system
hull construction plan

fundations/ steelconstruction
engine-room layout

engineering shaft, couplings etc.
engineering of main piping etc.

main engine make/type
select engine alternatives
position valves etc.
pricpiple design prop. system
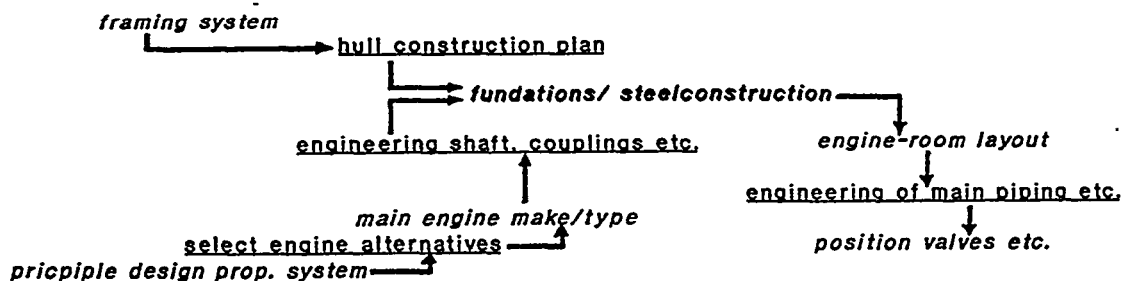
picture 2: interrelated decisions and actions

Watching this example a project can be defined as a scope of interrelated uncertainties that need to be eliminated in a logic consequence and order, and in a logic relationship with many actions that take place within the process. See also picture 2.

Taking into account the given 'model' of a project: what happens if the project is not being dealt with as is called up for in this model ?

First: something about the relation between costs and time in a project.
As we, shipbuilders, all know:
 - the fitting of a roof-mounted ventilation duct against a deck that forms part of a deck-section laying upside down is much cheaper (or: gives the yard-manager more profits...) than fitting it somewhere far away in a ship laying at the outfitting quay.
 - the changing of the position of, for example, a ventilation duct in an engine-room is much cheaper to carry out on the drawing board than on board of the actual ship.
So: what will a 'cost-thinking engineer' do: try to engineer the duct in such way that:
 - he is early enough to enable the yard to fit it into the deck-section
 - he is co-ordinatinu carefully his 'own' engineering with the engineering of other components that might require dramatic changes of the duct once fitted.
For the, engineer (and for his collegues !!!, and for the entire organisation !!!) this requires careful scheduling and a reliable co-ordination and co-operation.

Generally spoken: the engineer, and the organization in which he works, take into account two important 'laws' in project-management:
1. deciding too late means oftenly: deciding too expensive
2. deciding early requires utmost respect to the interrelationsship that exists between all the decisions to be made.
   This means for the engineering management: careful identifying and scheduling the decision process !!

Let's go back now to the project-model as we discussed earlier.

Each decision, like the engineers decision above, can be
seen as a mini-version of the model given in picture 1.: you
eliminate an uncertainty and after that you carry out your
action. In many cases the result of this actions forms the
input for a new decision.
By thinking like that, you can see the entire project as a
structure of interrelated decisions. See picture 3., and for
a detail of this structure: picture 4.
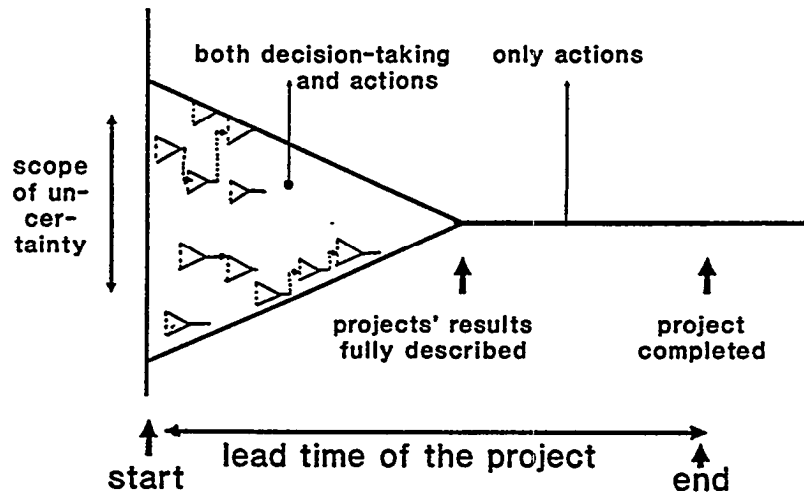

picture 3: interrelated actions/ decisions
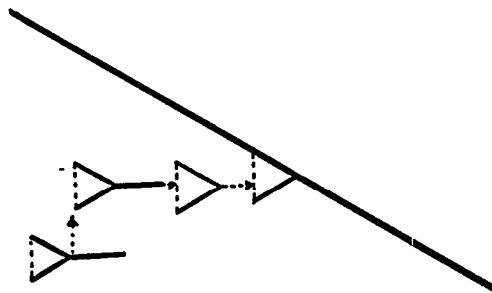
picture 4: detail from picture 3

What actually happens if:
- you decide too late ?
- you decide un-coordinated and thereby causing yourself or
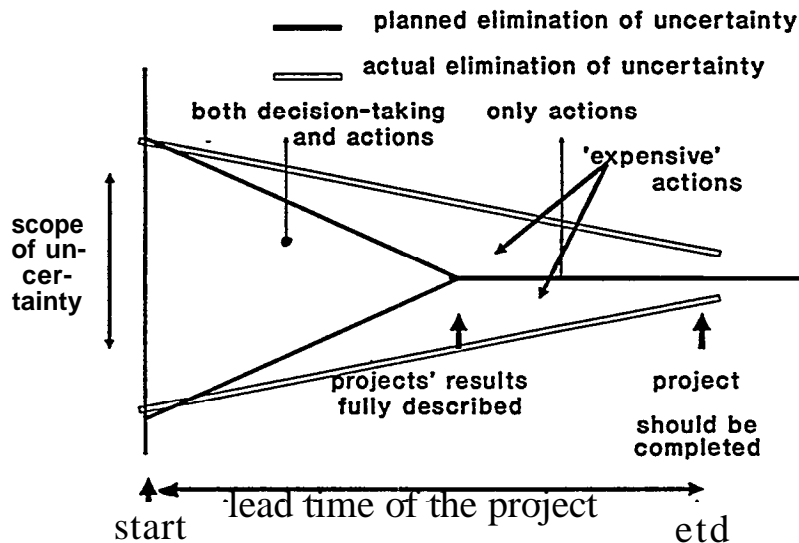 other people to do their work again ?

In these cases you make the scope of uncertainty exist
longer. You cause that many decisions need to be taken in a
later stage.
Within our model this is shown in detail in picture 5.

realised reduction of uncertainty

planned reduction of uncertainty
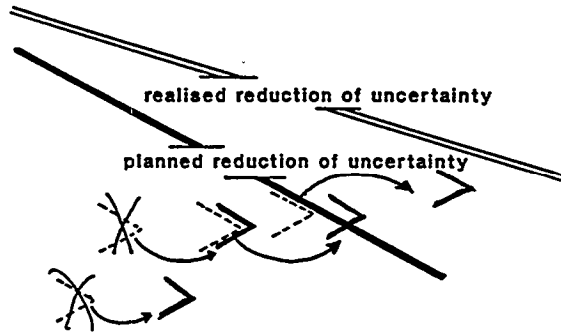
picture 5: delayed decisions.....

Have you, operating shipbuilders, ever had sea-trials that
took place while some problems still required a solution ?
(Thus: while some uncertainties still existed ?) In terms of
our model: have you ever been in a situation as shown in
picture 6 ?

planned elimination of uncertainty

actual elimination of uncertainty

both decision-taking   only actions
and actions

'expensive'
actions

scope
of un-
cer-
tainty

projects' results
fully described

project

should be
completed

lead time of the project

start   etd

As was illustrated in the example of the duct pipe: in many cases the action resulting from a decision may become more expensive is the decision is taken too late !! This means that the decisions that are taken within the areas, indicated in picture 6 as 'expensive areas', cause actions that are more expensive than necessary if decided earlier.

Some conclusions can de drawn:
- a project is a complex of decisions and actions that have an intense interrelationship
- During the start of a project this interrelationsship isn't totally clear. The identification of this interrelated structure needs to be carried out as a separate action.
- Showing respect to this structure in managing the project engineering, in close co-ordination with all the other project actions, may result in a effective project realisation.
- Denying this structure however, will result in many under-optimal operations and may require the need of many expensive corrective actions.

2. Some ways to manage projects

In the following some different ways to manage projects will be discussed. These different kinds of project management will be illustrated by the conceptual model as was developed in the previous chapter.

2.1 The Japanese/far east way to manage projects

What do we see if we look to the way that projects are managed in Japanese organisations ?

The first thing that is done is making up very detailed project break-downs. These break-downs form the basis for elaborating detailed project-schedules.
In doing all this, many modern project management techniques are used like network-planning, computer programmes for optimal allocation of man-power. In many cases the schedules will anticipate to the use of additional modern management techniques like, for example, 'simultaneous engineering'.

Especially when compared with the western way of preparing a project the Japanese involve many people in making these

break-downs and, after that, in working out the project schedules.

Japanese projectmanagers won't let a project start with the actual carrying out of the work before all these careful preparations are finished in good order. It is oftenly seen that, in comparable projects, the Japanese start the actual work later than their western collegues do.

In later phases the project will be carried out exactly according to schedules, which are of a high quality.
If, due to unforeseen circumstances, a delay is expected, the managers will pay a maximum effort to get back to original schedules.

This way of managing projects is applied very strictly: if schedules say that all design work is to be finished, absolutely no changes will be accepted anymore.
The result of this way of project management is well known: as was scheduled, a sure moment will be met that no uncertainties are left anymore, and only 'work' needs to be done. The projects will be realised in relative short lead time, and: according schedules.

Within the conceptual model as developed earlier, this way of realising projects looks like picture 7.
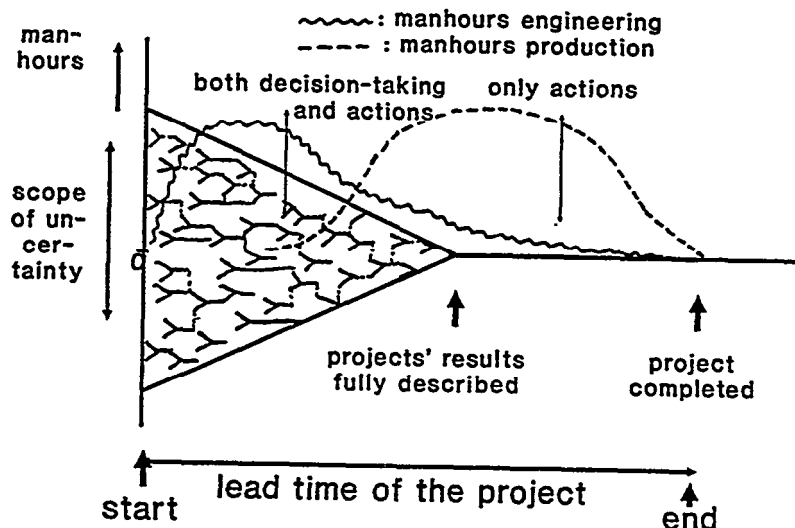
picture 7: Japanese managed project

2.2 The Western way to manage projects

In the (traditional) western way to manage projects, another appraoch can be recognized.

A very detailed project breakdown is not the first activity. The first actions the project leaders will focus on are:
 - identify the typical leadtime aspects, start them up,
 - identify the jobs that allow action soon, prepare them
   and start.
Of this approach many examples can be given. In the automotive the management is proud to have a first 'research centre prototype' running soon after the decision to develop a new type of car. In shipyards you had a reason to be proud if the first keel-plate was being laid only one month after order.
Generally spoken : the western organization focus on a quickstart of the actual work.

During the further course of the project much of the projectmanagement can't be characterized as a process of careful 'anticipated and scheduled actions'. Lots of the things to be done are indicated by the actual, physical progress of the project.
This consequently results in many decision to be taken in the later phases of the project. These late decisions oftenly result in an expensive way of carrying out the work. Especially during its later phases, this causes that the project is experienced as very difficult to control.
Then, of course, lots of manhours are being made that haven't been foreseen and scheduled.
A large amount of flexibility is required to realise the project not too much delayed from original schedules.

Happyly it is a typical strength of the western culture to be that flexible: in the latest phases of the projects the impossible is turned into the possible. And finally, when the project is ended we, western managers, are proud of presenting the project by speaching like:
  . . ..Especially taking into account the severe delays that were caused by some unforeseen difficulties, our company is proud of the flexibility that enabled us to deliver this project only four days later than originally scheduled.....'

Using our conceptual model of project management, a typical western project can be illustrated by picture 8.
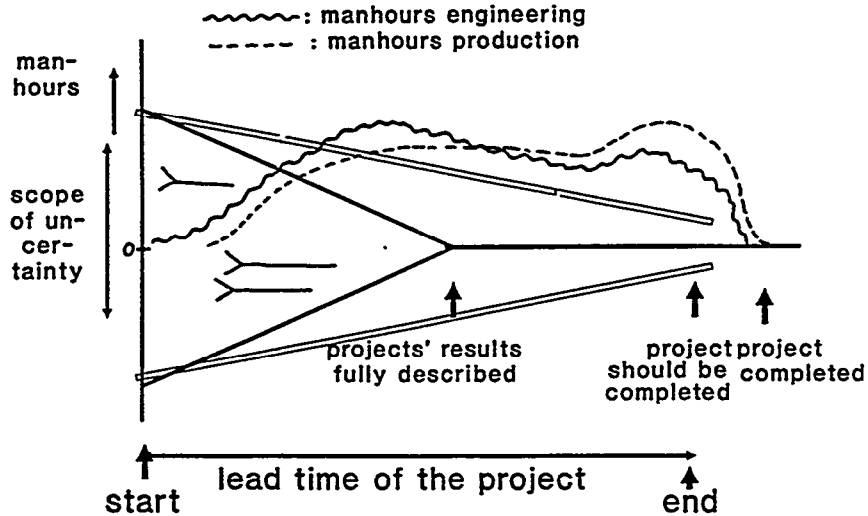
picture 8: western managed project

2.3 Westerns improving their project management....

Western managers, of course, experienced that the way of projectmanagement explained above, was far from optimal.
As a consequence, many organisations tried to improve their projectmanagement.
What actually did these organisation do ?
1. they introduced modern project management techniques as in common use in the far east industries. Techniques like network-planning, simultaneous engineering, project budget control etc.
2. they introduced programmes to improve the personal involvement of the individual employee.

The first thing was a clear question: if these techniques prove to be succesful over there, why shouldn't they over here ?

The second thing was a logic consequence of choosing for applying these techniques. It was obvious that these techniques require a lot of discipline of the people involved.
Discipline can be obtained by two alternative ways:
 - by force, law and order : 'If fou don't...., I will . . . . you'.
       (......- something very unkind to people)
   This approach won't work in the western culture.
 - by creating a high level of personal involvement. It is hoped
     that personal involvement will motivate the employee to show respect to the discipline, required to apply modern projectmanagement techniques succesfully.

What was the result of all this ?

1. Applying and understanding the 'new' management techniques as such wasn't too difficult, and was done properly according to the 'technical rules cases. (As a matter of fact: it is interresting to know that some of these techniques are typical western inventions)

2. These techniques however ~~did not~~ result in an improvement of the performance of dealing with projects in an optimal way:

   Why ? Even with highly motivated people the discipline, necessary to work with these techniques succesfully, was bound to come. So: after an enthousiast start-up many projects 'fell back' to the traditional way of project management: reacting in a flexible way to what the physical progress of the project tells you to do/ decide.

See also picture 9: 'far east' techniques in western organisations.
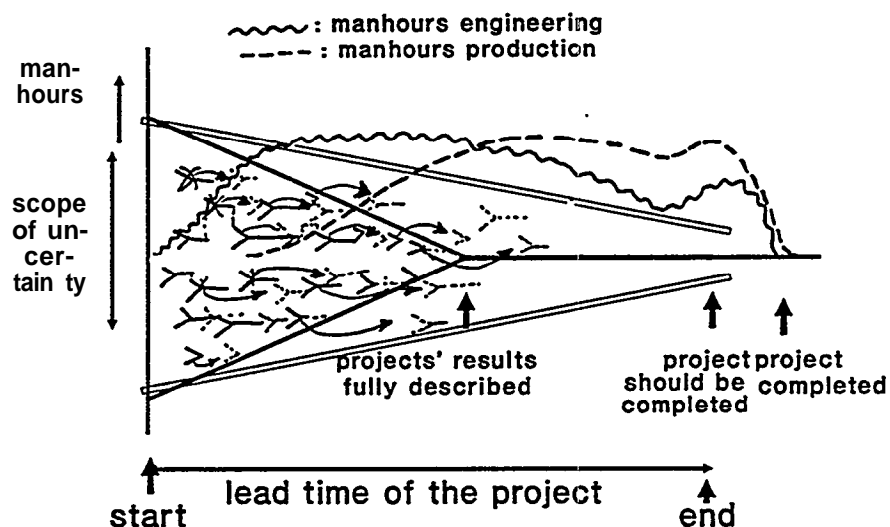

Picture 9: trying sophisticated techniques...

2.4 far east companies managing projects in western companies

Looking to the way far east companies manage projects in their western daughter-companies, four main elements can be recognized:

1. The main schedules within which the project will be carried out is developed extremely careful. In this work modern techniques of project scheduling are extensively used.

2. Based on these schedules, all the main decisions to be
   taken are identified. All the leadtimes of the various
   aspects of (preparations for) these decisions are
   identified as well.
   All this will result in a reliable schedule for taking
   the most important decisions in the project.
   Derived from that the most important milestones to be met
   are scheduled as well.
3. For the further the schedules aren't as tight and
   detailed as could be expected when reading chapter 2.1.
   The detailed scheduling of actions is a matter for the
   people who actually will carry out the work.
4. The main element in controlling the project;
   - is not the monitoring of the actual progress of the
     project activities, and carefully prescribing the
     people what to do in order to keep on meeting all the
     schedules,
   - but is keeping a maximum pressure on the organisation
     to meet the identified decisions and the identified
     milestones. It is left over to those who do the actual
     work to decide how they do that work. (This is
     different from what is described in chapter 2.1)
This way of project management is shown in picture 10.
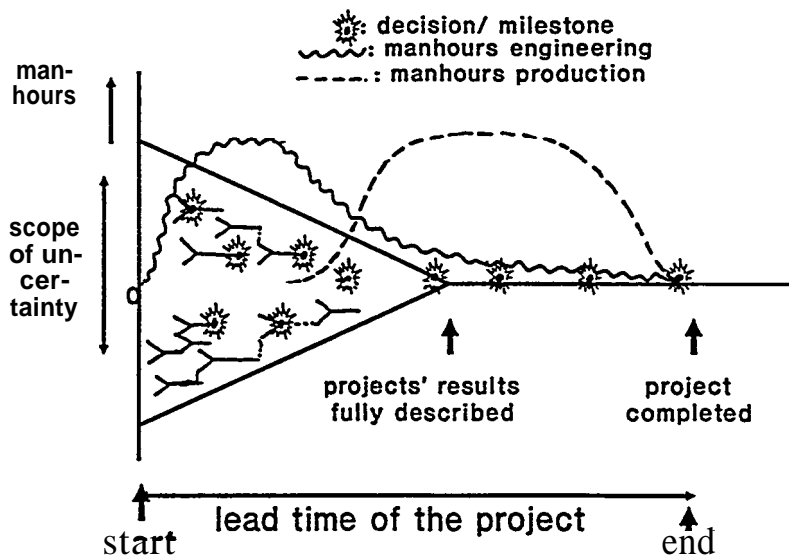
picture 10: 'milestone'-projestmanagement

How does this look alike in daily practice ?
 * a careful project-breakdown is executed. The interrelated
   decisions/ milestones are being consequently identified.
 * the scheduling is done by projectteams in which
   representatives of all operating departments take part.
   These representatives play an important role in
   determining feasible leadtimes involved.
 * All this will result in project plans in which clearly
   'phases' can be recognized, and in which clear
   milestones/ decisions to be taken (and all the
   preparations that MUST be ready by then) can be
   indicated.
 * These schedules form the boundaries within each operating
   department has to de their work.
 * To motivate the organisation to meet milestones/ decision
   moments: - management puts extreme effort in monitoring/
             putting people under pressure for meeting the
             milestones in a proper way. The daily progress
             of the actual work is a responsability for the
             people themselves.
           - sub-contractors' payment terms are intensively
             related to the meeting of the identified
             milestones and decisions. These payment-terms
             oftenly differ from what we traditionally see.

3. Some general conclusions

Comparing the above mentioned ways to manage projects,
especially considering their operational performance, some
conclusions can be drawn:

 - Tight and detailed scheduling, and consequently working
   in accordance to that, requires a kind of discipline that
   isn't the strongest point of the western culture.

 - Under condition that flexibility and the capability to
   work under pressure can be performed, working to meet
   milestones that can't be denied doesn't require a tight
   and detailed scheduling (people can do it 'their own
   way').
   This flexibility and the capability to work under
   pressure is a strong point of the western culture in
   comparison with the far east culture.

- If decision-moments and 'milestones' are choosen right, and are being met, a very important condition for properly realising a project is fulfilled.

- 'Far east project management' requires detailed scheduling, detailed prescribing people what to do and a detailed monitoring of progress within these instructions and schedules.

- 'Western' project management requires:
  * careful identification of milestones and decision-moments,
  * and keeping the people sharply focused on meeting these moments, without describing too much how they should do that.

4. An example for shipbuilding ?

4.1 Where to get the profits ?

Talking about modernisation of project management for the shipbuilding industry may very interesting, it has no sense if we don't choose our goals right. In this discussion the goal is very simple: how to get higher profits out of shipbuilding projects when thinking about projectmanagement ?

Taking into account the many discussions that take place about the shipbuilding process, the 'big profits' must be found in two aspects of shipbuilding:
1. Attainment of a high degree of pre-outfitting of ship sections, in combination of preparing the piping as much as possible under optimal production circumstances. (This means: if possible NOT somewhere in a corner of an engineroom)
2. Reduction of the leadtime of the assembly, final outfitting and commissioning process.

These discussions won't be repeated. In this paper we recognize them as the goal that ought to be set for succesful improvement of projectmanagemnent.

4.2 An example for the shipbuilding industry ?

An interesting question now is: how should the shipbuilding process, including its preparation, look alike is it was managed according to the example from the automotive industry, discussed in chapter 2.3 ?

Parts of this process will be the following actions:

1. A detailed break-down will be made of the <u>physical</u> location of all components and systems throughout the entire ship.
2. Of all components the necessary main actions will be identified; the most important interrelationships between these actions will be identified.
3. (Meanwhile) the ship is divided into sections.
4. Action '1.' and '3.' will be brought together: components and systems will be identified per ships' section.
5. Meanwhile rough timing schedules about the section building process will become available.
6. Pre-engineering- and pre-outfitting action-schedules can now be compiled, based on the section building schedules. Techniques like 'network-planning' may be of great help in this process.
   Considering the schedules for section building, 'milestones' and 'decisions to be taken' can be defined and scheduled. This will be done by extensive discussions in which all responsible people involved will join:
   * project manager
   * if possible: ship-owner representatives
   * heads of various engineering departments
   * representatives of class societies
   * head of purchasing departments
   * if possible: representatives of main sub-contractors
   * main responsible people of the production/ scheduling departments
   These discussions must end with <u>feasible</u> schedules of milestones that must be met by:
   - the commercial people in their discussions with the ship-owner about matters that they have to decide about.
   - the engineering people about the availability and sequence of their drawings
   - the purchase people about the quotations that must be available within time-frames, about the orders that must be realised within time-frames etc.
   - the suppliers (that will have their orders in time due to the above mentioned 'purchase-milestones'.....)

about when and what they will supply:
                              - drawings/ informations
                              - materials and equipment
  - etc. etc.
These schedules must be comparable with an internal
agreement: the discussions haven't ended succesfully when
there isn't agreement between all !!
For illustration: If the desire is fitting of the
steering gear, incluiding hydraulic pumps, into the aft
ship section,
the following decisions/ leadtimes must be passed:
  - (leadtime for) general decision of shipowner about
    type of gear.
  - (leadtime for) selection of supplier/ type of steering
    gear and of hydraulic equipment
  - leadtime for production and delivery of equipment
  - (leadtime for) class etc. approval of engineering
proposal
  - engineering of fundations
  - etc.
7. All these activities must be done <u>as early as possible</u>
   after the order has been signed. This requires firm
   management by the shipyards' managers: many of the people
   involved will be very busy with running projects !
8. Management of the further project will mainly consist of
   monitoring the meeting of the agreed milestones.
   - if possible the contract must contain phrases that
     limit the decision time-span for the shipowner
     concerning the questions the shipyard asks him.
   - during the project all milestones must be monitored
     and maintained strictly. This includes of course all
     the milestones in the engineering-, purchasing- and
     developing process !!
     If problems are foreseen, all action and all
     'management pressure' must have one goal only: no
     delay permitted !! In the case of inevitable delay:
     next milestone must be met according to schedules.
   - create incentives for the sub-contractors: fixed
     relations between milestones and payment terms,
     penalties related to 'their' milestones, etc.

4.3 Feasible ? Conclusions

Two arguments are oftenly heared when discussing this approach:
1. the shipbuilding process is too complex, and too undefinable to work according to the policy of 'common anticipation' as described above.
   In shipbuilding oftenly unforeseen difficulties appear that show the unpredictability of this process.
2. even if the process should be definable: technically/ geometrically a ship is too complex to be succesful in pre-engineering in detail of installations and piping systems in advance.

A reaction:
1. It is the authors opinion that the shibbuilding process isn't too difficult to define/ schedule in advance to create the basis of a well controllable project. Lots of the unforeseen problems that shipyards face during the building process aren't caused by unpredictability, but by a lack of careful scheduling and coordinating the engineering process. These problems concern matters like pipes running through each other, not enough space to fit the right ventilation ducts, hydraulic pipes to be fit on a wall that has allready been wainscotted completely etc. The actual problem is that the shipbuilding process, and especially its engineering process, isn't fully recognized as, and managed as, a project that requires intense coordination: in timing/ scheduling aspects and in geometrical/ technical aspects.

   The far east automotive industry (and in many aspects the offshore industry) show that in large projects many of these problems can be prevented by careful applying project-management in the engineering process.
2. It must be recognized that the geometrical arrangement of a ship and its installations is sometimes extremely complex and difficult to engineer in detail in advance.
   In this aspect the shipbuilding engineering process meets difficulties that hardly exist in, for example, engineering of buildings or tunnels.
   Two recent developments may however facilitate this:
   - application of a modular approach: define geometrical 'areas' and 'pipe/ duct/ cable lanes' that are reserved for specified systems; in these areas systems to be developed as much as 'hook in' modules fitted on a frame.

This approach requires, of course, intense coordination between many people when dimensioning and allocating the various 'areas' and 'lanes'.
- Computer systems, that enable to make a projection of complete piping systems into a ships' construction are nowadays available. An example is the system as now developed by 'Engineering Centrum Groningen b-v.', the Netherlands.

These systems allow extremely detailed engineering of all ships systems within the ships' structure in 3D. It is obvious that modification of a 8' pipe is much cheaper on the CAD-screen than in a ships' engineroom....

Some conclusions can be drawn:

1. The process of shipbuilding can perform much better if-it is recognized fully, especially in its pre-building phases, as a project that requires a projectmanagement approach.

2. In choosing a projectmanagement approach, you have to accept the people the way they are. Western people are different to far east people. Management approaches that are succesful in the far east won't be automatically succesful in the western world.

3. A projectmanagement approach requires that the project should be defined <u>in advance</u>, as a consequence of logic thinking by all people involved, instead of partially being a result of its own physical progress. Projectmanagement therefore requires a management choice: a choice to <u>invest</u> in an intense analysis of the process, as a basis (and an important condition !!) for defining and scheduling the milestones and decision through which the project will be realised.
All this concerns an effort in the start-up phase of a project that is new for many shipyards !

4. If this 'framework for project-control' is set-up properly, the shipyards' management possesses a reliable tool:
- that forms the basis for engineering and pre-production required for extensive pre-outfitting of sections
- to control the project, without interfering with the 'natural' way western people like to do their work: their own way.

Within this frame-work it is a ~~management task~~ to be very strict in not accepting delays and postponements.

5. The use of modern CAD-facilities, and the aplication of a 'modular' approach of engineering allows an additional high degree of pre-engineering, and hereby: of pre-outfitting.

THE ROLE OF GOVERNMENT IN MARINE SAFETY

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ABSTRACT

The role of government in marine safety has traditionally been viewed as one of regulator or oversight control. The understood purpose of such control being safety of life and protection of the environment. Today, however, labeling the government's role as one of regulator is a gross simplification. While it is true that the development and enforcement of safety rules constitutes part of a governments work in marine safety this paper shows how regulations are just one way in which it seeks to promote marine safety. The responsibility for marine safety lies with several parties. Vessel owners and operators, flag administrations, port states, classification societies, and insurers/underwriters all have a specific role and responsibilities which must be met. Regulations alone cannot assure that an adequate level of safety is maintained. The roles and responsibilities of the various involved parties can overlap and appear to be conflicting at times. Frequently, government must serve as a unifying link between the affected parties. Experience has shown that the promotion of mutual cooperation and the identification of commonly held goals is the best approach to use in accomplishing governmental mandates. From this, clearer delineation of responsibilities can be made. This paper outlines both the pragmatic duties of government and the less obvious responsibilities implied in carrying out these duties to their logical conclusions.

INTRODUCTION

In order to fully appreciate and understand the role of government in marine safety some historical perspective is necessary. Since the early days of commerce the transport of goods by water has been recognized as an effective and prosperous means of conducting trade. However, the hazards associated with

ocean shipping quickly manifested themselves and the position of underwriters was firmly secured. Classification societies then came on scene as a means of resolving conflicts between the owner and underwriters. It is correct to say that the concern for marine safety largely predates any government role. Because of the unique assortment of interests which impacts on the maritime industry the role of government in marine safety is unusually complex when compared with many other regulated industries.

Regulation of shipping was first seen in the form of domestic legislation by the mid 1800s, for their own vessels in their own waters. No international efforts were visible until 1913 when just thirteen countries (although they were arguably the thirteen countries which essentially constituted merchant shipping at the time) met in London to discuss the tragedy of the TITANIC. Sixteen years later SOLAS 1929 became the first truly international effort to improve marine safety. The role of government must be examined within the intricate relationship of regulatory bodies, insurers and owners/operators which has developed over the years that provides the framework in which the maritime industry operates. It is a dynamic role distinguished by a multinational character which is constantly changing while seeking to maintain long standing maritime relationships. The colnmonly held viewpoint of governments being "regulators" oversimplifies their responsibility and overstates the obvious.

PARTIES INVOLVED IN MARINE SAFETY

One interesting and particularly important aspect in marine safety is the large number of parties which have a vested interest. A list of parties must include: governments (flag administrations and port states), ship owners and operators, insurers (both hull underwriters and protection and indemnity clubs), labor unions, shipbuilders, classification societies, cargo interests and various trade or specialty groups. Some argue that the interests of the parties are often naturally opposed to each other. Also, with such a diverse and wide-ranging breadth of involved parties it would seem that there should be enough "safety nets" to catch any problems. In actuality, an interdependent relationship exists between the parties. A few examples are:

- Flag administrations and classification societies: Almost no flag administration has a sufficient number of qualified personnel available to perform all the duties required of it by various International Maritime Organization (IMO) conventions and national legislation. Help has traditionally been sought from other organizations. For example, load line assignment is a task commonly delegated to classification societies along with the issuance of SOLAS safety certificates and IOPP certificates. Furthermore, in many cases administrations use the expertise and experience found in classification societies rules by adopting

them as their standard for ship construction.   Classification
societies can be thought of as subcontractor playing an important
role in filling out "gaps" in an administration's infrastructure.

- Classification societies and insurers: Perhaps no relationship
in the maritime industry is older than that which exists between
classification societies and insurers.   Classification societies
originally helped resolve the conflict of interest between owners
and underwriters.   Today, as noted above, classification
societies serve in a much more broader capacity.   But the
original basis still exists, that is, providing a   form of risk
management for the insurers.

- Flag administrations and vessel owners/operators: In addition
to the well established regulatory relationship between these two
parties, Flag administrations also perform a more subtle but
nevertheless important function involving business matters. A
definite trend towards the adoption of international rules and
standards has become more common over the last thirty years.
Flag administrations must help ensure that the pursuit of
standardization does not create an unfair economic disadvantage
for its shipping industry.   This responsibility is in part
evidenced by actions taken by a government to ensure that all
vessels calling at their ports are meeting the same level of
compliance as their own vessels.

Several observations are appropriate at this point.

- The emergence of IMO as a forum in which to develop and agree
upon international standards for marine safety is a particular
valuable asset which must continue to be fostered.   In
particular, IMO facilitation of cooperation between parties on
technical matters and distribution of that information must
continue.

     The interdependency of involved parties described above is
firmly in place and is unlikely to change soon.

     The government is one of several integral players in the
system which affects marine safety.   Therefore, it is vital that
the various players realize their full potential.

Experience has shown that the promotion of mutual cooperation and
the identification of commonly held goals among the involved
parties is the- best approach for a government to use in
accomplishing its legal mandates.   From this a clearer
delineation of responsibilities can be made. Government is often
in a unique position to   act as a common link between the
parties.   Sometimes overlapping, and on occasion, conflicting
objectives may occur in the parties.   Even if it is not always
clear what the parties respective responsibilities are it is
abundantly clear that they all have some role in the safe

operation of vessels... This must be the point of departure for all future discussions. But where voluntary cooperation and compliance is not forthcoming it is the clear duty of the administrations to impose sanctions where appropriate.

QUANTIFYING MARINE SAFETY

In trying to quantify marine safety, or safety in general, one must discern between absolute safety (i.e. the state of no accidents and loss of life or property occurring) and the goal of achieving an acceptable level of safety. Ships can always be built stronger, inspections can be made more often, and additional rules can be imposed. Pragmatically however there is a finite limit as to what can realistically be done to improve materiel conditions aboard ship. For example, ships can be made tremendously strong but given a big enough rock they will still split open. It is therefore incumbent that the involved parties seek the most effective combination of factors that will improve marine safety. It is a harsh observation for a technical organization to make, but regulations addressing only materiel conditions will not guarantee an acceptable level of marine safety is achieved. The logical corollary of this statement is that government must perform a role of more than just regulator, if it is to continue to improve marine safety.

One goal of government is to promote marine safety with the objective of reducing casualties while seeking to minimize the adverse consequences which may occur. Two problems present themselves in efforts to quantify marine safety.

How do 'you measure success? If success implies the effectiveness of rules, regulations, etc. then data must be collected to demonstrate this.

- Even with accurate statistics it is often difficult to assess and compare accident data. For example, a simple grounding can be a catastrophic event on one occasion while an insignificant event on another. How much effort is appropriate in trying to prevent groundings?

Human factor concerns are being given increasing recognition in terms of preventing accidents. In this regard, the United States has placed more emphasis on casual factors that impact on a vessel's safety record. Causal factors include, company management practices, maintenance records, overall safety philosophy, crew training and the vessels service and trade. The use of Critical Area Inspection Plans on tankships and the adoption of IMO resolution A.680(17) are both examples of this change in direction and approach involving marine safety. However, the collection of casualty and inspection data is an area that offers great promise as a means to improve marine safety.

DEVELOPMENT OF SAFETY REGULATONS

Historically, the United States, as many countries, has seen a reactive approach being taken in regards to marine safety. Reactive because laws affecting marine safety were enacted as a result of a casualty rather than employing a rationale or analytic method to anticipate needed regulations. Accidents are often highly visible events pointed to as evidence of declining safety. The purpose of regulations is to provide a minimum acceptable level of safety. Regulations cannot easily embody every aspect impacting on marine safety. And of course, the realities of the situation means incentives for compliance or noncompliance have to exist.

Two current methods used in the development of regulations are;

    - The use of "round table" discussions among subject matter experts is a proven and reliable way of developing regulations. When a general consensus can be found the result is usually a sound one. IMO is an example of this method.

    - When it is possible to explicitly identify a goal a more scientific approach is possible. A scientific approach involves a formal problem definition in terms of identifying what needs to be improved, quantifying it in terms of cause and effect, and developing possible solutions to the problem. There will, of course, always been some element of judgment involved.

Governments are faced with the dilemma of a "no-win" situation when it comes to regulations. If a casualty occurs the public asks... why wasn't there a rule to prevent this from happening? On the other hand, if government proposes a rule in the absence of overwhelming evidence that such is needed they are accused of over burdening industry. Additionally, the role of regulator is easy one to criticize. Accusations of regulators being bureaucratic lacking of any appreciation of profit consideration and being the creators of unnecessarily expensive changes are often heard. Governments are therefore enjoined to work in close cooperation with maritime interests in developing regulations. Another concern with regulations is that they are often vessel performance oriented rather than applying a specific set of maintenance procedures which must be followed (this is particularly noticeable when examining the difference between regulations in the marine and aviation industries). In addition, when regulations are made specifying a particular standard the result is sometimes a rule which can become technologically outdated or overly restrictive for the ship designer. such impediments to the adoption of new technology ultimately harms the flag states own carriers more than anybody else. For this reason, government must strive to constantly update and revise regulations. Nevertheless, regulations provide that "all important benchmark", which is necessary in identifying substandard performers. The use of regulations to achieve an

acceptable level of marine safety is a difficult and complex effort but the alterative, no regulations, is clearly worse.

Domestic legislation activity can sometimes cause a redirection in efforts, an example is the United States Oil Pollution Act of 1990. Certain provisions of the' Act severely limit the ability to develop regulations which are in consonance with international standards. An effort must be made to develop standards through IMO whenever possible but if government properly perceives progress as being too slow the responsibility to protect its interests may have to take precedence.

Fortunately, many positive changes have been made, especially in the last twenty years. United States regulatory efforts have seen a shift from an emphasis on domestic regulations to an emphasis on development and recognition of international standards. One useful change in the United States has been a movement towards either adopting industry standards within the body of our regulations or simply incorporating by reference an existing industry or IMO standard. A valuable feature of IMO is the pooling of ideas and thoughts which have materially improved ship safety through the sharing of the latest design techniques and operation approaches. The development of numerous IMO codes such as the Gas Carrier Codes, Bulk Chemical Codes, International Maritime Dangerous Goods Codes as well as several important conventions, Load Line - SOLAS - MARPOL, has been remarkable. The contribution that IMO has had on marine safety since its establishment in 1958 is noteworthy. IMO is unique in its ability to react quickly and decisively when clear cut changes are needed. Recent examples of this trait include heightened stability requirements prompted by the Herald of Free Enterprise, MARPOL changes in response to the Exxon Valdez grounding and various initiatives involving bulk carrier losses.

The increasing involvement of professional organizations is another area that holds great promise. The International Association of Classification Societies (IACS) is a valuable partner in the promotion of marine safety. It continues to offer suggestions for improvements in safety standards, providing input for the interpretation of conventions and resolutions in its IMO consultive status, and as liaison for the exchange of information of views and information of interest to class societies. Other organizations performing similar roles include the Baltic and International Maritime Council, Oil Industry International Exploration and Production Forum, International Maritime Pilots' Association and the Hellenic Marine Environmental Protection Association.

SPECIFIC DUTIES OF GOVERNMENT

Given the foregoing it is now possible to describe some of the more pragmatic duties of government in promoting marine safety.

The United States Coast Guard is mandated.to save life and property at sea and to protect the marine environment. In doing so it performs the following functions:

- Flag administration: This involves carrying out certain duties specified in numerous IMO convention instruments as well as domestic work. In order to do this task effectively it requires an objective and stable regulatory framework. Unfortunately, not all governments have an adequate infrastructure in place to exercise their convention responsibilities.

- Port State: Governments must take steps to verify that visiting foreign vessels are safe to proceed to sea and to ensure they are meeting the same international as well as domestic standards, if more restrictive, as their own vessels. This is especially important when the foreign ship's flag administration is unable to perform their duties. Port state action then acts as a form of "safety net".

- Casualty investigation: Although casualty reporting to IMO is a responsibility of flag states it is decidedly in governments best interest to have an aggressive and extensive casualty investigation procedure in place.

Through casualty investigation, and the valuable statistics which come out of it, lies the key to earlier identification of problems with the opportunity for assessment and proposal of solutions. One must recognize that opposition to casualty investigations exists out of fear of penalties/fines and damage to company reputation.

- Facilitation of commerce: Public safety and environmental protection is, and must remain, of paramount importance to government. However, government should balance proposed rules and regulations against cost and viability. As noted above, regulations can serve as an effective technological impediment to progress. Government must be open and receptive to regulation changes that recognize advances which improve productivity or efficiency while maintaining the desired level of safety and environmental protection.

- IMO Interface: Government must represent the interests of their shipping industry and the public at IMO. The value of having such a widely recognized and effective forum as IMO cannot be understated. If current trends towards the development of international standards continues at its present rate this particular role cannot help but become increasingly important.

- Regulator: As described above, government occupies the role of regulator for domestic legislation and implements IMO instruments.

SUMMARY

As means of summary and to highlight several important future goals for government in marine safety the following points are offered:

- A concentrated effort must be made to improve *sources* and means of collecting casualty and performance data. Through this a more scientific and rationale based approach can be developed for improving marine safety. Particular emphasis should be given on the effect of human factors. This will also lead to more technically sound regulations and help identify outmoded ones.

- More joint ventures must be fostered between the various parties involved in the marine safety equation. The parties must draw on their respective strengths *in* correcting deficiencies in our present system. By working together more effectively we are in a better position to move ahead on our common goals.

- Sharing of information between port states can help reduce substandard performers. No matter how high the standard is raised it is of little value if some mechanism is not in place to identify those substandard performers who manage to go under or around it. We all must equally share in our responsibility to marine safety.

- Research programs are a key element *to* developing a scientific approach to marine safety regulation formulation.

- Standards for flag states must be developed. Without a sufficient infrastructure in place to ensure implementation of IMO conventions problems will continue.

Ship collision experiments as a tool in navigation riskmanagement.

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ABSTRACT

In december 1991 several full scale ship collision tests where Carried out in the Netherlands. One of the initiators was the Dutch Ministry of Transport and Public Works. This paper describes the Dutch risk assesment and risk management policy, concerning inland waterway transport and especially that of hazardous material. After an introduction, section 2 deals with the dutch risk management policy, section 3 discusses various aspects of risk assessment, and in section 4 the role of the full scale tests is described. In the last section the future plans are outlined.

1. Introduction.

Why has the Dutch Ministry of Transport and public works spent a lot of work and paid a substantial amount of money to contribute to a collision of ships while its policy is to promote the safety of transport on inland waterways?
For an answer to this we have to go back in history.

In the Netherlands, during the middle eighties there was a serious discussion about the acceptability of the transport of goods over the main Dutch waterways by means of six barge push tow vessels.

There was concern about the manoeuvrability of these units. Would the introduction of six barge pushtowing lead to more collisions with bridgepiers and ships and what was the risk for the penetration of dikes?

After thorough research [1] an agreement was reached. At first as an experiment and under certain conditions, permission was given in 1986 for the waterway from Rotterdam to Germany, in the confidence that the current level of safety would not be affected. However this raised questions about this current level of safety and whether this was sufficiently low, These questions where asked to the minister of transport by an advisory committee of "three wise men". The minister decided to dedicate a thorough research to the subject.

As a part of a long term Dutch national planning on Traffic and Transportation (Structuurschema Verkeer en Vervoer) the project Weiligheid Vervoer over Water" (Safety of Inland Waterway Transport) was started in 1988.

Because of the impact of accidents with hazardous materials, in this project special consideration has been given to such transport although accidents with these ships are very rare in the Netherlands, especially during navigation. The risks for surroundings and environment as a result of the loading and unloading of ships from and to land-based installations, which actually are an important part of the transport process, are not considered in this project. The main reason is that legislation for these handling activities is not under the jurisdiction of our -ministry, while naturally transport is. And transport brings the hazardous material near people in residential quarters; their safety is one of our most important concerns.

The various possibilities for a further improvement of the safety level are studied as wel as the prospects of a developed Risk Assessment Model. This model will show the results of the implementation of safety measures separately or in combination. This is not an easy task, as in general we can say that apart from potential bottlenecks where safety might indeed be significantly low, the safety level of the transport over inland waterways is already very good.

This is mainly due to:
- The special education needed to transport dangerous goods. On all Dutch inland waterways the international regulations for

the transportation of hazardous materials for the Rhine, drafted
by the Central Committee for the Rhine in Strasbourg, apply,
according to the Treaty of Mannheim and the Dutch legislation
on the transport of hazardous material.
- The traffic control systems (Vessel Traffic Services)
- The quality and equipment of the ships (due to international
  Rhine regulations of the CCB)
- The low speed of ships

But the transport of hazardous materials is growing. Bulk transport
in ships is not the only mode. As a result of international
developments, combined transport, and the policy in many countries
(Netherlands, Germany) to move goods from the road to rail and
inland waterways more hazardous materials will be carried in ships
and many of these goods are stored in smaller quantities in
containers. One Europe-containership can carry as many as 75 to
80 times as much as trucks can contain. It is expected that
containers are even safer than tankships, but it is not clear how
the risk levels will change with a possible increase of transport
volume. This underlines the necessity of the "Safety of Inland
Waterway Transport-project".

Despite the relatively good safety prospects of inland waterway
transport, the waterway transport risks are given seemingly
exaggerated attention. This is not so much for the high probability
of a severe accident, for this probability is not high at all.
But if an accident occurs and there is loss of hazardous material,
the possible impact of such an event might be socially unaccep-
table. Because of the large quantities of hazardous materials that
is transported, the possibility that many fatalities result is
not entirely theoretical.

It is, therefore, with transport quite the same as with fixed
installations: there are to be limits on their allowable risks.
Especially risks for people outside the system, people living on
the banks near the transport waterways or people living near
industries, are to be finite and small enough. But how small are
they to be? And how are fixed installations to be compared to

transport routes? In the next chapter we will briefly discuss this matter.

2. Dutch risk management policy.

Within the framework of the National Environmental Policy plan the note "Omgaan met risico's" (risk management) was published. It described the way to deal with risk in the case of new residential quarters near risk.sources, or in the case of new risk sources near existing living area's. The general philosophy behind the note was that building new residestial quarters nearindustries puts limits on the possibilities for design of the quarters, whereas new industrial risk sources were to be safe enough as not to put risk on people already living there, beyonda certain limit. Naturally, as far as there are (potential) problems in the field of physical planning, this philosophy yields massive cooperation with provinces and communities if necessary, because often there are conflicting interests.

However, the risk limits of the Dutch Department of Environment contained in the note, were not made for mobile sources of risk, such as the transport of hazardous materials, but for fixed installations. Fortunately, the risk dimensions used are still quite useful to transport problems. In fact, in the note two risk dimensions are used, of which one (the individual risk) can be applied to transport without problem. The other is group risk, which shows the probability of an accident with many fatalities. For individual risk, which is the probability of death for someone staying permamemtly at any certain spot, the limits of risk because of fixed installations can be directly applied to transport. For group risk, the limits for fixed installations could not (easily) be applied to moving risk sources over long distances.

Therefore, one of our many sub-projects called risk limit development for the transport of hazardous material, considers 3 possibilities for a transport group risk dimension at the moment:
- norms for a fixed part of the waterway of 1 km.

- norms for parts of the waterway, related to a risk-contour
  of 10^{-8}
- norms related to the transport performance (tons/km)

Presently, we are stillfaroff a choicebetweenone of them. First
a "consequence-research" is being carried out, to clarify the
implications of any of them, and of the choice of the 'final risk
limit value. In the mean time it is still possible to try to
establish the current risk levels along the Dutch waterways. Even
without settled risk limits, it is possible to calculate and
compare risk values. In the next paragraph we will briefly show
how this is done.

3. Various aspects of risk assessment.

For all the main Dutch inland waterways a study has been carried
out, showing the risk- contours and possible bottlenecks that
deserve further consideration. In [2] the results of this study
are outlined. The method that was used is described in [3]. Here
we will only give a brief overview.

1. From accident casuistry the probability of an accident on a
specified part of a waterway is assessed. Only accidents with
transport vessels are taken into account, and only sufficiently
severe accidents are used.

2. The registered transport volumes of several distinguished
classes of hazardous materials (in single or double hull ships)
is used to calculate the probability of a severe accident with
a ship carrying such cargo. This can be done because in the
Netherlands as a result of agreements with trade and industry
and regulations there are reporting and tracking systems where
information about ships carrying dangerous goods is collected and
(confidentially) kept. Also registration at locks is used.

3. Given a hypothetical accident with a hazardous cargo ship, the
probability of loss of containment (for single hull or for double
hull ships) is used to calculate the probability of a toxic or

explosive cloud, a flammable pool of hazardous material on the water, and a few more scenario's. The probabilities of loss of containment are only estimated thus far. For single hull ships a reasonable guess was made using casuistry of loss of containment, but for double hull ships, the used probabilities were only agreed upon between shipping industries and our ministry, but these values were by no means proved to be right.

4. With the calculated probabilities of occurence of toxic clouds a probability of death (POD) can be calculated for locations on the banks near the waterway. These calculations involve many parameters, among them wind speed, wind direction and wind stability. For flammable and explosive materials one more stochastic variable is needed, namely the probability of ignition, but essentially calculation of POD goes along the same lines as with toxics.

It is because of the uncertainties in the probability of loss of containment for double hull inland waterway tankers, that our ministry had to go through a long traject of research, that has almost reached its end with the full scale collision test.

4. The role of full scale tests.

As we have shown before the probability of fatal accidents (i.e. accidents which lead to loss of containment) with double hull-ships is rather low. The information available about actual accidents is insufficient to make a right judgement of the possible safety measures to limit risks. In fact, up until now no such accidents were ever registred in the Netherlands, though for single hull ships fatal accidents indeed (but rarely) occur. As the impact of loss of containment from double hull ships is much more severe than when a single hull ship is damaged (because of the nature of the cargo), we cannot just estimate the probability of such an accident to be zero. Therefore it is obvious that it is necessary to estimate this probability.

In the Safety of Transport on Inland Waterways-project different types of measures have been chosen that can contribute to safety. Moreover a Risk Effect Model (REM) is under development with which the application of these measures can be made visible. One of the measures under consideration is legislated use of double hull ships for several kinds of cargo that currently may be transported in single hull ships. But as long as it is not clear what effect such a measure has on the calculated risk, it is possibly premature to decide upon it.

On the other hand it is not unthinkable that some time in the future several kinds of hazardous material that are now not allowed in ships at all, may be transported in double hull ships. To decide upon this, the safety of those ships has to be known.

Therefore there was a need to estimate the probability of loss of containment for double hull inland waterway tankers. We started our research in this direction by calculating the mechanical damage on a double hull tanker, caused bu a collision. The MacNeal Schwendler Company (MSC) carried out these simulations (eight in all) [4]. The method that was used was, however, not generally accepted as absolutely to be relied upon. Especially the shipping industry requested verification of the method, as the implications of the result of MSC might be far reaching. We saw only one possibility for verification, namely a full scale collision test.

Such a test would, of cause, wreck two ships, possible beyond repair, and this would cost millions. However, as there is a special demolision regulation, according to which only after demolition of an old ship, a new ship can be built, it was possible to organise the collision test at much lower cost.

Still, the plan seemed to be too expensive to be worthwhile, but when CMO showed interest, and participation of the Japanese ship building industry became probable, the wild ideas were finally put into practise, and were indeed carried out by TNO-CMC.

Several collisions were carried out with different side structures of the struck ship and different speeds of the striking ship,

showing the differences between the resistance of single and double hulls. The data were carefully stored and filmed and are used again in the MSC numerical simulation method.

Now that the calculation methods, used by MSC, are validated, the next step will be the derivation of a probability distribution of thevolume of loss of containment, given a severe accident with a double hull ship. This step is currently being carried out, and involves the results of all calculations of MSC, but also a thorough screening of the Dutch database of registred accidents in navigation, to find out the distributions of speeds, mass, angle of impact, and several other influencing factors. Only when this project is concluded, and the calculated loss of containment according to MSC's results is transformed into a real life over all distribution of loss volumes, we can resume our risk assessment with a new approach for the safety of double hull tankships.

5. Conclusion

The results of these simulations and unique collision tests are very important for trade and industry and the authorities. Instead of estimations solely based on haphazard casuistry, additional information about instrumented collisions is now available. The results will be the basis for the consideration of the necessity of certain provisions concerning double hulls, if a risk analysis shows bottlenecks, either in space, in category of hazardous material, or in type of ship.

Some measures can be taken at a regional or national level, others need an international unanimity, such as the ADNR-regulations. To get such a unanimity, convincing facts are necessary.
A new ADNR is due at the beginning of 1993. For the European inland waterways where the ADNR is not applicable there will be new ADN-recommendations (based on the revised ADNR) of the United Nations (Inland Transport Committee of the Economic Commission for Europe) shortly after the new ADNR comes into force.

Especially Dutch trade and industry is anticipating on these new regulations. Double hull-ships will be able to take also the cargo that will no longer be permitted in single hull-ships.
The validated simulation model, to gether with the Risk Effect Model will prove that the transport of hazardous material on inland waterways is a very safe mode of transportation.

The ship collision experiment has been an important contribution to navigation risk management and the policy concerning the transport of dangerous goods in the inland navigation.

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DEVELOPMENT OF ONE SIDE SUBMERGED ARC WELDING OF PLATE PANELS AND HULL SECTIONS IN SHIPBUILDING

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1 ABSTRACT

In West Europe, shipbuilding has been characterized for a long time by experience, good workmanship and qualitative excellent ships, rather than by advanced production techniques. In the last decade, this absence of advanced production techniques has been changed by the introduction of the so-called panel-lines. Some of these panel-lines include a one side welding station for the production of long, wide plate panels from relatively small rolled plates. Authors will describe how social aspects and technical capabilities have initiated the development of the one side submerged arc welding of double walled hull structures and box shaped girders. This technique uses the high penetration of the submerged arc welding process to join the stiffener and the plate panel from the outside of the construction. Essential in this technique is the system used for supporting the liquid weld metal, and the process tolerances in the welding parameters in relation to fit-up, positioning and bevel shape of the joint

This production technique is only one aspect in a totally new concept for designing and building ships. The basic philosophy behind this concept is briefly explained in this paper.

2 HISTORICAL BACKGROUND

The design of ships, whose outer skin consisted of large more or less flat plate panels, has led to a continuous development in the production procedures to lower the required amount of manhours per ton steel weight.

Conventionally, plate panels are welded using the two run submerged arc process (in a lot of shipyards better known as the Union Melt process). This submerged arc process is characterized by a high penetration and deposition rate and for a shipyard perhaps also important a high process reliability. The latter means that the process is not or little susceptible to all kinds of problems coming from the equipment used and skills of the operators.

By using this two run S(ubmerged) A(rc) process, the plate thicknesses currently used in shipbuilding (approx. 6 to 20 mm) can be welded quite conveniently. The welding speed is high: optimum penetration is achieved with welding speeds of 50 cm/min and above.

The only weak point in the two run SA technique, is that after having welded all seams on one side of the plate panel, the entire panel has to be turned for backgouging and/or backwelding.

This   turning operation requires

      a production hall with enough height, to turn the platefield with large dimensions,
-     large crane capacity, and special lifting equipment to handle Unstiffened   platefields,
-     skilful crane drivers, which often have to work in pairs in close cooperation,
-     patience when waiting for the available special hoisting and turning tools, for the turning operation (by the panel fabricator).

In addition, this turning is known to be not free from danger. It has occured, that when turning the panel, with SA welds on one side, cracking of one of the welds led to dangerous (collapsing platefields) situations.

It was for the reasons mentioned above, that in the seventies some yards renewed their involvement in the one sided SA welding of plate panels.

3   PANEL. LINES, INCLUDING ONE SIDED SA WELDING OF THE PLATE PANELS

The design of ships, consisting of a lot of (more or less comparable) plate panels, either single or double walled, made it interesting for shipyards to standardize the production methods of these panels.

The basic step is to put all necessary equipment in line, and to built the panel on a production floor, that makes it possible to "feed" (transport) the panel along all production equipment.

Before dealing with the production of a plate panel, with dimensions of e.g. 12x25 m, the general outline of such a panelline has to be indicated.

First of all, the bulbs (plate stiffeners) are positioned and tack welded. m Then they are welded to the plate, using a double sided MIG/MAG or SA device.

Over these bulbs, the webs (longitudinally and transverse stiffeners) are positioned, and welded by hand with stick electrodes or MIG/MAG.

After having completed, cleaned and inspected all welds that can be welded before the tanktop is placed, the welds and their adjacent Heat Affected Zone are locally covered with a shop primer.

After having positioned the tanktop, it is manually tack welded to the webs in the overhead position, and then the boxtype module can be turned to make down-hand welding procedures possible.

Composing the flat plate with dimensions of e.g. 12x25 m can be done by means of the two run SA technique, as mentioned before. However, some shipyards have already invested in a one side SA equipment for joining plates to the required dimensions.

The basic principle is drawn in <u>Figure 1,</u> and consists of a SA machine, and something to support the liquid weld metal

The SA process is used for its high penetration, and the use of the weld pool support material is obvious.

Of course, there is needed some device for positioning and clamping the plates. And it is this rather basic necessity, that determines to a great extent the quality of the weld of a one sided SA station.

For supporting the liquid weld pool, several systems can be used. In principle, one could simply use a copper strip as a backing material, just as is done in one side welding of aluminium. However, the risk of copper pick-up is very great with the high penetration and heat input of the SA process. Because of the problems that arise then, this copper backing is not recommended.

Two systems that are frequently used are a woven glassfiber tape, and a special encased flux layers, both supported by a liquid cooled copper bar. This copper bar is pressing the backing material onto the back side of the plates to be welded. In some cases this copper weldpool supporting system is designed as a flexible plate line following system (spring loaded).

With this system one sided welds can be produced in plates with a thickness up till approx 15 mm in one pass or up to 25 mm in multiple pass execution

4   BOXTYPE GIRDERS AND THE ONE   SIDED CLOSING   PRINCIPLES

4.1 General:

When producing platepanels with one side welding of butts, one easily gets the inclination to
extend this principle towards the fabrication of one sided closed boxtype girders.
These girders have a more and more wide spreaded field of application in modem shipbuilding
and in general utility steel construction works. Examples are : double bottom tanks, side
tank, floating cases, blistertanks, cofferdams, double deck constructions, rudders,
propellemozzles   in shipbuilding and the Construction of platforms, cargodecks, loadingbridges,
dockdoors, doublewalled cargotanks and other types of secondary isolation barriers for
continuous or emergency purposes, etc.
The solution for the production of such type of constructions is nowadays mostly found in the
use of slot-welds or plate-edge welding on permanently applied steel backingstrips and where
possible by means of manual (mostly in position) backwelding from the inside of the enclosed
constructions.
The new concurring insights in the required and preferred labour conditions makes the present
working attitude questionable in the longer run. Besides there is a strong international trend
and legislation to the prohibition of human labour to be executed in such enclosed
environment, without the use of extensive personal protection devices such as facial breathing
m a s k s .
 Such equipment is in this application most unpleasant for the bearer and not ergonomicaly
justified.
For solving or avoiding this problem a huge change in attitude of both the designer and user
of boxtype products are necessary.

4.2 The new approach of boxgirder design and production:

A.   Starting points for the conceptual approach of the design:
1   To create a universal applicable solution for the modular design of boxgirders, primary
     doublebottom units of ships.
2   To conceive a construction fit for mechanised or automated welding by dedicated
     automation or robotics.
3   To supply a design, fit for manufacturing under acceptable labour-ergonomical and -
     environmental   conditions.

B.   Designers options to fill in this principles:

To cope with these contradictory demands the designers came with the following approach:
In close cooperation with the classification societies, it must be possible to create a separation
in the basic functions of the product, which can lead to a different way of production
This means one part of the construction accounts mainly for the absorption of the external
loads, including the overall longitudinal loads and the other part takes care of the
(cargo)loads from the innerside of the construction.

This means two basic loadsituations:

B1   bottomside:
-    the   external waterpressure and local dockingforces, etc
-    the longitudinal bending forces from the integrated unit or product in its final application
     (e.g. wavebending forces).

B2   topside:
-    the internal forces on the tanktop by cargo inside of the compartment or applied from the
     top by cargo or incidental   loading-equipment (e.g. forklift trucks).

Target of the designers:
To combine   these two segregated principles to one integral design for a   boxconstruction
Several discussions were held to find a basic design principle which could be approved by a
Classification   Society.
One of the disputed points was the idea to deliberately withdraw the tanktop panel and its
internal stiffeners from the influence of the longitudinal strength. For proving the principle
basic finite-element calculations of different stiffener-end   constructions were executed.

C.   Additional design principles to be accounted for:
1   Each unit to be assembled from the lowest amount of parts as practical possible.
     This means as much as possible flanging of plate elements, or use of commercial
     available standard profiles.
2   The unit must be constructed in such a way that it can be welded for the major part by
     mechanised welding.
3   During production the need for three dimensional manipulation of the boxgirder from the

welding point of view, should be avoided as much as practical possible.

4   It must be clear that inside welding of the enclosed construction is not allowed anymore and therefore to be avoided from the design point of view.

This means that all the internal welding must be executed in "the open situation" and the "lid" must be welded to the internals. from the outside.

D   Production tests in laboratory to simulate workshop conditions

Special tests were executed with one side welding by means of the submerged arc process. The advantage of pulsed SAW was investigated to obtain a controlled penetration with a meltpool as small as possible.

Additional tests were executed with different types of meltpool supports and different combinations of material thickness both in horizontal (tanktop) and in vertical plates (webplate).

The results are promising, but a long way still has to be followed before a practical acceptable solution is reached.

One of the major problems to be solved, is to develop a sensor system capable of determinating the actual position of the members to be joined underneath the tanktop-panel.

Several principles are studied in a pre-investigation program but no actual tests have been executed yet.

We believe that it is essential, both for shipbuilders and for mechanical engineers to join us in this development in order to cope with the human- and legislative demands of the coming era ill steel construclions.

Both authors, Mathu and Vuik from TNO Industrial Research, invite you to share your ideas with us, to define a good solution for the mentioned problems and to take care of a good humane working environment for our esteemed working force in the future of shipbuilding and steelconstruction
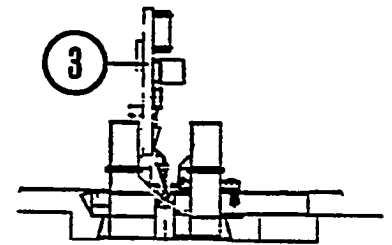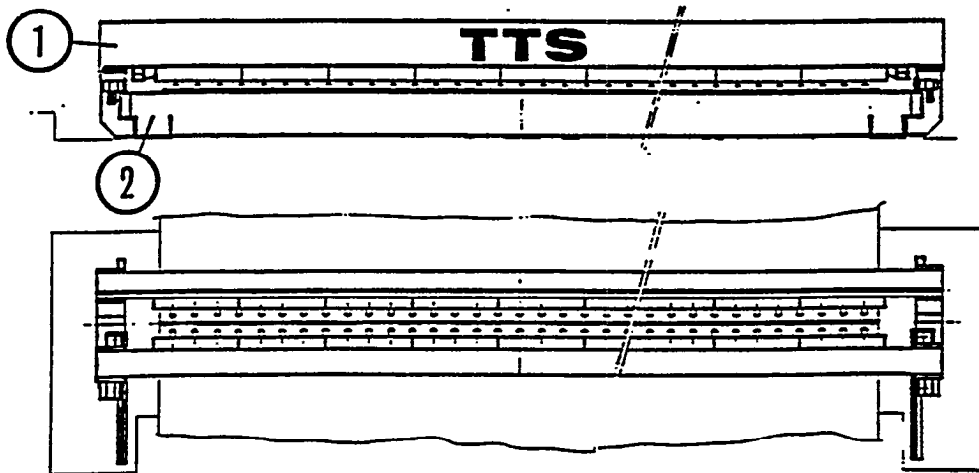
TTS One Side Buttwelding Station
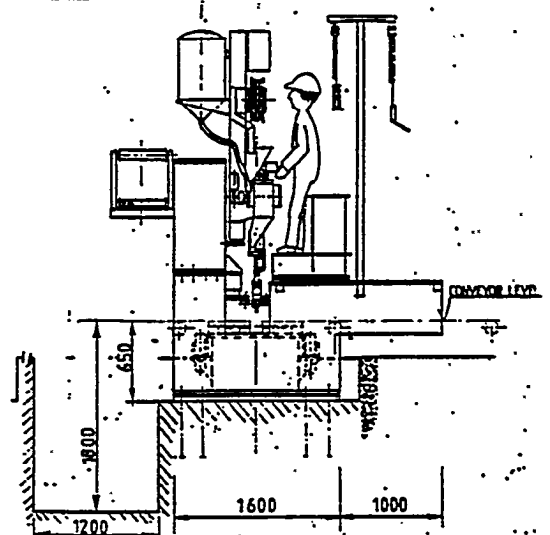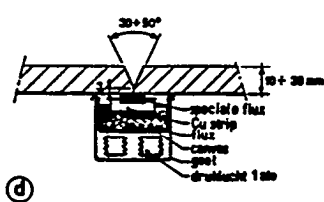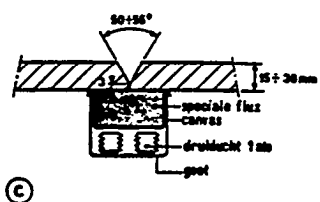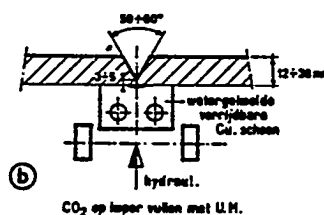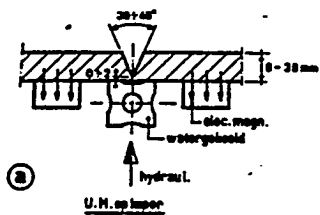## "TTS glassfibre backing/CO/Sub.arc" welding method
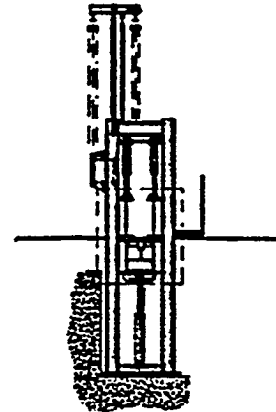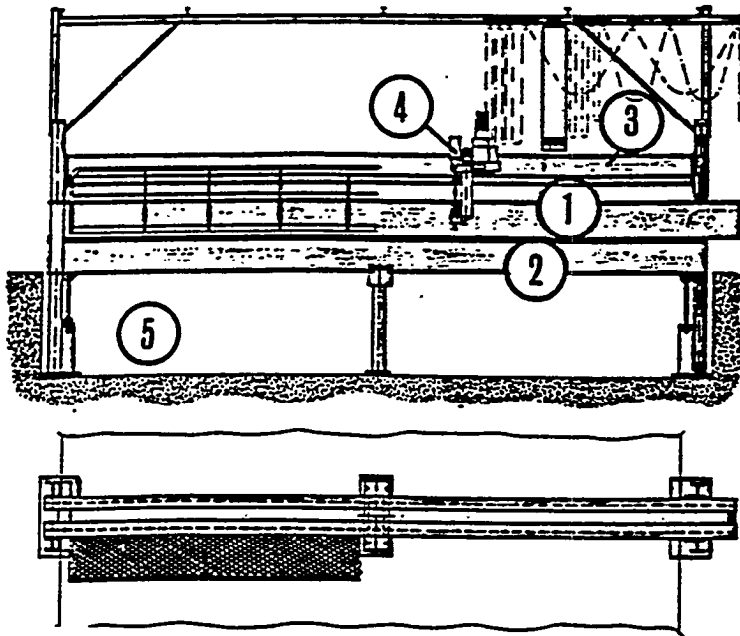
1. Upper clamping beams
2. Lower clamping beams
3. Welding tractor running beam
4. Sub. arc. welding tractor
5. Inspection pit

"Flux covered backing" welding method

1. Upper clamping beams
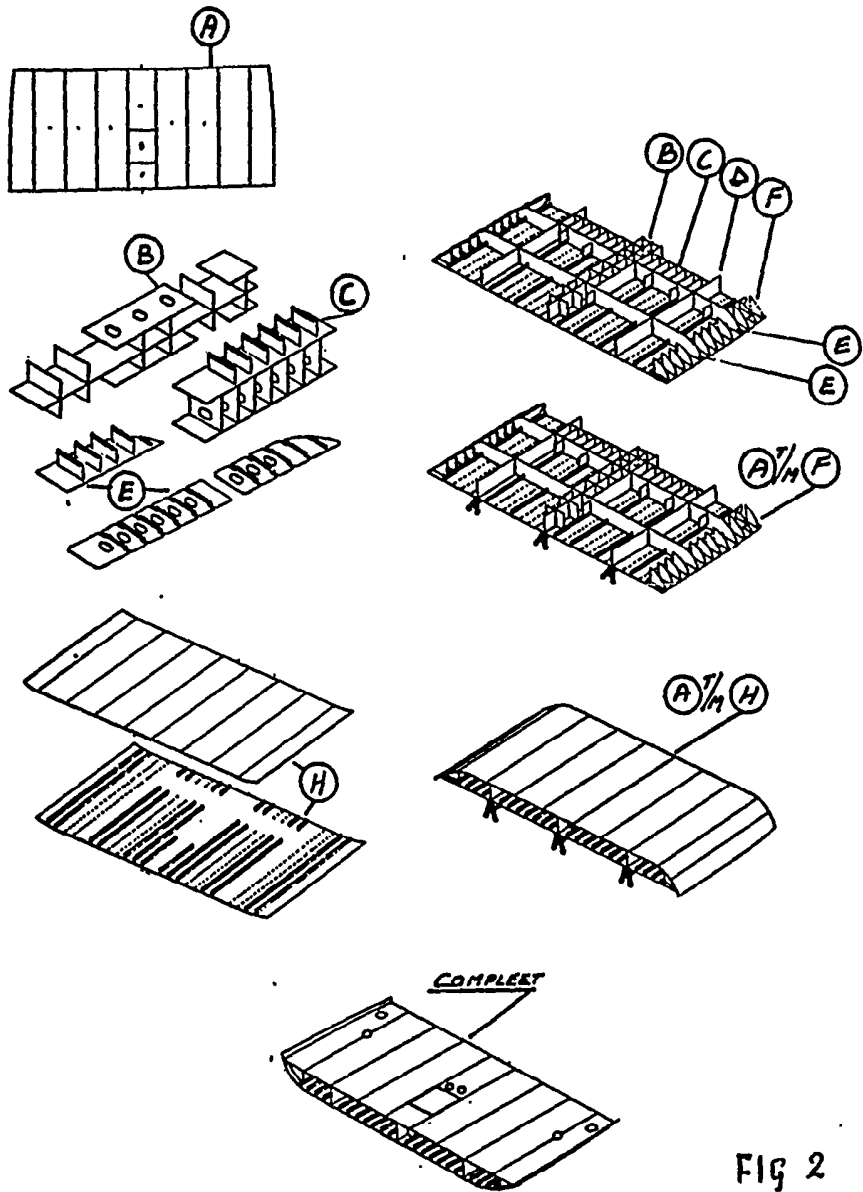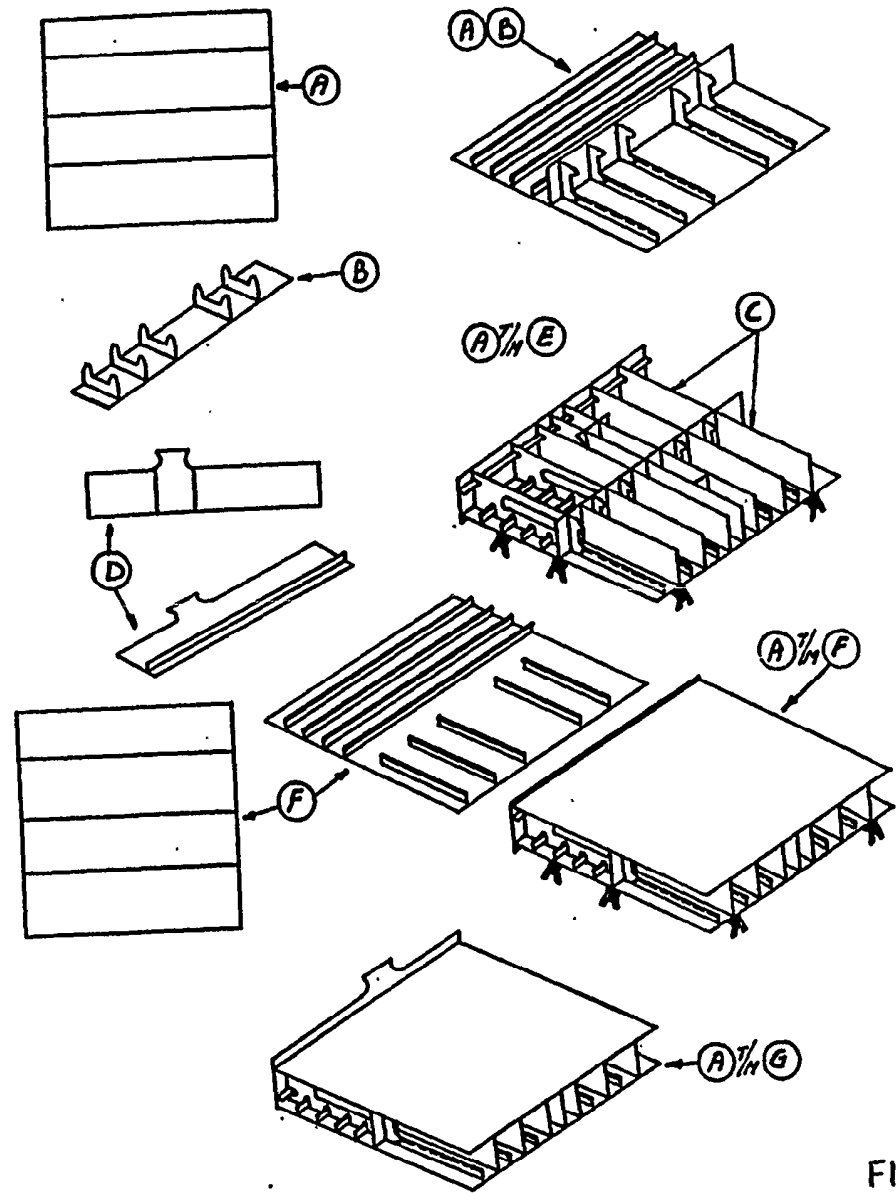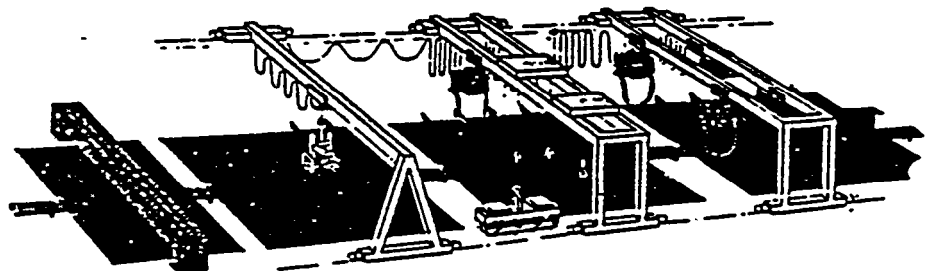2. Lower clamping beams
3. Welding tractor
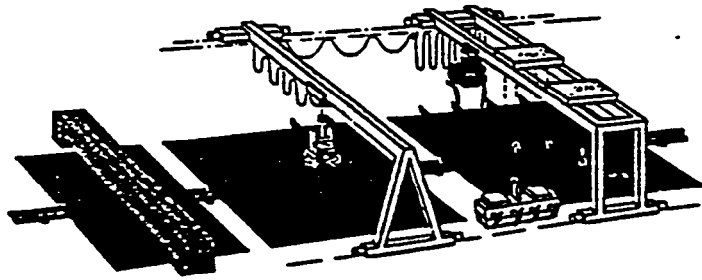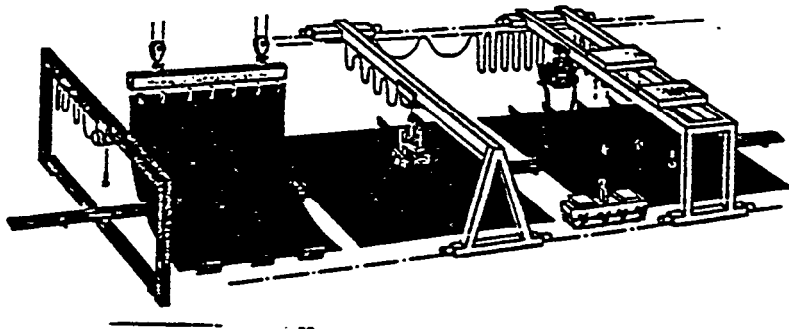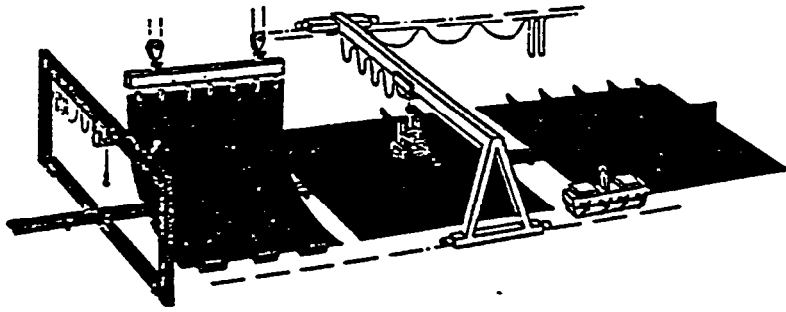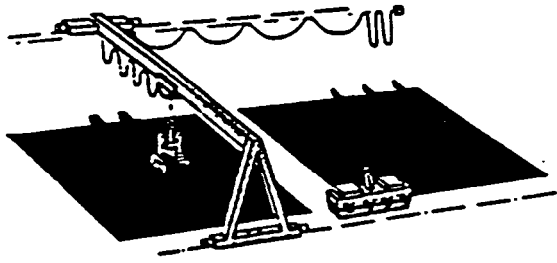
FIG 2

FIG 3

COMPLEET

FIG 4

A METHODOLOGY FOR EVOLVING COST AND SAFETY EFFECTIVE SHIPS

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ABSTRACT

The paper begins by outlining the marine business environment before stating the basic requirement of the shipbuilder's customers. The term cost and safety effectiveness" is explained and the contributions of interested parties are summarised. In order to achieve it, an approach is proposed based on establishing the ship's life-cycle and then applying the PREVENT-IT safety methodology to each phase while also incorporating the cost criteria. Basic stages of the approach are used to illustrate its application. Key conclusions are, first, that a positive attitude is needed in dealing with cost and safety, and secondly, that by using the proposed approach, it is possible to achieve cost and safety effectiveness in ships that meet customers' specifications.

THE MARINE BUSINESS ENVIRONMENT

Anyone connected with marine activities can appreciate the special characteristics of this industry: its cyclic and international nature, capital intensiveness, competitiveness and dependence on the level of world trade at any given point in time. Much less well understood is the long lead-time needed betweeen an idea's conception and the generation of cashflow, and the narrowness of the profit margin in this industry where building up reserves requires large volumes of business.

To forecast future development accurately is an extremely demanding task but success depends very much on the ability to respond positively and speedily to the few attractive opportunities on offer. In order, therefore, to make at least an attempt at identifying the likely direction of marine business in the period up to the year 2000, we must make good use of all available information and learn to read the signals regarding future trends.

It is *very* clear that the business world is moving towards ever greater globilisation and decisions made in one part of the world, e.g., the Far East, will have an immediate and significant effect on the rest of the world. Planning must increasingly respond to market demand and organi-

zations will need the ability to meet it effectively. The
customer will also want a range of choices. It has been
argued that for success in this environment an organization
must have the right market, management, money and manpower
 (representing all human resources), and also ensure that
these four M's are developed in a balanced way at all
times, see (Kuo, 1992).

The marine industry customer will increasingly be specify-
ing high quality, coupled with cost effectiveness and an
acceptable level of safety in relation to both human life
and the ocean environment. This will put high pressure on
technically trained staff to innovate, and even to invent
solutions which will be more satisfactory. There will be
no shortage of data or techniques but learning to priori-
tise alternatives is essential as it will not be possible
or desirable to consider all options in detail.

The role of the providers of maritime education will be
crucial, as everybody with a contribution to make -
especially future graduates - will have to combine tech-
nical capabilities with a proper understanding of the com-
mercial implications of their decisions. It is only thus
that we can expect to evolve cost and safety effective
ships for the future.

This paper will concentrate on the methodology for meeting
that last goal.

THE BASIC REQUIREMENT

As already indicated, the prime requirement of the customer
is to make a profit. In the present case, the customer of
the ship's supplier/builder is the owner or owner/operator
of the ship. Where the owner is not also its operator the
management of the ship would be handled by a specialist
organization responsible for seeing that the requirements
are satisfied. It would therefore be useful to state
explicitly what the basic need of the customer is, i.e.:

    "To be profitable in the selected operation, by employ-
    ing a ship-with the agreed specifications, which at the
    same time satisfies the demand for cost-effectiveness
    and an acceptable level of safety."

It is important to understand the implications of this
statement. They are that the profitability of a project or
operation depends on the use of a ship which meets three
separate sets of criteria in equal measure. These relate
respectively to specification, cost-effectiveness and

safety. Generally, each set on its own can be readily met.
For example, it is possible to build a low-cost ship if the
specifications are not demanding and a high level of safety
is not called for. The real challenge is to provide a ship
that meets demanding specifications, is cost-effective and
also incorporates every desirable safety feature.

The problem requires a multi-level and multi-variable
optimisation formulation. Its complexity stems from the
qualitative and subjective nature of some of the relation-
ships between the variables. To satisfy the requirement,
therefore, it is essential to have a suitable methodology.

WHAT CONSTITUTES COST AND SAFETY EFFECTIVENESS?

In order to understand the composite term "cost and safety
effectiveness" it would be useful to begin by defining the
individual elements.

Cost Effectiveness
There are a number of ways of fulfilling the requirement
for any task and each involves a specific cost. Variations
in such cost can be wide-ranging, depending on the nature
of the task. In the days when the quality of a product was
judged by technical criteria alone, the cost of a specific
task was a secondary consideration. A good example of
this relates to the exploitation of oil and gas in the UK
sector of the North Sea in the 1970's. The national goal
was to be self-sufficient in oil by 1980 and the solutions
adopted were those which had proved successful in the
shallow waters of the Gulf of Mexico. "Cost" was a factor
well down the agenda. However, with escalating costs and
strong competition from alternative solutions, it eventu-
ally became necessary to seek value for money or cost-
effectiveness. This should not be confused with low cost.
It may be right to pay a high amount for an item or service
if it will yield the desired level of effectiveness. The
most obvious example is the choice between a product at a
low capital cost with high running costs and one at a high
capital cost but with much lower running costs. The cru-
cial factor is "effectiveness" and the decision on this
must be based on both commercial and technical conside-
rations.

Safety Effectiveness
"Safety" is a word frequently used in many different
contexts but the users' interpretations can vary widely.
They range from the dictionary definition of "avoidance of
personal injury to the commercial one of "not losing

money". Questionnaires circulated to a wide spectrum of
technical personnel yielded the following results:

0   Practising engineers believe safety is concerned with
     design and rules and regulations.

0   Academics think "reliability studies" and "risk
     analysis** are most relevant to safety.

0   Operators would regard operating procedures as most
     closely associated with safety.

In the engineering context, "safety" is defined as follows:

     "Safety is a perceived quality that determines to what
     extent the management, engineering and operation of a
     system is free of danger to life, property and the
     environment.**

There are a number of words in this definition which need
clarification:

Quality: Safety is not something absolute but a
                 quality that has to be specified according
                 to given circumstances and can be continu-
                 ously enhanced over a period of time as a
                 result of increased experience and new
                 situations.

Perceived: Safety is a perceived quality because it
                 depends on actual circumstances and the
                 competence and experience of those involved
                 in the situation.

System: The term **system** is used to represent any
                 complete structure such as a ship or some
                 component of an installation, process or
                 project.

Management: A system is introduced to meet a specific
                 objective which is implemented by the
                 management of the organization. Excessively
                 demanding managerial decisions can greatly
                 affect the level of risk incurred.

Engineering: Many of the factors affecting safety are
                 related to technical factors.

Operation: Operation is important because even the most
                 carefully thought-out system could fail
                 through incorrect operation. It is also

virtually impossible to cater effectively for the interaction of all possibilities, especially in the case of the more complex systems such as ships.

Life: Safety is most closely associated with human life, and that is the right emphasis. In practice, a human being is exposed to many different types of danger in different activities, and it would be impossible to achieve absolute and total safety in this respect.

Property: The term "property" covers both the system of interest and other systems that may be endangered by it in any way.

Environment: Marine failures, and others as well, can affect the environment in a most significant way.

"Safety effectiveness" determines to what extent the requirements relating to safety are satisfied in the best possible way.

Cost and Safety Effectiveness
If the cost and safety aspects of a project are combined, then both will be given equal weighting and the two factors can be incorporated simultaneously and at the right level.

THE CONTRIBUTIONS OF INTERESTED PARTIES

Three groups who can contribute directly or indirectly to improvements in cost and safety effectiveness are:

Group A : Customers
This group can be divided into three subgroups: those who use ships, e.g., passengers; those who work on ships; those who own them. The interests of these subgroups may differ slightly in emphasis but it is their demands that will bring about higher acceptable levels of safety and value for money.

Group B : Implementers
The influential people in this group are: ship operators; ship designers and regulators, and the level of cost effectiveness that can be achieved in a specific vessel is determined by their efforts. For example, many significant cost factors are affected by design decisions.

Group C : Supporters
This group includes: suppliers of equipment and materials
to shipbuilders, researchers working on ship technology,
and the educators who train both naval architects and ship
operators. Each of these can indirectly help to determine
the extent to which cost and safety effectiveness can be
achieved in new ships.

When evolving new ships in the future it will be essential
to take into account the views of all these groups.

PROPOSING AN APPROACH

Having outlined the requirement there is a need to have a
suitable methodology that can be applied to evolving ships
which will have cost and safety effective features. A
number of possible approaches have been examined. Typical
examples include incorporating cost and safety criteria
into the spiral design cycle (Erichsen, 1989) and decision
based paradigm (Mistree, 1990). While all these approaches
have strong points they also have some drawbacks and it was
decided to adopt a methodology which involved the following
steps.

STEP 1:   *Establish the Life Cycle of the Ship*
           The first step is to identify the phases in the
           life cycle of the ship after the owner/operator's
           general specification has been obtained..

STEP 2:   *Apply PREVENT-IT to Safety*
           Based on the concept of prevention, the safety
           methodology called PREVENT-IT is employed to
           evaluate the safety factor in each phase of the
           ship's life cycle.

STEP 3:   *Integrate Cost Criteria*
           In deriving the desired ship, cost criteria are
           introduced in each phase of the life-cycle after
           the application of PREVENT-IT.

Each of these three steps will now be examined in the
sections that-follow.

THE LIFE-CYCLE OF A SHIP

To enable cost and safety to be taken fully into conside-
ation in the evolution of a ship it is helpful to under-
stand the complete process that begins once the ship owner
has outlined the basic requirement. One very flexible way

of representing it is to examine the **life-cycle** of a
ship, which can be regarded as, comprising eight phases
which are summarised as follows:

Concept: The objective of this phase is to prepare
                     a selection of sound possible concepts
                     which would meet the owner's requirements.
                     This will involve tasks ranging from
                     brainstorming sessions through the evalu-
                     ation of suitable ideas to estimation of
                     approximate costs and the level of safety
                     which can be offered.

Feasibility: The aim here is to establish whether the
                     preferred concept will meet the require-
                     ments in the most effective way, so that
                     the owner can decide if the proposed ship
                     is suitable. The alternative name for the
                     phase is "preliminary design**. Typical
                     tasks involved are preparing the layout of
                     the ship, calculating estimates of the
                     costs involved, and considering its safety
                     features.

Detailing: The work of this phase should provide all
                     the necessary information for procurement,
                     construction, operation and other relevant
                     purposes. It is sometimes referred to as
                     the "engineering" phase and should yield
                     a complete description of the project and
                     its individual components. This will in-
                     clude the full specification of each part,
                     based on the appropriate code of practice
                     and backed by comprehensive calculations
                     to verify how well the design criteria
                     have been met. The output consists of
                     drawings, material specifications, plan-
                     ning data, procedures, etc. It is also at
                     this stage that details of the resources
                     required are established.

Procurement: The aim is to purchase from the most
                     suitable sources all the materials and
                     equipment for the ship, as defined in the
                     previous stage. This involves building up
                     a list of approved suppliers and negoti-
                     ating with them for the items that are
                     most suitable from the points of view of
                     price and quality.

Construction: The main aim in this phase is to convert
                    the established details and procured
                    materials into the hardware of a ship,
                    with the greatest possible efficiency.
                    The tasks involved include planning,
                    production processes such as cutting,
                    welding and assembling materials into
                    units, the installing of equipment, the
                    control of progress and outfitting.

Commissioning: The aim is to check that the structure and
                    its equipment will meet the specifi-
                    cations. Acceptance tests and ship trials
                    are performed in this phase and adjust-
                    ments are made to ensure conditions are
                    satisfied.

Operation: This is the phase in which the ship has to
                    fulfil the customer's requirement of gene-
                    rating income. Tasks involved include
                    familiarising the crew with the running of
                    the ship, close monitoring of performance,
                    maintenance and repairs.

*Decom-
missioning:*   After the useful life of the ship is
                    completed the aim here is to dismantle it
                    in an environmentally acceptable manner.
                    The tasks involve the systematic down-
                    grading of the functional capabilities of
                    the ship and its eventual breakup.

It will be noted that cost and safety aspects have a role
to play in each phase, and their maximum impact in the
phase of interest will stem from effective decisions made
in the earlier phases.

THE PREVENT-IT SAFETY METHODOLOGY

The safety methodologies most suitable for use in this
approach include PREVENT-IT, see (Kuo, 1990). (Note that
the term PREVENT-IT is a registered trademark). It con-
sists of the following nine steps:

STEP 1:   Predict Potential Hazards
           The first step is to predict potential hazards
           for the concept, design or ship as appropriate.
           Typical examples of such hazards would be fire,
           flooding, instability and collision. Techniques

such as HAZOP and HAZAN are applicable.   (Kletz, 1986).

STEP 2:   Research into Risks
           The risk of occurrence should be calculated for
           each of the hazards identified. Risk is defined
           as the product of consequence by probability.
           Typical techniques such as Fault Tree Analysis
           (FTA) can be used, see (ASTEO, 1987).

STEP 3:   Establish the Role of Human Factors
           The human factors of interest are management,
           competence, confidence and communication skill.

STEP 4:   Verify the Scope for Design Modifications
           On the basis of the previous three steps it may
           be possible to reduce risks by careful design.

STEP 5:   Engineer the Containment Systems
           Many factors contribute to the occurrence of a
           major accident, see for example (Charlton, 1989).
           However, the introduction of containment systems
           may well be sufficient to a turn a potential
           major accident into a minor one.

STEP 6:   Nominate Viable Emergency Solutions
           Emergency solutions will always be required, no
           matter how far potential hazards are minimised.
           Typical solutions in ships include escape routes
           and lifeboats.

STEP 7:   Transmit Quality Requirements
           Failures often occur because design details were
           not correctly fulfilled or procedures were not
           followed. The management must insist on the
           highest quality in everything connected with the
           life-cycle of the ship.

STEP 8:   Interface with Regulations
           Steps 2 to 7 can be regarded as the **good prac-
           tice** of any organization. But ships have to
           satisfy a variety of national and international
           rules and regulations as well. Proper interface
           with these must therefore be achieved.

STEP 9:   Train the Personnel
           To ensure that a high standard of safety is
           maintained, all personnel must be trained to
           recognise potentially dangerous situations, to
           take appropriate action to correct them, and to

provide feedback on experience gained in prac-
tical situations.

It will be noted that PREVENT-IT provides a mnemonic of
the first letter of the title of each of the nine steps.

INTEGRATING COST WITH SAFETY

Application of the appropriate steps of the PREVENT-IT
safety methodology to each of the relevant phases of the
life-cycle of a ship makes it possible to reach the
required level of safety systematically. The first three
steps, for example, can be applied to the concept phase and
the first five can be used to study the feasibility phase.
It is therefore a matter of direct addition to apply cost
criteria at each stage after safety has been considered.
This is best illustrated with the aid of an example.

EXAMPLE OF APPLICATION

Any practical application would contain too much detail for
this paper, but Appendix 1 provides highlights of the key
stages for evolving a cost and safety effective ship for
stand-by duties in the North Sea.

DISCUSSION

The following three issues call for brief examination:

Attitudes to Cost and Safety
Those associated with ship technology and ship operation
must take a positive attitude to both cost and safety and
see them as complementary rather than contradictory. Safer
ships need not be more expensive provided the two factors
are considered and implemented at an early stage.

Life-Cycle Approach
The whole life-cycle of a ship should be considered when
cost and safety are being examined, because the impli-
cations of their effectiveness vary in each phase and they
must be taken properly into consideration each time.

Role of Education
In the 21st century engineers will need to have a high
level of competence, confidence and communication skill in
balanced proportions in order to cope with ever-changing
demands for cost and safety effective ships. Education has
a key role to play here as it will not only help to build

up the right level of technical capability but also ensure that they also have a proper appreciation of business fundamentals at an early stage.

CONCLUSIONS

The main conclusions to be drawn are:

a) A positive attitude must be taken by all concerned with shipbuilding, so as to recognise that it is possible to meet customers* specifications and at the same time be cost effective and have an acceptable level of safety.

b) Ships that are cost and safety effective can be evolved in practice by the application of both cost criteria and the PREVENT-IT safety methodology to every phase of a ship's life-cycle.

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APPENDIX 1:   HIGHLIGHTS OF THE COST AND SAFETY
                 EFFECTIVENESS APPROACH

The Customer's Requirement

This can be stated as follows:

    "To examine what would be the most suitable ship for
    the market for standby support duties for an offshore
    platform in the North Sea. The proposal should give
    good value for money and meet a high standard of
    safety.**

The Initial Stages of the Approach

The Approaches involves the following key stages:

Stage A : Implement the Concept Phase of the life-cycle by
applying the first three steps of PREVENT-IT to a number of
possible concepts developed through brain-storming sessions
or via the previous experience of those involved. Compare
the cost implications of each concept. The decision on the
preferred concept will be based on how well it satisfies
both the cost and the safety criteria.

Stage B : The Feasibility Phase is implemented by applying
the first six steps of PREVENT-IT to the preferred concept.
After its safety level has been clarified the preferred
concept will be evaluated against cost criteria using
either the payback method or the net present value method.

Stage C : The output of the previous stage will allow the
customer to decide whether to go ahead with the proposal or
to consider fresh concepts to meet amended requirements.

Other Stage of the Approach : When the decision is a
negative one Stages A and B are repeated until such time as
a positive decision is reached. Following selection of the
preferred solution, each of the phases in the life-cycle
will be implemented and the relevant steps of PREVENT-IT
applied, together with appropriate cost criteria. Thus,
Stage D will examine the Detailing Phase, Stage E the
Procurement Phase, and so on.   It should be noted that
some of the phases, for example, the Procurement Phase,
have a greater impact on cost while others, such as the
Operational Phase, relate more closely with safety.   To a
large extent the steps implemented in a given phase will
depend on the amount of information that is available at
that time.

QUALITY ASSURANCE IN SHIP OPERATION

THE ISO STANDARD, CERTIFICATION; THE ROLE OF CLASSIFICATION
SOCIETIES.

J.R. Smit.
BUREAU VERITAS

Quality - Definition

In typical "quality assurance "style I should perhaps start
by giving some definitions of the terms used. One of the most
difficult terms to define is "quality ". The ISO standard
8402 - Qaulity - Vocabulary. defines quality somewhat dryly
thus:-

> The totality of features & characteristics of
> a service that bear on its ability to satisfy
> stated or implied needs.

Elsewhere and more simply quality. has been defined as the
ability of a service to satisfy a given need. Coupled with
this definition it has been observed that the concept of
quality is not static - constant improvement in quality is
considered necessary to retain (never mind improve) market
share. In some instance quality is associated with a statutory
reqiurement to establish if **a** product or service is fit for
purpose. In this respect our expectations of quality which
were perfectly acceptable 100 years ago are not acceptable
now. When Columbus crossed the Atlantic it was sufficient to
arrive (almost) alive. Now we expect to make the same journey
on shedule with the minimum of discomfortand without damage to
cargo.

Quality - Pinnacle of Excellence ?

Because of the richness of the englisch language we are some-
times tempted to think of quality as the pinnacle of excel-
lence but within the scope the subject we are addressing in
this seminair such thoughts must be discared in favour of the
defenition given in ISO 8402.

The same ISO standard defines quality control as: -

> The operational techniques & activities that
> are used to fulfill requirements for quality.

In other words, quality control is the method by which a manufacturer or service supplier measures and monitors the product during manufacture or supply to make sure that intended standards are maintained. For a manufacturer this will include accurate measurements of components to make sure that parts will fit together and meet intended standards of appearence and performance. For the supplier of a bus service quality control might include monitoring the maintenance of a schedule or perhaps regular inspection of hardware for cleanliness and continued serviceability.

Quality assurance is defined in IS0 8402 as:-

> All those planned & systematic actions necessary to provide adequate <u>confidence that a service</u> will satisfy given requirements for quality.

From this definition it can be seen that quality assurance has demands and requirements additional to those of quality control. To produce confidence in the system or product it may be necessary to provide additional checks and maintain records for both internal and external use.

Good quality control may be seen as an essential ingredient of quality assurance. Indeed IS0 9004 says:-

> A quality management system has two inter-related aspects:-
>
> > a) the company's needs and interests
> > - For the company, there is a business need to attain & maintain the desired quality at an optimum cost:
>
> > b) the customer's needs & expectations
> > - for the customer, there is a need for confidence in the ability of the company to deliver the desired quality as well as the consistent maintenance of that quality.

And what about the "quality" (totality of features etc.) the supplier may be aiming to achieve? This may be stipulated in a contract and/or in the professed standards of the supplier. ISO 9002 in fact requires the supplier to define and document its policy and objectives for, and commitment to, quality in a quality policy. A definition of quality policy is furnished by ISO 8402 as:-

Quality policy: The overall quality intentions & direction of an organisation as regards quality. as formally expressed by top management.

Quality management

But I digress. You have not yet been given a definition of quality management nor yet of quality system. Again ISO 8402 gives definitions for both:-

quality management:- that aspect of the overall management function that determines & implements the quality policy.

quality system:- the organisational structure, responsibilities, procedures, processes & resources for implementing quality management.

The Standard

When we talk about ISO 9002 we should really address a series of quality standards which it is convenient to refer to as ISO 9000 although more correctly this is the first number of a current series of six inter-related standards.

ISO 9000 : 1987 Quality management and quality assurance standards- Guidelines for selection and use.

ISO 9001 : 1987 Quality systems- Model for quality assurance in design/development, production, installation and servicing.

ISO 9002 : 1987 Quality systems- Model for quality assurance in production and installation.

ISO 9003 : 1987 Quality systems- Model for quality assurance in final inspection and test.

ISO 9004 : 1987 Quality management and quality system elements - Guidelines.

ISO 9004-2 : 1991 Guide to quality management and quality systems elements for services.

As you can see from the date suffix on ISO 9004-2 this standard has only recently been published.

In its opening paragraphs ISO 9000 declares its purposes to be two fold:-

> to clarify the principal quality concepts

> to provide guidelines for the selection and use of ISO 9001/2/3 for internal quality management and external quality assurance purposes.

The three models (ISO 9001/2/3) each describe those elements of a quality system considered appropriate by the authors for a specific span of activities. ISO 9001 is considered to be most appropriate in situations where a contract specifically requires design effort and the product (or service) requirements are stated principally in performance terms or they need to be established.'

ISO 9002 is considered to be the most appropriate model for contractual situations when the specified requirements are stated in terms of an established design or specification.

The third model is considered most appropriate for situations where the product is complete and only requires inspection and test before delivery.

For some reason it is often stated that ISO 9001 is the highest or most stringent of the three models. It is not. It simply covers more topics since it must cover the requirements of design and post-delivery servicing.

<u>Criticism of the Standard</u>

In terms of ship management ISO 9002 is considered to be the most appropriate of the three models and it is at this point that a degree of criticism invariably appears. The Press of late has been liberally sprinkled with cries of horror that the Standard is meant for manufacturing industries and doesn't meet the needs of the shipping industry. It is correct that the Standard can be difficult to interpret within the requirements of some industries but it is not correct to say that it is not applicable to services. The Standard is written with the needs of both manufacturing and service industries in mind as can be seen from the several references in 9000 and 9004 to "product or service". The key lies within ISO 9004, especially since the publication in September this year of ISO 9004 part 2 which amplifies the needs of the service industries. ISO 9004 is a much-neglected part of the series yet it is essentially the heart of the

series since it outlines the philosophy behind it. All too frequently users refer solely to the chosen model. ISO 9004 deserves much greater attention, especially when applied to service industries.

An important statement in ISO 9004 is:-

> An effective quality management system should be designed to satisfy customer needs and expectations while serving to protect the Company's interests. A well-structured quality system is a valuable source in the optimisation and control of quality in relation to risk, cost and benefit considerations.

With regard to scope and field of application ISO 9004 says that the selection of appropriate elements in the Standard and the extent to which they are adopted and applied depends on such factors as the market being served, nature of product, production processes and consumer needs.

The main difficulty in applying the Standard so far as third party certification is concerned is not any lack of suitability for the service industries: it is because the Standard and its various models was designed principally for direct contractual situations. During pre-contractural discussions the first and second parties can agree which of the models are most appropriate and within the model which elements, if any, are unnecessary.

As for the suitability of the Standard for service industries it is significant that more than 25 per cent of the certificates awarded by BVQI have been to service companies and it is believed that a similar proportion have been awarded by the other major accredited certification bodies. Some of the areas of activity in which organisations have so far been certificated include:-

> Education
> Road transport
> Legal services
> Consultancy
> Shipbroking
> Ship agency
> Frieght forwarding
> Technical ship management
> Tank cleaning
> Distribution & storage

<u>Certification</u>

When we talk about certification to ISO 9002 we are implying that an organisation's quality system has been tested against this particular quality standard model and, within the agreed requirements of the industry concerned, has been found to comply. This type of certification is somewhat different to the certification of a product (e.g. the issuance of a type approval certificate by a body such as Bureau Veritas or indeed the classification of a ship). Product certification has been with us for years - certainly since the days of Henry VIII with the branding of cannons and since the appending of an assay mark on fine metals. It was perhaps understandable therefore that, with the advent of such a certification procedure to a standard that is somewhat more subjective than those associated with the certification of a product that some attempt would be made to regulate the standards of the issuing organisations. The U.K. and Holland were the first countries to set up formal systems for accrediting certification bodies. Both use the criteria laid down in the European standards EN 45011 and EN 45012 as the basis on which to assess whether or not to accredit a certification body.

The UK accreditation body is the NACCB (National Accreditation Council for Certification Bodies) In Holland it is the RVC.

The NACCB assesses an organisation by examining its quality manual and operating procedures. This includes observing a selection of assessments. Once accredited the certification body is subjected to regular procedural audits by the NACCB .

The certification body is only accredited to issue certificates under the Government Mark for sectors of industry in which it has proven capabilities and expertise. The Department of Trade & Industry publishes a register listing all accredited certification bodies and giving their accredited scope. The certification body may apply for an extension of scope and, given the relative infancy of the system both the list of bodies and their individual accredited scopes are under constant review.

One of the criteria laid down by the NACCB is that all assessments carried out must be led by a registered lead assessor. To gain registration an assessor must have attended

an approved course, passed the course examination and have taken part in a number of quality assessments. In addition the assessor must be professionally qualified, usually to degree level but it is possible to accept alternative qualifications if the candidate has taken part in a greater number of assessments. In this way the national accreditation body sets out to maintain a level of consistency in applying a standard which remains highly subjective.

From the above it can be seen that to date the only certification "watchdogs" are national ones. This is probably the main reason why the major international classification societies have so far worked through comparatively small British registered subsidiaries to issue system certification. As the need for certification becomes more international in nature- as is the case in the marine industry- the case for an international watchdog becomes stronger.

ISO 9002

ISO 9002 is divided into the following paragraphs:-

> Management responsibility
> The quality system
> Contract review
> Document control
> Purchasing
> Purchaser supplied product
> Product identification and traceability
> Process control
> Inspection & testing
> Inspection, measuring & test equipment
> Inspection & test status
> Control of non-conforming product
> Corrective action
> Handling, storage packing & delivery
> Quality records
> Internal quality audits
> Training
> Statistical techniques

While these are the 18 main paragraph headings we could re-group them as:-
> THE CONTRACT
> THE MANAGEMENT & ORGANISATION
> QUALITY CONTROL
> RECORDS

AUDITING, REVIEW, IMPROVEMENTS
TRAINING

The contract

The contract is a good starting point not only for us but
also for the assessor. It is the "contract" which determines
the "totality of features etc." This determines the stated or
implied needs.

The Standard requires the supplier to have procedures for
reviewing the contracts it enters into with clients. The
object of the review is to ensure that the requirements of
the contract are adequately defined and documented. that any
requirements differing from the tender are resolved and that
the supplier has the capability to meet contractual
requirements. Later, where the Standard talks about process
control it can be seen that the supplier must identify and
plan the service procedures which directly affect the quality
of its services. It also obliges the supplier to ensure these
processes are carried out under controlled conditions.

From a study of the contractual obligations entered into by
the company and with knowledge of the services the company
claims to offer the assessor can gain some idea of the range
of processes which the company's quality system might need to
control. The assessor must then conclude which of these
procedures might be expected to be documented.

Suppose for example that the company has signed a BIMCO
Shipman agreement and has agreed to provide Technical
Management and Crewing services, as defined in the standard
BIMCO form.

In such a case the assessor would expect to find written
evidence that the company had addressed all parts of the
BIMCO form and verified that it had the ability and facility
to meet its requirements together with any agreed riders
placed on it by the client.

Furthermore the assessor would look for evidence of company
procedures and specified requirements for:-
            -locating and selecting competent crewing sources
            -verifying that these sources were sourcing
             personnel in accordance with specified
             requirements
            -monitoring performance (of crewing source
             and of personnel provided)

-arranging prompt and reliable delivery of crew
  to and from vessel (sourcing suitable travel
  agents
-specifying and monitoring training requirements
-specifying shoreside skill and competence levels
-drawing up repair/conversion specs
-vetting and placing drydock and voyage repair
  subcontractors
-verifying efficacy of repair work
-following class and statutory requirements
-issuing specific and necessary operating
  procedures and standing orders (e.g.cargo hold
  cleaning, planned maintenance schedules, fabric
  inspection rotas
-checking and recording the continued operations
  of the crew and the condition of the vessel.

The assessment

When a certification body assesses a company to the Standard
the process is quite simple. The company makes a written
application to the certification body stating the model which
it seeks to be certified to and the scope of it's activities.
At this stage it is important that the company establishes
that the certification body it selects is accredited for the
scope of activity concerned. If it is not then the
certificate subsequently issued cannot carry the national
quality management system mark.

The procedure followed by BVQI is to first review the
company's quality manual to see if this covers the
requirement of the model. The manual should be submitted for
review at least six weeks before an assessment visit is
required. If the quality manual does not contain a list of
the procedures currently operated by the company then such a
list should be drawn up for submission with the manual. If
some areas are not clear, or clearly do not comply, the
company is advised in writing. It may be necessary to modify
the quality manual prior to the assessment proceeding.

The manual assessment is carried out by an assessor nominated
to be the team leader who, based on the preliminary
examination of the quality manual and the questionnaire
completed by the applicant will get together an assessment
team and draw up an assessment timetable. Depending on the
size of the company and the geographic placement of its
vessels the team will usually be not less than two nor more
than three assessors.

The assessment starts at the administrative office of the company, with a meeting chaired by the team leader and attended by the company's senior management and the members of the assessment team. The main objectives of this meeting are to confirm the scope of the certification, explain the procedure to be followed during the assessment of the offices and selected ships and to discuss any specific requirements or difficulties with the proposed timetable.

The team then splits up to carry out the assessment as far as possible within the agreed timetable. It may be necessary for the company to provide each member of the assessment team with a guide to take the assessor from one department to another. It is preferable that these guides are familiar with the Standard and with the various company procedures.

The assessors visit the appropriate departments of the company to ensure that, based on a random sample, all relevant areas of the Standard are covered. Some departments can be expected to be tested against more parts of the Standard than others.

If the assessor discovers that relevant parts of the Standard have been ommitted or are not being effectively implemented he will immediately advise the appropriate section head or the appointed guide of the nature of the non-conformance. Set times will be appointed during the assessment at which the assessment team will confer. At these sessions, if time permits, the assessors will draw up formal non-conformance reports and hand them to the company's appointed quality representative. Each non-conformance is presented on a separate but brief report. This report states the paragraph of the Standard concerned and states the nature of the non-conformance. The company has the opportunity to sign that it agrees with the non-conformance and space is provided for the appropriate person in the company to propose a corrective action. The report is drawn up as soon as possible since in many instances it is possible to clear the non-conformance before the first part of the assessment is completed.

In any event at the end of the assessment of the company's offices the team leader, in conjunction with members of the team, draws up non-conformance reports for each of the non-conformances witnessed together with an overall summary of all of the reports. A closing meeting is then held together with representatives of the client's senior management at which the team leader advises whether or not

there are outstanding non-conformances and discusses the course of any outstanding corrective actions. At this stage the team leader will select which vessels the team wishes to see. In general a ten per cent sample will be selected but where several distinct types of vessel are concerned (e.g. a mixed fleet of ro-ros and gas ships) the sample must be representative of the whole fleet.

A timetable will be drawn up and suitable dates arranged. Generally from one to two man-days should be allowed for each vessel. Assessment of the vessels will follow a similar form to that at the company's office and any non-conformance reports will be handed over to the company quality representative immediately on completion of each vessel assessment.

When all of the selected vessels have been assessed an overall summary will be forwarded to the senior management of the company. It has been found in practice that in most instances outstanding non-conformances can be cleared by correspondence but occasionally it may be necessary to return to the site of the non-conformance to verify that the corrective action was truly effective.

Maintenance of Certification

Certificates are isued with a validity of three years and are subject to satisfactory six-monthly surveillance visits. These visits are planned such that all relevant parts of the Standard are addressed over the three-year period. The visits will also be planned to include several of the company's vessels over that period. Usually vessels other than those seen in the initial assessment will be selected.

Ship management certification

Although this paper is principally about the application of ISO 9002 to ship management it is opportune to say something about the Bureau Veritas Ship Management Certification Scheme. While this scheme utilises some of the concepts of ISO 9002 it is not intended to comply with the Standard in full. That is why the scheme is offered by Bureau Veritas and not by BVQI.

 The main objective of this scheme is to assess a company's management systems to see whether the safety and environmental pollution management requirements of IMO are being met. The scheme was introduced as a response to the

publication of IMO Res 647 (16) with the object of providing companies who so wished with a Certificate of Conformity stating that as far as could be ascertained by an independent assessment the company was meeting the requirements of that Resolution. At the time of presentation of this paper the original Resolution has been revoked and a broader document has been developed. There is now some pressure from some Administrations to make the new requirements mandatory. It must be clearly understood however that while some parts of 'the Resolution bear a passing similarity to some parts of ISO 9002 the Resolution is not a quality standard; neither is the possession of an ISO 9002 certificate any guarantee that a company is effectively implementing the requirements of the Resolution unless of course the company has built in the requirements of the Resolution into its quality policy statement and the issued certificate has taken it into account. The Bureau Veritas Ship Management Certificate is intended for those companies who do not wish to or **are** not ready to implement the requirements of ISO 9002 but who want to be satisfied that they comply with the safety and environmental protection requirements. Nevertheless we have utilised those aspects of ISO 9002 which we consider provide a basic operating system against which an assessment can be made.

Benefits

Finally I would like to say something about the benefits of the ISO 9000 series to ship operation.

As a buyer (and it must not be forgotten that owners are major buyers) knowledge of the standard increases your negotiating power when purchasing. It provides you with a tool to compare the probabilities of several suppliers to consistently provide the service or product you require. By buying from certificated companies you can reduce your own inspection requirements.

As a supplier the Standard provides you with a valuable management tool, reducing or eliminating wasteful effort and providing a means of continually assessing your procedures. Moreover, by having your quality management system certified by an independent body you can demonstrate both inside and outside your company that your quality management systems meet an Internationally recognised standard.

MANAGEMENT SYSTEMS IN SHIPPING:
QualitY or Safety Management, do yоu follow IMO or ISO?

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ABSTRACT

Quality Assurance, Quality System Certification, Quality Management and Safety Management are terms more and more commonly used in shipping. Each of them represents different aspects of two trends that shipping companies must face: "Quality" and "Safety".
Both lack of Quality and lack of Safety can be considered as a cause of financial losses to a company. They are however of a significant different origin. Quality is entirely market driven where safety is the avoiding of damage to the vessel, the people on board, its cargo and its environment.
Although there are common causes why losses occur and hence some overlaps there also exist considerable differences between the management of quality and safety.
The purpose of this paper is to illustrate these similarities and differences and to place both Quality and Safety in shipping in perspective.

SUMMARY

Det norske Veritas, the norwegian classification society, has been in
the front line of technological Safety at sea for over 125 years.
Already in the early eighties however it was recognised that over 80% of
all marine accidents do not originate from a technological cause, but
result from what is called the "human error".

Based on its world wide experience with Quality assurance in the shore
based industry, extending over more than 15 years, DnV is of the opinion
that more than 95% of these human errors are caused by lack of
knowledge, lack of skill, lack of instruction or lack of motivation of
the people involved. In other words human error is to be seen as the
symptom of a failure in the management system, and not as the real cause
of accidents.

NUMBER
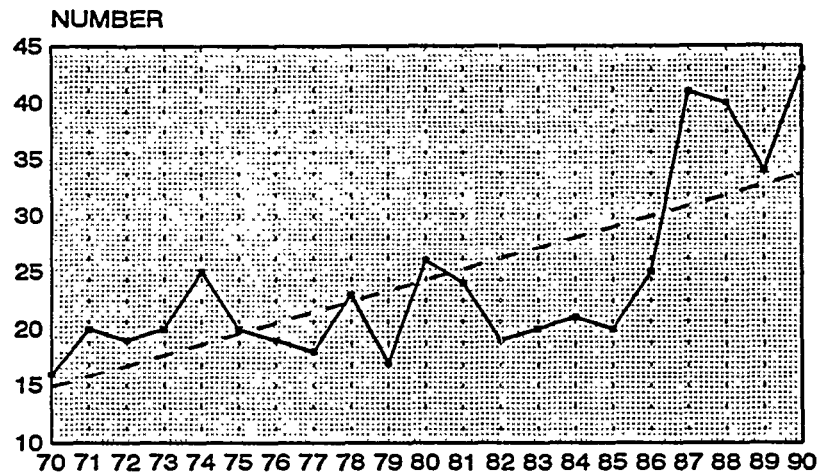
SHIPPING CATASTROPHES 1970-1990 990

From Herbert Fromme. Bonn

This justifies the conclusion that 80% of all accidents in shipping are
caused by failures in the systems through which vessels are managed.
Therefore DnV has issued its own tentative **rules** for the "Management of
Safe Ship Operation and Pollution Prevention" in July 1990.
This adds an other standard to the numerous standards the industry has
been confronted with in the recent past. DnV is however of the opinion
that none of the standards, adopted within shipping up to now addresses
Safety specifically enough, whilst at the same time leaving the
operators sufficiently freedom to find organisational solutions which
suit their own organisation.

Whereas the DnV Rules are based on the principle that management shall
systematically work to avoid "unsafe conditions", "unsafe acts" and to
"maintain emergency preparedness" at all times", the Rules allow other
standards to be added at the same time.

Where IMO, port states, insurance companies, charterers and others in
the game tend to come up with seemingly conflicting requirements towards
the management systems of ship operators this last aspect is of great
importance

On the other hand it is to be expected that within short time IMO will adopt a common Safety management system standard for the maritime industry, the Safety Management code which will be made compulsory for large parts of the world fleet. As a consequence many of the standards, being used today will most likely disappear or be modified to conform the IMO requirements.

Due to the specific nature of shipping DnV has opted not to use its existing organisation, which mainly is engaged in Quality System Certification for the manufacturing industry-

Technical

.... Human

Procedural

1840

Technical

Human

Procedural

1990
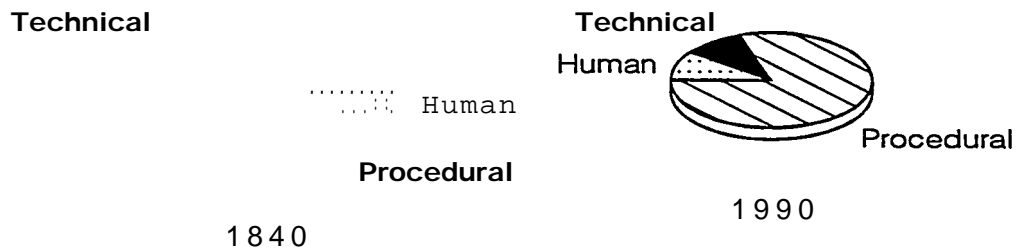
BASIC CAUSES OF SHIP LOSSES

DnV uses people with experience in shipping which have been specially trained to understand and appreciate the specific problems which the shipping industry has in the management of safe ship operations.

DnV is able to certify that a Safety management system complies to its own tentative rules. These Rules cover the existing IMO guidelines completely. In addition a certificate can be issued that the management system meets the requirements of the ISO standard, if required by one of its accredited organisations.

Since Safety and Quality management systems are new to many companies, DnV also can assist in providing its experience in the development of the system. This however is done at arms length in order not to compromise DnV's integrity.

MANAGEMENT SYSTEMS

Ships get damaged; cargoes contaminated, people hurt or killed, clients are lost, beaches are polluted.
This not only represents a significant cost to the shipping industry, either direct or by ever increasing insurance premiums, but it is giving shipping a bad reputation with the broad public.
Politicians react on this and the result is a continuous tighter system of requirements and regulations from authorities and port states and more intensified inspections which the industry has to live with.
The progress made in technology has given an ever increasing improvement of maritime safety and service quality. However in spite of this improved technology, accidents continue to occur with what seems to be increasing financial losses to the individual owner or his insurance companies.

It has been recognised already some decades that over 80 % of what goes wrong in every sector of industry is not the result of failing technology but the ultimate result of failing human behaviour.
Further investigation has learned that only less than 5 % of this human failure can be classified as the so called human error, the error which happens whilst the person know5 and is motivated to behave correctly.

Considering that instructing people how to act and to motivate people to comply to their instructions is a management task, this justifies the conclusion that around 80 % of all accidents are the result of failing management.

This view has resulted in an increasing tendency with authorities, insurance companies, charterers and other interested parties to obtain more confidence that management has adequate control over the behaviour of the people they manage.

Since this behaviour is primarily depending on the companies policy towards quality and safety and the procedures and working instructions which detail these policies down to work floor level, the requirement that these policies, procedures and working instructions are properly documented is rapidly increasing.

POLICY	WHAT WE WANT
SYSTEM	HOW WE ORGANISE AND CONTROL
PROCEDURES	WHO DOES WHAT WHEN
INSTRUCTIONS	HOW

HUMAN BEHAVIOUR
SAFE ACTS/CONDlTlONS
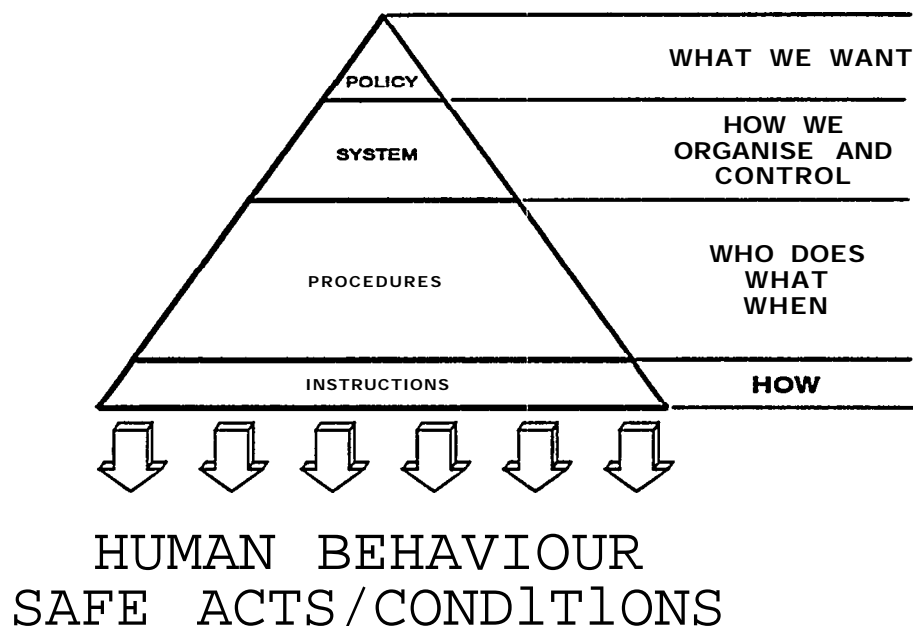
The principles behind management systems

These policies, procedures and working instructions shall be assembled in a systematic way in what is called a Safety- or Quality management system.

The most known requirements which ship managers are confronted with are IMO Resolution A647(16) (Safety Management) and ISO 9000 (Quality Assurance and Quality Management)

QUALITY ASSURANCE AND QUALITY MANAGEMENT'

Quality is realised when a client has the perception that a suppliers delivery meets his expectations.

This implies that the three aspects which needs to keep control of in managing quality are:

> The perception the client has of the suppliers products/services
> The expectation the client has to the suppliers products/services
> The noticeable characteristics of the supplied products/services

During the past decades shore based industry has massively adopted a strategic view on the quality of their products/services since they realised that customer satisfaction was a pre-condition for their commercial survival.

In addition analyses has shown that as much as 30 % to 40 % of their turn-over was lost due to non-quality, resulting in rework, scrapping of products, after sales services, lost management and commercial efforts etc.
This made them realise that substantial savings could be achieved by replacing the traditional final inspections by in-process inspections in order to verify that the products/services still comply with the specified requirements. If needed corrections can thus be made before unnecessary value is added.

Because they were aware that non-quality is the result of human behaviour they realised that they had to include their policies and procedures which should achieve their strategic and cost-saving objectives in management systems. Since the requirement to have an implemented Quality System also became an element in the commercial interaction between companies, the industry has achieved an almost world wide consensus through the International Standardization Organisation on one common standard to which these Quality Systems should comply, i.e. the ISO 9000 standards.

These standards are commonly used by both manufacturing and the service industry and are now so widely accepted that shippers of goods start to require from the maritime sector to comply with this standard as well. This because shipping is one of the many services they buy, and they want to have the confidence that the shipment of the goods, either bought or sold, does not lead to deterioration in quality.

The result is that more and more ship operators are getting faced with the requirement that they have to comply with the ISO 9002 standard. This standard however does not refer to safety or pollution prevention at all and every attempt to restructure the ISO standard to include safety as an additional issue has in our opinion created a standard which may be implemented in the management company ashore, but is impossible to implement onboard ships.

This is, because the shore based organisation of a ship operator has some similarity with other shore based industries. The operation of the vessel however, and the unique roll the master has, is entirely different to any other industrial process.
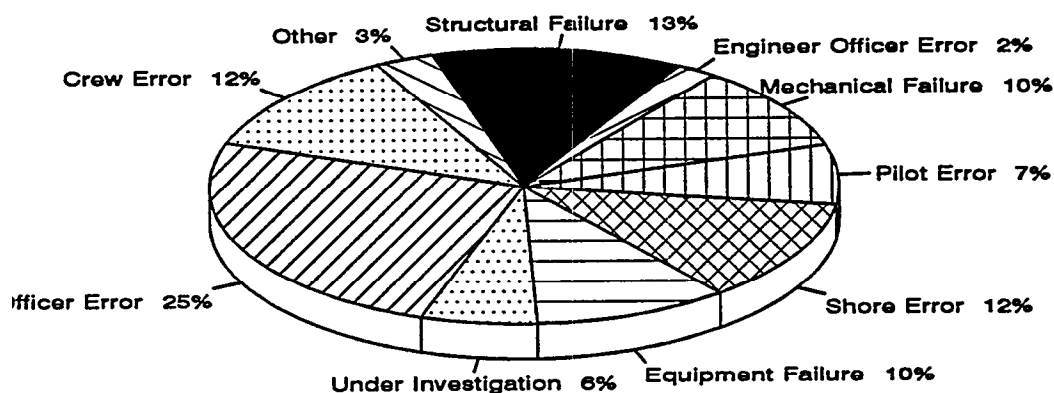
This criticism even is applicable to the ISMA Code, a very worthwhile initiative of a group of ship management companies (known as "the group of five") which resulted in a derivate of the ISO standard. In defence to alleged criticism to the quality of their services the International Ship Managers Association has made compliance to the requirements of the ISMA Code a condition to their membership.

SAFETY MANAGEMENT

Safety in the shipping industry is realised when any damage to the vessel, its crew, its cargo or its environment is avoided.

Society at large, especially in the western countries, is getting more and more demanding towards the quality of life and gets more aware of the limitations which industry puts on them in this respect. Telecommunication technology has been confronting them with the most dramatic consequences of disasters as with the Herald of Free Enterprise, Scandinavian Star, Exxon Valdez, what happened off Genoa last year and many others.

This has triggered public criticism towards the way safety of ships operations is managed.

Other 3%   Structural Failure 13%   Engineer Officer Error 2%
Crew Error 12%   Mechanical Failure 10%
                                    Pilot Error 7%
Ifficer Error 25%   Shore Error 12%
Under Investigation 6%   Equipment Failure 10%

Result of a recent analyses of 918 P & I Claims > £ 100.000 by the U.K. Club
CAUSES OF MAJOR CLAIMS

In turn this resulted in a political reaction which not only led to debates about double
hull/double bottom concepts for tankers or other technological safety barriers, but also the roll of the human element in all these maritime disasters has been extensively emphasised. Inevitably this has resulted in politicians and authorities criticizing the quality of the management of ships operations.

In response to this a resolution was adopted within IMO, known as res. A647(16) and which may seem to be only a "Guideline for the Management for Safe ship Operation and Pollution Prevention" but should be seen as a very strong signal on how the thinking within regulatory bodies will develop in the future. The guidelines under IMO A647(16) call upon the shipping community to develop and implement management systems in their companies to take proper control of safety and pollution prevention.

A number of port states have interpreted this signal and since short a Safety Management System is mandatory for all vessels carrying passengers in Norwegian waters. Other North-European port states are working on incentive schemes in which safe vessels get benefits in reduction of harbour duties, priority in pilotage etc. In these schemes an implemented Safety Management System scores high credits.

A different approach has been taken by the U.S., who in response to the Exxon Valdez accident, through the Oil Pollution Act 1990 have put repressive and unlimited financial consequences in front of the ultimate owner of any vessel that can be held liable for the pollution of American water.

In addition to this extensive policing has been implemented on vessels entering U.S. waters. Realising that this reactive approach is to labour intensive and not fully effective, they started to work on "greatly simplified inspection processes", based on the USCG "model company concept", which requires a Safety Management System to be implemented as well.

For the insurance sector Oil Pollution Act 1990 ads new uncertainties in times that substantial losses are suffered in the maritime sector as well. Consequently insurance companies start to look more critically at ship management. Since short signals are vented that premiums should be more in line with the actual risk for the insurance companies and that this risk should be based on a more forward thinking risk assessment instead of retrospective statistics.

Now already a some insurance companies use pre-assessment of the ship operators Management System as a main tool in assessing their risk (and possibly rejecting it). When this policy proves to be economically successful this trend will be taken over by others.

In addition a number of operators started to realise that not only increased insurance premiums will put pressure on their competitiveness. They also realise that most of the small damages below their franchise limits, which up to now they have accepted as being inherent to the business they are in, can be reduced by limited investments and consequently can increase their profitability dramatically.

THE DnV TENTATIVE RULES

Based on its extensive expertise with Safety and Quality Management Systems together with its independent position DnV launched its own Rules for the "Management of Safe Ship Operation and Pollution Prevention" in July 1990 to serve the maritime industry, which contains so many different-interests.

These Rules encompass the IMO Guidelines entirely and specify in global terms how the requirements in these guidelines can be met.

They require that to obtain a certificate the company shall have policies towards the safe operation of its vessels and these policies shall be detailed in procedures and instructions.

There shall be a management system which clearly defines responsibilities, reporting lines and working methods and which shall not only cover the ship board organisation but the shore based organisation as well. This because within todays ship management the

influence of shore based management on the ships operations is so big that safety on board is bound to be affected from ashore.

ASPECTS
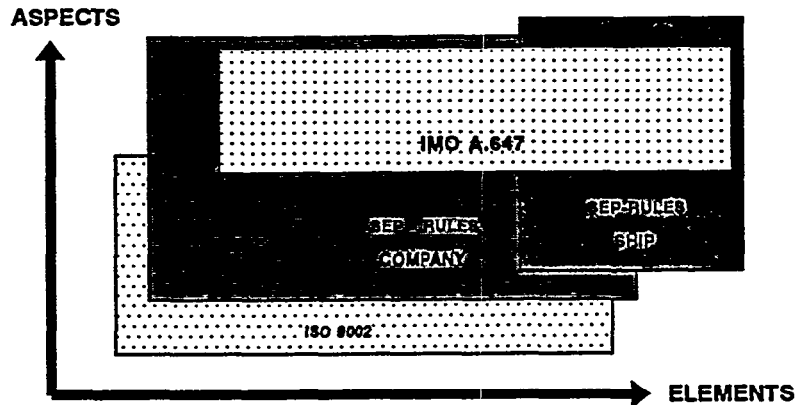
Different Management Standards in Shipping and how they overlap

However the unique position of the master being ultimately responsible for the safety of the vessel is maintained. In addition he is assumed to be the manager, being responsible for the management system on board within the companies policies

Contrary to many other standards which are emerging in the shipping industry the DnV rules are not intended to be a straight jacket but are formulated in a global manner in order to allow companies to find their own organizational solutions.

Based on the philosophy that every trade has its own characteristics and that no two companies are the same the Rules allow operators to base their management system on their existing organisation and working procedures. It is required that the operator shall analyze the risk in his operations in a systematic manner and create the necessary organisational safeguards against the accidents which are most likely to happen.

This selection of *"the vital few and the trivial many" is* considered to be one of the most essential aspects in the development of management systems.
The amount of paper shall be kept to the absolute minimum!
It shall be avoided that procedures are developed for activities which are trivial to safety. This has a negative effect on the acceptance of procedures and adversely influences the safety behaviour of people.
Besides care shall be taken that procedures or instructions shall not replace the existing skills of people. Either such procedures are not accepted or, what is even worse, they contribute to the reduction of skills after some time. The *use* of check lists for routine operations is recommended in stead.

In selecting "the vital few" activities which are crucial to safety managers shall assess all activities in their operations to the key requirements in the DnV Rules, i.e.:

*   Safe Practices
*   Safe Conditions
*   Emergency Preparedness
both ashore and on board, are maintained at all times.

The DnV Rules is the only standard which requires explicitly that the management of ship operations shall:

*   Comply to mandatory Rules and Regulations.
*   Observe industries own perception of safe practices, as laid down in industry guides and standards.
*   Management apply their minds to safety to identify possible additional hazards not covered by regulations or standards.

The DnV Rules are formulated in a way which allows flexible interpretation. They are based on general loss-control principles, assuming Accidents and Pollution to be the main losses to be controlled. Because some of the administrative elements from the ISO standard have been adopted
this easily makes it possible to define Quality as a potential loss in addition.
This gives full opening to include requirements from other standards to the management system, which allows for certification to different standards at the same time.

DnV EXPERIENCE WITH SAFETY MANAGEMENT CERTIFICATION

The DnV Tentative rules for Management of Safe Ship Operation and Pollution Prevention were issued in July 1990.
So far, 6 companies have passed certification. More than 30 companies have signed contracts for future certification when system development and implementation is completed.

To keep in contact with an experienced auditor during system development, and get feedback as system elements are worked out, is a definite advantage to the companies.

Development based on project plans, and being committed to specific milestones, assists in keeping up the pace and in providing commitment from management and participants. Working against a fixed date for the implementation audit is particularly important in this respect.

Even if the audit shows that many system improvements have to be performed, the companies do not consider this as a negative experience. On the contrary the findings of an external auditor tend to support motivation for system development and implementation.

Contrary to what some people believe most auditees consider the audit to be a pleasant exercise. One explanation may be that most people find pleasure in discussing their work with others-and that is what an audit is, planned and structured job discussions.

The audits have confirmed that perhaps the most important qualification an auditor should have is the communication skills, particularly the ability to listen to and understand people. However, one of the conditions for that is a thorough professional understanding of the area subject to audit.

Establishing the audit capacity that the possible enforcement of mandatory requirements of safety management will require is a major undertaking that should not be underestimated. Audits should support motivation and promote safety awareness-even if they reveal much that must be improved.

FUTURE DEVELOPMENTS

Maritime industry for the time being shows a hesitant attitude towards accepting Management Systems as a valuable tool to their operations. This has been seen in shore based industry before and it is to be expected that more and more operators will recognise that a management system is not a limitation to the SO much appreciated freedom of the ship manager, but an asset which generates revenues.

The driving forces behind "Quality System Certification" are commercial, strong and self-sustaining-and for the moment quality system certification gets most of the attention.

In a longer time perspective, however, the impact of Safety Management development may very well be the most important one.

At its meeting in May 1991, the IMO Maritime Safety Committee (MSC) decided to develop mandatory requirements to Safety Management. The IMO Guidelines were not suited for certification of Safety Management. Consequently, MSC also decided to work out the "International Safety Management Code".

To avoid too many different Management Standards being imposed on the industry development within IMO of the "International Safety Management' Code" should be supported. This is the organisation most likely to succeed in providing harmonisation throughout the industry.

In making this code mandatory throughout the industry some crucial questions still have to be answered.

*   How long time will the shipping industry need for its views on Safety Management to mature?
*   How longtime will be needed to establish the enforcement capacity that mandatory requirements will demand?
*   How long will the shipping industry need to respond to mandatory requirement5 to safety management?

Other just as important questions are:

*   Can safety management be implemented through mandatory requirements at all?
*   Have more positive means to ensure the support from the industry that is required?
*   Should the Maritime Administrations and others choose a strategy of "carrots" to those who succeed in maintaining high standards and "sticks" for those who do not?
*   If the industry organizations support the development towards mandatory safety management requirements will this than stop the increasing development of detailed technical and operational requirements.

The answers to these questions should be based on maturity and experience and not on prejudices and misconceptions. Safety Management development represents a new area in shipping. Success is vital. If the industry needs time, then time should be given.

NUMERICAL SIMULATIONS OF THE DUTCH-JAPANESE FULL SCALE SHIP COLLISION TESTS

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ABSTRACT

One of the reasons for setting up the Dutch-Japanese full
scale ship collision project was the verification of a
methodology that had been developed for the numerical simu-
lation of collisions of Dutch inland waterway vessels.
A total of four ship collision tests have been performed
with two fully instrumented ships to obtain verification
data.
Each of these tests has been simulated using the numerical
methodology in which the structure-structure interaction is
computed with MSC/DYNA, an explicit finite-element program
which enables the full simulation of the dynamics of the
collision events. Fluid-structure interaction is taken into
account by means of a system of springs and dampers, of
which the characteristics are determined using the
MSC/PISCES program.

This paper describes the numerical methodology that has been
used for the numerical simulations of the full scale colli-
sion tests.
For each of the four numerical simulations, the computed
collision process and resulting damage will be shown.
The computations were successful in simulating the main fea-
tures of the collision process and the resulting damage, like
hole size and penetration depth.

INTRODUCTION

Explicit transient finite-element simulation is since many
years a powerful tool in the design and development process
in defense-, aerospace- and automotive industry. Especially
in the field of safety analysis (e.g. car-crash) this tech-
nology has been heavily, used during the last few years. The
use of numerical simulation allows the investigation of dy-
namic phenomena and also suggests directions to optimize the
design of a structure. Until recently, transient dynamic
finite-element analysis of ship collisions did not play an
important role in safety studies for ship transport.
The increasing concern regarding environmental damage and
casualties as a result of ship accidents, has led to the de-
velopment of a numerical methodology that has been employed

over the last two years to numerically simulate collisions of Dutch inland waterway tankers. These numerical simulations were performed to compute the amount of damage (e.g. possible hole size) for estimating the probability of a loss of cargo from a double hull tanker.

No experimental data was available for comparison and verification of the obtained results and the Dutch-Japanese full scale collision project was set up to provide this verification data for the numerical methodology.
Four full scale collisions were performed with two Dutch inland waterway tankers. The first two collision tests were carried out on an unmodified (single hull) ship and the last two collision on a modified (double hull) ship. During the third test the double hull was stiffened with stringers and in the fourth test these stringers were replaced by a stringer deck between outer and inner wall. A complete description of the experiments is given by Vredeveldt [1992].

NUMERICAL   METHODOLOGY

General   outline
This section will concentrate on the numerical methodology used in the ship collisions simulations. This methodology has been used for each of the four ship collision simulations and consists of three separate computations.
In a first step the collision of both ships is computed as a pure structure-structure interaction problem without the influence of the water. In this step both ships can move freely in a horizontal plane only. The collision process is computed by employing the three-dimensional explicit transient dynamic finite element program MSC/DYNA. The result of this step 1 calculation is a first estimate of the time-dependent collision force.
In a step 2 calculation this collision force is applied to a rigid (undeformable) model of the struck ship that is afloat in water. By employing the explicit transient dynamic finite difference-finite volume MSC/PISCES program, the motion of the ship under influence of the collision force is computed. This motion yields an estimate for the magnitude of the time varying water resistance force acting on the struck ship during the collision.
The step 3 calculation again with the MSC/DYNA code is the final collision calculation in which the water resistance force from the step 2 calculation is taken into account by a system of springs and dampers attached to the numerical model of step 1. During this simulation there is no constraint on the motion of the struck ship any more. Under influence of collision force and water resistance force the struck ship will have a three-dimensional translational and rotational motion.

Structure-structure collision calculation (step 1)
In this calculation the three-dimensional MSC/DYNA program
is employed. This program has extensively been used in im-
pact and penetration problems and car-crash analysis and is
therefore a logical choice for the use in ship collision
analysis. Available are volume-, shell-, beam- and rigid
elements for the modeling of ship structures.
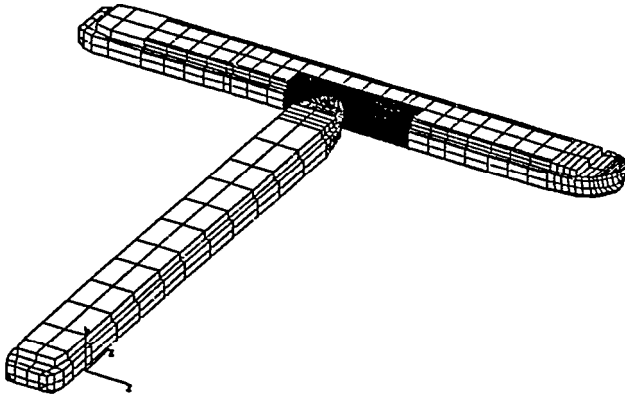The ships that are investigated have a length of about 81 m.

Figure 1 Numerical model layout

and a cross-section of
8.15 m by 3.95 m. For
reasons of computer time
reduction, the ships are
not completely modeled in
detail. Only in the col-
lision region (half of
the ships width and over
a length of 18 m)the
struck ship has been mod-
eled in detail with shell
and beam elements as a
deformable structure. The
remaining part of the
ship has been modeled as
a undeformable rigid body

A typical model layout is given in Figure 1.
In the collision region every sub-structure of the ship is
modeled in detail and all stringers, frames, stiffeners and
plates are taken int0 account (cf. Figure 2).
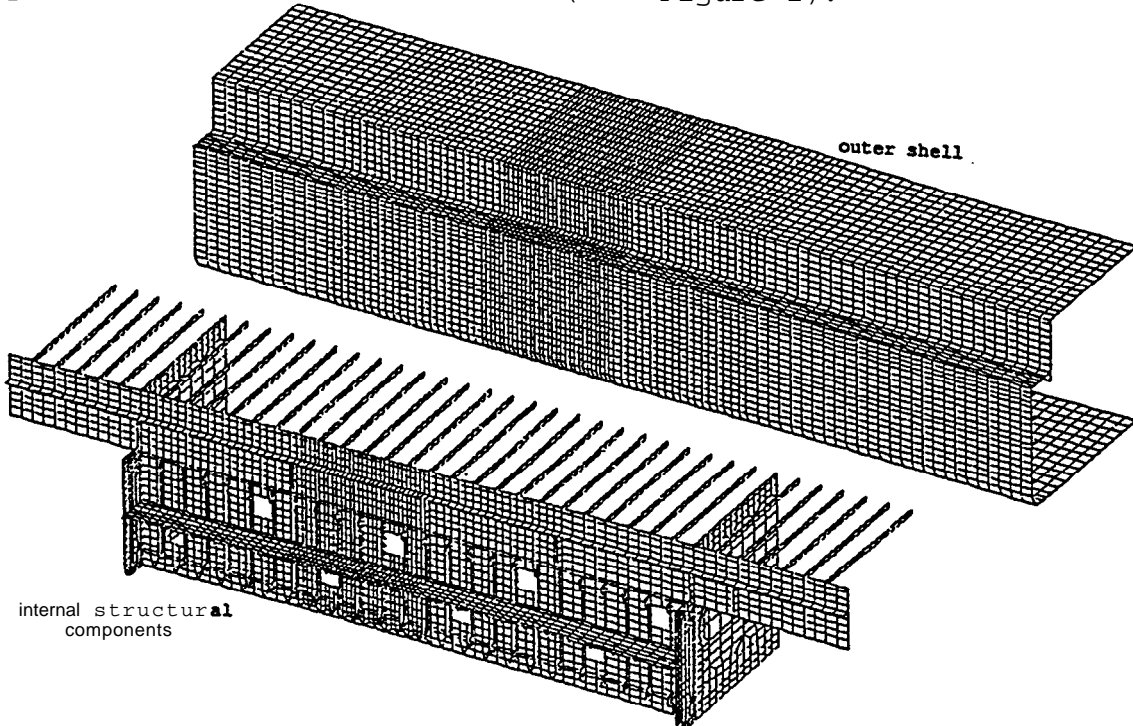
Figure 2 Detailed numerical meshing in the collision area.

The whole striking ship is modeled as an undeformable rigid body without internal structures,.

The structural interaction between struck- and striking ship is computed by using a contact algorithm. The shell elements of the bow of the striking ship and the collision region of the struck ship are defined to be contact surfaces. These contact surfaces provide a very simple and flexible way of modeling the interaction between parts of the finite element model, allowing continuous contact between deforming bodies. Initially the contact surface of the bow and the struck ship are distinct and separate. At each time-step it is checked if gridpoints of the contact surface of the bow have penetrated the contact surface of the struck ship. If none have, then the calculation continues. If they have penetrated, then forces are applied normal to the surfaces to prevent further penetration of the contact surfaces (cf. Figure 3).
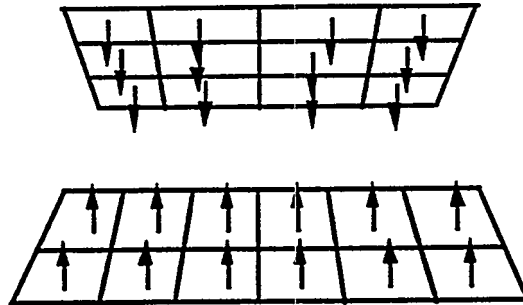
Figure 3 Forces exerted on the contact surfaces.

The magnitude of the forces depends on the amount of penetration and the properties of the elements at both sides of the contact surface.

The MSC/DYNA User- and Theory manual provide more background on the use of contact algorithms (see "References")

The hull of the struck ship will be loaded by the striking ship and deform severely during the collision process. The elements in the numerical model have an elastic-plastic material behaviour with yielding that takes strain-hardening into account. A numerical element will fail after reaching a pre-defined maximum plastic strain (20% in these simulations), which means that the element has broken and that the stresses in the element are put to zero and that it can not take loading after that time.

Material behaviour itself was not a parameter to be studied, but a wide range of material models are available.

A typical result of a step 1 calculation (for test 4) is given in Figure 4.

Figure 4   Time history of velocity
of the colliding ships.
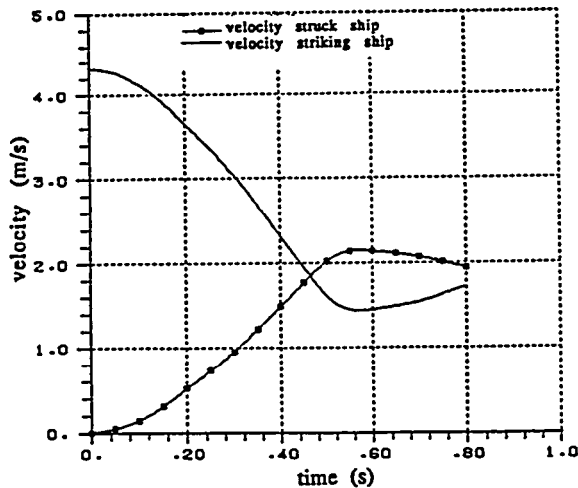
The collision (without water) is over after 0.45 s. After that time the struck ship will move faster than the striking ship and the plastic deformation process has come to an end. The collision force can be obtained from the deceleration of the striking ship and will be used in the step 2 calculation to obtain the water resistance force.

Water resistance calculation (step 2).
During the collision the struck ship will mainly get a translational motion and a rotation along its longitudinal (roll) axis. The rotation along the vertical- and transverse axis will be very small. For this reason and also because more than 90% of the struck ship has a prismatic cross-section, the water resistance force acting on the struck ship can be obtained by using a two-dimensional cross-section floating in water and computing the motion of this cross-section with the MSC/PISCES computer code.

This program uses a two-dimensional explicit finite volume method and has been heavily used in dynamic fluid-structure interaction. The water is modeled in an Eulerian frame of reference, which means that the computational mesh remains fixed in space and time, with the water moving from cell to cell. The cross-section of the struck ship is modeled as a rigid body and will act as a continuously moving wall boundary for the water in the Eulerian mesh. The water then acts as a continuously changing external pressure boundary at the surface of the cross-section.

The MSC/PISCES User- and Theory manual [see "References"] provide more detailed information about the fluid-structure coupling mechanism.

This two-dimensional approach is not a limitation of the current numerical methodology. In case of a 3-dimensional motion of the struck ship through the water, a three-dimensional version of the MSC/PISCES program (MSC/DYTRAN) can be used, but for the 4 collisions under investigation the use of a two-dimensional approach is very cost effective and can be justified as discussed above.

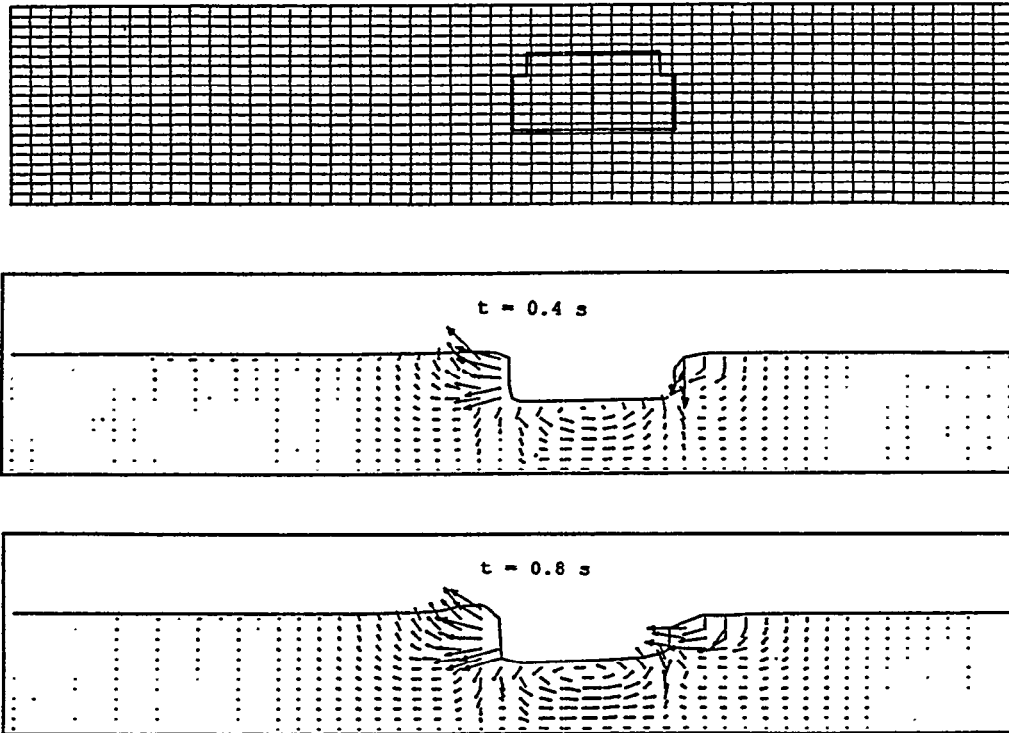The numerical mesh of the ship and water that has been used in the step 2 calculation is given in Figure 5.

Figure 5   Initial numerical mesh and velocity vectorplots at different times for the step 2 computation.

Initially the ship is at rest and floats in the water. The time-dependent collision force of step 1 is then applied to the struck ship. The ship will now move under influence of this force and the resistance of the water. In Figure 5 the two-dimensional motion of the struck ship through the water is visualized.

The water resistance force F_w (per unit length) can be computed from:

$$F_W = m_S * a_S - F_{cl} \qquad (1)$$

where m_s is the mass of the cross-section, a, is the acceleration of the cross-section found in the two-dimensional calculation and F_{cl} is the collision force (per unit length) from step 1 that is applied to the two-dimensional cross-section.

Final combined fluid-structure calculation (step 3). This simulation is the last calculation and yields the final solution of the ship collision problem in which the influence of water is taken into account by a system of springs and dampers (cf. Figure 6).
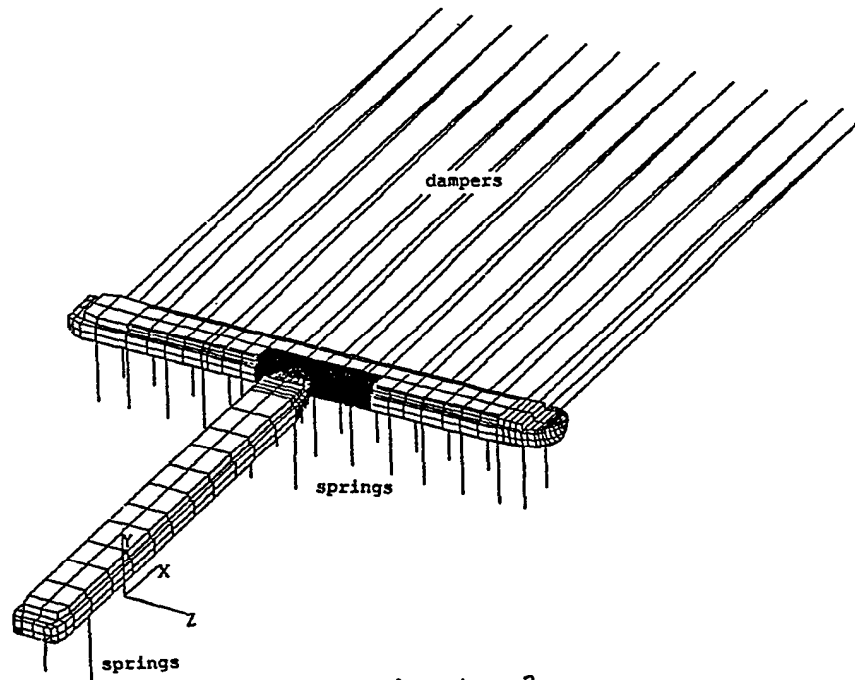
Figure 6   *Numerical modeling for the step 3.*

The water resistance force is modeled by 26 dampers attached to the unstruck side of the struck ship. The characteristic of these dampers is obtained from the horizontal force found in step 2 as a function of velocity of the struck ship. The total force is obtained by multiplying the water resistance force per unit length of step 2 with the length of the ship. This total water resistance force is divided evenly over all 26 dampers, thus all dampers have the same characteristic. This approach neglects the three-dimensional end effects at the bow and stern of the struck ship as mentioned before.
To allow the ship to have roll motion, a system of 26 springs are attached to the bottom of the struck ship. These springs model the static hydrostatic upward forces according to the formulas below:

$$f_1 = \frac{\rho g}{6 \, \mathrm{Cos}\varphi} \left[(2h_1 + h_2)\, B + \frac{h_1^3 - h_2^3}{B \, \mathrm{Cos}^2 \varphi} \right] \quad (2)$$

$$f_2 = \frac{\rho g}{6 \, \mathrm{Cos}\varphi} \left[(h_1 + 2h_2)\, B - \frac{h_1^3 - h_2^3}{B \, \mathrm{Cos}^2 \varphi} \right] \quad (3)$$
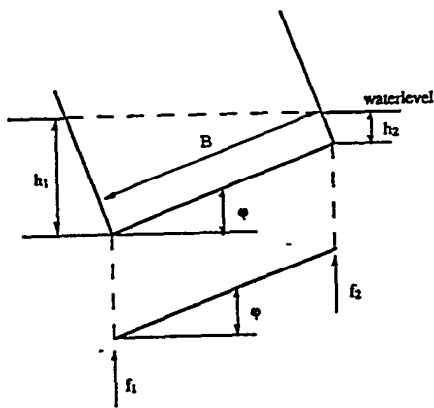
$$\mathrm{Cos}\varphi = \sqrt{1 - \frac{(h_1 - h_2)^2}{B^2}} \quad (4)$$

Figure 7 *Hydrodynamic forces acting on a section of the ship.*

where f_1 and f_2 are the forces exerted by the springs on the ship per unit length, g is the gravitational accelera- tion, p is the density of the water, B is the width of the ship, h_1 and h_2 are drafts on both sides of the ship and Cp is the roll-angle.

A typical result for a step 3 calculation is given (again for test 4) in Figure 8.
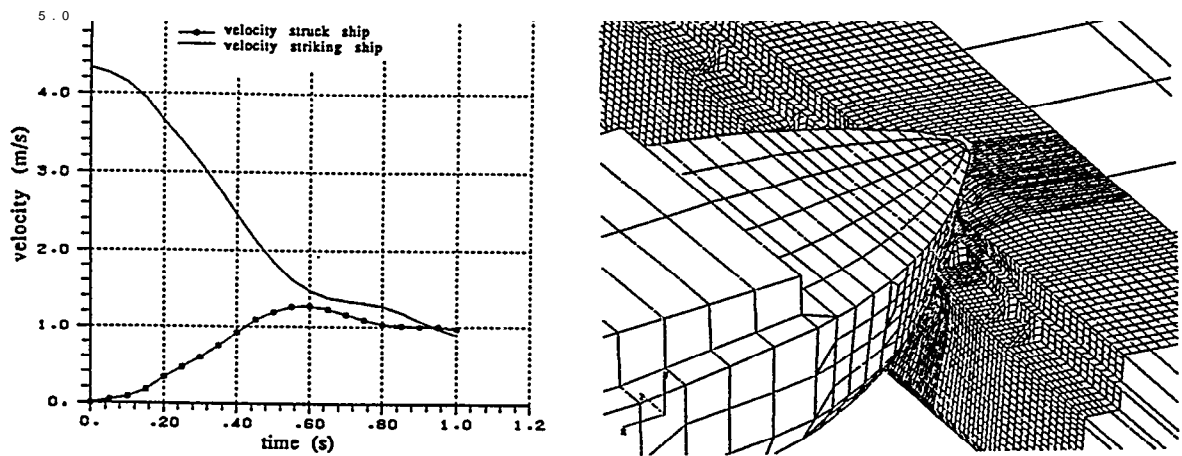The residual velocity of striking and struck ship immedi- ately after the collision is lower than that obtained in the calculation without water.

Figure 8 Time history of velocity of the colliding ships and deformed geometry (step 3).

In Figure 9 the energy dissipation during the collision pro- cess is depicted.
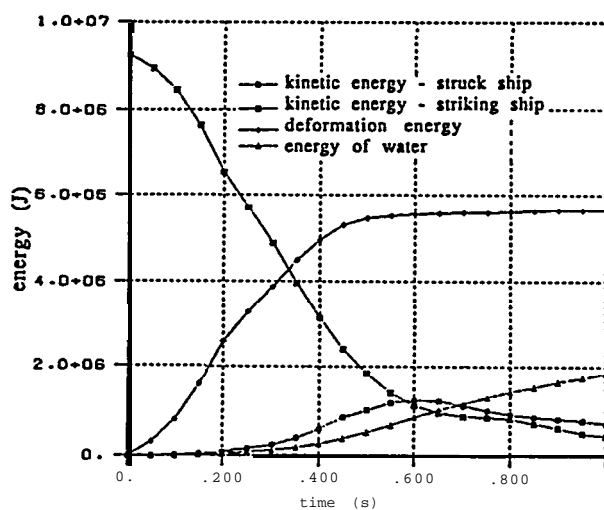
Figure *9 Energy dissipation*

The water has now dissipated a considerable amount of en- ergy during the collision and therefore the total amount of energy that has been dissipated during the collision has increased with respect to step 1. This in- crease in energy dissipation results in a decrease in residual velocity of both **ships immediately after the collision. These results show without any doubt that** a combined fluid-structure approach in numerical ship collision simulations is necessary. A pure structure- structure interaction, like in car-crash analysis is not sufficient to give accurate results.

The effect of the application of springs at the bottom of the struck- and striking ship in the collision simulation is revealed in Figure 10.
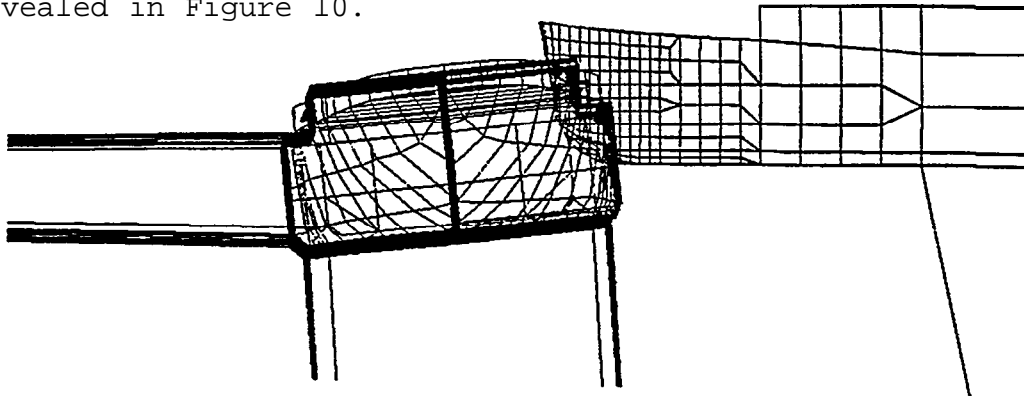

Figure 10 Roll-motion of the struck ship

RESULTS   OF   THE   NUMERICAL   SIMULATIONS

Introduction
In this section the results of the four ship collision simulations are presented. These results are a summary of the results presented in a report by Thung and Lenselink [1992]. The most important characteristics of the four collision scenario's are given in the table below:

	Striking ship			*Struck Ship*	
Test	Velocity (km/h)	Total Mass (kg)	Velocity **(km/h)**	Total Mass (kg)	Configuration
1	5.3	985140	0.	1296900	single hull
2	14.8	985140	0.	1280600	single hull
3	15.2	985140	0.	1299100	double hull-stringer
4	15.6	985140	0.	1303000	double hull-stinger **deck**

Table 1. The different collision scenario's

Collision   damage
The amount of damage inflicted on the struck ship is given as a series of deformed geometry plots after the collision in Figure 11 to 14. In these figures the numerical elements that have failed on maximum plastic strain are removed and holes in the ships hull can be visualised in this way. Also a top view of the struck ship is given in which the measured deformation at deck level is plotted.
In all the experiments small scale buckling has occurred at the gangway as well as on the trunck deck. The dimension of this buckling is smaller than 0.1 m. In the simulations this buckling behaviour has not been found because the numerical element dimension in those regions was much too coarse to resolve this buckling behaviour and instead a number of failed elements are found at these locations.

test 1

The damage caused by the collision in test 1 is visualised in Figure 11. A dent has been made in the hull of the struck ship but the hull itself did not fail. The final penetration computed at gangway level is .36 m. During the test a crack (about 30 cm long and only a few cm wide) has been found at the strike location.

In the simulation the maximum plastic strain at the inside of the hull has already reached 20 %, but the shell has not yet failed over its full thickness. So, the ships hull in the simulation is starting to fail .

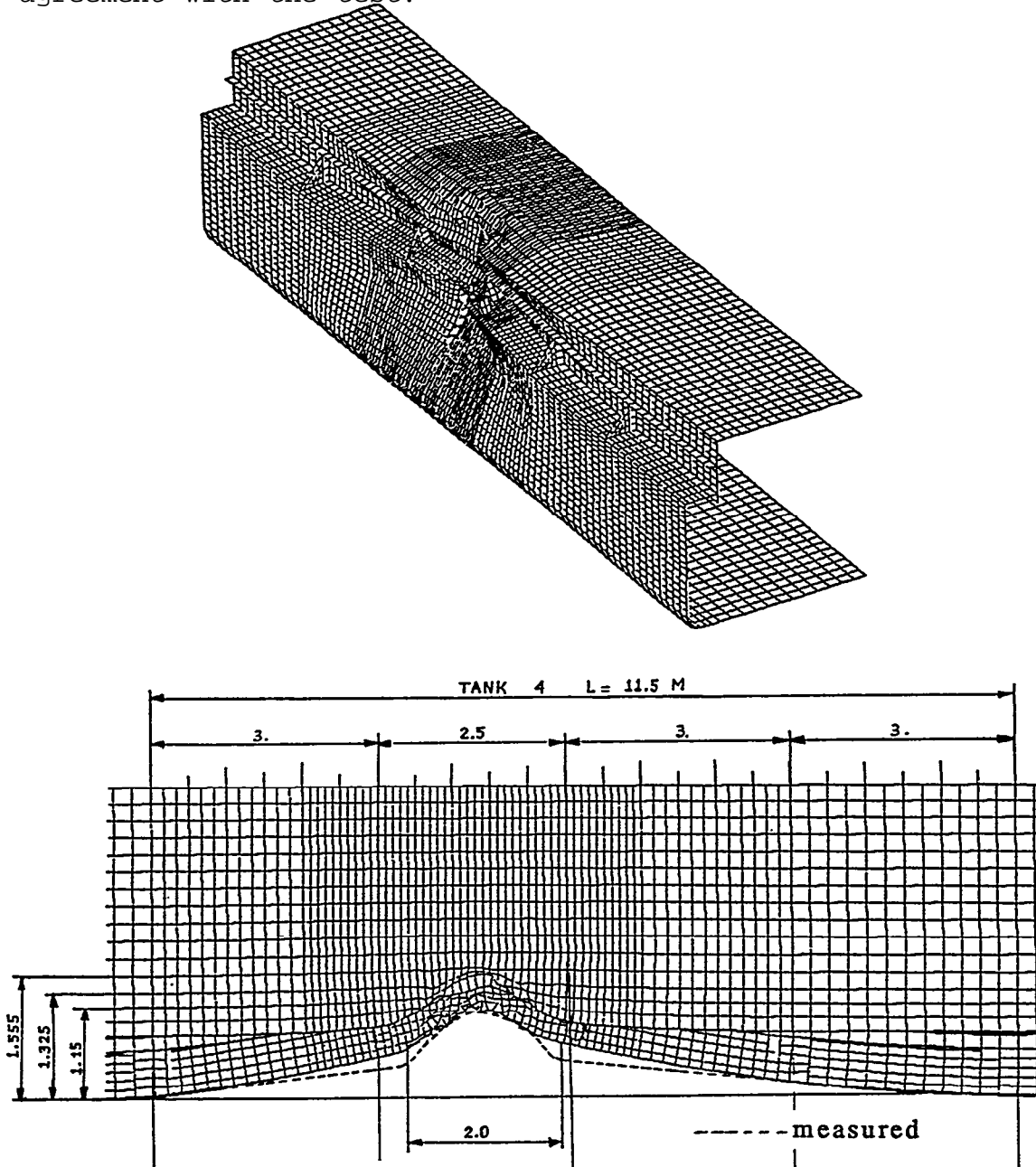The final deformation in the experiment was in good agreement with the simulation.
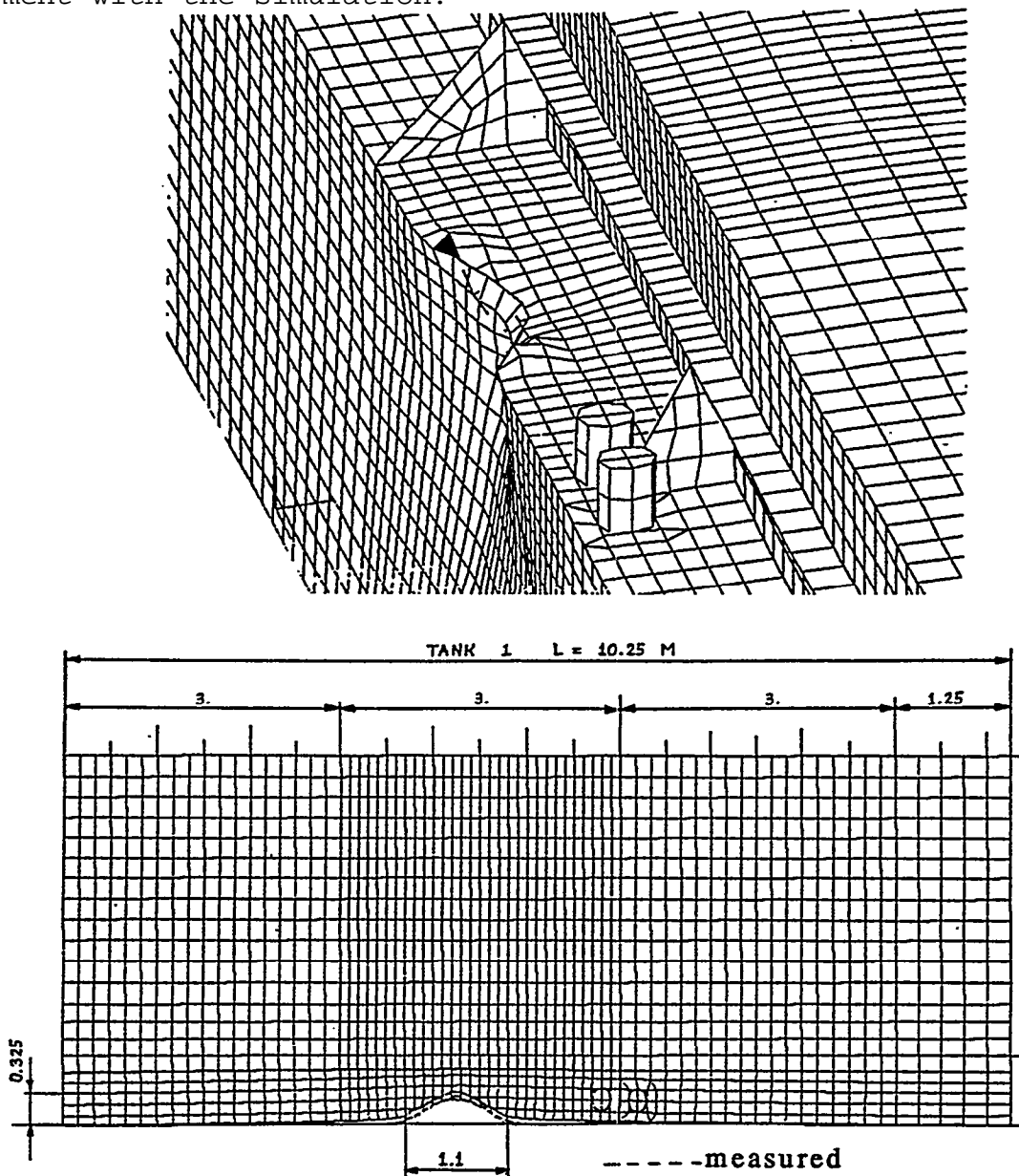
Figure 11   Damage after collision test 1 (dimensions are in meter)

test 2
The damage caused by the collision in test 2 is visualised in Figure 12. A large hole has' been formed in the hull of the struck ship. This hole runs down from the gangway to the horizontal stringer in the hull. The ships structure has been pushed inward between the two transverse tank bulkheads and the hole is located at the strike location. The final penetration computed at gangway level is 1.15 m.
During the test a penetration of 1.02 m was found and the the deformation pattern in the simulation is in very good agreement with the test.
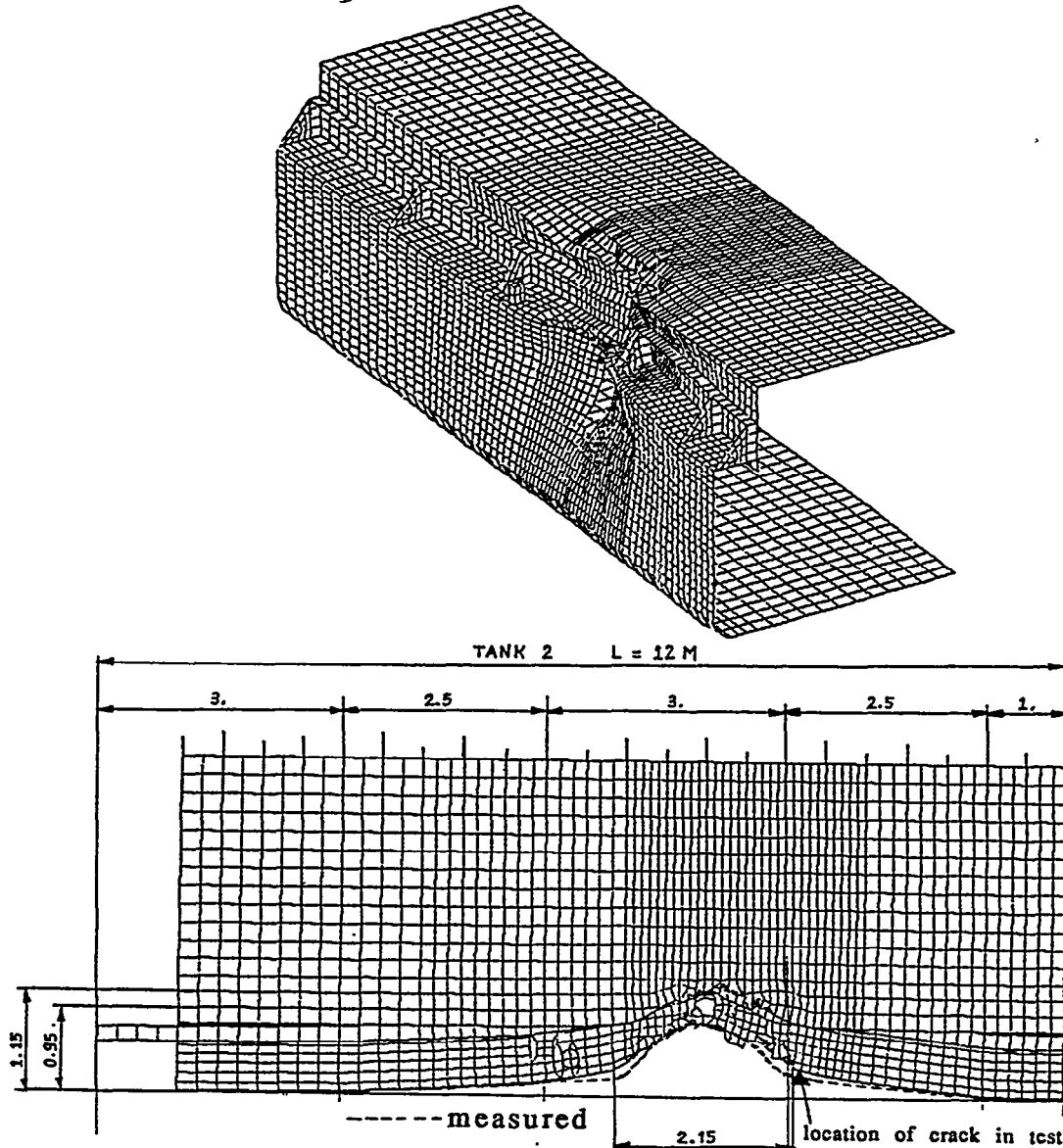

Figure 12 Damage after collision test 2 (dimensions are in meter).

test 3
The damage caused by the collision in test 3 is visualised
in Figure 13. A large hole has' been formed in the hull of
the struck ship. This hole runs down from the gangway to
just below the horizontal stringer in the hull. The ships
structure has been pushed inward between the two transverse
tank bulkheads, but not as far and over a smaller extend
than was the case for the unmodified ship in test 2. The fi-
nal penetration computed at gangway level is 1.0 m. During
the test a penetration of 0.77 m was found and the deforma-
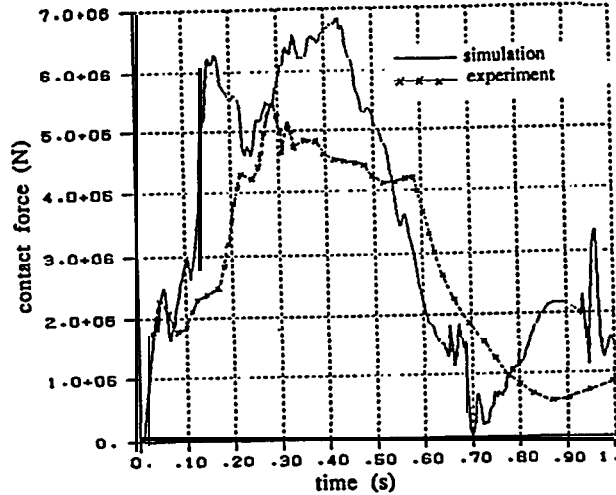tion pattern in the simulation in good agreement with the
test. In the experiment no hole was found at the strike lo-
cation, but instead a crack has been found just outside the
collision area. The crack was initiated from a weld line in
the shear strake just beside the web frame.

Figure *13 Damage after* collision *test 3* (dimensions *are* in meter).

test 4

The damage caused by the collision in test 4 is visualised in Figure 14. A large hole has been formed in the hull of the struck ship at the strike location. This hole runs down from the gangway to just below the stringer deck. The ships structure has hardly been pushed inward between the two transverse tank bulkheads. The stringer deck and the tank inner wall are not penetrated and have only undergone a (small) plastic deformation. The final penetration computed at gangway level is 1.0 m.

During the test a penetration of 0.92 m has been found and the deformation pattern in the simulation is in excellent agreement with the test.
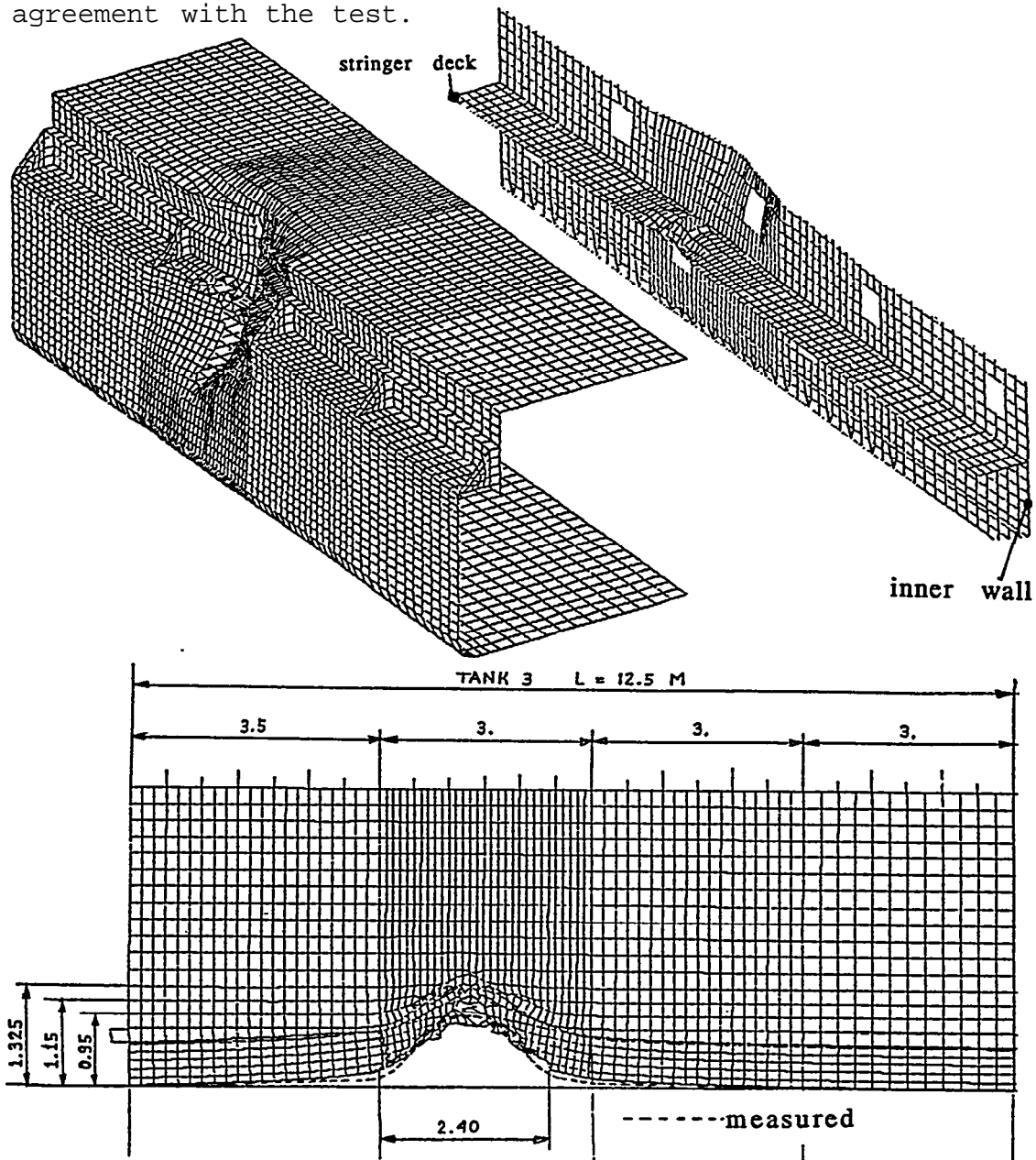
Figure 14 Damage after collision test 4 (dimensions are in meter).

Collision force

For all the tests the computed maximum collision force is higher than the measured maximum collision force. As a typical example, the computed and measured collision force for the test 4 collision are given in Figure 15.

In the experiments the contact force was determined by force transducers,that were situated just behind the bow. The collision force was measured as the force between the bow and the rest of the striking ship. The deceleration of the bow is not measured in this way and therefore the measurements will differ approximately 5% from the actual collision force. The collision force in the simulations is computed from the deceleration of the struck ship that behaves as a rigid body. However, in the experiments the striking ship is not a rigid body but can deform (elastic) and absorb collision energy that will be released at the end of the collision process. This effect will lead to an increase in collision time and a decrease of the collision force.

Figure 15 Collision force history.

The duration of the collision in the simulations is in good agreement with the experiments.

Ship motion

The transverse motion of the struck and striking ship is resolved quit well in the simulations (c.f. Figure 16).

Hardly any roll of the struck ship was found in the test, but in the simulations a much bigger roll-angle was computed when the collision was over (t > 0.6 sec). The characteristics of the dampers are only valid during the collision when the struck ship and water are accelerated and they should not be used to compute the ships motion after the collision.
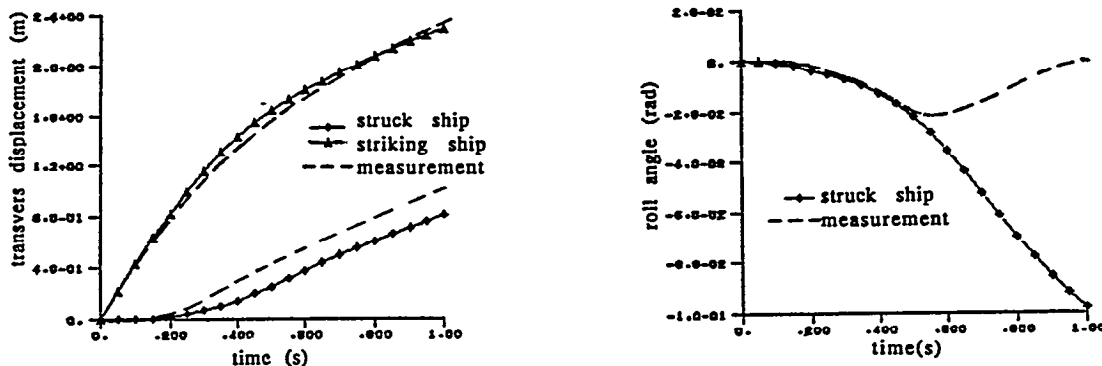

Figure 16 Transverse and roll motion of the struck ship.

Conclusions

- In the cases where no crack initiation by a weld-line outside the strike area occurred, the numerical simulations were in very good agreement with the experiments when penetration depth, shape of collision area and hole size are regarded.
- In the case where crack initiation by a weld-line outside the strike area occurred (test 3), the numerical simulation did not resolve the crack because it was not taken into account in the modeling. However, a better match with the experiment can be obtained when at that spot the weld-line would be modeled by a number of numerical elements with a material model with a substantially reduced maximum plastic strain.
- Small scale buckling occurred at the gangway and at the trunck deck during the experiments. The typical dimensions of this buckling behaviour was smaller than 0.1 m. In the simulations this buckling has not been found, because the element dimensions are to big to resolve this behaviour. A very fine zoning would be required to resolve this phenomena and this is only feasible when techniques like "sub-cycling" can be employed
- The maximum computed collision force is for all collisions higher than the measured maximum collision force.
- The computed collision duration agrees well with the experiments.
- The ship motions after the collision (especially rolling) can not be computed accurately when the system of springs and dampers is used. A better solution will be obtained when the structure-structure interaction can be handled simultaneously with the "full-coupled" fluid-structure interaction, resulting in one computer calculation in which the water resistance is computed exactly. With the MSC/DYTRAN program this approach is now possible.

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SHIP WEATHER ROUTING FOR SAFETY AND ECONOMY

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Abstract

Since the 1950's a large number of vessels have been operated in oceancrossing voyages with the help of shore based ship weather routing.
Recent developments in fast PC's and data communication via satellite have made it viable to transmit on request relevant metocean data to the ship where the optimal routing procedure is executed on the onboard PC using the predicted metocean data, available climatological data and the ship perfomance models.
The otimal route together with the predicted vessel performance parameters along the optimal route such as speed, rolling, pitching, fuel consumption and probability of slamming and shipping green water are presented to the operator in an ergonomical justified way. Interfaced with a performance logging and analysis the system is called a voyage management system.
Descriptions are given of the used isochronen method for minimum time routing, the shipper performance models, the data logging system and the system integration.
Simulation results and fieldtest plans on board of an ocean going tanker for spring 92 are presented.

1   .

Strategic ship weather routing is a procedure to determine an optimal route for a particular vessel on an ocean transit, based on the forecast of weather, sea state and ocean currents.
Optimization can be perfonmed in terms of
(i)   minimum passage time.
(ii) minimum consumption within specified passage time.
(iii) minimum damage to ship and/or (deck)mrgobythe sea.
(iv) maximum comfort to passengers.
(v)   a combination of the above mentioned criteria.
For most cammercial purposes a combination of (i) and (iii) will be applied in the start phase of the voyage, going gradually to the combinationof (ii) and (iii) in order to arrive just in time at the destination.
Strategic routing will not avoid high (head) seas under all circcumstances; in adverse conditions the shipmaster has to heave to and decide

an course and speed to save and cargo for heavy damage. The deci-
sion process for these short time goals is called "tactical routing".

The shipmaster is responsible for the routing decisions, he will do
this on the basis of his appreciation of the ship performance, the
forecasts of weather, sea, currents and icelimits, conditions in the
Charter and possible instructions from the shipowner. As it is not
feasible for the shipmaster to make a quantative analyses of different
routes, he will often make use of a routing advice from a Weather rou-
ting bureau.
Aninquiry under 100 active shipmasters showed that 80% of them had
positive experiences with weather routing advices, although most *of
them had additional* requirements for the advice given [Teeuwen 1988].
A similar investigation under Japanese shipmasters showed that *65%* of
them made regularly, use of routing advice form a weather bureau. Their
confidence had grown in recent years, *but they also expressed additio-
nal wishes for the quality of the information given [Yamamoto 1987].*
The most important short comings of present weather routing advice are:
-only one so called optimal route is advised, no alternatives are
   given;
- **backgrounds and motivations of the advised route are insufficient;**
   the shipmaster is not able to validate the advice given;
- only minimum time routes are given;
- **the exchange of information between routing bureau and ship should**
   be improved.
In spite of these short comings remarkable successes are achieved with
weather routing. During 25 years of service the Royal Netherlands Me-
teorological Office achieved about 80% succesfull routings, i.e. the
advised route was shorter in time than the greatcircle route. The ave-
rage time saving from the EngLish channel to the Gulf of was 12
hours and to New York 4 hours; the fuel. savings were estimated 3-5%
[KIWI, 1985]. Because route ,vessels encounter less high (head)seas -
Constantine (1981) mentions twice as many unrouted ships in signifi-
cant wave heights of more than 6.5 m than routed ships - the damage on
routed ships will be reduced. According to the Naval Weather service
in the USA (1976) an average ship will experience on the average 1000
USD damage per day in significant wave heights of 6 m., whereas this
increases dramatically to 10.000 USD per day for waves of 8 m. height.
The system described in this paper will cope with the short comings of
today's weather routing, all the available and necessary information
for routing decisions is then where it should be: *on the ship's
bridge. The system will assist shipmaster* and bridgeteam in performing
a safe and efficient voyage and with the prediction of a reliable time
of arrival.

2. The modified isochrone method.

The t-hour isochrone is defined as the outer boundary of the attai-
nable region after hours of passage time taken into account ship
performance and environmental factors. A practical way to Compute the
t-hour isochrone is described in Spaans and Hagiwara (1987). Every
next isochrone (after12hours)isfoundbyasearchprocedurewhere

the maximum distant point is determined in a small subsector originating in the point of departure. Every point on an isochrone determines a track backwards to the point of departure. When the computed isochrone approaches the destination, the passage times from all isochrone points to the destination are determined; the track segment with smallest sailing time indicates the minimum time route, see figure 1 (after Hagiware et al, 1991).

The method can also be used to compute the optimal route with the required constant number of propeller revolutions along the route to arrive just in time at the destination, see Hagiwara (1989).

Also in Hagiwara (1989) the method is used in a stochastic optimization procedure to predict additionally the standard deviation of arrival time and fuel consumption. The shipmaster is then, for instance, able to decide for a southern route with larger expected passage time but with smaller standard deviation, because of "just in time" requirements.

The method is not suitable for optimization by variation of both course and speed, therefore the isopone method is developed at the Royal Shell Laboratories in Amsterdam. The backgrounds of this method will be published at a later stage.
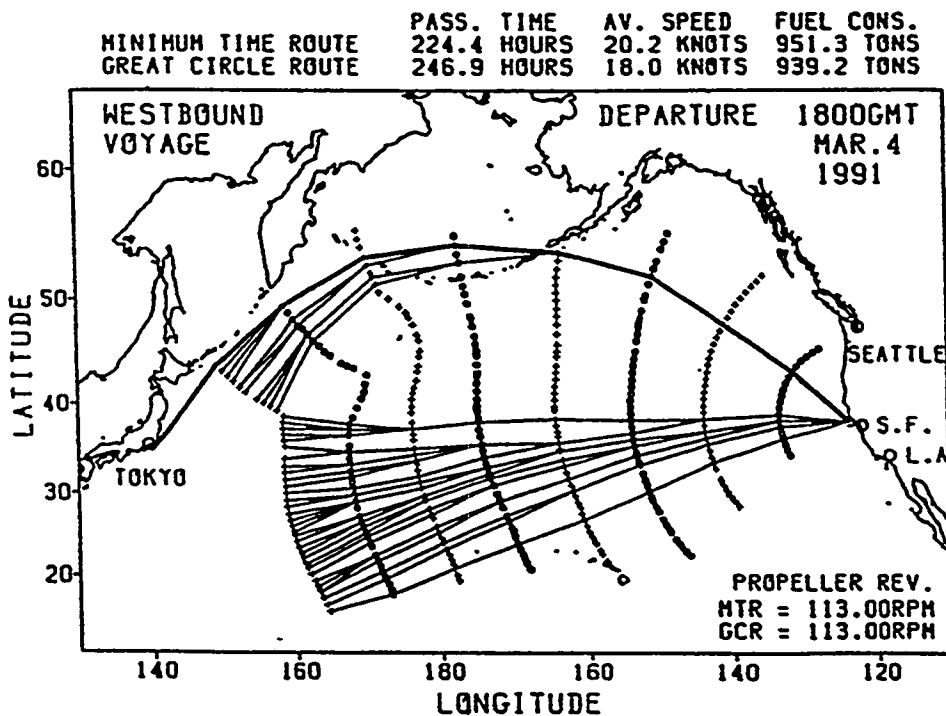

	PASS. TIME	AV. SPEED	FUEL CONS.
MINIMUM TIME ROUTE	224.4 HOURS	20.2 KNOTS	951.3 TONS
GREAT CIRCLE ROUTE	246.9 HOURS	18.0 KNOTS	939.2 TONS

Fig. 1: True minimum time route to Tokyo (thick line)
(Voyage no. 5, departure time: 1800 GMT, Mar.4 1991),
after Hagiwara et al (1991).

3.Ship performance models,

An important factor in ship weather routing is the accurate prediction
of the ship speed. The factthatapoweCEul computer is available on-
board allows scientific and accurate calculation method. The calcu-
lation of the ship speed is based on Newton's principle: Force -
Mass * Acceleration; this means that the derived ship speed is found
when the resulting force on the ship is zero. For the practical appli-
cation of ship speed calculations this concept was introduced by
Journee et al [Journee et al, 1987]. The propulsion force of the pro-
peller must be equal to the sum of still water resistance, wind resis-
tance and wave resistances. With this equilibrium the speed through
the water can be calculated. The speed over the ground is found when a
current component is added to the speed through the water,
This speed calculation can be made accurately because detailed ship
information is used, such as the hull form, engine and propeller cha-
racteristics, fouling parameters and the loading conditions. In the
final system some of the used ship parameters will be tuned with mea-
surements on board.
An advantage of this speed calculation method is that not only the
speed is predicted, but also the fuel consumption and the shipmotions
are calculated. The operator can set thresholds to shipmotions in the
route selection procedure for the objected transit. Examples of mo-
tion criteria are the maximum number of slams per hour, the average
roll amplitude and the predicted time of shipping green water.

4. Weather and communication.

Ship weather routing requires forecast information on wind and waves.
Also the current has direct influence on the ship progress. With the
newly proposed routing method meteorological and oceanographical
information is gathered up to five days ahead by a weather bureau for
five ocean regions, covering all major shipping routes. Ships in a
specific region can down load the prepared set for their region by
Inmarsat-A satellite communication facilities. The information can be
downloaded or updated at any time from a shore based electronic
mail box, on request of the master.
The environmental data are:- (10 meter level) and direction,
sea height, period and direction and swell height, period and direction.
For swellthemost dominant group (direction) is taken. The addition
of wave period information is a major improvement for routing calcula-
tions, shipmotions and therefore also wave resistances are sensi-
tive for wave frequency variations
Additional to wind and wave information also airpressure at sealevel,
ice limit and hurricane information is added. This information will be
processed and stored in the datafile for that region. Furthermore an
experienced meteorologist wil make a general interpretation of the
weather, the weather systems and the predicted in that
region. Also possible errors in the model data are examined. The
meteorologist will then write down his evaluation in a bullet in, which
is also stored in the data file.

The written analysis will help them master with his interpretation of the weather, especially in difficult situations. The analysis together with the masters basic knowledge of weather systems and his practical experience with the analysis of weather facsimile charts provides a good basis for a correct interpretation of the weather in his region. Extra meteorological information which is available at the office, but which is not transmitted to the ship (because of high communication costs) will in relevant cases be mentioned in the written bulletin. The extra information can consist of satellite images, other computer model result or special bulletins.

Because transoceanic voyages often take longer than five days, a climatological data base is stored onboard with average wind and wave information that can be used after five days. This information is gathered form measurements over a long period of time and is given in monthly averages.

The main advantage of the new approach is that the bridgeteam has a complete overview of the weather up to five days ahead from one reliable source, instead of fragmented information form many different sources.

5.Datalogging

Integrated in the Voyage Management System are provisions to collect and record perfomance and voyage parameters. A measurement interface is assumed to be available (e.g. the Ship Performance Monitor (SPM) on shell vessels). The SPM interfaces the shipboard instrumentation (sped log, power meter, fuel meter) and provides the information via a serial Line to the Voyage Management System. Real time records are produced and stored on disk. These records provide the possibility to monitor the accuracy of the predictions of the ship model by comparing the predicted paramters with the store data. The ship model that simulates the behaviour of the vessel is at the basis of the routing calculations and accuracy is therefore required. Provisions to modify the ship as fouling occurs (hull,propeller) have been , made.
The voyage parameter are stored in a voyage log. At regular intervals the progress of the vessel is recorded. The information is stored for future reference but also to facilitate the assessment of the impact of the Voyage Management System at some later stage.

6. The Voyage Management System.

Recently a cooperative development between Shell Research and Meteo consult Wageningen has been initiated. This cooperation will combine the complementary work and ideas on voyage management and weather routing of bath parties. The result of this cooperation will be a voyage management system to be field tested on board a Shell tanker during 1992.

The system is operated on a Personal Computer (PC) and will serve as a management support tool to be used on board. Its functionality includes interactive voyage planning, weather routing, ship perfomance prediction, perfomance logging and analysis. The user may select from various optimisation criteria i.e. time, fuel, maximum profitability. A satellite link with a shore based weather data based is provided. The infra structure feed this data base with world wide up to date weather predictions is currently being set up by Meteo consult.

6.1 System.

The Voyage Management System will be implemented in a 386/486 compatible computer. All hardware will be embodied within one PC configuration. A standard Ship Performance Monitor (SPM) *and/or Other external* equipment (e.g. navigational instruments) may be interfaced directly to the PC via standardised interfaces. The Voyage management system will have the following functional modules, see figure3.
a. Integrated navigation.
b.Ship Perfomance Prediction.
c. Performance Monitoring and Analysis.
d. Weather routing.
e. Voyage monitoring and Analysis.
f. Communication.

a. Integrated navigation.
GPS will be integrated with other sensors to calculate and maintain a 'best estimate' of the actual position and the speed/course vector. Speed is obtained as speed over the ground.

b. Ship Performance Prediction.
The system will contain a module to predict ship performance in terms of power, speed and related parameters as influenced by loading condition and prevailing environmental conditions.
An essential part of the ship performance prediction module tailed ship which has to be tailored to the actual ship parameters. The performance prediction module is called upon by the higher level routing module.

c. Performance Monitoring.
The Performance Monitoring is optional. Interfacing with a ship Perfomance Monitor (SPM) is required. This module will continuously monitor and Convert the data from the shipboard instrumentation via the SPM. Performance data will be stored on disk. These logs are accessible for (graphical.) inspection.

d. Routing.
The routing module will calculate the course and speed settings leading to the optimal completion of the present voyage. The user is re--to select the criterion to be applied (time, fuel, profitability) and define the boundary conditions (motion criteria, arrival

time). As the voyage progresses and the routing calculation is repea-
ted - say - every 24 hours, the results of the voyage so far will be
taken into account as well. This implies that any deviations from the
original plan will be taken into account.
The weather routing process requires the availability of the following
categories of data:
- voyage`data   : interactively entered by the user.
- weather data   : communicated to the ship.
- climatic data : available on disk/
The routing provides input to the higher level business mo-
del. A maximum profitability muting is constructed from a range of
minimum energy routings.

e.Voyage Monitoring and Analysis.
The performance of the vessel in terms of economics and fuel will be
logged continously. A voyage log is constructed updated as the vo-
yageprogresses.The performance will be made visible in relation with
the original and the updated voyage plan. The logs will remain availa-
ble on disk for purposes of inspection at a later stage. They will be
the basis of the assessment of any improvement in performance due to
the use of them voyage management system.

f. Commuication.'
Two categories of communication (ship -shore) can be identified:
 (i) -uploading of logfiles (voyage and perfomance).
      -Down loading of software/datafiles.
 (ii) - Collection of weather data.
Meteo Consult is now testing the MEMOCOM 400 system (PTT Telecam).
This electronic system will be used to hold the recent weather
data. Users may login and load the data sets to the ves-
sel.

6.2 User aspects.

The voyage mangement system is in fact an information management sys-
tem. Embedded with in the system are the tools to plan and monitor the
voyage of a vessel in terms of fuel economics, earning and sche-
duling. An important factor to influence the beneficial effect of this
system however is the supply and the quality of weather data. One can
assume that the better the quality of the weather data, the more bene-
fit will be gained from operating the system.

The user of a voyage management system (a shipowner) will expect a re-
turn on investment and is well advised to provide the means to monitor
and measure the performance of such a system. All relevant information
for such an analysis is available in the voyage logs as they are pro-
duced by the system. Considering the flexibility of the system it is
anticipated that any user onboard may appreciate the support of the
system for specific elements of the operation (planning the voyage,
calculating estimated time of arrival (ETA), position fixes). However
to obtain an objective measure of the return of the system a central
facility for voyage analysis should be part of the organisation of the

shipowner. This will also provide the possibility to advise vessels on the settings of various fouling coefficients that are included in the performance prediction module.

7. Field test results.

The performance prediction module and the data logging routines were included in a prototype system which has been tested during a field trial on board a tanker in 1989. Both loaded and ballast conditions were tested. The Vessel was extensively equipped with instrumentation (wind mater, EM-log, Doppler-log, 2 independent power meters). The standard deviation of the prediction was 3% over a range of environmental and operating conditions. The system also provided an on-line measurement ship with an accuracy of 1%. The speed estimates were verified with "a Dutchman's log" (oranges). Integrated in the data loggin routines are filter routines which correct for bias in the speed log. Examples of the speed log are included, see figure 2. The filter routines also provide accurate estimates of the wake, an important parameter in the perfomance prediction module. The performance prediction module and the filter routines will be included in the Voyage Management System to be tested this year.

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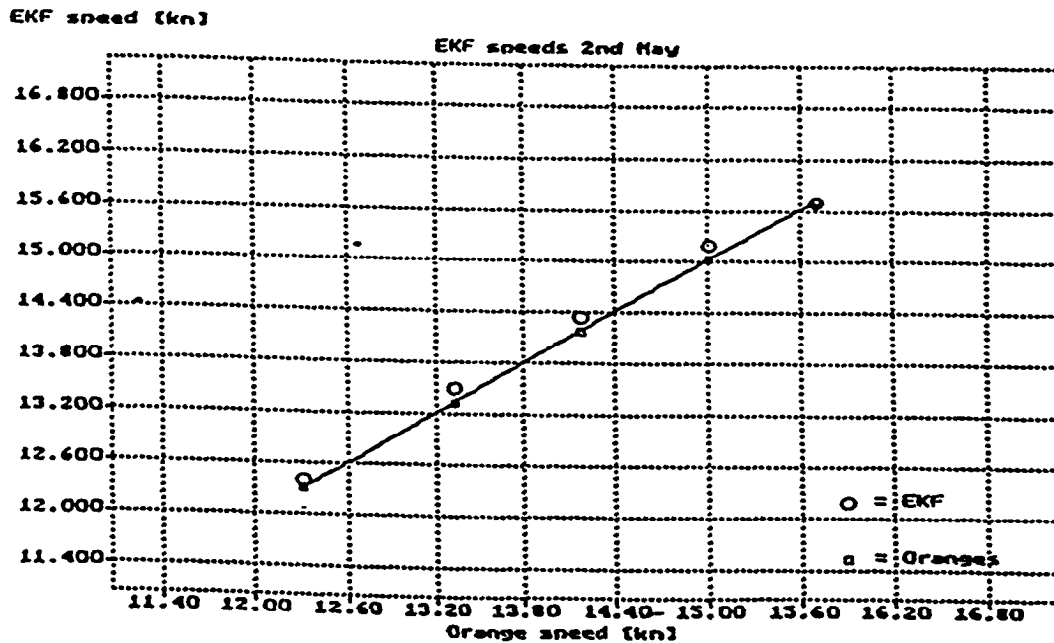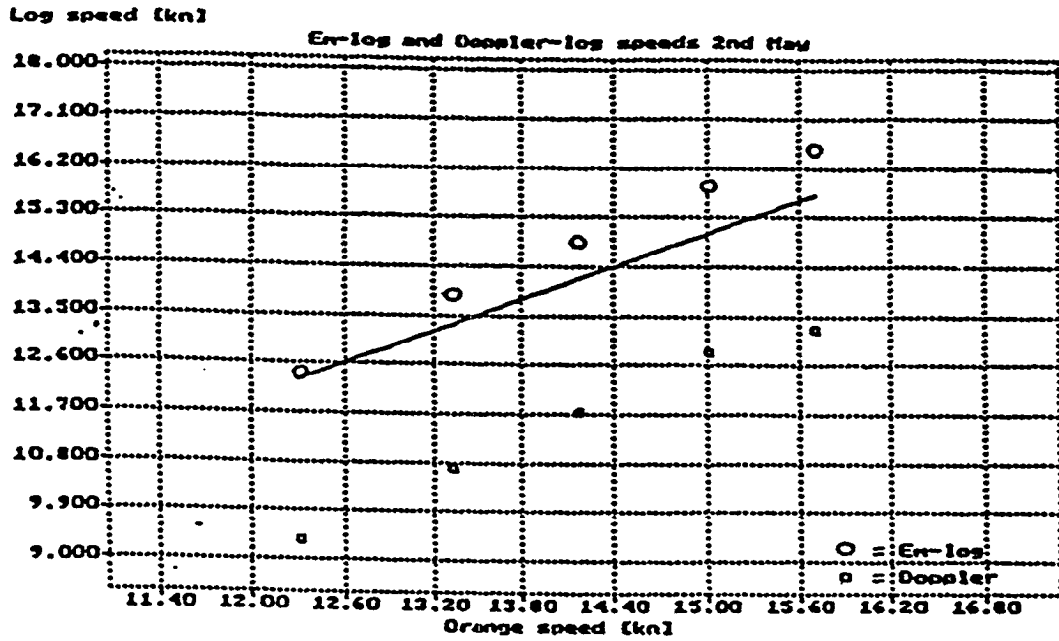International Seminar on ship weather routing
Tokyo.

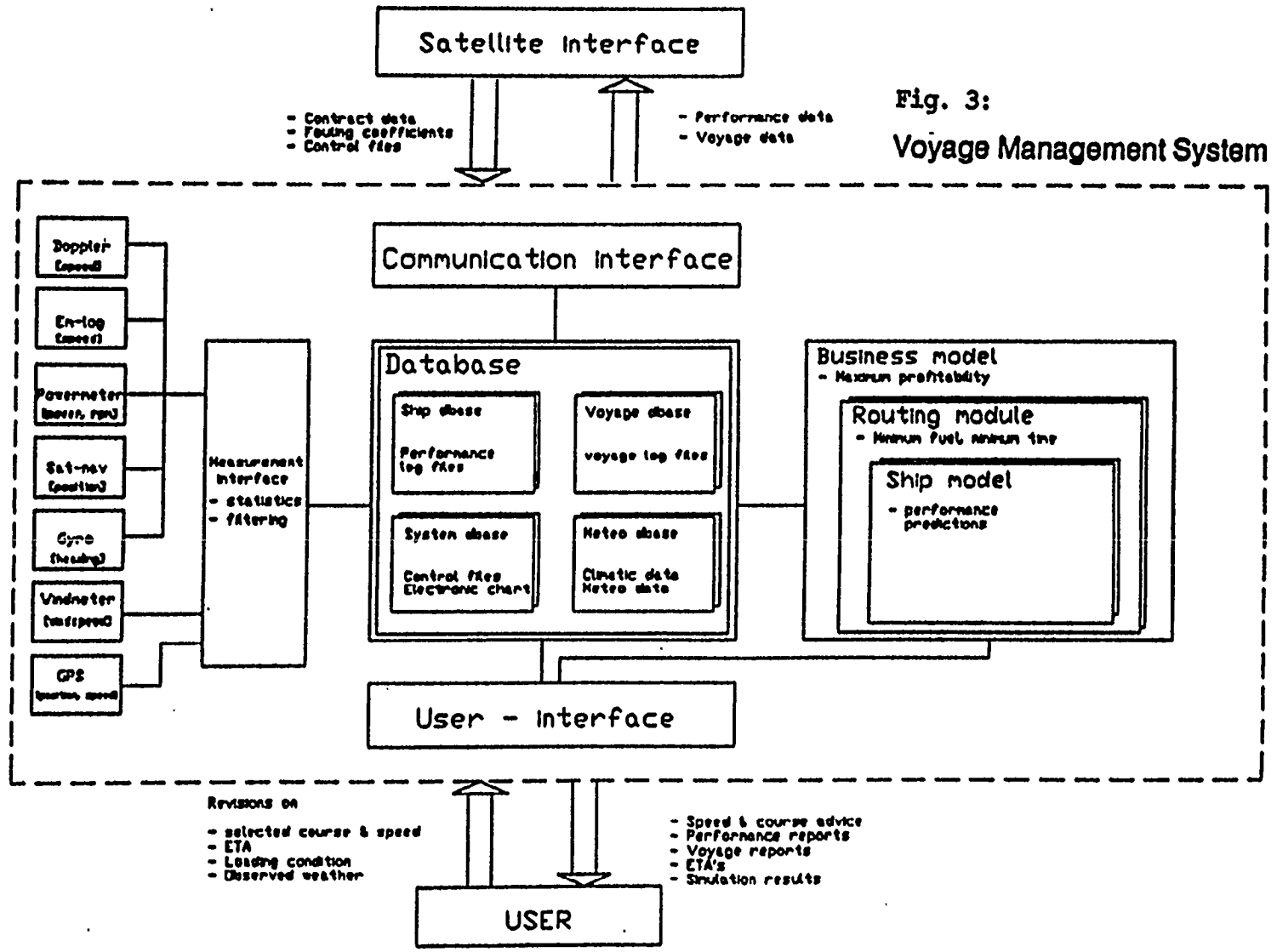Fig. 2: Plot of Doppler, EM-log and EKF speeds versus 'orange' speed
2nd May

Fig. 3:

Voyage Management System

Satellite Interface

- Contract data
- Routing coefficients
- Control files

- Performance data
- Voyage data

Communication Interface

Doppler (speed)

En-log (speed)

Powermeter (power, rpm)

Sat-nav (position)

Gyro (heading)

Windmeter (windspeed)

GPS (position, speed)

Measurement Interface
- statistics
- filtering

Database

Ship dbase

Performance log files

Voyage dbase

voyage log files

System dbase

Control files
Electronic chart

Meteo dbase

Climatic data
Meteo data

Business model
- Maximum profitability

Routing module
- Minimum fuel, minimum time

Ship model
- performance predictions

User - Interface

Revisions on

- selected course & speed
- ETA
- Loading condition
- Observed weather

- Speed & course advice
- Performance reports
- Voyage reports
- ETA's
- Simulation results

USER

APPLICATION OF INFORMATION TECHNOLOGY IN SHIPPING AND COMMUNICATIONS

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A B S T R A C T

Since the invention of radio and its subsequent use at sea, there has been constant development in the application of information transfer between ships and the shore, resulting in new maritime communication technology.

The utilization of satellite communications at sea, and in particular the Inmarsat system, has opened-up an avenue for data communications, that in the past was unavailable to either the on-board staff, or the shore-based personnel of the shipping community. This form of information transfer has become applicable to the management of ships, maritime distress and safety functions and direct support to the navigation systems on-board.

By using the Inmarsat system, the larger shipping companies have proceeded towards developing software programmes, which encompass the important aspects of managing their ships when on voyages, and providing easier facilities for direct communications between the technical staff ashore and the ship. This has led to saving time and effort and in the long run has enhanced the profitability of operations. The Inmarsat system also plays an important role in the Global Maritime Distress and Safety System (GMDSS) and supports the applications of electronic charts.

This paper describes development in this field and a future outlook.

Human ability to communicate information between two points has been measured in relation to the medium used. For most of history communications over distances has involved travel, if use was not made of crude methods of visual signalling by flares, smoke and light. The first milestone in distant communication was reached, when electrical telegraph communication began in 1837. The second milestone was reached when the telephone was invented in 1876; by then there were two completely different but complementary methods of fast communications over distance. The third milestone, which created a large impact on maritime communications, was the invention of radio by Marconi in 1895. Subsequent development of radio communications paved the way for maritime satellite communication systems.

It is doubtful if any new development in recent history has had such a wide-spread effect on Industry, commerce or the general public as the development of the computer. The arrival of the computer may also be considered as another milestone in the annals of communications, and progress of mankind has to a certain extent been measured by how successfully one has been able to communicate with computers and how efficiently they have been made to communicate with one another. Data transmission can be defined as the movement of information in coded form over a transmission system, generally prior to or after processing by a computer. Data communication, however, has a much wider meaning than data transmission and embraces not just the transmission but many other factors involved in controlling, checking and handling the movement of information in a communications-based computer.

This blend of computers and communications is now taken for granted and has gradually crept into the maritime industry. The communication systems used play an important role in the quality and speed of the data transmitted and received. Initially transmission over cable facilitated the development of information transfer on land. However data-via-radio has not led to advancement of the process and subsequently the mariner has not been able to utilize its technology to the fullest extent. Radio (utilizing ground waves or ionospheric propagation) has never been a good medium for the transfer of data. The quality of communication is not very high and subsequently the *bit error* rate is also very high. This led to a situation where a repetition of the transmitted data was always necessary in order to eliminate the error; furthermore the repetition was so frequent as to produce an uneconomical mode of communication. In certain areas of the world "blind spots" prevented or interrupted data transmission over radio, making it significantly unreliable. A prominent method of low-rate data transmission at sea has been telex-over-radio; difficulties attached to this system are well-recorded. In certain areas of the world some systems of HF data

transmission to ships have been developed, but these are mainly special purpose systems and have not been extended to international use.

Data transmitted on land through cable was gradually developed over the years to attain improved quality, reaching a stage where the bit error rate was almost eliminated by the recent development of optical fibre cables. When data was introduced to satellite communications over the fixed services (e.g., Intelsat), it was an alternative form of transmission media, which provided good quality communication through the use of line-of-sight frequencies (L-Band and Ku-Band). Although satellite data communication may not provide the same quality in comparison to cable, yet the bit error rate (using advanced error correction techniques) is very low indeed and makes it a desirable system of communication.

Inmarsat was established in 1979 and began operating its space segment in February 1982. In the maritime sector, Inmarsat's purpose is to provide the space segment to improve maritime communication, thereby assisting in improving communications for distress and safety of life at sea, the efficiency and management of ships and maritime public correspondence services and radio-detemnination capabilities. All these functions, in one way or another, involve the use of data communications between ships at sea and locations on-shore. Therefore, Inmarsat soon embarked upon developing its own range of information transfer systems.

More recently the Global Maritime Distress and Safety System (GMDSS) has emphasized the need for a worldwide communication system to be used for distress alerting, search and rescue operations and maritime safety information. Data transmission over the Inmarsat satellites has provided a facility that satisfies the functional requirements of the GMDSS.

INMARSAT

Inmarsat was established as an internationally-owned cooperative to meet the needs of the world shipping community for reliable communications. It was envisaged at an early stage that Inmarsat could, in the future, provide a shared satellite system for both aeronautical and land-mobile services. Inmarsat has evolved to become the only provider of global mobile satellite communications for land, sea and aeronautical applications. The headquarters is located in London and the Organization has more than 60 member countries from all regions of the world. Participation in Inmarsat is done on two levels, namely:

(1) THE PARTY: means a State, which has ratified the Inmarsat Convention.

(2) THE SIGNATORY: means either a Party or a competent entity (usually a public or private telecommunication organization),

designated by the Party to sign and implement the Inmarsat Operating Agreement, which is attached to the Inmarsat Convention.

Inmarsat is fully financed by its Signatories; the level of investment in the Organization is directly proportional to an individual Signatory's utilization of the Inmarsat system. In order to function, it has a three tier organizational structure consisting of the following:

- The Assembly: composed of representatives of all the Parties, each of which has one vote. The Assembly meets once every two years to review the activities and objectives of Inmarsat and to make recommendations to the Inmarsat Council.

- The Council: has 22 members; 18 representing Signatories, or groups of Signatories, with the largest investment shares. Four others are selected by the Assembly on the principle of just geographical representation, with due regards to the interests of developing countries. The Council meets at least three times a year to oversee the activities of the Directorate. During these meetings a Council member has a voting power equal to its investment share.

- The Directorate: the permanent staff of Inmarsat comprising about 50 different nationalities working under the supervision of the Director General. The Directorate carries out the day-to-day operations of Inmarsat.

The Assembly forms the political hierarchy, the Council functions as the board of directors and the Directorate implements the decisions and policies of the Council.

THE INMARSAT SATELLITE SYSTEM

To provide its services, Inmarsat uses its own Inmarsat-2 satellites and leases the Marecs B2 satellite from the European Space Agency, maritime communications subsystems (MCS) on several INTELSAT V satellites from the International Telecommunications Satellite Organization (INTELSAT) and capacity on three MARISAT satellites from COMSAT General of the United States. The system is currently configured with operational satellites over four Ocean Region Areas as follows:

Ocean Region	Satellite	Location
Atlantic (W)	Marecs B2	55.5 w
Atlantic (E)	Inmarsat-2 F2	15.5 w
Indian	Inmarsat-2 Fl	64.5 E
Pacific	Inmarsat-2 F3	178 E

Ship Earth Stations (SES) transmit and receive signals to and from the shore via the satellite; Coast Earth Stations (CES) interface the satellite traffic with the national and international networks and each Network Coordination Station (NCS) acts as a switch operator, assigning, controlling and monitoring the traffic channels between the *SESs* and the CESs. At least one NCS is used for each Inmarsat system in each ocean region area.

NCSs of the different ocean regions are linked into a central Network Control Centre (NCC), which monitors, coordinates and controls the communication networks. The satellites are operated from the Satellite Control Centre (SCC), which performs the functions of station-keeping, telemetry, tracking and command. Both the NCC and SCC are located at Inmarsat's headquarters in London. Monitoring, control and coordination of the systems are carried out over an international network of communications to tracking stations, coast earth stations and network coordination stations.

Figure (1) The Inmarsat Network

- - - - NCS common channel   NCS Network Coordination Station
· · · · · · · Request and assignment   CES Coast Earth Station
——————— SES-CES message channel   SES Ship Earth Station
ᴨᴨᴨ National / international
     telecommunication landlines
                                    Shore - based subscriber
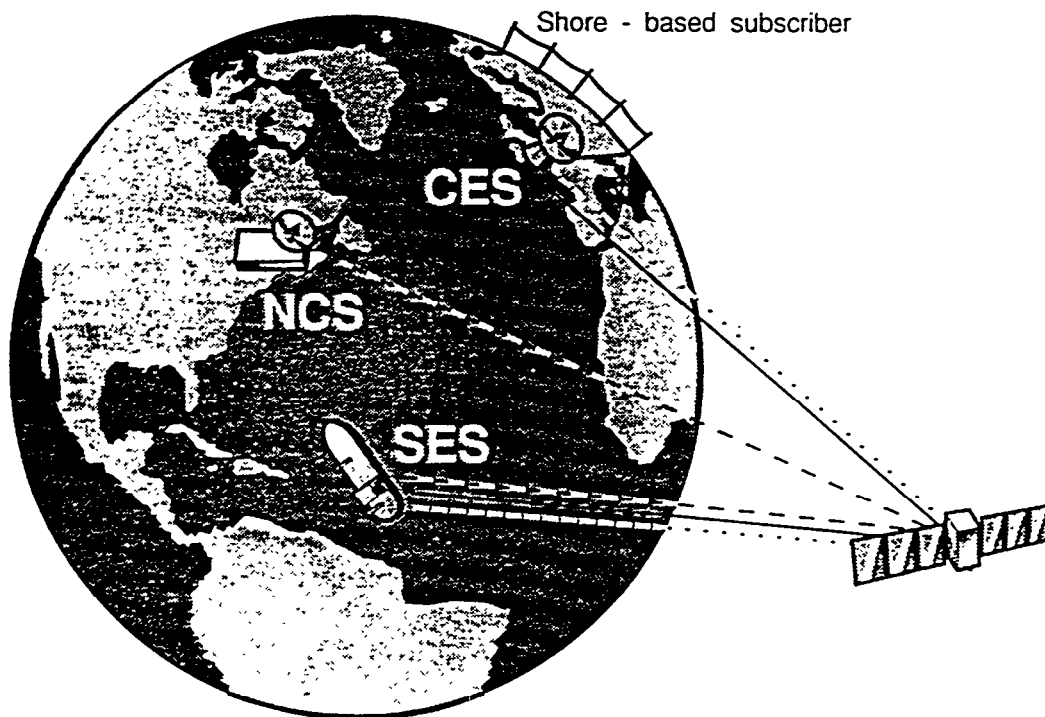
THE INMARSAT COMMUNICATION SYSTEMS

Inmarsat presently has two systems in operation, namely:

1) The Inmarsat-A System: The first operational Inmarsat system which provides direct telephony telegraphy capabilities. Services offered over this system are telephony, telex, facsimile and data transmission. Distress alerting is also a main function of the system for maritime users, providing Distress Priority on both telephony and telex as well as having a Distress Message Generator capability for telex only.

2) Inmarsat-C System: A digital message store-and-forward system, which has received wide acceptance for the Global Maritime Distress and Safety System. Inmarsat-C does not offer a voice circuit. Baseline services provided over this system are generally message and data. The system also supports the Enhanced Group Call (EGC) function, which allows sending a message to virtually an unlimited number of predesignated ship earth stations.

Inmarsat is currently developing three new systems, namely:

1) The Inmarsat-B System: The digital successor to the Inmarsat-A system. It is based on modern digital technology in order to achieve more efficient utilization of satellite power and bandwidth resources, which will potentially reduce communication charges. In addition to voice and telex services, Inmarsat-B offers a wide range of data and facsimile services, user facilities (e.g., direct dial-in from shore) and safety-related features.

2) Inmarsat-M System: This system is being developed in parallel with the Inmarsat-B system and its design is based on low-cost, lightweight ship earth stations offering voice and low speed data/facsimile.

3) Inmarsat-E System: In conjunction with the Global Maritime Distress and Safety System, the Inmarsat-E system employs Emergency Position Indicating Radio Beacons (EPIRBs) transmitting on the L-Band frequency of the Inmarsat satellite. The system allows EPIRBs and coast earth stations uninterrupted access to the satellite to give fast distress alerting. The EPIRB may also be linked to the ship or other navigational systems to provide details of the ship course, speed and position.

INFORMATION TRANSFER THROUGH THE INMARSAT SYSTEMS

INMARSAT-A

The Inmarsat-A system presently provides automatic dial-up two-way telephony and telex to more than 13,000 ship earth stations. The Inmarsat voice grade channels can also be used

successfully for facsimile and data transmission at channel speeds up to 9.6 k.bits/sec. The data communication software and hardware required for this purpose is readily available, but may vary depending on specific requirements, such as average data volume to transmit, number of calls per day etc.

In general the basic on-board ship data requirements are as follows:

-A COMPUTER: that will process the information and run the programme.

-APPLICATION SOFTWARE that will contain the data programmes selected by the shipping company.

-VOICE BAND DATA MODEM: that will interface the computer with the ship earth station for data transmission (handshaking).

-COMMUNICATION SOFTWARE: that will provide the transfer protocol in order to maintain fast and simple operation and ensure end-to-end data integrity.

-INMARSAT SHIP EARTH STATION: That will perform the link with the coast earth station.

The requirement on shore (e.g., at the shipping company) will be similar to that required on-board, replacing the ship earth station with the public switched telephone network (PSTN) or a direct leased line with the coast earth station.

Figure (2) Data Transmission Via Satellite

Any^{pc}

usedwith
serial port speed 192Kbps,
Hardware flow control

MOdems   **Traffic**

V.22bis   less than 1kbytes
courier (HST)   less then 50 Kbykes
V32   more then 50 Kbytcs

Inmarsat-A
SES

Coast Earth Station

Telephone line

PSTN

(Public Switched Telephone Network)
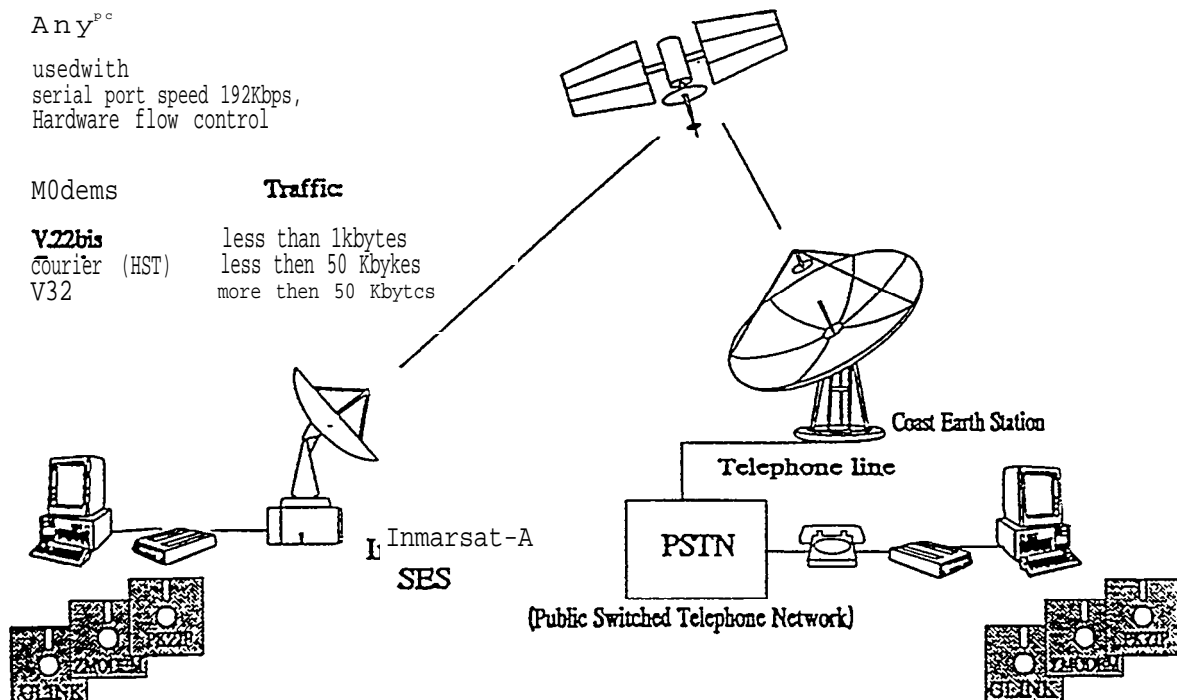
Add-on options to the above facilities are available either to improve the data transmission functions or to provide other functions; they include:

-DATA COMPRESSION SOFTWARE: that will significantly increase the transfer rate and consequently save time and money.

-PHOTO TRANSMISSION EQUIPMENT: available for both Macintosh and IBM PC compatible computers; they allow display of live video on the computer screen, to freezing of a frame, compression and transmission as a data file via a modem and a ship earth station.

INMARSAT-A   APPLICATIONS

-VESSEL   MANAGEMENT:

A wide range of management tools exist that can assist the ship owner in the operation of his vessels. In general, lists, statistics and monitoring data are a basic requirement for information exchange between the shore and the ship. This may include stores and supplies, staff records and payrolls, cargo operations, stability and damage information, maintenance, monitoring machinery performances and supervising running costs.

Those applications provide an improved ship management process, utilize an efficient communication system at reduced cost and enhance the safety of the vessel. The use of such features can motivate the crew on-board, resulting in an increase in their performance standards.

-OPERATIONAL AIDS:

Photo transmission via satellites has been achieved through both analogue and digital equipment for transmitting and processing high resolution colour photographs, in a very short time. This technology can benefit the engineer on-board, the maritime insurance sector, cruise vessels marketing, maritime law enforcement agencies, marine scientists, off-shore operators and fishery experts. For similar purposes still video applications have also been demonstrated, where the video signal coming from a video camera can be manipulated by the computer as an ordinary graphic. Zooming, resizing, rotating the picture, changing its colours, creating contrasts or even using special effects are possible modes of operation for specialized applications.

Another operational aid, available over the Inmarsat-A system is the differential GPS position *correction.* Purpose built receiving equipment, interfaced to the Inmarsat-A terminal, decodes the correction data and applies the same to the ships GPS measurements. Such an application contributes to navigational accuracy.
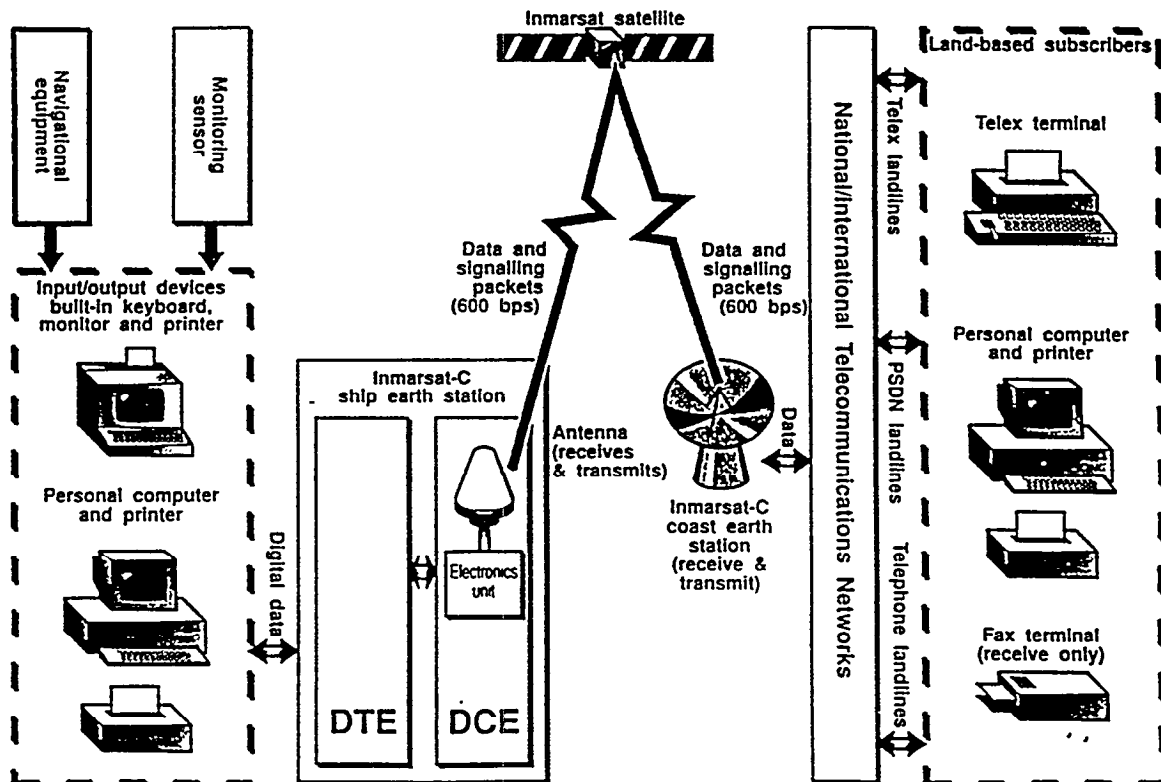
FUTURE APPLICATIONS:

Inmarsat is now starting to introduce data transmission
service at 64 k.bits/sec. Multiplexing will become a feature
of the service providing additional applications, and in
particular allow a ship to support several simultaneous voice,
fax and medium speed data calls. This will give the ship an
opportunity to lower its own communication costs whilst
increasing the volume of communications. With 64 k.bits/sec,
a two way video system will become feasible to support
applications like video conferencing and video-phones. The
64 k.bits/sec. services may become a requirement on-board
passenger and ferry ships,

INMARSAT-C

Since Inmarsat-C is a digital messaging system, all its
operations are conducted on a data transmit and receive basis.
In general, ship earth stations manufactured nowadays will
incorporate the computer, the application software and will
not require a modem. On the coast earth station side the data
signal is stored then forwarded through telex lines, Packet
Switching Digital Networks (PSDN), or telephone lines to a
telex terminal, personal computer and printer, or facsimile
terminal, as appropriate. In respect of facsimile, the coast
earth station will initiate the fax message to the end-user
after receiving it from the ship in the message store-and-
forward system. Facsimile in the Inmarsat-C system operates
in one direction only, i.e., in the ship-to-shore direction.

Figure (3) The Inmarsat-C Communications System

INMARSAT-C APPLICATIONS

-ENHANCED GROUP CALLS (SC): An advanced group call facility supported by the Inmarsat-C system, which allows a land-based centre to broadcast messages to selected groups of ship earth stations, which may be located anywhere within an ocean region.

Two EGC services are available:

(1) SafetyNET: This service provides an efficient low cost means of transmitting Maritime Safety InfOrIIBtiOn (MSI) to vessels at sea. MSI may include navigational warnings, weather warnings and forecasts, rescue coordination communications (shore-to-ship), ice hazards and other urgent warnings.

(2) FleetNET: This service is designed to allow authorized information providers such as commercial subscription services, shipping companies,and governments to broadcast messages to selected groups of ship earth stations. Typical information provided includes fleet or company broadcasts, news broadcasts, commercial weather services, market quotations and government broadcasts to its own vessels.

-DATA REPORTING: The data reporting protocol is optimized for the transmission of bursts of short packets of data. In addition to the normal format of the report, information may be included in a further compressed form by the use of Macro-*Encoded Messages (MEMs).* These use unique binary codes to represent a predefined text. An example of the MEM can be for instance a small number of bits to represent "The vessel *has been exposed to weather damage".*

Typical ship reports may include sailing plan, position report, deviation report, arrival report, departure report, shipping company position report and weather data report.

-POLLING: Operates in the same manner as data reporting, but in the reverse direction. Organizations ashore such as shipping companies and control centres may send polling commands to either individual or groups of ship earth stations. The polling command may include instructions to send report(s) immediately, at random basis, or at pre-set regular times. -Polling may be used to trigger information flow if the Inmarsat-C terminal is being used to monitor on-board operations (e.g., machinery or navigational monitoring).

-DATABASE APPLICATIONS: Inmarsat has developed an evaluation pack consisting of a database and an Inmarsat-C interface. Its main feature is that it implements a *"Standard Query Language (SQL)* I'. This language, is in fact a set of commands supported by several database products from different manufacturers. This means that a command written for one product will have the same syntax for another database. A

service provider transmitting information to its subscribers would therefore not have to worry about the hardware or the software that customers are using aboard their ships. Such databases may include details on ship management, spare parts tracking, maintenance and inspection, medical chest management, customs and immigration rules, port information, notices to mariners and others. Update of the database can be continuous, in accordance with the service providers, conditions.

-TOUCH SCREEN APPLICATIONS: Inmarsat has also developed a demonstration package enabling a user aboard ship to send handwritten messages via an Inmarsat-C terminal. A computer using the package will require an interface and a compatible PC, and features a touchscreen and an electronic pen. Basically, what the user has to do is handwrite the name of the vessel, (the computer translates the handwriting into computer data), tick a few boxes on the screen with the metallic stylus, write some additional comments and click on the "send" button. This application removes the barrier between people. The built-in hand writing recognition algorithm presently supports a limited number of languages.

FUTURE TRENDS

The present maritime communication systems over satellites have enabled an exciting application process, with a focus on distress and safety, proper ship management, aid to the navigation system on-board and facilitation of shipping. The future is even more exciting; the development of digital terminals, new hardware and software computer facilities and increased on-board automation will lead to new applications that are bound to enhance the future of maritime satellite communications.

Some of the ideas that are being considered for the future have included the following:

(i) The development of Wide Area Networks (WANs) providing added-value services such as electronic mail, on a global basis.

(ii) Integrating the maritime mobile system with on-shore cellular networks.

(iii) Increased videophones and image transmission with an integration of those services into the wide area networks.

(iv) Advanced computer interface (e.g., voice input for Inmarsat-C and development of the touchscreen computer application).

(v) Group 4 facsimile with colour and high speed.

(vi) Use of satellite communications to aid the automated operations of ships.

IN CONCLUSION, it has been shown that maritime satellite communications have created an impact resembling the opening of a door, through which new technologies are emerging, to aid the shipping community. A number of shipping companies are structuring their ship management systems on the use of satellite communications, to enhance operations and to save time and money. The GMDSS has also identified reliance on the Inmarsat system within its coverage areas, which account for 95% of the world total water surface area, where the majority of ships operate.

Maritime satellite communication provides resolution to a number of problems that were encountered through the use of conventional maritime communication methods. In fact, with those earlier methods, a saturation limit has been reached, beyond which it was difficult to generate new maritime communication technologies. With satellite communication, however, the modern era of maritime communications is just beginning. Future developments offer many exciting applications to the ship staff, owners and managers and will draw them together causing the shipping industry to become a compact unit.

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Application of Telematics in safety and environmental control

DELFT,
June 4th 1992

Mr. Willem van Hezik
INTIS Research & Development

SAFETY CONTROL
  By control of information

CONTROL OF INFORMATION
  By control of information-exchange

CONTROL OF INFORMATION-EXCHANGE
  By application of information technology
  in telecommunications □ telematics

DANGEROUS GOODS NOTIFICATION

SHIP

Name agent
Name ship
ETA
BERTH(S)

SUBSTANCES

Proper technical name
UN   – number
IMO – class
      – flash point

Quantity

Colli

Stowage

- to be loaded
- to be unleaded
- in transit

protgr12

EXCHANGE OF INFORMATION
ON DANGEROUS CARGO

SHIPPER

fax/telex

D.G. declaration
("to be loaded")

LINER AGENT

LINER AGENT

fax/telex

fax/telex

LINER AGENT

D.G. Manifest
("to be unloaded")

Document
+ copies
fax/telex

D.G. Notification

Port Authority

PORT B   PORT A   PORT R
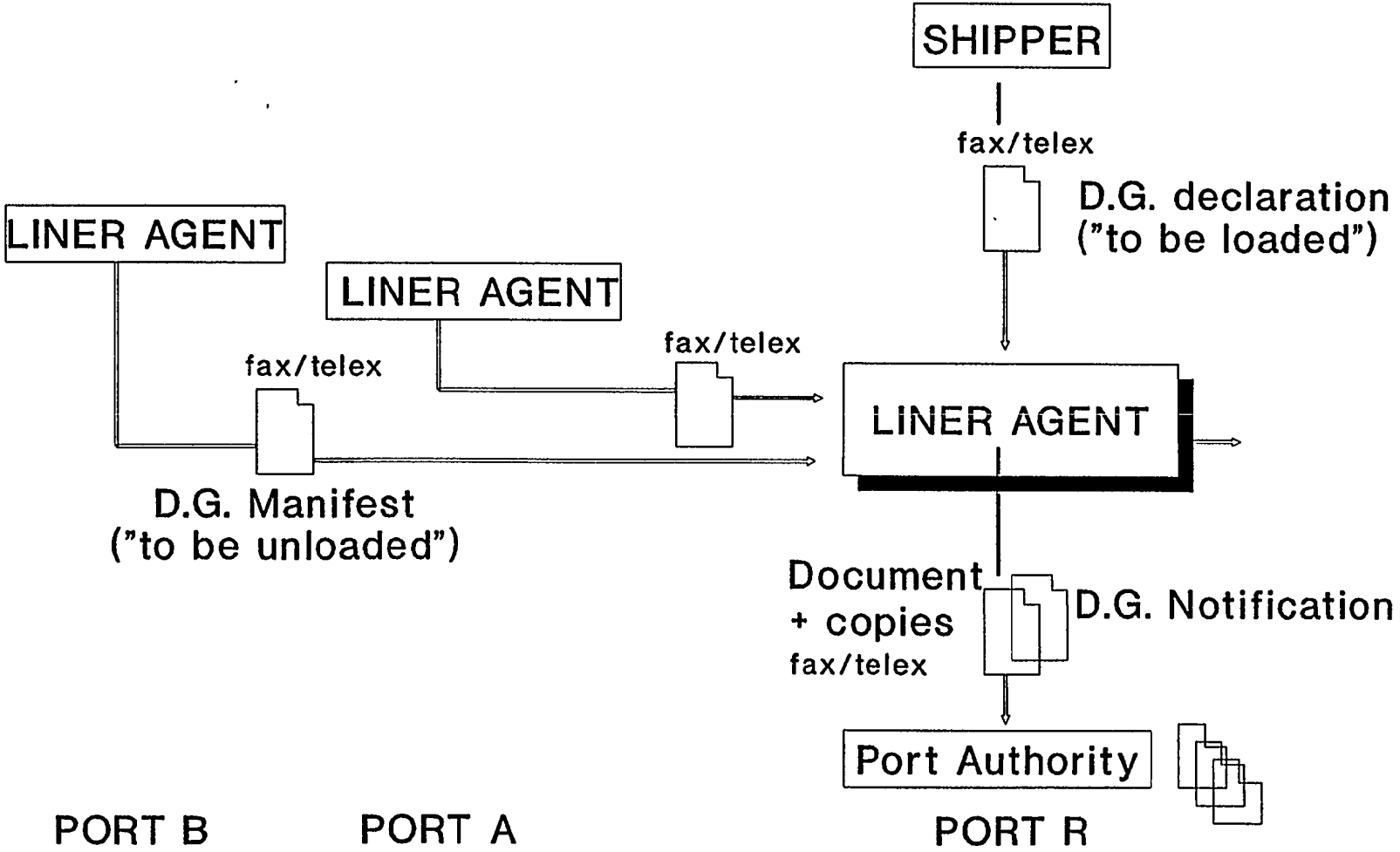
PORT AUTHORITIES
OBJECTIVES

- Improve and speed up
  the exchange of information
  on maritime dangerous cargo

- By means of EDI
  (Electronic Data Interchange)

protghr01

PROTECT

- Initally a limited number of ports in NW EUROPE, to set up pilots in short sea

- To be extended to deep sea trades

- Participants in PROTECT are:
  - DBH, Port of Bremen
  - DAKOSY, Port of Hamburg
  - INTIS, Port of Rotterdam
  - MCP, Port of Felixstowe
  - Seagha, Port of Antwerp
  - SOGET, Port of Le Havre

PRGHR03

EDI ARCHITECTURE

| Shipper Forwarder | Liner agent Forwarder | | Liner agent Forwarder | Shipper Forwarder |

C

Port Community System

B

Port Community System

D

A

Port Authority

A

Port Authority

A = D.G. Notification

B = D.G. manifest

C = D.G. Declaration
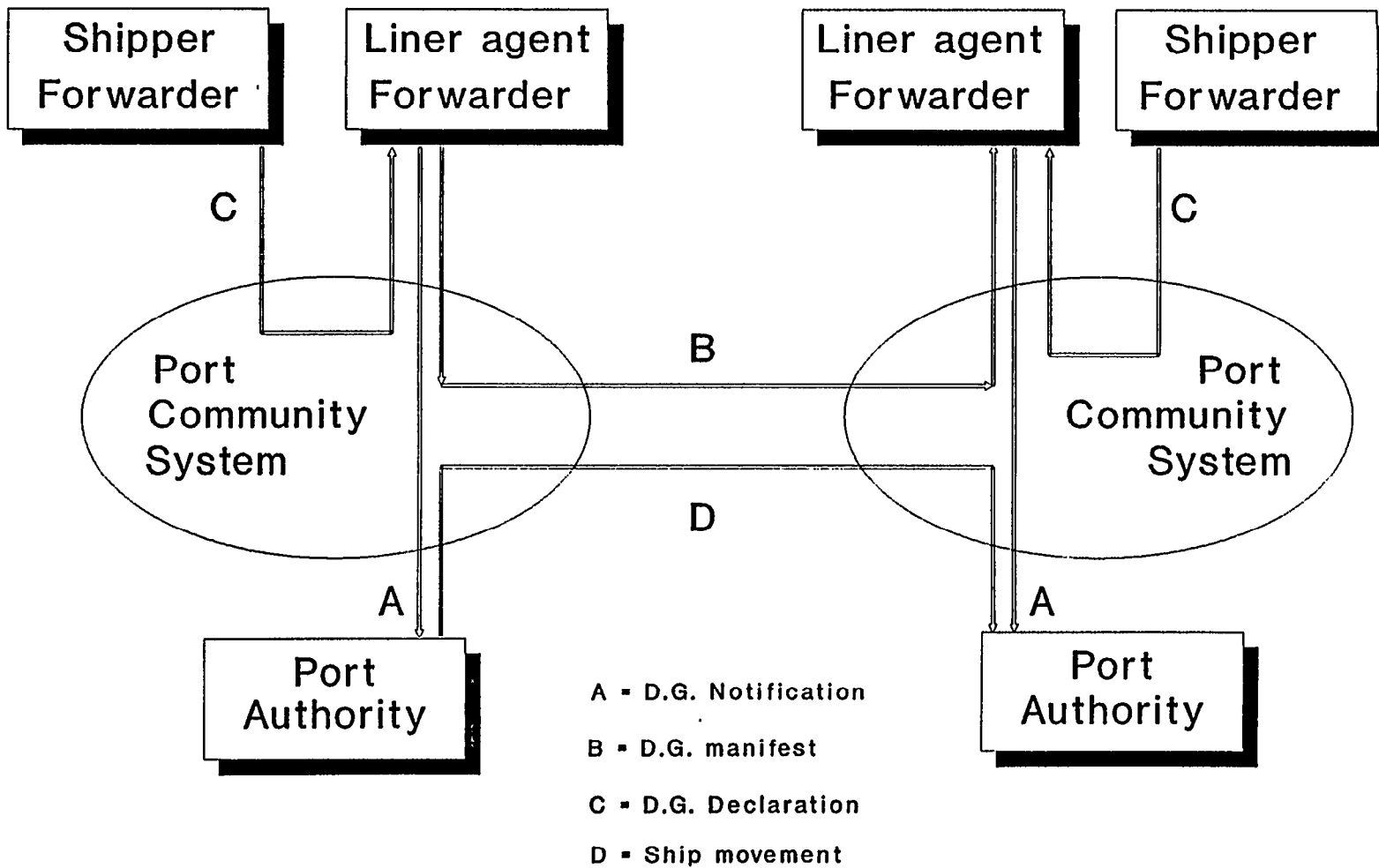
D = Ship movement

Overall Projectteam

Secretariat — Message Design

Antwerp | Bremen | Felixstowe | Hamburg | Le Havre | Rotterdam

local projectteams

GOALS OF PROTECT

- Provide for standard EDI Messages
  * on dangerous cargo
  * on shipmovement

- Provide for interport communication-network

- Provide for models of Interchange Agreements

- Carry out local and international pilots

- Promote the operational implementation

protghr02

UN - EDIFACT STANDARDIZATION

UN / ECE ——————————— ISO

WP 4
Facilitation of
International
Trade Procedures

UN / EDIFACT
Rapporteurs ——— JOINT MEETING

EDIFACT BOARD

Western Europe
Eastern Europe
America
Australia / New Zealand
Asia

Technical
Coordinating
Committee

Message
Development
Group 2
Transport
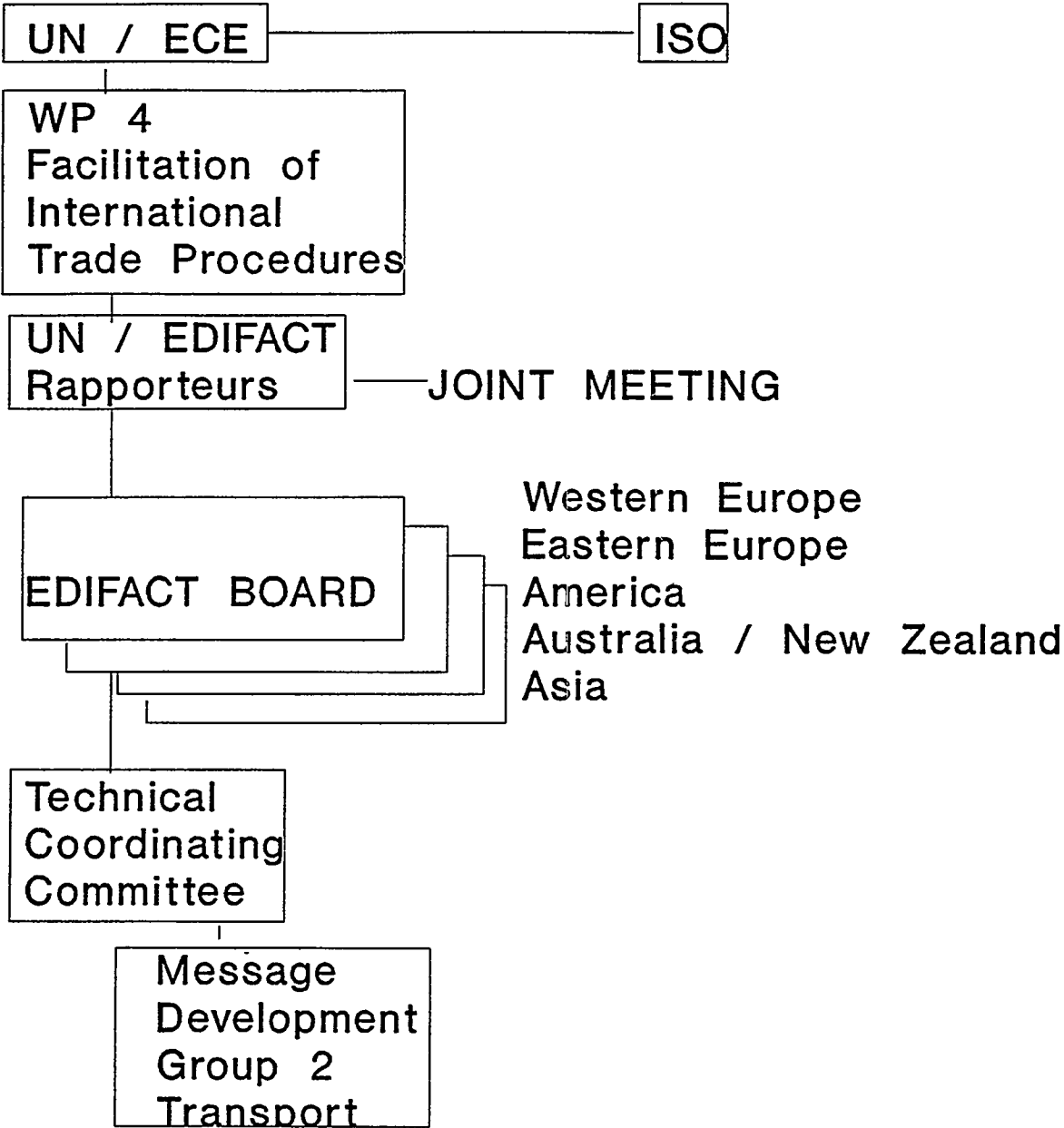
STATUS QUO .
Protect Messages

- D.G. Notification
  - available for tests
  - announced to EDIFACT BOARD
  - status 0 expected in sep 92

- Ship movement message
  - available for tests
    (implemented in Australia)
  - sep 92 to EDIFACT BOARD

- D.G. Manifest and D.G. Declaration
  - under development
  - sep 92 to EDIFACT BOARD

THE ROLE OF EXPERT SYSTEMS AND NEURAL NETWORECS'IN THE MAR-
INE INDUSTRY

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Abstract

This paper discusses the roles played by expert systems
and neural networks onboard ship concentrating upon their
uses for machinery diagnostics. It describes the type of
advanced system which may become available and require
evaluation in the foreseeable future.

Work on the 'Knowledge Based Ship' is described and two
future sub-systems, the Collision Avoidance Support System
and the Emergency and Damage Control Advisor and Trainer,
introduced.

The merits and potential of early and accurate fault
detection, diagnosis and estimation of fault severity are
discussed together with the relative virtues of steady
state and transient monitoring. The abilities of neural
networks and expert systems applied to diagnostics are
compared and their enhanced effectiveness achieved by
using the two techniques together is illustrated by the
description of a research fault detection and diagnosis
system which utilises this concept.

Introduction

In the early 1980's, Lloyd's Register clearly saw the future importance of computer based engine diagnostics as an aid to efficient machinery supervision and control. At the same time, IX's established policy of promoting research into the application of advanced technology, in support of proper standards of quality and safety, enabled the application of its research resources to the technology of fault detection and diagnostics and other uses of expert systems in the marine industry.

Work also began with research into the fundamental structure and components of diagnostic systems, which then progressed into a study of the nature and characteristics of diesel engine expert systems, In order to gain a proper understanding of the design problems involved, LR decided to develop a diesel engine expert diagnostic system. This has been tested successfully on engines of different design. Other work has involved the study of on-board decision support systems to assist shipboard management, particularly in emergency situations.

A significant amount of work has been carried out into the use of "advanced algorithms" such as genetic algorithms and neural networks. Neural networks in particular are most promising diagnostic tools which can facilitate the correlation and analysis of multiple data streams, such as those generated by the sensors fitted to diesel engines. Interest has focussed on their incorporation in expert systems to allow the benefits of both to be used to best advantage.

The monitoring of transient as opposed to steady state machine conditions is also under investigation and is already proving to be a powerful technique. Its ability to amplify symptoms which may be very difficult to detect at steady state not only provides-=&he-possibility of detecting faults earlier, but also requires less precise measurements with potential benefits such as reduced sensor accuracy and cost. Success in this work can be expected to show the suitability of computer based diagnostics for wider employment where the operation of machinery or systems is entirely transient.

The Knowledge Based Ship

In these times of reduced manning and the difficulty in obtaining experienced crews, there are very good reasons for having onboard systems which can detect and diagnose problems and support decision making. Such systems can

add an element of the experience and consistency in decision making which may be lacking, thus increasing awareness and reducing the possibility of misjudgement. This improved performance will be reflected in improved reliability and safety.

The EC Esprit Shipboard Installation of Knowledge-Based Systems (KBSSHIP) Project, in which LR was a partner, successfully demonstrated the concept of a shipboard decision support system. KBSSHIP is composed of a System Manager supported by an expert database containing regulations
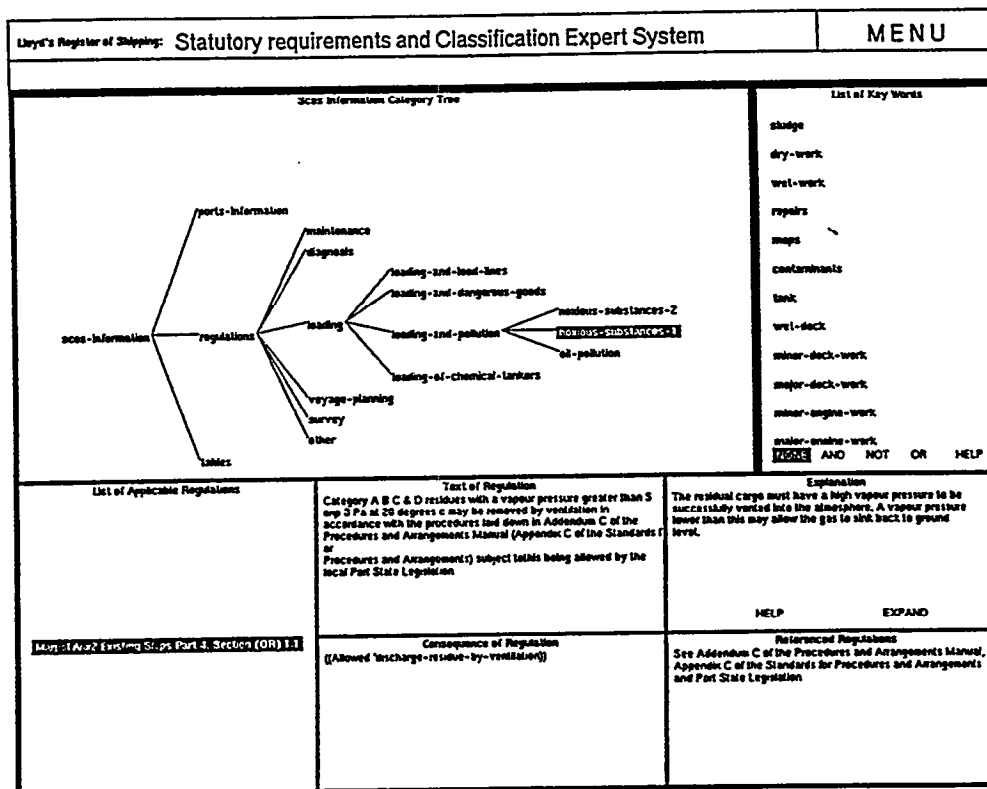
Figure 1. Screen from the SCE System

pertinent to the running and operation of the ship (the Statutory Requirements and Classification Expert System, Figure 1). The System Manager supervises the communication and co-operation between four decision support tools designed to carry out voyage planning, fault diagnosis, maintenance scheduling in the form of the Expert Maintenance System (Figure 2) and cargo planning.

KBSSHIP can be viewed as a successful prototype for ship-board decision support expert systems. It is a practical demonstrator of the types of applications and methods which will allow the introduction of appropriate information technology in support of ships' officers and crews in

Figure 2. Screen from the Expert Maintenance System

the future. It will enable the shipboard integrated knowledge base to expand to the full extent required. Such expansion might include a Collision Avoidance Support System which would provide guidance for the Watchkeeper to help him avoid dangerous situations and if they arise give advice and alternative courses of action to prevent collision.

The expansion is also expected to include an Emergency and Damage Control Advisor and Trainer which will provide support for those in command when emergencies occur. Reports of ship accidents show that a support system would assist control of an emergency and could reduce the seriousness of the outcome. Experience in the air transport sector reinforces this view. The benefits would include reduced injuries and loss of life, and reduced damage to both the installation and the environment, with consequently reduced monetary cost.

The Emergency Command Aid part of the system will help the person in command by assisting with assessment of the situation and provide advice about immediate necessary responses and recommended additional actions for controlling the emergency. Conversely the Emergency Simulator Trainer will provide a means for practising the management of fire, damage, or other emergencies as they might occur in the user's environment. It would consist of a simulator designed to represent the individual ship or installation concerned. It would allow ship or control staff to practise the management of emergency situations as if they were in the real control situation.

Foreseeable improvements and refinements in machinery condition and health monitoring techniques will assist the early detection of machinery faults and their prompt diagnosis and severity estimation. This earlier and better knowledge of machinery problems will be used in conjunction with computer based maintenance planning and ships' voyage planning tools to minimise any adverse effects on the ships' operation. The majority of diagnostic systems are built from rule based expert systems, but there are other methods which can be employed. One set of algorithms which are proving to be very successful are Neural Networks.

The majority of current shipboard applications of advanced support systems are based on expert system technology. An expert system is built upon rules; the harder and faster the rules, the better will the system function. Unfortunately expert systems perform less well when dealing with uncertainty or probability. This is because the expert system reasons according to algorithms in its 'inference engine'. It combines facts from its knowledge base according to the 'book of rules' it has been given. Expert systems, therefore, require an 'expert', either in the form of a 'book of rules' or an authority on the subject, to provide the knowledge and the symbolic model of the task.

However, for many tasks rules are difficult to' formulate, consequently rationalisation of the problem is far from easy, creating difficulties in constructing a symbolic model.

By comparison, such tasks can be accomplished by neural networks. Neural networks learn by example; trained on data which represent the problem. Neural networks are trained to adjust the connections between the processing elements (or nodes) so as to correlate the input and output patterns. This means that computing using neural nets is non-algorithmic; there is no algorithm describing the trained network The 'algorithm' of the trained network together with its 'rules' and *knowledge base' exist within the complex pattern of connection values which the learning process has produced. Furthermore, this information is not located in one particular place; it is spread throughout the network.

This is known as distributed memory and has the advantage of making neural networks fault tolerant. Because the information is spread throughout the network the loss of some connections, or even nodes with associated connections, does not result in the total loss of information. In fact a reduction in performance may not even be detectable, whereas damage to even a very minor part of a conventional expert system will render it useless.

NEURAL NETWORKS

The various types of neural network have been described in detail by Lippmann, 1987 and in the NeuralWorks Software documentation. Karna and Breen,1989 also provide a very good introduction (in the form of a tutorial) into the workings of neural networks, as does Fougleman-Soulie, 1990.

Description
Neural networks can be thought of as general purpose pattern classifiers or matchers which are trained on a representative set of patterns or data. They are capable of classifying patterns which are not in the training set, in other words they can generalize or interpolate. They also have the ability to recognize noisy or partly corrupted patterns. They are fault tolerant in that the network will accept a certain amount of 'damage' before any significant reduction in performance can be detected.
Simulated neural networks are software models based on various interpretations of the structure and functioning of the brain. The artificial neuron is called a processing element or node. It has many input paths and com-

bines, usually by summation, the input values 'it receives. The combined input is then modified by a transfer function to a new value. This new value becomes the output and can be connected to the inputs of other processing elements through 'weights' which correspond to the synaptic strength of biological neural connections. Each weight has a value which is used to modify the data passing through it. As in the biological brain the neural network learns by altering the values of its weights to try and reduce the error between the output the network produces to a particular input pattern and the required output. This is an iterative process, carried out as the patterns to be learned are presented; an algorithm calculates the error and changes the value of the weights accordingly.

Thus a trained neural network contains all its knowledge in the values of the connections between the nodes, i.e. the value of the weights. The network consists of many processing elements joined together. They are usually collected together in groups called layers. A general structure of a net would be a sequence of layers, starting with
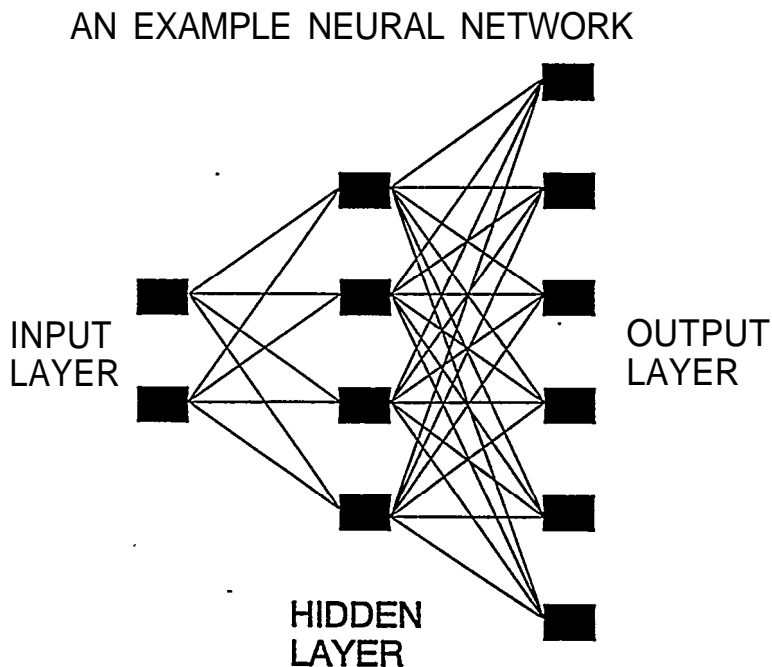
AN EXAMPLE NEURAL NETWORK

INPUT
LAYER

OUTPUT
LAYER

HIDDEN
LAYER

Figure 3. An example neural network

an input layer, followed by a number of hidden' layers
(hidden in that they have no direct connection to the out-
side world) and concluding with an output layer.

Figure 3 shows an example of a simulated neural network
with an input layer consisting of 2 nodes, connections (or
weights) to the middle or hidden layer of 4 nodes and con-
nections from the hidden layer to the output layer of 6
nodes. Figure 4 shows the connections to one of the
nodes in the hidden layer and Figure 5 shows how this node
processes the data coming into it from the input layer.
The incoming value from node 1 (yl) is multiplied by the
value of the connection from node 1 to node 3 (weight
w13). The same procedure is carried out for the value from
node 2. The values coming into the node are first of all

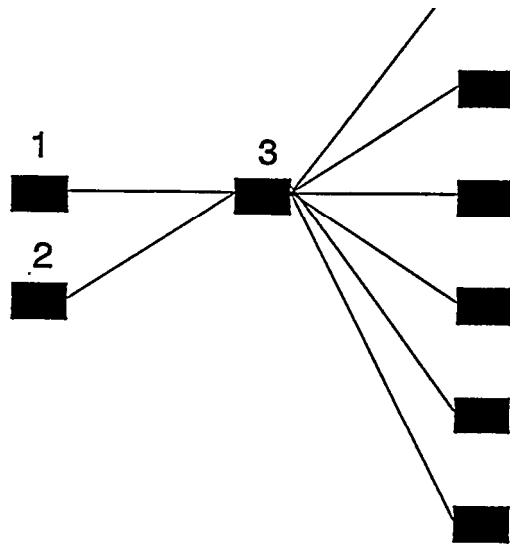A VIEW OF NODE 3 AND ITS
CONNECTIONS (Weights)-

Figure 4. A view of node 3 and its connections

summed producing a value X3, which is then modified by the
node's transfer function, which in this example is a sig-
moid. The transfer function alters the value of X3 to Y3
which is the output value from this node to the nodes in
the next layer where the process is repeated.

FUNCTION OF NODE 3

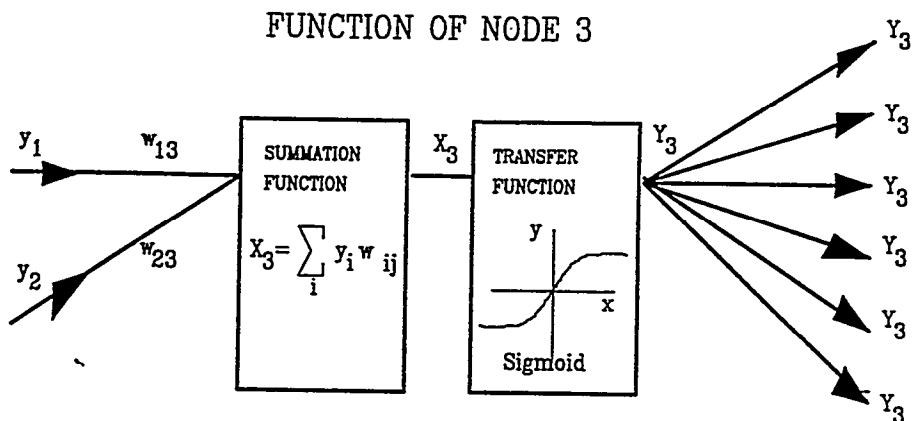$$X_3 = \sum_i y_i w_{ij}$$

Figure 5.   Function of node 3

There are many types of network, each with various attributes and suitable for different applications.   They can be distinguished by:

   a) the mathematical formula which the processing elements use to combine the input values (the summation function).

   b) the mathematical formula which the processing elements use to modify the combined input values. This is the transfer function.

   c) the method of training - the way in which the values of the weights (strength of the interconnections) are adjusted as the network learns.   This is determined by the learning algorithm.   The learning algorithm is the only preprogrammed part of the network. It determines how the values of the connections in the net are altered in response to the training patterns.

d) the way in which the processing elements in the
   network are connected which may be described as the
   network architecture.

Neural networks appear to provide a powerful tool which is
likely to be incorporated into future diagnostic systems.

Future of Diagnostics

Steady State Diagnostics

The diesel engine expert diagnostic system (DEEDS), devel-
oped under an initiative led by LR,nis a steady state
monitoring system. The engine must be settled at a steady
operating condition before fault detection and diagnosis
can take place. The DEEDS system has demonstrated that
such systems can achieve high success rates of fault diag-
nosis (85%) (Banisoleiman et. al. 1991). A great deal was
learned through this work and it has formed the basis for
further research. One interesting development has high-
lighted the complexity of symptom patterns at different
engine operating points and this confirms the view that
more complex rules would be required to be able to improve
the expert system's diagnostic success rate. An alterna-
tive is to train neural networks to be able to diagnose
faults from these complex patterns. In this role the net-
works are used to the best advantage. The neural network
does, however, have the disadvantage that it is difficult
to extract the reasoning behind its decisions.

Transient Diagnostics

LR's involvement with the DEEDS project has provided ex-
pertise in detecting and diagnosing faults for diesel en-
gines based on artificial intelligence techniques. Whilst
high rates of diagnostic success were achieved, the DEEDS
project highlighted the fact that this relied on the use
of expensive, delicate and accurate instrumentation. The
instrumentation problem appears, from the ship owners'
viewpoint, to be the main obstacle to general use of this
technology, however, other approaches to diagnostics ap-
pear to offer advantages which could help to alleviate
this problem. One such approach is the monitoring of
transients - monitoring the machine or system during
changes from one operating condition to another.

Work being conducted within LR has shown the value of
monitoring the transient response of a machine. The main
benefits being:

a) The detection and diagnosis of faults during the
   transient which could not be seen during steady
   state running.

b) The accuracy of the instrumentation required is less critical due to the differences between comparable parameters being exaggerated or amplified during the transient.

c) The combination of the reduction in required instrumentation accuracy together with amplification of fault symptoms reduces the cost of detection and diagnosis.

d) The amplification of the fault symptoms increases the possibility of early fault detection and diagnosis.

The majority of work to date has been carried out on gas turbine transient data. The next phase of the research will aim to investigate to what extent the same benefits of transient monitoring apply to diesel engines and devise fault detection and diagnostic techniques which can take advantage of them. Use is currently being made of a research project into diesel engine emissions produced during transients (Bazari, 1992) to test these ideas.

Fault Severity
Once a fault has been detected sensible decisions concerning the operation, maintenance and repair of machinery can only be made if information about fault severity is available. Being able to estimate and monitor the severity of a fault with confidence greatly assists the decision making process whether it is carried out by man alone or by man supported by machine.

One of the main problems with building systems which will estimate fault severity is lack of adequate data. It becomes very time consuming and expensive to conduct seeded fault trials on a test engine or carry out endurance running hoping to encounter faults. During the diesel engine expert system project, LR conducted comprehensive seeded fault trials incorporating, where possible, two fault severities for each fault. Whilst this set of data gives positive information about how symptoms change, a finer graduation of fault severity is required to provide sufficient data to -produce a system to estimate fault severity. This can be achieved by the use of computerized engine modelling and simulation.

LR's MERLIN engine simulation software has been used to model engines for which there are both healthy and faulty engine test data. It has then been possible to seed the engine model with faults of gradually varying severity and record /monitor the way in which the engine parameters

change. To ensure that the symptoms produced-by the simulation are realistic they have been compared with the real engine data.

The advantages of using a simulation to provide the data, compared with collecting it from a live engine, are that:

    a) it is much more economical in terms of time and resources

    b) symptoms of any level of severity can be produced

    c) any engine can be modelled.

This last point is very important for both designers and appraisers of diagnostic systems. The engine diagnostic system designer needs to be able to produce a system which will match the engine required to be monitored. In order to do that he must have examples of the symptoms the engine produces for the faults of interest. The engine simulation route, provided it is proven to be faithful to the real engine, is a very economical way to obtain the necessary engine parameter data. It is also very important for the appraisers of diagnostic systems because any system presented for appraisal can be tested against data from the engine for which it was designed relatively easily and economically. The appraisal can cover the full range of faults and engine operating envelope and, of course, fault severities. With this test of the functionality of the system it will be possible to determine not only whether a fault can be detected but also when.

Work has progressed to produce a system which will diagnose the engine fault and estimate its severity using neural network technology. Currently the work has been based upon steady state engine readings and is still being evaluated. It is intended that this would allow condition monitoring technology to move a step closer to the estimation of the remaining engine life before breakdown or unacceptable performance can be expected. This information could then be used to determine the scheduling of maintenance.

Neural Networks and Expert Systems together

One of the important lessons of the work that has been undertaken has been that while expert systems and neural networks working on their own can be extremely effective, if they can be made to work together the combination can be even more powerful. The comparison between expert systems and neural networks has already been covered. With

knowledge of the attributes discussed it is possible to
devise systems which take advantage of both technologies
to fulfil specific tasks and there are many ways in which
this can be done. One which LR has examined combines two
neural networks and an expert system arranged to monitor
transient data during the start of a gas turbine as de-
scribed below.

The Gas Turbine Start Fault Detection and Diagnostic Dem-
onstration System

The demonstration system shows neural networks and an ex-
pert system working together. It was designed to monitor
gas turbine starts, detect and diagnose any faults which
occur and give advice and warnings.

A diagram illustrating the workings of the demonstrator is
shown in Figure 6 and is described below.
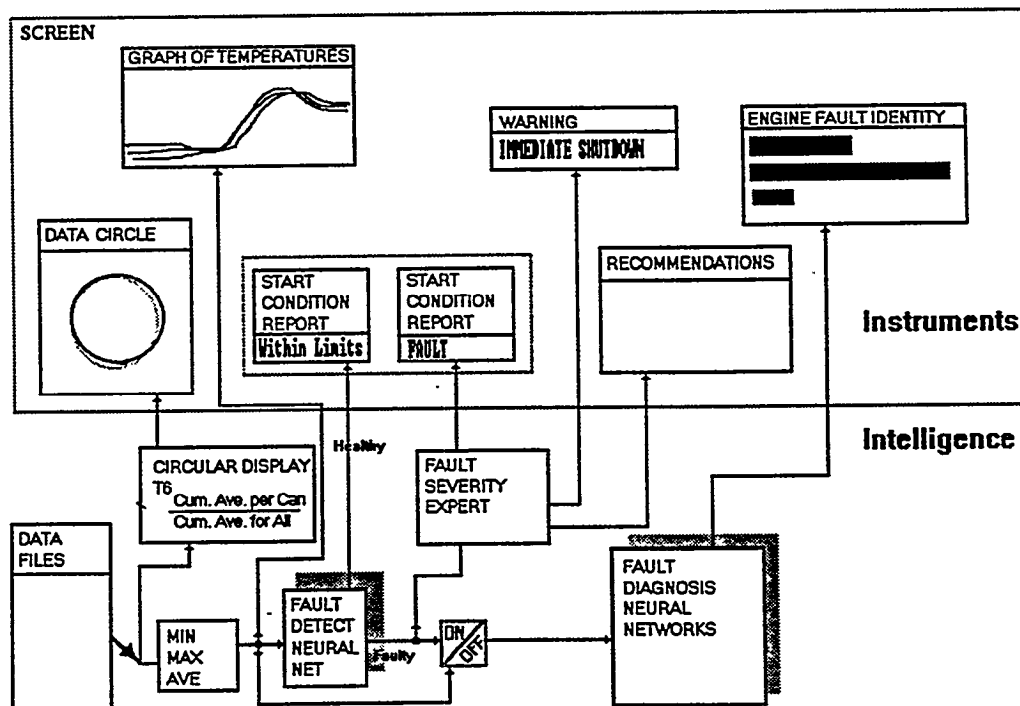

Data Flow in the Fault'
Diagnoslic System

Figure 6. Data flow in the fault diagnostic system

The demonstration consists of three examples of intelligent analysis each triggering an associated graphical output event.

1: The fault detector - a neural network trained to produce a single True/False output. Is there a fault or not? The results of this network are displayed as text in an engine status window. These results would also determine the behaviour of the rest of the program.

2: The fault identifier - a more complex network, only trained on fault data, to differentiate between different types of faults. This is used to interrogate a look up table of fault descriptions.

3: The advisor - an expert system built to decide the severity of the fault. If the fault is classified as serious an immediate warning window is popped up, in a prominent position, advising the user that there is a combustion problem and where it is (Figure 7). If the fault is a temporary, non-serious one then at the end of the
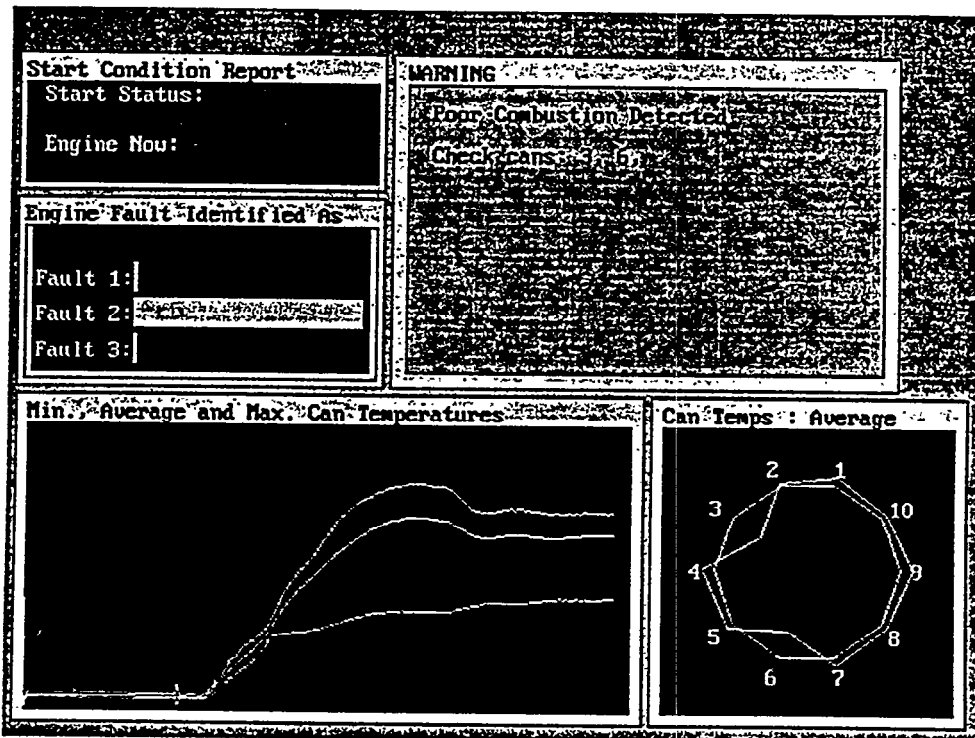

Figure 7.   A Serious Fault Detected

and LP engine spool speeds together with the gas generator
outlet temperatures used to monitor combustion.   Once se-
lected the data are read sequentially from the file as if
they were being taken directly from a data logging system.
It is displayed in the circular display and the average,
maximum and minimum calculated for use by the fault detec-
tion network with HP and LP spool speed and for display in
the form of a graph.   Figure 9 shows this for a healthy
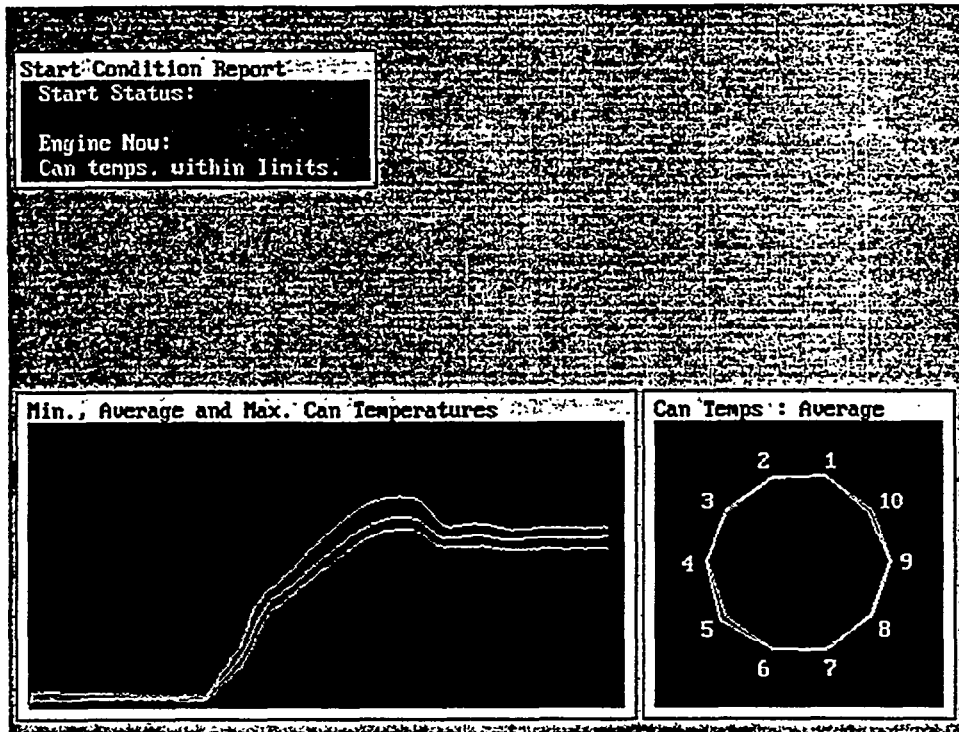engine start.

Figure 9.   A Healthy Engine Start

Once the network detects a fault, that information is dis-
played in the Start Condition Report window on screen and
the input information passed to the second network.   The
second network-is used to diagnose the fault during the
time it persists.   A window displaying the diagnosis is
displayed on screen.   This takes the form of a bar chart
with the length of each bar proportional to the likelihood
of a particular fault being present over the duration of
the fault.   The length of the bar is calculated from the
cumulative average of the outputs from the fault detection

demonstration (when a real engine would have reached idle)
a window pops up giving the diagnosis of the fault ident-
ifier and recommending that the user has the engine exam-
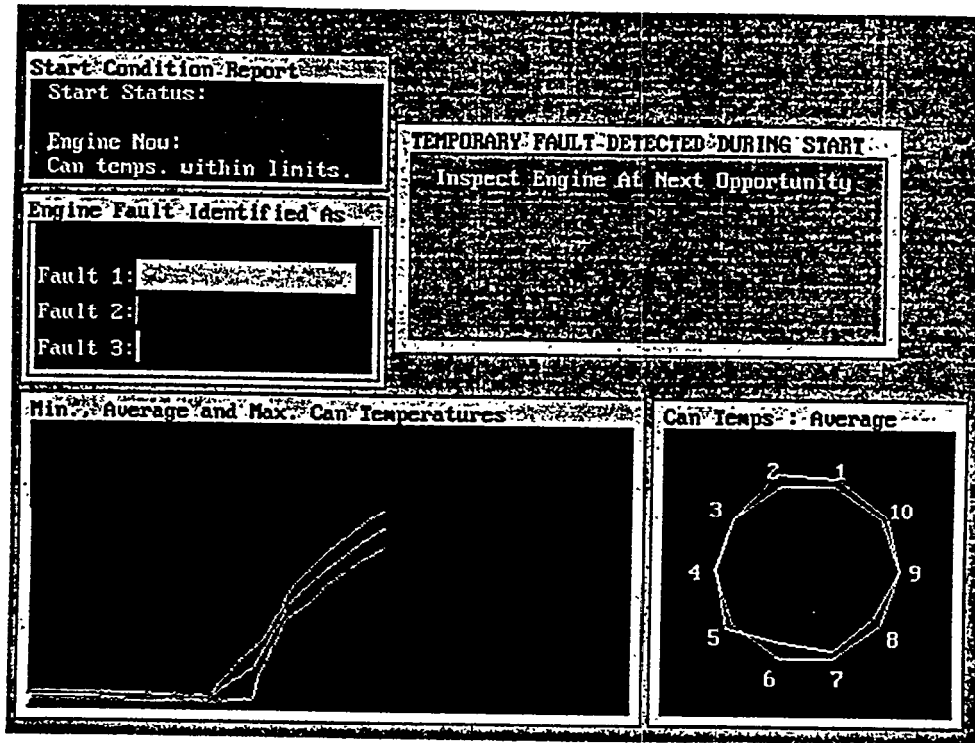ined at the earliest convenient opportunity (Figure 8).

Figure 8.   Detection of a temporary Fault

In addition graphical instruments were incorporated. One,
a graph of the minimum, average and maximum gas generator
outlet temperature for each combustion can over time was
included so that the user could keep track of the start
and see when the networks were making their decisions.
The second instrument, a circular graph of each combustion
can temperature divided by a reference (the average can
temperature) allows the user to see the state of the en-
gine combustion graphically.   This method of displaying
data is proving to be illuminating and is a very useful
monitoring concept (Hobday, 1988) and the opportunity was
taken to implement it in the demonstration to show it
working with transient data.

The demonstration is started by selecting a start data
file from the menu.   This file contains the measured HP

network, giving a fault diagnosis based upon the whole time that the fault persisted.

This demonstration shows that the two technologies can complement one another and carry out a function neither could easily achieve if used alone.

Conclusion

In this paper we have discussed some of the roles which expert systems and neural networks can perform in the marine industry to give support to the decision makers and thus improve safety, efficiency and availability.
Work on the 'Knowledge Based Ship' has been described including two future sub-systems, the Collision Avoidance Support System and the Emergency and Damage Control Advisor and Trainer.

The merits and potential of early and accurate fault detection, diagnosis and fault severity estimation have been expounded together with the virtues of steady state and transient monitoring.

A comparison has been drawn between neural networks and expert systems and the advantage of using the two technologies together to enhance their effectiveness has been explained. A system, constructed as part of a research project, which demonstrates this in a fault detection and diagnosis system has been described.

The knowledge gained in the course of this work will enable the benefits of expert system and neural network technology to be taken properly into account in future ship systems. It will help ensure the safe and correct implementation of this technology with the accompanying benefits of improved quality and safety,of operation of the ship and its machinery.

The continuing research programme which is exploring advanced techniques will ensure this knowledge remains at the forefront of technology.

Acknowledgements

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EXPERT SYSTEMS FOR MACHINERY SDRVEIILAWCE.

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Present-daymachinerymonitoring systems present on vdu'sthe operational mode
of the machinery, the values of system variables and generate alarms. In most
cases they do not contribute to evaluation of system health or diagnosis of
faults.
More intelligent monitoring systems should be able to asses system health,
predict developing failures, diagnose the failure causes and to give recommen-
dations for operation and maintenance.
These expert systems can be based on heuristic knowledge or on deep process
knowledge. Model based systems, relying on physical process knowledge, have
good possibilities to improve the condition monitoring function. Some aspects
of model based systems are reviewed.

Introduction.

Ship machinery installations have a high degree of integration. Electric power
and heating are frequently supplied by the propulsion system. This integration
is justified by economic reasons: either capital, fuel or maintenance costs
or a combination of those are reduced considerably. The plants are provided
with a high degree of automation and show, due to technical progress, few
failures. On the other hand the integration leads to rather complex plants,
where interpretation of condition and diagnosis of malfunctions becomes more
difficult.
Furthermore the complement on board ships is changing. The nautical officer
controls the ship including the machinery plant. The engineering officer
becomes a maintenance manager and hardly has operational duties. Moreover the
education of officers has changed: no longer nautical and engineering officers
are trained, but "multi-purpose" maritime officers.
All these changes may lead to less experience of the operating officers with
interpretation of machinery condition and diagnosis of possible failures.
These developments lead to higher safety risks. In order to reduce these
risks, more intelligent machinery monitoring systems are required. These may
also contribute to a further reduction in ship's personnel.

Present-day computer basedmonitoring systems present on vdu'sthe operational
mode of the machinery, system variables and generate alarms. However these
systems do not contribute to the evaluation of system health or the diagnosis
of faults. Intelligent monitoring systems have a number of additional advisory
tasks:
-continuous evaluation of machinery health and indication of developing
trends.
-diagnosis of failure causes.
-prediction of the time when a developing failure becomes critical and indica-
tion of maintenance tasks.
-indication of how to operate the machinery with a (developing) failure.
-explanation of the reasoning behind the diagnosis and advises.

Such "expert" systems can be based on heuristic and/or on knowledge of the
process physics. Heuristic knowledge is the result of experience of designers,
operators and other experts with the machinery plant and its behaviour after
failures have become manifest. In such a case the relation between symptom5
and causes is known, but frequently the physical process cannot be explained.
In case of sufficient deep knowledge of the physical process being available,
one will be able to make mathematical models of the machinery. These models
can be used to predict the operational behaviour of both the healthy and the
malfunctioning system. For machinery expert systems one can use both heuristic
and process knowledge. For complex machinery the real process knowledge may
be too limited to rely on. Heuristic knowledge, however, is difficult to
acquire and experts frequently have contradictory opinions. Implementation of
heuristic rules in diagnostic systems can be time-consuming. On the other hand
deep process knowledge enables better prediction of machinery behaviour and
diagnosis of faults. This paper discusses some aspects of intelligent

monitoring systems relying, as much as possible, on knowledge of the process physics.

Projects on machinery expert systems.

Both type5 of systems, heuristic and model based, are the subject of research all over the world. Research, aiming at marine applications, is reported for instance by: [Ahlgvist, 19911, [Dabbar e.a., 19891, [Elliot e.a., 19901, (Katsoulakos e-a., 1988, 19891, [Richards, 19881, (Roselund e.a., 19881, [Ruxton e.a., 19881, [Siebert e.a., 19891, [Shamsolmaali e.a., 19911.

Delft University is involved in the ICMOS project. ICMOS involves research in Intelligent Control and Monitoring of marine machinery Systems. The project is sponsored by the Dutch Foundation for Maritime Research, the Shipowners' Association5 and Royal Netherlands Navy. Other partners in the project are NRVRSBU/LOGOS, Stork Wzirtsila Diesel and Croon.

DUT is cooperating in the following Sub-projects:
-with Stork W&tsilg Diesel an intelligent diesel engine monitoring system is being developed, which will be able to asses the engine health, to diagnose the causes of faults and to indicate the remaining life before limits will be exceeded. The project addresses primarily the thermodynamic process. A basic feature of this system is that the number of sensors should not be increased compared to a standard surveillance system. [Jaspers e.a., 19901
-with van Buuren-van Swaay a study is being conducted to the feasibility of an expert monitoring system for compressor cooling/refrigeration plants.
-a fundamental research project into diagnostic methods for machinery and sensor failures. In this project the cooling system of a diesel engine is used as an example.

Hodel based systems.

For determination of machinery condition it is necessary to know which values process variables should have in healthy state. For an alarm system these references consist of limit values, which should not be exceeded.
For a more intelligent system, one wants to have early information about the machinery condition. This requires a reference model of the machinery which can predict variable or parameter values, with a high accuracy, in all operational conditions. By comparing actual values of variables of the running machinery with those of the reference model, it is possible to conclude whether the system is healthy or whether there is some form of malfunctioning.

After having concluded that there is a malfunction, one wants to diagnose the cause. Therefore, diagnostic techniques are needed which are based on the relation between symptoms (deviations of actual and reference values) and possible causes. The diagnostic model can consist of a set of rules, based on heuristic and/or deep process knowledge, but can also be a mathematical procedure, which translates symptoms into possible causes.

Sensors are an essential part of the monitoring system.. They produce measurement values, which can deviate from the real values due to sensor drift and failures. Sensors are recognized sources of trouble in monitoring systems. In order to realize a reliable expert monitoring system it is therefore necessary to include sensor monitoring.

Deviations from healthy machinery operation should be detected in an early stage. It is next of much interest to predict when the machinery condition will have deteriorated 50 much, that correction of the looming fault, i.e. maintenance, is required. Therefore trend analysis and prediction are essential, as well as advises how to operate the machinery with the lowest risk for critical situations.

Reference models.

The simplest form of reference model is a set of formulae, which have been obtained by curve fitting using test bed or sea trial measurements. During

development of the reference model the machinery system must be healthy and running in an operational condition close to the actual, preferably with the same sensors as used for the monitoring system. The result is a reference model with a good accuracy, but, because no process knowledge is included, only suitable for the operational conditions at which the measurements have been taken. Such a reference model, as for example a diesel engine running on propeller law, generates the relevant variables (temperatures, pressures, speeds, flows) as a function of a few operational parameters (e.g. engine speed). The model will show deviations in circumstances other than during trials, for instance due to increased propeller load or another ambient air temperature.

Good process knowledge enables reference models, based on the physics of the process. In general this makes the model more suitable for variations in ambient and loading condition. When, however, a model is based on theoretical data only, the accuracy might be insufficient. A sound way of developing a reference model therefore is to use physical relations which should be matched to the actual machinery on basis of measurements.

An empirical reference generator can be made rather easily for the complete machinery system, as for example the model of a diesel engine as discussed above. A physical model of the complete system will be more difficult to develop, because not all necessary knowledge might be available.or development and matching might take much time. Both for condition determination and diagnosis tasks, it is however not mandatory to have a reference model of the complete system. Smaller models of system components could be sufficient and be more powerful.

In a component reference model the healthy output variables (measurement signals) are, based on physical knowledge, given as a function of inputvariables, which define the operational condition, see figure 1. The reference model could also involve the determination of component parameters, such a8 a heat transfer coefficient, see figure 2.
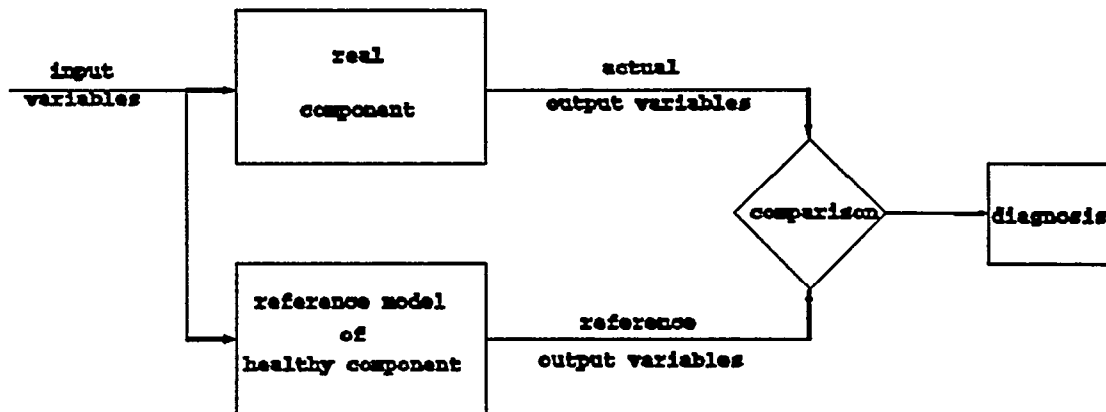

figure 1:   A *component reference model to determine its condition: healthy or malfunctioning.*
The input variables should determine the operational conditioning completely.
The output variables are *direct measurements such as temperatures and pressures.*

As an example the reference model of a diesel engine air cooler is described and compared with the model of a complete engine.
In the complete engine model the temperature after and pressure drop over the cooler might be given as a function of engine speed only. A more detailed description of the engine model, with more input variables would be too complicated. With these two variables the cooler operational condition is not fully determined however. The cooler function is depending on inlet air and water temperatures, air pressure and mass flows as inputs. As output variables the air and water temperatures after the cooler and pressure drops can be regarded.
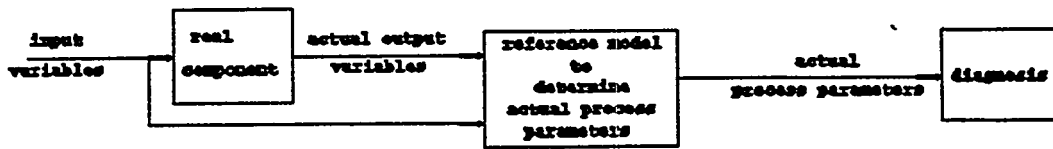
figure 2:   A component reference model to determine actual process
            parameters, such as a heat transfer coefficient and a pressure
            loss coefficient.

With the engine reference model one may conclude there is too high a temperature after the cooler, which, for example, not only could be the result of:
-cooler fouling
but also of:
-too small a cooling water mass flow due to a pump problem
-too high a water inlet temperature due to a control valve failure
-too high an air inlet temperature due to a compressor malfunctioning
This means that, with such an overall model, a deviation from the healthy
state does not give a direct clue to the origin of the problem.

With a cooler reference model, involving a set of input variables, which fully
defines its operational condition, the influence of other components is
eliminated. Now a too high air temperature after the cooler can be the result
of a cooler problem only.
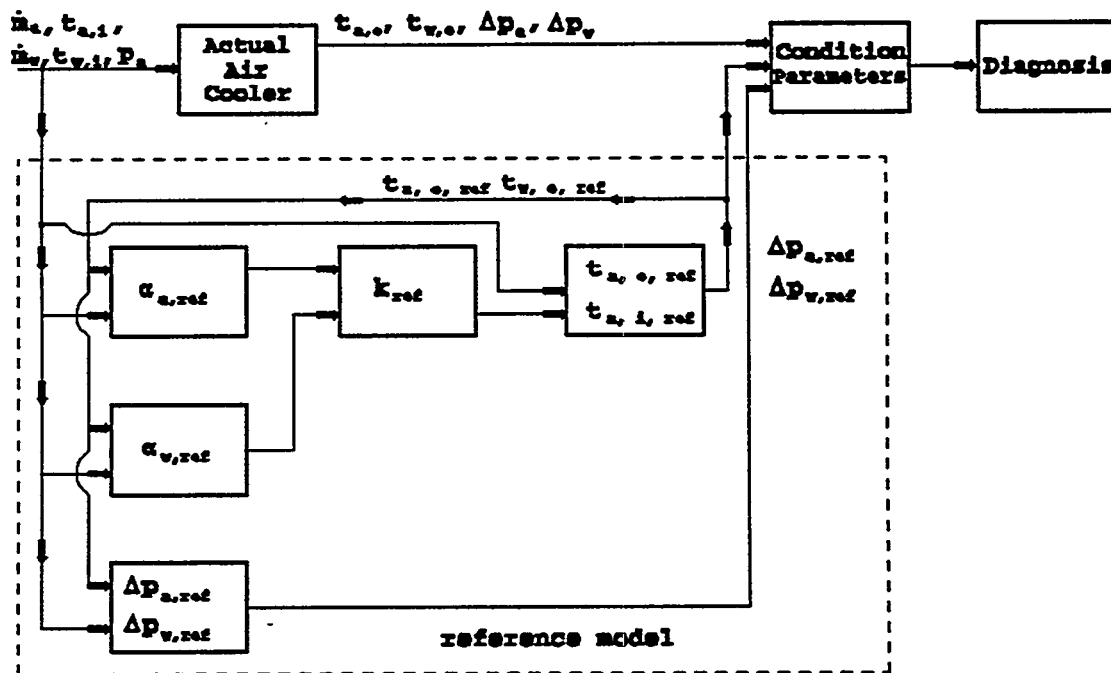
figure 3:   Use of a reference model for diagnosis of faults in an aircooler.
            Inputs for the model are air and cooling water mass flows, air
            and water inlet temperatures and air pressure.
            Conditioning parameters are derived from predicted outlet
            temperatures and pressure drops for healthy/clean cooler.
            It is not always necessary to measure all variables: e.g. mass
            flows can be estimated with sufficient accuracy, preventing the
            use of expensive sensors.

This example shows that component reference models may be more powerful for

diagnostic tasks. The component is separated from the influences of other system parts. The model leads to conclusions about the condition of that component only. In addition it is more likely that sufficient process knowledge for a component reference model is available than *for* a complete system model.

Figure 3 gives an indication of how the reference model for a diesel engine air cooler could be set up. This model produces the temperatures after and pressure drops over the cooler and can be used to diagnose fouling problems. Figure 4 shows a reference model which produces parameters like an additional thermal fouling resistance and a pressure 1055 coefficient, which can be used for the same problems.
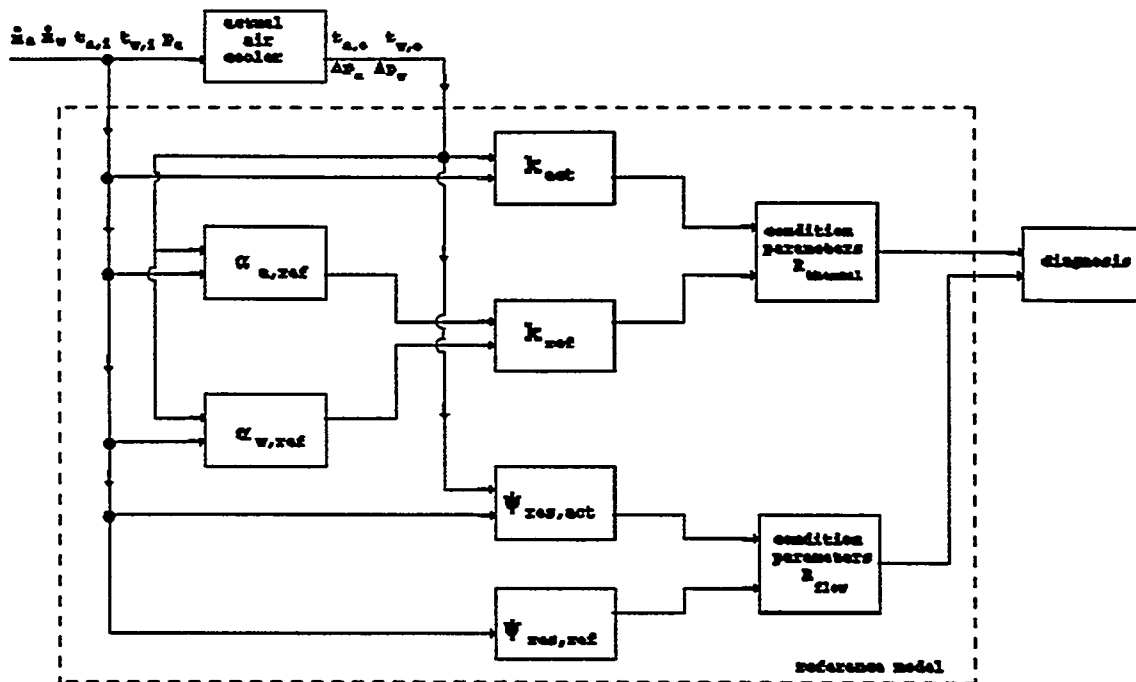

figure 4: **Use of a reference model for diagnosis of air cooler faults.**
In this model condition parameters are determined which indicate:

- $R_{thermal}$ = *additional thermal resistance compared to healthy cooler*
- R_{flow} = *increase of resistance factor both on air and water side*

These conditioning parameters are to a large extent independent of the cooler loading condition. This facilitates the evaluation of trends during different operational conditions.

Diagnostic techniques.

After having concluded that there may be some form of malfunctioning, it is necessary to determine the cause. Therefore one needs to know the effect of failures on system variables and to have diagnosis techniques at one's disposal.

Both cases, the reference model involving the complete machinery system and involving only a component, will be discussed. For a complete system the number of possible failures can be large.

failures and failure-svmntom identification.
The possible failures in the system have to be determined, for which two methods can be applied:

-interviews with experts, like designers ,operators and maintainers.
-analytic methods, where failure possibilities are systematically reviewed, for instance by a failure mode and effect analysis.

It is important to have a complete list of failures, otherwise one can expect difficulties during the diagnosis process when an unforeseen fault occurs. In such a case the diagnosis probably will lead to one or a combination of wrong conclusions. In the DDT projects both methods: interviews *and* analytic techniques are being applied. In this way a check becomes available both on the outcome of expert interviews as on the analytical study. Less probable faults should be considered too. The operator needs the expert system especially when an unprobable fault happens.

The Symptoms, deviations of actual measured variable8 compared to the reference values, caused by a failure, need to *be* known. These relation5 between failures and symptoms, in the form of a failure-symptom matrix, can be given in a qualitative or quantitative way.
Qualitative information is given as a pattern per fault: some variables will show an *increase,* some will decrease and others may be unaffected compared with the reference value; certain variables have no relation with the fault. Atypical example of these patterns is given the matrix of table I. This type of knowledge can be obtained by interviewing experts. It is however difficult to get good information how big a deviation will be. Usually the experts know how the system reacts to a failure but, especially for rare failures, they do not know whether a deviation will be 1 %, which probably is within the tolerance range of the sensor, or 3 or 5 %.

table I. example of a qualitative failure-symptom matrix.

	variables - symptoms								
faults	a	b	c	... p	q	... x	y	z
A	>	=	≤	≥	=	>	≤	?
B	=	=	≥	>	<	?	?	?
C	<	<	=					
D								

A better method to obtain quantitative information is to use measured data of the malfunctioning system. This is USed for instance by [Shsmsolmaali e.a., 19911. Unless measured information is available from actual operation or trials, not specifically done for this purpose, tests are very expensive. Therefore use of simulation can be an attractive alternative. This requires good process knowledge and an accurate and reliable simulation model *of* the system, in which one can introduce the failures. For the diesel engine expert system, being developed by Stork Wartsila Diesel and DUT, this method ha8 been applied [Fase, 1992). Here use has been made of a diesel process cycle programme, developed by SWD for design evaluations. Adaptations to the model enabled simulating faulty conditions. Much attention has been paid to match the programme to the actual engine, 50 that the reliability of the symptoms will be high. The matching was done for normal operation, where a lot of engine data are available, but also for a number of off-design conditions. The results of the matching simulations warranted confidence in the other results. Also special attention had to be paid to how faults should be introduced in the simulation. As an example compressor fouling cannot be introduced directly in the simulation, but reduction of compressor efficiency and pressure ratio is possible. The relation between fouling and efficiency and pressure ratio is, however, only marginally known. Therefore it has been decided to investigate instead of *compressor* fouling two independent other faults: reduced efficiency and reduced pressure ratio. This means, that the diagnosis cannot directly conclude there is a fouling problem, but some combination of efficiency and pressure ratio reduction. This dual diagnosis leads of course to the probable conclusion of fouling.

qualitative failure diaanosis.
With the failure-symptom matrix known, it is possible to diagnose the probable failures, after establishment of the deviations between actual and healthy condition. If the matrix is available in a qualitative form, the diagnosis task can be performed in a number of ways, for example by:

-a reasoning procedure, with rules, as is the case with many expert systems

-pattern recognition

In a rule based system it is fairly easy to recognize a faultwhenthe symptom
pattern is equal to that of the matrix. However it is more difficult to
diagnose a fault by reasoning when the symptoms are not fully, but only
partly, identical to those of the matrix. Reliable diagnosis, also with
partial symptom identity, is important, because such situations may be
expected to happen frequently. This can occur due to stochastic influences,
sensor inaccuracies, combinations of failures and when a failure is in an
early stage. A reasoning procedure, for a large machinery system, capable of
coping with these situations, proved to be complicated due to the combinato-
rial explosion of rules. It also appeared to be difficult to develop such a
complex rule base.

Another pattern recognition technique [Herwerden, 19921, which can be imple-
mented in an easier way and nevertheless leads to reliable conclusions, is the
following:
for each known fault in the matrix a probability score is evaluated, which is
an indication how much the matrix symptom pattern is in conformity with the
actual pattern. This is achieved by giving each pattern element a score. The
maximum score of all symptoms of a failure equals 100. The score for each
element is determined on the basis of knowledge about the particular failure
symptoms. A variable which shows a very distinct reaction to a fault will get
a higher *score* than a variable which shows only a limited reaction to that
failure. As an example, failure A of table I could have the following scores:

variable	a	b	c	...	p	q	...	x	y	z
symptom		=			=			>	≤	?
score	30	5	10/5		10/5	5		30	10/5	-

Depending on the total score, a classification of the probability *of* the
faults can be made, e.g. as follows:

score ≥ 90   : probable fault
score ≥65 & <90   : possible fault
score <65   : unlikely fault

During a limited number of tests this method *of* pattern recognition appeared
to be effective. In the near future more extensive testing of the method will
be performed on the basis of computer simulations. The method can be extended
to diagnose multiple faults. A comparable method is described by [Shamsolmaali
e.a., 1991).

uuantitative failure diaunosis - vector analysis.
When the failure-symptom matrix is known in a quantitative form, it becomes
possible not only to diagnose failure occurrence, but also to calculate the
severity of that fault. The matrix contains influence numbers (m), which show
for a "standard" fault (e.g. a faultwiththe maximum allowable severity): the
change of a variable compared with the healthy reference condition.
As the number of measured variables is p and the number of defined faults is
q, the matrix can be regarded as a p-dimensional space in which the maximum
of each fault is represented by a vector, whose projections are equal to the
influence numbers (figure 5).
If a linear behaviour of the faults is assumed, the symptom can, depending on
the occurred faults, be expressed as follows:

$$s_i = m_{i,1}f_1 + ... + m_{i,j}f_j + ... m_{i,q}f_q$$

where s_i =   symptom: deviation of variable i compared with reference
                    condition
                    influence number for variable i due to failure j
       f_j =   severity of failure j
The number of these equations will be equal to the number of sensors, which
is the number of measured variables: p. For a running machinery system the p
variables can be measured, and using a reference generator the symptoms s can
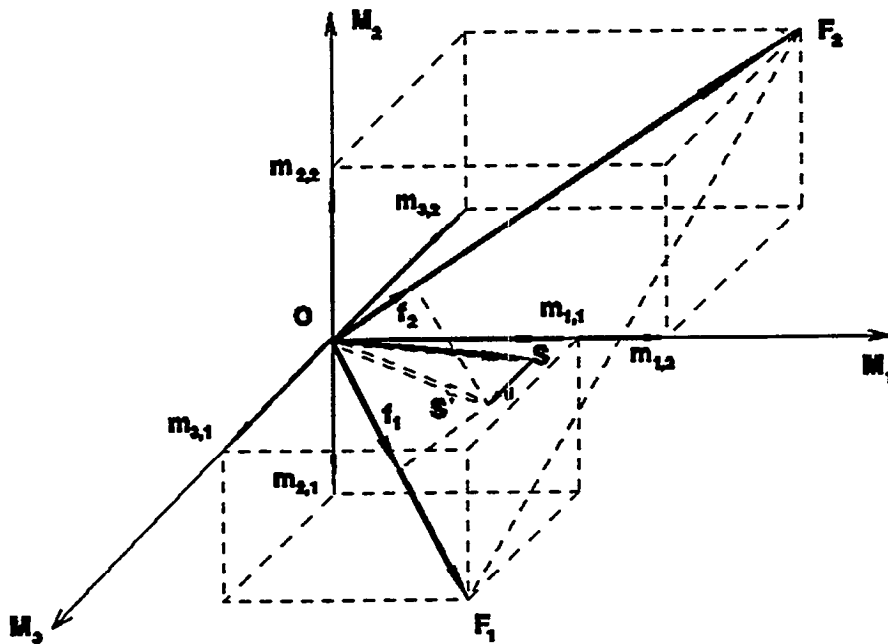be determined which leads to a set of p linear equations with q unknown
failure severities f.

f i g u r e 5: **The principle of diagnosis according vector analysis.**
This example shows the situation with 3 measured variables
(sensors) M_1, M_2 and M_3.
There are two known faults in this system, indicated with F_1 and
F_2.
Fault F_1 has as influence numbers, the projection on the main
axis' M_1, M_2 and M_3: $m_{1,1}$, $m_{2,1}$ and $m_{3,1}$. ($m_{1,2}$ is the symptom of
variable 2 due to standard fault F_2)
S is the measured symptom vector in actual running condition.
Without sensor and model inaccuracies S should lie in the plane
OF_1F_2.
In reality S is outside that plane. The projection of S on OF_1F_2
is S'. The deviation vector d between S and S'complies with the
least square criterion. f_1 and f_2 are the projections of S' on F_1
and F_2.
They represent the diagnosed severities of faults F_1 and F_2.

This set of equations has, in matrix notation, the following **form** :

$$S = M.F$$

where $S(P)$ = symptom vector
             $M(P8q)$ = matrix of influence numbers
             $F(q)$ = failure severity vector.

The failure severity f will have the value 0 in healthy condition and 1 for
a failure with severity according to the "standard" failure.
If the number of variables p is larger than or equaltothe number of failures
q and if the matrix is regular, it is possible to solve this set of equations
leading to the desired diagnosis: the severity of the faults. With p > qthere
are more equations than unknowns and there is also *more* than one solution. *A*
single solution, according to the least square criterion, can be obtained by
pre-multiplying the set of equations with the transpose of M:

$$M^T.S = M'.M.F$$

This is a set with q equations and q unknowns, which can be solved with
atandardmathematfcal routines. The resulting diagnosis may show inaccuracies
due to faulty influence numbers of the failure-symptom matrix, as well *as*
sensor and reference model faults.
Investigations showed,that these diagnosis faults can be minimized by more

advanced mathematical methods, where pre-multiplication of the equations with
the transpose of M is not necessary [Nielen, 1991). This method, within ICMOS
called vector analysis, uses singular value decomposition and scaling of rows
and column5 of the matrix.

Even with advanced solving methods it remains essential, that the faults of
matrix and sensors is kept low. With a reasonably good conditioned matrix it
is possible to diagnose the faults with an accuracy of 30 %, when the faults
of the matrix and sensors are in the order of 10 % and 4 %. An accuracy of the
failure severity prediction of 30 % is felt to be acceptable, especially when
trend analysis techniques are added, to get more feeling for development of
failures.

The singular value decomposition technique, used for solving the equations,
also provides a lot of information about the condition of the failure-symptom
matrix and indications of how to improve it. When two (or more) failures show
a strong dependency, which mean5 they give almost the same symptoms, it is
hardly possible to discriminate between these failures during diagnosis. With
the developed technique it is possible to predict in advance whether the
defined failures can be discriminated and, if not, which failures are strongly
interdependent. In such a case one may be forced to combine these failures to
a single failure, which can be diagnosed much better, or to look for an
additional measurement resulting in better information. The technique also
gives information whether all sensors are really necessary for reliable
diagnosis, or whether diagnosis is still possible with failure of a certain
sensor.

comnonent monitorinu.

With a component reference model, diagnosis of faults is relatively easy. For
the cooler model of figure 3, it is obvious that an increase of the tempera-
ture at the cooler outlet indicates a fouling problem on the air or on the
water side, whereas an increase of pressure drop is a result of reduced flow
area. The model of figure 4 also easily leads to conclusions: a positive
additional thermal resistance means cooler fouling.

Within ICMOS this type of reference model and diagnosis is called component
monitoring [Bergman, 19921. It is felt that this technique can be very
powerful. Its limitation lies in the fact that all actual input and output
variables for the component reference model need to be known. For the cooler
example this means that one needs four temperatures (air and water, in and
out) two mass flows and one pressure. Especially measurement of the mass flows
could be complicated, costly and also not very accurate. To reduce this
drawback, use of estimators instead of sensors can be considered. As an
example it is possible to estimate the air mass flow of a four-stroke diesel
engine rather accurately with a model which includes engine speed, receiver
air pressure, swept volume and a correction for scavenging.

Influence of sensors.

Sensors play a vital role in any machinery monitoring system: wrong sensor
information easily leads to wrong conclusions. It is also well known that a
100 0 reliable sensor does not exist. Based on these considerations the number
of sensors should be kept low and reliable types should be selected.

In order to prevent an incorrect condition assessment and a wrong diagnosis
it is essential that also sensor reliability will be checked in an expert
monitoring system.

Sensor diagnosis can be based on individual sensor behaviour. This means that
some trivial checks can and should be made:
-a check for short circuit and wire failure
-is the raw sensor signal within the measuring range?
-is the rate of change of a sensor signal compared to the previous sample
physically possible?
Next to individual sensor surveillance it is possible to use redundancy. In-
stallation of more than one sensor for an essential variable is an obvious
solution. However in the maritime industry this option is not much apprecia-
ted, because it adds complexity, costs and additional possibilities for
failures. A more attractive type of redundancy is the use of redundant
information of different sensors. Checks, which can be made in this sense,
are :
-is the sensor signal, before starting a "cold" system in accordance with
ambient conditions?

-is the measurement physically possible in relation to other sensors?
Observer and filter techniques can play a role in this type of *sensor diagnosis*.
In ICMOS sensor surveillance will be adopted as far as possible. If the monitoring system detects a possible sensor malfunction, the operator will be informed about this conclusion and the reason for the suspicion. The operator has to decide whether the sensor information *still.* can be used, or that the system should discard the concerning sensor. In the last case it may be that a part of the diagnosis is not longer possible. With vector analysis a missing sensor means that the number of equations has been reduced. This can imply that the same failures can be diagnosed as before, but probably with lower accuracy. The other outcome could be that certain failures cannot be discriminated anymore and have to be combined. For proper reaction of the system on sensor failures it is important, that one investigates what a mfssing sensor means on the diagnostic capabilities and the relevant modifications to the diagnostic process are included.

Trend analysis and prediction.

Surveillance of a machinery system should be possible during all operational conditions. It is also desirable that the diagnosis can be performed in each situation. Further one wants to have a feeling for the trend of system variables and malfunctions. To enable the interpretation of trends, it is important that the information is not depending on the operational condition. An example may illustrate this:
The *pressure* drop over an air filter is measured, because it can be used as an indication of fouling. When the filter is always in the same operational condition: filtering a constant air mass flow with a constant temperature and pressure, trend analysis will pose no problems. In that case pressure drop indeed will be a good indication of filter cleanliness and a trend plot will have a clear meaning. The situation changes in case the filter operates with a varying air mass flow. Now the pressure drop will not only be a function of filter cleanliness but also of mass flow: a trend plot will not show a clear picture.
To make trend analysis meaningful it is thus desirable to determine system variables, which are load independent. For the filter this could be done for instance by division of the actual pressure drop by the reference presoure drop. The reference value being the pressure drop, with clean filter, as a function of the operational condition (e.g. mass flow). This relative pressure drop would be a much better indicator for filter fouling than the actual pressure drop. Another solutionmightbe to calculate a resistance factor from the measured pressure drop and the air mass flow. This parameter also will be a good indicator of filter condition.
For a cooler load independency is a bit more difficult to achieve. If the relative outlet temperature of the cooler (actual outlet temperature divided by the reference outlet temperature) is used as an indication of cooler condition, the following problem would arise. The effect of cooler fouling at high thermal load will be much larger than during low loads. This means that a fouled cooler at high load will show a higher relative temperature than at low load, which results in an unclear trend plot. A better solution might be, to use the additional thermal resistance due to fouling, as a condition indicator, instead of outlet temperature. The calculation of such a condition parameter in different loading conditions requires of course a thorough physical model. The relevant model is shown in figure 4.
In ICMOS much attention is paid to get load independent variables or condition parameters. In general it requires good process knowledge and awareness how failures affect system variables to achieve this goal.

During condition monitoring it is important that the conclusion of a machinery health deterioration has a high reliability. One is not interested in unjustified indications of malfunctioning. On the other hand it is essential that developing faults are detected in an early stage. These requirements are contradictory and are much influenced by sensor and model accuracies. Because sensor accuracies frequently are of the same order of magnitude as the deviations of process variables betweenhealthy and malfunctioning state, this aspect deserves attention.
In ICMOS the problem has been tackled by using not only the realtime symptoms for condition assessment, but also by using the available trend information.

If the real time symptoms are used large tolerance ranges have to be applied to prevent too many unjustified conclusions of health deterioration. This means that such a conclusion may be drawn in a far developed stage of malfunctioning for the first time. When, however, also the trend information is being used it is possible to reduce the tolerance range considerably, because a major part of the sensor inaccuracies have a stochastic behaviour. This means that much earlier detection of malfunctioning becomes possible, without an increase of unjustified conclusions. The resulting systemuses real time and geometric weighted history data. It ensures a low probability of unjustified conclusions, a reasonable quick reaction time for slowly developing faults and an almost instantaneous reaction for fast developing failures. Investigations, for the diesel engine project, indicated that the tolerance ranges could be set such, that the probability for a false indication of deteriorated condition is in the order of 0.3 %.

For a quantitative diagnosis process, such as vector analysis, it is important to use, as inputs, data which are as little as possible disturbed by inaccuracies, because this may lead to diagnostic misinterpretation. Thus it may be advantageous not to use the last measured data, but to use "corrected" data, based on trend information. The implementation of trend data in the diagnosis input can be done in several ways. One tested method is described. The trend prediction has been made with a linear and exponential function. The function is determined with a least square method, based on the recorded history and last measured data.
This technique has been applied on a diesel engine on a test bed, which experienced, during the period of testing, a.o. fouling problems in the turbocharger. The diagnosis, according vector analysis, has been performed, during the test period, several times. The diagnosis based on the measured data came to correct results, but showed in the time for some faults a variation, due to inaccuracies in the input data, of approximately 30 %. With the corrected data, according to a linear trend, the variation was (somewhat) reduced. With a correction, according to an exponential trend, the improvement was less. From this experience one may not conclude that a linear trend will always give better results than an exponential. It is assumed, that this is much depending on how the particular deterioration progresses in time.

The trend prediction as described can be used also to give an indication of future behaviour of the machinery system: when a limiting value might be exceeded and thus when maintenance has to be performed.

Conclusions.

Intelligent monitoring systems for ship's machinery installations can contribute to safety and economy. As, in the near future, ship operators will get a general nautical and not anymore a specific engineering education and also will have less experience with machinery surveillance, expert systems may improve safety of machinery plants. The economical advantage of intelligent systems is achieved through possible crew reductions and improvement of the maintenance function.
Many machinery expert systems are still based on heuristic knowledge. Deep process knowledge, often in combination with experience, will improve the capabilities of the intelligent monitoring system. A lot of the expert systems now in operational use are regarded by the present engineers as "nice to have toys". They contribute to health analysis and fault diagnosis but are not yet indispensable. In the future more advanced systems may make themselves indispensable, especially due to crew developments.
Cost considerations, most probably, will prevent that very extensive instrumentation will be installed on line, with the only purpose of the intelligent monitoring system. The optimal machinery surveillance therefore might consist of an on line system, with a relatively limited set of sensors plus an extensive off line diagnosis system, with advanced measuring techniques. The off line system can be used for a complete fleet instead of one ship and needs only to be used after the on line system has indicated that there is a malfunction, with the probable cause or location of the fault.

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VOYAGE OPTIMIZATION, THE DMI EXPERT VOYAGE PILOT

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Abstract.   An on-board voyage optimization system – the Expert Voyage Pilot – has been developed and its main functionalities are described in the paper.

The EVP optimizes the voyage plan with respect to fuel consumption and/or overall costs, considering relevant data as satellite-transmitted wave and weather forecasts, ocean currents, propulsive and kinematic performance of the vessel, seakeeping criteria, charter requirements and restricted areas extracted from electronic sea charts.

The user interface, the interface to electronic chart display (ECDIS), the propulsion model, the motion performance model and the optimization strategy are described, and results from sea trails are presented and discussed.

Introduction Optimizing a ship's route with respect to wind and waves has been one of the navigator's most important duties since the beginning of the sailing era. Whereas it was evident to the ancient navigator, that to reach a place directly against the wind, without special attention to the prevailing winds and sea currents, would be impossible. The challenge in optimization of to-day's sailing lies in the economical aspects involved in sailing the ship.

The past decades have, however, seen a growing interest in weather routing as a tactical tool for increasing both the safety of the ship as well as the economy of the ship. Hence, the development of both automated weather routing system Marks et al. (1968), Witt (1989), Andersen (1988) and Calvert et al. (1991) and design of integrated system for navigation and steering Kristiansen et a1.(1989). Of course with the increasing power of small computers the area of development has turned in the direction of development of an integrated voyage planning-and optimization system, cf. Loukakis et al. (1991). The development of the Expert Voyage Pilot (EVP) is a step further in the development of such a system containing a total integrated solution to the combined voyage planning and optimization system for on-board use. The EVP has been developed under a EEC-programme, KBSSHIP, with participation from Danish Maritime Institute (DMI), S0ren T. Lyngso A/S (STL) , National Technical University of Athens (NTUA) and Krupp Atlas Elektronik GmbH, Bremen.

The User Interface Routes can be entered and optimized through a graphical interactive user interface. The user interface contains specific interfaces for entering charter contract information, loading information, generation of sea-charts, and managing weather reports. This section presents the sequence of interfaces used to enter and optimize a route.

Appearance of the EVP's User Interface. To present the appearance of the EWP's user interface, this section demonstrates the planning of a voyage and presents different interfaces. First, charter information must be entered. Charter information consists of a sequence of harbours that the ship must visit on her voyage together with arrival and departure times. Harbours are selected from a sorted menu, and their positions are automatically displayed. Duration and distance of the voyage are updated, as harbours are included in the voyage. The charter contract interface is shown in Figure 1.

```
charter fypc................- .:  Liner scrvics

Departure....................:   Rotterdam
   Position...................:   151 SS'H 4 ZB'S9"EJ
   ETD.......................•   1992-01-14 13:30



1. Destination............--.:   Portland
   Position................. .   143 41vi 70 iewi
   ETA....................- .... .  1992-01-25  04:ZS
   E m.......................:.   1992-01-26 00:00
2.  Destignation............-:   New-York
   Positlon..............~ ...... .  100 29'N 73 OS'WJ
   ETA........................ .   1992-01-28  07:1S
   ETD......................-:
3. Destination..............  .

   ETA........................ .
   ETD........................ .
Duration ....................  .   329.75  Hours
```


Figure 1. Charter Contract.   Figure 2. Route-Planning
                                               Display.

Secondly, the route must be entered, using the route planning display. Routes are entered, by connecting a set of predefined statically waypoints, using the mouse. When a route is entered it can be optimized by choosing the optimize command on the top pane of the display. Figure 2.3 shows the route-planning display with a non-optimized and an optimized route.

The optimization algorithm described in a later Section calculates a cost optimal or fuel route and determines the speed and heading along the route. Information on both a non-optimized and an optimized route can be retrieved. This information is shown in a window that pops-up on the route-planning display. More information is available for an optimized route than for a non-optimized route.

The information consists of fuel cost, speed, heading, etc. Information for an optimized route is shown in Figure 3.

Information is available both for each segment in a route and for a complete route. It is possible to enter more than one route, optimize them, and compare their cost.

Beside the charter contract and route planing interfaces the EWP also contains interfaces for entering loading information, construction of sea-charts, and managing weather reports.

```
Latitude ............ 50 21'21"N     Time of passage ..: 1992-03-04 03:27
Longitude ........... 28 15'39"W     Type .............. NonFixed

                                  Outgoing Segment    In-g   segRlent
Fuel (bislmptim ...... .              0.59                   0.62
Roll Angle ............ .             1.07                   0.57
Vertical Act. Fp........               0.33                  0.31
Vertical Act. Bridge ...               0.24                  0.20
Lateral Act. Bridge ....               1.46                  1.10
Slauming Rate ......... .             0.00                   0.00
Jleckwetness Rate ...... .            0.00                   0.00
ShaftHorsepower ...... .           3930.86                4117.33
Shaft HorsepowerLimit.:            7328.74                7421.43
Propeller RPM ......... .            62.29                  63.08
Speed through Water ... .             9.92                   9.94
SpeedmadeGood ....... .               9.58                   9.58
Heading ............... .           264.46                 261.30
Course made Gocd ...... .           265.60                 262.25
Wave Height ........... .             2.32                   2.59
Peak Periode .......... .            10.92                  11.92
Wave Direction ........ .            40.57                  58.79
wind speed ............ .            11.15                  11.82
Wind Direction ........ .           244.14                 256.69
Sea-current Speed ...... .            0.39                   0.40
Sea-current Direction .:             55.05                 !37.89
```

Figure 3. Information on Intermediate Conditions On Route.

Integration to Electronic Chart Display (ECDIS). The EVP communicates with the ECDIS in both the planning phase and the optimization process. To show this the planning scenario is described in the following *6* steps:

1. Step: The EVP generates a file with the definition of the desired background chart for the planning part. This definition will include the positions of the chart corners and the required resolution.

2. Step: The ECDIS then extract only the land areas of the desired chart and generates this as a list of polygons with the required resolution.

3. Step: The EVP User defines now a rough waypoint list of a navigation corridor. (E.g. an island has to be passed on a given side, so only this chart data must be transferred).

This list of desired waypoint positions (latitude and longitude) will be transferred to ECDIS including a value for the width of the "navigation corridor" and a value for the ship's safety depth (e.g. 10 metres).

4. Step: The ECDIS will then select the sea-chart data along the navigation corridor. It extracts and reformats all "forbidden" and "proposed" polygons (incl. necessary attributes) of the selected cells that are defined to be relevant in the list of the object classes. These polygon data will be transferred to the EVP for the calculation and generation of the optimized route.

5. Step: The EVP does the voyage optimization by avoiding the forbidden polygons and integration of the proposed polygons and the attached attributes. The optimized route is then transferred to the ECDIS.

6. Step: The optimized route will be displayed on the ECDIS sea-chart display.

Manual checking and editing of the route may be done on the ECDIS display, to be able to handle small modifications (additional waypoints, etc.). The final route plan may now be transformed to a steering sequence and transmitted to the navigation command system. To decide whether an object has to be transferred to the EVP, attributes are attached to the object. Relevant attributes are:

Land Area.
Depth Range: Depth, Dredge, Intertidal area.
Dumping Ground.
Restricted Areas such as: Undefined, Offshore Safety Zone, Nature Reserve, Military Area, Restricted Area, Inshore Traffic Zone, Safety Zone, Mine Field.
Forbidden areas such as: Anchorage Area, Cargo Transhipment Area, Ice Area, Military Practice Area, Offshore Production Area, Traffic Separation Zone".

The non-navigable polygons covering forbidden areas as prohibited or restricted areas will be generated with their available resolution in the ECDIS. From the type of attribute it is evident that not all areas will be relevant as restricted areas to all ships. For instance "intertidal" zones and ice areas will vary with the loading and time of year. Therefore, generation of chart information has to take place at each run of the EVP.

Satellite Transmission and Handling of Weather Forecasts.
Forecasts of winds and waves are transmitted by satellite INMARSAT-C, cf. Ref. Guinard (1991) from a weather forecasting center, i.e. the Danish Meteorological Institute

The INMARSAT-C is restricted for communication of written messages in a S-bit telex format. This calls for vigilance to the amount of data to be transmitted. The benefit of using INMARSAT-C is that it is simple, relatively cheap and reliable both with respect to the actual transmission and the hardware necessary.

An update of the weather forecast for the relevant ocean area may be broadcast to the system when available and when it has been specified which part of the ocean should be covered. This means that from the ship's actual position it is calculated where the ship is likely to be at what time within the duration of the next forecast. A short telex message describing the ship's position and corresponding time in the vicinity of the start of the forecast is given along with a maximum as well as minimum of speed to be maintained, a position of arrival and corresponding time of arrival, and a maximum deviation from the great circle course is sent to the forecasting office. From these information it is decided which points and hours should be included in the forecast and send to the ship. See Figure 4. Only data within the geographical positions and corresponding to a time interval limited by "fast" and "slow[1] sailing will be included. It is up to the user / navigator to decide which are the appropriate limits on deviations in geographical positions and speeds to be used.
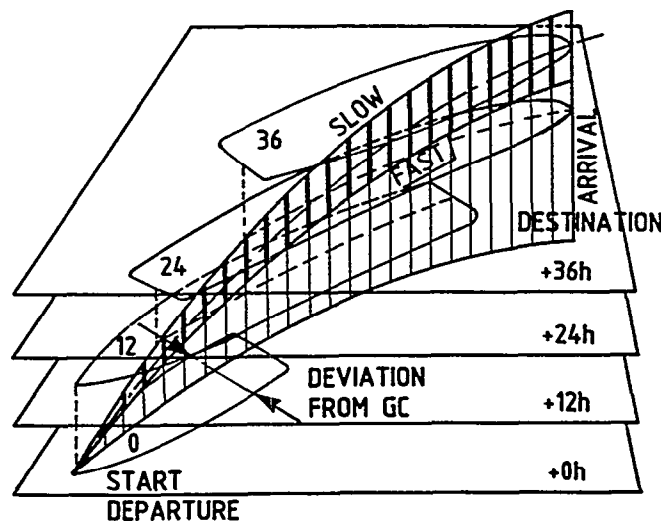

Figure 4. Selection of Relevant Data for Transmission to the Ship.

A forecast send to the ship once every 24 hours would consist of three files containing the following information: 1) Wind information 0 - 36 hours from OZ at time intervals 12 hours.

The geographical resolution is 1.5 degrees. 2) A short-term wave information 0 - 96 hours at intervals 24 hours and a

geographical resolution of 2.5 degrees. **3)** Finally, a combined long-term wind and wave prognosis covering the time 48 to 156 hours at 12 hours intervals and a geographical resolution of 3 degrees.

Each file containing wind or wave information are ranked hierarchically to avoid ambiguity in data available for a given place and time. The EVP will then search for relevant data in the highest ranking data file that contains the relevant data.

Thus, by ranking a 0 - 96 hours wave prognosis higher than the wave / wind 48 - 156 hours, prognosis will make the EVP pick-up information from the first data file (0 - 96 hours) even if it is overlapped in time and geographical positions by the latter data file.

Ship Model. A mathematical model describing the performance of the ship was derived from existing mathematical formulations. In this context performance should be interpreted as both the speed and power relation as well as the seakeeping ability of the ship in a seaway. That is the mathematical ship model will for given input of speed and sea and wind conditions calculate the fuel consumption, shaft horsepower, the significant motions of the ship and the probability of slamming or shipping of green water on deck.

Resistance. The still-water resistance is calculated using the standard ITTC-formulation:

$$R_{still} = \rho v_s^2 \cdot (C_F (1+k) + \Delta C_F + C_A + C_r) \cdot S \qquad (1)$$

where:
ρ : Density of sea water.
V_s : Ship's speed.
C_F : Frictional resistance coefficient.
ΔC_F : Added frictional resistance due to fouling.
C_A : Allowance coefficient.
C_r : Residual or wave-making resistance coefficient.
k : Hull form factor.
S : Wetted surface of the ship.

C, is a function of both speed, draught and trim of the ship, whereas k and S are only functions of the draught and trim, and finally C, only a function of speed. A set of C, curves representative for a bulk carrier is shown in Figure 5.

Very often information about C, and k vs. trim is not available for the ship, in which case it will be necessary to omit the variation with trim.
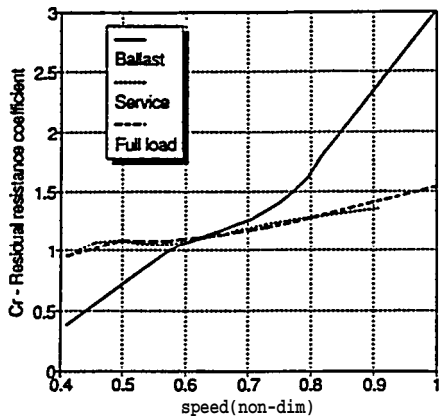
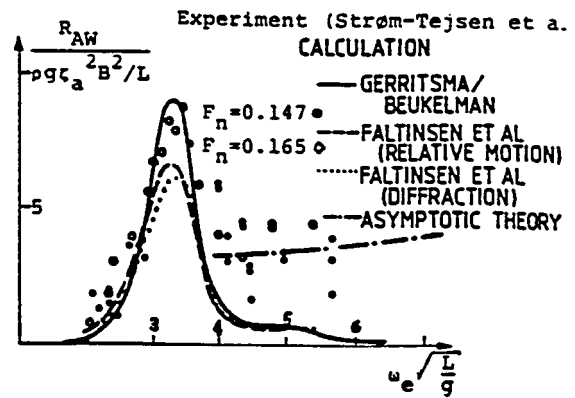Figure 5. Coefficient of Residual Resistance.

Figure **6.** Coefficient of Added Resistance. (From Hearn, Tong and Lau).

To the still-water resistance, resistance from wind, waves, shallow water and steering is added. The shallow-water resistance is calculated from the relation between the resistance at infinite water depth at speed V and the corresponding speed yielding the same resistance of finite water depth given by Lackenby (1963).

$$\frac{\Delta V}{V} = 0.1242 \left(\frac{A}{h^2} - 0.05 \right) + 1$$

$$- \left(\tanh \frac{g \cdot h}{V^2} \right)^{\frac{1}{2}} ; \quad v \frac{A}{h^2} > 0.005 \tag{2}$$

where:
ΔV : Is the speed loss compared to infinite water depth.
h : Water depth.
A : Immersed cross-sectional area of the ship.
g Gravitational constant.
This formula was derived from Schlicting's (1934) graphical method for predicting shallow-water resistance.

Opposed to the approach used by Marks, Goodman et al. (1968) and more recently Calvert et al. (1991) and Andersen (1988), the wave resistance model in the EVP is derived from the huge amount of work-done to calculate in a direct way the added resistance in waves. Contributions to this effort are among others given by Faltinsen (19801, Wada & Baba (1987), Salvesen (1975), Hearn, Tong and Lau (1987), Naito, Nakamera and Nishiguchi (1987). The wave-induced added resistance is divided into two contributions each describing different ship-wave interactions. One contribution arises from the fact that small waves compared to dimensions of the ship are reflected by the ship hull.

Thus, the energy of the wave train is reflected resulting in a corresponding force acting on the ship.

The second contribution is related to the induced relative motions of the ship. The relative motion of the ship generates waves which are radiated from the ship. This dissipation of energy is directly connected to the loss of speed of the ship.

Since resonance between especially the pitch motion of the ship and the incoming waves may occur and hence the amplitude of the relative motions become huge, the speed loss associated with this phenomenon may be very significant. Figure **6** illustrates the nature of the two types of wave resistance.

The wind resistance is calculated from measured wind-resistance coefficients. An example of the wind-resistance coefficient for a bulk carrier is given in Figure 7.
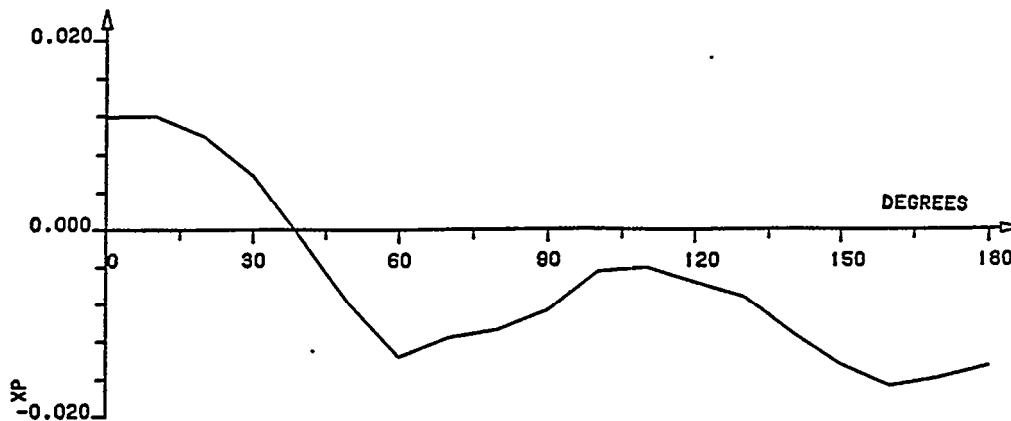

Figure 7. Wind-Resistance Coefficient of Longitudinal Wind Force on a Bulk Carrier.

Power and Engine Model. Having determined the total resistance as the sum of the individual resistance components the required power can be calculated, when the propeller rpm, the wake, the thrust deduction and relative rotative efficiency are known. The brake horsepower P, is then given by:

$$PB = v_c \cdot \frac{R}{1-t} \cdot \frac{1}{\eta_o \, \eta_R \, \eta_s} \tag{3}$$

$v,$:   The ship speed.
t :   The thrust-deduction coefficient.
   :   Total resistance.
η_o :   Open-water efficiency of the propeller.
η_R :   Relative rotative efficiency.
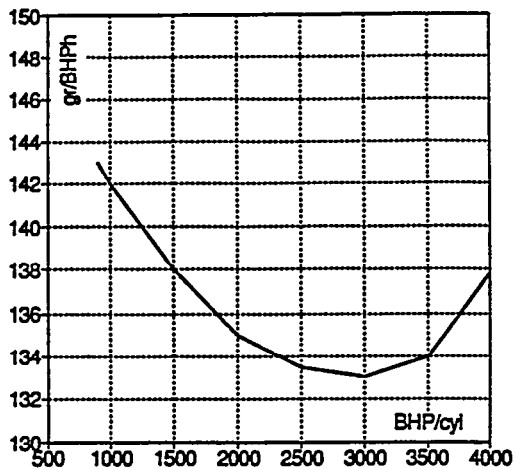η_s :   Shaft efficiency.

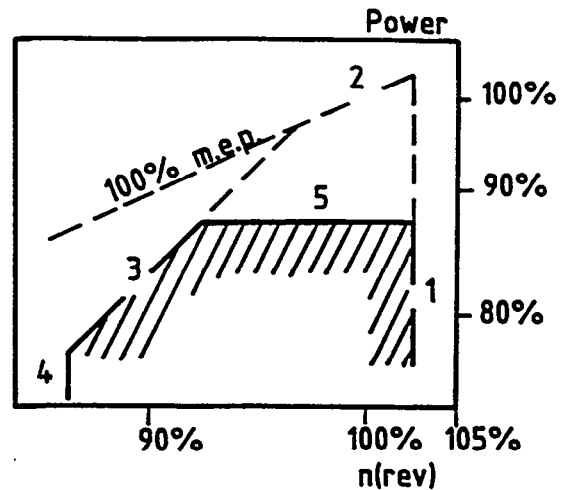**Figure 8.** *Specific Fuel Consumption of a Two-Stroke Engine.*

Figure 9. *Engine Load Diagram Relevant for Two-Stroke Diesel Engine.*

To convert the brake horsepower into fuel consumption a relation for the specific consumption has to be available. Usually, the specific consumption or economical efficiency of the engine kJ_{out} / kJ_{in} is supplied with the documentation for the engine. Figure 8 shows a typical diagram valid for a two-stroke diesel engine. By making corrections for the specific gravity and calorific value of the actual fuel the consumption may be calculated directly in kilograms and hence the fuel cost calculated directly by multiplying by the fuel price, i.e. $ / ton.

In addition to the calculated loading of the engine expressed in terms of the number of revolutions on the engine and the mean pressure (function of fuel consumption and RPM) the load limits of the engine have to be calculated to check whether the engine is overloaded or not. A typical set of load limits for a two-stroke diesel is shown in Figure 9. The load limits are normally determined by 4 or 5 curves in the diagram. 1) The max. RPM line, 2) the maximum mean pressure, 3) the overload limit at RPM variable mean pressure determined by the pressure of the·scavenging air, and 4) a minimum continuous RPM, and in some case also a 5) maximum allowable power output - an owner's horsepower instruction -.

Ship Motions. Response amplitude operators for the motion characteristics are calculated for the ship in different loading conditions. Interpolation in these pre-calculated values is made to estimate the RAO's for the actual loading condition.

The motion characteristics relevant for the ship-routing problem will be the accelerations at the perpendiculars, relative motion of forward perpendicular for determining the probability of shipping green water on the deck, and the roll angle. If prediction of propeller racing would be applicable, also the relative motion at or near the aft perpendicular should be included.

The RAO's are calculated using strip theory c.f. Faltinsen (1988).

Optimization Algorithm. A method for reaching the route - track and speed profile - that minimizes the overall cost of the route is described in the following. A more complete derivation of the method can be found in Scheller (1989). The method will take into account restriction on the route so that travelling over land, travelling at a speed that will require exceedance of the installedhorsepower, etc., will be avoided.

Track Optimization Algorithm. The route is presented by a number of waypoints each describing a position and a time of arrival to the waypoint, c-f. Figure 10. The ship is assumed to travel a constant speed and course between the waypoints.
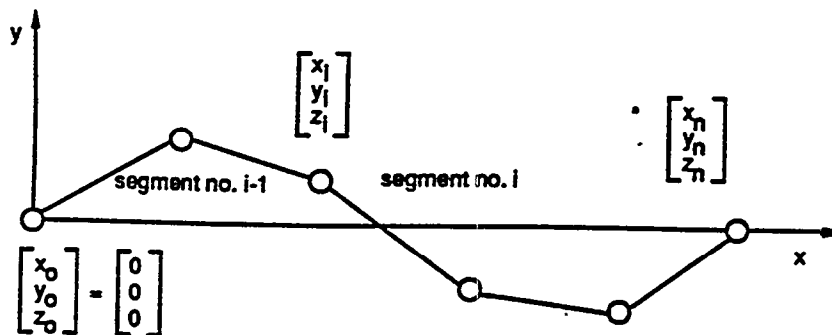

Figure 10. Definition of Track Segments.

With the route being uniquely defined by the waypoints, and the overall costs being a function of the route, the overall cost of the route can be regarded as a function of the waypoints:

$$T_c = (\underline{x},\ \underline{y},\ \underline{t}) \tag{4}$$

This is the function to be minimized, while observing a set of constraints. Constraints can be any of the following:

1. Waypoints, fixed in time and position. That is e.g. arrival at a certain harbour at a certain hour. This constraint is only relevant for defining start and end points of the route.

2. Ordinary waypoints. That is points that are fixed in position but not in time, e.g. travelling through a narrow passage at a non-fixed hour.

3. Time-fixed points. All points must have at least one of its parameters fixed, if agglomeration is to be avoided. Therefore, graphically non-fixed points have to be time fixed.

4. Geographical restrictions, e.g. islands or seasonal load-line zones.

5. Restrictions on the route due to power limitations, ship responses, etc.

It may not immediately be obvious that Condition 5 "Restrictions on the route due to power limitations . . ." is a limitation on the optimization in terms of a constraint. However, by prescribing a very high cost associated with exceeding the power limit, roll limit, limiting number of slam, etc., the constraint will be treated in a "soft" manner. The softness of the constraint is determined by the steepness of the associated cost function. Exceedance of the limits will be paid for by an additional cost, which if sufficiently high will prevent the route from being cost effective unless exceedance is avoided.

Segmented Length Strategy. The Track Optimization Algorithm as described in the preceeding section optimizes the position / time of arrival of a number of waypoints that defines a route. It is, however, possible to change the number of segments on the start track by placing additional waypoints along the track. This will not effect the start track, but may influence the optimization.

It is evident, that the more waypoints there are on the optimized track, the more complicated the optimized track can be. A complicated route converging against continuous change of speed and course, will be able to reflect changes in the weather along the route better than the simpler route. Continuous changes in speed and course are, however, inconvenient to the captain (and do not reflect the discrete nature of the weather data base), so a weighing between gained cost reduction and route complication has to be done.

This can be done by optimizing a given start track, record the cost, then double the number of segments by placing additional waypoints halfway between each two original waypoints and finally, redo the optimization. If the relative cost reduction is less than say 10^{-3}, the route complication cannot be said to be outweighed by the cost reduction.

If, however, the cost reduction is big enough, the entire process can be redone using the new track as a start track.

This procedure can be refined by taking into account that segment length do not need to be constant over the route. If a segment is defined by waypoints A and B, the additional waypoint C halfway between A and B can be constructed. If the route now is optimized, transferring A, B and C into A', B' and C', it can be determined whether further refinement should take place by looking at the cost of the original segment defined by A and B and compare it with the sum of the cost of segments A' - C' and C' - B'. Only if the latter is smaller than the former, refinement is to take place.

What remains, is the question of how many segments there are to be on the start track. The factors to take into account are the following:

- Calculation time for each iteration.
- Convergence speed.
- Numerical span of the problem space.

Fortunately, all three factors lead to the conclusion, that the start track should have as few segments as possible. The reason will be described here.

Calculation time for each iteration is clearly influenced by the number of segment. Although calculation time is not proportional to the number of segments, if the cost rates are numerically integrated over the segments to obtain the cost functions, the amount of geometrical operations is reduced, if the number of segments is decreased.

Convergence speed is influenced by the number of segments for two reasons. First of all more segments will give more degrees of freedom to be optimized, thus making optimization more complicated and increasing the number of iterations necessary in order to find the optimum. Secondly, the "Stevees cage" problem increases as the number of degrees of freedom increases, thus not only increasing the number of iterations necessary to find the optimum, but also increasing the risk of not finding the optimum at all. This effect is small, if the strait track is close to the optimized track and increases if the start track is further from the optimized track.

Gradually increasing the number of segments as described, has the benefit that the convergence speed will be much faster if the track had been totally refined from the start.

As explained, the Track Optimization Algorithm always finds the nearest local minimum.

It is interesting, however, that what is the local minimum
with one number of segments on the track is not necessarily
a minimum with another refinement of the track.

By having the algorithm search as much of the problem space
as possible (increasing the numerical span), it should in
principle be possible to find the global minimum. Clearly the
numerical span will be the biggest, if the start track
consist of as few segments as possible, thus increasing the
probability of the algorithm finding the global minimum.
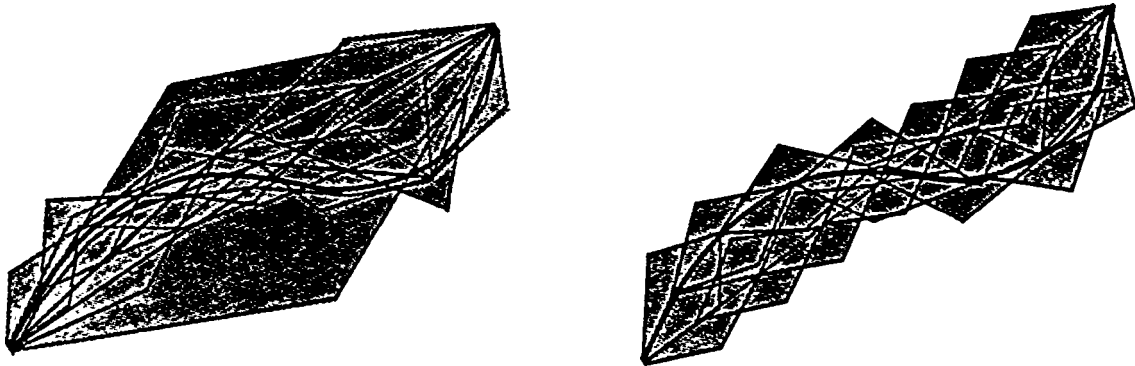
Segment Length Determination
Strategy.

Simple Track Optimization
Algorithm.

*Figure 11. Simple Illustration of the Bigger Numerical Span
using the Segment Length Determination Strategy than using
the Simple Track Optimization Algorithm.*

Sea Trial. The EVP has been tested during a single voyage on
board the Danish bulk carrier. The test took place in May,
1991 on a voyage from Colombia to Denmark.

After the initial impression made by a lot of computer
technology brought on board a ship with no previous experi-
ence of computers except a PC, a number of valuable points
was high-lighted. These points are compiled as follows:

- Many navigators graduated 10 years ago or earlier, have no
experience with computers. Solutions obtained by use of
computers are therefore judged with suspicion until adequate
training has been given.

- There exists a lack of understanding of the optimization
philosophy. This is partly due to the fact that ships not
sailing in liner traffic, although they principally have an
open time of arrival, very often have to take a dictate on
when to arrive, and very importantly the dictate may be given
very late on the voyage.

The master's incentive to do an optimization is very little since he will surely be blamed for a late arrival, but not necessarily credited for a cheap passage. There is not always a complete agreement on the economical aspects in "buying" a safety margin against being late compared to the cost of being late. This is a problem which also has its foundation in the natural scepticism of the validity of the weather report broadcasted to the ships. If the master is not familiar with the theoretical background in the optimization he will not accept its results if they are not immediately acceptable for himbased on his own judgement of the possible development of the weather.

Conclusion. A prototype EVP has been developed to a point where it has been shown that voyage planning and optimization can be utilized in an on-board system.

The functionalities of the EVP have proven to be adequate for the purpose. Before an EVP will be used successfully on-board ships it appears to be necessary to develop a common standard for broadcasts of weather information.

Training of the personnel using the system will also be a key issue in the successful introduction of an EVP. The comments about this matter made in Section 6 are of course not valid for all ships, often will the attitude towards such a system be quite different in ships sailing with a tight schedule such as for instance a container ship.

The results obtained from the optimization will of course not be any better than the input given to the system. The major contributor to the uncertainty of the results is therefore the uncertainty of the weather input and especially the wave forecasts. Unfortunately, the development of ocean wave models is pushed to the very limit of what is possible today.

The accuracy of any optimization system is therefore closely connected to the development of such models.

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Closure session

WHAT ARE THE IMPISCATIONS FOR EDUCATION IN MARINE TECHNOLOGY?

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It is argued that because of growing concern, reviewed in the first part of the paper, about maritime safety, responsibility for the assurance of safety will tend to move away from the regulatory agencies towards designers, builders and operators. Therefore, as discussed in Section 2, the marine technology professions must prepare themselves to accept such responsibilities, not least by appropriate changes to their programmes of education and training.

Part 3 of the paper reviews some of the problems of safety assurance, such as the identification and quantification of hazards, the influence of human factors, and the determination of acceptable levels of risk. This is followed by a brief discussion of design for safety where some areas of needed work are identified.

Based on the foregoing, in the final part 5 of the paper the Author's personal views on some needs and priorities in undergraduate education are given. Suggestions are made as to how safety considerations might become a more integral part of marine technology education, in order to prepare our graduates for their probable responsibilities in the 21st century.

1. INTRODUCTION : THE GROWING CONCERN FOR SAFETY AT SEA

Three months ago, at the end of February, **1992,** there was published in London a Report entitled "Safety Aspects of Ship Design and Technology". This Report was prepared by the Select Committee on Science and Technology of the House of Lords (1992), who had been receiving and considering evidence during the preceding year from a wide variety of organizations, companies, research and educational establishments, as well as individuals concerned with various aspects of safety at sea. For its timing, content and recommendations, this Report is significant in the context of this Conference here in Delft. In the course of gathering evidence for their Report, members of the Select Committee visited only two Universities; and the fact that one of these was the Technical University of Delft testifies to the high regard in which thii University is held internationally. It is thus a pleasure and an honour to be able to participate in thii celebration of 150 years of service and achievement by one of the world's foremost centres for teaching and research in marine technology.

That a Select Committee of the House of Lords has devoted so much time and concern to ship safety underlines the growth of public concern following a series of highly-publicized marine disasters, too familiar to need to be listed here. There

can be little doubt that this increasing concern for the safety of life, property and the environment, and the associated pressures of litigation, will bring designers, operators and regulatory authorities under ever more critical scrutiny. It is essential that the maritime community - individuals as well as orgrurizations - should respond in a professional way, and should be able to demonstrate that the assurance of safety at sea is based on the best available knowledge, techniques and procedures. Can we now honestly say that this is what we do? If not, what needs to be done? And what are the implications for the future education of marine architects and engineers? These are the principal questions which the Author will try to answer in this paper.

2. THE ENGINEER'S RESPONSIBILITIES FOR SAFETY ASSURANCE

In giving evidence to the Select Committee, the Author expressed the view that the marine professions suffer `from` a significant disadvantage : they are "over-regulated".   Or, to put it more precisely, the many regulations to which, for example, ship designers must conform, are too detailed and prescriptive. Such regulations, whether concerning stability, subdivision, strength or almost any other aspect of design, prescribe that certain (generally empirical) criteria should be satisfied. The levels of safety (or risks of unsafety) thus obtained are seldom, if ever, explicit; nor is it easy to quantify how a proposed change in design would affect the real safety of the ship. In the absence of explicit liiks between design, regulations and safety, there has developed an understandable tendency in design to regard compliance with regulations as the main (almost the only) guarantor of safety. The general result has been to create a culture of "dependence on regulations" as a substitute for genuine "design for safety".

There will be many who argue, with some justification, that the availability of a wealth of detailed, prescriptive regulations has served the marine community well. They will point to the overall record on marine safety (Fig.1) showing a general downward trend in marine casualty rates. They will remind us that regulations which have evolved over a long period of trial and experience represent much accumulated wisdom; and by prescribing the resulting design requirements in detail, they save the designer `a` great deal of effort, time and cost.

Space does not permit a detailed discussion of the arguments for and against "design by regulation".   But in the Author's view, as discussed more fully in Caldwell (1992), there will be a growing pressure for marine designers to take more explicit responsibility for safety assurance. Whether because of the difficulty in applying prescriptive regulations to novel designs, or because of the growing use of formal safety assessments in other branches of engineering, the need to move towards marine "design for safety", using modem ideas and techniques, must now be recognized.   A similar **view** was expressed in the conclusions in the Select Committee Report (1992). Just a few months before the Committee began its work, there had been published the Report of the Committee of Inquiry into the disaster to the PIPER ALPHA oil platform in July 1988.
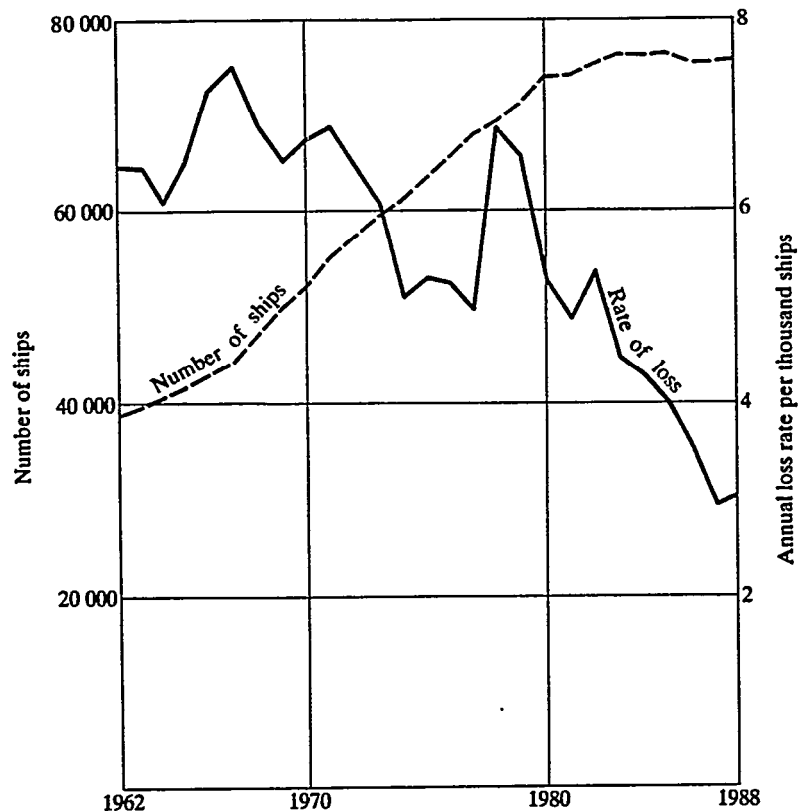
Figure 1 - Ship Casualties Show a Downward Trend

Although the findings of this important and influential report were specifically concerned with the safety of offshore structures, there is a widespread view that they have implications also for shipping and for the design, operation and management of ships. Thus the Cullen Report (1999), with its advocacy of formal safety assessments for offshore installations using the best available techniques of hazard analysis and risk assessment, indicates the way in which the assurance of safety at sea is likely to develop.

Of course any change from the present regime of safety assurance through the well-established system of regulatory authorities and prescriptive regulations towards the methods recommended by Cullen cannot, - and indeed should not - take place overnight. We are already seeing, for example in the evolution of IMO regulations governing the subdivision and damage stability of ships, a recognition that rational rules must be based on a probabilistic approach to such hazards. Similarly the Classification Societies are increasingly using long-term statistical data in setting strength standards, and are carrying out various types of risk assessment for novel shipping ventures.

Such developments, however welcome and timely, are still largely centred in the regulatory agencies; whereas the view is clearly growing (e.g. in the references quoted above) that more of the onus for assuring safety should be borne by those directly responsible for the creation, operation and management of a ship - in short by the individual marine architects and engineers themselves. In the United

Kingdom, the Engineering Council, which has an overall responsibility for the whole profession of engineering, has recently published for discussion an "Embryo Code of Practice" (1991) entitled "Engineers and Risk Issues". Thii draft Code is intended to encourage engineers to recognize, and to prepare themselves to accept, a professional responsibility to ensure safety of life and of the environment. Thus the Code suggests that all engineers should, *inter alia:*
- recognize the need for a disciplined approach to risk issues and hence to human safety;
- continuously use their professional judgement and experience to ensure that risks are properly identified, assessed and controlled;
- be aware of the methods of risk assessment associated with their work and should regularly make necessary systematic studies to fully identify potential hazards.

Although Conferences such as this testify to the growing awareness in the marine community of our responsibilities in regard to safety, it must be doubted whether marine architects and engineers are yet properly equipped to deliver the kind of professional, numerate approach to safety assurance implied in the references noted above. This, then, is a challenge to our marine professions : to change our culture from over-dependence on regulations to acceptance of more individual responsibility for safety aspects of our work.

3. SOME PROBLEMS OF SAFETY ASSURANCE

To be able to accept such a challenge, and to take more direct responsibility for marine safety assurance in the artefacts we design, construct and operate, marine architects and engineers should be thoroughly familiar with the hazards of maritime operations, and should have the technical expert&e to ensure that the risks of failure to withstand those hazards are likely to be acceptably small. Each of these elements of safety assurance - hazard identification, risk assessment, and design for acceptable safety - can pose severe problems; and it must be admitted that the education to which most marine architects are exposed probably does not yet equip them adequately to carry out these tasks.

We return later to the educational implications of preparing marine architects for the more safety-oriented responsibilities likely to face them in future. First, however, it may be helpful to review some of the particular problems of maritime safety, and the shortcomings (in the Author's view) of our present systems of safety assurance.

It is not reasonable to expect that a formal safety assessment (FSA), of the kid which the Cullen Report (1991) proposed should be prepared for all offshore structures, would be required for each and every ship which goes to sea. But it is quite plausible to envisage a situation, perhaps five or ten years hence, when any new marine vehicle which embodies some significant innovation that might affect its safety, should be subject to FSA. It would be for the relevant national maritime authority, possibly guided by IMO, to decide what would constitute a "significant innovation". This could refer to a novel concept of overall design (e.g. a Uhybrid

lift" type of vessel), or the use of new combinations of materials, or propulsive systems; or it could result from a step-change in operational features, such as a reduction in manning or increased use of intelligent systems on board.

The task of "designing for safety" would then need to anticipate the main features of FSA, with the overall objective of assuring the certifying authority that the risks of incurring damage or loss during the prescribed lie of the vessel, and in face of all the foreseeable hazards which it might encounter, would be acceptably small. The designers' difficulties in doing thii will be compounded by the need to work within tight financial constraints; - the cost of "designed-in" safety means that the definition of acceptable risk levels must be influenced by economic factors. Certainly designing for zero risk is not a practical option. We return to this point later.

Hazard Identification

The starting point of FSA is to identify the various hazards that the vessel must be designed to withstand. It might be thought that these are well-enough known from the accumulated international experience of seafaring; and in the general, qualitative sense this is true. But a quantitative safety assessment recognizes that the probability of loss of a ship is influenced both by the probability P_r of encountering a hazard (such as an extreme wave) and the probability P_z of not surviving that hazard (e.g. by capsize). Quantification of P_r for a novel type of ship, perhaps with an ill-defined life and mission, and exposed to a variety of hazards from the environment (winds, waves, rocks, ice, other ships) or from within the ship (fire, explosion, cargo &ii, human error), is a formidable task.

Historical, statistical data will be a major source of data for the quantification of P_I. Thii includes not only the growing bank of data on meteorological, environmental and hydrographic conditions in the oceans of the world; but also the many sets of casualty data relating to losses of ships or lives at sea. Presentations such as Figs.2 and 3 are typical of the increasing volume of information which ascribes losses of ships and lives to certain categories of causes.

Such casualty data can be useful for makiig general deductions about maritime safety, for example in demonstrating general trends, or comparing performances under different flags, or showing the influence of ship age or operating area. But such data do suffer from some serious shortcomings, of which the following two are particularly relevant to the problems of quantifying marine hazards:-

•   the standard categories of causes of loss are too coarse and ill-defined, and it is difficult to deduce from them the real weaknesses or deficiencies (in design, construction, operation or management) which precipitated the loss;

•   it is very rarely possible to ascribe a ship loss to a single event, as implied in the conventional casualty data. Almost always there is a sequence of events, each due to some mischance, malfunction or error, that eventually leads to the "top event" - the casualty itself.

Such deficiencies in the categorization of casualties are exemplified in Fig.4, taken
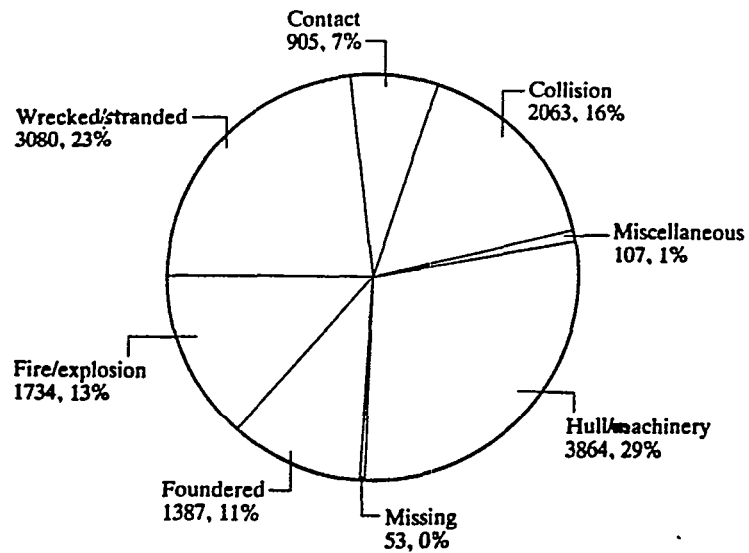
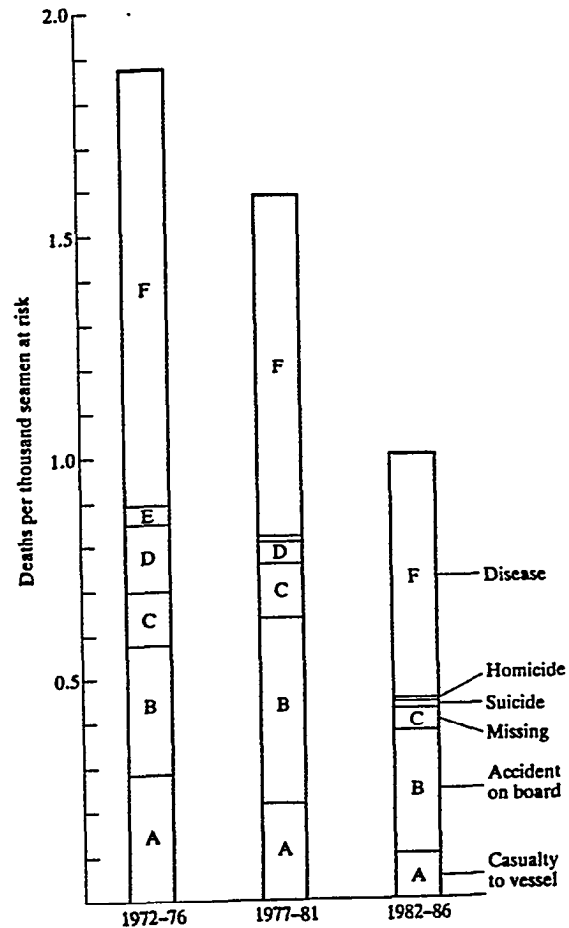Figure 2. The Broad Categories of Ship Casualties

Figure   3.. Pew Deaths Result from Casualties to Vessels

from Caldwell (1992), showing the interacting sequence of events which led to the disaster to the HERALD OF FREE ENTERPRISE. Statistics will record this as a ship that "foundered" or perhaps "capsized" (the distinction is not always clear). But the lessons learnt from this tragedy have as much to do with managerial and operational influences on safe&, as with the actual design of ro-ro ferries. And such lessons can only result from a detailed unravellmg of the full train of events preceding the top event, rather than by concentration on the final event as recorded in the casualty data. It follows that such data alone can be an unreliable pointer towards measures to assess hazards or improve safety.

Furthermore, it is evident that conventional sets of casualty statistics must be used with great care as a basis for assessing the risks of ships encountering various hazards. In the Author's view, a clearer insight into the hazards affecting marine safety would result not from the compilation of more "coarse" statistics of ship losses, but rather from more detailed studies of those accidents where the sequence of events can be reliably constructed, and weaknesses in the chain identified.

Human Factors

Herein lies another difficulty. It is well known, and confirmed by plentiful experience, that the weakest link the chain is often the human component. This predominance of human error in marine casualties underlines the crucial part which standards of training and competence play in ensuring the safe operation of ships. The setting of competence standards, and their enforcement, are primarily the responsibilities of national administrations and company managements; but the ship designer needs to be aware of what can reasonably be expected of competent operators. The growing use of smaller, perhaps multi-national, crews with more diverse qualifications and experience, underlies the importance of "design for operation", for example through the ergonomic design and arrangement of equipment to maximize user-kmdliiess. Statistics of fatalities at sea (e.g. Fig.3) remind us that accidents or sickness on board account for a significant proportion of deaths. The designer can contribute to greater safely by seeking to eliminate any hazardous features in the design, construction and positioning of equipment. He will be greatly helped in this by having himself had experience of seafaring, perhaps as part of his education or training.

But perhaps the principal way in which the designer can explicitly make allowance for the much-maligned "human factor" in ship casualties is to recognize that it will never be eliminated, because people are imperfectible. Since accicdents due to human fallibility will continue to happen, it must be a cardinal point of design to provide as much "damage tolerance" as is consistent with the efficient and economical operation of the ship. We need to explore further the implications and applications of this concept, though some useful ideas are now coming forward from recent research. In retrospect we can see that the principal design defect in the HERALD OF FREE ENTERPRISE was not that the ship was more likely to incur an accident (i.e. P_r was acceptably small), but that it was unable to tolerate the consequences of a rare but credible accident, so that P_z was unacceptably high
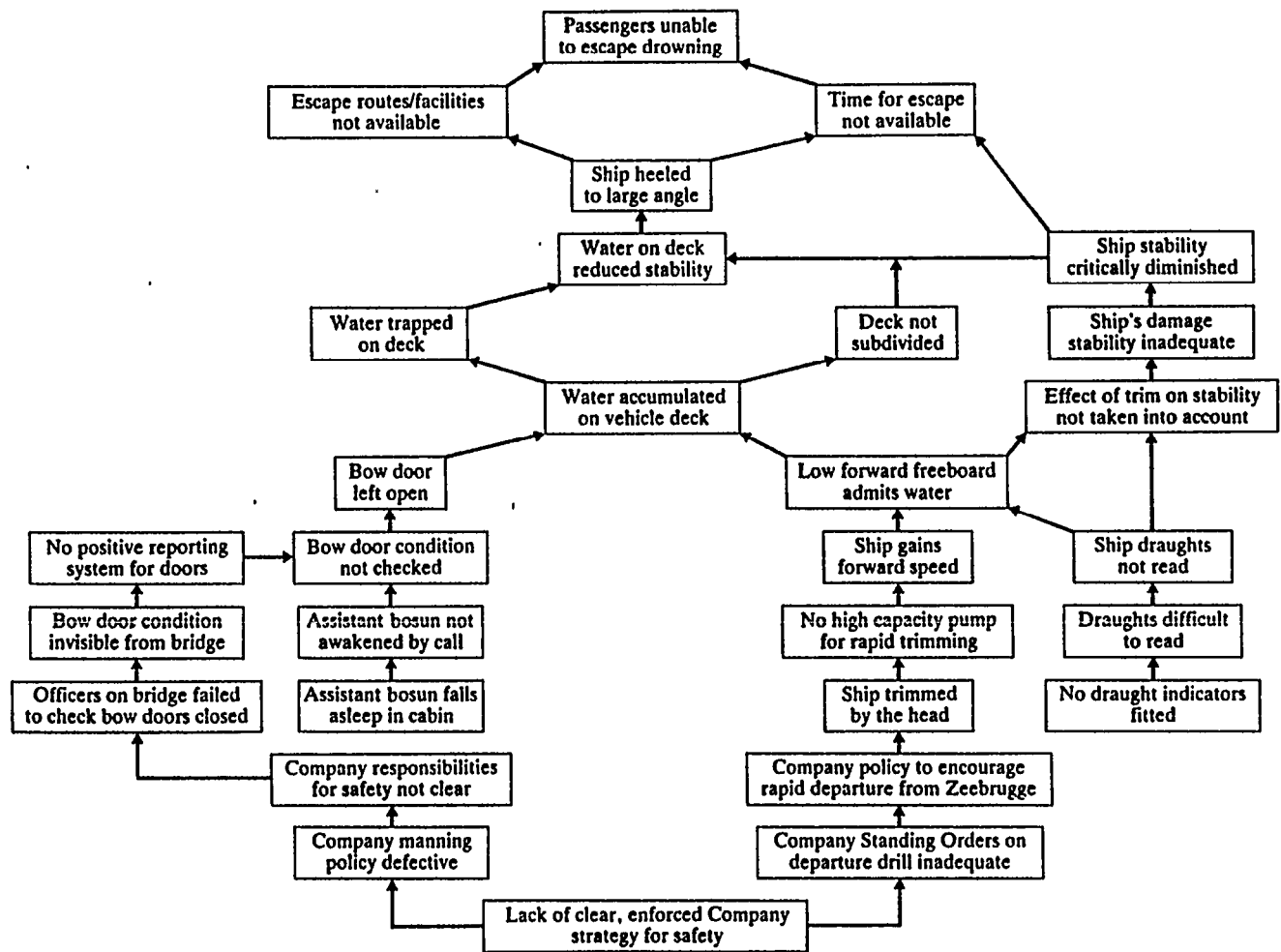
Figure 4. The Herald Disaster Typified the Multiple Events Which Cause Ship Casualties

in relation to this particular hazard (crew negligence in not closing bow doors).

Acceptable levels of risk

Even if both components, P1 and P2, which determine the overall risk of damage or loss due to each significant hazard can be estimated, there remains the problem of defining what (non-zero) level of risk can be tolerated. The growing use of a probabilistic approach to safety only ultimately makes sense if safety levels and standards are then detied by reference to maximum permissible risks. Thii question is already being faced in other sectors of engineering (e.g. chemical, aeronautical, nuclear) and tolerable risk levels detied. In marine work, apart from some interesting and valuable recent studies of some specific marine hazards, the development of a probability-based approach to overall ship design is evident in the evolution of new IMO regulations governing subdivision and damage stability. Even here, however, such concepts as the Required or Attained Index of Subdivision have a largely comparative value, and cannot yet be related to the actual risks implicit in the observance of such rules.

Thii is not to criticise this welcome development, but rather to emphasize that much remains to be done to bring marine risk evaluation to the stage achieved in some other areas of design and operation. Assuming, as argued earlier, that marine safety will be expected to move in thii direction, it is therefore not too early to begin to address the problem of setting acceptable risk levels for marine vehicles and operations. The matter is discussed more fully by Caldwell (1992, 1983); here there is space only to note one difficulty and a possible way ahead.

Specification of permissible levels of risk will probably be based on two approaches : the use of historical data to deduce risk levels apparently incurred in seagoing operations; and comparisons with other occupations and activities to derive risk levels which appear to tolerable or unacceptable to society. A formidable literature already exists in this field, and risk specialists make much play with notions such as "perceived" versus "actual" risks, and "voluntary" versus "involuntary" risks; all of which must influence the setting of risk standards. But for the maritime community there is an added complication resulting from the international nature of many seafaring activities. As Spouge (1990) has demonstrated in relation to ferry operations in the Philippines, the risks which society appears willing to tolerate (or can afford to reduce) vary greatly among maritime nations. The risk of death of a passenger on a Philippine ferry has been estimated by Spouge to be about 150 times as great as for a passenger on a U.K. ferry; but the HERALD tragedy, resulting in 193 deaths, seems to have stimulated much greater change in U.K. ferry design and operation than that following the loss of the DONA PAZ in which about 4400 passengers died.

Here is an aspect of marine safety which IMO may need to address on behalf of the global maritime community. Such disasters remind us also of the need to ensure that levels of permissible risk should somehow relate to the seriousness - in terms of the number of lives which might be lost, value of property at risk, or potential damage to the environment - of failure to withstand any hazard. The Author has

long favoured the development of risk standards derived from curves relating the frequency of accidents F to the seriousness N of their consequences - now referred to as F-N curves.

Fig.5, based on information provided by Lloyd's Register of Shipping, illustrates how such F-N curves might be used to define permissible levels of risk. The curves were derived from historical accident data for various types of ship. Clearly both the general slopes of such curves and their relative positions are important indicators of relative safety. The use of an "iso-risk" line (such as FN = 10 in Fig.5) to define risk liits in relation to potential consequences seems well worthy of further research and development.
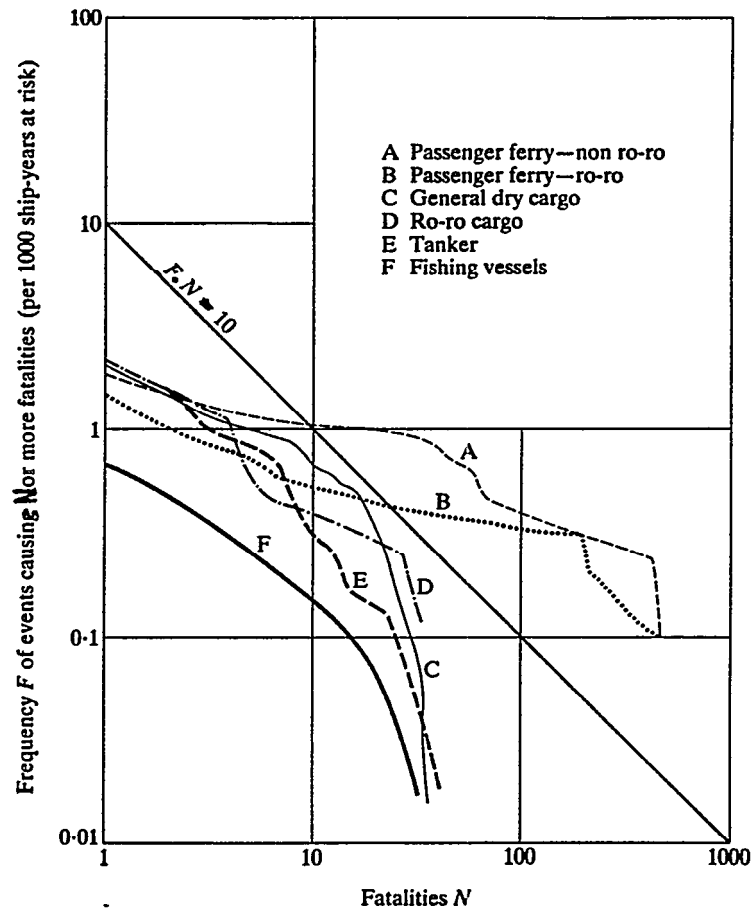

Figure 5 - Frequency - Consequence Diagrams May Provide
A Basis for Defining Acceptable Levels of Risk

4. DESIGN FOR SAFETY

If ship designers in the 21st century will be expected - perhaps required - to provide explicit evaluations of the safety of proposed designs, there must be available suitable methods and analyses to underpin design for safety. Such a methodology is not yet available; and in the Author's view, its creation should now be given high priority in the funding of R & D.

Some of the essential ingredients in design for safety have emerged in the discussion above. They include the capabilities to:-

(a)   identify and quantify all significant hazards;
(b)   evaluate the risk of damage, loss or death if any hazard is encountered;
(c)   define limiting levels of acceptable risks of such events;
(d)   develop designs (and operational procedures) which comply with such levels.

(a) and (c) have been discussed above. For (b), there is now available (at least in principle) a variety of techniques for risk assessment, some of which are beginning to be applied in marine work. Other papers presented to thii conference illustrate ways in which formal safety assessment techniques, includii reliability analysis, probabilistic evaluations, failure mode and effect analysis, fault *tree analysis* and others can be brought to bear on design, engineering and operational aspects of ship safety. Some of these techniques are rather new to marine technologists, and few have yet been included in most undergraduate educational programmes. Some of them also make considerable demands on computing capabilities and facilities, but this becomes less of a problem as such capabilities increase.

In the Author's view, the main aspect of item (b) above in which more R & D is required is in the modelliig of unsafety. In much of the scientific and mathematical work which provides the foundation for education in marine technology and for ship design, the main emphasis has been on the classical "linear" response of engineering systems to *external* stimuli, such as changes in their environment. In many cases, the system behaviour is also treated as quasi-static. Much of the traditional teaching concerning marine structures and stability, for example, is presented in these rather idealized, albeit analytically elegant and tractable, forms. But, in safety matters, the reality is often very different. The behaviour of a ship, as it nears a limiting state at which it (or its occupants) become casualties, may well be highly non-linear, dynamic and possibly influenced by events (such as progressive or cyclic flooding) which are neglected in conventional assessments - and in conventional regulations - concerned with safety assurance. For how much longer can we justify the fiction of believing that the static **GZ** curve is a proper criterion to judge the safety of a damaged vessel undergoing extreme interacting motions in severe confused seas?

Thus the challenge to the ship science community now is to develop more reliable models of extreme responses of vessels, structures, systems and equipment, from which their limiting capabilities can more accurately be assessed. Thii would be *a* major contribution to marine safety. Even if, as an interim stage before requiring formal safety assessments of ships, we move from the present dependence on satisfying prescriptive regulations towards the use of performance criteria as the principal tool in safety assurance, the assessment of performance and the liits of that performance will still require greatly improved methods of modelling system responses to extreme conditions.

The final item (d) noted above calls for the creation of efficient synthesis procedures of design for safety. The main need is that safety considerations should

increasingly permeate the design process, and influence design decisions, from its earliest stages. Hitherto the ship designer's main concerns-have been to ensure efficiency and economy in his product. Safety has generally been handled by post-design checks to ensure that the relevant prescriptive regulations have been satisfied. It is well known that decisions made at the concept design stage can have a profound effect on efficiency and economy. So also do they influence safety; so procedures are needed for assessing the effects of alternative design options on safety. Such procedures need to be of increasing sophistication as the design proceeds, culminating in FSA as ,tlie final check ,011 the developed design.

Some indication of the way in which Intelligent Knowledge Based Systems can be developed to provide the core of such a design process has recently been presented by Sen and Gerigk (1992). Although this is concerned primarily with safety against foundering following flooding damage, the methodology appears c'a$able of exten- sion to design against other hazards. The same research group is now working on a more ambitious research project entitled "Design for Safety" one of eight major projects in a programme for which the Engineering Design Centre at Newcastle University has been awarded grants exceeding one million pounds. The overall intention of thii project, as its name implies, is to-create a practical and versatile methodology whereby the design of large made-t-order artefacts, such as ships and 'ogshore structures, can incorporate safety considerations `ab initio`, working within the constraints of whatever safety regulations or regime are in force.

In the early development of such procedures of design for safety the emphasis will ,no doubt be primarily on generating designs which combine optimal 'efficiency (in the- functional sense). with adequate safety (as prescribed by regulatory authori- ties). There remains the question, touched on earlier, whether there also exists an optimal level of safety. This in turn raises the question of the cost of safety, a delicate matter on which much work remains to be done. A strong case for a more sustained and scientific approach to the study of the costs and benefits of safety was made by Goss (1989) and re-stated in hi evidence to the Select Committee on Science and Technology (1992). But we are still some way from having available agreed methods for putting a value on loss of life, damage to the environment, or on the public perception of safety.

For the immediate future then, the designer can probably do little more than attempt to include cost in design for safety by reference to the effects of design changes on capital costs, and possibly on revenue, repair and insurance costs. Again there may be value in studying developments in other sectors of engineer- ing (e.g. aeronautical, offshore) where some interesting efforts are being made to determine optimal levels of safety. This involves examining the trade-offs between risks of failure and the resulting lie cycle costs and benefits. Of course any "op- timal" level of safety thus obtained must be not less than the prescribed level. Which brings us again to the basic requirement that acceptable and actual safety levels must be made much more explicit than is presently the case.

Clearly design for safety has a long way to go and much is to be done. Not least, our

future designers need the ski and attitudes to equip them to take responsibility to ensure the safety of our seafarers and marine community the coming years They should be educated accordingly.

5. EDUCATION FOR SAFETY

Should we, therefore, make any ignificant changes in the way we educate and train marine technologists to face their future responsibilities? This paper has attempted to sketch the kind of safety scenario which future naval architects and marine engineers might. have to work, and has touched on some of the professional and technical problems 'which may need to be faced, especially if designers: are required to accept more .explicit responsibilities. for safety assurance. How then;. if at all, might their "formation" as engineers of the 21st century need to change?

Although 'engineers at all levels have a contribution to make 'to the assurance of safety it seems ,appropriate, since this Conference is to celebrate the achieve ments of a diitinguished'Universits;, to limit this discussion to the 'education professional, graduate (in U.K., chartered) engineers. Again in the 'light of 'Delft's notable contributions to the education of marine technologists', 'the Author '(because of his own experience. also) will address particularly the education of naval architects and marine engineers.'

Educators and curriculum designers 'these days are caught in a dilemma. On the one hand, the relentless expansion of knowledge, and the recognition' that professional engineering, often requires managerial, financial and communization skills as much as engineering science, has led to enormous pressures not -only to "broaden" courses, but also to include new analytical topics aspects of the. subject. On the other hand, Universities in 'most countries now are under pressure to be more "productive", to increase output, to reduce'unit costs, to spend more time fund-raising, to interact with industry and commerce, etc., etc. In U.K. Universities, the triple pressures of expansion, accountability and commercialization have transformed (for the worse?) the environment in which academics can fmd time properly to define and deliver a higher education appropriate to the needs of future graduates. Pressures to equip graduates with particular skills of current value to employers must be moderated by the recognition that such skills can now more rapidly become obsolete. Likewise pressures to produce various kinds of specialist graduate, even within our particular sector of marine technology, may ultimately disadvantage the graduates themselves, who surely need a broader base of engineering education to face an uncertain future. Moreover, any segregation into specialiit streams or "tubes" of study can lesson the healthy and informative influences of developments in other sectors of engineering. This is especially true of safety engineering.

So the Author has come to the view that Universities should seek to redefine the overall philosophy and objectives of their educational programmes, and perhaps return to some of the original ideas which informed undergraduate education. These might, for example, lead to curricula which:
0   develop the ability to think creatively rather than to perform specific routines

emphasize, and build on, the unity of engineering, rather than encourage its continuing fragmentation

give priori&' to knowledge and skills which are' enduring;, adaptable and versatile

provide more time to "learn by doing"

-encourage the art and science of synthesis alongside those of analysis.

Against, such I generai desiderata for undergraduate education, how then might education for safety" be stimulated and introduced? In the light'of the foregoing opinions, the Author would reject the idea that safety engineering should now be "bolted on?', to our already overcrowded curricula in marine technology. 'This is not to deny that probably at postgraduate level or as part of Continirmg Professional Development (CPD) there -could,be'value in specialized' intensive courses 'concerned with the techniques and applications of safety engineering. 'Such:courses should preferably cover many disciplines of engineering to ensure cross-fertilization of ideas' and techniques

The main need at undergraduate level is to develop in the engineering student a consciousness (as well as a conscience) that safety is an important part of his pro fessional' responsibility;'that? safety engineering is an indispensable part of design; 'that technical method 'of safety assurance are becoming available, but that safety assurance has human, operational and managerial as well as technical dimen-sions. The main 'mfluence vvhich marine. architects exercise over safety is through design; so it follows that the' main trust of education for safety should be through the teaching, and practising, of design. There is (at least in U.K.) much current debate about- and criticism of the teaching of)design ,inUniversities; and there is no general agreement yet as' to what'constitutes a good course in design. But if design is- to be presented as the process of decision-making under constraints and uncertainties in order to define the artefact with the "best" set of attributes for its intended function, then what is being suggested here is that those attributes must explicitly include safety.

Undergraduate education, however, should do much more than just pay lip-service to the importance of safety through general exhortations and qualitative state-ments. The naval architect of the future needs to be able to assure safety; he needs a rationale, methods, equipment. But if there is no room to add to his course specialized studies of reliability analysis, FMEA, and the like, (which might be the subject of postgraduate study or CPD), what can be done to prepare the ground, to sow the seeds of safety engineering, and to cultivate the right approach to safety during his undergraduate studies?

The brief survey of the problems of safety and design for safety given earlier in this paper, suggests a number of ways in which undergraduate courses might change some priorities and emphases in order to encourage a more safety-conscious formation in marine technology:-

(a)   In introductory courses concerning ships and the sea, *as much attention should be paid to failures* us *to successes.* Not only does failure promote more

progress than success;. a study of casualities can show students the variety and nature of the many hazards against which ships must be designed.

(b) Statistics *and probability are* of such fundamental importance to safety engineering (and to many other aspects of marine technology) that this branch of applied mathematics should permeate the entire undergraduate course. Study of the sea and ships and casualities provides a rich source of examples and applications of statistical and probabilistic concepts which give reality to what is often (to the student) a rather dry and formal area of science.

(c) Likewise the concepts of *uncertainty, risk, reliability and safety* can be introduced and exposed in many topics within marine technology. Emphasis on certainties and single-solution problems must be replaced by a healthy realization that the real world is uncertain, open-ended, capable of many possible solutions.

(d) Work in engineering science should give greater prominence, as suggested earlier, to the *prediction of the way things fail* under extreme conditions as much as to "linear", day-to-day behaviour under normal operating conditions.

(e) The *ability to model the "real" world,* - imperfect, dynamic, irregular, - rather than an "idealized" world should constantly be borne in mind in developing the analytical capabilities of students.

(f) The idea that safety is basically assured by designing so that the *capability* of a system or structure to withstand changes in its environment exceeds the *demand* made upon it, should be seen as fundamental. The fact that both demand and capability are probabilistic, and often time-dependent, reinforces the importance of (b) and (c) above.

(g) Although students must be made aware of the regulatory system, and the principal regulations, within which the designer must currently work, it is suggested that *less time should be spent on detailed study of current regulations.* The emphasis in design for safety should move from the satisfaction of empirical, prescriptive rules, towards the assurance that certain explicit standards of performance will be achieved.

(h) The concept of *damage tolerance* through fail-safe design should be developed and encouraged in lectures and course work in design. In systems design, especially, the value of redundancy or alternative load paths should be emphasized and demonstrated.

(i) In the teaching of management subjects, the *responsibilities of management,* as well as individuals, in relation to safety should be explained and emphasized. Factors influencing human response to emergency include not only individual competence and training, but also the operational system and managerial culture within which work is carried out.

(j) The development of *design for operation* through the increasing use of techniques such as ergonomics, simulation, IKBS etc. can do much to improve safety, not least through the reduction of accidents on board and the effects of human error.

(k) The value of sea-going experience for students cannot be overemphasized, Here[i] is an aspect of education for safety' to which shipping companies can make a most crucial contribution by affording opportunities for undergrad-_ uates to learn from living and perhaps working, on board ships during vacations or soon after graduation

A final general point. Teachers, as well as students, of marine technology must avoid living in "watertight compartments'. So much of -recent advances in safety assurance have ,come from other branches of engineering ,that it is essential for us to learn and' adapt ideas and techniques from other disciplines, and to distil the best of these into our courses and curricula,

Let us hope that, in such-ways, when TU Delft next has cause to celebrate an anniversary, it can look back with pride on real and demonstrable progress towards ensuring greater safew, for the who tiork and travel OR the waterways of the world. We ,will a& wish the. University well 'in its future endeavours.

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