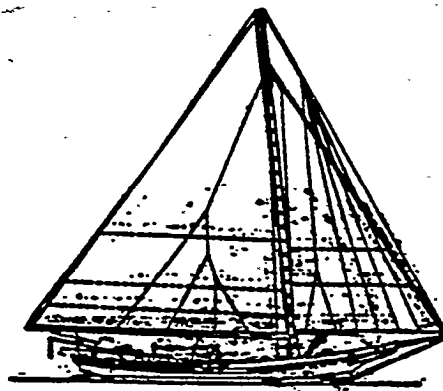
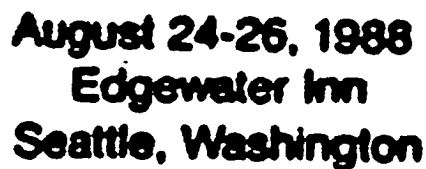


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THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

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The Use of Computers in Advancing Group Technology.

No. 1

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ABSTRACT

When introducing product oriented work breakdown techniques as the means of defining work within a shipyard, it is worthwhile considering the use of computers and how they may be utilised to improve the success of this task. This document addresses experiences gained and reflects on the systems in place in some of the shipyards within the United Kingdom.

INTRODUCTION

Modern and effective shipbuilding requires close control of material and labour at each stage of the process that begins at pre-contract specification and continues through commissioning such a high degree of control and the ready access to information that is required to meet that objective can be achieved by the introduction of an integrated computer based solution.

The computer industry has attempted over the years to provide a material and labour control solution for manufacturing based industries and some success has been achieved where the design, material procurement and manufacturing schedule are stable and the product well defined. This environment does not prevail however in shipbuilding and a different style of computing system must be made available to address project based manufacturing.

The initial design of a complex product such as a ship is commonly undertaken by using a system by system approach. This ensures that the final product will perform to specification. Production, which traditionally followed the same system oriented approach, now utilises a product oriented work breakdown structure which crosses these traditional boundaries. This product oriented organisation of work is required in order to reduce time scales, constrain costs and utilise a work force more effectively.

This reorganisation of the production process does not fundamentally change the nature of the continuing design process

which is characterised by continual iteration and refinement. In industries where the design process may be completed before procurement and production commence this is of little consequence. In present day shipbuilding however, time and cost constraints necessitate the overlapping of these processes. This has a major effect on the nature of any system which can successfully control the entire process, in that early estimates of material required will be changed in the light of more detailed design.

The effect of such changes must be automatically highlighted to the relevant departments to ensure appropriate modifications to procurement and indeed to work processes take place.

Given that the case for the use of computer systems in shipbuilding can be made, then the introduction of these systems can be of benefit when coupled with the change from a traditional shipbuilding approach to the increasing use of group technology, associated product work breakdown organisation of work and the introduction of mixed disciplines in composite labour groups. This change brings with it problems within the shipyard in being able to physically reorganise the shipyard where appropriate, ensure that the work force understands the new organisation of work and, most importantly, still achieve contract timescales. As any shipyard that has undertaken this type of program clearly understands, the problems retraining personnel and coordinating the introduction of this work organisation are daunting.

Almost unavoidable in this scenario is the introduction of new coding schemes to identify the revised method and sequence of manufacture, assembly and installation. While the actual selection of coding schemes that reflect this requirement is in itself a difficult task, the subsequent method employed to introduce these codes to the work force is of paramount importance. This problem has been overcome in part by the use of computer systems and the discipline they

can bring to the use of coding conventions. The problem is then restricted, to a large extent, to the department who must initially introduce a code or its application for a contract. The computer system is then required to impart this code and associated information in a meaningful manner to subsequent and dependent personnel so that they do not have to understand the implications of a code beyond their use of that code.

It becomes apparent then, that programs for training personnel in the ways of group technology should be coordinated with the definition and introduction of computer systems to assist this process. Additionally the level of management information required to effectively operate these programs can also be identified and addressed at the same time by the system to be introduced.

The criteria outlined above may be used to evaluate the applicability of available packaged systems to the shipbuilding process. The remainder of this document addresses the principal elements of shipbuilding technology with production in mind and also addresses the experiences gained in preparing a computer system package to support the introduction of that technology.

At the outset of the change from traditional to product oriented shipbuilding a package capable of handling the process implicit within shipbuilding was not readily available. Packages that were available and where initial efforts at implementation of these had already been made, proved too rigid in the relationships between design, procurement and production. As a result the effort to modify these systems to the specific needs of shipbuilding and thereafter maintain these systems through the introduction of a revised method of working negated the benefit of the traditional package solutions.

More importantly, any system to be introduced had to be capable of supporting a shipyard's requirement through the transition from traditional to interim product oriented organisation of work. This, in terms of computer systems, means that the system must have a flexible design and provide a rapid development process in terms of database and program modification. While this definition of what a computer system should be is widely considered as an ideal in this case it was considered mandatory. This requirement of a computer system was recognised very early in the overall initiative to support the step by step approach undertaken in the introduction of shipbuilding technology and the varying pace at which individual shipyards or departments could progress in the adoption of new working and organisational practices.

The computing solution to this problem lies

in the use of 'fourth generation languages' where the ease of modification of data and the rate of program development most closely meet the criteria established. While the process of determining the content of any proposed system does not change significantly, the productivity of data processing personnel in providing the system once it is defined, is increased considerably. Added to this factor is the ability when using fourth generation languages, to produce and agree within acceptable time frames and costs a prototype version of a system. This initial conversion of a specification into a system that covers the main topics of the system function can be viewed and critiqued by a prospective user. This serves to eliminate many mis-interpretations of the written specification sometimes apparent only during implementation and contributes significantly to the acceptance and use of the system by the work force.

It is when a system has been defined and written and is subsequently being implemented that difficulties traditionally arise. What may have been considered a preferential method has now changed or, as is the case when change of the scale made in converting from traditional to product oriented build, separate functional departments within a shipyard progress at different rates. The timescale for a DP department to react to these changes when using fourth generation languages can be measured in days rather than weeks or even months as has been the case for DP in the past. Thus by using a fourth generation language the ability is present to produce a flexible design and to support a shipyard through the stages of introduction of new work organisation.

For the purposes of this document the following topics are those I see as forming the basis of an integrated system in support of shipbuilding technology.

- Requisitioning
- Purchasing
- Receiving
- Stores Control
- Product Definition
- Product Breakdown
- Work Packaging
- Labour and Material Cost Control
- Invoice Clearance
- Manufacturing Demand
- Marshalling and Issue
- Production Feedback

Planning systems, CAD/CAM systems, finance systems, detail shop scheduling systems are therefore defined as being non-integrated but all of these systems require an interface, in some cases bi-directional, with the production administration systems listed above.

The result is an integrated system that, in summary terms, and identifying the

significant change seen functional area operates as follows:

PRE-CONTRACT AND FUNCTIONAL DESIGN

within the pre-contract and functional design phases the objective is to ensure that the vessel conforms to and will perform the required tasks with consideration to function, payload, space, speed, etc. Typically it involves production of a preliminary hull form, general arrangement drawing and basic operational calculations (see figure 1).

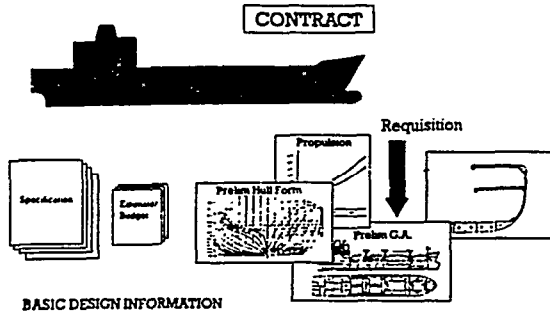


Figure 1. Contract commencement and the means to plan, monitor and control the contract.

At the time of the contract award cost estimates are confirmed and entered to the computer by ship system for material, and by skill or composite groupings for labour.

Prior even to the identification of this information, it may be necessary to identify long lead material items and to commence procurement of these items. This can be achieved by direct entry and use of the requisitioning and procurement facilities within the system.

At contract award a Build Strategy is also confirmed which defines the Company's policy as to how construction will take place. This strategy is applied to the primary construction zones of the vessel which are the first level of work breakdown. Here areas of like difficulty are grouped as a shipyard standard and are addressed independently for material identification at this stage. Typical primary zones would include accommodation areas, machinery spaces, cargo spaces etc.,

Within each primary zone a further definition is made as to purchasing or material ordering zones. This assigns a series of estimated start dates to each section of the primary zone that are keyed to the build strategy and become the initial targets for material availability. (See

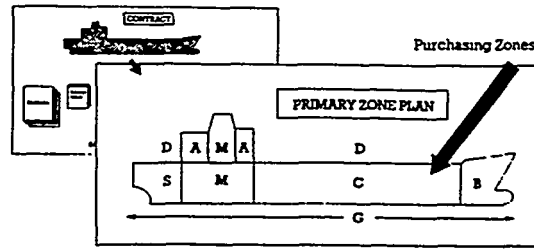


Figure 2. First targets dates targets dates for purchasing REQUISITIONING

In order to allow for the overlapping of design, procurement and production activities, the ultimate purpose of which is to reduce any delays in the production phase, estimates of the material requirements are made from information available at this stage. These requisitions are submitted to the system and are represented as material lists by system (MIS). When organised correctly, this interface from CAD/CAM systems can provide a significant improvement to the accuracy and timeliness of the transfer of data at a critical stage of a contract. The system, however, must accept that a complete and total interface may not be possible, at least initially, and must provide the means for the submission of data, tailored where appropriate, according to the type of material involved.

PROCUREMENT

The purchasing department is tasked with the responsibility of ensuring that the quantities of material specified in requisition form are obtained at the optimal cost and quality in the time frame designated.

It is the purchasing departments role to open inquiries on this material from preferred (best) suppliers keyed to the delivery dates required. The computer system assists in this process by virtue of a link between the Supplier files and material requisitions which shows the range of products or raw material offered, past performance and lead time for delivery. This information combined with the delivery dates required prompts for action on inquiries, quotations and orders.

Having undertaken this process by using system facilities and having received quotations from suppliers on cost and lead time this information is added to the data available within the system. The purchasing department is now in a position to place orders by the combination of requisition, quotation information and part specification. The data available is

supplemented, where appropriate, by textual information detailing and amplifying the specification of material and quality expectations.

While this represents the simplest form of procurement, to a contract specific requisition, the computer system must also provide for other methods of raising requisitions or the handling of orders.

Stock material, maintained at specified levels, is monitored by the system as to reorder level, economic order quantity and lead time against the demand in production. The system raises requisition and prompts procurement for action to ensure timely replenishment. A sub-system for cyclical inventory must also be available, monitoring on value and frequency of use.

Certain orders will be placed specifically as detailed above but for other material the system provides the ability to group requisitions and/or demand to form a contract wide order. Within this facility options are utilised to release partial orders of the total requirement keyed to the timing and use of the material at a selected level within a single contract or across all contracts currently in build.

The most important aspect of this part of the system must be its capability to recognise any change in the quantities associated with requisitions or by production demand as it is detailed and specified in the product work breakdown of interim products. When these changes or discrepancies are identified then the system prompts the purchasing department to respond to the change thereby maximising the possibility of full material availability to production departments.

TRANSITIONAL AND DETAIL DESIGN

Concurrent with the procurement inquiry and quotation process the transition from the initial system oriented view of the vessel to a product oriented identification of work is being defined. This entails the identification within each primary zone of units or blocks and major outfit modules. The required sequence of the erection and installation of these entities will be determined by the use of planning systems. Several iterations of the contract plan may be produced by these systems before an agreed plan produces an interface to the production administration system identifying the units of the build process and the planned start and end dates of each. This interface will be bi-directional as completions of work, at the level specified by the shipyard, will be communicated from the production administration systems to update the contract plan in the contract management planning system.

In turn, these units are submitted to a process analysis and detail design stage where components of a unit are

identified and the availability of the unit for work or access (known as a stage) is determined (see figure 3).

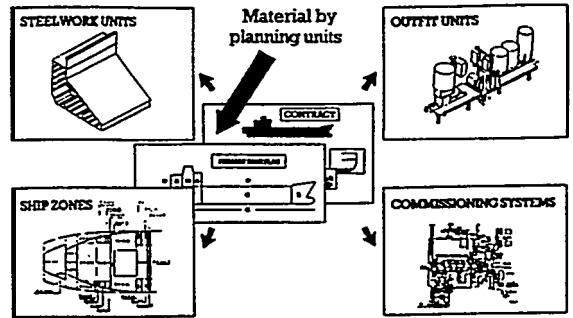


Figure 3. Material identification in a product oriented breakdown.

The computer system, as part of the introduction of this work breakdown, provides a number of options to enable this specification of material to be made. It has been the experience in UK shipyards that it is very difficult to move to early work package definition in one step. Accordingly the system recognises this difficulty and provides facilities to allow identification of material either at unit or block level, stage and work package. Additionally all subsequent material handling also recognises this interim stage of development and provides a corresponding level of facilities within each functional area of the system. Finally, discreet packages of work are identified which when performed in the desired sequence will produce the necessary interim products required for assembly, erection and installation at the appropriate stage in the construction of either further interim products or a unit or nodule. Material requirements both for in house manufactured and purchased items are identified during this phase and are assigned to the work package (see figure 4).

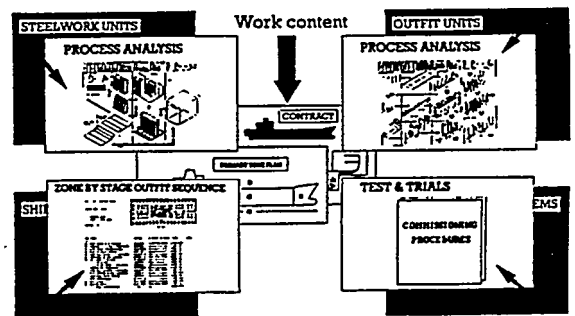


Figure 4. Definition of work content and work packages.

Process analysis to the work package level will also determine the volume of work associated with each work package and will establish, from shipyard performance criteria, the manhour targets (see figure 5).

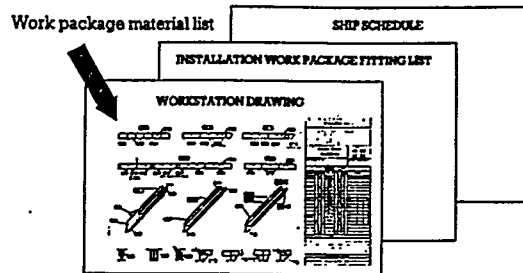


Figure 5. Detailing of work packages

The work package becomes the focal point for all work within a production environment. Each work package now contains material lists, manhour targets, location of work, start date, etc., From this information the demand for material and labour availability can be determined, the progress of work to timescale can be monitored and a forecast to completion can be calculated (see figure 6).

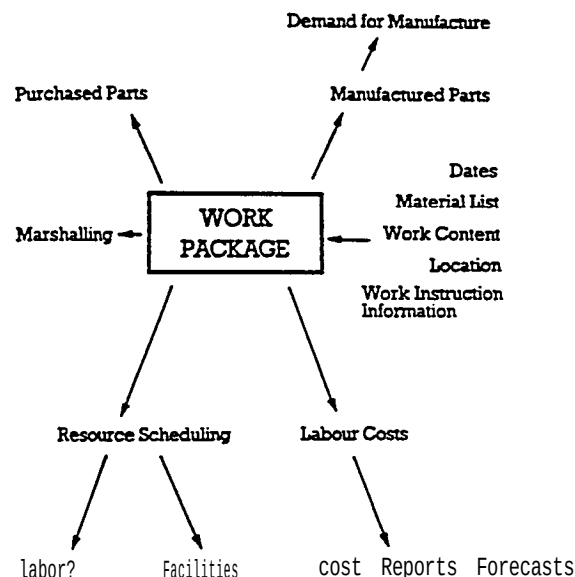


Figure 6. Work package implications.

The computer system fully supports this process and provides a number of options to accommodate varying degrees of skill in attaining this product work breakdown.

Perhaps the most efficient option being a second interface to CAD/CAM computer systems where detailed work instruction drawing complete with material identification is interfaced and related to the work package.

For its own parts and by using the work package as the primary source of data, the system has the capability amongst a number of other facilities to aggregate material required as a result of the detail design process. This data, which defines the specific material requirements of the contract, is compared to those quantities held in the system oriented requisitions being processed by the Purchasing department. Advice is forwarded to the purchasing department in the form of reports or via computer terminals as to where a shortfall has been detected and remedial action is warranted. This facility is also available at unit and stage level to ensure early confirmation of quantities for procurements.

MATERIAL HANDLING

As the process of design and procurement advances and the schedules for production are advance, the flow of materials into the shipyard will commence. It is necessary to receive and inspect these materials for initial acceptance. Subsequently the material must be stored and the location recorded for future use. In turn as the material is required in production it must be withdrawn from its store and palletised and shipped to the production work site.

Again the computer system supports this standard business practice by providing terminal access to data for recording of receipt and inspection and the status accorded the material at that time. Rejections are recorded and reported to the expediting and purchasing departments. the location(s) of the material storage are recorded on the system and the material is recognised as being in inventory for use upon production demand.

Also contained within the system is a method of applying cycle inventory for stock items and those shipyard standards maintained stock items in order to provide a margin of safety stock or inventory. The system provides facilities based upon a classification of usage to ensure that physical inventory is reconciled to that held in the computer files and financial accounts.

In advance of the production demand, routines will provide a pre-marshalling audit of all material required for a work package. These routines will produce reports for use by expediting personnel identifying any deficiencies determined by this process.

In due course and according to scheduled dates, marshalling of material is required to fulfil in house manufacturing or work

package requirements. The system produces reports that identify the material required, including mill mark for steel plates and sections, the location and quantity of the material (including steel stockyard handling routines), the pallet identification, shipping destination and requirement date. The stores personnel marshal and ship the required pallets to the production environment where assigned staff accept and record the receipt of complete work package material lists. This triggers the withdrawal or issue of material from inventory within the system.

The effect of the computer system in this area, when coupled with procurement and product work breakdown data, is a significant improvement in the provision of complete material packages for use by production. Stores personnel have the opportunity to organise material far more effectively than in the somewhat informal methods prevalent in the issuing of material in a traditional build process. This ability is significantly aided by the ready availability of data on the requirements, the storage location and material identification that the computer system provides.

PRODUCT DEMAND

As has been stated earlier, the product breakdown has been organised and scheduled at unit, stage and work package levels in accord with shipyard strategy and key dates of planning determined in the specific build strategy. At the lowest level of work package however, certain items are specified as in house manufactured components. Each of these components has a product structure of the individual piece parts required to form the completed item and each is associated with a process necessary to complete this work. Within each process the operations while not identical may be similar and are known as part family operations and are the basis for the application of group technology.

Within the system each of these parts to be manufactured is identified and the components required are also known. The system also relates this manufacturing process to a particular part family, the location of work, sequence of operations and standard lead time.

Based upon the product work breakdown requirement dates, the system collates and groups, based upon a selected horizon, the loading on each manufacturing centre and issues a demand to detailed shop scheduling. Since the grouping of demand is a theoretical load the manufacturing facilities have the ability to group the items into manufacturing work packages that are associated with part family and requirement date. Marshalling instructions for the raw materials, including nesting identification for steel, is issued to

stores for their action. At the completion of the production runs, the output from these work packages are accepted and recorded by Stores personnel as available inventory and the storage location or holding area is appended. This process is repeated through the build cycle of a vessel and the computer system is used to coordinate the various manufacturing facilities via the production demands.

This process provides a better control mechanism for manufacturing as they are able to gauge the demand upon their facility by the selective use of current and projected manufacturing demand.

COST CONTROL

The preceding sections have dealt primarily with the process required to progressively complete the build of a vessel. Just as important during this process is the monitoring and control of costs associated with the contract.

To this end the computer system provides a number of facilities to aid this task and wherever possible uses activities described earlier to trigger the collection of costs.

In the first instance the contract estimates are entered to the system and are recorded as material and services costs or shipyard labour costs at the level of cost control required by the shipyard.

In the case of material and services costs, the accrual of actual cost against these estimates is generated to the costing portion of the system by facilities that recognise the trigger action. Thus as purchase orders are issued, as receipts are confirmed, as issues to contract are made and when a suppliers invoice is authorised for payment the system generates transactions to post and record the associated cost value. The net effect being that material costs can be monitored against contract estimates (including post contract award amendments) as committed cost, cost and duration of material inventory, cost of actual material issues and actual cost paid to suppliers.

Similarly the manufacturing process attracts both material and labour cost in the production of in house manufactured items. These costs are also recorded and the system provides several options on the final cost distribution either to a manufacturing centre or as contributory costs to the provision of material to work packages.

The work operations when performed, attract material issued cost and labour cost which is retained as both manhours and in a monetary manner. This latter method also has options which include interfaces to payroll for actual costs or by use of departmental standard rates which can include overhead cost ratios.

As material and labour are incurred by the completion of work packages the system must provide alternate forms of cost reporting. Firstly, based upon contract estimating, the system can apportion costs incurred to a work package across the component systems held within that work package.

Alternatively, these costs can be recorded by skill group or trade where contract estimates are made on this basis. Material costs are booked directly to the system to which they apply as the computer ascertains the system identity across the components within a work package. All of these costs are monitored and controlled against the contract estimates as entered at contract commencement and subsequent amendments to contract when applicable.

The second cost reporting form is by aggregation of work packages to stage and unit level. This is especially important in respect of manhours as work content estimates and thereby target manhours for the contract have been made across all units either at unit level or following detail design to the work packages forming that unit. This aggregation of hours allows for forecasting of manhours to completion and the likely cost and delivery timescale. The forecast is based upon one of a number of options that can be selected by a shipyard. Typical is the use of actual performance to date on work completed against the corresponding targets. This is used to calculate a ratio which is then applied to the remainder of incomplete or future units. The target hours for these future units can be modified by a shipyard to reflect performance or productivity factors organised by labour skill group. These modifying factors can be applied to acknowledge current levels of performance as opposed to the levels attained when the contract commenced. These same manhour recordings are also used to monitor against performance indices by skill group and cost centre.

In this management reporting area, the use of a fourth generation language proves most valuable. While the base data can be defined and maintained in a fairly standard manner, the variations of reporting against this data can vary widely. This is true from shipyard to shipyard and also within a single shipyard dependant upon the stage of implementation of shipbuilding technology and the computer system itself. The data, collected and recorded once, can be viewed from a number of directions and can be reported on according to departmental requirements. The fourth generation language can be used to provide the variation of reports in a timely manner and can be used to modify the same just as quickly as experience or a changing environment dictates.

While the above discussions have centred on contract related costs, it is also important to recognise that the indirect departments

should also be able to utilise the same computer system. This ensures that everyone is using the same form of recording and the ability to procure, control and cost all items can be represented from the same source for the entire shipyard.

Suppliers invoices must also be verified against the purchase order and receipt of material. Invoice registration provides this opportunity to match invoices on agreed cost and quantity and posts the actual cost to the cost ledger. The invoice is interfaced to an accounts payable system within the financial systems for appropriate processing and payment.

At points in time determined by a shipyard, the cost ledger is summarised and interface to a general ledger is created and contract costs are entered to the appropriate accounts within that system.

SUMMARY

The previous sections have dealt with the approach to product oriented shipbuilding in a summary form. Correspondingly, the references to the function and facilities within computer systems do not do justice to the full range of transactions, data handling techniques, interfaces, expediting activity and reporting that have been included within the systems.

It is fair to point out that following the initial definition and implementation, the system have been developed in close consultation with shipyards who are applying product oriented techniques. These computer systems are in use in these shipyards and have in fact been instrumental in some cases in the successful adoption of these principles.

As in the case in every industry, one company will vary to a certain extent from another involved in producing very similar products. As stated earlier this is acknowledged by the fact that the systems are developed in a fourth generation language and database manager which enables the system to be customised far more easily than has been the case with traditional computer system packages. A by-product of this ease and rapidity of development allows a shipyard, even with its own personnel, to specify the format and content of reports or computer terminal displays where that provided within the system does not correspond closely enough to local requirements.

Implementation of systems must also reflect both business considerations and human factors present in a shipyard. The system, while it is primarily a fully integrated shipbuilding solution also must have the flexibility to allow introduction of the functions on a modular basis.

Computer systems using the most current

computer techniques, enhance and facilitate the introduction and continuing development of product oriented shipbuilding together with the administrative tasks required in a business environment.

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System Strategy Teams: A Participative Management Adaptation

No. 2A

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ABSTRACT

"Management in the United States often falls into the trap of invoking Theory Y programs in Theory X ways" (1). Perhaps nothing conceptualizes the plight of American businesses implementing new programs and techniques quite as succinctly as the preceding statement. Many of the buzz words of celebrated methods and techniques used in Japan have been popularized in the U.S. Unfortunately, the implementation of these techniques is not given the careful consideration it demands.

Although participative management did not achieve full potential in the U.S. with the introduction of quality circles, the foundation was laid and lessons were learned. The organization and operation of a company needs to be considered for a successful implementation. System Strategy Teams represent an adaptation of participative management developed specifically to function within Peterson Builders.

BACKGROUND

Peterson Builders, Inc., is a small, nonunion shipyard in the Midwest. At this point, PBI's major contracts are solely with the U.S. Navy. Currently, most of PBI's work is generated by contracts for wooden hulled mine countermeasure ships. Although detail design is not done inhouse, an Engineering staff is maintained that works closely with the subcontracted design agent.

As PBI moved into the minesweeper contract, more and more problems surfaced. Problems with design had a rippling effect all the way down the line. The more problems that occurred, the more adversarial departments became. Adversarial relationships were even occurring within departments. The lack of communication and lack of direction were evidenced in manpower overruns, excessive rework, and an inordinate amount of scrap material. The nature of the vessel generated many restrictive requirements necessitating penetration

through bureaucratic policies and procedures for any deviations from specifications. In the Pipe Shop, the problems were accentuated because of the complexity and extensiveness of the piping systems. Many programs and techniques were tried to improve the situation, but none were given the conviction, or support, or direction necessary to be effective.

After approximately four years into the contract, upper management issued a directive to determine what was responsible for the problems the Pipe Shop experienced and determine the impact of trying different programs and techniques for problem resolution. After some discussion, it was decided that it would be much more effective to direct efforts toward preventing recurrence. It was decided that a team needed to be developed which could cross departmental boundaries and solve system problems. Supervision had recently changed in both Piping Engineering and Piping Production and the new supervisors recognized the need for a change. It was an ideal time to invoke a participative management program.

SYSTEM STRATEGY TEAM

Conception

With the initial charter of finding out what was responsible for the minesweeper problems, over twenty interviews were conducted with people involved in the piping system design to products process. Once the charter changed, it was easy to choose participants. The following criteria were most applicable. A good candidate

recognizes that there is a problem and a change must occur.

has the power to induce change. This does not necessarily mean they have the authority or responsibility to induce change. It means they are in a position to influence and support.

is not afraid to admit that he is fallible.

is willing to contribute.

- is a key player - instrumental to a smooth flowing system.

Many of the people interviewed would have been good candidates for the team, but, importantly, the group was kept small and balanced (ten members). Engineering, Production, Purchasing, Planning and Testing are represented on the team. The candidates were asked to participate - offered an alternative.

The idea of a team first met with some skepticism. Interdepartmental meetings had been held before and had turned into "finger-pointing" sessions. One major difference was to concentrate on problem solving - not problem finding. Additionally, upper management was asked to not attend the first few meetings to keep participants from feeling they had to defend their department. An open exchange was fostered.

Development

System Strategy Teams were strongly modeled after Performance Action Teams (PAT's). PAT's originally evolved from studies performed at Ohio State and continued at Oklahoma State University (1). The purpose of PAT's is to directly and positively impact the productivity of an organization. Originally titled Productivity Action Teams, the name of the process was changed to Performance Action Teams to capture the extensive and integrative aspects of the concept.

PAT's are three to four member committees of a larger group, Performance Action Group (PAG), assigned to solve a specific problem. The PAG, formed by key people from various areas, addresses problems identified and prioritized by the group. The solutions are presented to management, at which point management has the alternative to modify, implement, or reject a proposal.

PAT's offer a definite advantage over Quality Circles. An organization is a series of related and integrated sections. It must be viewed as such. The majority of problems cross departmental lines. Although Quality Circles get the people involved who are effected, they do not have the jurisdiction to cross departmental lines. They cannot solve system problems.

At Peterson Builders, there was an additional problem. So many techniques and programs had already been tried that employees viewed a new program as another halfhearted, unsupported waste of time. It was critical to program success for the control of implementation to lie in the hands of the participants. The level of the employees in

the group allowed this. If not directly involved in implementing changes in his area, the participant was very influential.

The most distinguishing factor of the System Strategy Team is its ability to solve problems within the group. Problem solving and solution implementation lie in the hands of the people directly effected.

Although the absence of upper management at the first few meetings insured against department defenders and promoters, it became evident that the team did need to see that there was upper management support. They needed to see that upper management was acknowledging their efforts. If it was known in advance that one of the vice presidents would be attending the meeting, the result was complete attendance.

Evolution

The team evolved surprisingly fast. While initially making a superficial attempt at problem solving (looking at symptoms of the problem rather than the problem) the group evolved and began to address true system problems, thereby taking advantage of the experience and ideas of those involved.

Before this was accomplished, the group had to feel that they could be effective - that they did have some control. Also, they needed to feel like a team working toward a common goal.

The composition of the group has also changed. Depending on the identified problem, people have been added to the group or "put on reserve". The number in the problem solving group has stayed quite constant (around ten). The original participants still receive weekly memos so they are familiar with progress and problems.

Technique

A brainstorming session was conducted to generate a list of problem areas. The list was then reviewed. Problems were eliminated if they really fell outside the scope of the team (i.e., design agent error) or if the problem was too extensive for a beginning team to undertake. Similar problems were combined.

The group was asked to vote on the altered list of problems. Each team member prioritized the three major problems he viewed as most serious. The weighted votes were tallied and scores were assigned to each problem.

"Drawing Accuracy" was targeted as the topic for most concern that the group could quickly and successfully address. After generating a list of

problems associated with drawing inaccuracies, the group voted and the top three problems were listed. Volunteers were asked to pick one of the three topics, become subgroup leaders and pick two other people to address the problem. The team facilitator became a member of each subgroup.

The first subgroup, "Pipe Detail Problems", addressed the problems associated with prefabricated piping units. The final result was a presentation given to Engineering by the Pipe Detail subgroup regarding information that needed to be included and standardized among Engineering.

The "Bill of Material Inaccuracies" subgroup also delivered a presentation to Engineering regarding complete, correct, standardized information.

The third subgroup, "Loss of Realistic Design Approach", chose to look at the problems caused by lack of communication between Engineering and Production. Part of the solution included sending an Engineer with a Production worker for a week. The people involved gained a mutual respect for the other's position.

The approach used by the subgroup for developing and implementing a solution is quite dependent on the subgroup leader. Although the first set of solutions was superficial, major progress was made. The team learned that they could work together and they would receive management support. Additionally, other groups were started with outside support. From the "Loss of a Realistic Design Approach" subgroup, an Accuracy control program that had been previously dropped was once again started.

The team has now reorganized and is analyzing each piping system. Preferred methods and materials are being recorded in addition to past problems encountered. The manual will be used by detail designers. Plans also include a maintenance scheme.

Results

The results have thus far exceeded expectations particularly in the area of improved communication between departments. Point nine of Demings 14 points for management specifies "Break down barriers between staff areas." (2) Improved relations will play a major role in avoiding recurrence of problems.

The team is currently working on a set of standards for the detail designer that will indicate preferred methods and materials. Completion of the project should trigger similar

projects in other areas of the yard.

FUTURE DIRECTION

The success of the Piping area team generated teams in the Electrical and Hull areas. Both teams are still in the early stages of development evidenced by a tendency to look at problem symptoms and by a suspicious attitude toward management's commitment to participative management.

The Hull team was just recently started, but it appears they will be successful.

Although the Electrical team started before the Hull team, they are progressing at a slower pace - probably much of this is due to personality clashes within the team. Another factor is that the Electrical team started out trying to solve a deep and involved problem and success will not come easily. If they fail, they may not have the desire or conviction to continue. Working on a superficial problem to achieve quick success and establish team spirit may be an essential step in the evolution of the team. The fate of the team rests on their ability to effectively implement their proposal and their succeeding reaction.

The Piping team is quite autonomous. Problems are identified and the people best suited to solve the problem are asked to participate.

CONCLUSION

Productivity suffers for many reasons, but perhaps the most inexcusable reason is lack of communication. Participative management provides a platform for open communication. The real value of System Strategy Teams lies in their power to cross departmental lines - to follow the system through.

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THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

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5248-2B

An Integrated CAD/CAM Network for Work Packaging Development and Database Management

No. 2B

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ABSTRACT

The Zone Logic Technology CAD/CAM and networked Database Management System is an integrated system of commercially available, off-the-shelf computer hardware and software products. These products have been carefully selected, tailored, and integrated to specifically satisfy and support the Philadelphia Naval Shipyard (PNSY) Zone Technology Program in support of work packaging development, computer aided graphics and an on line, real-time, distributive database management system.

The process used publishing this paper serves as a small example of some of the capabilities of the system at PNSY. The on-line document, including graphics, was generated on the system. Scanners, CAD and PC systems were utilized to input, develop and convert the graphics files into appropriate formats for import into a technical publications software package. LAN interconnection capabilities provided option developing portions of this document on different systems and at different locations with the ability to access the appropriate files remotely.

INTRODUCTION

Philadelphia Naval Shipyard has thrust itself into the 21st century in both new management and automated technologies. Senior managers are making bold business decisions necessary to the shipyard's survival. A pilot project has been initiated to develop and execute a transition phase to improve shipyard productivity. Major changes to management, work packaging, production, planning, and design execution are currently ongoing. Computer assistance has been developed and is being coupled with these changes, thus forming a Zone Logic Technology (ZLT) Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) and networked Data Base Management System (DBMS).

BACKGROUND

In understanding how Philadelphia Naval Shipyard (PNSY) developed ZLT CAD/CAM and networked DBMS one must first go back to the genesis of why this system was developed.

The largest and most comprehensive conversion overhaul and repair work done throughout the world to any vessel is that done to United States Navy Aircraft Carriers under the Service Life Extension Program (SLEP). The objective of this 37 month program is to refurbish non-nuclear aircraft carriers which have reached their designed life of 25 to 30 years, thereby obtaining another 15 to 20 years of serviceable ship life. Economically, this has proven to be much more efficient than scrapping them for new replacement aircraft carriers. To date, PNSY has successfully completed the SLEP program on three U.S. aircraft carriers (USS Saratoga (CV60), USS Forestal (CV59), and USS Independence (CV62)).

Currently, USS Kitty Hawk (CV 63) is undergoing SLEP at PNSY. However, in addition to the already defined ship alteration and repair work package, the Navy wanted to include the Hull

Expansion Project in the SLEP program. This project called for the replacement of approximately 80 percent of the aircraft carrier's existing hull with a new but wider hull. The amount of steel to be replaced and added to the hull was greater than that used to erect the Eiffel Tower. This would have been the largest ship alteration and repair to occur to any vessel in the history of shipbuilding, conversion overhaul and repair work.

A project of this magnitude would normally have been given to the existing shipyard three to four years ahead of a scheduled start date. However, in order to be able to execute the Hull Expansion Project in conjunction with USS Kitty Hawk's SLEP, PNSY was given only one year to plan, design, identify, order and receive material as well as to begin execution. The shipyard realized that if this project were to succeed, special action would need to be taken such as that under a war time condition. A Naval Shipyard is ideal for this and is more than capable of rising to the challenge. To successfully be able to meet the one year time table, a special project team was established and a most aggressive plan of action and milestones was developed. This plan of action called for special procurement authority of needed materials and services and a reorganization of the shipyard's normal working procedures.

In development of this plan of action, a world wide tour/investigation and analysis of major US, Canadian, British and Japanese shipyard practices was conducted. Also, numerous key members of the National Shipbuilding Research Program (NSRP) of the Society of Naval Architects and Marine Engineers (SNAME) were consulted in order to learn state of the art technology being used in today's shipbuilding and repair environment.

Since the Hull Expansion Project was a combination of new construction and repair work, the procurement of special tools, installation devices, and additional CAD/CAM and Automated Data Processing (ADP) equipment support would be required as well as the needed steel plates, beams, etc. Also, changing the shipyard's working procedures to support the most efficient new construction and repair technique utilized today called for the obtaining of new technology and processes. This meant a technology transfer between Ishikawajima Harima Heavy Industries (IHI) of Japan, the recognized world leader in shipbuilding and repair productivity, and a U.S. Naval shipyard. It should be noted that to date IHI of Japan has provided the transfer of shipbuilding technology to ten North American shipyards as well as to South American, European and Indonesian shipyards. Realizing this and the task at hand, PNSY felt that obtaining IHI services was paramount to the successful and timely completion of the project.

Concurrently, senior leaders at the shipyard had already been internally reviewing ways to eliminate waste and affect a needed paradigm shift. In fact, the timing of the Hull Expansion project would serve as the perfect impetus to execute needed changes to improve shipyard productivity. The road to improve shipyard productivity through this project led only one way. That way required changing universally accepted model of accomplishing ship conversion overhaul and repair work from a systems approach to an interim product approach through the use of a true Product Work Breakdown Structure (PWBS). This approach, known as Product Orientation, or family manufacturing and called Zone Logic Tech-

nology (ZLT) by the Navy, was viewed by progressive shipyard managers as the correct and most efficient/productive way to manage the Hull Expansion project. As the total scope of the Hull Expansion project was analyzed, it was found to impact some 30 percent of the already identified SLEP workpackage. Therefore, not only would the Hull Expansion project be done under the ZLT principle, but so would 30 percent of the regular SLEP workpackage. Once the shipyard started planning this work there would be no turning back to the traditional methods without spending millions of dollars in rework and adversely impacting the overall SLEP schedule.

Even with IHI's help, it was realized that a certain amount of ADP and CAD assistance would be needed in support of the ZLT effort. IHI would be instrumental in teaching managers how to develop and execute a PWBS, which included the development of work packages in the form of thousands of Unit Work Instructions (UWIs). They indicated that this would initially be a major manual undertaking and recommended that once the process is learned and understood, it should be automated wherever possible. Therefore, the need for an integrated CAD/CAM network for Work Package development of UWIs and a DBMS became apparent.

Considering the level of expertise required to put together a computerized system that would meet the project's requirements, it was decided that a Systems Integrator (SI) would be needed. The concept of utilizing an SI is standard in the private sector but is somewhat new in Naval Shipyards. This is due to several reasons, such as not truly understanding the concept or how to manage an SI. Some think that it is not cost effective, and a few even let pride stand in their way. But the use of an SI, if managed properly, is far more efficient in effectively integrating various computer hardware/software components than any naval shipyard could ever hope to be. Naval shipyards should not be expected to have the same level or broad range of computer expertise and talent that a technically qualified SI has. Considering an SI's diverse mission capabilities and resources, it should readily be apparent that they are the best qualified to integrate different computer operating systems as well as various pieces of hardware and software. The level of technical knowledge and practical experience that the SI brings to the effort more than offsets their cost. An SI has greater resources available to check all technical possibility and the expertise in integrating different hardware and software systems that must work together. However, it is essential for the Navy to provide technical input related to the requirements of the intended system and interfaces to be installed on the systems as a whole. That is, for the system to perform well it must be not only technically sound, but it must also "fit" the environment and its users.

Under the normal environment of procurement that exists in the Navy today, the acquisition of extensive ADP support and foreign assistance is a request of no trivial proportion. Under normal methods of ADP procurement, each system would be procured separately. Integration would have had to be accomplished through available standards, which do not cover the needs for interfacing various types of data. The shipyard would have also had to complete the integration after installation. The outcome of this method was extremely suspect and was not viewed as a practical solution. Also coupled with this was the fact that normal ADP procurement times range between one and three years from initiation of request to actual receipt of equipment. Therefore, the success of this project hinged on an alternate solution.

Fortunately, permission was obtained from the Under Secretary of the Navy to acquire all needed items in support of the shipyard's requirements. This included the acquisition of IHI services from Japan as well as those of an SI from the United States. Once the go ahead was given to obtain these services, immediate action was taken. A Memorandum of Agreement between the Department of Defense (DOD) and the Ministry of International Trade and Industry (MITI) was obtained allowing IHI to assist PNSY. Martin Marietta Data Systems (MMDS) was selected as the SI. Both IHI and MMDS have had a most formidable challenge to face: IHI to teach PNSY managers how to develop and implement ZLT, and MMDS as the SI to upgrade existing equipment and integrate with new equipment a CAD/CAM network for production, planning

and design Use as well as for Work Package development via a ZLT DBMS.

Due to the high cost and risk associated with executing the Hull Expansion Project in conjunction with the USS Kitty Hawk SLEP, it was first greatly reduced in scope and then finally cancelled in February of '88. There was sufficient time to halt the execution of the Hull Expansion Project with only sunk cost occurring to planning and ADP support. However, as was mentioned earlier, there was no turning back on the 30 percent of the SLEP work package that was planned utilizing ZLT principles. Thus, the services of IHI and of the SI continued to be used. Though the Hull Expansion Project has been shelved, other low risk ship alteration and repair work designed to obtain similar ship mission capabilities as the Hull Expansion project will take its place. Many of these new items will be done under ZLT concepts and will utilize the new computer support services as required. Further, major productivity improvements are projected to be achieved not only on the replacement work but also on the 30 percent of USS Kitty Hawk's SLEP work being done by ZLT principles.

This lengthy but required explanation as to the genesis of the ZLT CAD/CAM and Networked DBMS was needed to show the critical and short fuse environment that PNSY was required to accommodate. The remainder of this paper deals with the development of the ZLT computer system.

ZLT SYSTEM DESCRIPTION

The primary functions of the ZLT system were laid out conceptually and a for final development. Their requirements for the ZLT system are (Figure 1):

- 1 Upgrade and link existing CAD/CAM equipment needed to support SLEP.
- Convert non-electronic technical data (manually created engineering drawings, patterns, work instructions, technical reference material etc) into electronic computer formats.
- 1 Provide a Relational Data Base to manage the project.
- 1 Provide direct file transfers between VMS, UNIX and DOS operating systems using networking technology.
- 1 Provide the capability to create additional new or modified engineering drawings, patterns, process tapes, work instructions, etc., using computer workstations.
- Provide interface connectivity for convenient access to other established PNSY databases, i.e. Job Order and Job Material List data resident on a Wang VS100 system and the Management Information System residing on the shipyard's Honeywell mainframe.
- 1 Provide computer workstations and the associated software application packages necessary to create, retrieve, modify/manipulate and store data as necessary to producer
 - a. Unit Work Instructions
 - b. engineering drawings
 - c. patterns
 - d. process control tapes
 - e. Process Instructions
 - f. Naval Ships' Technical Manuals
 - g. drawings and/or documents to support other shipyards and naval offices.

Additionally, the ZLT system provides the following capabilities

- 1 word processing
- 1 spreadsheet/graphics design
- 1 PROMIS, an integrated project management and scheduling system

The first thing required by PNSY was to develop a set of specifications as fast as possible that would be technically accurate and realistically achievable. It was immediately decided by the ZLT Project Office that commercially available, off-the-shelf hardware

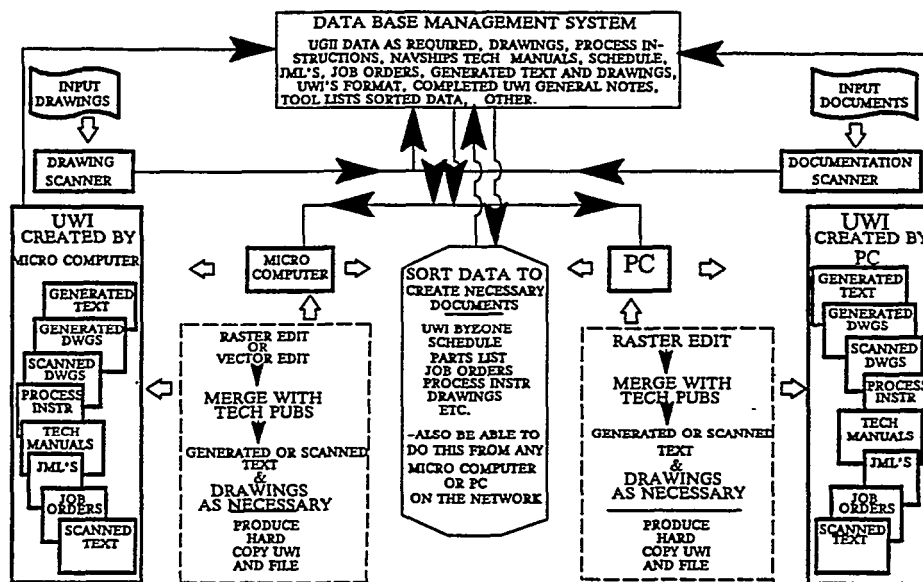


Figure - 1 ZLT System Process Requirements

and software products would be integrated and networked through the use of an SI. Direction was given to steer away from any computer futures, as so often many buyers of computer systems have failed to do. A team of seven computer knowledgeable people from within the shipyard was put together to write the needed specifications. Under the time constraints allocated, specifications were developed in only seven consecutive twelve hour days with all SI requirements being spelled out.

The functional requirements of the ZLT system are both complex and extremely varied. In recognition of these factors, the ZLT system has been developed as three major subcomponent systems

- Unigraphics Subsystem
- Computer Subsystem
- Personal Computer Subsystem

Each subsystem consists of specialized computer hardware/software that is uniquely adapted to perform specific ZLT CAD/CAM functions. The subsystems are integrated and interfaced via the ZLT database(s) and networks to fully satisfy all ZLT CAD/CAM requirements to develop and publish UWIs. Figure 2, PNSY Zone Logic-CAD/M System Logical Hardware Relationship Chart, graphically presents the complete ZLT hardware profile. Figure 2 also reflects a detailed breakout of subsystem hardware by geographic location (Zone) and the inter/intra connectivity provided by the ethernet and fiber optic networks which support the UT system.

In analyzing the shipyard's CAD/M requirements in support of the ZLT Project, it became immediately apparent that production's existing CAD/CAM Unigraphics I (UGI) system would reach full maturity within six months of this analysis. This meant that continuous vendor support would be limited in resolving software and hardware maintenance problems. In addition, the UGI computer system was longer in production by the manufacturer McDonnell Douglas Corporation. Any system expansion required to support the effort would be difficult at best. Therefore, immediate action had to be taken to maintain support of production's CAD/CAM facilities.

It was also realized that, due to previous technical incompatibilities, design's Computer Vision (CV) 4X system was not linked to production's UGI system. Drawings done on design's CV 4X system could not be transferred to the UGI system either by

hardware or magnetic tape. As a result, all CAD drawings done in design and passed to production to support production CAD/CAM or lifting efforts had to be redone on the UGI system. This duplication of effort needed to be eliminated in any future CAD/CAM upgrades.

Different CAD/CAM systems were surveyed at various shipyards, aerospace and manufacturing facilities throughout the country in an attempt to observe efficient, state the e-of-the-art CAD/CAM facilities in action. From here a game plan was formulated that would support the extensive CAD/CAM requirements needed for the ZLT Project. Results of this survey found that the most efficient approach to improve PNSY CAD/CAM facilities would be to upgrade the already existing systems vice scrapping them for new systems. This was primarily driven by six major factors

- 1) Upgraded systems of both UG and CV products have matured to the point of being extremely user friendly.
- 2) These upgraded systems could easily support all of PNSY's requirements.
- 3) Both production and design personnel using UG and CV systems respectively felt more comfortable using upgraded system.
- 4) Minimal personnel training time would be required to shift to the upgraded UG (called UGII) and CV systems.
- 5) The upgraded UGII system would have a special translator written to accept all CV CAD drawing thus making that all important link up.
- 6) Upgrading the system would allow already existing shipyard software to be used.

UNIGRAPHICS (UC) SUBSYSTEM

The Unigraphics subsystem is the manufacturing support component of the ZLT system. The major functional capabilities of the UG system include the production of flat pattern layouts and

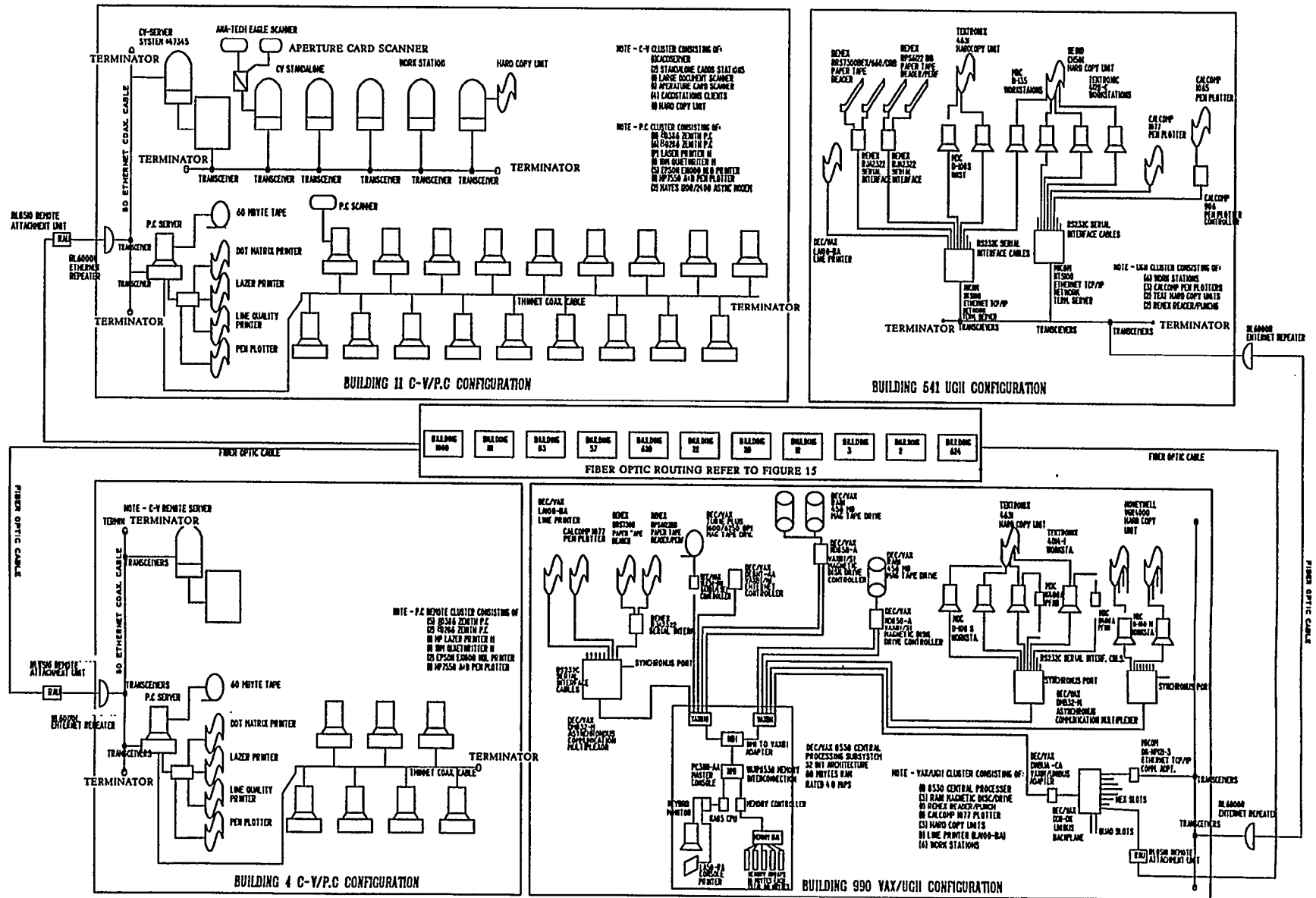


Figure - 2 PNSY Zone Logic CAD/CAM Network

TheUG system also provides an extensive database library of completed and in process shop drawings. The shop drawings may be retrieved for reuse or modification, as necessary, to reflect required design additions or changes.

- System consoles
- TapeDrive Unit
- Graphic Workstations
- Line printers
- PenPlotters
- Paper Tape Punch
- Disk Storage

In order to properly support Zone logic programme requirements, UG system components have been installed in two shipyard Production buildings: the Mold Loft (bldg. 541) and the Central Production CAD/CAM Center (bldg.990). Both intra and inter system communications are provided by the ZLT networks to insure the full availability of UG system capabilities at all workstations.

The central Production CAD/CAM UG facility located in building 90 of the shipyard and is primarily responsible to support Sheet Metal, Shop 17, work requirements. The term central facility

The following is a summary list of the UG hardware equipment installed in the Central Production CAD/CAM UG facility:

- DEC VAX 8530 CPU*
- RA 81 Magnetic Disk drive**
- TU81E Magnetic Tape Drive • *
- REMEX Paper Tape Reader
- REMEX Paper Tape Reader/Perf
- line printer (LA100-BA)
- Tektronix Hard Copy Unit (4531)
- Honeywell Hard Copy Unit (VGR40)
- MDC Workstation (D-100s)
- MDC Workstation (D-100M)
- Tektronix Workstation (4014-I)
- NOTE: *Includes master console, printer and monitor-
- **Includes controller.

It should be noted that the remote facility relies completely on the ZLT Network for connectivity to the VAX 8530. This requirement necessitates some additional logon procedural steps as opposed to those used for the central facility.

Figure 4, Mold Loft (bldg541)UGII configuration, provides a detailed logical view of all hardware components installed in the remote UGII facility. Figure 4 graphically portrays the inter-relationship of the design workstations and the associated output product devices as well as the communication system interconnect to the central facility and/or other ZLT subsystems- For a more

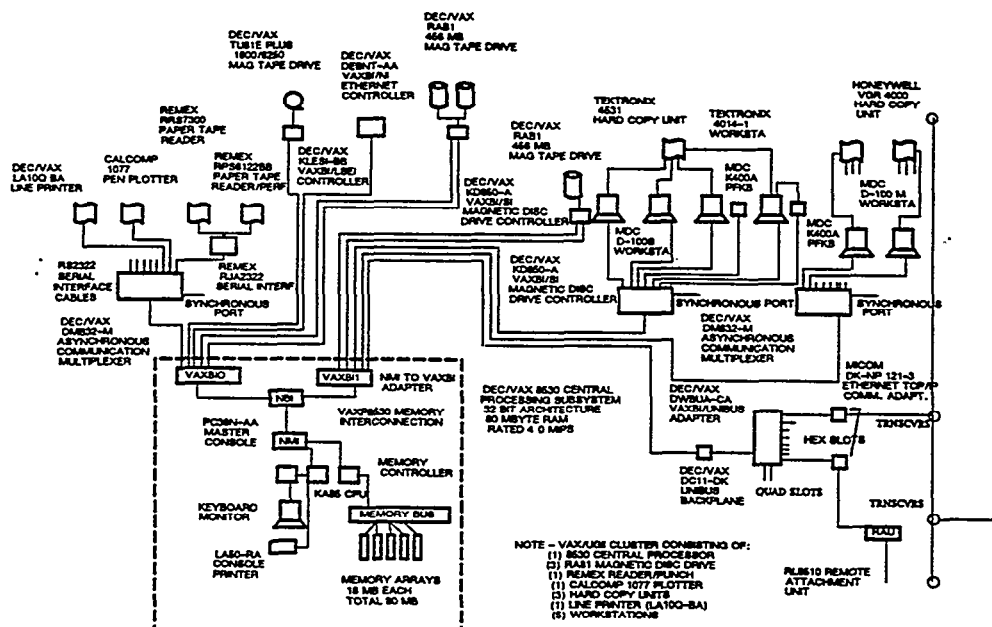


Figure - 3 Central Production CAD/CAM (bldg 990) UG System

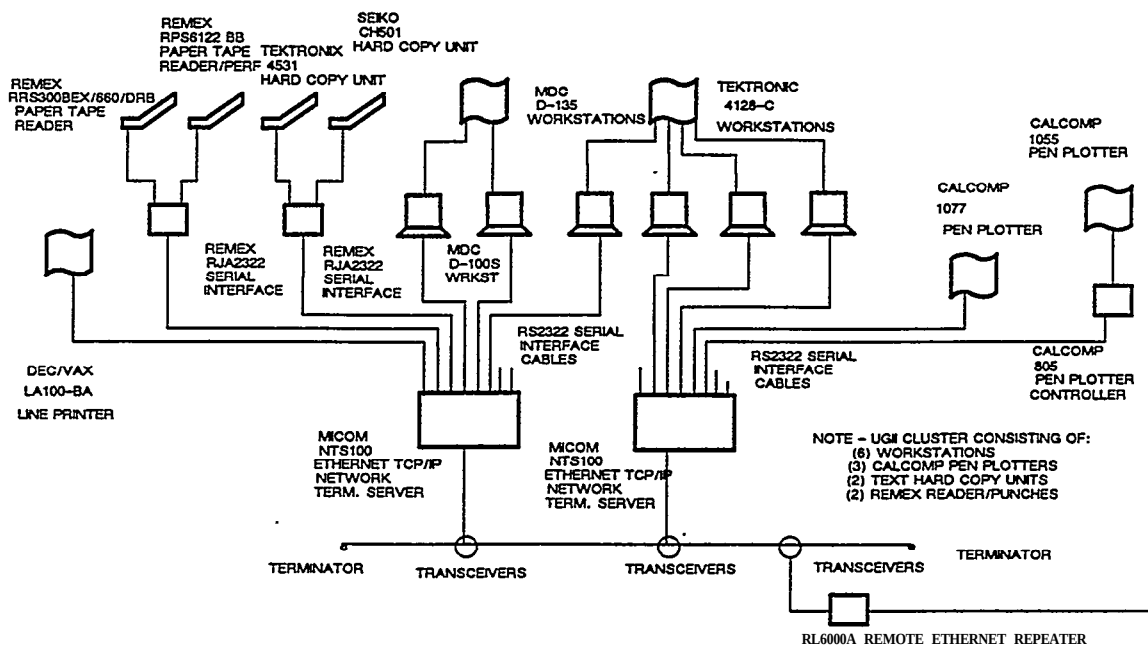


Figure - 4 Mold Loft (bldg 541) UGII System

Scanner Utilization

detailed view of the relationship of the remote facility to the entire ZLT system, refer to figure 2

The following is a summary list of the hardware components installed in the Mold Loft:

- MDC Workstations (D-1005)
- MDC Workstations (D-135)
- Tektronix Workstations (4128-C)
- Line Printer (LA100-BA)
- REMEX Paper Tape Reader
- REMEX Paper Tape Reader/Perf
- Tektronix Hard Copy Unit (4631)
- SEIKO Hard Copy Unit (CH501)
- Calcomp Plotter (1077)
- Calcomp Plotter (1065)

COMPUTERVISION (CV) SUBSYSTEM

The primary role of the CV subsystem is to provide the capability to input and/or to create technical documents or images for storage in a UWI publishing database. Existing engineering drawings, technical reference manuals, and process instructions maybe scanned and converted into computer based files, addition- all new engineering data and images may be generated using the CV workstation facilities, and the CV system may access other PNSY computer system databases via network facilities while performing this major function. Using the CV Caddstation, the data necessary for specific UWI development is assembled/generated, integrated, formatted and published. The UWIs are then routed and distributed to the appropriate Zone manufacturing or repair/maintenance shop for scheduling and work accomplishment.

The CV Subsystem, as with the UGII Subsystem, is installed as dusters in two separate zones. The central CV duster, which supports the Zone Technology Outfit Planning Team and the Zone. Technology Production Group, is located in the ZLT Outfit Planning Section (bldg.11), while the remote cluster is located in the Engineering Management Center's Central CAD/CAM room (bldg. 4). Each cluster is then interfaced and connected through the ZLT communications network (both ethernet and fiber optics) with all ZLT CAD/CAM subsystems in order to facilitate system wide data transfer/access for UWI development.

In support of the ZLT Project, the ability to include hardcopy drawing information in the UWI packages is essential. The addition of Z-D or 3-D graphics in a UWI provides a total software package in support of a unit of production work. Initially this meant performing the tedious task of cutting and pasting thousands of drawings into UWIs. This task without a doubt needed to be automated to provide a more efficient process of UWI development. During the shipyard's investigation of various industrial and manufacturing facilities, the utilization of scanners in several applications was found. This information, coupled with the shipyards and the SI's technical knowledge of scanners, led to the only accurate conclusion to be drawn: today's scanner technology could meet the requirements and priorities to support the ZLT Project, the basic requirements being:

- 1) Scan drawings upto 40 inches in width and unlimited length (thus allowing for the scanning of A, B, C, D, E, F and H size documents).
- 2) Scan drawings off of Mylar, Velluma or paper.
- 3) Scan drawings from aperture cards.
- 4) Provide IGES, direct CAD Database, and networking-direct system to system interfaces.
- 5) Provide both raster and vectorization as well as raster and vector editing of geometry, line widths, fonts, etc
- 6) Allow for raster compression and decompression.
- 7) Provide optical character recognition of both standard fonts and various handwritten lettering.
- 8) Maintain the time required to rasterize from an E size sheet at or below five (5) minutes.
- 9) Allow rectification of dimensions vs geometry.
- 10) Support layering of geometry, text and borders as well as provide foreground and background

11) Scan document size pages such as those found in Naval Ships Technical Manuals or Process Instructions. This means allowing for recognition of various font types as well as graphics

12) Be compatible with the SUN processor, allowing the shipyard's existing CV system to act as the host. This would minimize the cost of hooking scanners onto the system

Once the basic requirements were met, there were three (3) major priorities for the drawing scanners:

1) Scan and provide raster images to be used on UWIs..

2) Scan and vectorize 'on the fly,' providing as many CAD entities as possible without user intervention (thus reducing the time required to produce full CAD drawings from existing hardcopy paper drawings). These vectorized drawings are to support the shipyard's design CAD CV effort

3) Scan and vectorize production drawings in support of the shipyard's UGII system.

The shipyard's decision to purchase ANA-tech's Eagle scanner and Versatce's aperture card scanner was based on their capability to meet all requirements and priorities as well as their ability interface with the shipyard's IBMPC/AT, SUN-3 and DEC workstations, ANA-tech's advanced editing capabilities were also a major factor during the technical evaluation of scanning devices. ANA-tech supports two (2) software utilities that are controlled interactively with mouse and menu RED is a raster editor that allows a raster file to be viewed, edited and archived time and time again; GE is a graphics editor that provides the ability to further enhance, clean up, and compress the data. The GE editor functions include addition, deletion and generation of graphic representations such as lines, circles and polygons as well as a text utility that allows the user to revise or define new and existing fonts. The final and most important factor was the ability to convert and transfer raster and vector files to a number of software packages such as tech pubs. CAD, and wordprocessors.

The typical data flow is shown in Figure 5, with an explanation of the various main steps provided below:

1) Scan an existing drawing

2) View and edit raster data

3) Raster data plotting output.

4) Transfer raster data to and from disk storage.

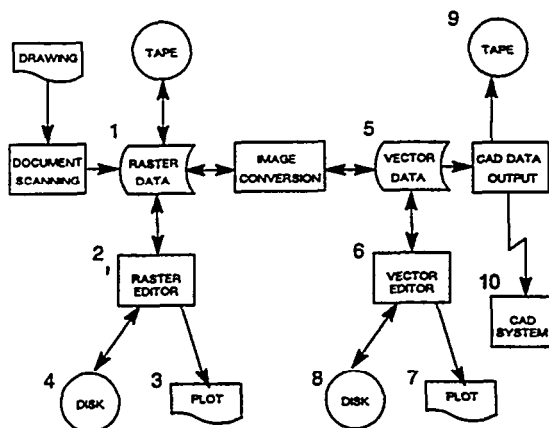


Figure - 5 Scanned Data Flow

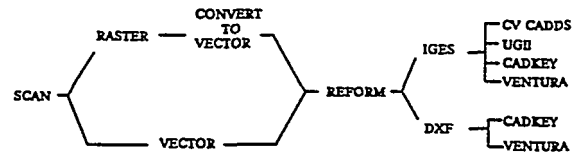


Figure - 6 Vectorizing How Path

5) Convert raster data to vector data.

6) View and edit vector data

7) vector data plotting Output

8) Transfer vector data to and from disk storage.

9) CAD formatted output to magnetic tape.

10) CAD formatted output networked to CAD system

note:4&8 can be same disk unit.

3&7 can be same plotter unit.

As illustrated in Figure 5, the scanner software supports the creation of raster files as well as CAD databases. The actual vectorizing data flow path of a scanned drawing is shown in Figure 6.

The path shown in Figure 6 represents a drawing that is scanned and converted to a vector file. Initially, short vectors are formed on the fly through ANA-tech's software. These vectors are not yet suitable to transfer to a CAD database. Therefore after the initial vector conversion the vectors are given CAD intelligence through a program called "Reform". The "Reform" process is somewhat lengthy in CPU time (i.e., one (1) to five (5) hours or more depending on drawing density). However, this process is basically transparent to the user because he need only give the command to execute the "Reform" program

Upon completion of the "Reform" process all vectors have been given CAD intelligence and are ready for conversion to an IGES or DXf file. From here, the IGES file can be transported to CV CADDs, the UGII CAD system, or to Cadkey directly, while the DXf file can be transported to Cadkey or Ventura directly.

Once a file is in the appropriate CAD program, it will still require some manual clean up. The amount of clean up varies with each drawing. For example, the time required to scan, vectorize and clean up a medium density drawing scanned at 200 to 300 dpi would be approximately eight (8) hours. Although this may seem lengthy, the alternative method of manual input and digitizing could take about five(5) times as long.

PNSY has begun working out the best procedures to reduce the overall time of this process. In some cases, it has been found to be more time enhancing to scan and raster edit before vectorizing. This saves in clean up time of the final CAD file because extraneous information not required to be vectorized can be deleted beforehand. However, this is dependent upon information needed for each scanned drawing. The shipyard's overall intentions are to define the best procedures to be utilized when scanning and to make as many steps as possible transparent to the user to reduce user intervention time.

The actual scanning process currently used at PNSY is shown in Figure 7.

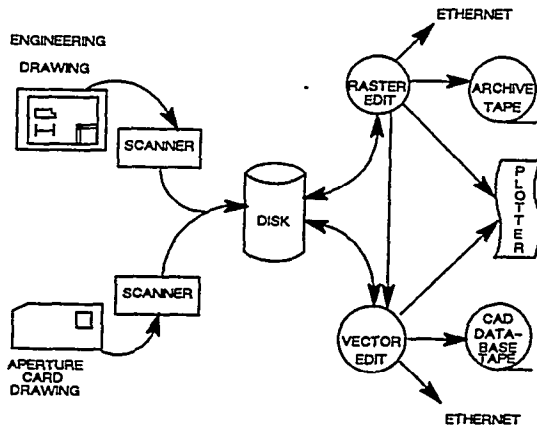


Figure-7 Scanning Process

The need for a scanner to handle the voluminous amount of documents consisting of both text and graphics required a stand alone scanner capable of supporting this specific requirement.

The Palantir Compound Document Processor (CDP) was found to be the leader in setting the standard for automated document capture in achieving nearly perfect recognition. The use of proprietary character recognition algorithms allowed for true omnifont character recognition and image processing in a single pass-through of the manner. No user intervention is required to define characters or otherwise train the scanner to recognize special characters, nor is there any requirement to download special fonts. Furthermore, automation is enhanced by using predefined templates which allow the Palantir document scanner to be instructed to read specific regions from every type of document that is to be processed, with the identified zones enabling matching of pages and templates so that a stack of different pages can be processed automatically without presorting. Thus the Palantir document scanner was chosen. It also provided the most flexibility in scanning documents of varying quality through features such as adjusting the thresholding for background intensity either manually or automatically, as well as registering the documents for skewing. Furthermore, a spelling dictionary is included. This scanner has also been linked into the networked system.

CV Central Cluster

The central cluster, installed in the Outfit Planning Section (bldg. 11), is the primary facility for the production of the UWI's. In addition to this functional responsibility, the central cluster also provides an extensive capability for the generation of detailed engineering designs and drawings necessary to support UWI development and publication. The scanners (ANA-tech Eagle drawing scanner and Versatech Acris aperture card scanner) allow scanning of numerous medias ranging from paper to aperture cards. There are two distinct forms of data created via scanning: raster and vector. This raster and vector data can be edited to clean up the drawings after the scan is complete. The system supports both a raster editor (RED) and a graphics editor (GE).

Figure 8, ZLT Outfit Planning Section (bldg. 11) CV Configuration graphically presents a logical view of the major hardware components installed in the central cluster. These components include the CV Server, standalone and client workstations, attached scanning and output peripheral equipment, and basic telecommunications devices/connectors. The CADD station configuration is shown in Figure 9. For additional details of the overall ZLT System and network relationships, refer to figure 2, PMSY Zone Logic CAD/CAM System Logical Hardware Relationship.

The following is a summary list of the CV subsystem hardware installed in building 11:

- CV Server System
- CV Standalone Workstation
- CV Client Workstations
- ANA-tech Eagle Scanner
- Versatec aperture Card Scanner
- Hard Copy Unit
- Imagen Laser Printer

CV Remote Cluster

The CV remote cluster, installed in the Engineering Management Center (bldg. 4), currently consists of a single CV server. This installation is primarily established to provide engineering design functional support for engineering and administrative support personnel located in Bldg. 4. The remote CV server is interfaced to the central cluster and other ZLT subsystems via the ZLT network, and when workload requirements dictate, is fully capable of supporting Bldg. 11 UWI production. Figure 10, Engineering Management Center remote CV/PC Configuration, depicts the logical view of the Remote CV hardware and PC hardware (colocated at the Bldg. 4 installation). It should be noted that the remote CV cluster, as in-

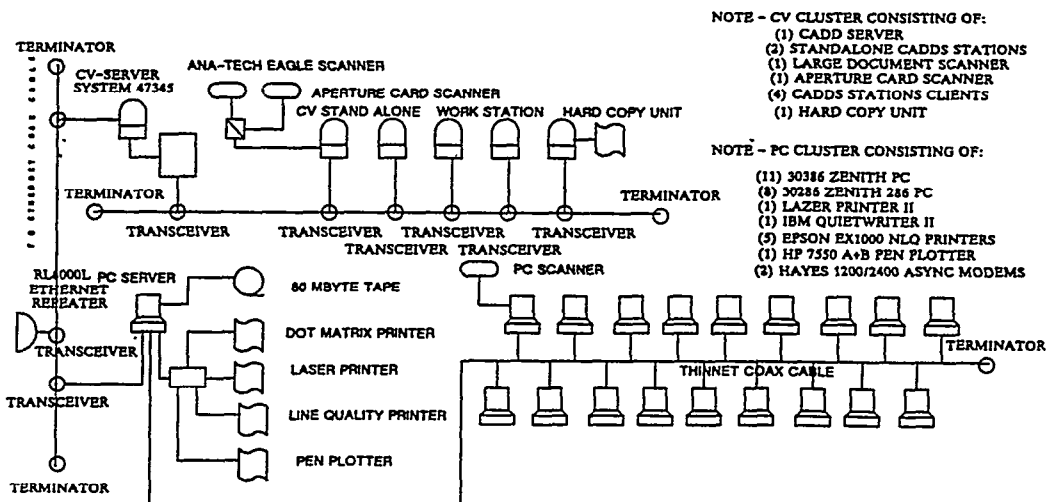


Figure - 8 ZLT Outfit Planning section (bldg) CV System

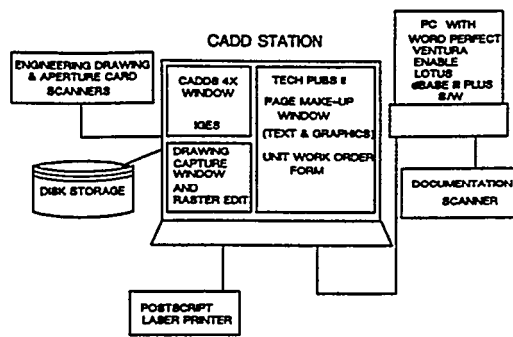


Figure - 9 Cadd Station Configuration

stalled, is also linked to the system's existing CV 4X workstations running on four (4) CGP200X processors. This CV cluster has been designed to be easily upgraded and enhanced with additional CV Caddstations should future work load requirements dictate the need for expansion. The CV remote system utilizes:

- cv server system
- CV stand-alone station

PERSONAL COMPUTER SUBSYSTEM

The microcomputer subsystem is intended to be the hub of the ZLT system. This hub is built around a core of Zenith 80386 personal desktop computers and is supplemented by Zenith 80286 PC's. These PC's are being utilized for several principal tasks: preparation and electronic distribution of UWI's, maintaining the Status and Control Database System, and an electronic mail system capable of passing text and graphics files. The UWI's are documents which consist of technical instructions and images. Technical reference manuals, process instructions, and CAD drawings which describe how work should be performed, form the input into these UWI's. In order to prepare the UWI's from these different sources, scanning and network facilities permit these documents and drawings to be scanned and converted into a computer-based file which can be readily shared by each PC workstation for merging and editing. Integration into the CV and UG subsystems via PNSY network

facilities permits easy to databases on these other PNSY computer systems

Technical desktop publishing software is used to integrate the instructions with the diagrams and pictures to generate the finished product. Professional instructions that are clearly illustrated are output on laser printers with typeset-appearing quality for distribution to the various engineering and repair shops in order to refurbish/repair ships at PNSY.

The Status and Control Database System provides the mechanism to maintain control over work that is to be accomplished by the use of Shop Work Instructions (SWIs) and UWIs. Scheduling and monitoring the status of SWI's and UWI's is accomplished through the use of a sophisticated LAN database in conjunction with a network of PCs. Integration of the PC network into the larger PNSY computer network allows access to and input from other computer database systems on the base via this network. In order to support these principal functions for the ZLT system, PC clusters have either been or are now being installed in several locations: the Engineering Management center (bldg.4), ZLT Outfit Planning Section (bldg. 11), Management Information System Center (bldg. 83), USS Kitty Hawk (CV 63) shore site (bldg. 620), and at the production worksite. Each of these is tied in with each other and with the CV and the UG computer systems via the PNSY fiber optic network providing a totally integrated, computerized database and technical publishing system in support of ZLT requirements.

Central PC Cluster - ZLT Outfit Planning Section

The PC cluster in the ZLT Outfit Planning Section (bldg. 11) produces the bulk of the UWI's and SWI's scanning for inputting existing documents, as well as editing and creating instructions and drawings using word processing and Cadkey Computer Aided Design software and merging these instructions with the pictures for final typeset quality printing using Ventura's desktop technical publishing software. The PC network configuration in building 11 consists of:

Item Description

- 1 Zenith 5MB386 Network Server 40MB 2Ser/Par Monochrome Card (also includes 150MB Core International internal H/Disk). Attached is an external Genoa 60MB tape backup device and automatic parallel/serial data switchbox for network printers and plotters using a Zenith monochrome monitor

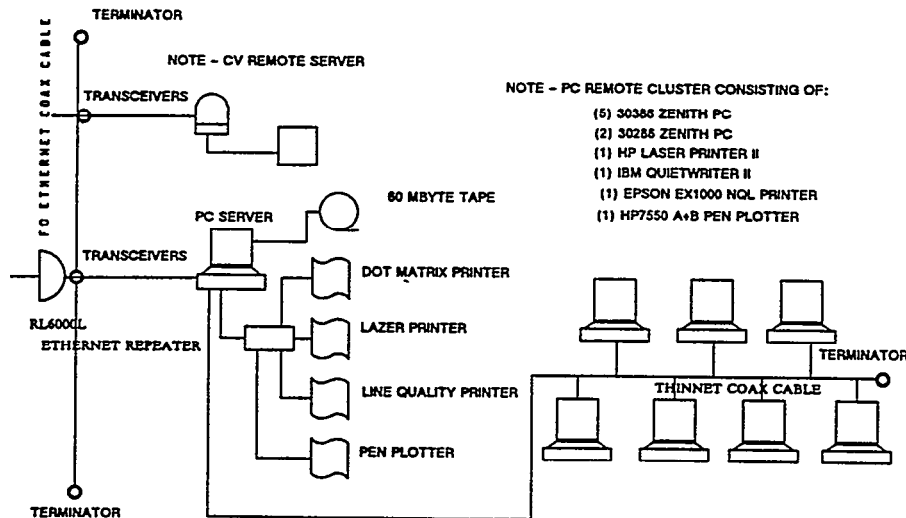


Figure - 10 Engineering Management Center CV/PC System

- Zenith 386 2MB RAM 2Ser/Par 40MBH/Disk80387 Workstations using Zenith EGA monitors
- Zenith 286 2MB RAM2Ser/Par 20MBH/Disk 80287 Workstations using a Zenith EGA monitor
- Mouse Systems Mouse
- Peripheral Equipment
 - HP Laserprinter II with 2.5 MB
 - Letter Quality printers
 - Highspeed 132cps dot matrixprinters
 - 8-pen Plotter capable of producing A and B size drawings
 - Palantir CDP optical character recognition/image scanner

Remote PC Cluster - Engineering Management Center

The PC cluster in the Engineering Management Center(bldg. 4) primarily uses the network for monitoring and controlling the production schedules and reviewing UWT's using the Status and Control database. The configuration of the PC's networked together in support of ZLT in Building 4 is as follows:

- | Item | Description |
|------|---|
| • | Zenith 5MB 386 Network Server 40 MB 2Ser/par 80387 Monochrome Card (also includes 150 MB Core International internal H&k). Attached is an external Genoa 60MB tape backnp device and automatic parallel/serial data switchbox for network printers and plotters using a Zenith monochrome monitor |
| • | Zenith 386 2MB RAM 2ser/Par 40MBH/Disk 80387 Workstations using Zenith EGA monitors |
| • | Zenith 286 2MB RAM 2Ser/Par 20MB H/Disk 80287 Workstations using Zenith EGA monitors |
| • | Mouse Systems Mouse |
| • | Peripheral Equipment <ul style="list-style-type: none"> - HP Laserprinter II with 2.5MB - Letter Quality printers - High speed 132 cps dot matrix printers - g-pen Plotter capable of producing A and B size drawings - Hayes l200/2400 Async modem |

Remote PC Cluster -Management Information Center (bldg. 83)

The PCcluster in the Management Information System (MIS) Center will link twenty (20) PCS on a Local Area Network (LAN) which primarily supports MIS functionally related responsibilities. More importantly in relation to the rest of the network is the ability of shipyard managers to be linked directly to MIS to acquire necessary real-time information. Currently, the Director of the Information Systems Resource Office is developing aplan to be able to down

load MIS information to the LAN for distribution to key sites in the shipyard via the server linked to the fiber optic backbone. The move in this direction is most significant because, in the shipyard's current environment, hard copies of needed MIS information must be printed and then distributed. Due to time delays in printing and distribution, often real-time data is not available as required This move is seen as a real enhancement to the shipyard and to the Zone Technology Project, which requires real-time Cost Schedule Control (CS') data compiled in MIS to ensure that the proper controls of production work can be realized.

Remote PC Cluster - U S S K i t t v H a w k (bldgs. 620 & 5)

The PC cluster is to be located in building 620 and will link via a LAN some thirty (30) PCs to be used by USS KittyHawk(CV63) personnel in monitoring, progressing, scheduling and working ship's force work throughout the SLEP availability. They will also be linked to the shipyard's Fiber Optic (F.O.) backbone through their server. This must be seen as not only a first for the shipyard, but as a major breakthrough in communications with its biggest customer.

This direct link up between the shipyard and aircraft carrier personnel will be a time as well as cost saver in passing real-time data, UWI, ZLT schedules, and routine information via electronic mail to any ship's force personnel linked to the system. This is because every ship's force department involved with the SLEP availability will be linked to the LAN and therefore have access to anyone in the shipyard on the F.O. backbone. Currently, USS Kitty Hawk Data Processing and Data Systems specialists are receiving training from the SI and the ZLT Project Office on how to operate and maintain this new system.

Building 5 in the shipyard is also being used to support USS Kitty Hawk's Shipboard Non-Tactical ADP Program (SNAP I) system There are a couple of PCs in that building that will be linked directly to the F.O. backbone to allow similar communications as in building 620. Should USS Kitty Hawk expand its PC use in building 5, a server and LAN will be installed to link all of the PCs together.

SOFTWARE PACKAGES AND TRAINING

The integration of the various operating and hardware systems involved with the ZLT computer system is an immense task. Perhaps the most critical element requiring integration, however, is the user and the various software packages installed to tie the user into the system in an efficient and productive manner. It was realized from the outset that the introduction of ZLT to PNSY required a substantial shift in the traditional philosophies of shipyard work structuring and accomplishment. Along with the restructuring would come the introduction of many new 'tools' whose successful utilization would hinge upon user acceptance.

The ZLT Computer System is one of the critical "tools" required to ensure success. A major hurdle recognized immediately was that many of the workers who would be required to utilize the system for design, planning, scheduling, workpackage development etc., had at best minimal experience, if indeed any, with computers. Therefore, it was necessary that the end users be introduced to the computer system and commence using it, even if only in a limited manner, as soon as possible. Accordingly, a large scale training plan was set in action to introduce the users to computer usage and to the various software packages installed in the system

Initially, the SI was approached with the task of procuring the extensive timing that would be required to cover the vast array of software packages involved. The SI recommended various outside sources and suggested that the shipyard contract directly with the training sources rather than utilize the SI. The cost savings realized by bypassing "middleman," on his own suggestion, were substantial.

A local community college was contracted to provide on-site training a dedicated classroom having been set up using ZLT computer equipment. Over the course of the subsequent eight months, more than three hundred training slots were filled covering more than six different software packages, including Enable, an integrated

package involving word processing, data base management and spreadsheets (though not the package designed for ultimate ZLT use, it proved to be highly successful in providing a basic introduction to the types of software that would be used), Ventura, a PC-based desktop publishing package, Cadds 3-D design, and the industrial version of Cadkey, a PC-based 3-D design package. Training for dBase III Plus, the intended data base management package, was obtained from yet another training source in the immediate area. Additionally, over thirty production personnel were given UGII training to support the major CAD/CAM upgrades.

Training support for the scanner and CV workstation software was obtained from the respective vendors. Workers were trained in the use of the ANA-tech scanning software resident on the CV workstations. This training covered use of the scanners and the paster and Vector Editor packages as well as the various conversion routines necessary for passing files to other systems. Selected individuals were also trained in the use of Interleaf, the CV based technical publication package.

Future training plans call for training in the use of the wordprocessing package WordPerfect, advanced training in dBase III Plus, additional training in Ventura and overall systems training on proper utilization of the LAN.

As a result of this extensive training effort the ZLT computer "tool" has been introduced to the critical end users in a manner that has changed the prevalent attitude from "I can't use this" to let me see how I can use it more effectively."

FILE CONVERSION/INTER-LAN FILE TRANSFER

The ZLT system consists of eight (8) separate LANs found in six (6) different buildings and locations and will support over one hundred (100) PCs, twenty (20) CV Cadds 4X workstations running on four (4) CGP 200X processors, seven (7) CV stand-alone CAD workstations, twelve (12) UGII CAD/CAM stations, a VAX 8530 CPU, and various pieces of peripheral hardware by end-summer of 1988. Each LAN is supported by a server and has a number of software packages running along with output devices

The ZLT system, illustrated in Figure 11, supports three operating systems (Unix,VMS,andMS-DOS) and several software packages (Cadds 4X, Engineering Documentation, Document and Drawing Scanning, Paster editing, Vector editing, paster to Vector

conversion, Interleaf, Unigraphics, Ventura, the industrial version of Cadkey, Enable, WordPerfect, dBase III Plus, Palantir software, Novell TCP/IP, Lotus, DBGraphics, MathCAD, Chartmaster and an Engineering QA statistical package). These all serve several software functionalities such as Design, Manufacturing/Engineering and Outfit Planning. They are all linked on a fiber optic(F.O.) ethernet backbone. The data flow between these systems is illustrated in Figure12

Future plans call for the shipyard's MIS terminals and numerous independently operated PCs (i.e., SNAP/Wang) to be linked to the F.O .ethernet backbone. However, Wang does not currently support ethernet This is an unfortunate situation not only for PNSY but also for the Navy as a whole The integration of Wang terminals to an ethernet backbone could save thousands of dollars annually in the reduction of modems and twisted copper pair phone lines. The other potential benefits are too obvious to mention and it is hoped that the Navy can persuade Wang Systems to capitulate on this matter before long.

Input to the system is handled a number of ways, ranging from the scanning of data to the manual input of data. The system has a number of conversion utilities that support file transfer to and from all LANs on the system. This section illustrates paths available for the transfer of data between LANs and output devices Figure 13, Data File Conversion/Transfer Paths, shows a number of paths available utilizing conversion routines on each system. The paths are numbered and a detailed explanation is provided below

1)ANA-tech Scanner Raster Files(Ird). Raster files area one to one picture. ANA-tech supports a raster editor allowing some clean up capabilities. ANA-tech also supports vectorization of these raster files and has a graphic editor for cleanup.

2) Palantir Scanner is a document scanner that allows the scanning of text/graphics. The file is broken into two seperate files editing is required. The graphics editing and text editing are handled by seperate pieces of software. The Palantir also supports conversion utilities allowing file transfer to other software packages.

3) This box shows a typical document (Text/Graphics) that has been scanned by the Palantir, converted and transferred into Ventura (technical publication package) and printed on the

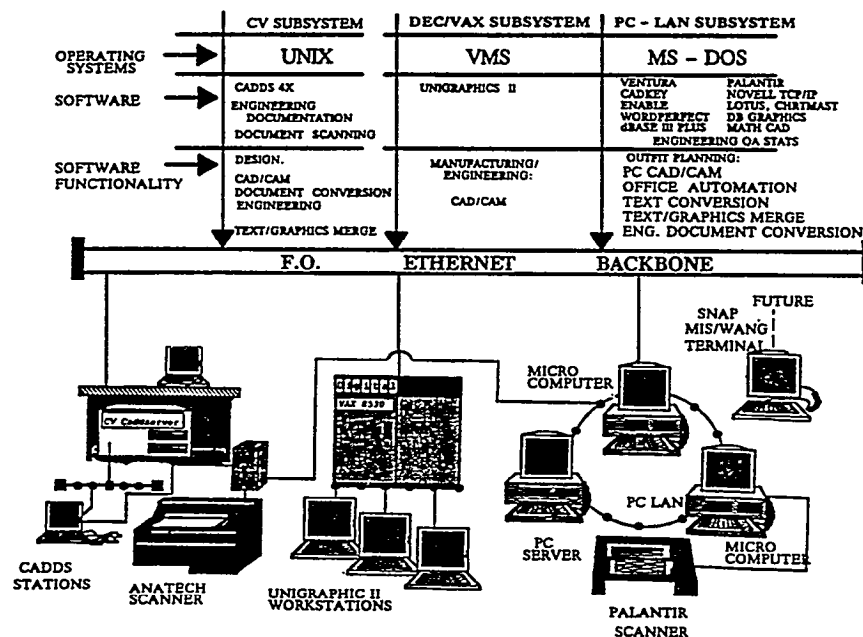


Figure - 11 ZLT Operating Systems

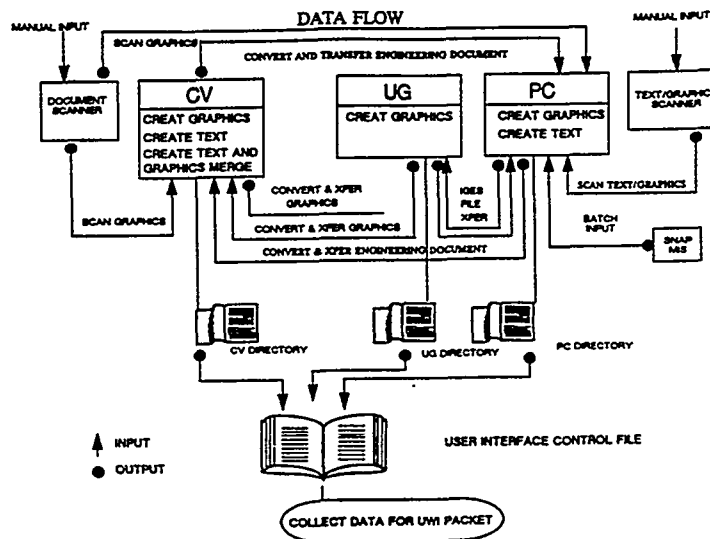


Figure - 12 Intersystem Data flow

HPLaserprinter. No editing can be accomplished in ventura when the We is transferred in as a text/graphics We.

4) This box shows a document (text only) that has been scanned by the Palantir, converted to ASCII and passed to Ventura and printed on the HP Laser printer. Text-only files and graphics -only files can be edited before printing.

5) This box shows an ANA-tech raster We that has been converted to img (Interleaf extension) and passed to Interleaf (publishing package) for printing on the Imagen printer, a highspeed laserprinter.

6) This box shows an ANA-tech raster We that has been converted to either a dxf (Cadkey extension) or iges (accepted by Cadkey) We and transferred to Cadkey for printing on the HP Laser printer.

7) This box shows an ANA-tech raster file being converted to an iges We and transferred to any system that supports the iges file transfer routines. CV, Cadkey, UGII and a large number of CAD/CAM systems support the Iges format. After completion of transfer and restoration of the iges file to a part We, plotting can be done as part of the normal routine. The ZLT system has access to a number of plotters such as Calcomp, Benson, P10, and Precision Image (a high speed color electrostatic printer).

8) This box shows the method required to transfer an ANA-tech raster We to Ventura to allow printing on the HP Laser printer. Since all of the software packages reside in different buildings and LANs, it is important to know that FTP (File Transport Protocol) is used to get the files from one system to the other. Each system has on-line tutorials on the use and applications of FTP.

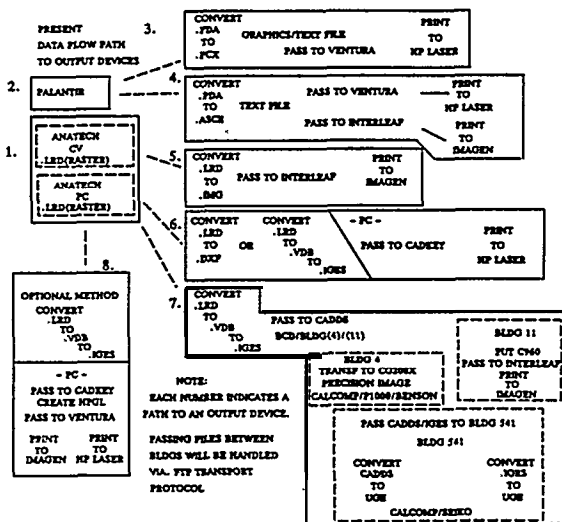


Figure - 13 Data File Conversion/Transfer Paths

Note: In figure 13, boxes are used to show full paths from one input to an output device. An operator is capable of starting at any point, generating a document and sending the data in a similar manner to the output devices referenced in figure 13.

Figure 14, Proposed Data file Conversion Transfer Paths, shows a breakdown of proposed paths currently being developed and refined for transfer of data from input to output devices. Item numbers 1 thru 5 show the possibilities of plotting raster data directly following the scanning process.

1) ANA-tech raster scanner (Jrd) to a Versatec plotter. Three items are required to support this application:

- 1 A Versatec Plotter
- 1 DA-Ver (Versatec output control interface)
- Lrd2Ver (conversion software)

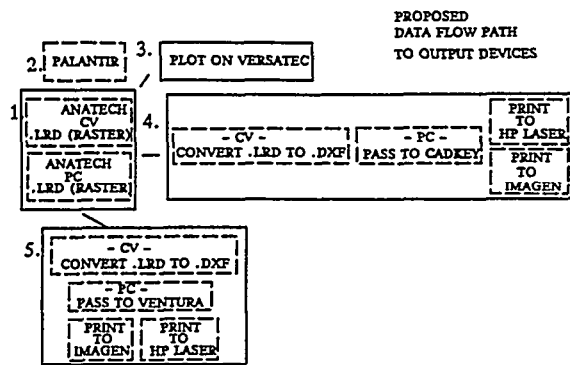


Figure - 14 Proposed Data Conversion/Transfer

These items allow a scanned document(Jrdraster)to be output directly to a Versatec plotter that is connected to the ANA-tech scanner. Drawing replacement and reproduction is handled quickly utilizing this method.

FIBER OPTICS NETWORK

A Fiber Optic (F.O.) Cable system has been installed at PNSY to link together building facilities for new and existing CAD/CAM and ADP equipment in support of ZLT. Sixteen (16) major shipyard sites have been linked on a central active star Local Area Network by approximately five (5) miles of F.O. cable.

One of the primary functions of this system will be to support ZLT/CAD/CAM requirements. The system uses the ethernet IEEE 802.3 networking protocol and provides ten million bits/second bandwidth or greater (Le. maximum data transfer rate) capacity. The cable plant has been designed to **satisfy ZLT requirements** and to provide a backbone for shipyard data communication. Initially, electronics are being installed to support all ZLT locations. However, this state-of-the-art fiber optics system will support over 1,500 transceiver cable ports. Also, with the use of terminal servers and multi-post transceivers, over 200,000 ports/connections maybe supported.

The overall potential to iii every shipyard computer system within the buildings indicated below, now and in the outyears, is possible. Immediate access to the fiber optic backbone wig be a function of each system's ethernet capability or supporting protocol Every shipyard computer system will be evaluated and appropriate software and electronic hardware will be specified for future procurement and hook up to the system. In the long run, this will yield cost savings in the hundreds of thousands of dollars in the reduction of twisted copper pairs currently being used to transmit data.

Numerous Wide Area Networks (WAN) linking the building facilities will provide support to local file/data exchange and the resource sharing requirements that will aid cost effective management throughout the network. Transmission is provided via a F.O. cable and an Ethernet coaxial 50 ohm cable in the LANs. Specifications for the 16 and 28 multimode F.O. system with capabilities of transmitting 10,000,000 bits per second (BPS) are as follows:

- cable sheath with a PVC outer jacket
- the center member is a Kevlar dielectric with reinforcement for tensile strength
- F.O. core diameter: 62.5 microns +/- .003
- F.O. core cladding diameter: 125 microns +/- .003
- Attenuation at 850 nm: 3.0 dB/km max
- Attenuation at 1300 nm: 1.0 dB/km min.

The Ethernet coaxial cable specifications are as follows:

- Cable sheath with yellow PVC outer jacket ring-band stripes at 2.5 meter intervals for transceiver tap-in
- Core: solid tinned copper .0855 rated at 1.42 Ohms per meter and 4.66 Ohms per kilometer
- Shield: aluminum/polyester shield bonded to dielectric 92% trimmed copper braid rated at 1.52 Ohms per meter and 5.0 Ohms per kilometer

The network links fifteen (15) buildings and four (4) trailers at one waterfront worksite in support of the Zone Technology Production Group. Figure 15 provides a geographic overview of the shipyard and the networked buildings, while the following table presents the major functional responsibilities housed in the various building:

Building	Primary Function
3	Production Department Service Group
4	Engineering Management Center
5	USS Kitty Hawk (CV 63) remote SNAP computer site and Shipyard Supply
7	Combat Systems
11	Zone Technology Outfit Planning Section and Zone Technology Production Group
12	Production Engineering Division and HP&A Test Division (Engineering & Executive Branch)
22	Production Dept. Mechanical/Machinery Group
57	Production Dept Structural Group
83	Management Information System Center
121	HP&A Test Division and Quality Assurance Offices
541	Mold Loft, Shop 11
620	USS Kitty Hawk (CV 63) ship's shipyard shore site
624	Supply Support Services
990	Central Production CAD/CAM Facility and Sheet Metal Shop, Shop 17
1000	Electrical/Electronics Production Group and site of Central Active Star
Trailer site	ZLT Production Trailers

The network consists of links between the following building facilities, building 1000 being the network hub:

Buildings linked	#F.O.pairs	Length of run
1000-121	16	1953'(595m)
1000-22	16	3078'(938m)
1000-11	28	3170'(966m)
11-4	16	2124'(647m)
11-7	16	705'(215m)
11-3	16	1059'(323m)
4-5	16	997'(304m)
4-83	16	1901' (579m)
83-624	16	1636' (499m)
10-57	28	2852' (869mm)
57-990	16	1601' (488m)
57-620	16	3380(1030m)
620-620ext	8	1690'(515m)

Figure 16 provides a systematic illustration of the overall F.O. network throughout the shipyard A description of this system is provided in the following paragraphs.

The total F.O. cable system runs 26,146'(495miles)or 7,968m (7.97km). Building 1000, the Hub of the outside plant system, provides the location for the Central Active Star.

The Central Active star network design has established building 1000 as the geographical hub linking facilities in the easterly and westerly sectors of PNSY. The network has established already-now system and provisions to meet demands for future expansions. The ready-now system services the following facilities:

Buildings linked	#F.O. pairs	Length of run
1000-11	28	3170' (966m)
11-4	16	2124'(647m)
1000-57	28	2852'(869m)

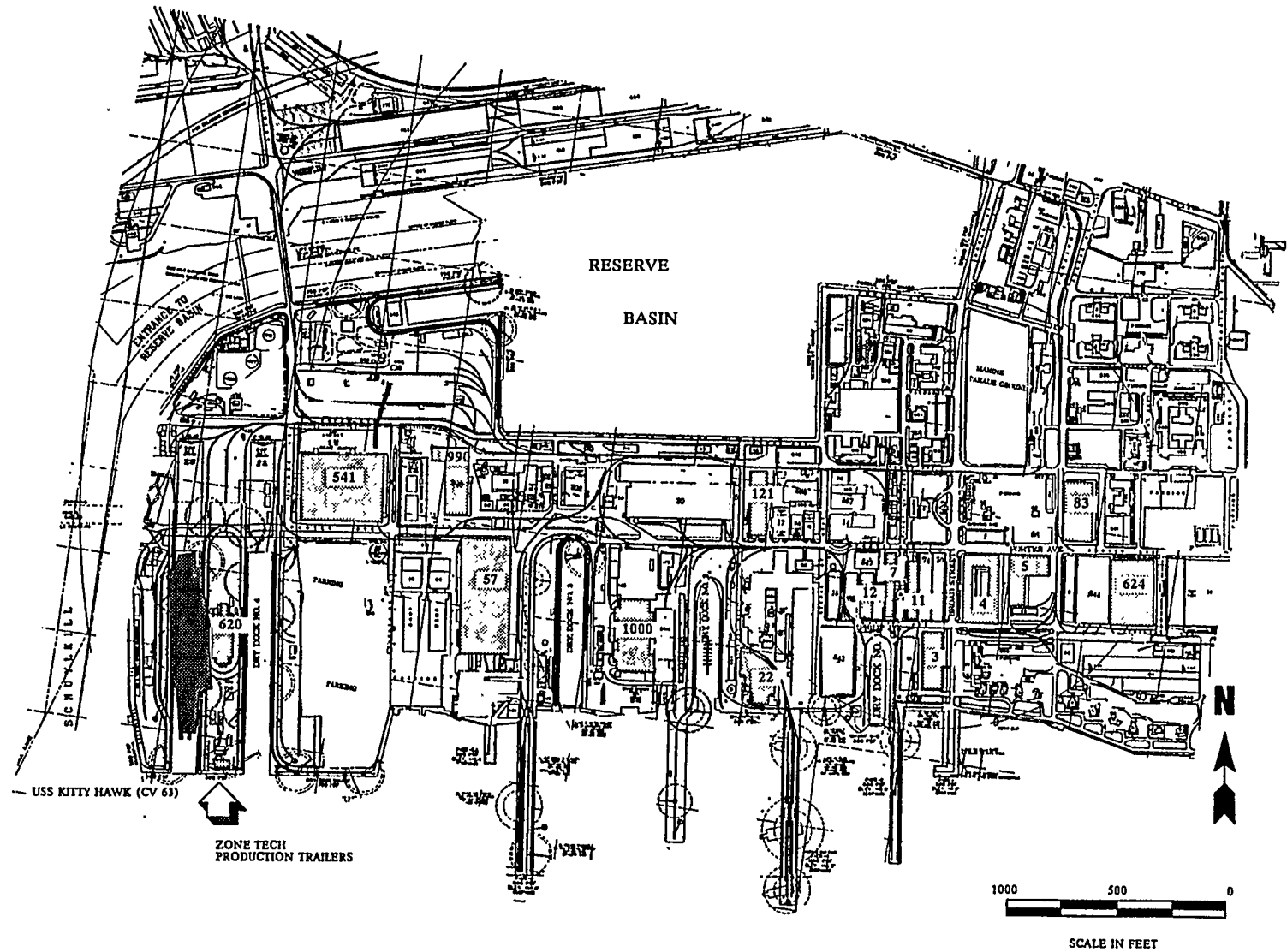


Figure - 15 PNSY F.O. Network Geographic Overview

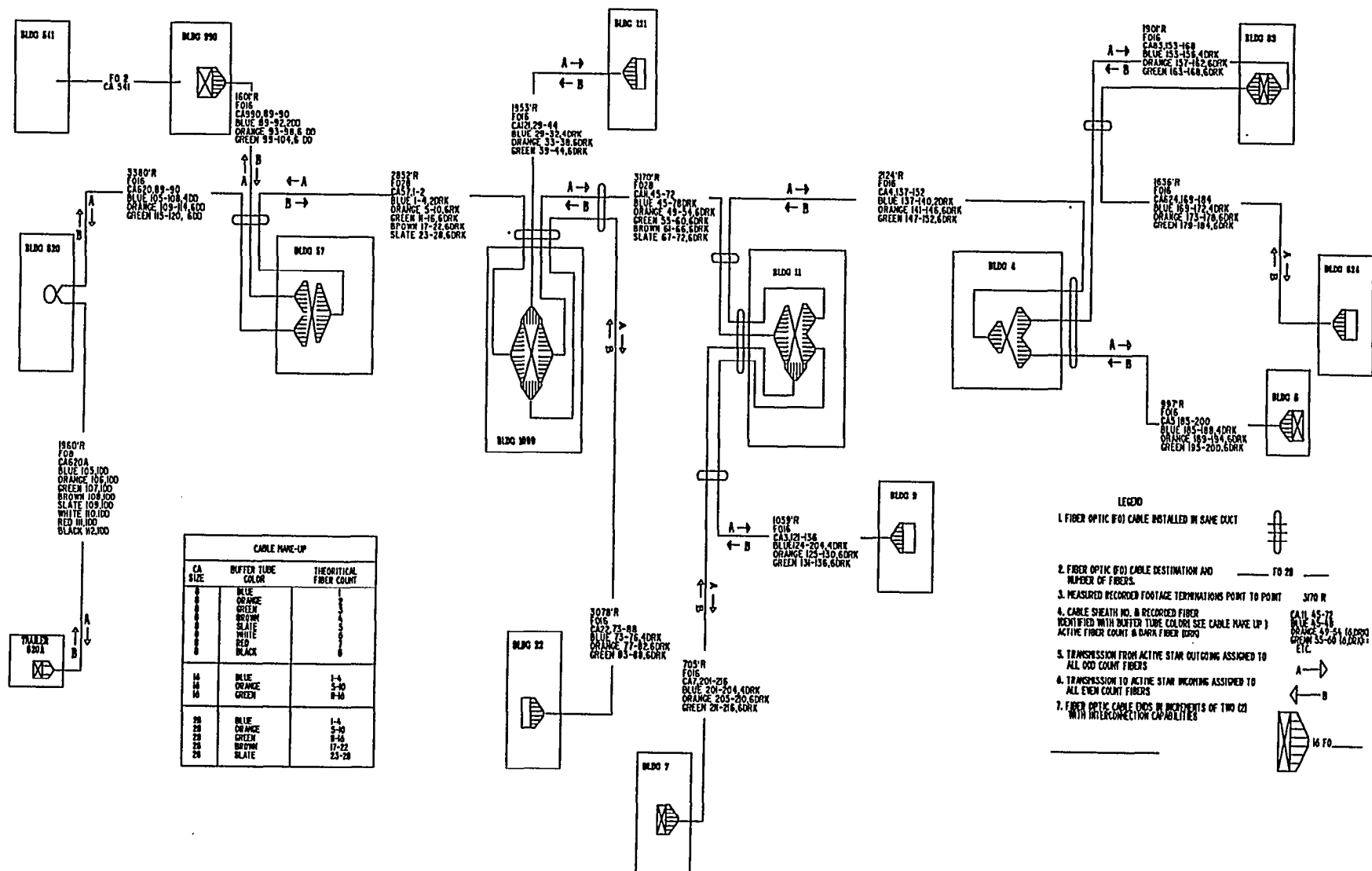


Figure - 16 PNSY F.O. Network Schematic Overview

The total Central Active Star F.O. cable system runs 9,747' (1.8 miles)/2,671m (3.0km). The PNSY demand for future expansion provides an additional 16,399' (3.1 miles)/4,998m (5.0km) of F.O. cable to link the following facilities to building 1000:

<u>Building Linked</u>	<u>#F.O. Pairs</u>	<u>Length of Run</u>
1000-121	16	1953' (595m)
1000-22	16	3078' (938m)
11-7	16	705' (215m)
11-3	16	1059' (322m)
4-5	16	997' (304m)
4-83	16	1901' (579m)
83-624	16	1636' (499m)
57-620	16	3380' (1030m)
620-620cxt	8	1690' (515m)

Utilizing building 1000 as the network design hub provides F.O. cable expansion capabilities of 26,146' (4.95 miles)/7969m (8.0km) that will ultimately link up and service sixteen (16) facilities. Already existing underground conduit provided a means whereby single ducts were used to accommodate several feeds into the building facilities.

The system design minimized connectorization by utilizing patch panel (pp) frames at designated building sites. The patch panel sites provide optimum utilization of F.O. for a Concentration Point (CP) in building 1000. The strategically located interconnection patch panel sites gain the advantage of circuitry (F.O.) traffic control management and diversification of full period F.O. performance.

The five PP interconnection sites interface a total of 72 F.O. pairs through the Central Active Star, with 80 F.O. pairs in reserve for future expansion. The elimination of F.O. field straight splices has provided a minimal attenuation loss. The F.O. cable was delivered at an average of 1.5 dB per km, providing a transmission advantage from the maximum specified 3.0 dB at 850 mm bandwidth.

STATUS AND CONTROL DATABASE MANAGEMENT SYSTEM

The Status and Control database is the heart of the Unit Work Instruction (UWI) and Shop Work Instruction (SWI) automated system. This control system development was, by design, restricted to the use of previously selected hardware and software elements of the Zone Logic computer subsystem. This decision required maintaining storage of data, graphics and text in its native form on the particular subsystem through which the data was input or generated. The major drawback to this is restricted configuration and limited data update control by the originator. Multiple versions of a file can exist if manual control procedures are not employed. Improvement of this limitation is to be addressed in a future update utilizing the incorporation of a distributive database concept, a concept which is very much a state-of-the-art technique in database management.

The Status and Control Database System is a multi-user database application developed using dBase III Plus technology (to go to dBase IV when available) and running in a Novell PC network environment. A discussion of the Global design information for the database system, covering the module structure of the system, module independent design criteria and the software technology used to implement the system is provided in the following paragraphs.

The fundamental software development technology used to implement the Status and Control Database System is dBase III Plus, a relational database system that incorporates a command language interpreter. It can be used to develop a database application running in either a single or multi-user environment. Because it is easier to develop code in an interpreted environment, the command language interpreter was used to do the initial source code develop-

ment. As modules were completed, initial testing was performed and necessary modifications were made.

In addition to traditional coding methods, a dBase III Plus program generator called the UI Programmer was used. The UI Programmer is a software tool that generates dBase III Plus source code for menuing, data entry and report forms. The code generation is based on source code templates provided by the programmer.

A compiler called Quicksilver that supports the dBase III Plus command language was used to produce the production version of the database system. The compiled code has several advantages over interpreted code in the production system, chief among these being the speed of execution. While interpreted code is in essence compiled every time it is executed, compiled code is only compiled once. Compiled code is also more immune to changes by the user community as the source code need not be kept on-line. This means that the syntax written by the programmer, once compiled, is the object code (machine language). Thus, the user can not make changes arbitrarily. This restricts changes to that individual or set of individuals controlling the compiler set by keeping the program of line and free from potential tampering. The RAM memory needed to execute compiled code is substantially less than that required to execute identical interpreted code because the memory space taken up by the interpreter itself is not required.

AdBaseIII Plus application consists of two primary elements: data tables and code modules. The data is stored in the data tables with the code modules providing an interface between the users and the data that allows for easy data access while still protecting the integrity of the data.

The Status and Control Database System consists of several primary data tables and a hierarchical set of code modules. These data tables and code modules are grouped into the following functional subsystems:

- 1 Job Order Production Control (JOPC) subsystem
 - UWI subsystem
 - Library Component subsystem
 - Material subsystem

The subsystem boundaries are not strictly enforced. Code modules from one subsystem may access data tables from a different subsystem and invoke additional code modules from yet another subsystem. None the less, the subsystem organization is a convenient one to use when planning the development of the system. Figure 17, Data Table Subsystem, provides a pictorial representation of the data table subsystem. A description of each of the data tables follows:

- 1) The master job order production Control (JOPC) List has one record for each JOPC in the system. It contains the JOPC number (#), its current production status, pointers to a number of subordinate databases and a number of related JOPC data items, such as its title and the planner's name.
- 2) The JOPC Shop Man-Hour List is subordinate to the Master JOPC List. It contains one record for each shop/man-hour pair on the JOPC. Each record includes a JOPC #, a shop #, and a number of man hours.
- 3) The JOPC/UWI Task Assignment List is subordinate to both the Master JOPC List and the Master UWI List. It contains one record for each JOPC task defined in the system. It also contains information that defines the task and specifies which UWI it was assigned to. It includes the JOPC #, the UWI# to which the task was assigned, a unique identification number, the shop # and the number of man-hours being allocated and, if possible, a descriptive definition of the task. A JOPC is considered to consist of a number of tasks, each of which must be assigned to a UWI before the JOPC can be considered completely allocated.

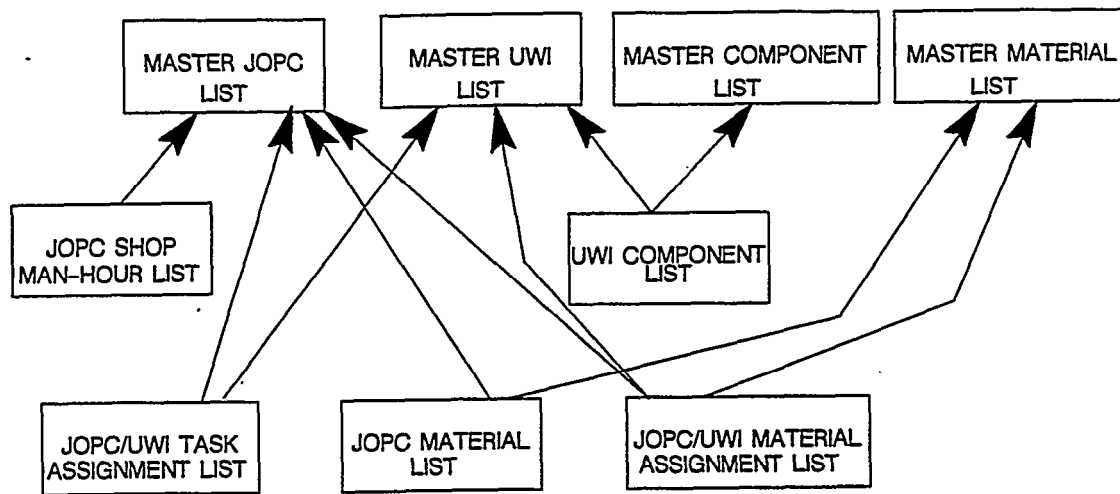


Figure - 17 Data Table Subsystem

4) The JOPC Material List is subordinate to both the Master JOPC List and the Master Material List. It lists the JOPC#, stock # and quantity of each item assigned to the JOPC.

5) The JOPC/UWI Material Assignment List is subordinate to the Master JOPC List, the Master UWI List and the Master Material List. It contains the JOPC #, the UWI #, the item stock # and the quantity assigned to a particular UWI.

6) The Master UWI List has one record for each UWI in the system- It contains the UWI #, its current production status, pointers to a number of subordinate databases and a number of related UWI data items such as the preparer's name.

7) The UWI Component List is subordinate to the Master UWI List and the Master Component Text and Drawing List. It contains one record for each text or graphic component required to complete a particular UWI and includes the UWI # and the unique component #.

8) The Master Component Text and Drawing List contains one record for each scanned drawing or text component. It contains a unique identification number, the original reference number for the text or drawing, descriptive information about the original reference material, and data concerning the scanning and on-line storage of the material.

9) The Master Material List contains one record for each stock item reference listed in a JOPC material list- It contains information such as the stock #, name, description and estimated cost of the item.

The Status and Control System is designed to be a 'bulletproof' system- It should not be possible for the user to issue inadvertent commands that destroy or corrupt the data- The user interfaces to the database system consist primarily of menus, data entry forms and report forms- All of these interfaces are similar in appearance. With a single interface type, such as data entry forms, the design and appearance of all instances of that interface type are identical, with only minimal allowances made for the differing requirements of each situation- This was accomplished primarily through the use of the UI programmer's software development tool.

In most cases, a data entry form performs three different user functions data entry, data modification and data review. In order to allow for review without the possibility of inadvertent modifica-

tion, all functions that update the database must be confirmed by the operator. All source code modules are formatted in a similar manner. It is not possible, with only a quick look at the file, to determine the programmer responsible for the code. Figure 18, Code Module Hierarchy, provides a pictorial representation of the code module subsystems. A description of each of the code modules follows

1) The Master Menu code module does not belong to any of the subsystems. It implements the initial user interface and prompts the user to select one of the subsystems (JOPC, UWI, Component or Material) and invokes that subsystem's menu module.

2) The JOPC Menu code module prompts the user to select one of the JOPC functions and invokes the related code module.

3) The JOPC Definition and Data Entry module supports entry and modification of the data from the JOPC form- This data is used to create or modify records in the Master JOPC List and the JOPC Shop Man-Hour List

4) The JOPC/UWI Task Assignment module supports the definition and modification of JOPC tasks and their assignment to a UWI. A record is added to the JOPC/UWI Assignment List for each defined task. If the UWI to which the task is assigned doesn't already exist, a record is added to the Master UWI List and the user is prompted to enter the UWI definition data (it calls the UWI Definition code module).

5) The JOPC Material Definition module supports entry and modification of data pertaining to the material allocated to a JOPC on its associated Job Material List (JML). One record is added to the JOPC Material List for each item- If the item is not already entered in the Master Material List, the user is prompted to enter the item definition data (it calls the Material Item Definition code module).

6) The JOPC/UWI Material Assignment module supports the assignment of a JOPC's material allocation to its subordinate UWIs. A record is added to the JOPC/UWI Material Assignment List for each assigned item. If the UWI to which an item is assigned doesn't exist, the user is prompted to enter the

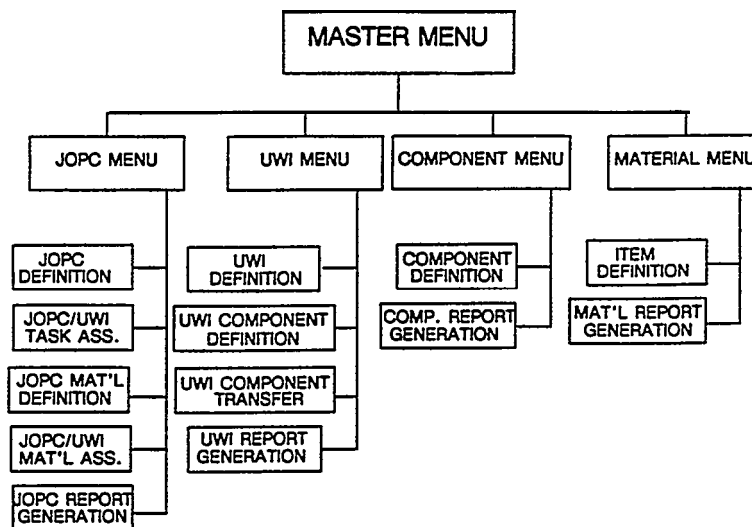


Figure - 18 Code Module Hierarchy

UWI definition data (the module calls the UWI Definition code module).

7) The JOPC Status Report Generation module generates a report listing all or some subset of the JOPCs in the system. This report can be generated in several formats- The short format shows only data that can be comfortably fit on an 80 character line and emphasizes production status. Option will allow the the to include UWI assignments, material allocations, UWI material assignments and, as a group, all the related data-

8) The UWI subsystem code modules will initially be operated without either the JOPC or Material modules. The Component modules will be present in the initial system-

9) The UWI Menu module prompts the user to select one of the JOPC functions and invokes the related code module.

10) The UWI Definition and Data Entry module supports entry, modification and review of the UWI boilerplate data and its publication status data- Records are added to the Master UWI List- This module is also invoked by several JOPC modules.

11) The UWI Component Definition module supports entry, modification and review of the list of teat and graphic components required to publish a UWI. A record is added to the UWI Component List for each component. If the component is not already on-line., the user is prompted to enter component definition data (the module calls the Component Definition code module).

12) The UWI Component Transfer module supports the transfer of on-line components from the system where they are stored to the local PC for further processing. This is accomplished by programming the dBase III Plus code to issue File Transfer Protocol (FTP) commands.

13) The UWI Status Report Generation module generates a report listing all or some of the UWIs in the system- The report can be generated in several formats. The short format will display only the data that can be comfortably fit on an 80

character line and will focus on the publication status of the UWI. Optionally, the user can request that JOPC task assignments, JOPC material assignments and/or related data be included in the report.

14) The Component Data Entry and Definition module supports entry, modification and review of the text and graphic components available for inclusion in a UWI. One record is added to the Master Component List for each component. This module can also be invoked by the UWI Component Definition module.

15) The Component Status Report Generation module generates reports listing all or some of the components in the system. The report can be generated in several formats. There are two short formats. Each will display only that data which can be comfortably fit on an 80 character line. One format will address those components that need to be scanned while the other addresses those components that are already on-line. The comprehensive format will display all stored data for each component.

16)The Material Item Definition and Data entry module supports the entry, modification or review of material item definitions. One record is added to the Master Material List for each new item. This module is also called from the JOPC Material Definition module.

17)The Material Status Report Generation module generates reports listing some or all of the material items in the system.

BENEFITS

while it is still too early to be able to provide detailed cost savings realized by the implementation of the ZLT CAD/CAM Networked DBMS, several instances of savings or benefits in design, planning and production man-hours have already been noted:

1) The scanner was utilized to help develop preplanned routing and location diagrams for the placement of tank suction and cleaning lines used to dean some 720 tanks onboard USS Kitty Hawk- This, coupled with ZLT principles of planning and management, helped realize over a \$2 million savings, with all tank cleaning work completing on schedule and definitely under budget.

2) The Mold Loft has used the upgraded UGII CAD/CAM system on various projects such as in the development of drawings for mast work, foundation work and for a new bulbous bow for USS Kitty Hawk. All of these tasks were completed on schedule and budget due to the assistance of this new equipment. Mold I-of personnel have found the UGII upgraded system so efficient that it is manned constantly and used to replace manual methods as much as possible.

3) The design division has utilized the new CAD equipment in developing a first for PNSY in a design for production work package of USS Kitty Hawk pump room number five (5). Original design effort amounted to 400 mandays. After becoming familiar with the new system, time requirements for the next pump room will be reduced by half and will be ahead of scheduled completion by one month.

4) Utilization of the new peripheral electrostatic color plotter allows for the printing of colored drawings in only ten (10) minutes. Compared with the previous norm of two (2) hours per color pen-plotted drawing this is proving to be a major savings not only in the production of multiple copies of multi-colored damage control plates, but also in the drawing of 2-D and 3-D configuration overlays.

5) Regarding the utilization of the numerous PCs, continual usage of the PCs has proven to be a necessity to handle the volumes of data to be sorted and distributed on a real-time basis in support of the shipyard's ZLT efforts.

6) The scanners are used daily to input drawings to the GAD system for supporting production work and allowing for clearer understanding and definition of work to be performed.

7) Total development of UWIs is not fully automated at this time, but at full implementation it is expected to significantly reduce the time/cost to develop UWIs.

In all, these illustrate only a few isolated eases of the benefits being realized from the installation of the ZLT CAD/CAM Networked DBMS.

SUMMARY

As is evident, many innovations have been implemented at PNSY in a relatively short interval. Major changes to management, work packaging, production, planning and design are in full swing in support of the ZLT efforts being applied to thirty (30) percent of USS Kitty Hawk's SLEP. The project is progressing well with all planned targets being met and the ZLT CAD/CAM and Networked DBMS scheduled to be completed by fall of 1988. Plans are also being worked to increase PNSY ZLT efforts on future ship overhauls.

The accomplishment of this much in such a short time can be mainly attributed to four (4) key factors. First, a "war time" condi-

tion was initially enacted to ensure the success of the Hull Expansion Project. Thus, even though the project was eventually cancelled some thirteen (13) months later, it would have been too costly to retreat, let alone stop what had already been put in motion. Second, senior shipyard management are behind the project and have given it their full support; it cannot be stressed enough how critical this has been to the success of the project thus far. Third a project Office was established to direct and manage all ZLT related matters. Fourth, an SI was used and has performed extremely well and been an irreplaceable asset to the program.

The basic approach in developing this project has been to maximize technology transfers with IHI and other sources wherever possible. Investigations of industrial and manufacturing facilities have proven invaluable, as has heavy involvement by PNSY with the National Ship Building Research Program (NSRP). The ZLT Project Office's philosophy has been one of "going out and kicking the tires, getting smart quick, analyzing the data, making the decisions that they are being paid to make, and following through on the execution of the game plan." Naval Shipyards must quickly become more competitive; buying "futures" or getting heavily involved in development efforts while needs go unfulfilled will only work to the detriment of shipyards.

With the rate at which the computer industry is moving, it is certainly realized that by the time computer hardware and software is received and installed, it is already obsolete. Or is it? The dozens of computer periodicals available (which basically sell futures) seem to always have computer managers looking for that one R2-D2 done that will solve all of one's problems in one clean sweep. Is it actually realistic to study periodicals and make plans based on just what one reads? Or is it more objective to actually perform real-time technical evaluations? These authors vote for the latter. Once you have seen and understood, there is no turning back.

A perfect example of this is the installation of PNSY's F.O. LAN. Initially, shipyard personnel managers were sceptic, basically out of lack of knowledge of fiber optics. Once the SI brought in highly qualified fiber optic engineers and technicians, shipyard fears and doubts were put to rest. In fact., it took only six weeks to install this system. If that isn't an example of "kicking the tires, getting smart quickly and making a sound technical and business decision" that fiber optic technology today is good enough to go with, then the authors are not sure what is. The decision to go with 32-bit microcomputers operating on MS-DOS vice going to OS-2 is another example of going with what the market has proven as a winner to date. Also, by following the lead of private industry and the SI, the acquisition of scanner technology has been made a reality at PNSY.

Regarding the use of an SI, as stated earlier, if managed properly and if true professional lines of communication are established and maintained, it is hard for the authors to see how anything short of success can occur.

Throughout this project, Cost, Schedule and Control (CS²) procedures were used as one of the major tools to monitor and progress the SI. To this end, the maintaining of schedule and budget has been a reality.



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Group Problem Solving-How to Matrix

No.3A

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ABSTRACT

PROBLEM-SOLVING GROUPS HAVE LONG BEEN PART OF SHIPYARD MANAGEMENT CULTURE, THE TRADITIONAL TITLE FOR THESE GROUPS HAS BEEN THE TASK FORCE. WITH ADVENT OF CHANGES IN CULTURE TO EMPLOYEE-INVOLVEMENT/PARTICIPATORY-MANAGEMENT, MANAGERS INSERTED QUALITY CIRCLES IN THEIR PROBLEM-SOLVING TOOLBOX, QUALITY CIRCLES AND TASK FORCES TYPIFY DISPARATE SITES ON THE GRID OF PROBLEM-SOLVING GROUPS, THE INCONGRUITY OF THESE GROUPS ENTREATS DEVELOPMENT OF ADDITIONAL PROBLEM-SOLVING GROUPS FOR THE MANAGERS TOOLBOX.

THE PAPER PROVIDES DEFINITION/CHARACTERISTICS OF FOUR PROBLEM-SOLVING GROUPS: TASK FORCES, QUALITY CIRCLES, STUDY CIRCLES, AND SPECIAL STUDY TEAMS, THE LATTER TWO GROUPS - STUDY CIRCLES AND SPECIAL STUDY TEAMS, REMEDY MANY OF THE DEFICIENCIES OF THE FORMER TWO GROUPS - TASK FORCES AND QUALITY CIRCLES. WITH THESE FOUR GROUPS THE SHIPYARD MANAGER HAS AN EXPANDED TOOLBOX TO TACKLE PRODUCTIVITY PROBLEMS.

GROUP - PROBLEM SOLVING

A matrix is introduced to assist employee-involvement/ participatory-management groups determine the most effective problem-solving methods given parameters of staff/budget/time, which are scare resources.

PROBLEMS

A problem may be defined as a source of perplexity, distress or vexation. A problem may also be characterized as a mystery. The shipyard manager may prefer a different definition of problem. To the manager problems fall upon a definition continuum - from distinguished to vague. Another definition continuum is from trivial to vital.

Once the shipyard manager has defined the productivity problem, the manager needs to select the solution process to fit the problem. When the productivity problem is distinguished (well-defined) and trivial, an individual should be dictated to solve the problem. Additional productivity problems - other than well-defined and trivial - need to be solved by groups.

SOLUTIONS

Solutions to these productivity problems fall upon a continuum. The range of this continuum is from quick fix to root cause. The quick fix solution mends the fractured wheel. The root cause solution prevents the wheel from fracturing, and becoming a problem at the shipyard.

PROBLEM - SOLUTION MATRIX

The problem definition continuum ranges from distinguished to vague (well-defined to ill-defined). See Figure 1. The problem definition continuum also ranges from trivial to vital (work-center to yard-wide). See Figure 1. The solution continuum ranges from quick fix to root cause. See Figure 1.

Lumping these continua stipulates the problem-solution matrix. Ignored in this matrix are distinguished and trivial problems, for these problems may be solved by an individual. The treatment of quick fix solutions to vague problems is also ignored as being beyond the scope of the paper. A visual representation of the problem-solution matrix is in Figure 2.

DISTINGUISHED	VAGUE
TRIVIAL	VITAL
QUICK FIX	ROOT CAUSE

FIGURE 1.

VAGUE	DISTINGUISHED
TRIVIAL	VITAL
ROOT CAUSE	ROOT CAUSE
VAGUE	DISTINGUISHED
VITAL	VITAL
ROOT CAUSE	QUICK FIX

FIGURE 2.

RESOURCES

Problem-solving 'by a group compels allocation of scarce resources; Time/staff/materials are resources. If resources have a cost; then, resources are scarce. For this paper time, staff, and materials are scarce resources.

Time may be the scarcest resource for many shipyard managers. Budget variances are wontedly incapable of adding time to a schedule. At a shipyard the continuum for allocating time - as a resource - is the workweek - from 1 to 40 hours.

Staff is another scarce resource for the shipyard manager. Staff are those individuals, whether from within the work area or through organizational boundaries, whom develop the group. The limits for staff run from drafted to voluntary.

The continuum for materials is not studied, for costs of materials allocated to the group are insignificant with costs for time or Staff. Stationary-type costs and utility costs allocated for the meeting room are typical material costs.

RESOURCE UTILIZATION

Having defined the problem and desired solution, whether quick fix or root cause, allocation of scarce resources is required by the shipyard manager. In the problem-solving toolbox are individuals and problem-solving groups.

As individuals are dictated, when the problem is distinguished and trivial, the role of individuals is ignored in this paper. Major problems beyond the scope of distinguished/trivial need a group to adequately solve the problem. The group needs to be trained in problem-solving skills specific to the group versus the individual. Group-problem solving is not a cookbook approach as with the individual. Hell defined, work-center problems only need an individual for resolution. Individuals rotely following steps readily solve these minor problems with minimal assistance from the harried shipyard manager.

The initial problem-solving group was the task force. The traditional management approach to problem-solving has been, and continues to be the task force. The participatory approach to problem-solving is the quality circle, a generic term used to identify a participatory management approach to problem-solving. Although long heralded and long honored in the breach, the quality circle is a revolutionary problem-solving group. As these two groups are disparate sites on the problem-solving grid, additional groups evolved for the problem-solving tool box. Study circles are a hybrid of the task force and quality circle problem-solving groups. The special study team is a cross of the task force and study circle.

The four group problem-solving tools are: the task force, the quality circle, the study circle, and the special study team. These four problem-solving groups for the tool box of the shipyard manager range from traditional to state-of-the-art.- Each problem-solving group is now defined for this paper (each appendix provides characteristics, and a stand-alone how-to guide).

Task force - temporary grouping of selected individuals under one leader for purpose of accomplishing a definite objective (see Appendix 1 for characteristics and how-to guide).

Quality circle - small group of employees and their supervisor with same work area interests, who voluntarily form a team, receive training in group problem-solving techniques, regularly meet to identify work related problems, recommend solutions to their management for approval, and monitor effectiveness of these solutions (see Appendix 2 for characteristics and how-to guide).

Study circle - systematic study of a common goal, with each member interacting and responsible for the circle, and with sufficient scope/flexibility to adjust activities

(see Appendix 3 for characteristics and how-to guide).

Special study team - temporary and facilitated group of volunteers for purpose of providing specific recommendations on a definite objective (see Appendix 4 for characteristics and how-to guide).

GROUP MATRIX

Resource continua for problem-solving groups includes time and staff. time continuum ranges from 1 to 40 hours in a workweek. A typical workweek - 8-10 hours/day, 5-days/week, is considered to be the range of hours. See Figure 3. The staff limits range from drafted to voluntary. See Figure 3.

Lumping these continua stipulates the group matrix. Ignored in this matrix are diametrically posed problem-solving groups. As an example having developed a voluntary group meeting one-hour-per-week, the paper will not develop a parallel drafted group. Permutations as a drafted group meeting one-hour/week are ignored, for these groups generally yield inferior solution. A visual representation of the group matrix is in Figure 4.

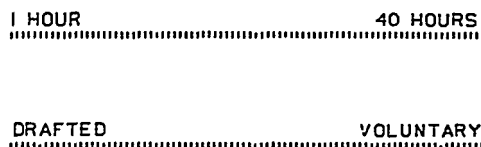


FIGURE 3.

1 HOUR	1 HOUR
VOLUNTARY	VOLUNTARY
Quality CIRCLE 1	[STUDY CIRCLE]
4 HOURS/DAY	40 HOJRS
DRAFTED	VOLUNTARY
[TASK FORCE]	[SPECIAL STUDY TEAM]

FIGURE 4.

DRAFTED v VOLUNTARY

The matrix suggests development of voluntary v drafted groups. Proponents of each group charge abuses and excesses of the other group. The argument of proponents of voluntary groups is ownership of the goal. While many adherents of the task force encourage the voluntary approach, these adherents

disagree with the ownership conclusion. Task force adherents argue against the negative aspect of the task force being involuntary participation. Although adherents encourage the voluntary approach, these adherents of the task force do not agree with the no ownership conclusion. Usually participants in the task force are selected by their respective bosses. While successes of task forces may not always "reap its just rewards," failures rarely go unnoticed by the bosses. When destructive criticism is absent, and arguments against voluntary groups are reduced to a common denominator, the salient objection of the critics is voluntary groups seriously vitiate contribution of the highly trained, well-informed, task force leader. Proponents of voluntary groups afford the reverse of the argument - if I do not recognize the problem; then, I will not implement your solution to my problem. Preferring to seriously take rather than deflect criticism, the argument posited is mastery of difficult problems may be achieved through voluntary groups, but not with permissive/unstructured approaches.

Experience at Mare Island Naval Shipyard prescribes establishing task forces to solve recurring problems. The initial chore of the task force ritually is to sift reports of prior task forces on the recurring problem. Oft the instance is the task force has admirably put out the fire. In solving the problem at hand, the task force rarely entraps the arsonist or prevents reoccurrence of the fire.

GROUP PROBLEM - SOLVING MATRIX

The problem solution matrix was stipulated in Figure 2. The group matrix was stipulated in Figure 4: As lumping continua stipulated the problem solution matrix and group matrix, combining these matrices stipulates the group problem-solving matrix. A visual representation of the group problem-solving matrix is in Figure 5.

VAGUE	DISTINGUISHED
TRIVIAL	VITAL
ROOT CAUSE	ROOT CAUSE
[QUALITY CIRCLE]	[STUDY CIRCLE]
VAGUE	DISTINGUISHED
VITAL	VITAL
ROOT CAUSE	QUICK FIX
[TASK FORCE]	[SPECIAL STUDY TEAM]

FIGURE 5.

HOW - TO

The group problem-solving matrix provides a rule-of-thumb. Given variances in scarce resources - time/staff/materials, which problem-solving group of the matrix is best suited to the problem? The matrix may be utilized via diverse approaches. Defining the problem (vague v distinguished, trivial v vital) and selecting the solution (quick fix v root cause) is an approach to the matrix. Using this approach with the matrix compels allocation of scarce resources. After defining the problem and solution process, the nature of the problem-solving group is determined by the matrix.

In another approach to the matrix the shipyard manager allocates scarce resources. With this approach the manager determines the amount of time/staff to devote to the problem-solving process. Upon allocating time (1 hour, half-time, full-time) and staff (drafted v voluntary) the matrix again determines the problem-solving group. The appendices provide a readily ensued map guiding the group over the problem-solving landscape.

RETROSPECT

Problem-solving groups are part of shipyard management culture. These groups are essential in effective solving shipyard productivity problems. The matrix provides a how-to approach utilizing in-house shipyard resources. The user - *the shipyard manager* - should be free to pinch, punch, squeeze, and kick the appendices to best suit the needs of their Shipyard. The guidelines of the appendices are not meant to enslave the group. The guidelines are meant to ensure the greatest scope for development of precious and needed abilities of the group.

APPENDIX 1

TASK FORCE

A task force is a temporary grouping of selected individuals under one leader for purpose of accomplishing a definite objective (example - leaking hull valves after reinstallation during an overhaul).

CHARACTERISTICS:

Participant Selection - individuals are usually assigned to the task force due to being subject matter experts (example - the "cracker-jack" mechanical engineer from fluid systems)

Participant Involvement - usually involuntary, individuals are assigned to the task force as representative of higher authority (example - as cognizant functional areas are identified, someone is delegated from the functional area - the engineer from fluids)

Training - individuals assigned due to being demonstrated subject-matter experts (yes), and presumed to be trained in sufficient group problem-solving techniques (no - needed)

Participant Representation - in generating the task force, determinations are made to assure representation in group covering all functional areas (example - shop, support, engineering)

Skill Level - individuals are subject matter experts from various functional areas, skill levels in group are advanced in subject/function (example - general foreman- from the shop, mid-manager from support, engineer from fluid systems)

Goal Selection - pre-determined as definite objective of the task force (example - leaking hull valves)

HOW - TO

After selecting individuals and leader for the group, what is the next step? Although the group has individual subject matter expertise, group problem-solving techniques are deficient in the group. To relieve this deficiency, the group needs a modicum of training in group problem-solving. Minimum training should consist of brainstorming and cause/effect analysis. A host of training organizations provide separate modules, which may be presented in-house. These modules will become an accepted addition to training libraries. The training should be introduced at the initial meeting of the group.

Many trainers insist on training before initiating the task force. Several NSRP publications regarding problem-solving teams specify classroom training before starting work. That the group receive training is more important than when the group is trained in techniques. Either approach - training before commencing the problem-solving process or training-as-you-go, may be used for the group. - The Mare Island experience is the logic of training-as-you-go suggests immediacy of application by the group.

A facilitator needs to be assigned the group. The facilitator would direct the training. The facilitator would be a pro-active resource. The function of facilitation is to help members communicate at about the same level. Oft group members have the frustrating experience of not understanding some aspect of the goal, and being unable to state the source of difficulty. The facilitator serves subject to canons of group development/dynamics. Group interaction inevitably generates communication problems. Group interaction also exposes new potentials for development. The facilitator function is to minimize problem effects, and maximize group potential. A good facilitator adequately handles communication problems, and maximizes the potential of the group. In the task force, the facilitator needs to be pro-active versus an individual literally sitting at the back of the room. The facilitator is part of the group . problem-solving process. The facilitator is not a reaction to the problem-solving process.

The task force - as a group - meets 4-hours-a-day until solving the problem. Some insist the group meet full-time, 40-hours-a-week. Adherents believe the full-time approach leads to speedier results. Adherents also believe this approach allows the group deeper immersion in the problem. The Mare Island experience has been full-time and half-time groups without any evidence indicating which one is better. Observation with full-time task forces suggest the application of one of Murphy's laws: work expands to fill the available time.

After solving the problem, what is the next step for the task force. Recommendations need to be presented in a face-to-face meeting with those at the lowest level responsible for accomplishing task force recommendations. The Mare Island experience also is to have the boss of the responsible manager at the presentation. At presentation conclusion, more oft than not the boss will train on the responsible manager, and request, "When do you think you will

have that in place, Harry/Mary?" This commits the responsible manager and the boss accomplishing recommendations.

STEPS

- I. Selection - team/leader/facilitator
- II. Training - by facilitator in brainstorming and cause/effect analysis
- III. Problem Solving - with pro-active facilitation
- IV. Presentation - face-to-face with responsible manager and boss

APPENDIX 2

QUALITY CIRCLE

A quality circle is a small group of employees and their supervisor with same work area interests, who voluntarily form a team, receive training in group problem-solving techniques, regularly meet to identify work related problems, recommend solutions to their management for approval, and monitor effectiveness of these solutions (example - new sewing machines for the sail loft).

CHARACTERISTICS

Participant Selection - voluntary, the participant is usually expert at the immediate function (example - journey level sailmaker proficient in sewing machine operations)

Participant Involvement - voluntary, the participant has same work area interests as rest of the group (example - all group members work in the sail loft)

Training - the participants have expertise at immediate function (yes), group problem-solving techniques (no - needed)

Participant Representation - as group is voluntary all functional areas may not be represented (example - an industrial engineer to determine methods/standards for the new equipment)

Skill Level - skill levels vary as participants are only expert at immediate function compared with subject matter (example - supervisor, mechanic, helper, temporary, clerk)

Goal Selection - any random goal is appropriate grist for the group (example - relocation/type of consumables carried in vending machines, Pepsi v Coke)

HOW - TO

The group problem-solving matrix (Figure 5) suggests a quality circle, when

problem definition is vague/ trivial, and solution is elimination of the root cause. Quality circle is a generic term used to identify a participatory management approach to group problem-solving. Typical evolution of a quality circle involves the supervisor. The facilitator initially trains the supervisor to become circle leader. It is the assignment of the supervisor to train circle members. Training may be a canned program of about 10 lessons. At minimum each lesson requires a meeting. Weeks in training usually exceed the number of lessons. In circle training, the facilitator literally sits at the back of the room, and only serves as a resource person. The Mare Island experience is to incorporate a current work area problem of the circle in the training. The training-as-you-go approach has advantage of immediacy of application by the circle.

Many organizations espouse teams/circles/groups met full-time (40 hours/week) until solving the problem. Adherents believe the full-time approach leads to speedier results. Adherents also believe this approach allows the group deeper immersion in the problem. Adherents argue that the one-meeting-a-week format saves nothing in total hours, but delays the solution for months. Proponents of quality circles even admit the weekly meeting-format retards problem resolution. With the weekly format for quality circles, the Mare Island experience is 6 to 12 months to solve a problem. A circle meeting full-time for one week uses an equivalent time as a circle meeting for 40 weeks in the weekly format. Circles meeting longer than one hour or more frequent meetings - when permitted in the work area - are not exceptional. The Mare Island experience has been circles meeting one-and-a-half hours., twice-a-week, without any evidence indicating disruption of the work area.

After solving the problem, the facilitator schedules a management presentation for the circle. The face-to-face meeting allows the circle to present recommendations to those responsible for accomplishing the recommendations. The Mare Island experience is have the boss of the responsible manager at the presentation. When the recommendation is accepted, the responsible manager and boss commit to accomplishing the recommendation. As quality circles are enduring entities, the Mare Island experience is to have the circle brainstorm the next problem, while preparing for the management presentation. The brainstorming activity affords a modicum of continuity, and allays post-presentation blues.

STEPS

- I. Training - of supervisor/leader
 - II. Organization - volunteers with work area interests
 - III. Training - of circle members by leader with facilitator as resource expert
 - IV. Problem Solving - with reactive facilitation
 - V. Presentation - face-to-face with responsible manager and boss, concurrent brainstorming for next problem
- Problem Solving - return to STEP I V

APPENDIX 3

STUDY CIRCLE

A study circle is a systematic study of a common goal, with each member interacting and responsible for the circle, and with sufficient scope/flexibility to adjust activities (example - hull patch coordination).

CHARACTERISTICS

Participant Selection - subject-matter experts volunteer to serve on group (example - naval architect from design)

Participant Involvement - participants hold ownership as group members share common goal (example - all group members agree have problem needing elimination)

Training - group utilizes facilitation, and receives training in group problem-solving techniques (example - facilitator trains group in brainstorming and cause/ effect analysis)

Participant Representation - in generating group all involved functional areas are assured representation (example - group requests mid-level management member from non-destructive test)

Skill Level - participants are subject-matter experts, and receive training in group problem-solving techniques (example - GF from shop, mid-manager from support, naval architect from staff)

Goal Selection - objective of group is pre-determined (example - lack of coordination between shops causes rework in reinstallation of hull patches)

HOW - TO

There are two rules the group needs to follow to be effective. The cardinal rule is the study circle is voluntary. The second rule is interest in the goal. Adherence or lack of adherence to these rules determines success or lack of success of the study circle.

It remains for the interested shipyard manager to select goal and participant representation for the circle. After preliminaries (goal selection, participant representation/involvement/selection) are discharged by the manager, an initial meeting should be scheduled by the facilitator.

The initial meeting is an organizational meeting led by the facilitator. Assignment of the facilitator is: to assure all are committed, the group determines the extent of the study circle, and the group determines regular members. After the initial meeting, the facilitator leads the group in training - brainstorming and cause/effect analysis. Leadership of the circle is given to members after training completion. Leadership of the circle is rotated among members.

Many trainers insist on training prior initiating the circle. That the group receive training is more important than when the circle is trained in techniques. The Mare Island experience is the logic of training-as-you-go suggests advantage of immediacy of application by the group. Many trainers also insist on selecting a leader before starting work. The Mare Island experience on leadership rotation exposes new potentials for members. Rotation enhances the process, assures group communication, adequately handles the problem, and realizes members potential.

The facilitator is a pro-active resource for the group. The role of facilitation is to help members communicate at about the same level. The facilitator serves subject to canons of group development/dynamics. In the study circle; the facilitator needs to be pro-active versus an individual literally sitting at the back of the room.

Many organizations espouse teams/circles/groups met full-time (40 hours/week) until solving the problem. Adherents believe the full-time approach leads to speedier results. Adherents argue that the one-meeting-a-week format saves nothing in total hours, but delays solution for months. The mean Mare Island experience is study circle accomplished the task in 19 weeks, with 15 meetings, taking 105 meeting-hours. A group meeting full-time for one week uses an equivalent time as a circle

meeting 40 weeks in weekly format. AS an example a group of three meeting full-time uses 120 meeting hours a week.

Rotating leadership in the group requires a pro-active facilitator. For the circle to be effective, the facilitator needs to devote time to evaluating inevitable group process problems. The facilitator needs to diagnose/evaluate circle effectiveness.

The point made is the method suggests the circle budget time for evaluation. The facilitator may be helpful by sharing diagnosis/insights/interpretations, what is occurring in the circle. This will give members a model to follow in the circle.

After resolving the problem, recommendations need to be presented in a face-to-face meeting by circle members. At this presentation are those responsible for accomplishing the recommendation. The Mare Island experience is to have the boss of the responsible manager at the presentation. This commits the responsible manager and the boss accomplishing accepted recommendations.

STEPS

I. Determine Goal - performed by the sponsoring manager, problem needs to be distinguished/vital, solution is to eliminate root cause

II. Selection - performed by sponsoring manager, team/facilitator

III. Organization - by facilitator; assures all are committed, extent of study circle, regular members

IV. Training - by facilitator in brainstorming and cause/effect analysis

V. Problem-Solving - rotating leadership with pro-active facilitation

VI. Presentation - face-to-face with responsible manager and boss

APPENDIX 4

SPECIAL STUDY TEAM

A special study team is a temporary and facilitated group of volunteers for purpose of providing specific recommendations on a definite objective (example - accurate job-order charges).

CHARACTERISTICS

Participant Selection - subject-matter experts volunteer to serve on group (example - industrial engineer from production)

Participant Involvement - individuals hold ownership as members share common goal (example - all participants have problem needing solution)

Training - individuals have subject-matter expertise (yes), group problem-solving techniques (no - needed)

Participant Representation - in generating team sponsor assures all function areas are covered (example - shop, support, engineering)

Skill Level - individuals are subject-matter experts, skill levels in group are advanced in subject/function (example - supervisor from shop, project manager from support, engineer from production)

Goal Selection - pre-determined as definite objective of group (example - charging accuracy)

HOW - TO

The stipulated goal of the special study team is quick fix solution to a distinguished problem vital to the shipyard. Elimination of the root cause of the problem requires a study circle. The special study team is a full-time for one week assault on the problem. At end of the week, the team has composed a report, and ready to make a presentation.

The problem needs to be distinguished, and comprehended by all participants. Upon defining the problem, representation areas need to be determined by the sponsor with aid of the facilitator. The representation areas need to be under control of the sponsor. This control assures volunteers will not be impeded team members. After selection the facilitator provides members all available background information on the problem before commencing team meetings.

At commencement the facilitator has each member state their comprehension of the problem. Upon concluding this activity the sponsor is introduced, and welcomes the team. The sponsor peruses the statements, and reconciles their comprehension to the goal. Upon sponsor departure the team states their goal. Having the team reach consensus on the goal reduces hidden agenda.

At this pass it is noted there is no leader, neither selected nor appointed by the sponsor or the team. This absence of a specific leader endures throughout the tenure of the team. The facilitator guides the team through the problem-solving process versus is the leader of the team. with continuous pro-active facilitation, the team does not need a leader to solve the problem.

Training is embraced in the 40 hours allocated to the team. Training is provided by the facilitator. Upon reaching consensus on the goal, the team enters training in group problem-solving techniques. The team is trained in brainstorming and cause/effect analysis. Depending upon prior group experiences of members, the team should complete training after 4 to 8 hours into the study.

In the special study team, there is continuous facilitation. Literally sitting at the back of the room, only serving as a resource person is not an apt description of this team facilitator. The role of the facilitator retains goal direction of the team, and minimizes dysfunctional group roles. Pro-active facilitation is needed for the team to match the 40-hour goal. The facilitator guides the team over the problem-solving landscape.

The Mare Island experience has been full-time (40-hour week) and half-time (20-hours per week for 2 weeks) special study teams. The experience is without any evidence indicating which duration is better.

As the week unwinds, the team composes a report. A sole sheet cover delineates the problem, identifies the enclosed body of the report, and lists recommendations. The body ensues the cover detailing how/why of the recommendations. Each member signs the cover at study conclusion.

To close the study, the facilitator arranges a face-to-face presentation with the sponsor. This presentation is arranged within a week ensuing study conclusion so the sponsor may have occasion to peruse the report. At the presentation any report ambiguities are clarified by the team/sponsor.

S T E P S

I. Determine Goal - performed by sponsoring manager, problems needs to be distinguished/vital, solution is quick

II. Selection - performed by sponsoring manager and facilitator

III. Organization - background information provided members by facilitator prior commencing study

IV. Training - by facilitator in brainstorming and cause/effect analysis

V. Problem-Solving - team guided by Continuous pro-active facilitation during study

VI. Report - signed by members at study conclusion

VII. Presentation - face-to-face after report perusal by sponsoring manager



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Zone-Oriented Drawings for Life Cycle Management

No. 3B

James Wilkins, Jr., Member

ABSTRACT

This paper presents the results of a study which was conducted to determine whether unit-oriented construction drawings, which are being developed and used by shipbuilders who are using modern zone-oriented, or modular, construction techniques, will satisfactorily substitute for system-oriented detailed arrangement drawings in the Navy's life cycle maintenance management process. The study concluded that modular construction drawings will provide the necessary data in a more usable format, and thus are the preferred approach for the Navy's use. However, the study also identified several additionally needed features that are not now being provided in unit-oriented drawings, but which *must* be included in order to meet the needs of planning and maintenance activities during the operational life of a ship. A number of other observations about drawing use and maintenance are provided.

NOMENCLATURE

Because agreement on nomenclature is essential to communication, and because there seems to be no existing "standard" of terminology that crosses the boundaries of individual shipyards, the following descriptions are provided to orient the reader to the terminology that will be used in this paper:

"Zone-oriented" - This term is very commonly used to refer to any ship construction approach which varies from the historically common system-oriented approach which has been used in US shipyards (except during wartime, when efficient production became the norm). However, because the word "zone" has come to be used in various places to mean any part of a ship under consideration, including systems, that term will be used in this paper only in its most generic sense, i.e., to mean non-system-oriented.

"Modular, or Unit-oriented" - The essential difference that has been (re)introduced into shipbuilding practice is that the whole of any ship may be broken down into a number of basic construction units, each of which can be finished to as complete a condition as practicable, virtually independently of the others. Then, the units can be joined together to make up the whole, i.e., the ship. It is not uncommon for several units to be joined together into larger elements, which will be called "Blocks" in this document, before being joined together with other units or blocks at the final erection site. In all other construction industries this practice is called "modular construction". The term "modular construction" seems to better convey the basic approach used in this technique, and therefore it, and related terms such as "unit-oriented" or "block-oriented", will be used throughout this document to describe the more current approach to shipbuilding.

INTRODUCTION

Background

As shipbuilders have made the relatively sudden transition to the use of group technology in ship construction, they have found it desirable to make significant changes to the format and content of many of the drawings used in the construction process. These changes have been initiated with a single purpose in mind - namely, to present information needed by production personnel in the format which they, the immediate users of the drawings, find most useful. One guiding principle inherent in achieving this purpose is to avoid providing information that is not needed for doing the task at hand.

Before the transition back to modular construction techniques, ships were built by system, the largest and

most extensive of which was the hull structure. Construction of the hull frequently was started as soon after contract award as possible, based more on the desire to meet a milestone for payment purposes and/or the need to keep the available structural construction personnel usefully employed than to ensure the most cost-effective construction scheduling. The installation of distributive systems, such as piping, ventilation and wiring, also was done by system. But since the development of the drawings for distributive systems was in part dependent on data from structural drawings, the distributive system drawings could not be finished until after the structural drawings. Thus, the structure was started first, and the distributive systems were installed after the hull construction was well advanced. The inefficiencies of this approach have been well documented elsewhere and will not be repeated here.

The significant point to be made is that those drawings whose purpose was to provide assembly and installation details in system-oriented shipbuilding programs were deliberately constrained to show information about a single system, because the workers who needed the information were working only by system.

Since the emphasis in modular construction is on the work content related to finishing a unit, the content of the assembly and installation drawings must relate to the unit. Most units contain parts of many systems, and seldom, if ever, all parts of any system. Thus, drawings which contain information about how to assemble and install the parts that make up a unit do not provide any information about any parts of any systems which are not in that unit. In other words, since the shipbuilders do not need system-oriented installation drawings, they are not producing such drawings. Consequently, system-oriented drawings are not available to the owner unless required by specific contractual language.

After ships are delivered to the owner, a whole new set of drawing users come into the picture. In the past, these users have received detailed drawings of each system, to use for whatever functions they perform. The procedures which they have developed for dealing with all of the elements of the life-cycle maintenance management process have been built, at least in part, around those system drawings. So the issue to be addressed is whether these users will be hurt or helped by having only the module-oriented drawings, which show how all the systems in some part of the ship are configured,

as opposed to the system-oriented drawings, which show how one system is configured throughout the ship.

The initial reaction of most individuals in the Navy who had not seen any drawings produced from modular shipbuilding projects, as might be expected, was that the Navy must continue to receive single system detailed drawings. However, many commercial and naval ships around the world have been built by foreign shipbuilders using modern shipbuilding techniques and have received only the drawings which naturally resulted from their building program. Because these ships have been operated satisfactorily with only those drawings, it was appropriate to study whether there were in fact, unique requirements of the U.S. Navy's life cycle management process that did demand detailed drawings of each individual system.

Scope of Project

In addressing the issues presented above, the following basic questions need to be answered relative to the ship's drawings provided by the shipbuilder:

1. What do the Shipbuilder's drawings provide?
2. Who are the Owner's Users?
3. What are the Owner's Users' needs?
4. Do the Shipbuilder's drawings provide what the Owner's Users need?
5. If not, what changes are required?

Before addressing the answers to these questions, it is appropriate to consider the planned and actual approach to obtaining the answers.

Study approach

The initial plan was to select two types of ship for analysis, each of which had two similar ship classes constructed recently; one class having been built using system-oriented methods and the other using modular construction techniques. The drawings prepared for the system-oriented ships and comparable drawings for the modular built ships would be presented to each of the user activities involved with that class of ship, for comparison and comment.

The ships originally targeted for the study were the AO-177 class and the TAO-187 class of oilers, both built by the same shipyard 9 but by different construction techniques, and the FFG-7 class, the early ships of which had been built using system-oriented methods, but the later ships of which

reputeously had benefited from application of group technology concepts.

The planned approach was to select one or more Ship Alteration packages being designed for the A0-177 class by its Planning Yard, Puget Sound Naval Shipyard, and identify which shipbuilder drawings, and specifically what data in those drawings, were used by the PSNSY designers for each phase of their effort. The next step would be to identify and obtain the drawings from the TAO-187 class which would contain the same type of data, and have the PSNSY engineers indicate whether it would have been easier or harder to have had such drawings available for their use.

The above steps were not able to be implemented as planned because of a number of factors. First, the TAO drawings were still in the process of being developed when the study was initiated. Thus, only a limited number of drawings were available for comparison. The Ship Alterations being worked on the A0 class were not particularly suitable to the analyses because a large number of the drawings being used were not the original drawings of the shipbuilder, but were drawings prepared by the Planning Yard for accomplishing prior system changes.

The choice of the FFG class had to be discarded because the changes in construction techniques were accomplished primarily by production planning documentation without making new drawings to suit modularization of the process. A revised plan, to use the DDG-51 modular drawing5 for comparison with the FFG system drawings in the development of FFG Ship Alteration planning, could not be effected because the DDG-51 construction drawings were in the earliest stages of development and their ultimate configuration was still a matter of discussion at the shipbuilding yard.

As a result, the approach which was actually carried out involved discussions with personnel at various naval activities, including Supervisors of Shipbuilding, Planning Yards and ships force, using typical A0 drawings and typical TAO drawings. of the personnel contacted, only those from PSNSY actually made the effort to visit Sup-Ships New Orleans and Avondale Shipyard to see first hand the products which has been being generated there and accepted by the Supervisor for several years. The author has visited a number of private and public shipyards to identify the format and content of the drawings which they are now producing.

The findings and conclusions in this paper represent the author's reac-

tions to all of these discussions, and are not intended to imply any agreement or disagreement by or with any of the personnel or activities with whom he had contact.

SHIPBUILDERS DRAWINGS

The Stages of the Detailed Design Phase

The Detailed Design Phase, which is carried out by or for the shipbuilder, consists of several separate stages. The drawings and other documents which are produced in each detailed design stage are quite different because they have different functions to perform. Reference (1) identifies four different stages, as follows:

1. Basic Design Stage
2. Functional Design Stage
3. Transition Design Stage
4. Working Drawings Stage

Stages 1. and 2. above are frequently classified elsewhere as a single stage. However, the above division recognizes the difference between the general space arrangement drawings and key structural drawings which must be defined immediately after contract award, (Basic Design Stage), and the system level drawings, produced during the Functional Design stage, for which the Basic Design Stage arrangement and structural drawings are prerequisites.

The primary impact of modular construction on the content of drawings is on the working drawings produced during stage 4, but all drawings have been impacted to some degree, as will be discussed in later paragraphs.

The Impact on Drawings of Different Types of System

The effect of modular construction techniques on content and format of drawings has not been the same for drawings of different types of systems. For the purposes of this discussion, it will be useful to categorize ship systems as either Structural, Mechanical, Piping or Electrical. In this classification scheme, Heating, Air Conditioning and Ventilation Systems (HVAC) are considered within Piping because of their functional similarities.

Electrical System wiring drawings have been modified the least, since most of the wiring installations are accomplished after the erection of the construction units into blocks or into the hull, i.e., they are installed "On-Block" or "On-Board". Where it is found more effective to install electrical wiring systems during the unit outfitting stage, then the drawing information should be oriented to the unit(s) involved. Wireway drawings,

for Instance, should be unit-oriented in order to allow installation of the wireways at the most appropriate point in construction. Normally this will be when the decks to which they will be attached are in the upside-down position. where all items which will ultimately be located on the overhead can be installed with the least manpower expenditure.

Many Mechanical systems drawings are unchanged for modular construction, because the information which they provide is normally more installation oriented, even in non-modular construction. If the equipment can be included in a machinery unit package, however, then the information will be provided in that installation drawing package.

The remaining discussion of drawing content will relate primarily to Structural and Piping Systems, because they are the most affected by modular construction techniques.

Basic Design Stage Drawings

General. In the United States, ship owners normally provide prospective shipbuilders with a number of drawings which, in addition to a set of shipbuilding specifications, describe the ship which they want to buy. However, since the contractual requirements usually make the shipbuilder responsible for delivering a ship which meets specified technical and performance requirements, the shipbuilder must check and verify every element of the design. Besides, it is often possible for the shipbuilder to make changes to design details which significantly decrease the cost of procurement and/or construction, without degrading the quality or the performance of the ultimate product. Thus, it is normal for the shipbuilder or his design agent go through the entire design development again, to verify the adequacy of the design and to develop the details of fabrication and installation which are not considered in the early design Phases.

The drawing products of this stage of design, then, are similar to those provided by the ship owner, but establish the baseline that the shipbuilder will follow in the remaining detailed design effort.

Space Arrangement Drawings. These drawings provide a description of where all the spaces in a ship are located, the purpose of each space and the location of all major equipment within each space. This classification includes the General Arrangement plans, the Inboard and Outboard Profiles, and the Compartment and Access (C&A) draw-

ings. It also includes the Arrangement drawings for major spaces such as Machinery Arrangements, Pilot House Arrangements, CIC Arrangements, etc. Such drawings identify the locations of major structural elements SUCH as decks, structural and non-structural bulkheads, and principal scantlings. These drawings do not need to be changed significantly in format or content for modular shipbuilding. In general, they are not system oriented, but provide the background for many other drawings and provide constraints which affect the layout of individual systems.

Key Structural Drawings. A number of structural drawings, such as the Midships Section Drawing and Shell Expansion, contain details of structural scantlings which define the adequacy of the structure to meet the loads imposed on the ship. These provide the basis for other drawings, which provide a description of how the transitions of structural details are to be accomplished. Because all other systems must be developed around the ship's structure, these drawings must be defined early in the detailed design effort.

Functional Design Stage Drawings

General. The drawings produced in this stage are in some ways the most important documents developed in the entire design process, because they must provide all of the information which will ensure that each system can and will carry out all of the system's requirements, including all interactions with other systems. As such, they not only provide the shipbuilder with all of the information which must be used in the further development of fabrication and installation instructions, but also provide the owner and the regulatory bodies with sufficient information for their approval of the design. As will be emphasized later, they also provide the operators of the ship with the information necessary to understand the system's proper operation and to control the system's configuration during the operating life of the ship.

Note - For modular construction programs, these are the only system oriented drawings which are developed. In that sense they take on even more importance than they have had in the past.

Experience has shown that schematic representations of the system frequently are the most efficient ways of providing the required information. Thus, such drawings have generally become known as "Diagrams". Very often, the schematic representation of the system is shown superimposed on a back-

ground that identifies the spaces through which the system passes. This is especially common with certain distributed systems, such as piping, for which the routing of the system must be considered, and for which elements, such as valve locations, which are vital to the proper design and/or operation of the system, must be defined.

System Diagrams. For modular, as well as system-oriented construction, one diagram is produced for each individual system in the ship. For very extensive systems such as the Firemain system or the HVAC system, there may be many sheets in a system diagram. In practice, the term "diagram" is primarily applied to piping or HVAC system drawings. However, this term will be broadly applied herein to include certain structural and electrical/electronic drawings, which, like piping diagrams, serve to provide all of the information necessary to ensure that the subject system will adequately accomplish every function for which the system exists. Electrical One-Line drawings, for instance, also provide the basic design data that control the overall system configuration and component sizing and do so in a schematic format.

In the structures area, drawings are developed for major areas of the ship, such as decks, bulkheads and frames, which may be considered the principal systems of the ship's structure. In general, these structural drawings are not schematic, although it has become standard practice, in a number of other countries using advanced shipbuilding techniques, to use simplified representations of actual structure and thus to improve the productivity of the design process. For the purposes of the following discussion, these structural drawings will be considered under the term "diagram".

The information provided in Diagrams reflects the results of the calculations which have been made to determine required component sizing, material requirements and performance requirements. Data is provided in graphical, tabular or textual form, - whichever is the most effective technique for presenting the information. Since the diagram provides all of the data necessary for describing a system's basic functional requirements, including all information necessary to replace any component or piece of equipment in the system, it follows that a diagram is the only document created by anyone who needs to know how the system is or should be designed, and what constraints must be satisfied when modification of the system is necessary.

Transition Design Phase Drawings

General. To fabricate system components and to install them properly requires precise, dimensional drawing data. The schematic drawings prepared in the Functional Design phase do not provide that kind of information. The "tool" that is used to take the data relating to individual systems from the diagrams produced in the Functional Design Stage, and to combine that data into a form that allows dimensioned Working Drawings to be produced in Stage 4, is the Composite Drawing.

Composite Drawings. Composite drawings also are arrangement drawings, but provide much more explicit detail. Their primary purpose is to locate, with dimensional accuracy, every portion of every system that exists in a volume of the ship. Composites have been commonly used for system-oriented shipbuilding, but in such cases their use usually has been limited to certain major, usually very congested, areas of the ship, such as machinery spaces, living areas, etc.

They are intended to preclude "interferences", the scourge of all shipbuilding programs. In most cases, composite drawings are too complicated to be used by anyone other than the people who prepare them. Thus, although they are essential to the shipyard's design configuration control process, they are not normally deliverables to a customer.

Conceptually, the content and format of composites are no different for modular-oriented programs than for system-oriented programs. However, in modular programs they are used more widely, extending throughout virtually every space in a ship. They are used for defining systems' details to a much finer level, for determining interfaces between construction units and other construction elements. They have, therefore, become of even greater importance to the shipyard.

With the advent of computer drafting programs with multiple 2D overlay capability or full 3D power, shipyards with sufficient computer capacity are developing composites in the computer. There is a major ongoing effort within the shipbuilding community to expand this capability to include more than just graphics. The term "Product Model" is being used to describe this total description of the ship system, including material identification, etc., as well as configuration data.

Working Drawing Design Phase

General. Working drawings are produced primarily for the shipyard's production work force, to provide them with two different types of information. Both types of information may be included on a single drawing, but frequently, as will be assumed in this discussion, information relating to assembly and/or installation is provided on one drawing and fabrication data is provided on another. Thus, the first of these types of drawings will be identified in this document as Assembly Drawings, while the second type will be designated as Fabrication Drawings.

Assembly drawings are developed before Fabrication Drawings, because the system configuration must be established before the system can be broken up into the elements from which it will be built. Therefore, although Fabrication drawings are the first drawings to be directly used in the entire construction process, they are necessarily the last to be produced in the entire design process.

The construction process also requires the development of some type of work instructions, usually trade-oriented, which describe the precise work which is to be accomplished, how it is to be done and which drawing(s) and other documents are to be used for direction or guidance. These work instructions are developed normally within the Production Department, rather than by the Engineering Department. This study effort did not address the content of work instructions, but it is worthy of note that these should be work site oriented for modular construction.

Fabrication Drawings. Although the ship construction process is primarily an assembly process, each shipyard will manufacture as many of the parts to be assembled as they can efficiently produce. The fabrication drawings provide the data needed by shop personnel for manufacturing those portions of a system which the yard will build. Fabrication drawings are sometimes produced by subassembly, although it is more common for fabrication drawings to be developed by unit, with part numbering systems used to identify the work site where the part will be installed.

Many fabrication drawings have been produced by shop personnel in the past, and, being considered shop sketches rather than drawings, have not been given to the ship owner upon delivery.

However, it is becoming more common; particularly since the use of computers for drafting, for these drawings to be developed in the Engineering Department and to be listed in the Ship Drawing Index. As such, they have ended up as deliverables. Thus, the Navy will receive more fabrication drawings as a result of shipbuilders using modular construction techniques.

Assembly Drawings. These drawings provide production personnel with all of the information needed for creating structural elements and for installing equipment and other parts of systems into the structure, including the dimensionally accurate location of each piece that is to be assembled. Although the function of these drawings is the same for system-oriented and modular construction practices, the drawing content is markedly different in each case. The differences will be discussed below.

System-Oriented Working Drawings

During the working drawing phase of system-oriented shipbuilding, designers produced a separate detailed assembly drawing for each individual system on the ship. Similarly, fabrication drawings provided data relating to only one system on each drawing. Work instructions covered the installation of a single system throughout the ship.

Structural working drawings showed the exact dimensions of each piece of steel from which a deck or bulkhead was to be built and also showed how the parts were to be welded together to build the "system". Thus, one drawing could be used to determine how to cut out and weld up all the pieces which made up one structural "system" of a ship. Decks were considered as structural systems in this approach, as were Bulkheads, Frames, etc.

Piping configuration drawings showed the distances of the system's piping from major structure, such as the deck overhead or a bulkhead stiffener, for example. One serious drawback to these drawings was that they did not show the location of other piping systems. It was therefore necessary to look at several drawings to find the configuration details of different piping systems, even if they were, say, running parallel for many feet. Separate piping fabrication drawings gave construction details for each piece used in making up a single system, throughout the ship.

For electrical systems, wireway routings were developed from the composites and shown deck by deck. The wireways were then installed inside the ship after spaces were all closed in.

Modular Working Drawings

General. A shipyard using modular construction techniques cannot effectively make use of the type of system-oriented assembly and fabrication drawings described above. Instead, drawings must relate to the units, sub-units or blocks of units in which the system elements are to be installed. Unfortunately, since at this point in time virtually every shipyard is developing their own, individualized set of drawing types, which they consider will best enhance their producibility during the modular construction process, it is not possible to generalize on the format and content of the drawings being developed. However, the differences relate primarily to the size of assembly which is addressed in the documentation and to the nomenclature used to describe the processes involved. Some assembly drawings address individual units, some address each sub-unit, while some address blocks of several units.

A shipyard may use each of these in various combinations for different system types, i.e., structural drawings showing fabrication and assembly by sub-unit, plus structural drawings showing assembly of sub-units into units and fabrication details of any structural elements which may be added during that effort; piping assembly drawings showing several units in one drawing, with separate fabrication drawing packages for each unit showing the pipe details for all the piping systems in that unit; and wireway assembly drawings by block of several adjoining units.

Unit-oriented drawings. Unit-oriented structural drawings define the configuration of each of the structural parts from which a unit will be assembled, provide all of the welding information, and all of the dimensional details which must be used by the construction workers to construct the unit. Ideally, these drawings identify every hole which must be cut for any piping or electrical system penetration as well as all structural cutouts, so that these all can be accomplished during the original fabrication of the structure.

It is common practice in many yards to provide additional drawings for each stage of subassembly of each unit, particularly if the subassemblies are to be constructed at different sites and assembled at another location or if there will be outfitting of the subassemblies before they are joined with other subassemblies.

Unit-oriented piping system drawings show all of the elements of

every piping system which are to be installed in one unit. Thus, each such drawing is a mini-composite of all the piping system in one unit. Part fabrication drawings provide, in one drawing, information pertaining to all parts of all of the systems to be installed in one unit.

System Drawings by Unit. At one shipyard, for one program, a separate drawing was produced for fabrication and assembly of the part of each piping system installed in each unit. This was driven by someone's perception that it was necessary to maintain the purity of the SWBS number in the drawing number. This approach represents the worst of all worlds, in that it provides neither a complete system description nor a complete unit description, and therefore doesn't serve the real or perceived needs of any user! This extremely non-productive approach is no longer being followed and is mentioned here only in the hope that it will serve to ensure that no shipbuilder will ever again follow it.

Block-oriented Drawings. Some shipyards have found it desirable to show all of the piping in several adjoining units in a single assembly drawing, even if the piping will be installed in each unit at a different place or time. This has not resulted in any confusion for production personnel during the assembly process, since the personnel at a given work site are provided with only the pieces which are to be assembled at that work site, and are given work instructions pertaining only to the work to be done at their work site. It has not been found necessary in all cases to provide separate drawings for each work site.

Sub-unit-oriented Drawings. Because most units are built up of smaller sub-units, and in many cases sub-units are outfitted before being joined with other sub-units into units, it is very common for separate assembly drawings to be developed to describe the work to be done on each sub-unit and/or at each work site. At some shipyards, these are produced in addition to the drawings which provide information at the unit or block level.

However, at least one shipyard is presently planning to prepare all drawings by system type at the subassembly level, and to combine all of the sheets for all of the unit's subassemblies into a single unit booklet. Although this would appear to provide all of the information needed in the future for any part of any system of that unit, it does so in such a fractionated way that it will be very inefficient for the life-cycle process.

Machinery Unit Package Drawings

Most of the units into which a ship is broken down for the application of modular construction techniques are primarily structural units, to which portions of other systems are installed during the construction of the unit. However, it is very cost-effective to assemble several items of equipment onto a common foundation in the shop and then move all of this equipment as a complete entity into its final location onto a structural unit or on board. This entity can include all of the gages, tubing, and other instrumentation necessary to operate or control the equipment locally. It can be hydrostatically tested in advance. This approach has many been applied in system-oriented construction in a very limited way, such as for preassembled piping runs for congested spaces, but is being applied much more broadly in modular construction.

Separate drawings are produced for these machinery package units. It is common for these drawings to include structural and system routing details on separate sheets of the same numbered drawing. Thus all information needed to build or modify the assembly of any part of the equipment in that package is available in that drawing.

USERS AND THEIR NEEDS

Introduction

One element of the study effort was to determine what information is actually needed at each stage of the post shipbuilding process, an obvious prerequisite to a decision about the adequacy of the builder's products to meet those needs. This involved, first, identifying the users and then assessing the information needs of each of the users. In the U.S. Navy, as well as in any other Operator's organization, there is a defined structure for maintaining and operating the ships. Since that of the USN is more complex than most commercial operators, this study has concentrated on the USN structure. However, the findings are applicable to any operator.

Users

Ship's Force - The personnel who operate and maintain a ship on a daily basis are an important source of information about the need for modifications to existing system installations in order to improve the ship's performance or simplify its maintenance. Since the standardization of ships and systems within classes is a high priority in the USN because of crew training and maintenance planning considerations, system configuration changes are not

intended to be accomplished by ships force personnel without authorization. However, if the ship's force are able to accomplish the changes within their own resources, it is not unknown for them to do so, with or without the knowledge and consent of others outside the ship who have responsibility for configuration control.

Operating Commanders/NAUSEA Headquarters - These organizations ultimately are responsible for approval of proposed changes to ships existing systems and configurations. They frequently initiate the process, but more of ten approve further development of changes that are proposed by others.

Planning Yard - One shipyard, usually a public (US Naval) shipyard, is assigned the responsibility for maintaining configuration control of a ship class. This yard is also responsible for developing any approved system configuration changes to a Class of existing ships. The Planning Yard responsibility always includes the development of the drawings which are to be used by the Installing Activity, i.e., that shipyard which is ultimately authorized to accomplish the work. Most often, the Planning Yard is not the Installing Activity.

Supervisors of Shipbuilding - The USN has established several offices in different parts of the country, each of which is responsible for the contract administration of assigned shipbuilding and/or overhaul programs. Their responsibilities for shipbuilding programs include drawing review, occasionally drawing approval, oversight of the procurement of material, as well as quality assurance and financial management functions. Their responsibilities for overhaul and repair work include putting together packages of prospective work, distribution of these data for bidding purposes, selecting the yard which will accomplish the work, and oversight of the work being carried out by that yard.

Installing Activity - The shipyard, either public or private, which is assigned the task of making specific changes to a ship's systems.

Users' Needs

Ship's Force

Operation, Operation of the ship by the ship's force does not require use of the construction drawings developed by a shipbuilder. However, Equipment drawings, Technical Manuals and other documentation which the shipbuilder obtains from the equipment supplier are of more direct use to the ship's force. These documents also are

used by the shipyard personnel when installing, checking out and operating the ship's equipment during construction, but they are not developed by the shipyard. There is no change needed or desired in the format or content of this type of documentation.

There are still other documents, such as Damage Control documentation, Maintenance Requirement documents, Ships Instruction Books, etc., which may be developed by the shipyard, but these are not used by the shipbuilder for his own purposes during construction, and thus are not being addressed herein.

Maintenance. Maintenance of a ship, on the other hand, may require some of the shipbuilder's documents, as well as some of the other documentation such as Equipment Technical Manuals addressed above. Maintenance problems are usually equipment oriented, rather than system oriented, and normally are local in nature. Therefore the ship's force relies much more heavily on the equipment oriented documentation than on the shipbuilder's drawings. Since most of the problems which occur during operation relate to equipment, and since the cause of most of them is obvious, it is not surprising that discussions with shipboard engineering personnel revealed that most of them never use the drawings which they carry on board. They indicated that, with minor exceptions, the only time they went to the drawing file was to satisfy inspection requirements or to provide drawings to visitors to the ship, such as to shipyard personnel who come aboard to do shipchecks for various purposes. The minor exceptions include the need to use certain electrical drawings when checking electrical problems and occasional use of diagrams for familiarization purposes.

Despite the response described above, it is more reasonable to believe that shipboard personnel actually do need to have copies of every system diagram on board, since these drawings provide the only complete and concise description of how the system is supposed to be designed and of its intended operational parameters. These drawings also contain the information the ship's forces need for ordering replacement items. Whenever they need to make minor modifications to a system, they can use the same guidance (USN Ship Specifications and General Specifications, ABS Rules, Coast Guard Regulations, etc.) that was available to the ship's designers.

It is also to be expected that a Fabrication drawing would occasionally be useful for manufacturing a replacement item such as a length of

pipe, ventilation duct, etc. However, since these types of items usually can be made by templating existing parts, the availability of fabrication drawings is by no means a necessity.

Since the ship's force have the as-built ship as a full scale model, it is hard to imagine any need which they might have for detailed arrangement drawings, except in the case of major damage due to collision or battle damage. However, even then, the emergency on-site repairs which would be made by the ship's force or by other repair activities, would constitute emergency repairs, for which the detailed drawing information would be very useful, but not essential.

Planning Yard

General. Planning Yards have the greatest functional need for the shipbuilder's drawings, since they must provide similar drawings to other shipyards for making modifications to the ships' systems.

Planning. The Planning Yard's efforts normally start with receipt of a Ship Alteration Record (SAR), which describes what changes are to be made to a system and identifies what equipment will be provided by the authorizing activity, and with authorization to develop the drawings and other data which will be needed by the Installing Activity to accomplish the work. The Planning Yard efforts require the availability of system diagrams of all systems impacted in any way, for evaluation of the impact on sizing of equipment or system components and for ease in identifying system material requirements.

Shipcheck. The yard then, using the Ship's Drawing Index as a guide for identifying the drawings needed, gathers together all of the ship's Assembly drawings which relate to the systems involved in the Shipalt. They take these documents to the ship and use them to check whether the actual installation is as shown on those drawings. They also verify or determine and document how the revised installation will be configured by either marking up the as-built drawings or developing sketches onboard.

Design Development. Following the shipcheck, the Planning Yard personnel develop all of the drawings that will be required by the installing shipyard for accomplishing the work involved. This may involve preparation of drawings which describe what parts of an existing installed system are to be ripped out, using the assembly drawing, as well as drawings which describe the new installation. Ripout drawings

can be made quickly and easily by tracing existing assembly drawings, in the manual mode. The modifications will be even easier to produce for drawings which exist in computer files. Fabrication drawings would provide much useful information to Planning Yard personnel if available.

Supervisors of Shipbuilding

Shipbuilding. Since the primary time frame of interest in this study is the post-shipbuilding life cycle of the ship, the Supervisors' need for drawings during shipbuilding is noted only in passing. Obviously, all drawings produced by the shipbuilder are needed by SupShips during the building phase.

Overhaul. In order to properly carry out their responsibilities for overhauls, the SupShips organizations would need only the drawings prepared by the Planning Yard if there never were any question of their accuracy. However, despite the fact that the Planning Yard is responsible for the technical adequacy of the drawings, the Supervisor must have both the System Diagrams and the Assembly drawings of the as-built ship in order to properly and expeditiously respond to technical questions which arise.

Installing Activity

Installation. The installing activity should need only the drawings provided with the government's contract to do the work, thus it does not have any functional need for copies of the original shipbuilder's drawings in order to accomplish the changes to the systems' configuration.

EVALUATION

Introduction

It has been determined in the foregoing that, with the exception of manually developed composite drawings, all of the different types of drawings developed by shipbuilders during the Detailed Design Phase are useful, in varying degrees, to each of the USN organizations which have life-cycle maintenance responsibilities.

In the past there has been no need for users to receive copies of the composite drawings, which are used by the shipyard for integrating all detailed system arrangements. However, with the advent of computer drafting, it ultimately will be helpful for the Planning Yard to have the computer tapes with the composite data.

Nevertheless, it was found during the study that certain changes must be

made to these drawings in order to make them better able to serve the life-cycle users' needs, even though there has been no need for the shipbuilders to significantly modify the content or format of the system diagrams for their own purposes in effectively converting to modular construction techniques.

The working drawings represent the area of greatest concern or interest, primarily because their format and content have changed so greatly from those with which users have experience, but secondarily because there are not yet any standardized techniques for providing the required data.

Each type of drawing will be discussed separately, after which a series of issues of general applicability to each type of drawing will be addressed.

System Diagrams

General. All of the information that has been provided by shipyards in system diagrams for system-oriented construction remains essential for modular construction. However, what has not been recognized, in general, is that additional information must be provided on the diagrams whenever all working drawings are developed to suit modular construction, i.e., to address units instead of systems. If it is necessary to call out these requirements in contract language as part of the shipbuilding specifications, then it should be done.

Correlation with Working Drawings. As has been covered in detail elsewhere, working drawings for modular construction seldom, if ever, show a complete system in one drawing. Major systems will appear in many separate block, unit or sub-unit drawings, instead of a single drawing. In the past, when it was necessary to go from the system diagram to the working drawing which covered a part of the system about which one needed additional information, there was only one drawing to find and look at. Even if the diagram did not include the number of the corresponding working drawing in its reference list, the working drawing's title would include the system name and its number would include the same SWBS number as the diagram, making it simple to quickly locate the correct number in the Ship's Drawing Index (SDI). This is not possible when, as in modular construction, working drawings are not system oriented.

During the course of this study, the author has not seen any system diagram which has provided any technique for leading one to the related working drawing(s). The only technique currently available for find-

ing the drawing which contains the details of interest is to go through the following steps:

- a. Find a drawing which identifies the ship's unit breakdown.
- b. Identify the unit number(s) most likely to include the volume of the ship in which the pertinent part of the system is located.
- c. Search through the SDI to find the working drawing which has that unit number in its title or in its own drawing number. This assumes that the working drawing numbering system or the drawing title will include the unit number. Otherwise, search through the SDI to find some other clue to identify the desired drawing, such as the compartment type.

This technique is obviously very inefficient. Of several possible solutions to this as yet generally unrecognized problem, the simplest would be to provide a matrix table in the diagram, to correlate each area of the system diagram to the number of the working drawing which contains the detailed information about that part of the system. It would be very helpful, but inexpensive, to show the location of unit boundaries on the diagram, as well.

Correlation with Compartmentation.

Once a ship is built, the easiest way to describe the location of a piece of equipment or of any part of a system is by use of the compartment number in which it is to be found. Therefore, the compartment numbers should be shown on diagrams. The most effective way to do this will vary, depending on the extent of the system, but in most cases it can easily be accomplished by using a schematic representation of the compartmentation as a background for the system routing shown on the diagram and labeling each compartment by number. Labeling the compartment by name would even further enhance the ease with which the diagram can be used.

Assembly Drawings

General. The major user of the Assembly drawings during the life cycle of a ship is the Planning Yard. Their primary use of these drawings is to verify, by shipcheck, that the data on the drawings is accurate, so that the designers can use that data with confidence when developing their new drawings. In the manual drawing mode, the original drawings sometimes are used for tracing unchanged portions of the system.

Numbering and Titling. As mentioned earlier, in order for the working drawings to be most useful to users, they must be identified in such

a way that they can easily be related to the portion of the ship to which they apply. Thus, the system used for the titling and numbering of working drawings must allow easy recognition of the unit, block or compartment(s) to which the drawing relates.

Modular vs System Orientation. Because these drawings are used by the Planning Yard for shipchecking of the existing layout of ships' systems and for planning how to modify the existing layout to most effectively accomplish the purposes of proposed system changes, it is obvious that the unit- or block-oriented assembly drawings, which provide a composite picture of all the systems in a given volume of the ship, will be much more useful to the Planning Yard than the single system drawings which they have had to use in the past. This will be true even when it is necessary to look at the whole system, which may involve looking at several unit-oriented drawings. When using system-oriented data, it is always necessary to look at several drawings, but even then the inter-relationships between systems are much more difficult to discern.

Area Coverage. To be of greatest use to the Planning Yard, assembly drawings should show data relating to an area of the ship which has some functional significance, such as at least one level of a machinery space. This will usually require that more than one unit be included in the drawing.

at the other end of the spectrum are Assembly drawings which show only the data relating to the construction and outfitting of each individual sub-unit. While such drawings may be considered ideal for the use of the building yard, they will not provide enough data to be useful to the Planning Yard. It will be necessary for the Planning Yard engineer to review top many drawings in order to obtain the information concerning a meaningful volume of the ship.

Since some shipyards have bypassed the block or unit level of drawing and are concentrating on producing only the sub-unit level for their own use, it is possible that shipbuilding contract language will have to address this issue. The two aspects to be considered are:

a) whether the shipyard needs to generate these block or unit level drawings (in addition to at least some sub-unit level drawings) for their own productivity and

b) whether the users need this level of drawing to most effectively carry out their responsibilities.

Since it has been evaluated in this study that the answer about the betond aspect is "yes", the first aspect must be addressed. At this time is in only possible to state that at least, one of the yards which converted completely to modular construction techniques has found the block/unit level of drawing to be sufficient for all work but structural work.

Specifically, in the building of the TAO program, most piping assembly drawings covered a block of several units and were used directly at each construction site by the shipyard production workers. Fabrication drawings for piping, on the other hand, were developed unit by unit. Structural drawings, containing both fabrication and assembly data were developed by unit and then used by mold-loft personnel to develop additional drawings at the sub-unit level. The sub-unit level structural drawings were the primary drawings used by production personnel during the construction process, but the unit-level drawings produced by the engineering department were continually available for reference. This combination was considered by that shipyard to be very cost effective, and has continued to be used in their subsequent shipbuilding programs.

It is also of significance that one Planning Yard has taken the trouble to visit this shipbuilder and review the content of the drawings being produced, and has concluded that the drawings as being generated will satisfy their needs, with the exception of certain of the matters being addressed in this report.

Other shipbuilders are pursuing different courses. It may be coincidental, but the shipyards which are developing the most detailed levels of drawings are the ones with the greatest computer drafting capabilities. It is possible that some drawing practices are being driven more by a desire to make maximum use of the computer drafting capabilities that exist than by the results of a demonstrated cost-benefit analysis. The results from these building programs, when completed, will be of great interest to the industry.

Readability. Many of the modular-oriented assembly drawings which have been developed to date are SIGNIFICANTLY harder to read than single system drawings, which can be difficult enough to follow, anyway. Although experience with the terminology and content of modular drawings makes their use less difficult, and obviously the shipyards themselves are using them successfully, an improvement in readability is a most desirable

goal. Systems which traverse large areas of a drawing need to be identified frequently enough that a user does not have to search all over a sheet to find what the lines represent. Scales must be large enough that all of the identifiers and dimensions on the sheet can be read without confusion. Common sense will ultimately prevail, but early attention to this need will be helpful to all concerned.

Fabrication Drawings

These drawings have been determined by Planning Yard personnel to be extremely useful for their efforts to provide information to Installing Activities for replacing existing systems. Fabrication details in the past of ten were left for the shop planners to develop, but are now a recognized part of the Design Engineering effort. As such, they are included in the Design Drawing Schedule and included as deliverables to the government at the end of the contract.

While not exactly a life-cycle issue, it is notable that these fabrication details, being deliverables to the government, can be made available by the government to the shipyards which produce follow ships of the class, and in the author's opinion should be. Whether they should be made available during the bidding process is arguable, but seemingly it would be in the government's best interest to provide these drawings as part of the follow ship contract award, at least, so that the follow shipbuilder would not have to expend the effort to replicate them unless he chose to do so because he had a more cost effective fabrication technique available. Unfortunately, the specter of Claims against the government, when documents provided by them are found to have any problems, is an overriding deterrent from doing some otherwise intelligent things. There are a number of fairly obvious ways of overcoming this problem, but it will require a greater desire to do so on both sides of the contracting table.

General

User Capabilities. Another important consideration in the evaluation of drawing format has to do with the customers' ability to use the data as developed. With many drawings being developed on computer drafting systems, it is frequently assumed that the shipbuilders will only have to turn over the data bases to the customer and the customer will be able to generate drawings in any format and with any content that the customer desires. It must be recognized that although many Planning Yards and other USN activities have ex-

cellent computer facilities, it is a fact that most lag well behind the private shipyards in the number of terminals available to design personnel.

Further, despite some excellent continuing efforts, the commonality of the systems which are currently available in various shipyards is by no means adequate, nor is there adequate ability to transfer and use data generated in different systems. Until a number of serious problems are solved, it will be absolutely necessary for the customer to require delivery of hard copies and reproducible masters of drawings that are in the format and that have the content identified herein as being most useful.

Drawing Maintenance. Discussions with Navy personnel, aboard ship and at the Planning Yard, have identified that the ships drawings are not being adequately maintained in an up-to-date status.

Drawings and other documents which are identified as Selected Records Data are supposed to be maintained current at all times. Specifically, within 90 days after any availability, all SRD is to be updated to reflect all changes made to the ship's systems' configuration since the last update, i.e., to include all authorized and unauthorized changes which have been made since the last update.

The first problem is that this policy is very poorly executed. Most ships are operating with most of their SRD at least one year out of date, with the documents to be changed sitting in some design office awaiting additional funds to complete the effort.

The second problem is that, except in submarines, most system diagrams are not included as SRD. Those portions of diagrams and other documents which appear as enclosures in Technical Manuals or Operating Manuals will be updated, since those documents are included as SRD, but the actual drawings will not.

The situation is exacerbated by the fact that there is no requirement for the Planning Yard to update the Assembly drawings, which are the only drawings which provide a true, dimensionalized description of the ship's configuration. The drawings produced by the Planning Yard provide the installing activity with just the information needed to rip out any portions of existing systems that are to be replaced and to install the replacement parts. Fabrication data may be left for the installing activity to develop. Thus, after more than one

change to any existing system, there may be three or more drawings which have to be reviewed together in order to obtain an accurate description of the current configuration of the system.

It is hardly surprising, under the circumstances, that the ships force personnel don't feel that they have much need of drawings of the ship or its systems (or for those who are responsible for providing this service to them). The ship as it exists is the only description of its configuration that they feel they need. Indeed, it is probably the only correct description that exists.

If there is any need for any of the drawings developed by the shipbuilder to be maintained in a current state of accuracy, (and there most certainly is), the priority should be given to system diagrams, space arrangement drawings and then assembly drawings. When computer composites exist and can be updated, then their priority would come after diagrams and before space arrangements, and their updating would eliminate the need to update assembly drawings.

Format Issues. One significant item concerning drawing format emerged during discussions with Puget Sound Naval Shipyard personnel. The introduction of computers into the design process has led to the typing of many portions of some drawings, such as General Notes or Material List information, at a terminal. The problem occurs when these sheets are printed out on paper of a different size than the rest of the drawing. This is not unique to drawings prepared for modular construction, because this problem already exists. The problem comes when someone attempts to obtain a copy of the drawing. If part of a drawing is prepared on large sheets, which are rolled up for storage, say in the Technical Library, and other parts are prepared in booklet form using 8 1/2 x 21 paper, the Technical Library will very likely end up stowing the booklet portion in a location separate from the rolled storage. Then, when someone orders the drawing, they may not get all of it. The solution that has been used by one shipyard is to develop the material information as a separate "drawing", with a unique title and drawing number. The essential element of any solution is that all sheets of any drawing be of identical size.

CONCLUSIONS

The conclusions of this study, based on the evaluations described in the preceding chapters, are as follows:

The Space Arrangement drawings and System Diagrams are needed by all activities involved with ship maintenance planning and configuration control.

The importance of System Diagrams needs to be emphasized. Updated versions of these documents must be available to the ship's force and to all involved maintenance activities at all times. The format of these drawings needs to relate directly to both the final ship compartmentation and the construction unit breakdown. The drawing content must include a matrix table or other technique for uniquely identifying the assembly and fabrication drawings which provide the details of how each part of the system is made and/or installed.

Composite drawings are needed only by the Planning Yard, and then only if they are in the form of computer data, suitable for use in producing copies of drawings by the Navy personnel.

The primary user of Arrangement and Fabrication drawings is the Planning Yard, but the ship's force also need to have copies available for potential use in emergency situations. Supervisors of Shipbuilding also will need these drawings for ships whose overhauls they are supervising.

There is no need for the Navy to receive detailed arrangement drawings of individual piping, structural or electrical systems, as long as they receive arrangement drawings which show the arrangement of all of each type of system in a reasonably large area of the ship. The modular type of drawing will actually meet their life-cycle management needs better than the individual system drawings.

The page size of all sheets of each uniquely numbered drawing must be the same.

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Improvements in Productivity Through Staff Integration

No. 4A

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Abstract

Too frequently, today's shipyards are a product of their history. Their organizations represent the experiences and successes of the personnel. In the past this has been adequate because the maritime business was largely subsidized by federal government programs. Reductions in these programs have directly reduced the business available to shipyards. As a result, shipyards are failing at a record rate. The prognosis is not good.

This paper addresses one facet of improving a shipyard's position in an increasingly competitive environment improvements in overall productivity resulting from integration of the functions of the shipyard staff. First, an organization is described, identifying the staff and defining its purpose within the shipyard. In a typical shipyard, the staff includes organizations for estimating, planning, engineering, purchasing, and contracting. The responsibilities of each of these groups is discussed and, in particular, the areas of interface between them are highlighted.

Using the information developed, the paper then examines known problems, based on shipyard experiences, which are responsible for reduced productivity. The paper then provides an outline for integration of staff functions, using simple process control and data processing which will reduce staff overhead and provide improved estimating, material flow, and scheduling support to Production.

Introduction

In 1878, as American enterprise was beginning to discover its place in the industrial revolution, an integrated shipyard was founded. Nathaniel Greene Herreshoff, hoping to get into the steam engine building business, joined his brother, John, with the provision that John would pay all the bills promptly, not borrow money for expansion or construction, and never undertake any work that would require more capital than was on hand. Although the agreement seems quaint today, everyone in this audience is familiar with the success of the Herreshoff Manufacturing Company.

Now, despite an ever-increasing world population and its demand for shipping, orders for new ships have dwindled. Five years ago, the west coast of the United States supported five major commercial shipyards and more than two dozen repair facilities. In 1988, only one shipyard has avoided Chapter 11 bankruptcy proceedings and a handful of repair yards remain. Shipyards throughout the country have imported expertise from around the world to improve their standing in the marketplace. By this time, most of the experts have gone home and the situation continues to worsen.

The purpose of this paper is to suggest a home-grown approach to the improvement of shipyard productivity within the narrow scope of the shipyard staff. For better understanding of the issues, it is necessary to define "productivity", and to review the typical modern shipyard organization. This paper will then identify the elements which made the Herreshoffs an integrated, successful organization. With that background, it will be possible to extrapolate the integrated approach into today's shipyards and demonstrate how the use of modern analytical and data management tools will permit managers to deal with increased detail without turning over control of the shipyard to disparate entities.

Productivity

Productivity is much like the weather: everyone talks about it, but no one does much about it. Perhaps this is because there is a lack of understanding. For example, it is simple to put up a barometer, a thermometer, and an anemometer to collect a few data points. But these are not likely to provide enough information to permit an understanding of the phenomenon. Similarly, to understand productivity, it may be helpful to collect data; it is essential to know how the data is to be correlated.

First, there must be an agreement about what productivity is, and how it is to be quantified. In general terms, productivity is the quality of creating goods, benefits and services. This paper will use a more quantitative definition: the ratio of the value received for the end product to the total cost of producing that end product.

Usually, there is not much disagreement about the numerator of that ratio. Except for change orders and claims, its value is known when the contract is signed. Therefore, in order to maximize the ratio during the post award period, shipyard management must effectively reduce the denominator.

The elements of the denominator are the cost of materials, the cost of the labor to assemble those materials, the cost of the facilities in which the assembly takes place, and the cost of the staff required to coordinate the entire process. Each of these elements needs to be considered separately, but such a study is beyond the scope of this paper.

For the purposes here, it will be assumed that the cost of materials and cost of facilities are simple quantities, varying from shipyard to shipyard by some small constant. Labor rates paid to the staff and production workers are, of course, highly variable. This paper intends to provide recommendations which will result in a reduction of the personnel costs which make up a large part of the denominator.

The Modern American Shipyard

In a modern American shipyard, the shipbuilding function is divided into many sub-functions, each with its own requirements and, too frequently, each with its own ends. There are probably as many organization charts for shipyards as there are shipyard vice-presidents. It is the intent of this section to describe a generic organization which approximates all the others.

The organization of the typical modern American shipyard has two weaknesses. First, the organization is often dictated by the personnel available, rather than the functions to be performed. Secondly, staff selection is based on personal relationships more than personal competence. Shipyard repair organizations abound with these "Good-Ole-Boy" relationships.

In the operation of a shipyard, there are functions which are strictly related to the end product, be it a new hull or a repair. At the same time, there are many functions which are necessary as a part of doing business and which have no specific relationship to production. Organizing the staff solely to support the project is inefficient overall because of the unique character of the project and the personnel responsible for it. Likewise, organizing for support of the administrative requirements is generally unresponsive to the needs of the projects, which are life's breath to the shipyards.

By this time, most American shipyards have attempted to create a sort of hybrid organization to serve the apparently divergent needs of projects and administration. By and large, these organizations have been carefully thought out by upper management. They are tailored to suit the particular strengths of the middle managers and staff which are present in each shipyard. Unfortunately, the failure of matrix management systems is not a failure of concept, but a failure of im-

plementation. There are two reasons for this failure.

First, the middle management of nearly every shipyard in the United States has come from within. Not necessarily a bad thing in itself, this instills a "trade-oriented" view of the shipyard operation. As a result, there are lingering loyalties and biases within middle management which permit breakdowns in communications between functions.

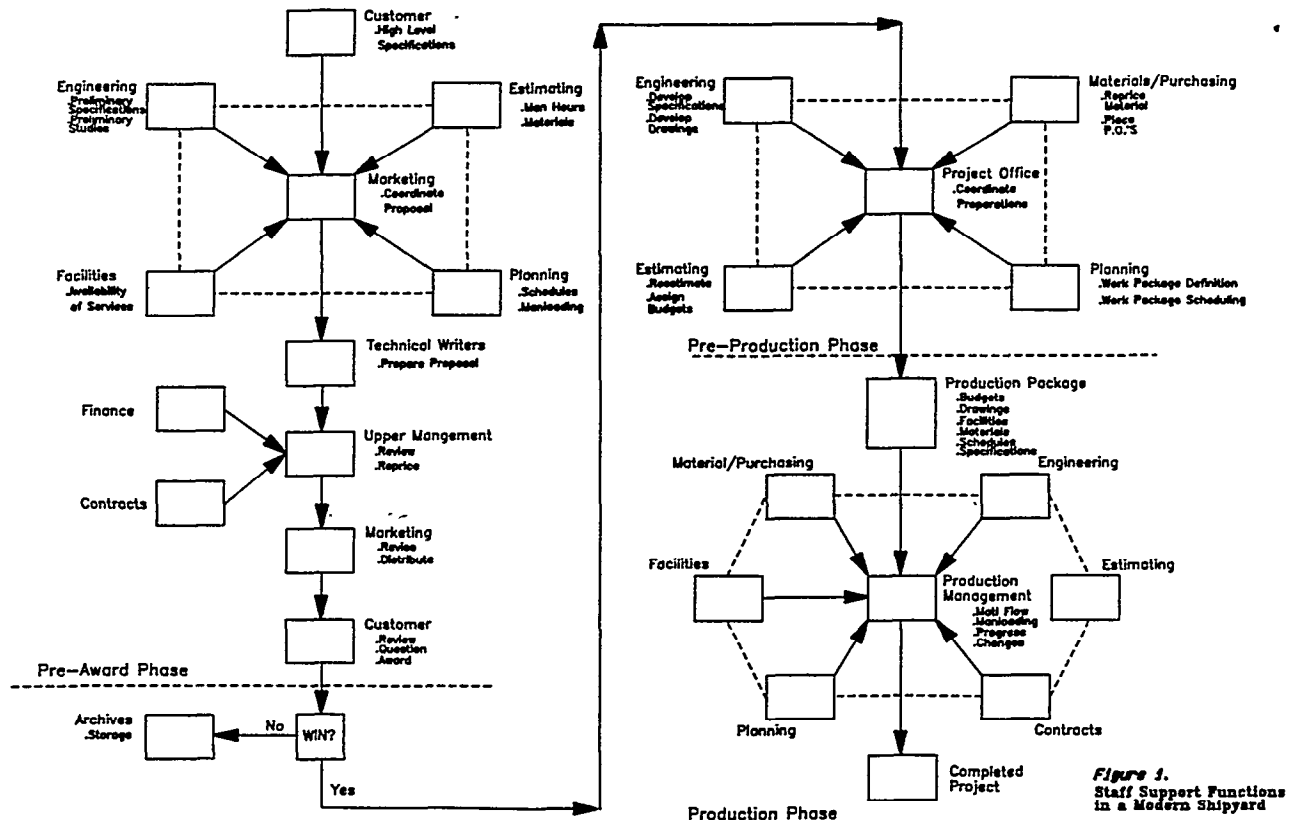
Second, staff organization is nearly always decided by upper management without reference to the staff. As a result, personnel are put into positions in which they have no real interest or talent, they have no sense of participation in their own destinies, and they judge that upper management is either ignorant of the true situation or doesn't care. As a result, the staff often continues to perform the same function, regardless of the organization, and the denominator of the productivity equation stubbornly refuses to get smaller.

Now, it is necessary to describe the functions which are to be performed by each segment of the middle management organization.

Contracts-Provides a legally competent interface between the shipyard and the customer. Is responsible for defining documentation requirements for matters such as change orders, accelerations, payments, and delays.

Engineering-Describes the end product (either a ship or a completed repair job) in terms of materials, specifications and producible elements. Describes the standards by which the end product is built and tested.

Estimating-Describes the end product in terms of total cost to complete- usually in manpower requirements, material costs, and facilities utilization.



Facilities-Maintains and provides the shop space, warehousing, erection areas, and utility services to support the construction of the end product.

Marketing-Coordinates the preliminary descriptions of middle management and presents them in a form which will be palatable to upper management and most attractive to the customer.

Materials/purchasing-Identifies materials and subcontractors which are required by the drawings and specifications; evaluates the cost of each alternative, selects material and subcontractor sources, negotiates final pricing and issue purchase orders to selected vendors.

Planning-Describes the process for assembly and installation of materials and producible elements within the construction time-frame.

Production-Using the materials, drawings, estimates and schedules provided by the staff, constructs the end product within the budget and schedule.

It should be noted that Production is not a staff function, but is a user of all the efforts of the staff. As a result, production personnel are almost completely dependent on the quality of the staff effort. Still, some shipyards evaluate their productivity only in terms of Production Department effort required to complete a particular job.

In order to evaluate the functioning of any mechanism, it is instructive to develop a model which describes the process which the mechanism performs. Figure 1 is a flow chart model of a shipyard. It describes the activities within the shipyard during one complete cycle-the construction of a ship. Since the central focus of this paper is to examine and integrate the workings of the staff, the figure emphasizes those at the expense of a more detailed examination of the production phase.

The process is started by the customer coming to the shipyard with a specification of work to be accomplished. This may be a high-level performance specification in the case of a new construction project, or detailed work specifications for a ship repair. Regardless, in most shipyards the process of developing a response to the customer is the same: Marketing parcels out areas of specific responsibility to each of the other staff groups. They, in turn, develop responses within their areas of expertise, working toward the schedules established by Marketing. Because of the compressed time frame allowed, all functions proceed more or less in parallel despite the obvious interdependencies. Furthermore, Production is virtually excluded from the pre-award phase of the shipbuilding process. As a result, production experience gained from previous contracts is not incorporated into the engineering and estimates for new efforts. This is particularly critical when developing proposals for Navy repair work: many of the work packages are virtually identical from ship to ship.

Meanwhile, Marketing hires an itinerant group of professional writers to create the shipyard's image by writing the technical proposal. In practice, of course, these relationships are longstanding; usually the technical writers are reasonably familiar with the shipyard organization and staff. Although this is generally desirable, there are two matters which to be considered. First, despite apparent familiarity with the shipyard and its operation, the consultant frequently describes technical details the way he believes they should be done, rather than as an actual process. Furthermore, the marketing staff is usually sufficiently removed from the shipyard that they will fail to detect the differences during their review. As a result, commitments may be made which later prove impossible to fulfill. Also, when the consultant has his purchase order in hand, the competition is over for him. From that point on, he has only to take the information provided by the shipyard staff and arrange it in the most attractive way; the outcome of the shipyard's competition is of interest only as future advertising.

About a month before the submittal date, shipyard upper management meets to review the proposal. In general, these reviews are limited

to two questions: have we committed to do something (such as reorganize our cost accounting system) which we are unwilling to do? And, do we need the work badly enough to take it on for this small a profit margin? Needless to say, there are a large number of considerations which go into these reviews, and those will not be addressed here. Most frequently, however, the Proposal emerges from the upper management review with significant editorial change and a direction to modify the pricing downward based on considerations of improved productivity. The proposal is then revised, printed, and submitted to the customer.

While the shipyard goes on to other things, the customer reviews the proposal, perhaps asks questions and, six weeks to six months later, may award a contract. If the generic shipyard loses, there is appropriate grumbling and internal recrimination and the proposal is retired to the archives.

If, however, the generic shipyard wins, there is brief elation followed by a period of questioning about just how the end product is to be created for the price. At this point, a new entity, the Project Office, is usually created. Personnel in the Project Office usually have not worked on the proposal, so are unfamiliar with its contents. The function of the Project Office is similar, in the pre-production phase, to that of Marketing in the pre-award phase. Instead of a deliverable package of proposal material, however, the Project Office will coordinate the development of a production package. This package will include all the budgets, drawings, facilities requirements, materials, schedules, and specifications which are required to accomplish the job.

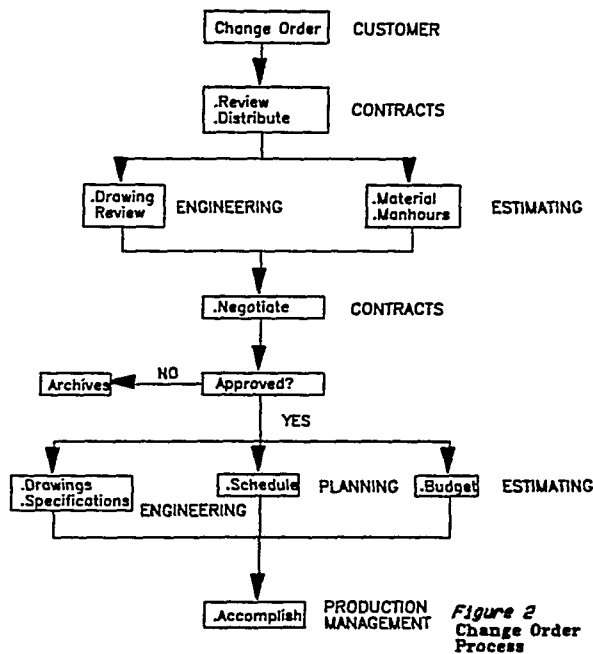
In developing this package, the entire project will be reestimated, repriced, and rescheduled. The proposal is now sent to the archives and supplanted by the new creation, and the result of any pre-award research which was done is lost to the shipyard. Again, because of time constraints, the functions which are serial in nature must be accomplished in parallel. This results in duplication of staff effort and discontinuities in the production package. At this stage, some shipyards begin to involve a few production foremen (particularly for engineering) to assist in selection of materials and lay-out for welding procedures.

Finally, the entire package is turned over to Production for accomplishment. Usually, the Project Office continues staffed to accommodate customer relations, monitor large-scale subcontracts, and coordinate between Production Management and the staff. In most shipyards, the Project Manager and the Production Manager report to different organizations, which results in differing priorities relative to the completion of the ship.

For example, Production is usually oriented to manpower and scheduling considerations; Project Management is usually concerned with contractual aspects. Figure 2 shows a typical sub-process the estimating and accomplishment of a change order. Frequently, the need for the change has originated with Production and, in that organization's view, the sooner it is completed, the better. Time is of the essence for Production because failure to accomplish this change is holding up progress on all subsequent steps in the process.

The staff, however, is concerned with assuring the change is properly documented and that the shipyard is adequately compensated. The customer, of course, has similar concerns. As a result, production is rescheduled around the staff efforts required to support that particular change. If no change is subsequently authorized, the scheduled time for that function may be irretrievably lost. Frequently, the schedule loss is more valuable than the cost of the change, but there is usually no compensation to the shipyard. As a result, the shipyard must file claims subsequent to delivery, making documentation essential and confirming the need for additional staff personnel.

One staff function which does not appear in Figure 1, but which has a profound effect on the shipyard's operation, is the data management system. Since the generic shipyard represents a typical ship-



yard, the data management system is under the purview of a staff manager whose background is in computer applications. The system provides support to engineering, accounting, payroll, materials, purchasing, personnel and production management. The system is outdated, and full of patches which have been installed to meet specific requirements for specific projects, most of which have been completed. There are access terminals throughout the shipyard, but they are used only by the anointed few. While management has great confidence in the voluminous reports the system produces, the same reports tend to gather dust in dark corners of production offices or are thrown away as soon as they arrive. On the average, management's confidence in these reports is undeserved, but so is the staff's disregard of them. Periodically, data management personnel venture into the shipyard to seek out grass roots suggestions, but they are met with sullen hostility, recommendations which are not in their power to implement, and/or misplaced enthusiasm from trade personnel who see an opportunity for themselves in a new and exciting field of endeavor.

Upper management personnel who wish to verify the effectiveness of their data processing system can easily do so by counting the number of personal computers which are seen throughout the yard. Each of these represents an independent data base—a failure of the existing system to meet the requirements for a truly integrated system. To be sure, there are specific applications which require the unusual security which is available because of the isolation of the personal computer, but these are relatively few.

Now some conclusions can be drawn about the process the generic shipyard uses to accomplish its work.

First, it has been shown that the various staff entities work essentially alone, isolated from other groups because of difference in function, time constraints and frequently, personal indifference. Each entity identifies with its function, rather than with its project. Each project is also isolated from all similar ones by a deliberate plan to avoid comparing estimates, drawings and specifications from one job to the next and by elimination of Production Department inputs during early phases of the process.

Second, it has been demonstrated that the staff bears no responsibility for the success or failure of a project because during the pre-award phase upper management modified estimates and projections without reference to staff; staff has no means of anticipating the im-

pact of contract changes, and there is no workable system to provide them with an evaluation of how well Production performed on the estimate or schedule.

This review of Figure 1 also makes it clear that the production phase is only the final step in a series, and that the productivity of the shipyard is as dependent upon the staff support as it is on production. The pre-award and pre-production phases provide the production worker with the tools he needs to accomplish his job; the better the tools, the better the job. The remainder of the paper will address improving these tools.

The Integrated Shipyard

It would be nice to say that responsibilities were neatly divided in the Herreshoff Manufacturing Company, but that would not be true. The only functional area in which one of the brothers was clearly in charge was engineering. Nat was the Chief Engineer largely because John was blind from the age of fourteen. In general, though, Captain Nat served as Chief Engineer, Chief Planner, and Head of Production. John directed the remaining staff functions and was senior partner until his death in 1915.

It appears that virtually all major decisions were jointly made by the brothers. To permit meaningful participation in the decision making process, both of them had to have access to all data which was critical to operation of the shipyard. Yet Captain Nat spent eight hours a day wandering through the production areas, supervising construction. And they never owned a single data terminal!

Without belaboring the Herreshoff brothers, there are three qualities which enabled them to fully integrate the operation of their shipyard. First, both were technically competent; they understood the workings of a steam engine as well as they understood the workings of the business in which they were involved. They could no more be misled by a craftsman than by a lumber merchant. Second, they had confidence in each other's integrity. Each was sure that the other had their mutual benefit in mind. And, although perquisites were certainly available (by 1885 they had built themselves a 94-foot steam yacht) they were never an end in themselves. Finally, they appreciated and respected their staff. It was their policy to hire the best personnel available, to pay them well, and to provide them with the necessary training. By consciously courting the employees, John, in particular, brought them into the company as mini-partners and earned a sense of loyalty which would not have been possible had he simply hired them.

The keys to creating and maintaining the integrated shipyard staff are much the same today as they were in the days of Captain Nat and John Herreshoff. Using these keys, the goal of upper management is to improve staff productivity in the development of the production package. The tools at their command include: eliminating redundancy in the organizational structure, upgrading personnel skills and performance levels, and improving staff utilization of capital-intensive systems. To achieve these goals, two major problems must be addressed: personnel and data management.

Both of these difficulties can be overcome by following four steps: evaluating, communicating, consolidating, and implementing. The paper describes each in general terms below. At each step, the manager should consider how he utilizes his technical competence, personal integrity, and regard for his staff.

Evaluating

First, what functions will the staff to perform? Figure 1 postulates an organization and specific functions done by each sector of the staff. Although that organization does not match that of any particular shipyard, it does reflect functions which are carried out by the staff. Management should carefully consider whether some of these functions might be better transferred to a trade-level organization because of their greater familiarity with production processes and materials. Management then needs to evaluate the personnel as-

signed to the staff. This evaluation must be based on two considerations: what the individual is presently doing to contribute to the productivity of the shipyard, and where his particular talents could be better utilized to improve productivity.

Having established the functions, the next matter of concern is the flow of information. Every shipyard has a well-established (but informal) system of communications. It is the telephone, the in-yard mail, and word-of-mouth. None of these accurately reflects the shipyard organization nor includes the data processing system. As a result, information critical to the staff is misdirected or lost and must repeatedly be regenerated. Since it is not efficient for all information to be available to all personnel, management must decide what the real information requirements are, and how they are to be provided.

In order to improve their productivity, the staff needs some tools with which to work. To minimize redundancies, they need the ability to file, retrieve, manipulate and transmit information readily. Upper management must determine which data is necessary to run the company. Then it must be determined where that data is presently located and how the present system can be streamlined to eliminate the superfluous. The most effective means available uses electronic data processing systems. The best data processing system is the smallest, most reliable and least expensive system which meets the company's need.

Communicating

In addition to hardware, the staff needs a good understanding of the plans management is implementing. Also, having worked with the present system for some time, they probably have some valuable insights and suggestions for modifications. By providing an open forum for the communication of managements goals, three important objectives can be achieved: the goals can be directly communicated; management can learn the lessons and gain the recommendations of those directly involved in day-to-day operations at the middle management level; the staff gains a sense of participation in their own destiny.

It would be naive to imply that all recommendations from the staff will be useful. Communication is a two-way process; upper management must provide the framework by establishing and maintaining a focus on the goals of the company. However, they must also be quick to recognize parochialism or self-serving interests within the staff, and be firm in setting these aside.

It is important that this entire process be public knowledge. This will encourage the staff by assuring them that management is aware of the true situation within the shipyard and is taking steps to rectify problems.

Consolidating

This audience is familiar with the basic principles of integration in terms of designing a circuit or system. First, the design must be based only on the functions to be performed. Wherever possible, functions should be combined to minimize the number of components. Communication lines should be shortened to reduce lost time and assure accurate transmission of information. Necessary supplemental services and systems must be considered part of the design and implemented with it.

These principles also apply to the development of an integrated organization. There will be, however, many conflicting ideas of which staff member is responsible for the accomplishment of each specific function. For example, under the existing scheme, Estimating will usually be responsible for doing material take-offs during the pre-award phase, but the trades must repeat the effort during pre-production. This is, in fact, a duplication of effort. Similarly, upper management usually has at least one extra tier of middle managers between themselves and the trades. As a result, the time required for clear communication is lengthened unnecessarily.

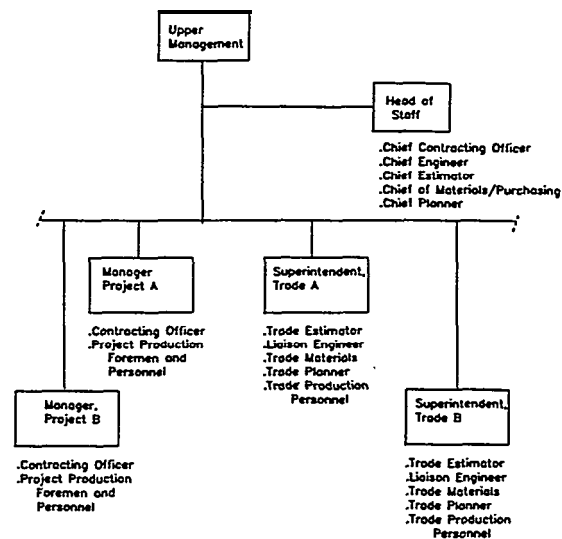


Figure 3
Organization of
an Integrated Shipyard

Implementing

Figure 3 is one organization chart for an integrated shipyard, showing several structural differences from the organization of the generic yard discussed earlier. To begin with, the lines of communication between upper management and each project are considerably shortened. Then, although upper management retains a small staff to provide an overview of key functions such as materials, planning and estimating, most of the personnel are reassigned to trade organizations. Next, the trade general foreman is responsible for providing estimates, schedules, and material support to both marketing and project managers. He is also responsible for augmenting the staff. In short, the trade general foremen become the focal point of all staff and personnel support for individual projects.

For example, if the staff responsibilities are assigned to the trade general foremen, and if the organization is designed to be supplemented by adequate data processing systems, the original material take-off done during proposal preparation could be used for rebidding, then reused to print out purchase orders.

The transition from the modern American shipyard to the integrated American shipyard will be a fairly lengthy one; many members of the current staff will decide that, under the new system, they will be unable to perform as they have in the past. The transition period will give them time to voluntarily seek other employment, reducing the number of lay-offs which finally must be made. Obviously, the shipyard cannot simply shut down for the transition period, so employees should be aware that this will be a time of change.

Summary

Using flow charts and generalized examples, this paper provides a brief outline of some staff-related problems which currently exist in American shipyards and suggests four steps to eliminate those problems by integrating the staff and providing it with adequate tools. These steps are: evaluating, communicating, consolidating and implementing. In the specific organization postulated by Figure 3, the staff functions are largely transferred to the trade organization to eliminate redundancy and shorten the lines of communications. Depending upon the individual shipyard, alternate solutions may be more advantageous. It is clear, however, that since the productivity of the entire shipyard is based on the skill and care with which the staff does their work, development of the staffing plan requires careful planning and implementation to improve overall performance.

**INFUSING PRODUCIBILITY INTO ADVANCED
SUBMARINE DESIGN**

LCDR B. BRUCKER

Discussion by Robert Baseler, General Dynamics
Electric Boat Division

The author has described a submarine design process which embodies technology and philosophy that is certainly not new to the industry. However, the application is unique and represents a significant advancement when applied to submarine design and construction. The tailoring of the technology and philosophy to produce the specific system described was made possible by a series of particular circumstances.

First, although the SEAWOLF design incorporates significant technological advancements over previous classes of submarines, the general form, systems, and arrangement criteria are common to other modern classes. Therefore, many lessons learned from previous design and construction could be applied in formulating the SEAWOLF program objectives. Second, all of the key players in procurement, approval, design and construction were known, since the submarine business is confined to a relatively small community. This limited the variables to be considered when evaluating producibility

desires and capabilities, design and construction methods, and approval/control parameters. Finally, the realization by each shipyard that the products of the design phase, generated nearly equally by two design agents who were also both potential construction agents, must be tuned to maximum extent possible to mesh with its own construction capabilities and techniques has focussed maximum attention on the producibility and standardization issues. The result has been a design and construction philosophy which may not be totally applicable to the general shipbuilding industry, but is eminently tuned to the needs of the SEAWOLF program and its initiators, the US Navy.

Among the accomplishments, as noted by the author, are the maximum use of computer design techniques which allow the design to be developed, as it must, by system and operational function. Then, when the design is complete and validated, the data can be resectioned to produce construction oriented drawings for maximum efficiency and commonality of construction approach. Also, the combination of detailed construction planning with the design phase not only abets the producibility goals, but verifies the construction schedules and reduces construction planning costs, since each potential construction agent is agreeing before the fact to a very specific construction approach. Furthermore, each phase of that plan is geared toward the capabilities of both yards rather than slanted towards one, as can happen with a single design agent.

As noted in the paper, important issues which have been recognized and resolved are the need for common material and design/construction standards coupled with a uniform presentation of construction drawings. Along with this has come an understanding of the fine balance between the development of construction drawings applicable to both construction yards and the tendency to drive the drawing detail down to "shipyard specific" processes. Constant attention to maintaining the design deliverables in a generic mode, while retaining the flexibility to apply shipyard specific sub-tier planning, has been required. Also, agreement to limit construction options and variables, and commitment to use of the construction plan developed during design, and to resist change for nebulous "improvement", are important to the success of the program.

Achievement of the successes outlined by the author has not been easy. Many discussions have taken place among the design agents and the Navy. Some have been heated, and some have resulted in polarized positions, but this is not unusual even within individual organizations when developing new concepts. In general, the process has worked well, and the arguments settled to the overall benefit of the program. Rarely has the Navy, as final arbiter, been required to make Solomon-like pronouncements. The results have been the shaping of a submarine acquisition program designed for the mutual benefit of all participants with the ultimate benefit going to the customer, the U.S. Navy and its attack submarine fleet.



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Infusing Producibility Into Advanced Submarine Design

No. 4B

LCDR B. R. Brucker, USN, Member, Naval Sea Systems Command, Washington, D.C.

ABSTRACT

The SEAWOLF submarine design is promoting the employment of a variety of advanced ship design and production techniques. Major goals of the design are to fully support a zone construction program, capture the data base in a digital format, provide digital products for construction and logistics support and to simplify, as much as possible, the construction effort. Four innovations that support these goals include:

- o Producibility Steering Group
- o Improved drawings
- o Planning and Sequence Documents
- o Producibility Review Process

The implementation of these producibility tasks into a new submarine acquisition has required extensive development by a creative group of designer's and a contingent of production planners. The SEAWOLF Producibility team has undertaken the task to understand and apply the advancements in shipbuilding technology that are in place and are being implemented today. The infusion of producibility is the result of this knowledge being reflected in SEAWOLF Design products.

INTRODUCTION

The SEAWOLF Advanced Submarine Program is presently in the detail design phase of acquisition. SEAWOLF is advancing technology in many areas. Admiral W.H. Rowden, Commander Naval Sea Systems Command, in a statement to congress, in March 1988 described the SEAWOLF as a ship that is "...designed to counter the rapidly increasing capabilities of the Soviet submarine force projected for the 1990's and beyond. SEAWOLF will be quiet, fast, and well armed with advanced sensors." In addition to the advances that make SEAWOLF a superior warship, the program strongly advocates the infusion of new technology in the design and construction phases of acquisition.

Producibility is the effort to make ships more affordable. Navsea, in cooperation with General Dynamics Electric Boat Division and Newport News Shipbuilding, is leading this part of the SEAWOLF detail design. Shipyard modernization programs at both Electric Boat and Newport News have dictated the need to change the philosophy and products of submarine design. The Producibility Program is responsible for assuring that the SEAWOLF design is optimized for production as well as performance. The Producibility team is working to review the design, create the right design products and infuse the needs of the construction effort into the SEAWOLF program.

Departing from previous submarine designs, SEAWOLF is being designed in a team effort. Newport News Shipbuilding is the Lead Design Yard and has responsibility for hull and all non-propulsion plant systems. Electric Boat Division is the Propulsion Plant Design Yard and through a sub-contract from Newport News is also responsible for the non-propulsion plant systems located in the engine room. The team arrangement is an outstanding asset from the standpoint of producibility. The discussion and integration of producibility issues by two experienced groups of submarine designers and planners has led to improved design products.

Infusing producibility into a submarine design requires the design yard to understand the New Technology in place and under development in the shipyards. The designer must have a working knowledge of Zone Oriented Construction and Interim Products in order to create the most useful construction drawings. The primary tool of the SEAWOLF designer is the Computer Aided Design workstation, which not only improves the designers capability, but also represents the front end of the Computer aided design and manufacturing (CAD/CAM) system.

Setting the goals and committing the resources to achieve a producible design is an important step. Implementation of the program requires a well structured effort by the design yards, augmented by construction personnel, and the customer. The SEAWOLF Detail Design Team is making the effort and has produced a variety of products that may provoke thought in future programs. Some of the products of the SEAWOLF Producibility program are the Producibility Forum, improved construction drawings, upfront planning effort, Producibility Design Review, and Digital Data Transfer. The Digital Data Transfer Project has been well documented in other papers and will not be re-presented. The remaining products are the result of infusing producibility into the SEAWOLF submarine design.

NEW TECHNOLOGY

The U.S. Navy is often involved in developing New Technology to improve the performance of its ships. American Shipbuilders have also been developing New Technology by bringing new hardware, software and method into the shipyard to solve construction problems.

Problem solving through the implementation of New Technology is a process that acquires a specific technology to fulfill a need. The shipyard then develops the required internal procedures and accomplishes the necessary training in order to utilize the new technology in the workplace. The development phase of implementation is critical for insuring that the new technology to achieve management's goals of improving the operation of their company. New Technology programs are an important part of the SEAWOLF Design, not only to improve performance as a warship, but also in the accomplishment of the goal to design a producible submarine.

The SEAWOLF Producibility effort primarily supports two important technologies; Zone Oriented Construction and Computer Aided Manufacturing (CAM). Zone Oriented Construction and CAM have been the focus of shipyard improvement programs for a number of years. However, a submarine design that is dedicated to more fully implementing these technologies is a first.

Computer Aided Design is the tool that has facilitated the Design Yard's task in creating the variety of products required in the SEAWOLF effort. Approximately four hundred CAD workstations are in daily use by the Design Yards to create three dimensional product models that are captured in the SEAWOLF Data Base. The Digital Data Base is a tremendous asset in supporting the iterative nature of the ship design process and is an essential element for the utilization of CAM technology. Additionally, its future utilization in the life cycle support of the ship will be substantial.

Zone Oriented Construction is a variant of group technology that has been developed for shipbuilding. Zone Oriented Construction divides the ship into modules that are defined on an arrangement basis or zone of the ship rather than a system basis. Electric Boat and Newport News have integrated zone construction into their submarine construction programs. The investment in bringing this new technology into the shipyards and developing it have been significant. Land Level Facilities have been built at both shipyards to assemble the large modules that are fabricated in shops. Previous submarine designs created a system oriented data base. For a shipbuilder to utilize a zone construction method, the system design had to be translated to define the module arrangement. Although the translation was a significant effort, the benefits of utilizing zone construction by better organizing the flow of work and also reducing the amount of work required within the fully assembled ship's hull made it worthwhile. Since SEAWOLF has been conceived from the outset with the requirement that its design fully support zone construction, the goal of maximum outfitting of modules prior to endloading into hull sections will be achieved. Figure 1 depicts the SEAWOLF structure of submarine zone oriented construction.

Interim Products are the units of work or product structure that supports zone oriented construction. The SEAWOLF product structure is divided into five increasingly complex levels:

1. Piece Parts
2. Items and Packages
3. Sub-Modules
4. Modules
5. Sections

The SEAWOLF hull is divided into eleven sections that receive parts, items, packages, sub-modules and modules directly. After a section is loaded to the maximum extent, it is moved next to its adjacent section and joined. Although all levels of product structure can go directly into the hull sections, in practice most of the volume and weight are loaded at the module and sub-module level. SEAWOLF is designed with twenty module size units. The modules are defined so that they are contained within a particular section without overlap. Each level of product structure, for some period of time, has a unique identity. Figure 2 depicts an example of an interim product. In Figure 2, a foundation is created and identified, for example, as item #1. Sometime later item #1 is joined to a deck with other items and packages to form sub-module #1. The uniqueness of foundation #1 is lost and sub-module #1 assumes an interim identity until it is joined to some other piece of the ship to form a higher tier of product structure (module or section). Each piece of assembly

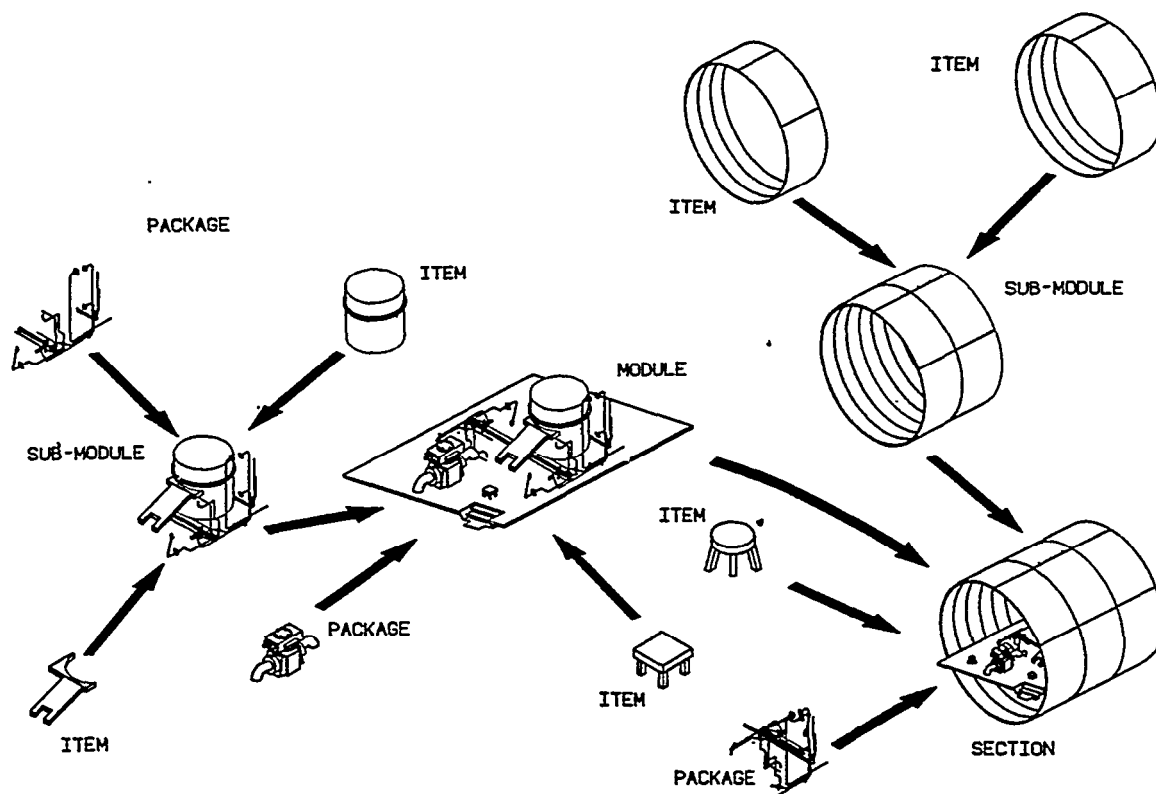


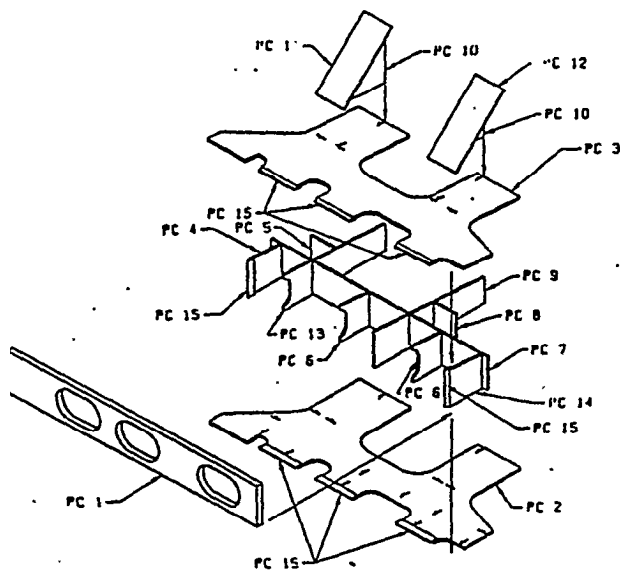
Figure 1. SEAWOLF Zone Construction Product Structure

is defined as an "Interim Product" and becomes important from the aspect of structuring worksite, and organizing construction drawings. Sectional Construction Drawings are based on this product structure and will be discussed later.

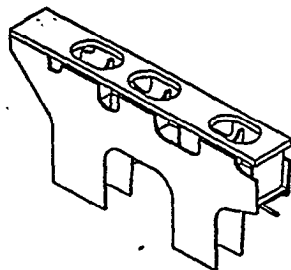
Computer Aided Manufacturing is a rapidly progressing technology that is being widely implemented today. Efforts to eliminate manual steps in manufacturing processes are being taken by shipyards as the capability of computer technology improves. Today's computer technology implementation at submarine shipyards is primarily being accomplished at the shop level to improve specific manufacturing processes. As the capability of today's computer expands, their application in manufacturing will follow closely. However, implementing CAM technology into the manufacturing scheme requires more than the investment in the necessary hardware. The shipbuilder must have available or create data that is in a computer usable form. The SEAWOLF Program has the goal of providing, design information in a digital form in

parallel with construction drawings in order to facilitate the use of Numerical Control machines.

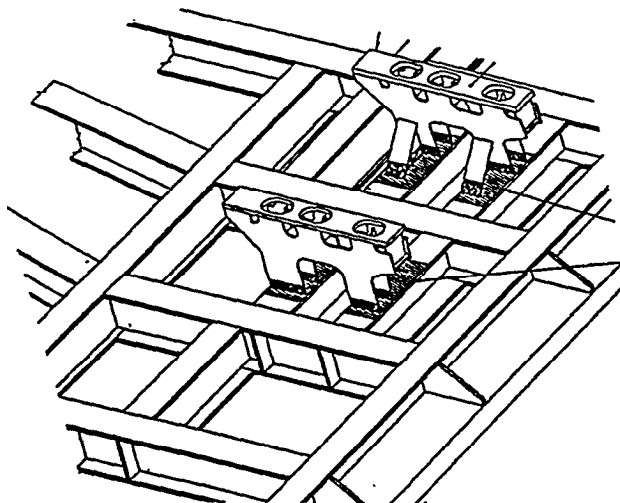
The future of manufacturing is involved in the effort to bring Computer Integrated Manufacturing (CIM) to maturity. Manufacturing the thousands of pieces necessary to build a submarine is a complex process that encompasses far more than the actual cutting, bending or machining of parts. The material requirements, schedule of manufacture, storage and retrieval of the product and progressing of work are all part of the manufacturing process. The task for people working in the various functions of manufacturing is to support the process so that each piece needed can be produced on time. Every part is touched in some way by the material, fabrication, scheduling and possibly storage systems of the manufacturing department. The task of constantly updating large amounts of information so the manufacturing will support the construction schedule is a tremendous undertaking and is usually handled by a semi-automated paper tracking system. The evolution of the computer network allows the manufacturer to set the goal of creating a paperless manufacturing effort.



a. Piece Parts



b. Item



c. Sub-module

Figure 2. Transition of a foundation from an item to part of a sub-module.

The SEAWOLF Digital Data Base and digital data transfer project are important steps in facilitating the Computer Integrated Manufacturing effort. The knowledge that a large amount of the SEAWOLF geometry will be available digitally has helped spur the computer integrated manufacturing programs at both submarine shipyards. The resources required to bring CIM to reality should not be understated; however, the effort by the design yards, in cooperation with their CAD software vendors and the IGES Committee, has crossed a significant boundary in providing a data base in digital form.

PRODUCIBILITY STEERING GROUP

In April 1987, the SEAWOLF Program transitioned from competing contract designs between Electric Boat and Newport News into a dual design yard arrangement. Part of the transition process was to formalize the recognized need to create a forum to address Producibility issues. The result was the creation of the SEAWOLF Producibility Steering Group (PSG).

The Steering Group is composed of Design Yard personnel from Electric Boat and Newport News Shipbuilding, with representation from NAVSEA. The group is sub-divided into working groups along the following design and construction functions:

- A. Piping/Ventilation
- B. Machinery
- C. Structure
- D. Electrical
- E. Drawings
- F. Construction Planning

The producibility ideas that had evolved during Contract Design were formalized into action items to be investigated, and new items were added as they were identified. Each item was assigned to a particular working group with lead roles alternated between design yards. The working groups exchange ideas and technical concerns on assigned action items and report the results of their effort at steering group meetings which occur on a regular schedule. The item is considered closed when the design yards reach a formal agreement describing the item and the resolution.

The Producibility Steering Group has handled a wide range of issues, including standardization of high use items, reviewing design standards to improve the utilization of automated processes, applying uniform references and tolerances, and creating uniform design products. The need to apply uniform standards to a ship design utilizing a dual design yard concept is apparent, since a single shipbuilder will use the products of both designers. However, their

is an additional benefit to the SEAWOLF Program. The starting point for the standards is usually each yards present method of doing business, which rarely coincide. After exploration and negotiation, these starting positions evolve into an agreement that embodies a better means to design a producible ship. Examples include the effort to minimize pipe joints, and the development of products that improve the zone oriented construction planning effort, such as the Planning and Sequence Documents.

THE SEAWOLF Producibility Steering Group was a necessary element of a dual design yard effort. However, the need for a producibility forum between design yard, shipbuilder and customer also exists in a single design yard arrangement. The need to deliver the best possible construction scheme coupled with the many items that can reduce the shipbuilder's effort can yield savings that far surpass any additional time in the design phase.

SEAWOLF DRAWINGS

A special effort of the steering group was the redefinition of the types, formats and levels of detail of SEAWOLF drawings. This redefinition was required because of the desire to improve construction drawings and support zone construction while recognizing the need to design and approve drawings by system. The SEAWOLF Ship Specification defines three general types of drawings to be created at the design yards:

- o Configuration
- o Sectional Construction
- o Ship Support

Configuration Drawings are system oriented drawings that are the framework of the data base. Many Configuration Drawings require approval from government agencies such as NAVSEA or the cognizant Supervisor of Shipbuilding. Configuration Drawings that require Navy approval are mostly diagrams or arrangement drawings that depict significant portions or critical elements of the ship. In addition, the design yard creates another group of more detailed configuration drawings as a means of gaining internal approval of smaller portions of the design. The Format of the Configuration Drawings has changed little from the "Class" Drawings that are common to all ship designs. The Level of Detail is reduced, since any detail that is required only for construction is unnecessary for approval is removed and placed on construction drawings. This change has caused some additional dialogue between design yard and customer, but the impact has been small. The greatest effort has been in the training of personnel to deal with the somewhat different SEAWOLF design products.

Sectional Construction Drawings (SCD'S) are a translation of the data base developed by the Configuration Drawings to support zone oriented construction. The intent of the SCD is to provide the shipbuilder with all the information needed to construct the ship in the most useful format possible. The structure of the SCD is discussed below.

Ship Support Drawings will be used in the life cycle support of the SEAWOLF and are composed of Configuration and selected Sectional Construction Drawings. Additional Logistic information is provided by a special group of drawings created for logistics support such as drydocking drawings, equipment removal flowpath drawings and selected record drawings.

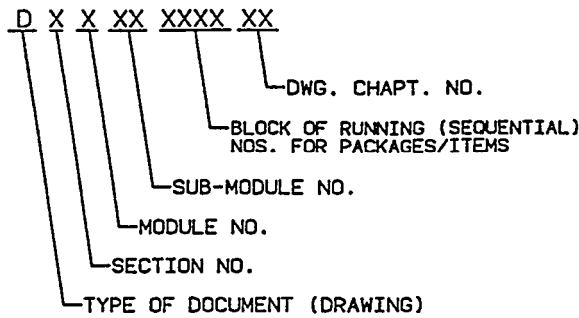
SECTIONAL CONSTRUCTION DRAWINGS

The SEAWOLF Ship Specification defined the purpose of a Sectional Construction Drawing, but it was left to the Producibility Steering Group to structure this new type of drawing. the goals in creating the sectional construction drawing were:

- o Support zone oriented construction
- o Create logical work packages
- o Insure the drawing could stand alone in the work place
- o Minimize additional planning by the shipbuilder

Supporting the construction scheme through the SCD's was accomplished by designing each drawing to create an interim product, whether the product be an item or a large module. The SCD identifies a list of material (Engineering Parts List) and goes through the necessary sequential steps that build the product. In the case of an item, the Engineering Parts List starts with raw material, consumes it in a manufacturing process and prepares the item for joining with other products. A module SCD would start with previously assembled interim products, such as items, packages, and sub-modules and then work through the required sequence to put the module together.

In order to aid the shipbuilder, a system to "intelligently" number the SCD's was created. The eight digit SCD number was constructed with fields that indicate in what section, module and sub-module the drawing's interim product would be located. For Example, all SCD's numbered between 40000000 and 49999999 cover work only in Section 4. more specifically the 42000000 series of drawings builds the fan room module (module #2) of Section 4. The usefulness of the numbering system extends beyond construction. During the life of the ship, knowing that the SCD number is tied to a specific area in the ship will be an aid in finding detailed logistics support information. Figure 3 shows the SCD numbering system.



EXAMPLE:

FAN ROOM MODULE (MODULE NO.2
IN SECTION 4)

D42XXXXXXX

PIPING PACKAGE NO. 26

D4200002630
D4200002631
D4200002632
D4200002633
D4200002639

Figure 3. Sectional Construction Drawing Numbering System.

Constructing an interim product is in most instances a multi-skill endeavor. Figure 4 depicts the assembly of a simple package of pipe that will require cutting and bending the pipe, welding fittings and valves, adding pipe hangers and assembling the package into a fixture. Outfitting a module would normally involve a variety of operations from Structural, Mechanical, Piping, Ventilation and Electrical trades. To make the SCD more useful it is broken into functional trade work packages called

chapters. The numbering of the chapters is uniform; for example, in a SEAWOLF SCD chapter 04 always assembles structural piece parts and chapter 80 always involves painting. Therefore, the painting supervisor will know that his share of the work load will always be found in chapter 80, no matter which drawing is involved. The breakdown of the SEAWOLF chapter numbering system is shown in Figure 5. The chaptering system not only provides a logical breakdown of work, but allows the central planner to distribute to the work centers only the chapters they need. The drawing chapters are tied together by chapter 00, the control chapter. This chapter lists all other chapters and keeps track of the overall revision history of the drawing.

Each chapter of the SCD is structured so that as a work package it can stand alone without other documentation. If a reference provides essential information, then that reference information must be extracted and placed on the SCD. The reference information is normally available to the designer as he is creating the design, but becomes a burden on the planner and tradesman to find, interpret and apply during construction. The chapters also stand alone from the viewpoint that they can be detached from the overall drawing and be sent to the work center that requires the information.

The SCD format must extend beyond the task of creating interim products if they are to be the vehicle for the entire construction process. The joining of sections and the outfitting operations that cover more than one section after joining must be addressed. The joining operation consists primarily of making the circumferential joint between two sections

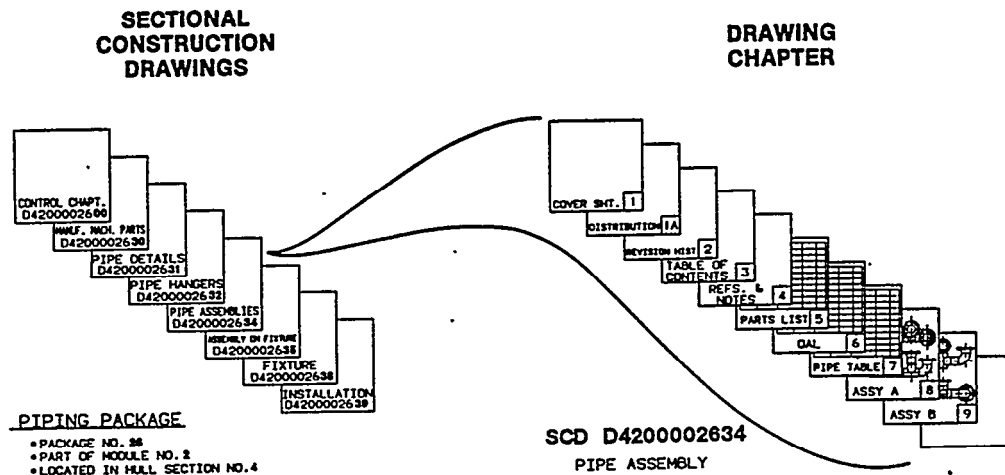


Figure 4. Chapter Structure of a Sectional Construction Drawing.

	DWG. CHAPTS .	TYPE		DWG. CHAPTS .	TYPE
STRUCTURAL	00	CONTROL	MACHINERY	20	MANUF. DETAILS
	01	DESIGN PART DETAILS		21	PRE-ASSEMBLY
	02	MANUF. DETAILS		22	ASSEMBLY
	03	PRE-ASSEMBLY		23	
	04	ASSEMBLY		24	
	05			25	
	06			26	
	07			27	CASTING/FORGING
	08	FIXTURES		28	FIXTURES
	09	INSTALLATION		29	INSTALLATION
HULL FITTINGS	10	DESIGN PART DETAILS	PIPE FITTING	30	MANUF. DETAILS (MACH. PARTS)
	11	MANUF. DETAILS		31	PIPE DETAILS
	12	PRE-ASSEMBLY		32	HANGERS
	13	ASSEMBLY		33	PRE-ASSEMBLY
	14			34	ASSEMBLY
	15			35	ASSEMBLY ON FIXTURE
	16			36	
	17			37	
	18	FIXTURES		38	FIXTURES
	19	INSTALLATION		39	INSTALLATION
HVAC	40	DUCT DETAILS	ELECTRICAL	60	CABLE PRE-ASSY
	41	HANGER DETAILS, MANUF.		61	WIREWAY MANUF.
	42	FITTINGS, MANUF.		62	LIGHTING MANUF.
	43	PRE-ASSEMBLY		63	SPEC. MISC. ELECTRONICS COMP. INSTALL
	44	ASSEMBLY		64	EQUIPMENT CABLE ENTRANCE
	45	ASSEMBLY ON FIXTURE		65	FIXTURES
	46			66	CABLE TERMINATION & HOCK-U'
	47			67	CABLE INSTALLATION
	48	FIXTURES		68	WIREWAY INSTALLATION
	49	INSTALLATION		69	LIGHTING INSTALLATION
ELECTRONIC	50	ENCLOSURE (OR CHASSIS) MFG.	MULTIDISC	70	PRE-ASSEMBLY
	51	MISCELLANEOUS MANUF.		71	ASSEMBLY
	52	PRINTED/ACTIVE CIRCUIT FAB.		72	
	53	FINAL ASSY 8. WIRING		73	
	54			74	
	55			75	
	56			76	
	57			77	
	58	FIXTURES		78	FIXTURES
	59			79	EQUIP. INSTALL
SERVICES				80	PAINTING
				81	THERMAL INSUL./LAGGING
				82	SOUND INSULATION
				83	DRIP/SPRAY SHIELDS
				84	TRANS. LOSS TREATMENT
				85	STAVE DAMPING
				86	LABEL PLATES
				87	INSTRUMENTATION
				88	INSPECTION
				89	TESTING
				90	MACHINING
				91	ALIGNMENT PROCEDURE

Figure 5. Sectional Construction Drawing Chapter Numbering System.

followed by the tying together of the distributed systems (piping and ventilation) and the pulling of electrical cable across the interface. The "J" drawing has been developed to meet this need. The drawing number will contain a "J" followed by the numerical designator of the two sections involved; ie, the SCD joining sections 1 and 2 will be number J12000001 (or higher if more than one drawing is used). The multi-section drawing is an "M" series drawing that will cover work that follows after the joining phase. This drawing will have a numbering scheme containing the designator "M" and the first and last sections involved. In the case of a forward ship task the number could be M13000001, indicating sections 1, 2 and 3 would be involved.

The complexity of Nuclear submarines has increased dramatically over the years, and SEAWOLF will continue that trend. The Sectional Construction Drawing provides the shipbuilder a tool to handle the complexity by presenting detailed yet simplified views of what is to be built, without extraneous information. The SCD presents the shipbuilder logical work packages that reduce the need for detailed waterfront engineering and planning. The completion by a shop of a drawing chapter will indicate that a product has been built, or a specific value added to a product, such as painting. The SEAWOLF Sectional Construction Drawing achieves the goals that are requirements of the ship's specification. It is a measurable achievement in zone oriented ship construction.

PLANNING AND SEQUENCE DOCUMENTS:

The process of creating interim products from the item level up to the section level evolves a logical sequence of assembly. As the design is iterated and the design spiral tightens, the assembly sequence becomes a parameter affecting design decisions because the changes may affect how work is packaged. To assist designers' in understanding the construction process, knowledgeable waterfront planners are brought into the SEAWOLF Detail Design effort. One of their tasks is to arrange the fabrication and assembly of interim products into a scheme that fits into the facilities and practice of submarine shipbuilders. The planning group utilizes a computer based scheduling system to produce a variety of networks. All the SCD's necessary to produce an interim product at the module or section level are networked together to permit analysis of the proposed construction sequence. These networks are titled "Sequence" documents and are the foundation for creating many useful products. An example of a sequence document is illustrated in Figure 6. The first

by-product is created by the addition of a timeframe to each event of the sequence network yielding the "planning" document. The utility of the planning document is the ability to capture information necessary to work out a finite construction period. A planning document example is depicted in Figure 7. Study of the planning and sequence networks will indicate the key points in the construction that are summarized to produce the Master Construction Schedule (MCS). Figure 8 illustrates the evolution of a MCS activity from the Planning and Sequence documents. Since the MCS is produced from a "bottom-up" approach based on a drawing by drawing evaluation, it is a valid scheduling tool that is available during the Detail Design process. From the MCS other products fall out, such as the drawing issue schedule and material ordering schedule. The products needed by the shipbuilder become the driving force in meeting schedules to provide design products, especially on the lead ship.

PRODUCIBILITY REVIEW

The role of NAVSEA and the engineering offices at the Supervisors of Shipbuilding is to review the work of the Design Yards from the standpoint of technical adequacy. Their responsibility does not extend into the arena of producibility. The technical reviewer does not pose the question "can the design be efficiently produced?". A major benefit of the dual design yard arrangement is the capability for review of the design products of the other team member by knowledgeable designers and shipbuilders. It is necessary to set producibility goals and standardize high usage items; however, a drawing by drawing review presents the opportunity to validate the SEAWOLF Design as a truly producible one. The SEAWOLF Program has formally involved both team members in a producibility review of design products. The "Producibility Review Procedure" was developed by the Steering Group to ensure that every SCD developed is reviewed not only in house, but also by an independent and highly interested second party. The original concept was to submit only SCD'S, regardless of content, to the other design yard. During the development of the procedure it was noted that many other documents being created or in review at the design yards, such as mockup drawings and specific process instructions, have producibility implications, and the procedure was modified to permit any document to be included in the review process.

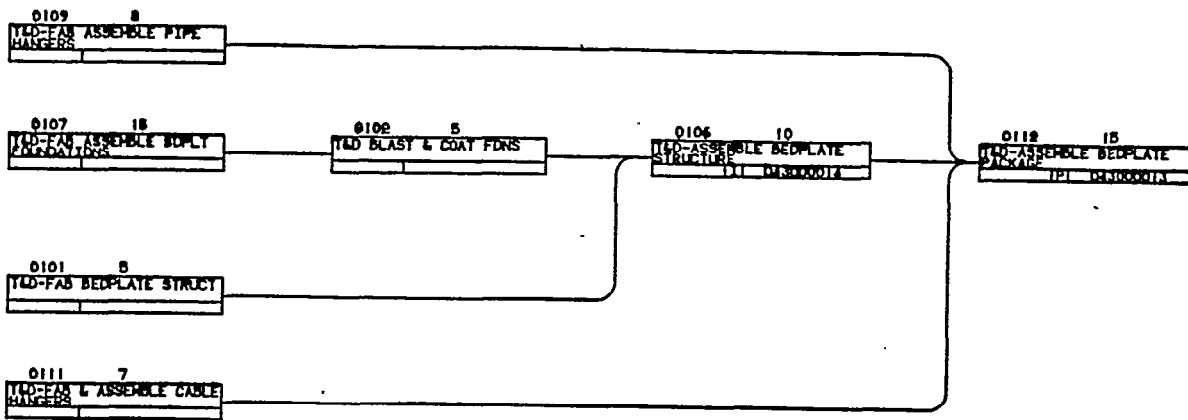
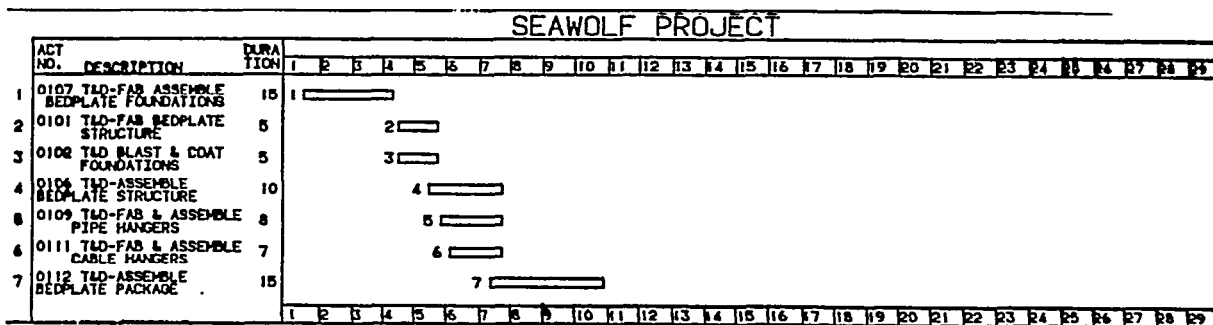


Figure 6. SEAWOLF Planning Document



TRIM PUMP MOD PLAN DOC
DOCUMENT NO. PL4300000002

Figure 7. SEAWOLF Sequence Document

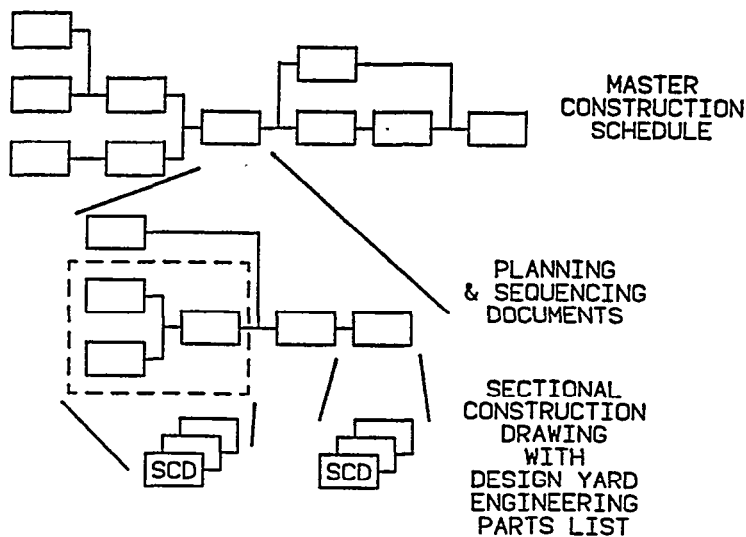


Figure 8. Evolution of the Master Construction Schedule

Implementation of the review process required the formation of a team to conduct the review. This review team is a combination of design, construction, planning, manufacturing engineering and quality assurance (NDP) personnel. The team can serve to review documents produced by its own design yard and also the documents received from the other design yard. The review primarily involves the comparison of construction experience to the design presented. Each member of the review team applies his own expertise and comments on changes that would improve the producibility of the design at hand. Review comments are formally transmitted to the design yard and they are incorporated into the drawing, or discussed with the reviewer if a difference of opinion exists.

The Producibility Review process has elicited a wide variety of comments from both shipyards. Examples of producibility issues include:

- o Replacement of welded fittings with pipe bends
- o Recommendations to improve machining
- o Alternate materials to improve fabrication
- o Addition of notes to improve clarity of drawings
- o Recommendations on tolerances and reference lines
- o Recommendations on welding sequence to reduce distortion
- o Improving the access for welding and installing mechanical joints
- o Improving clarity of welding information
- o Replacing structure composed of welded pieces with a single cold formed item

In some cases the desired improvement in producibility is offset by technical design requirements and the comment can not be incorporated. However, in most cases producibility comments can be accommodated and they are reflected in changes to SCD's.

The Producibility Review allows experienced construction personnel an opportunity to apply their hard learned lessons to the design process. This opportunity occurs at a point in the design when the comments can be acted upon with a minimum of disruption.

SUMMARY

The SEAWOLF Producibility effort has been successful in focusing energy to facilitate a zone oriented construction plan and to improve the manufacture of the ship. Completely capturing the design in an electronic data base is a major step toward the automation of the work place from the fabrication, material handling and production management functions. The philosophy is, that designing for production is an

investment with a tremendous potential for a substantial cost reduction for the Navy and its shipbuilders.

SEAWOLF Program experience has shown that when the appropriate resources are dedicated to creating a producible design, that it will succeed. A working forum, such as the SEAWOLF Producibility Steering Group is a necessary focal point to guide the effort. Complex projects such as creating the right drawings and facilitating a Producibility Review can be accomplished with the support of management and the enthusiastic cooperation of skilled engineers and designers. The Design Yard must maintain a constant dialogue with the shipbuilders to ensure that the output of the design meets his needs. The trade-offs between technical adequacy and ease of construction must be constantly evaluated so that the specifications are met and the results of the producibility effort are incorporated.

The shipbuilding environment of today necessitates that, for a shipbuilder to remain competitive, a continuous injection of new technology into the shipyard must occur. The desired cost reduction can be severely hampered when the design products do not support the shipyard's construction philosophy or facilities. Infusing Producibility into ship design is a major feature of the SEAWOLF Program. The potential for improving the construction of the U.S. Navy's advanced submarine is real, and future ship designs should consider building on the products of the SEAWOLF Producibility effort.

ACKNOWLEDGMENTS

The author wishes to express appreciation to those who have been the foundation of the SEAWOLF Producibility Team; the talented designers, engineers and planners of Newport News Shipbuilding and Electric Boat Division.

The considerable vision of the leadership of the U.S. Navy's SEAWOLF Advanced Submarine Acquisition Project in staying the course of a submarine designed not only for top performance, but also optimized for construction deserves to be recognized.

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Discussion on Paper #4-B, "Infusing Producibility into Advanced Submarine Design" LCDR B. R. Brucker.

by Howard M. Bunch, Member

Over the past decade I have had numerous opportunities to examine and study the U.S. Navy's traditional position with respect to emphasis on producibility of its designs. Almost without exception, those examinations led to the general conclusion that producibility was not an important item in the Navy's mind. It seemed like the terms "producibility" and "Navy design" were oxymorons, like "low-cost" and "*doctor*", or, perhaps, like "*painless*" and "*dentist*". For that reason, I consider this paper an indication of a major change in the Navy's traditional position relative to the importance of optimizing a ship's design toward better production efficiency. My general observation is, "it's about time"; and I heartily endorse LCDR. Brucker's acknowledgement where he states¹:

"The considerable vision of the leadership of the U.S. Navy's SEAWOLF Advanced Submarine Acquisition Project in staying the course of a submarine designed for top performance, but also optimized for construction, (emphasis added) deserves to be recognized."

The long-term implications of the productivity optimization are tremendous. Even a modest improvement, with the attendant cost reductions, will mean savings that could easily be in the billions of dollars, especially if the SEAWOLF production run attains the present projections. For that reason, I view the initiative described by LCDR. Brucker as one of major importance to every citizen of this country.

To me, the major issue now becomes what must be done to assure the transfer of the concepts being developed under SEAWOLF (and

¹"Infusing Producibility into Advanced Submarine Design, by LCDR B.R. Brucker, National Shipbuilding Research Program Symposium, Seattle, August, 1988.

similar initiatives) throughout the Navy design community and the U.S. shipbuilding industry. For example, the SEAWOLF digital data base and digital data transfer project are resulting in emplacement of significant technical knowledge at the two involved shipyards: Newport News Shipbuilding and Electric Boat. But how is that knowledge to be spread to the other yards? I'm sure that both Newport News and Electric Boat view the knowledge, software, and hardware they developed from SEAWOLF as their proprietary material and information, and they are not inclined toward the sharing of this knowledge outside their own organizations¹.

The threatened demise of the U.S. shipbuilding base requires, in my opinion, that its restored vitality be an item of national security and national industrial policy concern.² Such a restoration demands that technology transfer occur throughout the existing industry; the federal government, especially the U.S. Navy, is the agent for directing and facilitating that transfer. Thus, the Navy should heavily support an effort that will make the productivity improvement knowledge being developed under SEAWOLF (and other Navy initiatives) available to the U.S. design community and shipbuilding industry.

Several concepts immediately come to mind for facilitating technology transfers, like those described in this paper, into the entire U.S. shipbuilding and design community. One possibility (and the one I prefer) would be to establish such an initiative within the National Shipbuilding Research Program (NSRP)³ A second would be

¹I have, in fact, received correspondence [Mr. E. Campbell, Newport News Shipbuilding, dated 3/8/88] taking this position. The letter was in response to a suggestion that there be established an industry-wide initiative to develop a strategy and plan for emplacing computer-integrated-manufacturing-systems into American shipyards. And the position is understandable; the sharing of the information can easily be viewed as giving away important knowledge that relates to competitive position.

²For a fascinating (and disturbing) presentation of the effects of the U.S. government's position since WWII in its direction of the country's industrial policy, read Clyde Prestowitz's recent book, Trading Places: How we Allowed Japan to Take the Lead. [Basic Books, Inc., New York, 1988. ISBN 0-465-08680-2.] The book presents compelling evidence that the United States should rethink its industrial strategy, and implement policies that are consistent with the fact that national power demands capabilities in certain industries and certain technologies.

³Funding support for this initiative could be the allocation of a small portion (probably less than one-half of one percent) of the anticipated savings that are projected to accrue through a productivity enhancement.

to expand the SEAWOLF producibility steering group structure to include participants from other shipyards and design agents. A third could be a requirement that those yards developing the knowledge follow a prescribed plan for imparting the new knowledge to selected representatives of other yards, design agents, the supplier base, and academia.

Whatever the selection, the important thing is that one be made. As things now stand the process is so constructed that those yards and design agents actually involved in SEAWOLF will be the only significant knowledge beneficiaries; the result will be a widening gap between the yards with advanced technology know-how, and those yards without. This will ultimately lead to the latter group's further decline, and additional deterioration of the overall U.S. shipbuilding base.



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Revitalization of Industrial Engineering in the Naval Shipyards

No. 5A

Roy M. MacGregor, Member, Naval Sea Systems Command, Washington, D.C.

ABSTRACT

Recent developments in the ship repair industry have focused attention on the operation of the naval shipyards. The loss of commercial ship construction work to foreign nations and the declining commercial ship repair work market have resulted in aggressive competition among private shipyards for naval ship repair work. The naval shipyards have come under increasing pressure and scrutiny to become more productive and cost effective. This paper examines the impact of these factors on the naval shipyards, specifically with respect to the industrial engineering functions. The paper describes the initiatives taken to revitalize industrial engineering in the naval shipyards and summarizes some of the successes achieved in reducing costs. The paper concludes with a prognosis for the future and describes efforts to institutionalize the strengthened role of industrial engineering.

INTRODUCTION

There are 8 naval shipyards, 4 on each coast (considering Pearl Harbor as a West Coast shipyard), located as shown. (Fig. 1) Although they all share a common mission of repair and overhaul of US Navy ships, each shipyard has unique capabilities and specific mission assignments. Portsmouth and Mare Island perform work principally on nuclear submarines; Philadelphia does work on non-nuclear

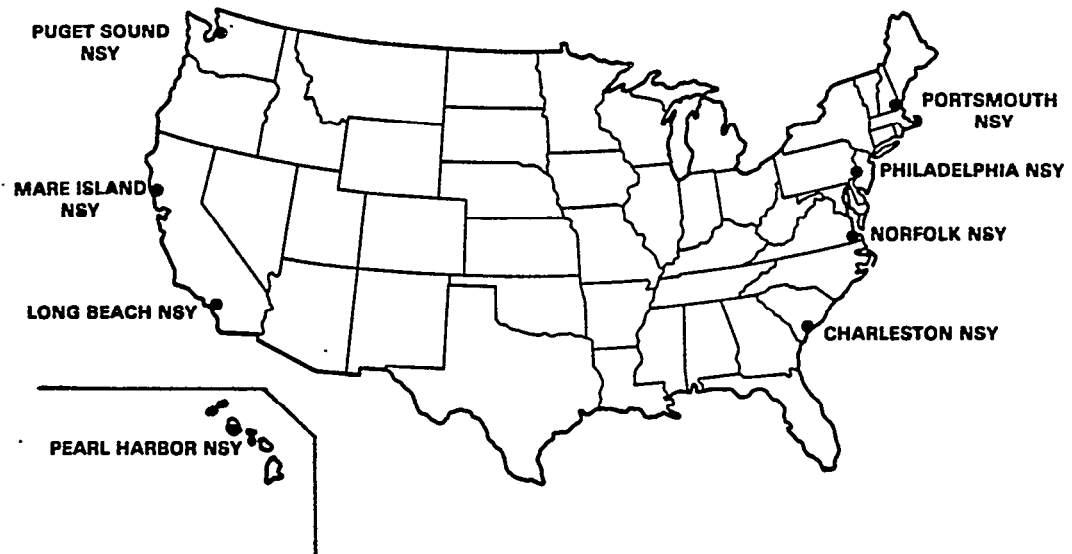
surface ships, including the Service Life Extension Program (SLEP) on non-nuclear aircraft carriers; Norfolk and Puget Sound repair nuclear submarines and surface ships, including nuclear aircraft carriers; Charleston works on nuclear submarines and surface combatants, (excluding aircraft carriers); Long Beach does work on non-nuclear surface combatants; and Pearl Harbor repairs all ship classes homeported in Hawaii. Although each shipyard is unique, they all pride themselves in delivering ships back to the navy after repair and modernization in fighting trim, and fully capable of performing their assigned mission. Quality of work has always been the hallmark of the naval shipyards. The naval shipyards are vital to our strategic defense. Maintenance of the skilled labor core and shipyard facilities are critical to our ability to respond in time of national mobilization as well as perform our peace-time mission.

BACKGROUND

The naval shipyards have a long history of serving the fleet: the oldest shipyard, Norfolk, was constructed prior to the Revolutionary War; the newest, Long Beach, was erected during World War II. Total employment levels have varied with a peak in 1943 of about 350,000 at the then 11 naval shipyards; currently

FIGURE 1:

NAVAL SHIPYARDS



about 70,000 are employed at the 8 shipyards. Up until the late 1960's, the naval shipyards were involved in shipbuilding as well as repair; today their mission is confined to the overhaul, modernization, and repair of naval ships; all ship construction being performed by the private sector.

Organizationally, the naval shipyards are a holdover from the early days of the Industrial Revolution, when the master craftsmen were the dominant force in directing productive efforts and in determining work methods. The shops in a naval shipyard, organized by trade, are to this day managed by former mechanics who, by demonstrating proficiency in their craft, have been promoted to the level of shop superintendent, or shop master as the position is still occasionally referred to. Cultural change comes hard in the naval shipyards: the long standing traditions of organizing work by trade boundaries are not easily changed - one reason why we have been slow to adopt newer work methods, such as zone

outfitting. Engineers have traditionally been cast in support roles, called upon to resolve problems, but not expected to play much of a role in establishing productive efficiencies or determining optimum work methods. In fact, since supervisory pay has historically been tied to the size of the work unit, there has been little incentive for shop managers to look for more efficient methods. Frequently, the reward for being productive has been the loss of resources in the form of budget or manpower. Additionally, the staggering number of constraining rules and regulations, particularly in the personnel management area, has fostered a defeatist attitude with respect to change. Furthermore, the emphasis in naval shipyards has historically been placed on meeting schedules, frequently at the expense of cost efficiency.

INDUSTRIAL ENGINEERING IN THE NAVAL SHIPYARDS

Industrial engineers are not new

to the naval shipyards. In 1946 the Bureau of Ships issued a directive to all the shipyards defining the responsibilities of the Heads of Departments and Divisions [1]. The Industrial Engineering Officer was described as the Head of the Management, Planning and Review Division, responsible for conducting studies and preparing reports for shipyard management, "in order to improve and simplify organization, administration, procedures, and utilization of manpower and facilities throughout the Naval Shipyard". A pretty broad charter, but without any teeth in it. Over the years the organization became known as the Management Engineering Office and they still provide reports and support to shipyard managers as well as staff support to the Shipyard Commander in broad areas with little direct control over shipyard operations. The Industrial Engineering identity has gradually disappeared and in recent years, only the Production Engineering Divisions of the shipyards have had much involvement with classical Industrial Engineering functions, and those mostly relegated to the development of engineered labor standards and facilities development.

As early as 1950 a major finding of a study conducted by a Management Engineering consultant firm was that "the navy must assemble a group of trained industrial engineers and appoint in the production shops experienced workmen to develop standards of performance under the technical guidance of industrial engineers" [2]. Although many of the recommendations of that study were disregarded, the Navy did establish a standards program, which has survived to this day albeit with limited success in controlling shipyard costs. The reasons for the failure of the standards program are varied; an underlying cause is the complexity and variability of the ship repair business. In addition, over the years many of the standards have been eroded through adjustment for contingencies, projected growth, personal bias, or specific problems, resulting in standards which have reduced credibility and effectiveness. Even when credible standards have been developed, they may or may not have been accurately reflected in the job estimates, which in turn have been frequently disregarded by those doing the work.

In 1984 another study of the naval shipyards (along with other industrially-funded activities of the Navy) was conducted, this time by Coopers and Lybrand [3]. Once again

they found that the shipyards lacked a directed cohesive industrial engineering program. Among their recommendations; "increase the size and involvement of the shipyard industrial engineering organization in all aspects of shipyard operations". The impact of this far-reaching recommendation was diluted by other findings and recommendations which focused on the need to reduce costs, particularly in the overhead area. As a result, although it was generally conceded by shipyard managers that there were inadequate industrial engineering resources in the shipyards, there was a wide spread perception that we couldn't afford to increase the industrial engineering staffs; that if anything, these staffs should be reduced in number along with other overhead functional areas. In fact, during 1985.

several shipyards did reduce the number of people in their Production Engineering Divisions, straining the limited industrial engineering resources to an even greater extent.

Fortunately, during the same time frame (1985) NAVSEA headquarters support for and understanding of the important role which industrial engineers could play in improving shipyard efficiency was increasing. Under the leadership of the newly appointed Deputy Commander for Industrial and Facility Management, RADM Roger Horne, additional impetus was given to enhancing the role of industrial engineering in the naval shipyards. Largely due to his personal interest and guidance, the stage was set to revitalize the industrial engineering function with the ultimate objective of bringing down shipyard costs. During this time period, it was becoming increasingly clear that the naval shipyards would have to reduce costs. Shipyards in the private sector were increasingly dependent upon Navy work, and as a result, were stepping up their efforts to get a larger share of the Navy workload. A decision was made in

the-1984-85 time frame to compete some ship availabilities between the public and-private sectors. A decision was also made to reduce the 1987 ship maintenance budget for the naval shipyards by \$500 million while keeping the workload constant, a 17 percent gain in productivity. At this time also, the federal deficit was getting increased visibility and interest - all factors which clearly showed the need for improved efficiency in the naval shipyards.

THE PLAN OF ACTION

In late 1985 RADM Horne asked that we identify the actions necessary to develop a strong and effective industrial engineering function in the naval shipyards.

In order to answer his request, a group of the shipyard Production Engineering managers was assembled for a two day brain-storming session. The result was a one hour brief to the Admiral, during which the following points were made;

1) The industrial engineering function should remain within the Production Departments of the shipyards since the primary focus of industrial engineering improvement efforts is with the production systems and processes.

2) In order to develop the industrial engineering role, many of the ancillary functions being performed by the Production Engineering groups, such as equipment maintenance support, tool engineering, manufacturing engineering, design of industrial support equipment, rigging engineering, and others, should be reassigned or minimized.

3) Additional industrial engineering resources will be required - both from reassignment of personnel from within the shipyards as well as recruitment of engineering talent from outside the shipyards.

4) Existing resources need to be better utilized, through leveraging of engineers as project team leaders, better training of engineers and technicians, and better screening and prioritization of work.

5) Shipyard management needs to be "sensitized" to the role and potential for industrial engineering in meeting the challenge to reduce costs and become more efficient in doing work.

6) NAVSEA headquarters needs to be more supportive and provide stronger leadership of industrial engineering than it has in the past.

The reaction from RADM Horne was generally favorable to the groups recommendations and we were tasked to "make it happen".

IMPLEMENTATION OF THE PLAN

One of the first things we did was largely symbolic, although very important; that was to change the name of our organization in NAVSEA from the Facilities and Equipment Division, to the Industrial Engineering and Planning Division. Simultaneously, we reorganized by establishing two principal subdivisions or "offices" - one for industrial engineering and the other for capital investments; each headed by a senior level manager.

In addition, we transferred people into the industrial engineering branch, gradually increasing the staffing to its current level of four engineers and four technicians.

Early in 1983 a group had been established which gained stature and importance as a result of the renewed emphasis on industrial engineering. The group, called the NAVSEA Industrial Engineering Steering Group, or "NIESG", was comprised of the shipyard Production Engineering Division Directors and the Director of the then Facilities and Equipment Division of NAVSEA. The purpose of this group was to facilitate the transfer of information among the shipyard Production Engineers and NAVSEA as well as to provide a forum to discuss policy issues of common concern. Initially, despite the name of the group, most of the issues discussed were not related to industrial engineering: they primarily focused on facilities and equipment issues.

When the industrial engineering challenge was recognized in late 1985, the NIESG was a natural vehicle to use in developing a strategy and action plan for the enhancement of industrial engineering. During a December 1985 NIESG meeting at Charleston Naval Shipyard, the NIESG was briefed on the presentation made to RADM Horne and his favorable reaction. At the following meeting, in April 1986, in Monterey California, the group discussed plans and progress being made at the individual shipyards to execute the recommendations approved by RADM Horne. We discovered that many of the Production Engineers were having difficulty in getting shipyard management support for some of the initiatives that they were attempting, such as the reassignment of functions. A RADM Horne policy letter had been signed out in March 1986 to help overcome the obstacle, but little impact had been observed in April [4]. The March letter reiterated the need for naval shipyards to become more cost effective and pointed out that investment in industrial engineering resources should yield favorable returns. Shipyards were strongly encouraged to increase their capability in the industrial engineering area.

1986 was a busy year for everyone involved in the industrial engineering enhancement efforts. At NAVSEA headquarters we began numerous initiatives to foster and encourage expansion of the function in the naval shipyards. One of the problems identified early on was a lack of shipyard management understanding of the industrial engineering function.

Several concurrent actions were undertaken to address this concern. A contract was established with a prominent consultant to teach an introductory industrial engineering course, aimed at Production Department managers who had received little previous exposure to the subject. To date, this course has been presented 10 times, at seven of the eight naval shipyards, and at NAVSEA headquarters. The success of this endeavor has been confirmed by an increasing demand on the part of production shop managers for industrial engineering support.

In August 1986 the NIESG members paid a visit to the headquarters of the Institute of Industrial Engineers (IIE) in Atlanta, Georgia to discuss ways in which the IIE could help to support our efforts. One outcome of the visit was that in October 1986 a Senior Manager from IIE addressed the shipyard production officers during a meeting at Mare Island Naval Shipyard, and described some of the favorable results being achieved in private industry through the application of industrial engineering techniques. Industrial engineering has continued to be an agenda topic for the Production Officers in each of their meetings held since October 1986, resulting in increased awareness of the potential benefits to be achieved through the use of industrial engineers, and support on their part for hiring additional industrial engineers.

In September 1986, the NIESG met in Sturgeon Bay, Wisconsin and visited Peterson Shipbuilders to observe the positive results being achieved by their aggressive industrial engineering efforts including active participation in SP-8. RADM Horne attended the two day meeting and shared with the group his vision of what industrial engineering should encompass in the naval shipyards; ranging from development of an overhaul strategy to the analysis of high cost jobs to effect improvements.

A significant outcome of the September meeting was the establishment of a subcommittee tasked to define the ideal naval shipyard industrial engineering system and to address short and long term implementation strategies. The final report of the subcommittee was issued in August 1987 [5]. Several of the findings and recommendations contained therein were significant and will be discussed in more detail later in this paper.

Also during 1986 a program was initiated for the NIESG to visit private industry corporations recognized for their active industrial

engineering programs and achievements. Companies visited to date include Dana Corporation, Caterpillar Tractor, 3M Corporation, Rockwell International, and the Quonset Point Division of Electric Boat. These visits have proven especially beneficial in helping to identify industrial engineering techniques which are effective in the private sector and which can be adopted to the public sector. Caterpillar Tractor for example, has recently gone through an adjustment period of dealing with a new competitor, requiring cost reductions. The approach they used in identifying potential efficiencies has direct applicability to the naval shipyards. In some cases these visits have resulted in a continuing dialog between our shipyard industrial engineering managers with their private sector counterparts, to their mutual benefit.

During 1986 a formal work sampling program was established at the naval shipyards. In May 1986 NAVSEA tasked the shipyards to begin conducting the studies and provided guidance with respect to the measuring of productive, ancillary, and non-productive activities [6]. The purpose of these studies which are to be conducted at least quarterly, are two-fold. First they can provide statistically reliable data to identify problem areas where corrective action will be cost effective. Secondly, work sampling studies provide shipyard management with information and indicators on productive levels and effectiveness of actions taken. NAVSEA has established a corporate objective of improving shipyard worker productivity by 20% - the work sampling studies results are an indicator of the success achieved in meeting that goal.

Finally in 1986, the Industrial Engineering and Planning Division became actively involved in the National Shipbuilding Research Program (NSRP). The Division Director is designated as RADM Horne's representative to both the Ship Production Committee and the Executive Control Board of the NSRP, and the Division also administers a portion of the NAVSEA funds provided to support the NSRP.

The hoped-for gains to be achieved through this active involvement in the NSRP include continuation of the development of shipbuilding and ship repair technologies generally fostered by the NSRP, as well as providing a vehicle for the interchange of information between the private and public shipyard communities in various areas of common interest, including industrial engineering.

INCREASING THE VISIBILITY OF INDUSTRIAL ENGINEERING

During 1987 the tempo picked up. In January 1987 the shipyard commanders were briefed on several industrial engineering topics, including the potential for effecting cost-savings through the application of industrial engineering resources, and the important issue of hazardous waste minimization to be achieved through analysis of industrial processes. Follow on briefings in these and other industrial engineering initiatives have been given at each of the shipyard commanders conferences since. These briefings were successful in building support for the industrial engineering revitalization efforts and facilitated the achievement of two of the recommendations made by the Production Engineering Managers. -Additional staffing was provided during 1987 and some suboptimal functions were reassigned within the shipyards.

Concurrently, an effort was made to sensitize the shipyard commanders of the future. A briefing was presented to the Engineering Duty Officers attending a seven week Basic Course at the Engineering Duty Officer School at Mare Island Naval Shipyard in January 1987, and has been repeated during each session of the course since that time: four times per year. Finally, other shipyard managers, particularly those in the Production departments, have also been briefed on industrial engineering applications in the naval shipyards in order to build a consensus of support for the efforts being undertaken.

In addition to increasing staffing, the Production Engineering Divisions within many of the shipyards reorganized and established Industrial Engineering Branches to give added visibility to the function. Personnel in these Branches were charged to conduct methods and process analyses, and to identify potential areas of cost savings. Several of the shipyards set targets for their engineers of 5 times their salaries in savings to be identified each year. Additionally, industrial engineers were assigned to work directly in the Production Shops, using industrial engineering techniques to analyze problem areas and develop recommendations for improvements to lower costs. The results of these efforts have been impressive and will be described later.

In mid 1987 NAVSEA issued a corporate business plan for the naval shipyards [7]. Specific reference to enhancing the industrial engineering

functions was as follows:

"More emphasis needs to be given to and by the industrial engineering functions to continuously seek ways of improving work processes to optimize resource effectiveness, reduce the volume/toxicity of hazardous waste generation, reduce incidents of rework and generally improve the output of the mechanic...."

Furthermore, application of industrial engineering techniques and resources is an-inherent part of many of the goals and objectives in the plan.

The shipyards responded by developing their own business plans showing the actions to be taken to meet the targets established by NAVSEA including the enhancement of industrial engineering. In order to assure the desired level of attention on industrial engineering functions, NAVSEA subsequently tasked the shipyards to develop a specific strategic plan for increasing their industrial engineering efforts with the ultimate objective of reducing costs and within the context of ten specific target areas [8].

A related issue also addressed by the NAVSEA corporate business plan is in the area of capital investments. Shipyards were tasked to take steps to ensure optimum use of their limited investment funds, based on economic analyses of their projects. Minimum acceptable thresholds of 15% internal rate of return, and 7 year payback were established. NAVSEA issued instructions for the performance of economic analyses to assure consistency and credibility of these calculations [9]. Shipyards were notified that they would have to defend their savings projections and show how and where they were effected through budget reductions. Industrial engineering analysis of capital investment projects were thereby emphasized and in fact, required for successful project development.

SUBCOMMITTEE REPORT

The report of the subcommittee established by the NIESG, referred to earlier in this paper, was issued in August 1987. The recommendations of the subcommittee were focused in five areas: organization, training, marketing plan, resources, and applications.

The principal organizational recommendation was that the Production Engineering Division be renamed the Industrial Engineering Division, still located in the Production Department, but with primary mission and objectives oriented around industrial engineering

functions and organized to support those functions. Earlier this year, in January 1988, NAVSEA formalized this recommendation by issuing specific guidance to the shipyards directing the redesignation of Production Engineering as the Industrial Engineering Division.

The second area of subcommittee concern; training, was addressed by short-term (1-6 months), mid-term (6-18 months), and long term recommendations. Short term recommendations included internal shipyard industrial engineering training and shipyard participation at IIE conferences. Although there has been some increase in shipyard activity in these areas, the subcommittee recommendations have not been fully met. Mid term recommendations included conducting IE workshops with customers and utilization of outside training resources such as SP-8 and the Army Management Engineering Training Activity (AMETA). To date these resources have not been used as much as we would like, although some shipyards have AMETA qualified instructors to provide this training locally. The long term recommendations include the development of a IE training curriculum by NAVSEA, and institutionalization of IE training in shipyard apprentice, supervisory, and officer training programs. Our principal focus to date has been on officer training, as discussed earlier. We in NAVSEA are however pursuing the establishment of additional training designed to refresh and enhance specific skills of our engineers and technicians.

The sub committee felt that an aggressive marketing plan would significantly enhance the chances of success of the industrial engineering organization. About half of the shipyards have developed such a plan and have been successful in building customer support through the use of briefings, presentations, and publicity in the shipyard newsletter. The other shipyards are gradually moving in this direction.

Resource recommendations were of two types; the more efficient utilization of existing resources, and the aggressive recruitment of additional resources. Steps have been taken at all eight shipyards in both these areas, but we consider that continuing attention and efforts will be required to assure optimum resource use.

Finally, the subcommittee

concluded that implementation of the recommendations in the areas described above would result in the successful application of IE principles in achieving real cost savings. Their recommendation was that each shipyard develop and implement a strategic plan to assure continued improvement and achievement of results. As discussed earlier, NAVSEA subsequently issued specific direction to the shipyards with respect to the development of such a plan.

RESULTS

Up to this point, the content of this paper has been largely descriptive of the initiatives taken to strengthen the industrial engineer's role. This was not however considered to be an end unto itself, the real underlying objective of all this effort was to achieve cost reductions. Although many of the actions taken are long term and will only show results over the long term, there have been improvements which we feel confirm that we are on the right track.

Such things as the consolidation of tank watches from up to 6 people to 1 person; the use of ultrasonic cleaning vice manual cleaning for certain valve components; in place air flask seal testing vice removing the flasks from the ship and transporting them to the inside machine shops; elimination of 55,000 gallons of industrial waste water through the use of an improved ventilation air scrubber design; are all examples of improvements that have been identified as a result of our renewed reliance on industrial engineers. The savings from the four examples cited above are estimated in excess of one million dollars per year and these are a small percentage of the successes we are recording. Industrial engineers are also playing an active role in adopting the use of zone outfitting techniques at some of our shipyards. Projected savings resulting from this innovative approach to ship repair are in excess of \$500,000 per ship. Adaptation of techniques and technologies from other industrial applications have yielded additional savings. The use of enzyme/bacteria culture for cleaning of sanitary tasks, previously cleaned by manual labor; expanded use of swaged marine fittings in certain piping systems, are but two more examples of the progress we are making.

Success breeds success, and as positive results are being recorded by our industrial engineers, the enthusiasm and support for increasing the numbers of industrial engineers

has been growing. We feel that it is vital to the success of our efforts to publicize the good things being done by industrial engineers in the shipyards. To this end, earlier this year, in March, we held an Industrial Engineering Symposium in Washington DC, inviting papers from naval shipyard industrial engineering personnel. The two day symposium included 12 papers on topics ranging from successful hazardous waste minimization efforts, to the use of group technology as a means of improving productivity.

Senior headquarters and shipyard managers, including shipyard commanders as well as members of SP-8, were invited to attend, and the large turnout confirmed the level of interest in these industrial engineering topic areas. We plan on holding symposia of this kind on a yearly basis as a means of providing continuing visibility and reinforcement to the efforts of our young engineers and technicians.

THE FUTURE

Where do we go from here? How do we continue to build the momentum achieved from our efforts to date? Most importantly, how can we institutionalize the use of industrial engineering resources and techniques so that it becomes an inherent part of the way of doing business at the naval shipyards, and does not languish from lack of interest as has occurred in the past? As stated previously, successes breed success. It is important to continue to highlight the real productivity improvements that are being identified and achieved through the efforts of the shipyard industrial engineering community. It is also important that we establish a process by which advances achieved at one shipyard can be shared with the other shipyards. To this end, the NIESG established a subcommittee at the January 1988 meeting at Philadelphia Naval Shipyard; tasked to investigate the sharing of information and develop recommendations as to the most effective means of achieving this. The results of this study will be available before the NSRF symposium and will be reported at that time.

We recognize that it takes time to institute change. We are trying to modify a culture and mind-set which has developed over many years in the naval shipyards. Not until an entirely new set of managers who have grown up with the idea of the importance of industrial engineering are in place, can we truly expect

full acceptance of the role of industrial engineering in the naval shipyards. Our shipyard military and production shop managers are a product of their environment, which has not fully recognized the advantages to be realized through the use of industrial engineering resources and techniques. In fact, our industrial engineers themselves are not having an easy time breaking out of the stereotype they have been cast in. Many of our engineers still think of themselves as waterfront problem solvers and developers of engineered standards. We must continue to focus on providing training, both for orientation of our managers, and for skills development of our industrial engineers. Finally, we must continue to develop our ties with our counterparts in private industry, through involvement in IIE and SP-8, and visits to private industry leading companies.

There are still many untapped opportunities for our industrial engineering efforts. Areas that we are looking forward to increasing involvement include design for production and industrial planning. Our ship designs have rarely given adequate consideration to maintainability - our industrial engineers have the necessary skills to identify changes which can be made in ship design to improve access and repairability, without compromising the system technical requirements. It is becoming increasingly apparent that investments made in the planning phase of ship availabilities yield high returns in the more efficient execution of work. Our industrial engineers need to assure a more proactive role in the planning function. Finally, industrial engineers must become more involved in the strategic planning of our shipyards. Decisions concerning trade mix, work sequencing, and other overhaul strategy issues have historically been made by managers based on their best intuition and have been frequently driven by workforce considerations. We need to manage our workforce to support our strategy rather than vice versa. Industrial engineering techniques should provide shipyard management with the information they need to make these strategic decisions..

SUMMARY

In conclusion, we are in the midst of exciting and demanding times at our shipyards. Increasing attention on reducing cost and competitiveness is here to stay. We have embarked on a process to increase and enhance our industrial engineering resources as one way to deal with these issues. We

have come a long ways from the days when industrial engineers were primarily used for work measurement and the development of standards. We have a long ways to go before we make full use of this valuable resource. I have a vision of the day when our naval shipyards are recognized as the standards for efficient and effective accomplishments of ship repair and modernization. My vision has the industrial engineers as an inherent part of the shipyard management process, continuously striving for improvement, and continuously achieving results.

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Discussion on Paper #5-A, "REVITALIZATION OF INDUSTRIAL ENGINEERING IN THE NAVAL SHIPYARDS" by Roy M. MacGregor.

by Howard M. Bunch, Member

This paper describes one of the significant initiatives undertaken by the Naval Sea Systems Command with regard to its shipyard operations. And, Mr. MacGregor is to be complimented for making an unbiased and accurate presentation of the evolution of this initiative. He correctly indicates that the industrial engineering activities in Navy shipyards have generally been weak and non-effective. And, there has been significant progress in the past two-three years to at least partially correct this deficiency, as he describes.

In 1986-88 I had the honor to serve the Undersecretary of the Navy as his special assistant. One of my assignments was to assist NAVSEA (Deputy Commander for Industrial and Facility Management) in developing a strategy for improving the industrial engineering function in Navy shipyards, especially as it relates to work processes. My recommendations were generally consistent with these actions that Mr. MacGregor described as being underway. I'm especially encouraged to hear Mr. MacGregor's report of the education and training initiatives that are programmed.

There is one problem area that continues to persist: the lack of industrial engineers among the Navy's uniformed ranks. I feel that one of the long-term reasons 'why industrial engineering concepts have not been emplaced in Navy shipyards is the paucity of professionally trained industrial engineers among the Navy's engineering duty officers (the uniformed ranks who, historically, have been responsible for shipyard operations). Today there are over 1000 engineering duty officers on the Navy's active officer roles. Of

this number less than 10 have degrees in industrial engineering¹. Additionally, the two primary schools where engineering duty officers receive their graduate technical training (Massachusetts Institute of Technology and the Navy Postgraduate School) have no accredited program in either undergraduate or graduate industrial engineering.

I suggest there is a need for the Navy to emplace into their engineering duty officer training program an accredited curriculum for graduate education in industrial engineering. There is sufficient demand throughout the Navy's industrial facilities (beyond the shipyards) for officers with training in this engineering discipline to support such a program. To delay the action on its implementation jeopardizes the permanent emplacement of the shipyard operational improvements that Mr. MacGregor describes. ~~Hopefully, the Navy will respond.~~

¹These statistics were quoted to me during a series of discussions with senior Navy engineering duty officers in 1986-87.



THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

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Zone Logic Applications for Submarine Overhauls

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No. 5B

Abstract

Japanese shipbuilding methods have typically been applied in new ship construction. As new buildings decline, the ship repair market has become more competitive and shipyards have started to apply some of these principles to ship repair. Public shipyards have been the most active in this technology development. This paper addresses some of the history and problems that have been encountered at Portsmouth Naval Shipyard in the application of zone outfitting methods.

Introduction

Interest in zone outfitting methods has grown as the Navy deals with reduced budgets and increasing costs. Portsmouth Naval Shipyard is one of several public shipyards that has recently started to use zone outfitting methods in the overhaul environment (specifically nuclear submarines). In this paper we will present our efforts in the hope that our experiences will add to the existing body of knowledge.

Portsmouth Naval Shipyard is located in Kittery, Maine on Seavey Island which is positioned on the border between Maine and New Hampshire. Unlike the other Navy shipyards, Portsmouth deals exclusively in repair, overhaul, and refueling of submarines. Application of zone outfitting methods to submarine work must be integrated with stringent quality control and documentation requirements that are not found in work on surface ships.

In efforts to reduce costs in maintaining and modernizing the fleets, the Navy has adopted a series of policies consistent with the Carlucci Initiatives (reference 1). These are:

- a) Implement increase competition
- b) Implement economic production rates
- c) Reduce time to procure
- d) Reduce apparent cost growth
- e) Improve reliability through specification

- f) Improve schedule realism
- g) Provide more apparent design-to-cost goals

Detailed goals and actions for putting these policies into place were identified in a study performed by Coopers and Lybrand on contract to the Secretary of the Navy.

Efforts at other shipyards

With the stage set by the Carlucci Initiatives and the Coopers and Lybrand report, public shipyards are beginning to adopt appropriate Japanese methods and new technologies. Significant among these are zone management methods similar to those practiced in new construction.

Puget Sound Naval Shipyard in Bremerton, Washington, has been very active in the implementation of zone outfitting methods (reference 1).

In most of these projects, no cost tracking was reported so benefits were recognized qualitatively. However, in one of these projects a reduction of 35% of total estimated cost and schedule performance improvement of 45 days was quantitatively documented.

Subsequently, Puget has applied zone outfitting to the structural work for ShipAlts on the forward end of SSN637 class submarines. On three submarines, traditional methods were used and on four zone outfitting was used. Final cost accounting reported an average savings of about 10% in man hours of which nearly half was overtime when zone outfitting was applied.

Technology transfer has not been limited to just zone outfitting methods. Pearl Harbor Naval Shipyard has begun a Program they call Total Quality Management (reference 2). This program is dedicated to constant process improvement and, thereby, quality improvement. Zone outfitting and work packaging are parts of this more general management

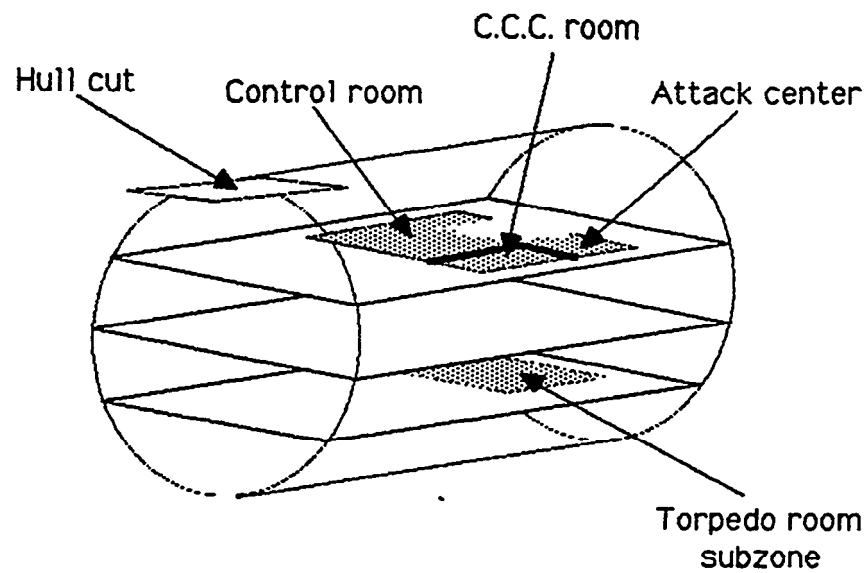


figure 1 - USS Bluefish Pilot Project

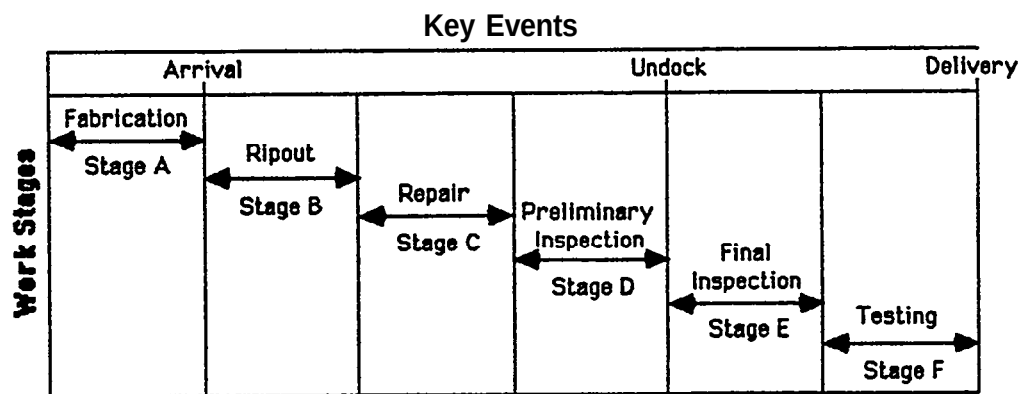


figure 2 - USS Bluefish Work Stages

philosophy. As did Puget Sound, Pearl Harbor has reported significant improvements in work performance on submarine modernization projects.

Philadelphia Naval Shipyard has retained consultants from Ishikawajima-harima Heavy Industries to help apply zone outfitting methods to the SLEP (Service Life Extension Program) of the USS Kitty Hawk. Although no papers have been published regarding these efforts, review of documentation provided to us shows that there is a high degree of schedule and resource visibility. The resulting control of the project will undoubtedly improve the overhaul performance.

Efforts at Portsmouth

In November 1985, Portsmouth Naval Shipyard management established the Adhoc Committee on Work Packaging to investigate methods to increase productivity through improved work instructions and better means of providing mechanics resources they need. The Major conclusions from their investigation were that significant improvements in cost and schedule performance could be realized by:

1. Developing detailed sequencing of work by geographic zone on the ship.
2. Grouping like work by zone in a set of work instructions.
3. Providing self-contained work instructions that cover events in a 1 to 3 week time horizon while minimizing support from assist trades.
4. Palletizing material to support the work instructions and schedule.

Since these findings were consistent with concepts from the National Shipbuilding Research Program (NSRP), transfer of these technologies became the committee's recommendation. Subsequent to the committee presenting it's findings, an assistant to the Planning Officer was assigned to facilitate implementation. His task was to identify pilot project opportunities and determine to what extent Portsmouth management should attempt to implement the committee's recommendations. The intent has been to gain experience with the technologies and management approaches and to best determine the path for transition.

Zone Outfitting on the USS Kamehameha

The overhaul of the USS Kamehameha was selected as the first opportunity to try zone outfitting concepts. The pilot project in this case was limited to sequencing component rip-out and reinstallation by zone. The ship was divided into geographic zones associated with common access cuts. Ship-checking of the areas identified major interferences in

the rip-out paths in those zones and these were considered in determining rip-out sequences. A strategy was developed for the rip-out sequence and a schedule was then created to control events and measure progress.

The project Management Team reported that the rip-out and reinstallation went smoother than on previous overhauls. Trade tasks were better integrated with less lost time, manning levels were lower than normal practice, and scheduled completion dates were met. This approach to organizing work was expanded in the next pilot project on the overhaul of the USS Bluefish.

Zone Outfitting on the USS Bluefish

Portsmouth developed a pilot project on the overhaul of the USS Bluefish. The intention of this pilot project has been to explore the technical, management, and organizational issues involved in evolving from a system-oriented philosophy to a zone-oriented approach to overhaul work.

Applying zone concepts to repair and overhaul and involved the following:

- a) Division of the ship into geographic work zones
- b) Division of the overhaul period into work stages
- c) Detailed sequencing of work in the zones
- d) Scheduling of the work by zone considering manpower resources and work space constraints

The above efforts have been supported by:

- a) providing detailed work instructions (Unit Work Procedures) such that no reference materials will be required by the mechanics
- b) palletizing of material for mechanics based on Unit Work Procedures
- c) participation of production personnel in the planning process

The pilot project has included all the authorized work within the zones shown in figure 1. The primary work has been ShipAlt (ship alteration) 1929 (K), CCS MK 01 MOD 0 installation, an upgrading of the torpedo fire control system. Work from other ShipAlt's and regular overhaul work requirements in the scope of zone planning.

The original zones were defined as:

- zone 101- attack center
- zone 102- control room, aft end
- zone 103- central computer complex
- zone 104- passage
- zone 304- torpedo room forward center

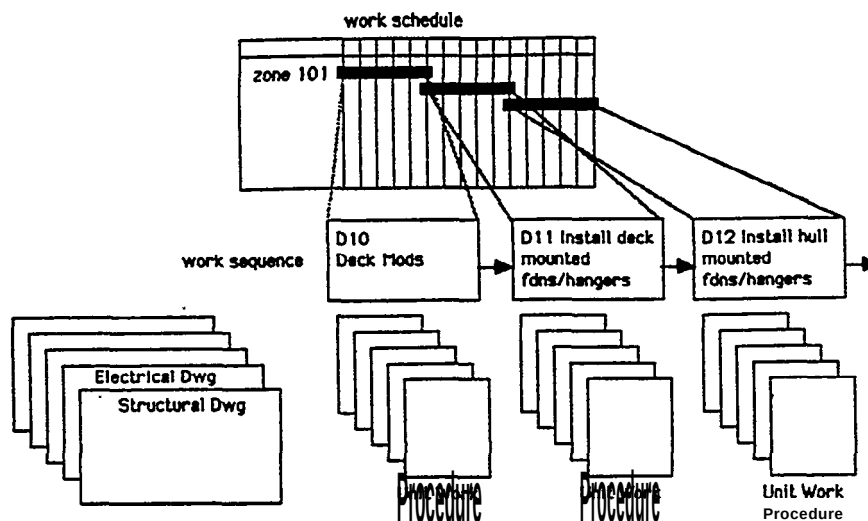


figure 3 - Diagram of Unit Work Procedure Development

Work stages were defined as shown in figure 2:

- A - fabrication
- B - rip-out
- C - repair
- D - preliminary installation
- E - final installation
- F - systems testing and completion

The methods described above were applied to the structural and electrical work. Unit work procedures were not generated for mechanical, piping, and ventilation. However, this work was included in work sequencing and scheduling.

Prior to the start of the overhaul, the decision was made to expand the project to include the operations compartment. This work involved extensive cabling modifications in zone 105, the sonar room, and zone 107, the radio room.

Major work included in the project was to upgrade sonar, radio, and navigation equipment in addition to upgrading of the fire control systems. This required extensive structural, as well as cabling modification. Changes were also required in several piping systems. All of these activities had an impact on insulation and painting.

Testing requires system orientation, that is, tests are conducted as systems are completed. Testing of systems in the zones was not part of the pilot project, but was taken into account in the scheduling. System completion dates to support the integrated test schedule were taken as zone completion milestones.

Unit Work Procedures

Unit Work Procedures were developed for this project similar in format and content to what was done at Puget Sound Naval Shipyard and discussed in reference 1. This process involves converting information that was presented by system into a package that presents it organized according to the ship's geographic zones and consistent with process sequences (figure 3).

Each package contained the information that a mechanic needed to perform the scheduled task. This included isometric diagrams of the components to be removed or installed, detailed work instructions, safety information, and a list of required material.

The Unit Work Procedures also provided the necessary signature documentation for verification of work completion, work quality control, and accountability. All of this information is critical to insuring the safety of the submarine and satisfying the quality control audit requirements.

CAD modeling and use of a database program have been transition planning efforts. CAD modeling of structural work was used to provide graphics for Unit Work Procedures in the same way as has been done at Puget Sound Naval Shipyard and documented in reference 2. However, what proved to be equally useful in the grouping of work was using a commercial database program on a personal computer. Using an appropriate coding scheme, the database program allowed retrieval of information to form work packages and identify similar work to be performed in a zone. This was used extensively for electrical work.

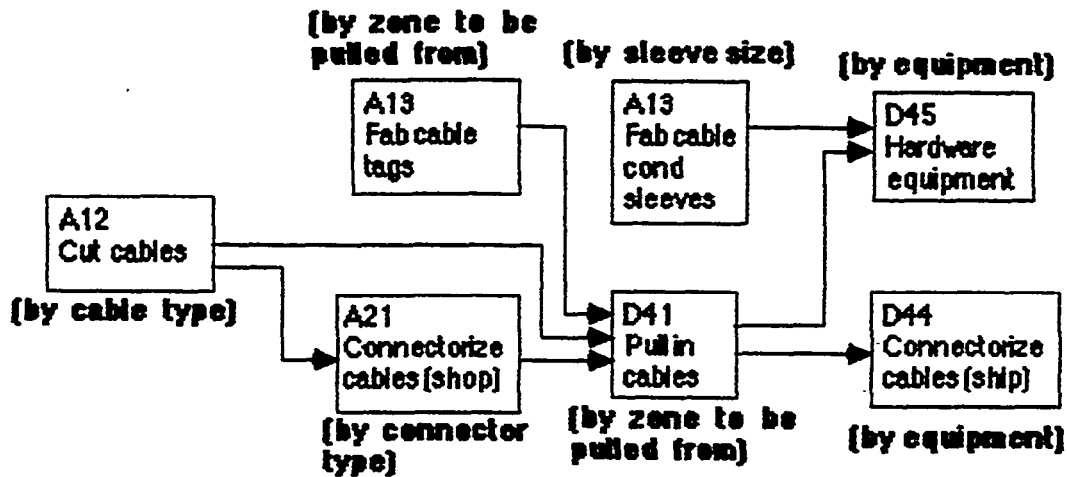


figure 4 - Organization of Unit Work Procedure
Information to Facilitate Use of Group
Technology in Electric Cable Fabrication/
Installation Process

In developing the PC coding scheme for effective retrieval of information, processes were defined and a coding system was established to identify interim products. The database could be sorted for selected features to facilitate application of group technology and development of Unit Work Procedures. This is shown in figure 4.

Organizational correlates

Zone outfitting is a management technology relying as much on who does the planning, scheduling, and control as the actual tools for organizing the work. The intent of breaking the ship down into zones is to reduce the management tasks in size by being product-oriented rather than by system. This allows the zone manager to integrate and control predecessor/successor events and resource allocation. In this case the resources are manpower, material, and calendar time.

The Bluefish pilot project used two organizational concepts to support zone methods. The first involved designating a Zone Manager whose responsibilities were to direct work in the zones and integrate trade efforts.

The second was creating a Zone Planning Team. Core members were representatives from Design Division and production shop personnel. Representatives from the Planning and Estimating department, scheduling, combat systems, and additional shop personnel were added as needed.

The Zone Planning Team gathered in a series of meetings for the purpose of

grouping and sequencing work. The meetings were chaired by the zone manager. Deliverables from these meetings were integrated work sequences for the zones.

Another responsibility of the core Zone Planning Team was to participate in the CAD modeling efforts and the development of the Unit Work Procedures. These tasks represented near full-time assignments for the shop personnel involved.

Lessons learned

Although the project is still in progress, several lessons have been learned that are worthy of sharing. The project significantly deviated from the normal methods of planning work and managing execution. Consequently the project could not be fully integrated into the Shipyard "system". The confusion this would cause during execution was not fully anticipated and has detracted from the successes achieved.

The Unit Work Procedures provided instructions to mechanics but did not replace the traditionally prepared Key Ops in the management system. This approach caused extra work for foremen in reporting costs and progress as well as preventing accurate UWP cost tracking. Since the UWPs did not replace key ops, they did not fully address trade requirements. This limited their usefulness as a manpower planning tool. In the next project, UWPs will be fully integrated.

Although material lists were included on UWPs, the material was not linked with ordering numbers in the

Shipyards MIS. This, also, caused considerable confusion and extra work. This will be corrected in the next project.

The zone manager, by virtue of his position outside the traditional Shipyard project management structure and with limited control over resources, had difficulty performing the trade integration function. His role was further weakened when schedulers with systems background had difficulty developing zone schedules that integrated all work. The credibility of the zone manager, however, has significantly improved since the early stages of the project with apparent corresponding work efficiency improvements.

The use of a relational data base manager for grouping like work and providing input to work instructions when graphics is not required has proven successful as a work management tool during execution of this work.

The mixing of engineering and production personnel in the zone planning team has proven to be an education to both groups. They enjoyed learning from each other. Some engineers have commented that this approach is their first realization that engineering should be concerned with execution cost effectiveness. A large scale and continuous sharing of knowledge between these groups has apparent potential to significantly improve shipyard performance.

The Depot Modernization Period

Portsmouth Naval Shipyard is scheduled to perform one of the first Depot Modernizations of a 688 class attack submarine. The philosophy of the Depot Modernization Period (DMP) is to reduce maintenance costs by going from time-based repairs and upgrading of systems to condition-based, fix-what-is-broken, repairs and upgrading of systems. The objective is to perform upgrading of systems within a rigid time frame and with a minimum of disruptive emergent work.

Portsmouth Management recognizes that such a concept is very different from past work that has been performed at the yard. Consequently, they recognize that a unique project management approach must be developed. Such management concepts require decentralization of decision making and rapid response to problems since no schedule slippage can be allowed.

Plans for the first DMP involve using a zone identification code with the cost collecting numbers (Key Ops). This will allow collection of work content information by zone. This

information can then be used to create zone schedules that integrate trade efforts.

Part of the management approach on latter DMP's will be to more fully incorporate zone outfitting concepts. Although it has not been decided when a fully developed zone management organization will be used, pilot projects are being defined in areas of greatest potential benefit. These projects will provide additional experience to facilitate implementation on following DMP's.

In particular, work to be performed in the after end of the engine room and the associated main ballast tanks is being considered as a zone technology project. The scope of this application would include all shipalt and repair work. Unit Work Procedures would be developed and a more flexible scheduling system similar to that used at Philadelphia Naval Shipyard would be used to control work.

Conclusion

As a result of our pilot projects at Portsmouth, we have concluded that zone outfitting methods can be effective in improving performance on submarine overhaul and repair work. The Shipyard will continue to implement zone methods on a selective basis. It is likely to continue to be refined and expanded in areas where it has the greatest potential benefit. However, factors unique to the nature of Portsmouth Naval Shipyard's work may prevent realization of the full potential improvements from shipyard-wide application of zone technology.

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Technology Assessment in Ship Production

No. 6A

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Abstract

This paper describes a research approach which addresses the format of general systems theory to examine technologies and processes which have the potential for being implemented in the shipbuilding industry. It seeks to create a systematic and logical procedure in which to examine technologies and institutional policies utilized in various other industries and has the potential for creating a strategy for technology and economic impact identification and policy evaluation. Decisions as to technologies are currently based on the readily available costs estimated to implement an alternative designed exclusively for the shipbuilding industry. The generation of extensive competing alternatives and innovations is often impossible to perform due to the lack of a comprehensive data source. Secondary institutional and economic impacts are often ignored. A technology assessment algorithm can develop a framework for an assessment revolving around a contingency hypothesis. The approach incorporates a cost analysis of primary economic benefits and disbenefits that will identify affected institutional parties and unanticipated impacts in as broad and long-range a fashion as available data will permit. Resulting recommendations can provide indispensable prerequisites for the definition of alternatives as to their technological, economic, social, and productivity impacts.

The shipbuilding industry in the United States has lost its world prominence in an atmosphere of sluggish demand, static ship prices, inefficiency and over competition. The desire to make the remaining shipbuilding facilities and products competitive with those abroad has brought about the current trends toward increased sophistication of

ships, and improvements in energy savings and reliability. An emphasis on cost reductions and the incorporation of technological developments in electronics, factory modernization and automation and communications such as CAD/CAM, FMS, industrial robots, and CIMS may be necessary to the future of the industry. The decisions as to when and where technologies such as these are to be implemented in response to the gradual obsolescence of existing technologies are aided by the process of technology assessment.

Technology assessment involves the examination of alternative technology and then evaluation of them in terms of the goals of the industry and the predicted side effects produced by the change. It is a systematic planning and forecasting process to maximize the benefits of technologies while controlling any potentially harmful or unavoidable secondary economic, environmental, or social impacts. Primary economic advantages and disadvantages can be determined by a benefit-cost analysis with the emphasis on impending issues rather than the current problems requiring corrective action. Technology imported from another company, industry, or country may fail to have the desired effect if it is not accompanied by the proper support systems. An environment that provides an understanding of the capabilities and limitation of the technology, the appropriate resources (machinery, skilled and unskilled labor, management, materials, energy), and effective operating decisions is most likely to promote the assimilation of new technologies.

This paper describes a methodology within the general systems approach to examine technologies which have the potential for being implemented in the shipbuilding in-

dustry. The manner in which a problem situation in the shipbuilding industry is defined at the outset directs all future analysis. If any phase of this initial activity is incomplete, the analysis will not proceed toward a best solution and may not even consider the full set of technology options available to the decision makers. Decisions dealing with the allocation of scarce resources to competing demands or the development of optimal strategies involving choices among a wide range of technology alternatives are best dealt with within the framework of the general systems approach. General systems theory isolates the issue requiring attention from a set of perceived disequilibriums and translates the problem into an analytical framework which can utilize techniques such as cost-benefit studies, contingency analysis, and decision methods. This series of steps will determine the key elements required to analyze the problem and its environment, as well as potential solutions and their repercussions. Figure 1 illustrates a functional flow chart for a technical systems study. The flow of decisions, calculations, and suboptimizations is shown by tracing the arrows and is broken into three main categories. The first category of steps involves those that conceptually formulate

the problem and includes boxes 1 through 4. Boxes 5 through 8 assess and rate the alternatives and optimize the choice of a combination of options. Finally, implementation strategies are developed as shown in boxes 9 through 11. At several points in the progression of decisions and analysis, the designs may be modified and a reiteration, through a portion of process performed. Technology assessment is a major component of the evaluation process depicted in boxes 5 through 7, and the concern of this paper.

The first step in generating technology alternatives for evaluation involves determining the existence of new technologies. The development of new techniques or modifications of those used in the shipbuilding industry or in other industries may be indicated after a thorough search of the literature and national technology sources. Government-sponsored research and development programs such as the National Shipbuilding Research Program, intra-industry professional societies (SNAME, ASNE), and inter-industry professional societies (ASME, IEEE, IIIE, ASHRE) provides a forum for the sharing of experiences and needs. New technology can also be purchased from other companies and hardware manufacturers, in some instances, or developed by a consultant.

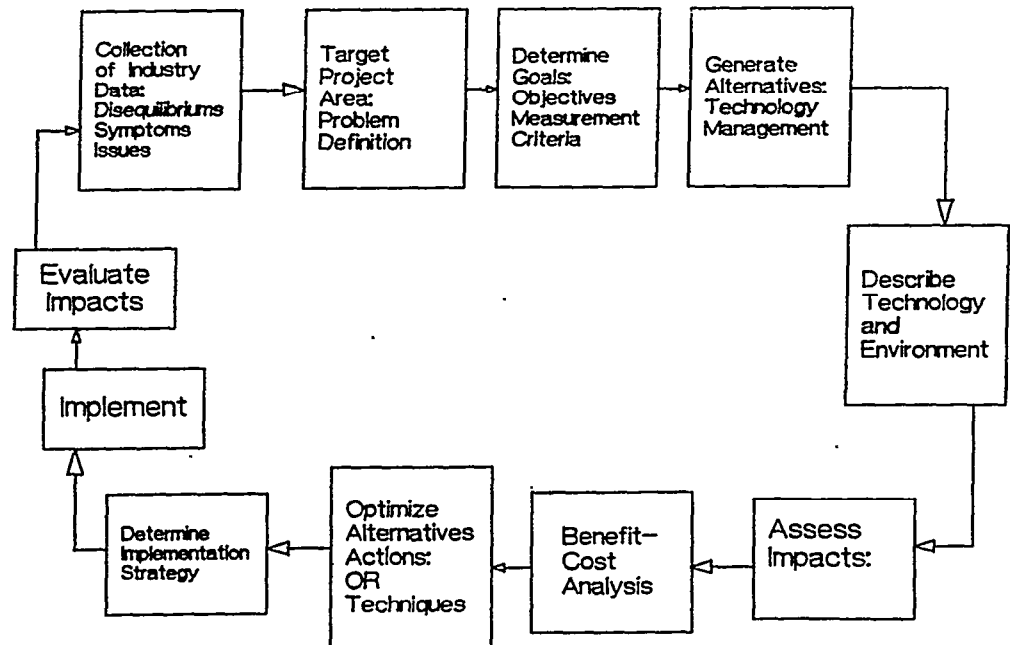


Figure 1. Technological System Functional Flow Diagram

With the generation of various alternatives, it is important to consider that each technology is associated with a set of characteristics that must be fully understood. for example, a particular technique may only be efficient when used in conjunction with sophisticated management techniques, computerized materials handling, or it may make specific demands of energy, transport, or water. When a technology is adapted from another industry it is necessary to recognize that it reflects the circumstances of the economy in which it was developed and is characterized by infrastructure, labor and administration of a particular design and quality. The evaluation of new technology requires a description of potential costs, benefits, personnel requirements, and other variables associated with it in order to be able to later accurately assess its economic, social, and environmental impacts. These items are detailed further in Figure 2.

NEW TECHNOLOGY DESCRIPTION	
Costs	hardware/machinery
	implementation
Benefits	personnel training
	maintenance
Personnel Requirements	material requirements
	additional input requirements (water, energy, transport)
	relative factor endowments
	relative factor prices
	information requirements
	Improved productivity
	improved safety
	social impacts/job satisfaction
	quality
	reliability
	flexibility

Figure 2

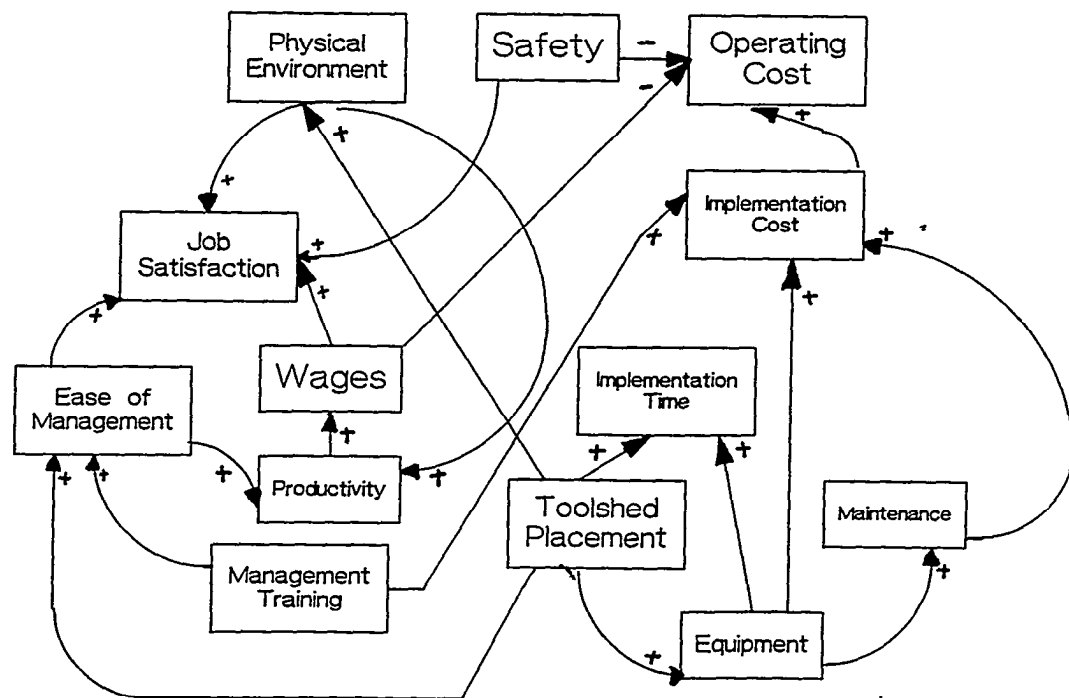
In addition to a description of the new technology, the environment characterizing the shipbuilding industry and the individual plant within which improvements are to be made must be scrutinized fully before any implementation is considered. Figure 3 depicts some of the concerns to be addressed at this stage.

ENVIRONMENTAL CONSIDERATIONS FOR TECHNOLOGY TRANSFER

Economic Circumstances	price and availability of inputs
	access to inputs
Market Competition	access to labor of different types
	factors holding up wages (government regulations, trade union activities)
trends in employment structure/philosophy (higher education levels, less physical labor, shorter work week, flex time)	
	position relative to other industries (wage levels, R&D expenditures)
Market Competition	specialty niche (ship repair, push boat construction)
	market served (local, global)
market saturation	market growth
	import/export restrictions (exchange rate, Jones Act)
status of competition (foreign subsidized)	
Infrastructure	supplier competition
	control over suppliers/degree of vertical integration
subcontractors	transport and communications available
	organization of labor market
basic industry support (domestic steel prices versus foreign)	
	scale of operations (may be only one technology efficient at each scale)
state of available managerial/technical knowledge	
Management System Interface	nature of decision-maker and objectives
	· maximization of profits after tax
	· maximization of local profits before tax
	· employment maximization
	· spread to opportunities to rural areas
	l commitment to change
	l perceptions of various parties about future of the product
	ability of management system to control technology
changes required in management structure	
	philosophy regarding motivation, incentives
Hardware Interface	compliance with present standards
	compatibility with infrastructure
Economic Assistance	
	Government
	l national industrial policy
	l tax structure
	· subsidies
	l research and information (NAVSEA 90M, Institute for Research and Engineering for Automation and Productivity in Shipbuilding, National Shipbuilding Research Program)
Private investment (banks, venture capital, stock market, customers)	
Legal System	intellectual capital
	restrictions on trade (relaxation of Jones Act to allow foreign built hulls on US flag ships)
World Trade	
	total volume
	cargo movements
	activities of competitors abroad
	patterns of demand

Figure 3

The arrow diagram is a valuable analysis technique for defining a system through the interrelationships of its major component elements. Arrows connect each pair of parameters that have a cause-effect relationship. When a change in one variable causes a change in a second variable in the same direction, it is defined as a positive relationship and denoted by a plus sign. If that effect is in the opposite direction, it is defined as a negative relationship and denoted by a negative sign. Figure 4 illustrates an example of an arrow diagram describing the dynamics of shipyard considering optimization of the location of its toolsheds. Through this diagram, the first and second-order expected impacts of the technology can be recorded. The total set of arrows comprising the model illustrate the economic, social and environmental impacts upon the shipyard that will result from modifications to combinations of elements.



New technologies often require a rethinking of production procedures, materials, design, and the management system. These changes are frequently inconsistent with standard operating procedures and it must be assumed that some of the changes required to implement new technologies will add sufficient cost to make the total cost of the new technology unacceptable. Some of the new and modified technologies in the shipbuilding industry are depicted in Figure 5. The relative desirability of technology alternatives is finally to be assessed with a benefit-cost analysis. This analysis essentially calculates the ratio of excess benefits over costs by dividing the project benefits by the project costs, with an incremental analysis performed whenever more than two alternatives are being compared.

Because of the absence of a comprehensive data source on alternative technologies for application in the shipbuilding industry,* and because technologies from their industries often undergo forced implementation, it is especially important that a systematic

framework for the evaluation of new technologies be adopted. The methodology described here for a thorough technology assessment can assist in the complicated task of evaluating the technological alternatives and the future consequences of their implementation.

Acknowledgement

The author wishes to acknowledge the helpful comments contributed by Dr. Richard L. Storch and Mr. Scott Churchill.

TECHNOLOGY FORMAT CHANGES IN THE SHIPBUILDING INDUSTRY

	<u>Traditional Shipbuilding New Technologies</u>	
Production	System oriented electrical, hull lay keel, build up multiple ship runs	Process oriented cutting, welding, outfit build by zone - unit, block, ship
Capital Equipment	Docks, ways	Welding lines, robots, cranes, paint shed
Lead Time	Long each run unique	Short - standardized modules
Inventory	Stored	Just-in-time
Working Plans	Blueprints	Formalized work packages, data-base intensive
Flexibility	Through floor level changes	Through feedback, module modification

Figure 5



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Product Work Breakdown: An Essential Approach for Ship Overhauls

No. 6B

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ABSTRACT

Some North American shipyard managers have successfully adopted a product work breakdown structure for ship construction. Adoption by those who would compete is inevitable. But, none have applied the same product-oriented approach for ship overhauls. Yet, significant such progress is being made by a naval shipyard.

In yards which accept both challenges, continuing to employ a system work breakdown structure for overhauls while applying a product work breakdown structure for construction, doesn't make sense. Two different management information systems are required.

Thus, this paper identifies how the same product-oriented logic successfully applied to improve construction productivity, also applies for overhauls.

INTRODUCTION

Many are familiar with or at least aware of the logic revolution irreversibly established in some North American shipyards. Basically, information that had been grouped only by system, e.g., as on a system arrangement and detail drawing, is now grouped in the design process to exactly anticipate the parts, subassemblies, and assemblies, i.e., the interim products, required to build ships. In each case, the build strategy which guides designers in so grouping information, is imposed before contract design starts!

When the interim products are grouped by the problems inherent in their manufacture, even for different ships being built simultaneously, production lines can be organized which are just as effective as counterparts in the automobile manufacturing industry. This.. approach which examines required interim products with different eyes so to speak, looks for manufacturing commonalities and ignores differences in design details. The organization of

alike work in this manner is called Group Technology (GT). GT is the most ideal way to process interim products of different designs in varying quantities as required for ships and for many end products other than ships. [2]

For certain interim products, production lines sometimes constitute real work flows wherein materials are conveyed from work station to work station. In contrast, when a team of workers is moved from site to site and the work category at each site remains the same, the effort is regarded as virtual work flow. The impact on people is the same as if they were at fixed work stations and a conveyor was transporting the materials being worked. The objective of work flows, both real and virtual, is to avoid the greatest single loss in any industrial endeavor, i.e., people waiting for work.

Rationalizing virtual work flows is extremely important because they are means for effectively organizing very much of the ship production effort. Particularly outfitting and painting, and because they are the means for bringing unprecedented order to nearly all shipboard overhaul activities. Whereas, traditional methods which feature system-by-system work packages assigned to different supervisors are always issued with the inferred management cop-out, "Somehow coordinate among yourselves."

As work on one system conflicts with work on other systems in an infinite number of ways, traditional supervisors are preoccupied with reacting to day-to-day changing circumstances. Such disruption is significantly reduced with the product-oriented (also called zone-oriented) approach because all work of one type, say gas cutting, is planned to be performed in a specific zone during a specific stage. No two work teams doing different types of work are unintentionally scheduled to be in the same zone at the same time.

In the absence of conflicts, productivity indicators, such as, man-hours per weight of material ripped out or man-hours per lineal feet of gas cutting, become very meaningful. Work performances become predictable. This association of man-hours with a discrete product is essential for true compliance with the U.S. Department of Defense cost/schedule control systems criterion for a work breakdown structure to "...define the product to be produced as well as the work to be accomplished..." [3]

Equally important, each envisioned interim product, i.e., what is to be worked in a specific zone during a specific stage, becomes a focal point for organizing prerequisite work instructions, materials, and manpower. Already, some overhaul strategies are being expressed in terms of zones/stages. As a consequence, the preparation of work instructions and the procurement and marshaling of materials, including materials overhauled in yard shops, proceeds in accordance with the exact same strategy to be applied by production people on board for each unit of work.

Also, because their system-oriented work packages are usually large and scheduled for implementation over relatively long periods, traditional supervisors become skilled at retaining unspent budgeted man-hours from one-system in order to charge them to another system for which they would otherwise have a budget overrun. Usually, their intent is not deceit. More often, they want to avoid having to make explanations when they are preoccupied with reacting to more unforeseen problems. The consequence is experience vested in supervisors only, i.e., inadequate Corporate experience.

The most important thing in any industrial enterprise is how to analyze. Corporate experience is crucial for accurately estimating future overhauls, for budgeting man-hours based on workers performing normally in a statistical sense, for scheduling with certainty based on mean values and standard deviations, and for constantly setting targets for improvement. As overhauls become more complicated, particularly overhauls of warships, their successful implementation with 'traditional system-by-system grouping of people, information and work, is becoming impossible. Adequate corporate experience can only be delivered from a product work breakdown structure with people and information grouped accordingly. Work organized by zone/stage which is also classified by problem area per GT logic, is susceptible to statistical analysis. When work is so organized,, Dr. W. Edwards Deming's fourteen points for management become alive even for overhauls.

Some traditionalists will remain skeptical. "Overhauls are different from construction!", they will say and they are right. In two very significant aspects, -overhauls are much easier! Most overhauls are not encumbered with having to integrate structural work to the degree encountered in construction. Also, management, supervision, and the workforce as an entity, knows an infinite amount more about a ship due to arrive for overhaul than does an organization awarded a shipbuilding contract know about the ship to be built. More often than not, an overhaul activity has previously overhauled a ship of the same type if not of the same class.

"What about open and inspect work?", traditionalists will counter. The lack of definitive information upon contract award is what both construction and overhauls have most in common! In the world's most effective shipyard, contract design is part of the shipbuilding process. With just preliminary design input, production engineers document a build strategy which will guide subsequent design-stages. Before, the contract protected only the owner's ship performance characteristics. Now, with incorporation of a build strategy in the contract design, the yard's manufacture system is also protected. This vigilance guarantees that the manufacturing system will retain its flexible nature and, through management by target, will continue to improve. Without such flexibility and constant improvement, competitiveness is jeopardized. The yard's very existence is at stake. A major production engineering effort, i.e., planning well before the fact, must commence with less information than is usually available when a contract is awarded for overhaul work. Devising an overhaul strategy in terms of zones/stages for a known ship type is much easier.

As shown in Figure 1, the design process for construction is organized in phases. The first, contract-design, is preceded by a product-engineered build strategy. As the progress of contract design makes more information available, production engineers refine the build strategy in time to guide the next design phase, i.e., functional design, and so on. By the time the last design stage is reached, the information being produced by the production-engineering effort is tactical in nature, e.g., it advises designers where to show on sketches of hull blocks, the reference points and lines needed to facilitate hull erection, it includes specific instructions for drilling and tapping fillet welds in portions-of blocks that will form oil-tight bulkheads so that such welds may be air tested in the shop, it includes instructions for dividing material lists in order to obtain

work packages of about 40 man-hours each, etc.

In the process depicted by Figure 1, information is first grouped in a large-frame sense, then in an intermediate-frame sense, and thereafter in a small-frame sense corresponding to work packages. In other words data always exists for the entire construction effort but in different degrees of refinement as time goes by. The process is the same for large overhaul endeavors as shown in Figure 2.

The boxes and flows shown in Figure 1 and 2 are identical only for discussion purposes. Open-and-inspect on board and open-and-inspect in Shops does not occur in distinct phases as shown in Figure 2. They occur bit by bit as various equipments are opened regardless of their locations. But, the effect is the same as in construction projects. Information describing required work is being refined as time goes by.

Overhaul traditionalists will persist, "What about materials? We don't know what is needed until open-and-inspect takes place!" To the uniformed it would seem that similar overhauls have never been accomplished before and that contingent work cannot be planned and scheduled.

CONTROL THROUGH CONTROL OF MATERIAL

One of the neatest things about a product work breakdown is that it facilitates production control through control of material. Man-hours required are always related to some physical characteristic of material regardless of whether something is to be ripped out, overhauled, fabricated, or reinstalled. With obsessive focus on identifying all material including contingent material at the bid stage, with rough assessment of where in the ship and when materials are to be processed, and with productivity indicators which reflect corporate experience, man-hours required are obtained and schedules are derived. The initial man-hour budget and schedule so obtained do not make sense unless they are in a large-frame sense commensurate with the grouping of information available. As the materials to be processed become more definitive, the man-hour budget and schedule are refined accordingly. At first some materials can be counted from an overhaul work list and from a list of ship alterations (shipalts). Other requirements have to be estimated per material classification, e.g., so many lineal feet of medium-diameter pipe.

What is required is a more effective material management approach which recognizes that material procurement and marshaling are production control func-

tions equivalent to man-hour budgeting and scheduling. It is for this reason that in the World's most effective shipyard, the material procurement manager reports to the production control manager and the production control manager is subordinate only to the general manager. Further, a prerequisite for being a production control manager is having been a production department manager. With procurement so drawn into production control, a much greater sense of urgency emerges about material.

With such emphasis it becomes clear why the most effective shipyard managers regard the computer program which maintains the material required status as the most important computer program, that for payroll not withstanding. For all projects underway, i.e., shipbuilding, overhaul, and other, the computer assimilates all material requirements which are the result of counts of some items and estimates of others. As work is more definitized by open and inspect reports and the development of shipalt detail design drawings, a sorting and collating function immediately asks:

- o "Were materials just designated anticipated in the initial material assessment in sufficient quantities?" if not
- o "Are they long lead-time materials, materials that must be fabricated either in-house or by a subcontractor, or are they short lead-time materials?"

If any materials are newly discovered, management is immediately alerted to the fact that the current man-hour budget and schedule are incorrect. If long lead-time materials are newly discovered, management is immediately alerted for procurement action commensurate with the problem.

An essential technique not generally employed by managers outside of Japan is use of a third material classification to supplement allocated material (often called "direct material") and stores stock. The third classification is called allocated-stock because it combines features of the first two classifications. Allocated-stock pertains to relatively expensive long-lead-time materials which are required in at least moderate quantities. Too many of them are required to conveniently regard them as allocated material and they are too expensive to be treated as stores stock.

The requirements for each item of allocated-stock are assessed periodically, usually monthly and for all contracts underway at the same time (ship overhaul, ship construction and other). Per allocated-stock item, questions that are answered each month are:

- o How many are in the yard's warehouse today?
- o How many are on order that are expected to be received in the coming month?
- o How many new requirements surfaced in the past month due to open and inspect reports, design development and/or change orders?
- o How many are scheduled for issue during the coming month?

When the net requirement is determined, a margin is added by the production control organization as an allowance to offset unforeseen needs, loss, damage, defects, etc., as determined from the yard's experience with that particular item. A purchase order amendment is issued accordingly, usually to an open-end purchase order which specifies a bulk quantity estimated when information existed in a larger-frame sense. Reduced to logic, the process is similar to that traditionally applied by shipyard managers for ordering structural steel. A mill reservation is placed based on bulk tonnage and as the design develops, the mill is instructed regarding specific-size plates and shapes and delivery dates.

Another necessary material practice includes limiting the number of suppliers to two or three for each item, i.e., just enough to maintain competitive pricing while keeping a practical limit on the amount of data to be maintained in a computer data bank regarding suppliers' products and past performances. Each such supplier's catalog item becomes, in a sense, shipyard standard. In the absence of such "standards" with which to guide the people performing material definition, effective sorting and collating as material requirements are refined and management of allocated stock, are elusive. In the absence of "standards", the use of computers for material management is inherently impractical.

If similar great emphasis on material was suddenly applied for complete overhauls of U.S. Navy ships, the first thing to emerge would be general awareness that planners are adversely handicapped. For each overhaul, they necessarily focus on the officially described ship configuration (list of components in a ship) for the purpose of ascertaining needs for technical manuals, replacement parts, and test equipments. The problem is that each official configuration intentionally lists only about 70% of what is purported to be in a ship. Of the 70%, reportedly, as much as 30% of the components listed are incorrect even for submarines. In other words, the basic records which planners rely on are both incomplete and inaccurate.

In traditional functional organizations which characterize most public and private shipyards outside of Japan, problems of this nature do not demand resolution commensurate with their adverse impact on productivity. In product organizations which control through control of material and focus on cost per product, the disciplines imposed would contribute to correcting this grave situation while clearly identifying the nature and scope of the problem with the utmost sense of urgency.

PRODUCT ORGANIZATIONS

People who have acquired overhaul experience only in traditional functional organizations will have a hard time accepting all of the foregoing. There are prerequisites for success that are unknown to them. One is a product organization in which people specialize differently. Another, is greater investment in the planning effort where planning consists of both production engineering and design engineering for integrated hull construction, outfitting, and painting. Production engineering becomes more professional, ultimately, with college graduates or people having equivalent ability to think analytically, assigned as generalists in all levels of the production organization and design becoming literally an aspect of planning.

Much is written in North American college textbooks about product organizations. Their great advantage is their obsession with cost per product, or more clearly in shipyards, per interim product. Initiatives by Panel SP-2 of the Society of Naval Architects and Marine Engineers for the National Shipbuilding Research Program, disclosed reliance on product organizations by Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) of Japan for ship construction, overhaul, and other work in order to maintain leadership as the world's most effective manager of shipyards.

At the time of the disclosures, IHI people concerned with outfitting in both design and production were grouped in accordance with the following specialties for both construction and overhaul work: deck, accommodation, machinery and electrical. For warships a fifth specialty was added: weapons. Thus, all disciplines required to perform work in a machinery space, for example, were under a common boss. The same applied to the other specialties with deck designating all spaces that were not accommodation, machinery or weapons spaces. At that time electrical was still functionally organized but electrical outputs were product oriented.

Design people were so organized in counterpart organizations. Each design

speciality and its counterpart in production was only concerned with costs per parts, subassemblies, and assemblies for the region for which it was responsible. The analogous organizational divisions for hull construction except for erection work, applied to flat-panel blocks, curved-panel blocks and super-structure blocks with all further subdivided in both design and production by parts fabrication, subassembly, and block assembly. The distinct products of each group were identifiable. This is product orientation. A separate product-oriented group in design and its counterpart in production were concerned with the virtual work flows needed for effective hull erection.

Recently, in response to unprecedented pressure to become more productive, IHI's Kure Shipyard shifted to a purer form of product organization. For example, its Hull Fabrication Shop is still responsible for producing all hull blocks. But, the Hull Fabrication Shop is now also responsible for outfitting and painting all forebody blocks. Thus for merchant-ship forebodies the Hull Fabrication Shop now specializes by blocks which represent perfectly integrated hull construction, outfitting and painting. Outfitters (people who work with stick welders and spanner wrenches), electricians, and painters are assigned to the Hull Fabrication Shop accordingly. Already shipfitters and painters are being trained to perform outfitting. This is one of the strengths of a product organization. When work is organized differently, labor will adjust to suit just as predicted by the head of the AFL-CIO Metal Trades Department a few years ago. [4]

A simultaneous initiative resulted in a target to reduce the total number of components to be purchased and parts to be fabricated for a very-large crude carrier (VLCC) from more than 70,000 to less than 40,000. In the first 10 months the number was reduced to less than 60,000. Now, square-steel tubing which doubles as ventilation duct is used in place of H-beams for support of engine-room flats. In many cases separate flanges have been eliminated by extending webs and forming flanges by bending. Wherever possible, holes are punched in the flanged surfaces before bending to accommodate U-bolts so as to eliminate need for separate pipe hangers. (Note: Reportedly, there are approximately 1,150,000 separate pipe hangers in a Nimitz-class aircraft carrier.)

The initiative to reduce the total number of components combined with the purer form of product organization will eventually force designers to reorganize so that in the future, the same people performing detail structural

design for forebody blocks will be simultaneously producing the forebody outfit details. Not only is there an analogy for overhaul work, the analogy is well underway in the U.S.

APPLICATION IN KITTY HAWK

Following precedent established by at least eight private U.S. shipyards to acquire benefits by either retaining IHI consultants or having floating drydocks built by IHI, the Philadelphia Naval Shipyard retained IHI to assist in planning a major portion of the Ship Life Extension Program (SLEP) overhaul of the aircraft carrier KITTY HAWK. As a consequence, about 400,000 man-days of work are being controlled by a product work breakdown. The areas being so controlled exclude the carrier's island, hanger deck, main machinery spaces and magazines. Included are pump rooms, air-conditioning machinery rooms, electronic spaces, storerooms, accommodation spaces, tanks, voids, steering-engine room, anchor-Windlass room, chain locker, etc. The application is purposely limited commensurate with resources available.

The specialities designated are faithfully in accordance with GT but are necessarily different from what IHI has applied to date for merchant-ship and destroyer construction and overhaul work. As shown in Figure 3 the specialists in design with counterpart specialists in production, are for:

- o electronic and accommodation spaces between the flight deck and the hangar deck,
- o accommodation spaces below the hangar deck,
- o pump rooms, air-conditioning machinery rooms, storerooms, etc., and
- o tanks and voids.

Two specialities involve- accommodation spaces because work in those between the hangar deck and the flight deck has to be carefully coordinated with work in various electronic spaces, including the combat information center, which are located in the same region. The same problem does not exist for accommodation spaces below the hangar deck.

The grouping of miscellaneous spaces, such as pump rooms, storerooms, etc. into a single specialty illustrates something that people do not at first understand. Product orientation is often called zone orientation and perhaps for this reason traditionalist immediately envision major divisions of a complete ship that usually coincide with transverse bulkheads. They then contemplate subdivision that coincide with compartments. But, per GT logic separations are

different because they are by problem category. It doesn't matter where in a ship work of the same problem category is located for organizing virtual work flows. Thus, as shown in Figure 3, the spaces that are assigned to each speciality do not comprise neat geographical divisions of the ship. In fact, the spaces for the miscellaneous speciality are not even contiguous with each other. Treating them as a single group is like gerrymandering in politics. Geographical boundaries, grouping of classes of problems and needed horizontal communication were all factors in developing the specialities for KITTY HAWK in addition to applying the basic GT principle, i.e., matching classes of problems to sets of solutions.

An additional concept that is hard for the uninitiated to understand is the nature of zone/stage. It is possible to control by divisions in geography, i.e., by zones. It is also possible to control by divisions in time, i.e., by stages. But, the most effective and flexible way to control large industrial endeavors is by combinations of both. Thus if a particular zone scheme is optimum at one point in time, as soon as time changes it can be abandoned for a different zone scheme that is more opportune. For example, planners are entirely free to organize an on-board zone/stage work package that straddles a bulkhead during hot work on the bulkhead, knowing full well that later in time, zones that coincide with the compartments on both Sides of the bulkhead make more sense for painting. Zone/stage designations are synonymous with opportunities. The greater degree of control afforded should be extremely attractive to people involved in nuclear submarine overhauls because specific systems must remain active during certain stages and because work durations must be limited in the vicinities of certain active systems.

Just as designers in IHI's Kure Shipyard are now focusing on all requirements of merchant-ship forebody blocks, Philadelphia Naval Shipyard planners focus *on all* requirements for overhaul work in each space within their assigned speciality. In one case the product is conversion of a pump room that needs overhaul to one that is overhauled. In other words, value added is synonymous with designation of an interim product. With such focus it became immediately apparent that 80% of the pump-room's components had to be ripped out. After evaluating various overhaul strategies, the team consisting of designers and people performing production engineering, determined that the most productive option was to redesign the pump room so as to facilitate zone/stage reassembly.

Because of the team's prudent decision, the redesign is likely to combine

some foundations, show some pipe runs in parallel-under walkways sharing common supports, have a greater percentage of straight pipe pieces, limit a greater percentage of pipe bends to 90 and 45 degrees, and increase average pipe-piece length. All such features enhance productivity. [5]

Significantly, the output of the design process now includes preparation of detail part drawings eliminating the need for such effort by production people. This is a clear example of a major design effort being geared to support production overhaul work. The benefits expected are assembly and painting of many outfit packages in shops, a significant reduction in rework, and perhaps less volume occupied and less weight in the overhauled pump room. On-board man-hours and the overall duration required Should be much less than that for the traditional system-by-system approach. Based on first-time experiences observed elsewhere, the associated production man-hours should drop by about 30%.

Another example of significant benefit being obtained arises from focus on the replacement bulbous bow as a distinct interim product by a team formed to integrate production and design engineering. Line heating was adopted for curving shell plates so as to reduce the number of separate shell pieces from 14 to 9. This action caused a 30% reduction in seams and butts to be welded. Significant savings should be reported, including savings in fitting, weld-inspection, and distortion-removal man-hours. As a further indication of more investment in planning, the team exploited a photogrammetric survey to insure accurate fit of the bulbous bow to the as-built ship.

Virtual work flows can be more readily visualized in the speciality for the more than 900 tanks and voids shown in Figure 3 than in any other speciality. About five different piping systems have to be ripped out and replaced. The zone/stage work packages by types of work are controlling the different teams like rolling waves one after another in the following sequence: tank cleaning, ripping out all pipe, blasting, holding-coat painting, inspecting structure, ripping out structure, replacing structure, touch-up blasting and undercoat painting, outfitting, and final painting. Each zone/stage work package consists of 6 or 7 sheets of 8-1/2" x 11" or 8-1/2" x 17" paper that are readily reproduced on photo-copy machines. Typically, that for tank cleaning conveys to a work team:

- o location of the zone in the ship,
- o safety instructions,

- o job description,
- o a sketch showing the locations of tank manholes,
- o routing instructions for temporary services.

No other drawings or references are required.

For the work involving reinstallation of piping, all fittings including pipe pieces regardless of system are fitted in a zone during one stage. The pertinent work instruction contains composite arrangement and detail sketches and an applicable material list limited to the zone. Shop personnel are relieved from all bother such as associated with hold-ups and revisions. Such problems are absorbed during the interaction of production engineers and design engineers.

For the product-oriented approach to the SLEP overhaul of KITTY HAWK, a project office has been created to direct, monitor, and expedite implementation of the overall strategy by all facets of the hierarchy in Philadelphia Naval Shipyard. The production part is shown in Figure 4. A group superintendent, i.e., the highest-level civilian manager second only to the Production Officer, has been assigned. The product for which he is responsible is converting spaces that need overhaul and modernization into spaces that are overhauled and modernized within the boundaries of the four specialties shown in Figure 3. Because the workload is so great, about 400,000 man-days, he is assigned two assistants called zone superintendents, one of whom has charge of the two specialties with accommodation spaces and the other having cognizance of the miscellaneous specialty and the tanks and voids specialty. This grouping reflects some commonalities in work problems and the proximity of the specialties for resolution of interface problems.

At the third level there are four zone managers, each of whom is assigned a specialty. Each is assisted by as many as five general foremen per product trade. The teams of foremen and workers that report to the general foremen are made up of mixed crafts as required to produce specific products. People, information and work are grouped in the same product-oriented manner. Throughout the hierarchy all managers and supervisors are generalists equivalent to factory managers for the products assigned. As maintaining the coordination of all work flows is of ultimate importance, every level has been delegated authority to transfer manpower as required. The degree of such authority is of course commensurate with the level.

Already, as has happened in IHI shipyards and as predicted by the head of the AFL-CIO Metal Trades Department, people of different trades are beginning to assist one another toward common objectives. For the first time they have something that is realistically measurable, i.e., cost per product. Now, much of the managerial advice expounded by Peter F. Drucker is coming into focus in Philadelphia Naval Shipyard.

Shipyards with less resources are well advised to ventured into product orientation in a more modest way. The course taken by some other naval shipyards, so far mostly for shipalts, is also good guidance. Applications were purposely limited. Puget Sound Naval Shipyard employed an ad-hoc product team as shown in Figure 5. The figure indicates the maximum number of possible incumbents, but positions are only filled commensurate with the needs of the product being contemplated.

On the production side, the team members were the actual general foremen who were to immediately manage the work. In a one hour meeting each week, they *conveyed* a strategy to the designers and constantly refined their strategy as designers were able to make more information available through design development. The results were dramatic. One case involved seven "electronic" shipalts in a confined region of a submarine which had been implemented in other submarines with traditional system-by-system work packages.

The shift to product orientation focused on everything in each zone at once, caused the different foundation requirements to be combined, and resulted in multi-system foundations that were completely fabricated, machined and drilled ashore. In one case, for a job on the critical path, the duration for on-board foundation work was reduced from seven weeks to three work shifts in one day! While the overall saving in man-hours was not reported, it is likely to be at least 30%. Really, all that has been applied is just common sense. That is, for the detail design and arrangement of anything that is part of a complex, everything in the vicinity should be considered regardless of the system it is part of. Similarly, for efficient implementation of on-board work, all work of one type in a region should be accomplished at the same time regardless of the different systems represented.

PERTINENT EXPERIENCES

Review of some experiences in U.S., U.K., and Canadian shipyards which have successfully shifted to product orientation for construction work and those which have not, is helpful for applying product orientation to overhauls. Most

problems to be overcome are people problems.

Only three types of managers have succeeded:

- o those who are practical, have a solid production background, and are confident enough to refrain from appeasement of traditional middle managers,
- o those who have financial/business educations and experience who regard how to analyze as the most important aspect of any industrial endeavor, and
- o those who have engineering degrees, but whose educations are not limited to applied engineering, who appreciate manufacturing as a system and who accept the obligation to constantly develop the manufacturing system while producing end products.

All employed IHI consultants to accelerate the transitions to product orientation. [6]

Others, have been either disappointed with progress made or have failed completely. In one case a manager whose predecessor was deposed for insufficient tact in an attempt at more formal organization for the purpose of obtaining useful corporate data, overreacted with cancellation of everything his predecessor invoked. This was followed by a directive which exempted the structural shop from effective material control. Both acts were politically motivated as they were concessions to hard-nosed traditional middle managers. The shipyard was committed to a downhill course from which it has yet to recover.

Elsewhere the first application was extremely large in scope and was soon overlapped by an even greater application. At the same time another revolution was being attempted to computerize the design process. Had the first attempt at product orientation been limited to one complicated space, the affect on all management information systems would have become known without people being overwhelmed by masses of data in different formats. Other Achilles' heels were the failure to shift to a product organization commensurate with the transformation being attempted and both inadequate build strategies and insufficient standardization for the purposes of directing designers in grouping information and defining materials.

In Still another case, a manager listened to a different drummer for at least two critical years before making a concerted attempt to shift into a product-oriented mode. IHI consultants were retained to assist in accelerating

the transition. But the investment was too little too late. A contract critical for the shipyard's survival was lost. A competitor had discovered the same need three years earlier and at that time made a far greater investment in IHI services. The message is loud and clear. It is not enough to be managing a transition to product-oriented methods with focus on constantly developing the manufacturing system, a firm must be making such progress ahead of its competitors!

In more than one instance, top managers were obsessed with acquiring expensive facilities s means to improve productivity without first developing product-oriented manufacturing systems. The corporate data produced by the latter would have provided a sounder basis for making decisions and would have resulted in less costly, if any, facility investments. Relative to competitors, they assumed increased overhead costs while losing valuable time for manufacturing-system development.

The most pitiful experience occurred in a shipyard where the top manager seems to have been preoccupied with other matters. The move toward product orientation was sparked by a few middle managers. Although applications were limited, significant amounts of assembly and painting work were organized zone per stage and performed in an orderly fashion in shops. Traditionally, the work would have been done on board with people assigned to various systems competing with each other for access to work. But, the yard's archaic management information system did not report all savings. When-common sense should have prevailed because people were obviously working smarter and savings were manifest, the absence of pertinent interest from the top permitted die-hard traditionalists to wine out the move toward modern management. Impact on the morale of those who dared to innovate, was devastating. Traditionalists 16 power might just as well have said to the innovators, "How dare you improve productivity?"

"The innovator has for enemies all those who have done well under the old conditions." [7]

In a category by itself, is the shipyard management team which rapidly and successfully abandoned its traditional methods in favor of a product work breakdown approach. Impressive command of integrated hull block construction, zone outfitting, and zone painting has been clearly manifest for more than one shipbuilding program. But, the same group has not adopted statistical accuracy control applied for production control purposes. With regard to levels of technology development, they have reached a plateau. Their manufacturing

system will never acquire the characteristic of constant self development until the Statistical approach is appreciated and adopted.

Regardless of the nature of work, e.g., overhaul work of the same problem category in a virtual work flow or construction of multiple ships of the same class, demonstration of a learning curve by itself is no longer an impressive achievement nor is it sufficient for survival. What is required now is bit-by-bit constant improvement which has the effect of constantly displacing the learning curve downward for product after product as shown in Figure 6.

For the benefit of people who have yet to appreciate the significance of statistical accuracy control, the advice of the world's most effective shipyard managers is reiterated:

"Statistical control epoch makingly improved quality, laid the foundation of modern ship construction methods and made it possible to extensively develop automated and specialized welding." [8]

Overhaul specialists in considering the foregoing should dwell on the problems they encounter with disassembly and reassembly of high-pressure pipe systems, particularly in submarines. The use of large-capacity chain falls to make up such pipe joints is common. Because of locked-in stresses they are more susceptible to failure during high-impact shock and are dangerous to disassemble. Statistical accuracy control applied for manufacture of new and replacement pipe pieces would greatly minimize such problems.

Regarding middle managers, not all having had only traditional experience were obstructionists when their yards began to transform. Some found that, despite the erudite terminology and the different organizations of people, information and work, a great undercurrent of common sense is inherent in product orientation. The many photographs published of IHI people working smarter-not harder appealed to them. Some of these middle managers fitted in quickly and graciously. Others wanted very much to participate but had never been educated in how to shift gears.

Second to no other problem are the dyed-in-the-wool traditional middle managers and design engineers. Advising of them cannot be better stated than in the following:

management must make commitments necessary to make it work. Commitments must transcend management hierarchy, trade boundaries, curators of ivory towers and traditionalists who

balk at new concepts. Failure to attend these considerations make it fairly easy for a single disbelieving or disinterested person or group to scuttle successful utilization." [9]

SUCCESSFUL ACTIONS

The implementation actions which follow are the most effective of those employed in U.S., U.K., and Canadian shipyards which have successfully shifted to product orientation for construction work and, more recently, for overhaul work.

Top managers, including a naval shipyard commander, made some judgement calls. Are shipyard operations, particularly for modern naval ships, now so complicated that they overwhelm traditional system-by-system based management? Does a management information system based only on a system work breakdown structure produce accurate enough corporate data and does it truly comply with the U.S. Department of Defense cost/schedule control systems criterion for a work breakdown structure to "...define the product to be produced as well as the work to be accomplished...."? Are competitors benefiting enough from product-oriented approaches to threaten traditionally operated shipyards? If so, is there time to self-develop a product-oriented approach or should special assistance be obtained to accelerate transition as has been done, or is being done by a number of private yards and Philadelphia Naval Shipyard?

After deciding to shift to modern product-oriented operations, the most effective top manager worked persistently on implementation. Senior and middle managers were advised of his decision and were then indoctrinated in basic logic and principles. Afterwards, each was interviewed separately so that the top manager could identify:

- o the majority that was willing to cooperate and was capable of cooperating,
- o those who were sincere in their willingness but who needed special assistance to make the transformation, and those few individuals who had to be weeded out because they were disbelievers, disinterested, dyed-in-the-wool traditionalists, or curators of ivory towers who constituted a threat to successful implementation.

When the management team was so conditioned, a second indoctrination effort was directed at people who perform design engineering. Similar interviews were conducted for the same purposes.

With assurances thus obtained, only then were workers immediate supervisors

and union leaders indoctrinated in pertinent logic and principles. They were also advised of the progress made by competitors in applying product-oriented methods for constructing and overhauling ships of all types and sizes and various end products other than ships. Thus, workers were not exposed to how people could work smarter before management was fully prepared to follow through. Part of the preparations addressed trade-union leaders' concerns even when they were expected to be just political in nature.

The managers who determined that they had to rapidly move ahead of their competition in commanding more effective methods, retained IHI consultants. Their common objective was to supplement their resources with people having extensive pertinent experience. This assistance is especially needed by designers when a "computer" revolution is undertaken simultaneously with the logic revolution, i.e., the shift from system to product orientation.

In one case where time was not critical and only modest resources were available, the first application was limited per advice proffered by Dr. H. Shinto, former President of IHI. For the first attempt he suggested selecting a single complicated space such as a tanker pump room within which product orientation would be applied exclusively. He further recommended relying on advice from everyone involved in that experience to suggest how fast and where else to expand the product approach. People were not overwhelmed by the limited size of the first such challenge and at the same time were obtaining knowledge of how all aspects of the yard's management information system were being affected. The experience instilled confidence and the people involved wanted to expand product orientation to all work as soon as possible. Those in the work force who were not involved wanted to work the new easier way.

For a few additional applications, continued employment of ad-hoc product teams is reasonable. But, each top manager has to watch carefully because traditional managers who are unsure of their abilities to become more generalized can be expected to try to preserve their roles as functional specialists regardless of the top manager's objective. Thus, changing the entire organization to a product organization should be planned and scheduled last as for key events during any overhaul or construction project, i.e., in the context of the shipyard's master schedule. If not a high-priority concern to the top manager, the transition, if effected at all, will be agonizing for many people and unnecessarily prolonged.

CONCLUSION

Obstructionists should be informed that in the U.S., abandonment of functional organizations by many successful non-shipyard firms, e.g., IBM and Exxon, started about 40-years ago. By 1960, IHI was actively managing a logic revolution and in 1963 started operations in the world's first shipyard rationalized to exploit product orientation for both construction and overhaul work. For many shipyards elsewhere, the time for adopting product organizations is long overdue. [10]

In North American shipyards, only one top manager provided thorough continuing education in the logic and principles of product orientation to his managerial staff, design engineers, first-line supervisors and union leaders. He retained IHI consultants to accelerate what turned out to be a very successful transformation. He weeded out uncompromising traditionalists. When asked why he personally attended all of the many pertinent seminars, he replied, "I want *everyone* in this yard to know how important this subject is to me!" Any commitment less than that will not suffice.

[1] The logic and principles of what is described herein reflect the very effective management system employed by Ishikawajima-Harima Heavy Industries co., Ltd. (IHI) of Japan as published by L.D. Chirillo Associates, P.O. Box 953, Bellevue, Washington 98009, U.S.A., in a series of booklets for the National Shipbuilding Research Program (NSRP). Some of the material so published is incorporated in "Ship Production" by Storch, Hammon, and Bunch; Cornell Maritime Press, Centreville, Maryland (ISBN 0-87033-357-71), Chapters III, IV, VI, VII, and VIII. Other pertinent booklets based on IHI methods and published for the NSRP by L.D. Chirillo Associates are: Precontract Negotiation of Technical Matters - December 1984, Product Oriented Material Management - June 1985, Shipyard Organization and Management Development - October 1985, (Reprinted in the May 1986 issue of The Society of Naval Architects and Marine Engineers' Journal of Ship Production, pp. 74-79.), Flexible Production Scheduling System - April 1986, Product Oriented Safety and Health Management - May 1986, Analytical Quality Circles - September 1986, and Flexible Production Indices - April 1987.

[2] In U.S. naval shipyards the term "Zone Logic Technology" is sometimes used in place of "Group Technology". The latter is preferred because of its general use in literature.

[3] U.S. Department of Defense Instruction 7000.2.

[4] Responding to a shipyard manager's statement that labor imposed trade separations impeded productivity advances, Paul J. Burnsky, President of the AFL/CIO Metal Trades Department said in effect, "We are not your problem. If you do not like the way we are organized, change the way you organize work. If you do, you will cause problems for people like me. but we will get to where you want to go. It won't be as fast as you want, but we will get there. Management infers leadership so act like leaders, take the first step."

[5] There is also great opportunity to achieve such benefits during ship construction. In at least four countries, frigates are currently being built in follow yards with less productivity than is achievable because the lead-ship design was not developed in the context of a product-oriented build strategy. Two such follow shipbuilders are using the product approach for other shipbuilding projects while having to revert to a corruption of the product approach in order to achieve some productivity increase for the frigates. To say the least, they are frustrated. There is much to be gained from a policy of constantly enhancing productivity by design changes in follow ships. Naval administrators should work to create practical approval procedures which would encourage follow shipbuilders to submit proposals that would, in ship after follow ship, constantly result in more combined foundations, more pipe runs in parallel, more straight pipe pieces, etc. Such benefits are achievable with nominal changes in machinery arrangements, focus on piping *runs*, and without changing any components which require spare-part provisioning.

[6] The consultants were made available to U.S. and Canadian shipyards by IHI Marine Technology, Inc. of New York City.

[7] Machiavelli.

[8] The Society of Naval Architects of Japan, 1967.

[9] Similar resistance to change was also noted by John F. Kenefick. JFK Inc., Indialantic, Florida, in "Transfer of Photogrammetric Technology to the U.S. Shipbuilding Industry. a presentation to the U.S. Naval Shipyards' Structural Group Superintendents Workshop. 3-5 November 1987. Paradoxically, in certain shipyards photogrammetric surveys are being beneficially applied in more and more repair and ship-alteration situations while in other yards which have identical work-

loads, there is no such response. Managers are well advised to investigate the motives of their people who do not pursue opportunities to exploit innovations that have been proven elsewhere. Some of the latest such photogrammetric surveys are for creating accurate data for manufacturing replacement gravity davits for which existing as-built drawings are useless, dimensioning foundation bolt-hole locations in rebuilt arresting-gear engines (about 6'x50') before they are landed in aircraft carriers, and determining required interface dimensions of as-built multi-leg masts before new mast tops are fitted.

[10] See "Shipyard Organization and Management Development", R.D. Chirillo, I. Inuki, and I. Kobayashi, SNAME Journal of Ship Production, May 1986, pp. 74-79.

FIGURE 1: A build strategy starts the shipbuilding process. Contract design describes the ship with information grouped in a large-frame sense. Functional design describes the ship system by system, i.e., with information grouped in an intermediate-frame sense. Transition design groups information zone/stage for the purpose of preparing work instructions, i.e., information grouped in the smallest-frame sense.

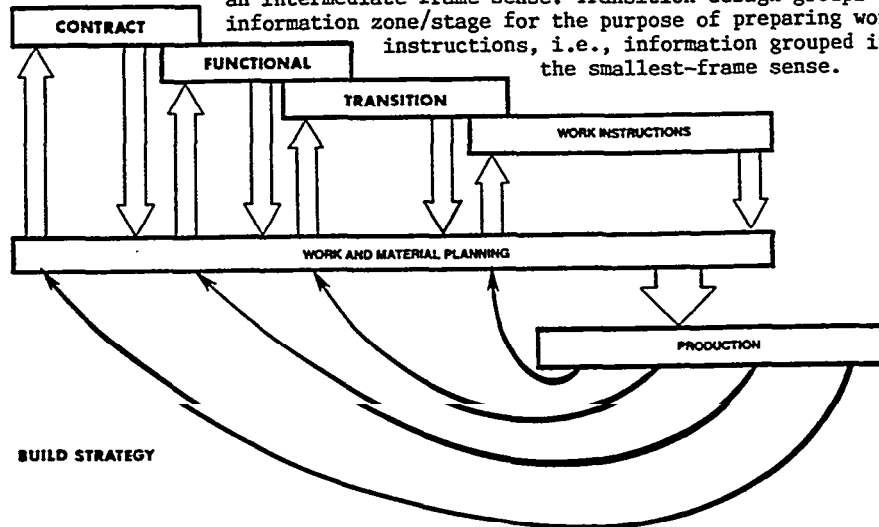


FIGURE 2: An overhaul strategy starts the overhaul process. While the information development phases are not as distinct as in shipbuilding, the effect is the same. As more becomes known due to open-and-inspect reports, information is refined until it is the form of work instructions, i.e., in the smallest-frame sense.

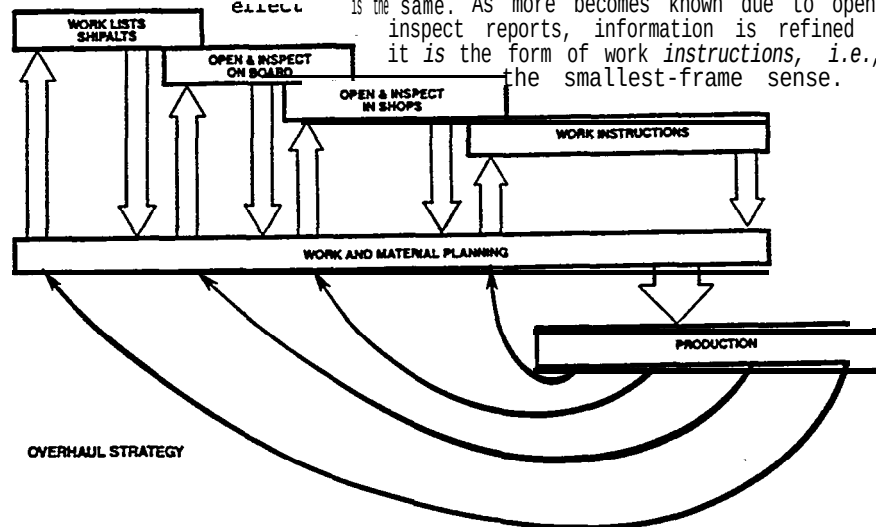


FIGURE 3: Specialities applied by Philadelphia Naval Shipyard for overhaul of the aircraft carrier KITTY HAWK are: (1) Electronic and Accommodation Spaces, (2) Accommodation Spaces, (3) Pump Rooms, Air-Conditioning Machinery Room, Storerooms, etc., and (4) Tanks and Voids.

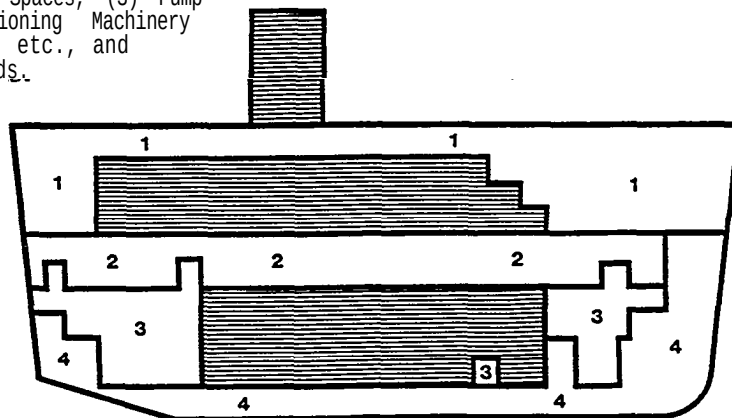


FIGURE 4: Product-Oriented Production Organization applied by Philadelphia Naval Shipyard for overhaul of the aircraft carrier KITTY HAWK.

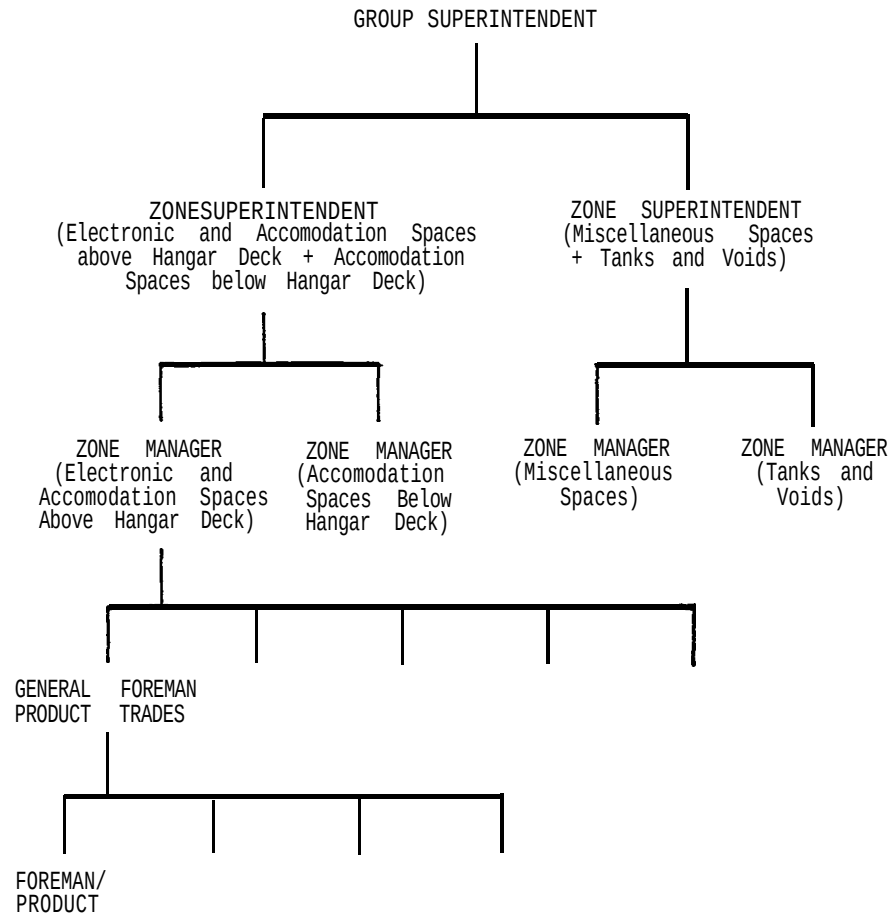


FIGURE 5: Ad-Hoc Product Team applied by Puget Sound Naval Shipyard for alterations, e.g., a close-in weapons system in the aircraft carrier RANGER, an outfitted and painted grand block for a Tomahawk-missile system in the cruiser TEXAS, and modification of electronic systems in 637-class submarines.

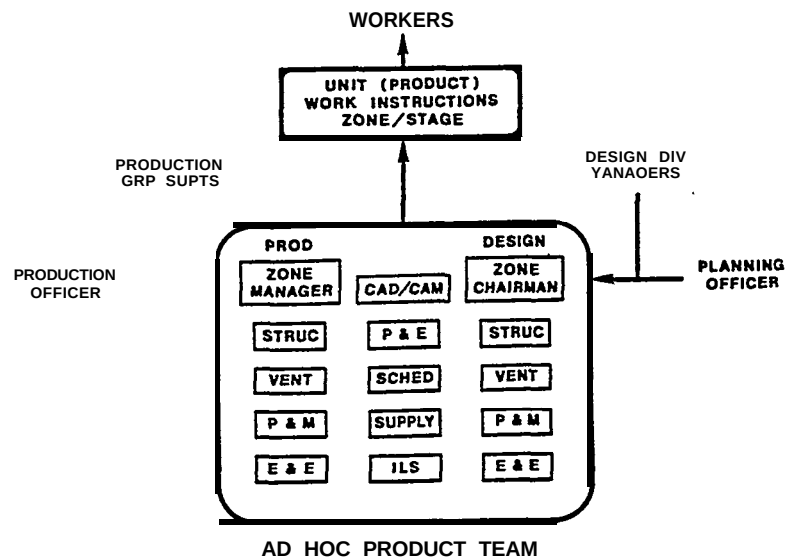
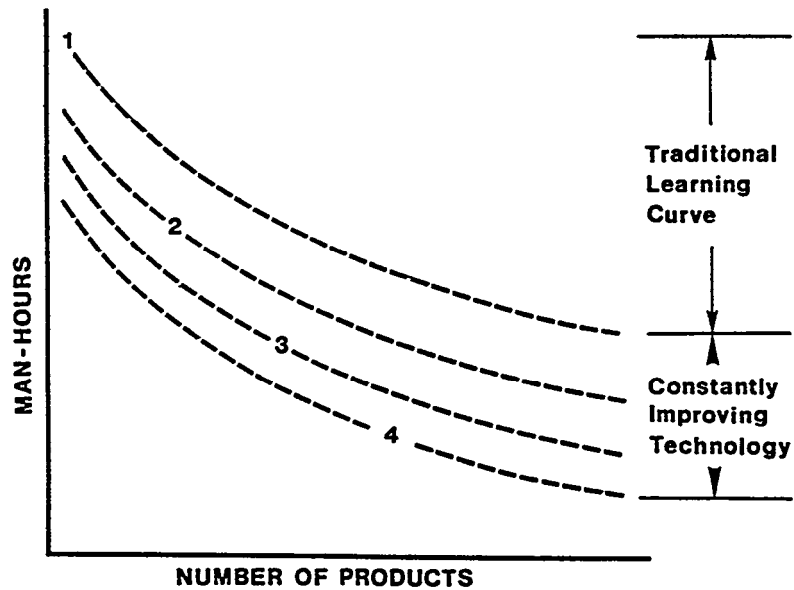


FIGURE 6: Modern manufacturing systems supplement learning-curve benefits with savings derived from constant improvements in technology. The effect is constant displacement of the learning curve downward. Per Dr. W. Edwards Deming, "The obligation to improve the system never ceases."





Management Development for the Shipbuilding Industry

No. 7A

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ABSTRACT

The current condition of the U.S. shipbuilding industry makes it vitally important for shipyards to develop company-trained managers with both business and shipbuilding management skills. In order to meet this need, the Bath Iron Works Corporation established the Management Development Program in April of 1986. BIW specifically recognized the need to develop middle managers with broad company backgrounds. The program was created to provide the company with a group of high-potential shipyard managers with sound general management skills.

This paper will address the evolution of the Management Development Program at Bath Iron Works. From the initial identification of the need for the program through the completion of the program by the first class of Management Development "interns". The paper will also include an analysis of the original program design and a discussion concerning the current status of the program. Based upon experience gained through the initial implementation of the program, some improvements are being made in the organization and general structure of the program. We will examine lessons learned, the future of the Management Development Program at BIW, and career development within the industry as a whole.

INTRODUCTION

The Management Development Program was initiated at Bath Iron Works by senior management in an effort to bolster the number of effective middle managers within the shipyard. The company's top executives identified the need for middle managers to understand all of the critical functions which make up the shipbuilding process. As in many companies with traditional functional

organizations, the tendency to become specialized in a particular functional area existed within the shipyard. Managers understood their own department, but their knowledge of the relationship between departments was limited. In order to develop middle managers with a detailed understanding of the entire shipbuilding process, BIW devoted the necessary resources to establish a Management Development Program.

The purpose of the program was to establish a talent pool of potential managers for the future leadership of Bath Iron Works by providing participants the opportunity to develop knowledge of the shipbuilding manufacturing process as well as general management skills (1). In order to implement a program of this magnitude, dedicated senior management commitment was essential. William E. Haggett, Chairman and CEO of Bath Iron Works, was, and still is, one of the leading proponents of the Management Development Program. In addition to Mr. Haggett, many other top executives in the company are strong supporters of the program. This unwavering commitment from top management laid a solid foundation upon which the program was built.

CAREER DEVELOPMENT

Recent research studies concentrating on management development have surfaced interesting and helpful findings. The Honeywell Corporation commissioned its corporate training group to investigate ways to improve the management development function. One of the findings of this research was a comparison of the relative importance of job experiences, relationships, and education to development. A weighting of 50% - 30% - 20%, respectively, was obtained (2). Drawing from this data, it was concluded that most development occurs outside of formal training. Therefore, to have more impact on

development. training must target activities that support the development which occurs as a result of job experiences and relationships (2). Experience is the best teacher. but it must be realized that for effective development. the experiences must be planned.

Experiences provide development through enhancing existing skills or developing new skills, providing broader perspectives and visibility. and improving confidence. Job experiences play a key role in new skill development, especially when it involves people making cross functional moves. Moving across functional areas exposes an individual to a variety of problems, forcing new skill development to be effective. Participation in tough projects can also provide a significant development job experience.

In addition to experiences, people develop through job relationships by increasing their effectiveness, learning new skills, learning corporate values, and shaping their management style. Building a network of relationships can increase effectiveness by establishing people who can act as advocates, assist in getting promotions or job changes. and share in the joys of success (2). The development of this network can be expedited by aligning an individual with a mentor or, coach. Building a relationship with a mentor or coach can enhance the development process of rising managers by providing a:

- Role model
- Sounding board
- Broader perspective
- Skill builder
- Sponsor, motivator, and confidence builder

Another component of development is education, of which the primary purpose is to transfer relevant skills. Improving communication skills and business knowledge are two of the most beneficial areas. Training also helps participants develop contacts and learn from others. Not to be underestimated is the role of education in broadening perspectives and challenging thinking. Through the learning process, solving problems outside of one's usual mode of thinking forces people to approach problems differently (2).

In a more detailed manner, a General Electric study explored the development process of technical leaders. GE defines a technical leader as an individual who combines

technical expertise with the leadership skills required to move an organization in a direction he or she identifies (3). Through their research, GE identified a set of career building blocks that top leaders had completed in developing their technical leadership skills. These building blocks included:

- Participation in essential experiences

- Assumption of key roles

- Progressive training in a defined set of knowledge and skills.

While there is no single career path or sequence, the above building blocks were completed within some fairly specific timeframes. These timeframes were:

- Formative First 5 years after beginning first post-Bachelor's Degree job

- Maturing - Next 10 years

- Broadening - 16 plus years.

By combining the building blocks with the defined career stages. GE developed a career development road map. (See Table 1.) The building blocks can be completed in separate assignments or often within a single assignment (3). From their research, almost every high-level technical leader had completed virtually all the essential experiences with each stage. The experiences provided opportunities for on-the-job development in the technical/business environment which were vital for developing leadership skills (3).

Bath Iron Works Corporation recognized the need for a program combining job experiences, academic education, skill development, and relationship-building in its design of BIW'S Management Development Program. The remainder of this paper will describe the design, implementation, and future plans of the BIW program.

PROGRAM DESIGN

BIW senior management directed the establishment of a Management Development Steering Committee in early 1986, whose role was to develop the structure of the program and participate in the recruiting and selection of qualified applicants. This Steering Committee was comprised of high-level managers from Engineering. Human Resources, Production.

STAGE	ESSENTIAL EXPERIENCES	KEY ROLES	TRAINING FOCUS
FORMATIVE (BY 5 YEARS)	. UNIQUE TECHNICAL SUCCESS . STRETCH JOB ASSIGNMENT . SUBSTANTIVE LEAD SUCCESS . BROAD BUSINESS EXPOSURE . SIGNIFICANT ROLE MODELS	. TECHNICAL CONTRIBUTOR . TEAM LEADER . PROJECT LEADER	. FUNCTIONAL ORGANIZATION . TECHNICAL COMPETENCE . BASIC INFLUENCE SKILLS . CHANGE MANAGEMENT . CAREER MANAGEMENT . PROJECT MANAGEMENT
MATURING (BY 15 YEARS)	. BROAD BUSINESS INVOLVEMENT . SELF IMAGE AS A LEADER . DEVELOPMENT OF A LEADERSHIP NETWORK	. TEAM LEADER . PROJECT LEADER . PROGRAM LEADER	. INTERFUNCTION RELATIONSHIPS . FUNCTIONAL STRATEGIES . STRATEGIC INFLUENCE SKILLS . RESOURCE MANAGEMENT . COMPETITIVE ADVANTAGE . CUSTOMER SERVICE . PROGRAM MANAGEMENT . TECHNOLOGY IMPLEMENTATION
BROADENING (16+ YEARS)	. HIGH BUSINESS IMPACT ASSIGNMENT . TOTAL RESPONSIBILITY ASSIGNMENT . EXPANDED EXTERNAL NETWORK	. PROJECT LEADER . PROGRAM LEADER . FUNCTIONAL LEADER	. FUNCTIONAL/OPERATIONS MANAGEMENT . BUSINESS STRATEGIES VISIONING . ORGANIZATION STRUCTURING AND CHANGE

Table 1: General Electric's Career Development Roadmap (Adapted from a Figure in "Developing Technical Leaders. Building Blocks for Success in Engineering and Manufacturing." Schoonover and Weiler, July 1987)

Systems, and Finance. including several members at the vice presidential level. The Committee faced several difficult decisions in designing the structure of the program, such as: How long will the program be? How many participants will be included in each year of the program? Where will the participants for the program be recruited? What are the qualifications needed for consideration for the program? These are only a few of the many critical questions that needed to be resolved to successfully implement the Management Development Program.

After months of deliberation and several meetings of the Steering Committee, the initial structure of the program emerged. The Committee created a 2-year program which included a series of work rotations through major functional departments, academic course work, management skills seminars, and weekly staff meetings.

The work rotations were structured in general terms in order to give the interns a degree of flexibility in setting up their work

schedule. Table 2 shows the required functional areas and the duration of each rotation in months.

FUNCTIONAL AREA	DURATION
ENGINEERING	6 MO.
PRODUCTION	6 MO.
PLANNING	6 MO.
OPTION TIME	6 MO.
TOTAL	24 MO.

Table 2: Work Rotation Breakdown

As the exhibit suggests, an intern is allowed 6 months of "option time" in addition to the required time spent in Engineering, Production, and Planning. This option time can be spent in any area within the shipyard which interests the intern (e.g., Contracts, Program Office, and Labor Relations), divided into 1-, 2-, or 3-month increments. In addition to

the departmental rotations, interns are required to successfully complete selective graduate level business courses. If an intern fails one of the required courses, he/she can be dropped from the program. Along with the course work, interns are required to attend numerous management skills seminars and workshops, concentrating on topics such as project management, presentation skills, statistical process control, ship production, contracts, and management skills.

The program was designed to accommodate ten participants in each year of the program, the first year having ten interns and a second class of ten interns being introduced in the second year. After the first year, the program would support 20 interns a year on a rotating basis, with a new class of 10 participants replacing the graduating class at the completion of the 2-year program. Organizationally, interns are considered employees of the Training Department for the duration of the program, reporting directly to the Manager of Employee Development. Interns' yearly evaluations of work performance are also administered through the Training Department by synthesizing evaluations from supervisors in each work rotation. At the completion of each rotation, the intern is evaluated by his/her supervisor. This provides the intern formal written feedback on performance 2 to 4 times per year.

REQUIREMENTS

Candidates for the Management Development Program are selected from current BIW employees and college graduates each spring. Minimum requirements of applicants for the program are a 4-year college degree or graduation from BIW's Shipbuilding Apprentice Program. The selection criteria for candidates includes the following components:

- . Leadership
- . Communication skills
- . Achievements/accomplishments
- . Maturity.

Applicants are evaluated on the relative strength of these characteristics through a two-step interviewing process. Initial interviews are conducted on college campuses during February and March of each year. First interviews of current BIW employees take place in June of each year. A series of second interviews, conducted by vice presidents, is held for selected individuals on-site at BIW. Offers of employment in the Management Development Program are

issued subsequent to the results of the second interviews.

PROGRAM IMPLEMENTATION

The BIW Management Development Program began in September of 1986 for the first class of interns. The class was made up of individuals with varied backgrounds, including engineers, liberal arts majors, and current BIW employees with significant production experience. The diversity of the group helped to integrate the members of the first class. The experienced BIW employees acclimated the new employees in the class to the culture and norms of the shipyard. Based upon experience gained through the initial implementation of the program, some improvements are being made in the organization and general structure of the program. One change in the structure of the program involves the work rotations. Originally, the program was divided into three 4-month increments in major functional areas and 6 months of option time. (See Table 2.) Due to a reorganization within the company and some recommendations from senior management and the program manager, the work rotations were revised. The current work rotation structure is shown in Table 3.

FUNCTIONAL AREA	DURATION
PRODUCTION	9 MO.
ENGINEERING	4 MO.
FINANCE	3 MO.
MATERIALS	3 MO.
OPTION TIME	5 MO.
TOTAL	24 MO.

Table 3: Revised Work Rotation Breakdown

The work rotations are the primary learning tool for each intern. Not only do the rotations provide an intern with detailed knowledge of the area and how the area relates to other departments in the shipyard, but also give him/her valuable exposure to key personnel in the company. Typical tasks that are given to Management Development interns include:

- Developing shipyard schedules
- Working as a production coordinator
- Negotiating subcontracts
- Documenting work practices

Preparing manning plans for a department

Supervising CAD/CAM operators.

At the end of each work rotation, interns receive written evaluations from their direct supervisor in the functional area. Interns are encouraged to discuss the evaluations with their supervisor to give personal comments or entertain further discussion about the department. If an intern receives unsatisfactory evaluations in more than one department, he/she could be dropped from the program pending review by the Manager of Employee Development. In addition, interns are required to write reports for the Manager of Employee Development on each functional area, summarizing their experience in the department. In addition to work rotations, interns are required to successfully complete graduate level academic courses, which are taught on-site at the BIW Training facility by business schools (University of southern Maine, Northeastern University). The curriculum for the 2-year program includes the following courses:

- Financial Management
- Operations Management
- Organizational Behavior
- Marketing
- Management of Technology.

Although the majority of each class is comprised of Management Development interns, additional company managers are also involved in the classes. These current BIW managers give the interns an additional perspective by relating the course work in the classes to shipyard problems and issues. Course work in each class is graded, and failure of any class could be grounds for termination from the program.

The third integral component of the program concerns supplemental workshops and seminars in managerial topics. Workshops are conducted on-site on a variety of topics:

- Presentation Skills
- Effective Management
- Interviewing Skills
- Blueprint Reading
- Statistical Process Control
- Ship Production Technology.

Some of these workshops are taught by BIW personnel while others are instructed by outside consultants. The majority of the seminars are not exclusive to the interns but are conducted for company management throughout the shipyard. This gives

the interns an opportunity to interface with company managers and facilitates a good discussion on important company issues. Each intern is also expected to attend at least one off-site seminar a year on a managerial topic of particular interest to the individual. The intent is to increase knowledge of general business functions, develop communication skills, and nurture leadership. Seminars have been attended on topics such as Project Management and Team-Building Skills, Problem Solving and Decision Making, Just-in-Time Manufacturing, and Operations Management.

Another important component of the program is the weekly staff meetings held by the program manager for the interns. These meetings perform a number of functions. They help provide a group identity and a supportive atmosphere. They also serve as a time for exchanging information, from current events company-wide to providing interesting developments in particular departments. On a frequent basis, the meeting serves as an opportunity to invite an upper level manager to share information from his/her perspective and allow the interns to question the manager on his/her management style, philosophies, and daily functions. Lastly, the staff meetings also function as an educational session with the program manager leading a session in topics such as communication skill development or techniques of managing group meetings.

One of the greatest concerns of the architects of the BIW Management Development Program was how the different elements (production workers, middle management, senior management) within the shipyard would react to the implementation of the program. Overall shipyard acceptance was positive in the first year of the program and has improved to the point where the Management Development Program has earned a highly respectable reputation throughout the yard. Production worker acceptance was seen as a possible barrier to implementation; however, the production workforce has accepted the interns and enjoys exchanging viewpoints with future company managers. In most cases, employees are eager to explain their job function and responsibilities to an intern. This relatively rapid acceptance of the program by production workers is due, in part, to the fact that three of the interns in the first class were selected from Production. In terms of middle management support, middle managers

were eager to have an intern rotate through their functional area. However, some managers were ill-prepared to assign tasks and responsibilities to an intern in the embryonic stages of the program. For the most part, this problem has been resolved through a year and a half of experience and greater understanding of the objectives of the Management Development Program and capabilities of an intern. In fact, in many cases, middle managers are requesting the services of an intern for a period of time. This exemplifies the fact that middle managers are realizing that having an intern in their area is an opportunity not only for the intern, but for the manager as well. As for senior management, the support for the program emanating from top executives has been nothing but outstanding from day one. Senior management is strongly committed to the ideals of the program and is encouraged by the quality of the people in the program. Interns meet with senior executives, at least quarterly, to discuss the status of the shipyard and other important issues. This explicit support reinforces senior management's commitment to the program as the building block of the future leadership of Bath Iron Works.

PROGRAM STATUS

The company quickly absorbed the graduating interns into a variety of positions. Interns found positions ranging from supervisory roles to upper level staff positions. Table 4 shows a sampling of the positions accepted. The interest of the different divisions in acquiring an intern was strong, reflecting the success of the program.

POSITION
• MANAGER OF CRUISER DESIGN
• SUPERVISOR OF PRODUCTION ENGINEERING
• SUPERVISOR OF MRP PROJECT
• PRODUCTION ENGINEER
• PLANNING SUPERVISOR

Table 4: Positions Accepted by Graduating Interns

At the time of this writing, the third class of interns is being recruited. The program is continuing at a level of ten participants per year with a greater majority coming as new hires to the company.

PROGRAM COSTS

As previously mentioned, the implementation of a Management Development Program is an investment in the future of the company. This investment can be segregated into three major elements of cost:

Overhead time
Academic courses
On-site and off-site seminars.

Overhead time refers to the time spent by interns in courses and seminars, staff meetings, and benefits such as sick leave, vacation time, and insurance coverage. The overhead cost element accounts for roughly half of the annual budget for the program.

The other half of the program budget is spent on education and training, coming in the form of academic courses and seminars. Two or three academic courses are taught on-site at BIW each year by an accredited business school. Courses of this type range in cost from \$12,000 to \$25,000 per course for the existing curriculum. The current design of the program also calls for two or three seminars a year, taught on-site by an outside consultant. On-site seminars typically cost between \$3,000 and \$10,000 per seminar. Off-site seminars are also included in the annual training budget and are arranged at the intern's request. These seminars cost up to \$2,000 per individual.

FUTURE PLANS

As the first class of management interns completes the 2-year development program, changes are being incorporated to reflect lessons learned thus far. While both company management and program participants acknowledge the program as highly successful, they also wish to build upon past experiences and plan for the future.

One of the changes to the program was a redistribution of time spent and departments visited during the 2 years as mentioned earlier. This was brought about by a recognition of the integral role these functional areas play in the operation of the shipyard. Also, as a part of a company reorganization, the planning rotation was combined with the production assignment.

Another need which was identified was the requirement for a structured placement process for the interns completing the program. For the good of both the company and the interns,

guidelines describing when interns are available for hire, appropriate jobs for interns, and what the interns' commitments are to the program until its completion were developed. Starting in the last 3 to 4 months of the program, interns and departments will begin discussions for permanent jobs. Permanent jobs should be at an appropriate level of responsibility and compensation. Each intern must remain in the program for a full 2 years even if they begin their permanent job prior to the end of the program. By remaining in the program, interns must continue with course work, staff meetings, and other workshops and seminars. In exceptional circumstances, where a particularly appropriate permanent job becomes available prior to the last 3 or 4 months of the program, consideration will be given to early placement. However, in these cases, the intern will still remain in the program until completion.

It was also recognized that some rather simple changes could be made to the logistics of the program to address the needs of the supervising managers of interns in their work rotations. Having a management intern in their group represented a new management challenge to these supervisors. For example, the interns often have additional requirements on their time, such as staff meetings, academic courses, and skill workshops. This situation was resulting in frustration on the part of some supervisors since they felt that they did not know when they could depend on the intern's support and presence. By combining several of these activities on one day of the week, it has helped to structure the intern's schedule, making it easier for the supervisor. This example exhibits the need to emphasize, at the start of such a program, that time must be spent educating and communicating with company managers the objectives and expectations of the program.

The administration of the Management Development Program is appropriately controlled by the Training Department. Unfortunately, this has started to foster an attitude that this is the Training Department's and interns' program, rather than building functional ownership. To address this issue, BIW is considering the formation of a committee which will help "champion" the program in the different functional departments. The make-up of this group and its mission would be decidedly different than that of the initial Steering Committee. This committee would consist of strong

middle managers who are concerned with their department's involvement in the workings of the program. They will help drive other department managers to develop appropriate assignments for visiting interns, ensure that interns receive the proper exposure, and serve as a concerned point of contact for the program's manager.

BIW has also identified areas to address in its continuing plans for career development. Naturally, with the company's investment in these individuals, BIW wants to ensure an acceptable retention level. By addressing issues and setting policy to cover areas such as leave of absence for continuing education, the company will support the needs of the interns and other employees. Also, as a result of this program, a more formal program of career pathing may be required for both graduated interns and other rising employees.

CONCLUSION

In less than 2 years of existence at BIW, the Management Development Program has proven to be a sound investment in the future of the company. BIW has implemented a program which emphasizes the three components of management development outlined in recent studies: job experiences, relationships, and training. The program combines work rotations, academic instruction, and skill development to develop capable people into high potential managers. The success of the program is evident by the intense interest displayed by different functional areas in obtaining an intern. The key to the continued success of the program lies in the ability to sustain this interest. In order to do this, senior management involvement and commitment must remain strong and middle management should continue to play a key role in the ownership of the program.

The need for strong management in the shipbuilding industry has never been greater. The intensely competitive environment in both the commercial and naval markets requires management with exceptional skills in a variety of areas. To be successful requires creative approaches to engineering, planning, and construction process technologies. Management systems that have effective cost and schedule controls must be employed. This requires leaders proficient in the technical requirements of the shipbuilding process in addition to strong leadership, motivational, and communication skills. The necessary

improvements for a viable long term shipbuilding industry in this country will not result from governmental policies, but will be a result of effective shipyard management. The development of personnel must become a priority for this industry to aggressively overcome the challenge of the present and the future.

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Initial Implementation of IHI Zone Logic Technology at Philadelphia Naval Shipyard

No. 7B

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ABSTRACT

Group Technology or Zone Logic Technology has been successfully implemented in several U.S. shipyards for new ship construction. This technology was originally conceived in the U.S. It was greatly refined by the Japanese and recently (beginning in 1978) reimported to the U.S. The technology replaces traditional system-by-system work with work organized zone-by-zone and by grouping similar work together with zones. This grouping of jobs enhances efficiency.

Those yards in Japan where Zone Logic is an everyday way of working, find that this technology is very effective in large scale overhaul and modernization projects covering both alterations as well as repairs. The traditional 'approach of 'working by systems is difficult to manage with the degree of difficulty being proportional to the size of the project. Work performed utilizing the principles of Zone Logic provides a more effective management method. The application of Zone Logic to Ship Overhaul, as advanced by Zone Logic advocates, has actually been made in small isolated cases ^{some} U.S. Naval Ship Overhauls

Philadelphia Naval Shipyard's application of Zone Logic to ship overhaul is neither small nor isolated. PNSY started its implementation of Zone Logic in the late fall of 1986, targeting the Service Life Extension Program (SLEP) for USS Kitty Hawk (CV-63) as the initial application. The technical services of Ishikawajima-Harima Heavy Industries Co. Ltd. (IHI), Japan were contracted to assist in this transition. This implementation on the Kitty Hawk is not a trial effort but involves about one third of the production mandays and covers over one-half of the compartments on the ship.

The actual SLEP production work on Kitty Hawk began in January 1988. Even though it is early in the three (3)

year SLEP, Zone Logic already is proving its worth. This paper explains the Zone Logic methods and methodology applied at PNSY on Kitty Hawk. It also discusses the future of Zone Logic at PNSY and its continued application.

INTRODUCTION

The establishment of the National Shipbuilding Research Program (NSRP) in the early 1970's and the reintroduction of Group Technology as refined by Ishikawajima-Harima Heavy Industry Co., Ltd. (IHI), started U.S. Shipbuilders on the road ^{modern} shipbuilding practices. Ref. (1)

The continuing ebbing of merchant ship construction and the high cost of construction in the U.S. have the surviving yards looking to the only work available; i.e., U.S. Navy construction and repair work. Thus, ferocious competition has private yards searching 'for every possible means to be more productive. Most of the surviving yards have implemented Zone Logic for new construction as the means of improving production. Many of them have consulted or contracted with IHI to make the transition to Zone Logic.

Increased productivity in new ship construction using Zone Logic principles is now a well accepted fact. These same principles can increase productivity in large scale overhaul/modernization and repair work. The Japanese yards practicing these concepts have demonstrated its value. The use of Zone Logic in U.S. Navy repair/modernization field, may be contested by American traditionalists even though its value may be immediately apparent to Demming type believers and industrial engineers. Those who do not completely understand Zone Logic concepts may not draw the same conclusions regarding the advantages of Zone Logic for repair/modernization projects. These people must spend time studying and working with Zone Logic concepts to really understand their benefits. With Zone Logic being embraced by the private

sector for its new construction, it is only a matter of time before they take the natural step of employing these concepts in large scale repair work.

Decreasing work the Marine Industry always fans the flames of the age-old question of Private vs Public Shipyards. Public yards are needed for national security, but are they cost competitive with private yards? This question becomes even more controversial in the case of the non-nuclear yards. Some feel that the public yards' very existence depends on their ability to remain cost effective in the ever increasing competitive environment.

Some public yards, however, have gotten the jump on the private sector. They are beginning to implement Zone Logic for repair work in limited ways. These implementations have been assisted by American Consultants and the NSRP Publications. However, Philadelphia Naval Shipyard is the first to contract with IHI, the innovators of this greatly refined technology. Many factors precipitated PNSY management to initiate Zone Logic on USS Kitty Hawk (CV-63) Service Life Extension Program (SLEP), Ref.(Z). The initial implementation was in support of the Hull Expansion project; but due to high risk factors associated with this work on Kitty Hawk, the work was eventually cancelled. Nevertheless, PNSY's management was determined to embrace Zone Logic. Therefore, alternate work of the same magnitude was earmarked for Zone Logic implementation.

A brief overview of Zone Logic is helpful to the understanding of the details that follow. First of all, there seems to be universally accepted term to describe this technology. It has been called IHOP (Integrated Hull Construction, Outfitting and Painting) by NSRP, Group Technology by Mr. Chirillo, Ref.(B), and Zone Logic Technology by the Naval Shipyards. IHI does not have a single term to express these concepts, so for this paper we will simply call it Zone Logic.

The name Zone Logic implies one of the concepts embraced; i.e., work by zones. But this expression sometimes causes misunderstanding, because it implies that all work must be done by zone. However, in a shipbuilding or overhaul project, there still exists some exceptional type jobs, such as through-ship cable installation, tests, etc., which should be performed by system. It should be noted that working by zone is a tool to increase production efficiency. Working with

Zone Logic principles should be understood as a comprehensive effort for the achievement of this purpose.

A test book definition for Zone Logic is a scheme by which work is subdivided with interim products as the focal point. Thus, it is the logical arrangement and sequencing of all facets of company operations in order to bring the benefits of mass production to highly varied and mixed quality production. This term in industry is also known as Product Orientation, Zone Technology or Family manufactory and is a detailed industrial engineering scheme for field as well as shop work.

This paper explains the initial implementation of Zone Logic at PNSY in support of USS Kitty Hawk SLEP project, evaluation of that implementation and where PNSY (and perhaps the entire Navy yard community) should go from here.

ZONE LOGIC AS APPLIED TO USS KITTY HAWK SLEP

Zone Logic Application In SLEP

SLEP intends to add 15 years to a ships' service life after approximately 30 years of service. This requires not only repairs and overhaul but also extensive alterations and modernization to keep the aircraft carrier in top fighting shape during this extended life. The massive scope of work consists of approximately 1.2 million mandays of production work over a 37 month period allocated for this program.

Initially the Hull Expansion Project, with approximately 350,000 production mandays, was to serve as the impetus to establish Zone Logic in PNSY. As the total scope of the Hull Expansion Project was analyzed, it was found to impact some thirty (30) percent of the already identified SLEP work package. Therefore, not only would the Hull Expansion Project be done by Zone Logic principles, but the other effected SLEP work as well. Once the shipyard started planning this work there would be no turning back to traditional methods. To revert later would cost millions of dollars in rework and adversely effect the overall SLEP schedule. Thus, when the Hull Expansion Project was cancelled, the other work had proceeded to the point where it would have been too costly to revert back to traditional methods to accompany the work. Proceeding with Zone Logic implementation was also consistent with PNSY management philosophy. It was also decided to apply these principles only to a portion of the SLEP considering the following:

It was required that the Zone Logic

Project show actual cost saving and not be just a trial effort.

• Design and planning for the SLEP had been going on for a year prior to shifting to the Zone Logic concept and obtaining IHI support beginning in January 1987. By this time it was too late to change the procedures and products of design, planning and estimation, job orders, material procurement, reporting, etc. The work of Zone Logic was to rearrange the system oriented drawings, Job Order Progress Cards (JOPC'S), Supplements, Key Operations and Material Lists produced by the existing organization in the traditional manner. Such a translation process had to be limited considering both availability of personnel for the project and benefit in budget savings as a result of Zone Logic application.

SLEP on Kitty Hawk is only a part of PNSY activities. PNSY carries out repairs and overhauls on other ships simultaneously. It was strongly felt that too much confusion would be generated by changing the whole system of the shipyard without enough preparation and training.

Areas For Zone Logic

Figure 1 shows the arrangement of 10 Major Zones used to divide the

entire ship from the viewpoint of Zone Logic. Four of these zones were chosen for application of Zone Logic principles. The main compartments or areas in the 10 Zones are as follows;

- Zone 1: Tanks and Voids (fourth deck and below), underwater hull, rudders, anchors and anchor chains.
- Zone 2: Four (4) Main Machinery Rooms, compartments on fourth deck just above these machinery rooms, shaft alleys, uptakes, propellers and shafts.
- Zone 3: Two (2) Auxiliary Machinery rooms, compartments on fourth deck just above these machinery rooms.
- Zone 4: Magazines and weapons elevators.
- Zone 5: Seven (7) pump rooms, Three (3) emergency generator rooms, Two (2) steering gear rooms, Two (2) steering motor rooms, air conditioning machinery rooms, refrigerating chambers and various other storerooms below third deck. (compartments below the third deck not covered in Zones 1 thru 4).

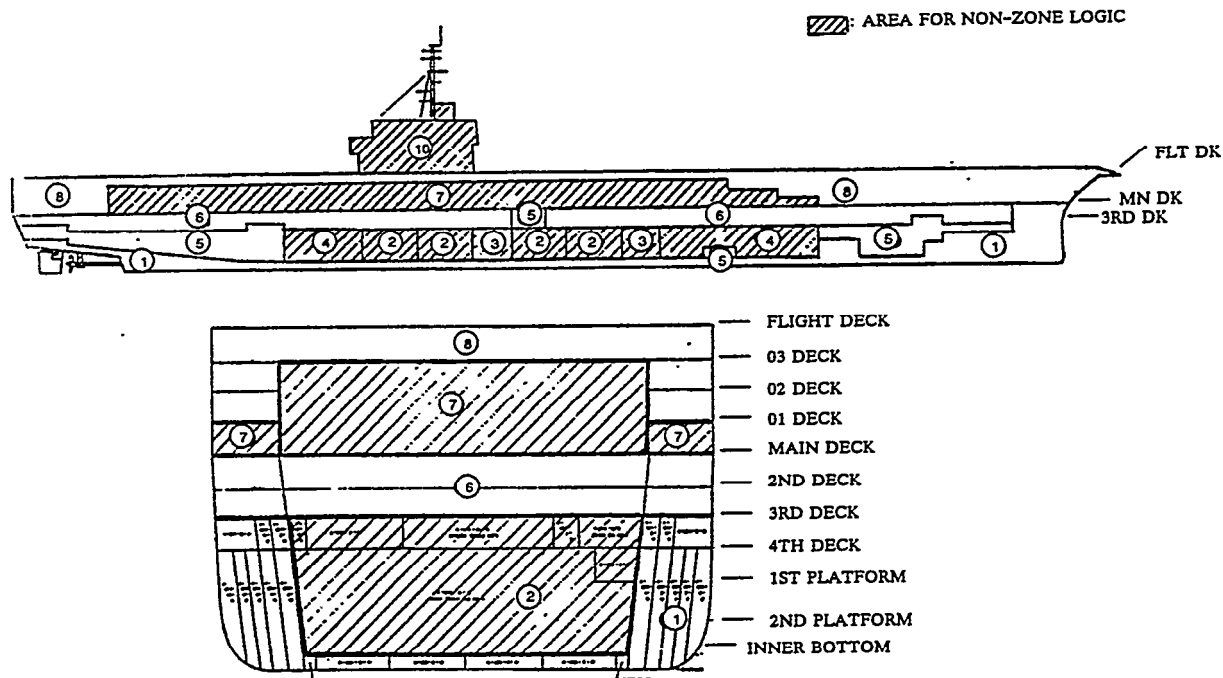


FIG.1 ZONE LOGIC IMPLEMENTATION ON USS KITTY HAWK SLEP

- Zone 6: Habitability on the second and third deck.
- Zone 7: Hanger Bay and the offices and storerooms related to Hanger Bay, aircraft elevators and the related machinery rooms.
- Zone 8: Habitability, offices and electronic rooms from the main deck to the flight deck, excluding compartments in Zones 2, 4 and 7.
- Zone 9: Flight deck, catapults and the related machinery rooms, catapult troughs with wing voids, arresting gears and the related machinery rooms and jet blast deflectors and the related machinery rooms.
- Zone 10: Island and other structures above the flight deck.

After close investigation, Zones 1, 5, 6 and 8 were the zones selected for Zone Logic application. The production work in these zones amounts

to about 400,000 mandays, approximately one-third of the total production mandays for SLEP.

Detail specifications of the zone boundaries are as described in Table I. The boundaries are basically defined by deck level except the following:

In case the compartment is continuous between decks the whole space belongs to the lower Zone.

Vertical watertight trunks belong to the zone where the lowest access is located.

Determining the zones to which each compartment belongs though is not enough. It is equally important to clarify which zone controls the boundary. In principle, the zone which completes work earliest at the boundary, controls the boundary. But, in Kitty Hawk's case, exceptions to the boundaries rule were made for boundaries between a Zone and Non-Zone Logic area. In these cases the boundary is controlled by Zone Logic. This is done because of more positive control and detail scheduling associated with Zone Logic.

TABLE I BOUNDARY DETAILS AND SPECIFIC RESPONSIBILITIES

ZONE	ADJACENT ZONE	ITEMS AT BOUNDARIES	INCLUDED IN (Responsible For)	LOCATION OF INTERFACE	HOOKE-UP & TESTED AT INTERFACE BY	INITIATIVE ON MILESTONES TAKEN BY
①	②&③	INNER BOTTOM PLATING BULKHEAD PLATING STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING INSULATION RELATED TO THE ABOVE	① ① ① ②&③ ②&③	MANIFOLD/Joint IN ②&③ JUNCTION IN ①	① ②&③	①
		INNER BOTTOM PLATING BULKHEAD PLATING STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING INSULATION RELATED TO THE ABOVE	① ① ① ④ ④	MANIFOLD/Joint IN ④ JUNCTION IN ①	① ④	①
		INNER BOTTOM PLATING/PLATFORM PLATING BULKHEAD PLATING STIFFENER, WEB, FOUNDATION, FITTING PIPING CABLING INSULATION RELATED TO THE ABOVE	⑤ ⑤ ⑤ ⑤ ⑤	MANIFOLD/Joint IN ⑤ JUNCTION IN ①	⑤ ⑤	①
	⑥	DECK PLATING BULKHEAD PLATING STIFFENER, WEB, FOUNDATION, FITTING PIPING CABLING INSULATION RELATED TO THE ABOVE JOINERS RELATED TO THE ABOVE	⑥ ⑥ ⑥ ⑥ ⑥ ⑥	JOINT IN ⑥ JUNCTION IN ①	⑥ ⑥	⑥ ① BETW 59&205 IN OTHER SPACES
	⑦	SRD DECK PLATING (DK ELEV MACHY RM) STIFFENER, WEB, FOUNDATION, FITTING PIPING CABLING	⑦ ⑦ ⑦	JOINT IN ⑦ JUNCTION IN ①	⑦ ⑦	⑦

TABLE I BOUNDARY DETAILS (Continued)

ZONE	ADJACENT ZONE	ITEMS AT BOUNDARIES	INCLUDED IN (Responsible For)	LOCATION OF INTERFACE	HOOKE-UP & TESTED AT INTERFACE BY	INITIATIVE ON MILESTONES TAKEN BY
⑤	② & ③	BULKHEAD PLATING STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE	⑤ ⑤ ② & ③ = ② & ③	— — JOINT IN ② & ③ JUNCTION IN ② & ③ JOINT IN ② & ③ —	— — ⑤ ② & ③ ② & ③	⑤ ⑤ ② & ③ ⑤
	④	2ND PLATFORM PLATING BULKHEAD PLATING STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING INSULATION RELATED TO THE ABOVE	⑤ ⑤ ⑤ ④ = ④	— — — — MANIFOLD/JOINT IN ④ JUNCTION IN ④ —	— — — — ④ ④ —	⑤ ⑤ ⑤ ④ ⑤ ⑤ ⑤
	⑧	DECK PLATING BULKHEAD PLATING STIFFENER, WEB, FOUNDATION, FITTING PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE JOINERS RELATED TO THE ABOVE	⑧ ⑧ ⑧ = ⑧ ⑧	— — — JOINT IN ⑧ JUNCTION IN ⑧ JOINT IN ⑧ —	— — — ⑧ ⑧ ⑧	⑧ ⑧ ⑧ ⑧
⑥	② & ③	3RD DECK PLATING TRUNK/UPTAKE WALL ABOVE 3RD DECK STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE	⑧ ② & ③ ⑧ ② & ③ = ② & ③	— — — — JOINT IN ② & ③ JUNCTION IN ② & ③ JOINT IN ② & ③ —	— — — — ② & ③ ② & ③ ② & ③	⑧ ⑧ ⑧ ⑧
	④	3RD DECK PLATING WPN/BOMB ELEV TRUNK STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE	⑧ ④ ⑧ ④ = ④	— — — — JOINT IN ④ JUNCTION IN ④ JOINT IN ④ —	— — — — ④ ④ ④	⑧ ④ ⑧ ④ ⑧
	⑦	MAIN DECK PLATING BULKHEAD PLATING (DK EDGE ELEV H RH) STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE JOINERS RELATED TO THE ABOVE	⑧ ⑦ ⑧ ⑦ = ⑦	— — — — JOINT IN ⑦ JUNCTION IN ⑦ JOINT IN ⑦ —	— — — — ⑦ ⑦ ⑦	⑧ ⑧ ⑧ ⑧
	⑧	MAIN DECK PLATING CAT PIPING TRUNK PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE JOINERS RELATED TO THE ABOVE	⑧ ⑧ = ⑧ ⑧	— — JOINT IN ⑧ JUNCTION IN ⑧ JOINT IN ⑧ —	— — ⑧ ⑧ ⑧	⑧ ⑧ ⑧
⑧	②	UPTAKE WALL ABOVE MAIN DECK STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING INSULATION RELATED TO THE ABOVE	⑧ ⑧ ② = ②	— — — JOINT IN ② JUNCTION IN ② —	— — — ② ②	⑧ ⑧ ⑧
	④	WPN/BOMB ELEV TRUNK STIFFENER, WEB, FOUNDATION, FITTING: PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE	④ ④ = ④	— — JOINT IN ④ JUNCTION IN ④ JOINT IN ④ —	— — ④ ④ ④	⑧ ⑧ ⑧

TABLE I BOUNDARY DETAILS (Continued)

ZONE	ADJACENT ZONE	ITEMS AT BOUNDARIES	INCLUDED IN (Responsible For)	LOCATION OF INTERFACE	HOOKE-UP & TESTED AT INTERFACE BY	INITIATIVE ON MILESTONES TAKEN BY
⑧ (cont.)	⑦	03 LEVEL DECK PLATING BULKHEAD PLATING/WALL STIFFENER, WEB, FOUNDATION, FITTING: RELATED TO BOUNDARY PLATING REPAIR RELATED TO OTHERS (SHIPALT, ETC) PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE JOINERS RELATED TO THE ABOVE	⑧ ⑧ ⑧ ⑦ ⑦ ⑦ ⑦	— — — JOINT IN ⑦ JUNCTION IN ⑦ JOINT IN ⑦ — —	— — — ⑦ ⑦ ⑦ — —	⑧ ⑧ ⑧ ⑧ ⑧ ⑧ ⑧
	⑨	FLIGHT DECK PLATING 03 LEVEL DK PLATING/WALL OF ROOM FOR ARST GR/BARRICADE/CAT/DK EDGE ELEV PIPING CABLING DUCT INSULATION RELATED TO THE ABOVE JOINERS RELATED TO THE ABOVE	⑨ ⑨ ⑨ ⑨ ⑨ ⑨ ⑨	— — — JOINT IN ⑨ JUNCTION IN ⑨ JOINT IN ⑨ — —	— — — ⑨ ⑨ ⑨ — —	⑧ ⑧ ⑧ ⑧ ⑧ ⑧ ⑧

Organization

A project with the magnitude of the Hull Expansion would normally have been assigned to the executing shipyard three (3) to four (4) years ahead of a scheduled start date. However, in order to be able to execute the Hull Expansion Project in conjunction with USS Kitty Hawks' SLEP, a special project team was established. Under this project team an aggressive plan of action along with milestones was developed to meet the short fused time table PNSY had to execute the Hull Expansion Project. This plan of action called for a reorganization of the shipyard's normal working procedures. In development of this plan of action, a world wide tour/investigation and analysis of many major U.S., Canadian, British and Japanese shipyard practices was conducted. Also, numerous key members of the National Shipbuilding Research Program (NSRP) of the Society Naval Architects and Marine Engineers (SNAME) were consulted in order to learn state of the art technology being used in today's shipbuilding and repair environment.

The project team was established with key members from all the shipyard's major departments/branches; Planning, Production, Supply and Design. After Hull Expansion cancellation, the project team continued with the newly defined Zone Logic work. The shipyard's existing Planning and Estimating branch made adjustments in their normal issuing of work practices to support the Zone Logic efforts. Similarly, the shipyard's Design branch established a Zone Logic design team whereby all Zone Logic efforts are coordinated.

The outstanding results of Design and Planning and Estimating branches are worth a paper alone and will be only addressed briefly here. Also an additional work packaging group called the Outfit Planning team was established. The primary mission of the Outfit Planning team is to package work by zone, product and problem category as well as to schedule this work. As the project developed a production group dedicated to do all production work under the Zone Logic concept was established.

As general foremen, foremen and the mechanics were brought in to start work in the Zone Logic Production Group and under the new concepts of Zone Logic, they received lectures and training for a better understanding of these concepts and procedures. Figure 2 depicts a line diagram of how these groups are structured and the interrelation with each other.

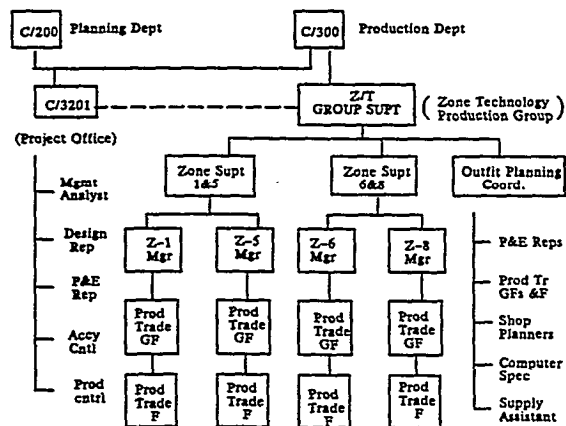


FIG.2 ZONE LOGIC PROJECT TEAM

METHOD OF ZONE LOGIC APPLICATION AT PNSY

Zone Logic Work Breakdown Structure

The historical work definition method at PNSY uses a JOPC and work center system. JOPC's define work on a system-by-system level; key or lead production shop are defined along with assist shops to accomplish needed work. As with the work statement (the JOPC), design direction and information (drawings), are produced on a system level. Because of the reasons stated above (the advance stage of design and work definition already accomplished, and the portion Zone Logic work represents in the overall shipyard workload), Zone Logic work would use the existing JOPC and systems drawings to develop work instruction for Zone Logic production. Since the current work packaging method did not efficiently support Zone Logic production, development of a new work issuing and identification system was necessary. This new work breakdown structure is called a Unit of Work or "Unit Work". Each Unit Work describes three components of the work:

Where the work is located (Zone),

What category or type of work it is (Phase),

Who will do the work (Product Trade).

Zone. A hierarchical structure was used to break the ship down into Zones, Intermediate Zones and Sub-zones. Major zone breaks were based on the function performed within that zone. The four major zones selected for application of Zone Logic were tanks and voids, pump room and miscellaneous auxiliary machinery spaces, and the upper and lower habitability spaces. These selected zones were then broken down to Intermediate zones. Work defined by Intermediate Zones was utilized for long term scheduling, setting priorities and planning. Sub-zones were the most detailed level and used to define Unit Work. Sub-zone breaks were carried out considering the work environment such as work accessibility, route for material movement, configuration of compartment, etc. For the Kitty Hawk, Zone Logic work was broken down into:

4 - - - - - Major Zones
117 - - - - - Intermediate Zones
388 - - - - - Sub-zones

Phase. Six phases or categories were set up to define the work.

- Pre-Overhaul Test/Inspection
- Ripout/Remove
- Shop fabrication/Shop repair
- Repair/Install
- Test
- Rework/Grooming/Titivation

Trade. There are fourteen (14) production shops and 147 work centers in PNSY. The traditional shipyard Job Order system is to break down the work by each shop and work center. This procedure is extremely ineffective for sequencing, scheduling and proper management. A *Product Trade System* was devised to simplify and make production more manageable.

Each Product Trade consists of multiple shop mechanics capable of accomplishing a series of work. To realize this concept, as mentioned earlier, the Production organization for Zone Logic was modified. The responsibility to accomplish each Unit of Work is given to a single foreman who manages multiple shop mechanics including part time assist trades. Nine Product Trades were set up:

- Steel work (with shipfitters and welders),
- Pipe work (with pipefitters and welders),
- Paint work (with blasters and painters),
- Tank cleaning work (with cleaners and gas free people),
- Joiner work (with sheetmetal men, welders, insulators and woodworkers),
- Electric/Electronic work (with electricians and electronic technicians),
- Machine work (with machinists and riggers),
- Scaffolding work (with staggers, riggers and welders),
- Assist/specialty work for assisting other Product Trades and performing special work.

A numbering system was designed during the definition of the Unit Work system or Zone Logic work breakdown structure. This numbering system fit within the structure of the shipyard Management Information System (MIS). Means were also devised whereby charges to Units of Work would be automatically

allocated back to their original system defined work for funding and reporting purposes. The five (5) digit Job Order field is used to indicate Zone, Intermediate-Zone and Sub-zone. The three (3) digit Keyop field is used to indicate Phase and Product Trade. Figure 3 shows the structure of this numbering scheme.

Certain categories of the work such as thru-ships cabling and system tests should not be defined by above mentioned Sub-zone levels. This work is better defined at higher zone levels such as Intermediate, major or multiple zones, depending on the nature and scope of work.

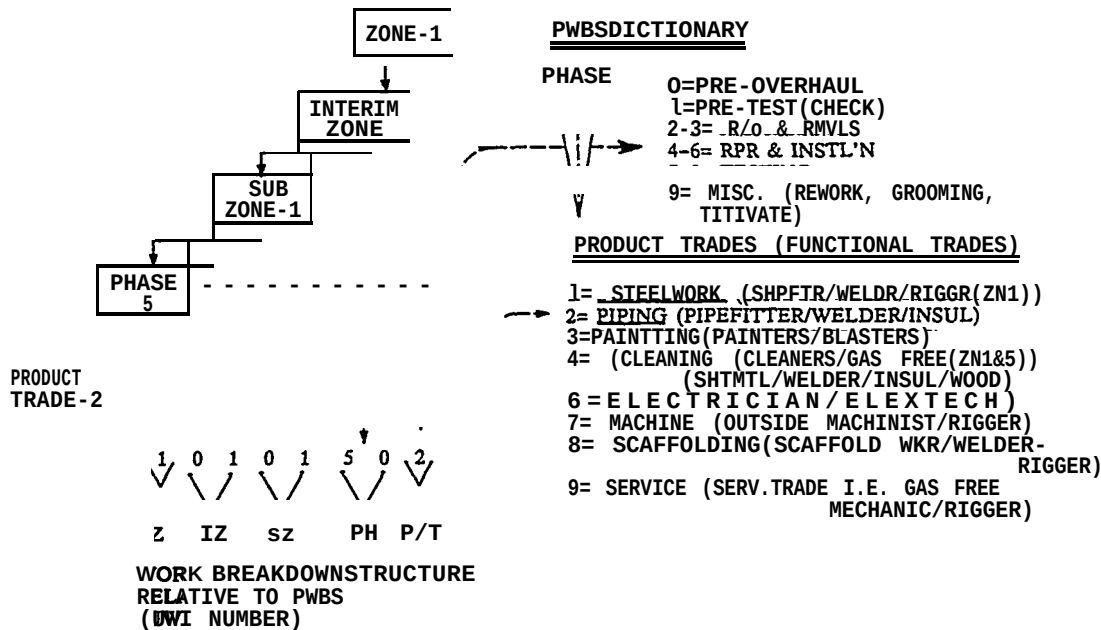


FIG.3 ZONE LOGIC PRODUCT WORK BREAKDOWN STRUCTURE (PWBS)

Unit Work Definition

The process used in re-defining Zone Logic work in accordance with the structure described above is labor intensive and time consuming. Figure 4 depicts this two-step process. First, each JOPC received which described work on the system approach, was analyzed in conjunction with applicable system level drawings. Each line item on each JOPC was allocated by Zone Logic Planners to Sub-zone, Phase and Product Trade. Gathering of various pieces from various JOPC's for specific Sub-zone, Phase and Product Trade produced a specific Unit of Work. The initial procedure for gathering information was done by hand. This gathering process is now being handled by PNSY's new Zone Logic Data Base Management System. (Ref.2) Each line item of every JOPC will be entered into this computer system. The data to be entered is:

- Sub-zone number
- Y Phase number
- Trade number
- Job description
- Budget hours
- Parent Job Order number
- Supplement number
- Drawing number

At a certain point in time the computer will sort the data by Sub-zone, Phase and Trade. A determination is then made that:

- all line items can be done at the same time,
- interference with other work does not exist,
- total budget man-hours is less than 800.

If the above criteria are met, this group of work is defined as one Unit of Work. If not, the work will be separated into two or more Units of Work using sequential phase numbers. The 800 man-hour limit per Unit of Work was established for ease of managing and controlling the work.

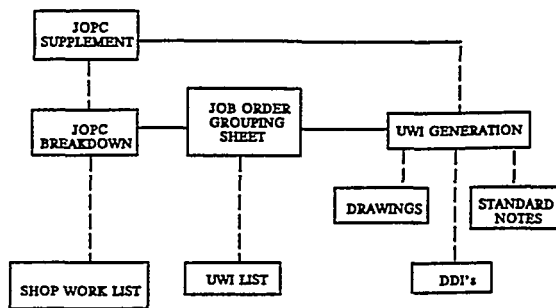


FIG.4 UWI GENERATION PROCESS

Unit Work Instructions

The second step is to write a Unit Work Instruction (UWI) for each Unit of Work. This is the only document needed to accomplish a Unit of Work. It contains all the information necessary by production and consists of:

- Work location
- Budget hours
- Source information
- General notes
- Job description
- Drawings
- Material List

In making each UWI, parts of drawings are extracted and portions of material lists are used so only applicable information is supplied in each UWI. Specific job descriptions are extracted from the JOPC reviewed. General notes are established for each Product Trade. When all the pieces of each WI are assembled, the package then contains all the information needed by production to accomplish that specific Unit of Work. This is a key to the success of Zone Logic. No longer must first line supervisors research references or look thru multiple sheet drawings for a single view applicable to the work being performed. All this is now done with the UWI.

Admittedly, this is a time consuming process. However, it is necessary for Zone Logic Implementation. Initially the UWI engineers did all this work by hand, and 60 man months of effort were required to define 3000 Units of Work, and to write 1300 UWI's which contained 560,000 man-hours of production work. This labor intensive process is being automated by PNSY as much as possible. Plans are also being formulated to structure future planning and design

work to better support Zone Logic Product Breakdown Structure without losing sight of funding and reporting requirements necessary at system levels.

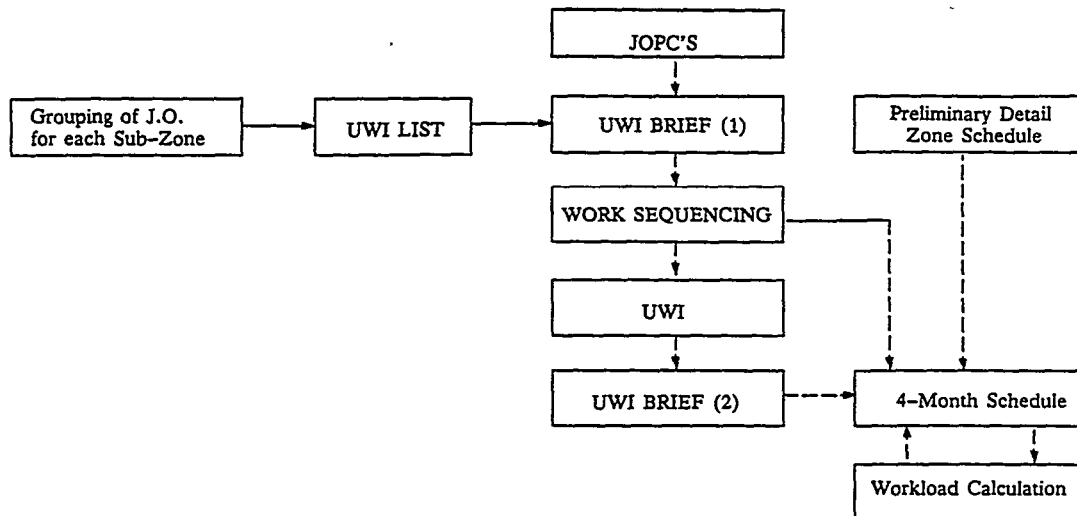
Scheduling And Manning

More realistic and reliable schedules can be produced through Zone Logic Techniques. Under the existing method of system-by-system Job Orders, it is virtually impossible to sequence work to be performed in a specific location. This results in scheduling work only within a time frame which includes time "float". No exact start and completion dates are scheduled. This method leaves too much for production workers to decide. They must decide work sequence, trade sequence, level loading and manning. In most cases under the traditional system, production workers will start work that can be done at the moment. This produces duplication of work and excess movement in the field. To combat this problem Zone Logic effort concentrates on:

- More detailed and exact l e s ,
- Work flow charts,
- Definite schedule dates without float,
- Y Work schedules reviewed and revised against manning,
- Continuous review of work and schedule updates,
- Monitor Work Progress and Productivity.

Zone Logic philosophy is to start and complete work zone-by-zone rather than allowing random starts anywhere. Zone-by-zone work is vastly more manageable than random system-by-system work. Zone-by-zone schedule is initially done on an Intermediate Zone basis, considering estimated work volume in the Intermediate Zones and the Key Milestone Schedule for the ship. Critical work takes first priority and this Intermediate Zone Schedule is the overall plan to be followed. This plan also used to make detailed schedules which are issued on a four (4) month basis. The procedures and process of Schedule and Manning are shown in Figure 5.

Flow charts are made for Intermediate zones prior to making detailed four (4) month work schedules. These flow charts show the sequence of the work within Intermediate zones, independent of Trade or Phase. The scheduler during this process looks at all UWI's to understand all the work to



- NOTES:
1. The purpose of UWI Brief(1) and (2) is to prepare for work sequencing and the 4-Month Schedule respectively.
 2. UWI Brief (2) is a refinement of (1) because of
 - a) Issuance of additional JOPC's.
 - b) Grouping or dividing UWI considering both contents and amount of work.

FIG.5 ZONE LOGIC SCHEDULING AND MAN LOADING PROCESS

be carried out in a particular area. For instance, there are vent ducts, pipes, joiner bulkheads and furniture to be installed in one compartment; which is first? The sequence is checked and determined during this process. During this process the scheduler may find some Units of Work which interrupt other Units of Work. Such Units of Work are divided and/or rearranged to suit the production sequence.

Definitive start and completion dates are given each Unit of Work considering the flow chart, budget hours and numbers of mechanics which are allocated to each Unit of Work. Allocation of mechanics is done considering not only the total manning of Zone Logic work, but also the appropriate size of the work force for each Unit of Work. These dates are used to generate a Bar Chart Schedule. Bar charts are used in place of the customary digital information because they are more pictorial and convenient for production to use in managing the work.

An obviously important factor in scheduling is to ensure the work can be accomplished with the available mechanics during the period of time being scheduled. Equally important is that the schedules produced make the workload as level as possible.

Additionally a total projected manhour accumulative curve for the entire period of the program is prepared based on total budgeted manhours. Specifically scheduled Units of Work are compared to the total manpower curve to show overall progress of the program towards completion.

An ideal condition exists when all the details of all the work are known in advance and schedules from beginning to end can be made. However, when performing repairs, it is almost impossible to know the total scope of the work in advance. Huge amounts of work come out continuously after the start of work because repairs are discovered when inspections are performed. With work definition changing, long range detail scheduling cannot be done. The only overall plan which can be made is the Intermediate Zone Schedule discussed above. Even so, Detail Unit Work Schedules must be done for level loading of production work. For the SLEP, these detailed schedules are set up for a four (4) month period. Unit work schedules and manning plans show a four (4) month window based on the latest job information as shown in UWI'S. The last month is overlapped by the next four (4) month schedule, i.e. a new schedule is issued every three (3) months. If changes are great the schedule is updated once a month.

Finally, work is monitored using the "Cost/Schedule Control System" (C/SCSC). Expended manhours and progress percentage of each Unit of Work is reported weekly by production. The c/scsc system figures out performance measurements based on budget data and schedule dates which come from the four (4) month schedules. Only firm data on work to be executed in the following four (4) month window is used because broad data pertaining to future work is not detailed enough for reliable reporting of production performance. Long-range forecasting of overall performance is accomplished by comparing actual accumulative manhours expended and the Budget Cost of Work Performed on an accumulative basis, with the projected manhour accumulative curve. This projected manhour accumulative curve is the plan for overall project based on the Intermediate Zone Schedule discussed above.

EVALUATION OF ZONE LOGIC IN SLEP

Merit of Applying Zone Logic Techniques to SLEP

The major merits in the implementation of Zone Logic in Kitty Hawk SLEP, are as follows:

- Efficiency is enhanced by performing all phased work which can be done by the same people, at the same time, in the same location, (Phased work pertains to work of like nature, i.e., ripout, repair, installation, test, etc.)
- Work sequencing problems are resolved by organizing workers into Product Trades and scheduling each Unit of Work,
- Work efficiency is enhanced and level-loading achieved by following the realistic schedule prepared by Unit of Work.

The first of the major merits and the original aim of Zone Logic in overhaul projects is the concept of the *same people, same type of work and same location*. This corresponds to Product Trade, Phase and Sub-zone being used on Kitty Hawk SLEP. The reason why this causes increased efficiency are self evident.

Planning and managing the huge amount of work included in a large scale overhaul project is not easy when thousands of Job Orders are produced for various shops. Work sequencing by shops is indeed one of the most difficult things to plan in such a project. This is especially true if the work is described system-by-system.

Work described by system is almost impossible to efficiently plan when trying to consider the work sequence of the various shops. Therefore, production schedules have normally been issued with *should be or must complete* dates and possible start dates. The Job Orders are issued and scheduled with *float*, not the exact date when a particular Job Order should be performed. Scheduling by this method leaves planning to production and it is easy to see why production people have difficulty in managing this way. Interference of work between shops is the result, and many of the jobs tend to start at the end of the scheduled time frame. The result is a tremendously high backlog of work as the scheduled completion date of the project comes close.

In Zone Logic, on the other hand, Unit Work Instruction are issued by Product Trade, and each Unit of Work is carefully scheduled with definite start and completion date. Unit Work Schedules- do not contain float and indicate what is the most efficient timing for each Unit of Work.

Organizing by Product Trade simplified and solved the trade sequencing problem. Unit Work Schedules are developed considering work sequence. This is not difficult because sequencing is done by Product Trades, not system Job Orders. The only thing left to production is detail sequencing within Product Trade on a daily basis.

Level-loaded work schedules are one of the major factors in keeping productivity high. The traditional method, of course, takes into account this level-loading in setting up events, but the scheduling with float allows postponement of work until the scheduled completion date approaches. This tendency makes a "bow wave" in manpower loading, which is obviously undesirable from the work efficiency point of view. In Zone Logic, schedules are developed based on both work sequence and level loading. Therefore, if the schedule is followed the bow wave does not appear and work efficiency will remain high. Unit Work Schedules are Four (4) Month duration for Kitty Hawk SLEP.

Other Merits

Beside the 'three (3) major merits above, several others the implementation of Zone Logic.

Overall Project Schedule Adherence
Traditional system definition of- and scheduling- with float may cause an extremely high bow wave as the project approaches completion. The extent of this wave may be so great as to

jeopardize the completion of the project on time.

Manhour Reduction by Carefully Arranging of Work. Scaffolding in Tank & Void for Kitty Hawk was planned for use by both piping and painting work. Such planning physically decreases the amount of scaffolding required.

Beside the enhancement of efficiency in direct work stated above, the indirect support work of temporary services can be reduced by providing the services from many Job Orders to the same sub-zone, same trade and same phase. This means that services are rigged fewer times than in a system approach.

Rework is Reduced. Rework is basically unavoidable in the traditional method because production people cannot know whether or not there exists other similar type of job when they receive a Job Order. Generally, several pieces of similar work at the same location are routed separately and consequently implemented separately. In Zone Logic this problem is greatly reduced.

Wait Time is Greatly Diminished. Zone Logic organizes production into Product Trades to more efficiently manage the work. The mechanics of necessary disciplines are within the group managed by each foreman. Because of this, lost time due to waiting for other trades will be remarkably reduced.

Information Availability. In the traditional method various reference information is shown in the Job Order. Production people need to collect the information before commencing the job. Unit Work Instruction includes all of this information. Unit Work Instruction also shows only the work associated with that Unit of Work as sketches or portions of drawings. These sketches and drawings are provided in a convenient size for field use. This makes it much easier for production to comprehend the work content of the Unit of Work.

Better First Line Supervision. Because of the Product Trade Organization and the form of the UWI, first line supervisors do not need to spend as much time arranging for support work or gathering reference material. They are able to devote more time to actual supervision.

Issues Raised During Implementation

The implementation of Zone Logic at PNSY has proceeded fairly well. Management has supported this change

and those working on the implementation have accepted and are enforcing the concepts diligently. As with any change, some areas and issues have proven to be troublesome. The following have created the major implementation problems:

Timely Availability of Information. The policy established for Kitty Hawk's Zone Logic was to develop Unit Work Instructions without changing upstream information such as drawings, Job Orders, etc. Job Orders were issued system-by-system, one-by-one, as the information became firm, not as total packages of work. Issuing work in this manner makes it extremely difficult for Zone Logic implementation. Consequently as Unit Work Instructions were being generated, it was not known whether all the information was received or whether more information was coming. This often caused the revision of Unit Work Instructions as additional information was received. Zone Logic becomes almost the same as the traditional method of work if many Unit Work Instructions are issued for each combination of Sub-zone, Product Trade and Phase. Many UWI's will result if the information is not diligently gathered for each Sub-zone, Product Trade and Phase.

The solution to this problem is to establish priorities for the issuance of all upstream information. This will ensure the availability of the needed information when developing a specific Unit Work Instruction. This priority should be in the same order as production intends to perform the work. In order to establish these priorities an overall production plan must be established much in advance of what is currently being done. In addition to this prioritization, a Master Schedule for all activities of the project should be established. Every organization, Design, Planning, Procurement, etc., in the shipyard should abide by this schedule.

Information Flow of Repair Work. SLEP work is divided into two (2) basic categories; Ship Alterations and Repair. Ship Alterations (Shipalts) are in a sense, similar to new construction and the initial design work for both Zone Logic and traditional approaches are the same. Initial design must be made on system level. Zone Logic takes a different step in the transition of initial design to production design. Traditional design remains at a system level. Zone Logic, through the Transition Design Stage, develops production design on a Zone-by-Zone basis.

Repair information basically originates in a zone-by-zone form

because the repair requirements occur in a specific part of a system or at a specific location. The traditional method requires the information to be transformed into system-by-system package for funding and authorization. In Kitty Hawk's case, it was necessary to transform this information back into zone packages for developing the Unit Work Instructions. It should be obvious that this information flow is very inefficient and should be simplified.

A solution for this problem might be to ensure the original zone information be retained when developing system repair packages for funding purposes. It would then be an easy machine process to reorganize the repair information back into zone packages to issue in accordance with the Priority List and Master Schedule discussed above.

Sub-zone Breakdown. Sub-zone definition in Kitty Hawk SLEP are in some cases to be too small. This was caused by Sub-zone definition being made early before the geometrical distribution of work was well known. Experience shows that if the amount of work for a particular Sub-zone is too small, it is more efficient to make that Sub-zone larger. Sub-zones should be defined when a good understanding of work distribution is known. Intermediate zones may be used for planning purposes before the Sub-zones are defined.

FUTURE APPLICATION

Zone Logic is being applied on about one-third of the total Kitty Hawk SLEP work, while minimizing the change to traditional shipyard operation. This policy was made because of the large amount of the upstream information which had been completed by the time Zone Logic Implementation started. However, in order to make Zone Logic more effective, it will be essential for many of the upstream activities in the shipyard to generate information more suitable for Zone Logic use. Some ideas for these changes are:

- o Assign each piece of work as it is identified to the appropriate Intermediate zone. Prioritize major work within Intermediate zones and prioritize Intermediate zones.

- o Prepare a Master Schedule for the entire project from initial planning to completion, using the information above.

- o Prepare a Design Schedule based on this Master Schedule. Issue drawings in accordance with this design schedule.

Develop Unit Work Instructions directly based on the drawings and information above without first generating a system level JOPC.

The above procedure will streamline the information flow for Zone Logic. It will eliminate duplicated work and provide information at the appropriate time. Without a doubt it is a key to the success of Zone Logic that every organization in the shipyard, from Design (upstream) to Production (downstream), follow the carefully established Master Schedule of the entire project. Abiding by the Master Schedule will maximize production efficiency.

CONCLUSION

This paper reports on the initial implementation of Zone Logic in Kitty Hawk SLEP project. It has been found that Zone Logic is highly effective in a large-scale overhaul project, especially when an enormous amount of alteration work is included. Thus, it is the writers wish that the entire Kitty Hawk project will be completed with successful results; that the Zone Logic portion of the work will show the savings known to be available by these techniques; and that Zone Logic Implementation at PNSY and in the Navy as well will continue and be widely applied in other projects and in other U.S. Navy shipyards.

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Discussion on Paper #/7-B, "Initial Implementation of IHI Zone Logic Technology at Philadelphia Naval Shipyard" by Koichi Baba, M.S. O'Hare, James C. Schaff, Takao Wada, and Soichi Kondo.

by Howard M. Bunch, Member

One of the most significant implementations of advanced technology to occur in U.S. shipyards in recent years is the attempt to introduce zone logic into a repair environment at Philadelphia Naval Shipyard (PNSY). The presentation by Baba, et al, is a timely description of this program. The paper gives a quick overview of the effort, and describes some of the complex issues that have had to be dealt with. I thank the authors for their effort in preparing this paper, and thus giving the industry an insight into the dimensions of the zone technology implementation in a major overhaul environment, i.e., the service-life-extension-program (SLEP) for an aircraft carrier.

One of the issues often overlooked in the discussions to implement zone technology is the need to develop new mechanisms to record production control data. And, the disruptions created by the introduction and use of the new production control methods are, potentially, sufficient to present major hurdles to a satisfactory implementation. It is apparent that the SLEP program management recognized the need for an effective production control data system, and took the necessary steps early in the project. And, the reporting concepts that were developed were impressive. One area, however, where significant work occurred, but which was not reported by the authors, was the methodology developed for converting the zone-oriented work status that exists at the production shop back to the systems-oriented monetary authorization document (known as the financial control number, or "FCN"). It was critical that a satisfactory system be developed so that the funding source(s) have realistic and current estimates of the status of their committed funds. The planning personnel at PNSY developed computer software to access the data files, retrieve the appropriate data, and to make the appropriate allocations to the authorization document accounts as work progresses. Hopefully, there will be a future presentation of this effort at some future NSRP meeting.

The zone logic technology implementation program has been underway at PNSY for nearly 18 months, and there should be indications appearing as to whether the potential savings, described by the authors, will be realized. Implementation of zone technology into commercial shipbuilding environments traditionally results in significant production man-hour savings.^{1 2 3} Budgeted estimates for the savings that would occur at PNSY on the CV63 (Kitty Hawk) overhaul were originally set at about 25 percent.⁴ In their paper the authors gave no definitive data as to how the actual costs were tracking relative to the budgeted costs at this point in time. It would be interesting to know what is actually happening; is the targeted budget of 25 percent reduction being met, and if not, why not.

One of the major factors to contend with in the implementation of advanced technology, such as zone logic, is the shift in the power structure that occurs. At Navy shipyards, the functionally-oriented group superintendents have traditionally been the most powerful force in the production organization. In my mind it is critical that this group of managers be committed to the concept of zone logic, in both word and action. This is especially critical since they could easily perceive the zone technology initiative as negatively impacting their traditional authority. It would be interesting to hear how the group superintendents have reacted to this new production concept, and what actions were taken (and are planned) to assure their continuing support.

For a period in 1987 I had the opportunity to work with the authors when they were in the early stages of implementing zone logic technology at Philadelphia Naval Shipyard. Then--and now--I felt that the initiative they describe in their paper is a significant effort to improve productivity in naval shipyards. I congratulate the PNSY organization on its effort to date, and wish it success in obtaining its goal.

¹Sasaki, H., "IHI's Experience of Technical Transfer and Some Considerations on Further Productivity improvement in U.S. Shipyards", Journal of Ship Production, May, 1988.

²Weiers, B., "The Productivity Problem in U.S. Shipbuilding", Journal of Ship Production, February, 1985.

³Lame, T., "Group Technology in Shipbuilding," Journal of Ship Production, February, 1988.

⁴Personal conversations with the authors during the period 7/87-12/87.



THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

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A Group Technology Approach to Master Scheduling of Shipbuilding Projects

No. 8B

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This paper describes the current Master Scheduling approach used at National Steel and Shipbuilding Company (NASSCO) in San Diego. Master schedules at NASSCO focus on key interim products involved in ship construction: units, blocks, (on-board) zones, and tests. Network scheduling algorithms (i.e., Critical Path) are used. Each interim product has an associated subnet. Categorization by type is used to simplify the task of developing and maintaining activity lists, dependencies (predecessor/successor relationships) and durations for the thousands of activities. Manual level-loading of critical resources is incorporated into and supported by the overall scheduling process. The paper includes some discussion of problems encountered in the implementation of this scheduling approach.

NOMENCLATURE

The following definitions are provided to clarify usage within the body of this paper. They reflect common usage within National Steel and Shipbuilding, San Diego. Definitions provided are not intended to imply industry standard practice.

The definition of interim products is somewhat circular. The intent behind defining interim products is to focus attention on a deliverable units of work having common process characteristics, in the spirit of the definition of Group Technology given below.

Block -- a structural assembly which will be erected singly or as part of a grand-block;

Group Technology -- organization of work to take advantage of common process characteristics, while accommodating minor differences in material, geometry and size, in order to bring the advantages of mass production to high-variety, mixed quantity production;

Interim Product -- an assembly or portion of work which can be logically scheduled and managed as though it were a deliverable product; e.g., unit, block, subzone, system test, etc.;

Pallet -- subdivision of a workpackage; a unit of work which has common work characteristics (process, tooling or material), and which can be performed by a single crew in a reasonably short period of time while working in a defined work area;

Subzone -- a geographic volume within a ship; typically bounded by watertight bulkheads fore and aft, decks above and below, and shell plating to port and starboard;

Unit -- piping unit; an erectable assembly composed both of structural components (structural framework, common foundations, floor plates and gratings) and outfitting components (e.g., pumps, motors, piping, gauges) and which is not an integral part of the ship structure;

Workpackage -- all work within a given stage of construction, of a given type of work (e.g., piping, vent, etc.), and for a given interim product (unit, block, subzone, etc.).

INTRODUCTION

This paper describes a method of developing the portion of the Master Production Schedule (MPS) associated with the assembly, outfitting and erection of hull blocks. The method discussed:

- o uses information available very early in the contract cycle
- o can accommodate some inaccuracy in available information
- o is sufficiently detailed to insure workable schedules
- o integrates the scheduling of engineering, material procurement, detail planning and production activities
- o uses Group Technology concepts and PC-based Project Management software to maximize efficiency of the scheduling process

The method discussed can, by extension, be applied to other portions of the Master Production Scheduling process.

MASTER PRODUCTION SCHEDULE

The American Production and Inventory Control Society dictionary defines the Master Production Schedule in part as follows:

"...the anticipated build schedule for those selected items assigned to the master scheduler...." 1

The Master Production Schedule for an individual ship or contract must take into account the contractual requirements, existing or anticipated backlog, availability of drawings and material, availability of manpower and capacity, and management objectives. The Master Production Schedule must therefore include or incorporate information from:

- o Milestone/Key Event Schedules
- o Procurement Master Schedule
- o Engineering Master Schedule
- o Manpower Curves and Capacity Plans

The Master Production Schedule integrates the efforts of different functional areas (production, engineering, materials) as well as various production sub-organizations (steel fabrication, assembly and erection, outfitting shops, on-block and on-board outfitting, test and trials, and subcontractors,). Different parts of the organization require different information. The shop requires a set of need dates, together with design and material availability dates. On-block outfitting requires steel assembly complete dates, design and material (purchased and fabricated) availability dates, and erection dates. The MPS provides the sets of dates necessary to do this, while allowing area managers flexibility to schedule within the required constraints. The responsibility to manage must rest with the manager, not the scheduler.

The Master Production Schedule becomes the basis of more detailed scheduling of engineering work, material procurement, manpower planning, training schedules, and capacity planning. Development of the Master Production Schedule therefore assumes a degree of urgency once a contract is awarded.

Methods must be developed which provide reasonable accuracy of schedule even when based on preliminary and incomplete information. Later changes to the MPS which result in earlier requirements for material or engineering products are difficult or impossible to accommodate. On the other hand, schedules which

introduce unnecessarily early requirements on engineering and material procurement work may result in higher costs for those functions.

GROUP TECHNOLOGY AND INTERIM PRODUCTS

The concepts of Group Technology are central to much of the modernization of shipbuilding production management methods and procedures. Application of these concepts within the shipbuilding environment has been well-documented within the shipbuilding literature.

Group Technology (GT) has been defined as:

"GT is a technique for manufacturing small to medium lot size batches of parts of similar process, of somewhat dissimilar materials, geometry and size, which are produced in a committed small cell of machines which have been grouped together physically, specifically tooled, and scheduled as a unit." 2

While such a definition works well in a machine shop environment, a modified definition is required for effective application to shipbuilding. The following definition by G. M. Ranson is suitable:

"The logical arrangement and sequence of all facets of company operation in order to bring the benefits of mass production to high variety, mixed quantity production." 3

Ranson's definition broadens the scope of application of the central concept of Group Technology: focusing on similarities in process, while accommodating differences in materials, geometry and size. This broader definition encompasses much of the work that has been done in applying GT to the shipbuilding environment. The key to successful application of Group Technology in shipbuilding is a focus on "interim product."

Ship construction is characterized by a single, deliverable end product. The ship is assembled from a number of major assemblies (structural hull blocks, main engines, shafting, piping units, etc.) supplied by the shipyard and by outside vendors. These in turn are composed of smaller assemblies and purchased components. The bill of materials explosion of a ship being built using modern shipbuilding technology would have levels similar to those shown below:

```

      ship
      |
      major assemblies
      (e.g., blocks, units, subzones, main
      engines, shafting)
      |
      minor assemblies
      (e.g., manifolds, structural panels,
      pumps, vent fans)
      |
      fabricated and purchased parts and
      components
      (e.g., pipe spools, vent pieces,
      valves, connection boxes)
      |
      raw stock material
      (e.g., plate, angle, pipe, cable)

```

At the middle levels of the ship assembly process, a variety of interim products can be defined. For example, at the major assembly level these include: piping units, outfitted structural blocks, outfitted subzones and tanks, shafting installation, etc. (Terminology varies somewhat within the shipbuilding industry.) Focusing on these interim products is the key to application of Group Technology to the shipbuilding process.

This article will focus on the scheduling of a particular interim product at the major assembly level: assembly, outfitting and erection of structural hull blocks, including the design and material need dates for each block. The scheduling approach discussed is applicable with minor modifications to other interim products at the major assembly level.

HULL BLOCK SCHEDULING ELEMENTS

Scheduling of all work associated with structural hull blocks was done using Project Management software running on an IBM AT computer. A project network was built for the purpose which included:

- o engineering activities
- o material identification, procurement and receipt
- o detail planning activities
- o all related production activities

The purpose was to integrate schedules at a level of detail sufficient to assure a workable schedule.

Building the scheduling network involved merging several pieces of information:

- o a scheduling network for a typical block which integrated the engineering, materials, planning and production activities associated with the block
- o a hull block breakdown showing the location of the structural breaks between blocks

- o an erection schedule showing erection dates for all outfitted structural blocks
- o tables of scheduling offsets and schedule durations for those activities and relationships which vary according to block type or individual block

These elements, from which the overall network schedule is built, will be discussed in turn.

Hull Block Network

The hull block network includes known scheduling information common to all blocks. Dependencies among and between engineering, materials, planning and production activities are incorporated. Desired lag periods between activities are included. Schedule durations which are standard for all blocks are incorporated. The activities and relationships represent the flow of materials and information, movement of the interim product through various processes and stages, and intervals of time provided for completion of activities not shown explicitly. Figure 1 shows a typical block network. Note that the network is not to scale since some activities shown may vary for given blocks.

Developing the network involves the balancing of several factors. Every activity or relationship in the individual network will be duplicated a number of times in the project network. For example, a 40 activity network used with 300 structural blocks will result in a project network of 12,000 activities. Excessive detail can lead to problems with file size, software constraints, processing time, report sizes, and so on. Activities that should be included are those which are required to establish schedule dates, schedule durations, utilization of critical resources, and those activities whose schedules will need to be tracked as the project proceeds.

Standard durations which exceed normal operational times for a given set of activities provide a means of absorbing delays, uncertainty in work content and work rate, correction of minor material problems, etc. Given the uncertainties which often prevail in the shipbuilding environment, this conservative approach makes sense for any area facing significant material problems, unplanned work, or uncertainties in work scope or sequence. It provides a means of minimizing the schedule impact of deviations from the plan, and works in conjunction with an iterative approach to planning.

Standard durations which exceed operational times also have several

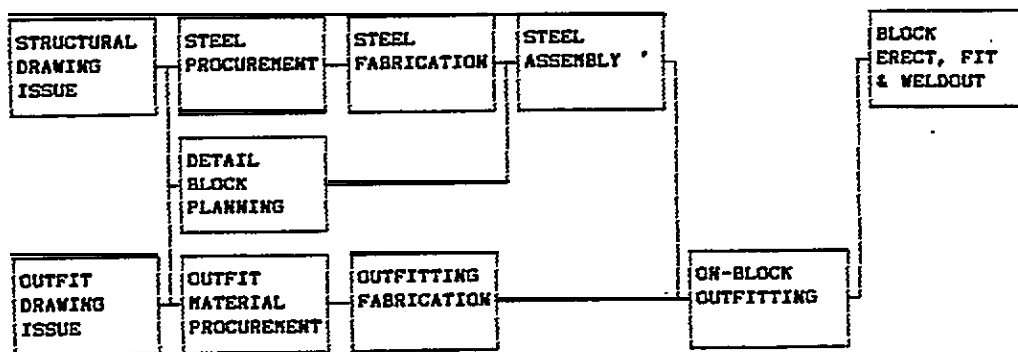


Fig. 1: Typical block scheduling network (precedence diagramming method)

disadvantages. First, line of balance scheduling of critical resources must be done separately using planned operational durations. Line of balance scheduling assumes that a crew moves from one job to the next, maintaining a smooth flow of work. Schedule durations which exceed the time required to perform the work will result in a delay between completion of one job and starting of the next if the jobs were scheduled end-to-end.

Second, longer overall program schedules may result. If the duration of an activity which is on the critical path exceeds the actual duration required, then the schedule based on that path will be longer than necessary. This can have local and/or global impacts on the project schedule. For example, if limited pin jig laydown area exists for assembly of curved shell blocks, the total time required to assemble all curved shell blocks will depend on how long each block must remain on the pin jig. This may or may not affect the overall ship construction project schedule.

Third, conservative scheduling durations imply acceptance of a certain level of schedule uncertainty. Variances in actual durations and schedule performance are hidden. Underlying problems which cause the variances are accommodated. The urgency of correcting such problems is thus reduced.

A pragmatic approach is needed to balance these considerations. Conservative (longer) scheduling durations can be used where required. If the resulting schedule does not appear optimal from any standpoint, shorter durations can be substituted and the schedule recalculated.

Hull Block Breakdown

The hull block breakdown establishes the list of blocks, their numbering, and locations of the erection breaks. This

information can be used in conjunction with contract guidance or other drawings in establishing block types and estimates of work content. These estimates can be used to define schedule durations and offsets for those activities and relationships which are non-standard and depend on the individual characteristics of the block.

Hull Block Erection Schedule

The hull block erection schedule establishes the need dates for the end assemblies, the outfitted structural blocks. This schedule is the backbone of that portion of the production schedule related to hull blocks. Any change to the erection date for an individual block is likely to affect every other activity for that block.

The erection schedule can either be in the form of a table of dates or can itself be a form of network. Figure 2 shows a portion of an erection schedule in network form. If the erection schedule is in tabular form (with no dependencies between erection of individual blocks) then the final project network will be composed on a series of independent subnets, one for each block.

Table of Schedule Offsets and Schedule Durations

The table of schedule offsets and schedule durations captures all of the non-standard features of the individual block networks. For example, assembly durations may vary by block type (flat deck or bulkhead vs. curved shell block) and/or by work content (tonnage or weld footage). Outfitting durations and routing may depend on the paint requirements and outfitting work content. A table of values matching block number with the particular values will be used to tailor the standard block network to the requirements of the specific block.

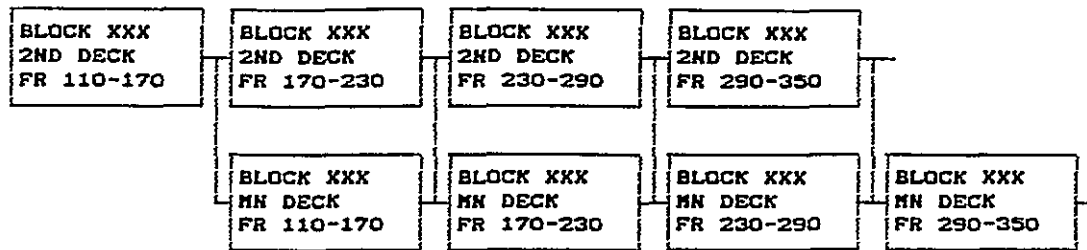


Fig. 2: Portion of an erection schedule (precedence diagramming method)

Group Technology can be used to advantage by defining families of blocks by type. For durations and offsets which are a function of some categorization by block type, the duration or offset can be provided for each block type in a separate table. The type associated with each individual block is then indicated in the block table. This encourages standardization, with the usual benefits.

BUILDING THE PROJECT MODEL

An integrated scheduling network is constructed from the elements discussed above. The network is created through the following series of steps:

- o make a copy of the block network for each individual block
- o incorporate constraining factors such as erection date into the individual block networks
- o incorporate block parameters which are unique or which depend upon some categorization into the individual block networks
- o introduce the relationships which represent dependencies within the erection schedule
- o add other activities and relations which form portions of the total project network

Each of these steps will be discussed in more detail.

Copies of the typical block network form the bulk of the overall schedule. Making the copies is straightforward with most project management software packages. It is also usually very tedious and time-consuming if more than a few copies need to be made. First, one or a group of block networks are copied. Next, the copied activities are renamed or renumbered so that all activities and relations are uniquely identified. Finally, copies are merged into a larger project network.

Many project management software packages allow definition of "hammocks." A hammock is a group of activities and relations which form a sub-network having single entry (start activity) and exit (complete activity) points.

Hammocks can be incorporated in the project network by establishing a relation to these entry and exit points.

The hammocking feature of the software can sometimes be used for incorporating standard sub-networks (such as the block subnet discussed above) into the project network. In some software packages, however, hammocks are represented by a single activity. In this case, it is not possible to tie a relation to an activity internal to the hammock. More flexible methods of incorporating standard subnets are sometimes required.

The next step in building the project network is to incorporate any necessary constraints into the project network. For example, each block has an erection or grand-block erection date. If the erection schedule has been developed by hand off-line, the erection date is a fixed date. This implies that other activities for that block (e.g., steel assembly, on-block outfitting) should be scheduled to complete in time to support the scheduled erection date. The erection date could then be represented as a milestone date for the block, as the late start of an activity (erect, fit and weldout), or as the late complete date of an activity (erection).

At this point the project file is composed of individual block networks, each of which may have a constraining start or complete date on at least one activity. The next step is to tailor the individual block networks to account for known differences. These differences may be due to individual characteristics of the block, or to characteristics common to a family of blocks. For example, the erection date is different for each block. In the case of individual differences, use values from a table of schedule dates, durations, or offsets.

Characteristics may also vary according to block type. Sets of blocks may be organized into "families" or "groups" based on some common characteristic. As an example, all blocks built in a particular jig may form a family having identical assembly durations. In this

case, one needs a table that identifies which blocks are members of the family, and another table which identifies the assembly duration for that family.

Relations which represent the predecessor-successor dependencies within the erection schedule can now be introduced. If the erection schedule is typically developed by hand, this step may be unnecessary. However, introduction of the computer as a scheduling support tool may provide opportunities for further refinement of schedules. This will be discussed later.

The last step in the process is to merge the completed block network with networks which represent other portions of the project. For example, it may be useful to include landing of major equipment and installation of key components in the overall project network. The installation schedule for propulsion machinery and shafting is directly related to the erection schedule and also to the critical path of the project. Including these relations within the scheduling network insures that they are not ignored when schedule changes are being considered.

SCHEDULING AND RESOURCE SCHEDULING

The network is at this point complete and can be scheduled. For the purposes of this discussion, critical path scheduling will be done using the Precedence Diagramming Method (PDM). Those not familiar with the concepts and techniques discussed are referred to the many excellent texts in the field.

Project start and complete dates, scheduled milestones, and planned activity start and complete dates are the constraints which limit the schedules for other activities. Most current software packages employ a two-pass scheduling approach. During the forward pass, successors of already scheduled activities are in turn scheduled, with the dates stored in the early start and early finish date fields. During the backward pass, predecessors of scheduled activities are themselves scheduled, and the dates stored in the late start and finish date fields.

Each activity then has early and late start dates, and early and late finish dates. Activities cannot be started prior to the early start, or later than the late start without either violating the project network logic, or affecting the overall project schedule. The early and late dates thus define the schedule "window" within which an activity can be worked without affecting the overall project. Each activity has float, which measures how much the activity schedule

can move within the schedule window without affecting the overall project.

If resource and capacity constraints are ignored, the late start and complete dates provide a workable schedule produced by back scheduling. This is similar to the schedule which results from scheduling back from end assembly completion dates down through a bill of materials explosion, taking proper account of durations and lead times.

The typical shipbuilding practice of back scheduling produces a schedule where every activity is on the critical path. This is equivalent to the situation that exists when the early and late start dates are the same -- there is zero float. Assuming durations are accurate, a one day delay in starting an activity will result in a one day delay in every successor activity. Given the unpredictability and frequent delays which exist in a shipyard, a more conservative approach to scheduling is useful.

Taking into account resource and capacity constraints, neither the early or late schedules are optimal. Neither results from any consideration of resource availability or levelling. High labor content and expensive shipyard facilities demand something more. Typically, some resources are critical, and constrain other schedules. Utilization of steel assembly facilities and manpower normally require careful levelling.

Many current project management software packages allow levelling of resources. One of two different algorithms is usually involved. The first is schedule constrained. Activities are progressively scheduled based on some assignment of priority (e.g. amount of remaining float for the activity). When this would result in starting an activity later than its late start date, the date constraint takes precedence and the activity is scheduled to start. This may result in resource utilization in excess of resource availability.

The second method also proceeds by progressively scheduling activities based on priority. Resource requirements are matched against resource availability curves. When a resource required by an activity is unavailable, the activity is delayed until the resource becomes available. Project completion dates will not be met if the start of an activity is delayed past its late start date. Scheduling proceeds staying within the bounds of the resource availability curve at the expense of schedule.

The resource scheduling features of project management software can be used to limit use of critical shipyard resources to within a capacity constraint or planned resource availability. The steel assembly schedule is a prime example. Manpower availability curves can be used to schedule steel assembly to maintain planned levels. If a special jig is to be used, a jig availability curve can be added to the resource file. Steel assembly records for those blocks to be built in the jig have the jig resource requirement added. If there is one jig, and it can hold only one block at a time, the resource file must show that one unit of resource "jig" is available, and the block file must show that one unit of resource jig is required. Pin jig areas can be divided up into a number of unit squares, and the number of unit squares required for the assembly of any given block or block type loaded to the project file. The total amount of available pin jig area can then be used to control the scheduling of assembly work through the area.

Once the critical resources have been scheduled, the resulting schedules should be examined carefully. Project management software is a scheduling aid, not a replacement for good planning. The software facilitates balancing of a large number of schedule and resource constraints, and examination of resulting schedules from a number of perspectives. Resource utilization curves should be examined closely. A sampling of the block schedules should be done to insure accuracy, and that the results make sense.

If problems are identified with the schedules and resource curves that resulted, adjustments can be made by hand to the schedule, and the schedules recalculated. "What-if" games can be played using copies of the network. The result should be a schedule which is logically consistent and which makes good use of key resources.

GENERAL COMMENTS

Existing project management software typically forces the user to work in a bottom-up fashion. Building a project network for a large shipbuilding project becomes a significant clerical effort. One loses sight of the overall project in the process of entering and maintaining 10,000 activity records, with associated predecessor-successor relations and resource requirements.

Building the project schedule should be a mixture of bottom-up and top-down scheduling techniques. Bottom-up scheduling can be employed to develop

those portions of the scheduling network for which a good history is not available, portions for which the available history does not meet current objectives, or portions which are known to be critical to the overall program schedule. Top-down techniques can be used where schedules have already been developed, where good historical information exists, or where the detailed schedule will not effect the overall program schedule.

The network will never completely model reality. The project management team must find the level at which the model is most useful in relation to the effort required to construct and maintain the model. The Group Technology approach outlined above simplifies the problem to one of standard families of assemblies, and instances of the standard. In addition, several strategies exist to make the effort more productive:

- o focus attention on activities which are critical to the overall project, schedules that are drivers of other schedules, and resources that are bottlenecks
- o avoid inclusion of activities for which schedules can be easily derived as offsets from the other schedules, and which are not themselves schedule drivers
- o be relentless in identifying standard durations, sequences, and categories -- look for families of components at all levels in the product hierarchy
- o develop a library of standard subnets
- o keep the project model as simple as possible, avoid unnecessary detail in the network, look for ways to reduce the size and complexity
- o where repeatability or predictability of schedule is low, more conservative scheduling approaches should be used -- longer durations to minimize impact of schedule delays
- o engineering and materials schedules can be frozen after initial development by copying the appropriate dates into the planned start and complete fields, or by keeping a copy of "the baseline" from which to run reports

The job of managing the network can become very unwieldy. If one has only 20 activities for each of 300 steel assemblies or other interim products, one has a network of 6000 activities (20 activities/product x 300 products = 6000 activities), plus the associated relations between activities. For some

packages which run on personal computers, networks of 5,000 or more activities can stretch the limits of available disk storage, and result in very long run times (30 minutes or more) for the scheduling operation. The network should contain only those activities necessary to preserve the schedule relationships and the offsets between activities.

Another method for reducing complexity in scheduling is to choose an appropriate time frame. Most project management software allows scheduling at a daily or even hourly level. But a weekly schedule may be more meaningful because it focuses attention at the proper level of detail. Scheduling by week can be done by setting durations and lag periods as multiples of 5, ignoring holidays, and setting all fixed start dates on Mondays, all fixed completion dates on Fridays.

The scheduling network can also be simplified through reducing the number of relations. If the supervisor in the field will exercise his own discretion in the scheduling of an activity between two milestone dates, then the only relations needed for that activity are those which tie it to the milestones. There is no need to add additional relations to the network to constrain the timing of the activity. Also, if simple finish-to-start relations will establish the desired work sequence, there is no need to establish a complex pattern of start-to-start and finish-to-finish relations and associated lag periods.

The schedules produced using project management software are dynamic. A single small change has the potential of changing the entire project schedule if it lies on the critical path. Once the initial schedule has been developed, it may be desirable to lock in certain schedule dates. Changes to engineering and materials schedules may cause unnecessary disruption and may impact vendors and subcontractors.

Several techniques are available to stabilize portions of the project schedule. The project schedule can be archived, and the archived dates used for scheduling selected activities. Schedule changes which conflict with the archived dates can then be handled on an exception basis. Some software packages allow preservation of the initial dates as baseline dates for each activity. The baseline dates can be used where desired, and reports produced to indicate activities having dates which are in conflict with the baseline dates. A third alternative is to copy the desired dates into the planned start and planned complete fields. When the project is rescheduled, activities whose

dates conflict with these planned dates will be shown as having negative float.

CONCLUSION

This paper outlines a method for developing the Master Product Schedule for a shipbuilding project using PC-based project management software. Currently available software offers functionality, power, and flexibility to PC users. The technique outlined here balances use of top-down and bottom-up scheduling techniques. They are designed to facilitate effective use of Project Management software in the shipbuilding environment.

ACKNOWLEDGEMENTS

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Wired for Disaster: Cableway Improvement Program

No. 9A

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ABSTRACT

Throughout a Ship's lifecycle, as systems are installed, modified, or removed, breaches of the technical requirement for proper installation of electrical and electronic cables occur. The majority of these deviations are a result of insufficient attention to cable installation requirements during ship design or production caused by shortcuts to reduce costs or meet schedules, and overall poor workmanship.

In January 1984 on the USS TATTNALL (DDG-19) a fire originating in a locked compartment spread through electrical cableways. Before being contained, this fire caused loss of life, extensive damage to critical system and prevented the ship from completing her assigned mission. An investigation revealed that the fire started as a result of cableway discrepancies. Further surveys performed on various ships revealed findings which included:

The cableway discrepancies found on the USS TATTNALL (DDG-19) were not isolated, but common to the fleet in great numbers. Fifteen to Twenty percent of all dead-ended cables were found to be still electrically energized.

To develop a systematic and trackable method of removing cableway discrepancies and reduce the risk of fire, Commander Naval Air Force, Atlantic Fleet (COMNAVAIRLANT) tasked American Systems Engineering Corporation (AmSEC) and Naval Sea Systems Command Detachment (NAVSEADET) (PERA CV) to develop a program to assist in correcting cableway discrepancies. The program since displayed great success evidenced by Navy wide attention and expansion of the program to include aircraft carriers under Commander Naval Air Force, Pacific Fleet (COMNAVAIRPAC).

INTRODUCTION

The objective of this paper is to introduce the cableway installation, repair, and removal program currently being implemented on U.S. Navy aircraft carriers. The program, entitled "Carrier Life Enhancing Repairs (CLER) Cableway Improvement Program (CIP)", is a four phased program and was developed considering the following objectives and goals:

- Train and certify shipboard personnel to inspect, install, end repair cables and cableways. Increase shipboard personnel awareness of cableway safety hazards.
- . Remove excess weight, especially on main deck and above.
- . Clear cableway congestion.
- Correct cable and cableway hazards and discrepancies.
- . Train shipboard personnel to perform quality assurance of work accomplished by repair or modernization activities.
- . Document work to be accomplished and completed work in order to effectively track progress of the program.

The four phases of the Program are as follows:

- . Phase one - Ship's Force training and certification program
- . Phase Two - Organizational Level (Ship's Force, correction of cableway discrepancies)
- . Phase Three - Depot Level (Industrial Activity) Correction of cableway discrepancies
- . Phase Four - Documentation and Tracking

The first phase trains and certifies selected shipboard personnel to properly and safely remove and install electrical cable and correct other associated electrical cableway adversities. It is conducted onboard each ship with each student

participating in both "hands-on" activities and formal classroom instruction. In the second phase, shipboard personnel utilize the skills learned in the training phase in the removal of unused cables and correction of associated cable and cableway hazards, prior to the scheduled overhauls or availabilities. The second phase work includes all cable runs up to the major cableways. The third phase accomplished by industrial activities during overhauls or availabilities. In this phase, the discrepancies in the major cableways are removed. The fourth and final phase is the documentation and tracking of completed or new work to be accomplished utilizing compartmentalization diagrams based on the ship's Booklet of General Plans.

A multitude of cableway problems have been detected and corrected as a result of the program. The most common types cableway discrepancies identified for repair include:

- . Exposed or improperly end-sealed dead-ended Cables
- . Improperly spliced cables
- . Exposed conductors in junction boxes, Power panels, fuse panels, and equipment
- . Violated firetight, smoketight and watertight boundaries
- . Overcrowded cableways
- . Overheated cables
- . Missing or improper cable banding
- . Insufficient or improper cable hangers
- . Chafed or cut cables
- . Cables run outside of cableways

PHASE ONE - THE TRAINING AND CERTIFICATION PROGRAM

The first phase implemented in the cableway Improvement Program (CIP) is the training and certification of shipboard personnel to identify and correct discrepancies associated with the ship's electrical and electronic equipment and cableways. The training is composed of a NAVSEA approved formal training course of instruction in modular form, developed from and adhering to the Electric Installation Standard Methods Manual (EPISM) S9300-AW-EDG-010.

Shipboard training involves 40 hours of formal classroom instruction utilizing selected Ship's Force personnel with electrical and electronic backgrounds. Class size is limited to a maximum of 20 students due to the extent of actual hands-on participation of each student in various phases of the instruction. The training program is conducted in 5 segments:

- . Video tapes which introduce the lesson topics
- . Lecturing by instructor with visual aids
- . Practice exercises located in student guides
- . Instructor demonstrations
- . Student "hands-on"

classroom instruction consists of 16 modules as follows:

- . Overview and introduction
- . Special tools and equipment
- . Stuffing tubes
- . Penetration of equipment and connection boxes
- . Multicable penetrators
- . Hangers
- . Banding
- . Chafing rings
- . Cable pulling techniques
- . Dead-ending cables
- . Cable splicing
- . Repairing insulation damage
- . Testing cables
- . Inspection of cables and cableways
- . Blueprint reading
- . Cable Removal Plan of Action

Student participation during the training is enhanced by use of a student guide which contains the 16 modular lessons with additional practice exercise sections. Each module, where applicable, is supplemented by excerpts from the EPISM to heighten student understanding of the subject matter as well as to encourage practical use of the EPISM. In addition, where specific equipment, materials, or tools are addressed, supplements have been inserted giving current noun name, manufacturer, national stock number (NSN), cost, and quantity needed to perform a given task. In the event that specific tools and materials are not available through the Navy stock system, manufacturer's data is provided with the information necessary to procure the required items.

To fully ensure success of the training in Phase One, tools and materials associated with specific modules are also included in the training package. These tools and materials allow instructor classroom demonstrations, and student hands-on practical application of the lessons taught. In some applications, classroom mock-ups are the only means of student training due to inaccessibility of equipment and time constraints imposed by numbers of students and training requirements.

At the conclusion of the training phase, NAVSEA approved certification forms are issued for each student completing the entire course of

instruction. The certification forms are designed to allow partial certification for students not completing the entire 16 module training. The certification forms are in two parts, part one being the certification of having attended the classroom training, part two of the certification form is for successful completion of the "hands-on" practical application portion of the training. Certification forms once completed will be forwarded to NAVSEA Code 07Q with a copy retained onboard the ship to become a permanent entry individual student's service record. Certified shipboard personnel become part of a NAVSEA inspection team under NAVSEAINST 9304.1A "Shipboard Electrical Cable and Cableway Inspection and Reporting Procedures".

PHASE TWO - ORGANIZATION LEVEL (SHIP'S FORCE) CORRECTION OF CABLEWAY DISCREPANCIES

I" the second phase of the program, shipboard personnel take an active and independent role in the correction of cable and cableway deficiencies, and the removal of unused cables. These activities are undertaken in preparation of Phase III which occurs during an industrial ship availability e.g., Complex Overhaul, Selected Restricted Availability (SRA), or Service Extension Program (SLEP).

Ship's Force personnel, use a "Engineered Maintenance Plan (EMP) for systematic Cableway Improvement and correction of ship's cable and cableway discrepancies. The EMP for Cableway Improvement is a major element in a successful shipboard effort. provides all of the program and ship specific information required to successfully implement and track the progress of the program. Specifically, the EMP contains background information, a formal statement of work, technical guidance for execution of the work and charts/diagrams for effective monitoring of program progress.

A comprehensive statement of work defines the work to be accomplished by Ship's Force personnel as cable and cableway discrepancies are discovered. The general approach dictated by the Statement Of Work is as follows:

- Electrically test all unused cables for applied voltage observing standard electrical safety precautions as outlined in OPNAVINST 5100 series.
- Remove banding from alternate hangers to maintain cables in place but facilitate the removal

Of unused cables.

- Open metal and nylon stuffing tubes
- Unpack chafing rings and multi-cable penetrations.
- Remove unused cable in 3 to 4 foot sections to prevent damage to other installed cables.
- Endseal all dead-ended cables not removed.
- Band all cables to installed hangers.
- Replace any missing or damaged cable hangers or cable hanger studs.
- Plug all open metal and nylon stuffing tubes, box connectors, multi-plugs, and multi-transits.
- Pack all firestop chafing rings with type HF sealant and firestop caulk.
- Repair all insulation damage.
- Splice cables if extensively damaged and continued use is required.

The formal statement of work is supplemented by specific technical guidance provided to assist shipboard personnel in a systematic method of discovery and correction of cableway related deficiencies. This technical guidance is first and foremost provided by the formal classroom training received by the shipboard certified inspection and repair team. guidance is provided by NAVSEA \$9300 AW-EDG-010/EPISM; "Electric Plant Installation Standard Methods" and by NAVSEAINST 9304.1A; "Shipboard Electrical Cable and Cableway Inspection and Reporting Procedures". Strict compliance to procedure and documentation coupled with a quality assurance program provides long term improvement to the material condition of electrical cables and cableways.

To facilitate the task of implementing and tracking the program, each aircraft carrier is broken into well defined zones from the Booklet of General Plans. Cable and cableway work is usually concentrated on main deck and above due to the fact that most of the ship's electronic equipment is located in the upper decks. In addition, the most favorable effects on ship stability are generated by topside weight removal. A zone is determined by three means, with the first consideration being major or suitable frames for boundaries. An additional consideration is the actual "umber of compartments within the designated boundaries. The last consideration is that a zone should not contain more compartments/work/area than is reasonable for a three man team to complete the inspection and correction procedures within 30 days. It should be noted here that the inspection and correction team is only dealing with

discrepancies within compartments and areas peripheral to the ship's main cableways. Dead ended cables and related deficiencies which enter into main cableways are tagged and recorded for accomplishment during Phase III.

The inspection procedure utilized by the ship's team is aided by two tools, NAVSEAINST 9304.1A and a NAVSEA generated deficiency report. NAVSEAINST 9304.1A defines cable and cableway deficiencies into three distinct categories:

Immediate Hazard Those items which are, or have the immediate potential to be, personnel safety hazards, electrical fire hazards, or which negate firebreak integrity.

Potential Hazard Those items which require corrective action to ensure continued reliable and safe performance or maintain watertight integrity but are not of immediate danger to personnel or equipment.

Nonhazardous - Those items which are not hazardous to personnel and equipment but are not in compliance with approved standard installation practices.

Fleet Commander funded NAVSEA certified inspection teams, using the criteria es outlined above, conduct initial surveys on selected aircraft carriers. The survey data is then compiled into a computer data base. Deficiencies found are sorted by level and compartment end linked to each respective zone. The correction of these identified deficiencies, es well as a thorough inspection procedure by Ship's Force, will restore the ship's electrical and electronic systems and cableways to a safe condition within the proper installation specifications. In addition, cableway space is made available for new shipboard installations.

A comprehensive tracking system and completion checklist to be utilized by Ship's Force to manage the cable and cableway repair effort is also included in the EMP. These tracking aids are used in conjunction with a detailed breakdown of the ship's zones. Each zone description contains information relating to location and a complete listing, by compartment number, of all compartments located within the zone. Lastly, the NAVSEA deficiency report for each zone is provided.

A removal schedule based primarily upon weight removal is also included for management planning. The actual prioritization of zone work completion is governed by criteria associated with ship alterations and modernization

installations. These priorities are therefore established by either the ship's Maintenance Planner or the ship's Maintenance Manager and Electrical Officer.

PHASE THREE - DEPOT LEVEL (INDUSTRIAL ACTIVITY) CABLEWAY IMPROVEMENT

The third phase of the program is accomplished by industrial activities during a Complex Overhaul (COH), Selected Restricted Availability (SRA), or Service Life Extension Program (SLEP). After Ship's Force purges deficiencies from the peripheral compartments leading to the major cableways, the industrial activity will open the main cableways, remove the unused cable end correct miscellaneous discrepancies. This work is generally funded by NAVSEA (PMS 312) under "eight removal ship alterations (SHIPALTS AVT 0040, CV 3800K, or CVN 3801K) and is normally concurrent with other cableway work being accomplished by other SHIPALTS or modernization programs. The amount of cable (tonnage) removed is then reported to the ship's planning yard to allow for weight and moment computation. The industrial activity accomplishing the work is then responsible for restoring the cableways in accordance with the guidelines set forth in the Electric Plant Installation Standard Methods Manual (EPISM).

During Phase Three, NAVSEA certified shipboard personnel and Supervisors of Shipbuilding (SUPSHIPS) personnel perform the quality assurance functions for this work. Shipboard personnel must inspect all opened cableways to be certain that all electrical cableway deficiencies are corrected prior to rebanding. In particular, attention is given to the following es quality checks:

- All dead-ended cables are removed or properly end sealed where they exit the established work zone.
- Unused stuffing tubes are properly blanked.
- Chafing rings are packed with high temperature sealant (Type HF).
- channel rubber is used around transmission, coaxial, or robber jacketed cables prior to bending.
- Cableways are arranged, "here possible, with the larger cables in the center.
- Open multicable transits are properly blanked.
- Newly installed chafing rings allow for an additional fifty percent growth for new cable installation.
- At least every fourth horizontal

hanger and every vertical hanger is banded.

- . Any damaged cable is either replaced or properly spliced.

The supervisors of shipbuilding (SUPSHIPS) are also required to perform certain quality assurance functions as follows:

- . Periodically audit contractor practices and conduct onboard inspections to ensure compliance with NAVSEAINST 9304.1A.
- . Establish a formal quality assurance program to ensure that the work done by private sector facilities conforms to the EPISM, NAVSEA S9300-AW-EDG-010.
- . Conduct a final cableway inspection in the areas affected by the work package prior to final ship acceptance and/or end of repair availability.

These two activities, Ship's Force and SUPSHIPS, working as separate and independent entities have assured a successful quality assurance inspection program for all aircraft carriers during a depot level availability.

PHASE FOUR - PROGRAM DOCUMENTATION AND TRACKING

Phase Four, the final phase of the program, entails the documentation and tracking of completed or new work. The tracking system consists of three distinct elements as follows:

- . Color coded Booklet of General Plans.
- . Tracking Matrix/Completion Check List
- . Automated Work Requests (AWR's)/ Ship's Maintenance Action Forms (2-KILO)

Copies of the Booklet of General Plans are color coded to track work completed in each zone. They aid cableway inspection teams to quickly identify compartments and zones where outstanding work remains to be accomplished. The tracking matrix/ completion check list used to record work already accomplished, or work yet to be completed is included in the Engineered Maintenance Plan (EMP) and serves the following functions:

- . Determines if the work was accomplished in accordance with the EMP
- . Provides a means of documenting and updating of work accomplished on the plan
- . Provides a means of feedback to monitor the effectiveness of the work prescribed in the EMP in order to make adjustments to the plan if required.

Upon completion of the removal/ repair work, the accomplishing activity conducts a final inspection in the applicable zones. The inspection serves to document the completed removal/repair work and complete the Pre-prepared Ship's Maintenance Action Form or Automated Work Request (AWR), utilizing the ship's SNAP computer system, indicating the number of feet of cable removed from the applicable zone. The size or type of cable is not identified, as NAVSEA engineers have developed a formula for computing approximate weight removed. This formula is based on the average size cable known to be installed in aircraft carriers in corresponding areas.

RESULTS

NAVSEADET (PERA CV), as Cableway Improvement Program manager for COMNAVAILANT, COMNAVIRPAC, and NAVSEA (PMS 312) is successfully providing designated shipboard personnel the training, tools and materials required to implement NAVSEAINST 9304.1A "Shipboard Electrical Cable and Cableway Inspection and Reporting Procedures". Since ninety percent of all cableways on aircraft carriers contain unused cables, removal of these cables by Ship's Force make it more cost effective to install new cables without having to construct new cableways. Cable weight removal costs are approximately eight to ten thousand dollars per ton, or about half the normal fifteen to thirty thousand dollars per ton for other weight removal items. The Carrier Life Enhancing Repairs (CLER) Cableway Improvement Program has integrated Type Commander repairs and NAVSEA (PMS 312) "Weight and Moment Compensation" SHIPALTS to accomplish the removal of these cables.

To date, certification training has been completed on fifty percent of the Navy's aircraft carriers and Cableway Engineered Maintenance Plans have been developed and implemented on about twenty percent of the carriers. The remaining carriers are scheduled to commence the implementation of the program in the near future.

In addition, students who attended the cable and cableway training course of instruction have returned to their respective work centers with useful knowledge for future application. In passing the training received to their peers, a higher degree of professionalism is realized by the ship and the Navy. Work center supervisors, division officers, and other ship's officers attest to the quality of workmanship generated by Ship's Force personnel having participated in the Cableway Improvement Program.



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Affordable Technologies for Small Shipyards No. 9B

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ABSTRACT

This paper attempts to recast some large shipyard production technologies in light of the needs of small yards. The importance of small shipyards to the nation's marine economy is addressed and three methods are offered as affordable ways of increasing yard productivity. These are operations management, numerical lofting, and zone outfitting. The paper concludes with a call for increased attention to the problems of small yards.

INTRODUCTION

As others have before, we will begin by taking a brief look at history in order to set the scene for this discussion. The history of modern shipbuilding has been well covered by many sources such as Ref. (1). However, past discussions have been directed at large yards building commercial or naval vessels. Lets look briefly at smaller yards.

Throughout America's history, the principal requirement for a shipyard has been a site along a river or harbor front and some skilled labor. For example the Story yard, set on the banks of the Essex river in Massachusetts, consisted of a sloping open area for the ways and some small outbuildings. This yard successfully built many Grand Banks schooners using the proven method laying a keel, installing sawn frames, and then planking. With the hull finished, work shifted to installing the deck structure and then final interior outfitting. Launching was a grand occasion for the yard workers and their families.

Bring the date up to 1988, substitute steel and welding for wood and nails, and you have a typical small yard (Fig. 1). The vessels have changed but the basic procedure of building them has not. Quite a contrast with large yard where more productive methods have been brought into play.

The current shipbuilding industry is a troubled one. Large yards nationwide are seeing a dearth of new construction in commercial vessels and the result has been the closing of yards such as General Dynamics in Quincy, Massachusetts, and Lockheed in Seattle, Washington. The slump that occurred in the mid-80's also affected many small yards since several segments of the workboat market were depressed concurrently. We are seeing some recovery in the offshore oil industry and fishing vessel work is strong in the Northwest. What does this mean for the marine industry? Small yards form a significant portion of U.S. shipbuilding and repair activity. Their pool of trained labor and consumption of marine equipment is vital to large vessel activity, both commercial and naval. If small yards can adopt improved shipbuilding methods then the entire marine community will benefit.

Before proceeding further, let's define some terms:

Small Yard

A small business can qualify for special federal considerations if it employs under 500 people. For the purpose of this paper a small yard is one that has less than 250 employees and has gross sales of under \$20M per year.

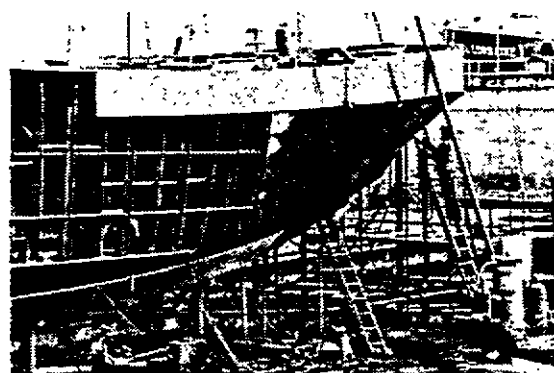


Figure 1
Construction of a Tractor Tug

Technology

Webster's Dictionary defines technology as "The Science or study Of the practical or industrial arts". we will narrow that vista to focus on new methods, not materials or equipment.

New construction

For the size of yards being discussed the vessel types usually encountered consist of workboats, passenger vessels, barges and fishing vessels, all of simple construction and non-exotic materials. Three hundred feet length overall is a practical upper bound.

Repair

small yards can often handle a wide range of vessel types for repair being limited typically by drydock size and/or available pier length. Repairs consist of annual maintenance, conversions, or damage repairs. Repair work is typically differentiated from new construction by less steel work and adapting to existing geometry and equipment.

In this paper we propose to present several examples of modern technology that can improve small yard productivity at an affordable cost. The ideas discussed below are familiar to readers of ship production journals so we ask for patience as we direct our remarks to small yard operators. We do not claim that these ideas are the only ones that small yards can implement. to improve their productivity. on the contrary, the Authors hope that this paper will engender a discussion on how small yards can work smarter and help the marine industry.

To be applicable to small yards any new technology must be flexible in its implementation and modest in cost. A small firm cannot afford to throw all procedures into the dustbin of history so implementation should be piecemeal. The methods involved in modern new ship production require extensive planning, a traditional weakness of small yards, so their use will involve some pains as the yards change methods but those pains need not be crippling. We feel that the following ideas are a place for small shipyards to start.

OPERATIONS MANAGEMENT

We will not presume to suggest that every small operation needs a management overhaul, but due to the competitive nature of the marine industry today we hope that all yards will actively seek a competitive advantage. The idea of a competitive advantage will be the cornerstone of this discussion.

To maintain competitive pricing each yard must be able to collect and analyze production cost data. This information is then translated into future cost estimates. Large yards have departments of estimators, planners, and accountants collecting and reviewing project data. Estimators provide a baseline for project cost control. planners schedule engineering, purchasing, and production to optimize available labor, materials, and facilities. Accountants compile the project costs which provide the information for project evaluation. small yards usually have only a limited estimating staff which results in a broad brush approach to estimating. General factors and ratios which have proven competitive are used to bid jobs. This approach carries a low degree of confidence when the time comes to trim prices. The problem of cost control arises after the project has begun with attention focusing only on completion with little or no control over resource allocation or material costs. Below we will discuss creating a standard production framework, project scheduling, and methods of project evaluation in order to gain greater control of project management.

standard production Framework

A standard production framework defines common blocks within departments or crafts. Each yard has a unique framework based on historical construction methods, breaking vessel construction into manageable sections. A simple framework would consist of the bow, midbody, stern, and superstructure. These four areas would then form the subtotals of a project cost estimate, the main blocks for planning, and the categories for cost control. Even though these areas differ from vessel to vessel, the required work remains relatively common. For example, a bow shape may change but the process of working the complex shapes is common to most self propelled vessels. This approach may appear much too broad to provide any significant information but experience proves otherwise. A figure for feet of weld per hour can not be calculated using this method, but steelwork labor hours per pound can be produced. AS information is collected for each block the blocks can be broken into smaller assemblies as further definition is encouraged by top management. Once again, the goal of the framework is to provide common construction blocks for production evaluation and estimating future job costs.

P r o j e c t

Project scheduling is accomplished using various methods. The most common scheduling tool has been the Gantt or

bar chart. The format is simple and the information is relatively easy to understand. Until the late 1950's this was the main tool of the project manager, but as projects became more complex the ability to determine interdependencies between activities became a necessity. Interdependencies are the order in which tasks must be performed, for example, completing the welding in areas before they are painted. Understanding the need to define interdependencies led to the realization that scheduling should be a dynamic process. This may be the greatest hurdle to overcome in understanding the benefits of project scheduling. A realistic schedule can not be compiled at the start of a project with the intent that nothing will change. This dooms the schedule to failure.

Two methods were developed to assist in managing these dynamic relationships: project evaluation and review technique (PERT) and the critical path method (CPM). The critical path method is used most often in construction where the tasks can be defined with a fair degree of accuracy. PERT was developed for use in designing the polaris submarine weapon system, where many task durations were highly speculative, lacking prior estimating data. Although the two methods were developed independently, they share many of the same principles. The major difference is that PERT uses probability analysis to help determine task durations and the confidence level for timely project completion. By developing a standard

framework to use as a template when estimating job costs and planning pre-project strategies, the information required to create a logical network will be available without starting over with each project. CPM is used to create a logical link between the tasks and milestones required to complete the project. Tasks are defined as items of work that require a" estimated duration of time to complete, where milestones are major events which are a result of the completion of a task or a group of tasks. The critical path is determined by the sequence of tasks which have the longest aggregate duration as shown in Fig. 2. By joining those tasks into a network the impact of a delay in the completion of any task can be observed while time exists to plan alternative action, such as double shifts, extra personnel, or shipping needed materials by air.

The dynamic nature of scheduling has traditionally required large computing capacity either through large numbers of people or expensive computer equipment to calculate the impacts of progress on the schedule. Mathematical equations are used to produce the float time and optimum completion dates for the schedule. With the increasing power of microcomputers, at a cost that even small yards can afford, the potential for effective scheduling is finally available to small yards. Several software packages exist that can handle project scheduling if the project steps are completely defined. Computer magazines can be a good source of infor-

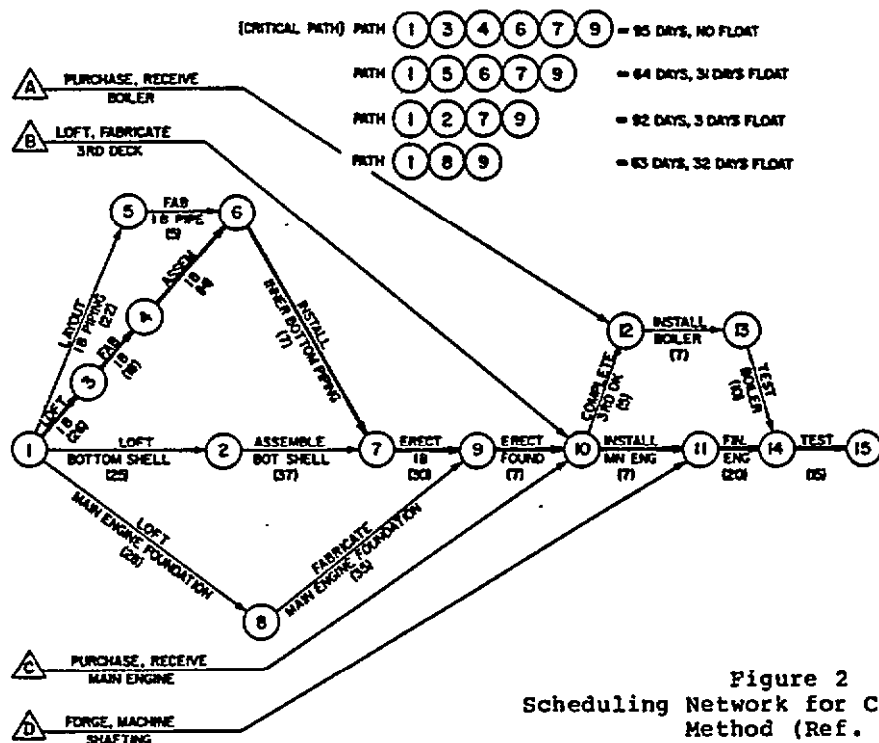


Figure 2
Scheduling Network for Critical Path Method (Ref. 3)

mation an software choices (Ref. 2).

Regardless of whether a computer is used, the key to effective scheduling is understanding how to define realistic project tasks with durations that will utilize the available labor most efficiently and recognizing the task interdependencies. A common question is: If we think out the project completely, why bother with a schedule? Such a question depicts the lack of understanding of interdependencies between departments, activities, material flows and other forces that are too complex to remain static over the duration of a project.

Material flows are often overlooked as a restraint on production. Manufacturing industries have out paced ship construction in their recognition of material flow problems. Materials must be available to the workers when needed. This requires material requirements to be defined long enough in advance to allow purchasing to arrange for delivery without paying a premium. By including purchasing of major materials and equipment in the schedule, fewer hours will be spent waiting for delivery.

Project Evaluation Methods

Project evaluation is most often done by subtracting the total costs at the end of of project from the contract price and hoping the resulting difference is a profit and not a loss. Creating a framework, as we discussed earlier, to provide a baseline for controlling project costs is a necessity to guide project management decisions during the course of job. To effectively monitor costs and maximize profits a method of progress analysis must be implemented. Without a framework of comparative estimated or historical costs and an effective scheduling procedure, defining standards for project evaluation becomes difficult if not impossible. To ensure the ability to gauge the project status, a baseline must be developed to compare estimated costs to actual costs. This is the only way to determine cost trends while action can still be taken to alter poor progress. Once again, the advancement of microcomputer technology offers a cost effective way to manage the cost control data. A serious problem in creating a computerized cost control system is that most software dictates that a yard follow certain standard accounting principles or only addresses basic bookkeeping functions. This may help with payroll but it will not establish a useful database for future bidding and project evaluation. custom software should be considered especially by a small yard that is concerned about maintaining their procedures and will not benefit by adhering to a generic

accounting package. Modern programming environments have taken some of the horror out of setting up a custom control system. The initial cost of custom software may be slightly more but the training time and general confusion caused by new systems will be far less. These systems should be set up to support, not to inhibit, effective production.

Implementation of a standard framework, scheduling methods, and project cost controls are difficult for most companies due to the general lack of operational goals and methods.. Large yards who deal mainly with the U.S. Government are required to adhere to certain procedures. Even though this produces mixed results it does Set some guidelines to aid in establishing Systems. The commercial customers with whom most Small yards participate care mostly about price. Effective scheduling and estimating offer a way to reduce costs by providing continuous feedback on progress and problems.

NUMERICAL LOFTING AND NC CUTTING

Surely one of the most critical aspects of vessel construction is the determination of the hull shape in full scale and the lofting of individual pieces for construction. Ref. 3 defines lofting as: "The process of developing the Size and Shape of components of the ship from the designed lines; traditionally, making templates using full scale lines laid down on the floor of the mold loft; today, largely performed at small scale using photographic or computer methods.* The fairness of the hull form and the accuracy of the cut parts have a direct impact on the time required for construction. Any means then to expediate this process or, more importantly, to increase the accuracy, results in decreased construction costs.

The advantages of traditional methods of lofting are few while the disadvantages are numerous. The primary reasons for continuing to practice full scale lofting are:

- Small capital investment required to layout a hull full scale.
- Lack of knowledge of more modern methods.
- Reluctance to deviate from proven methods.

The disadvantages of full scale lofting that are offset by more modern methods include:

- Large amount of space required to develop a hull form in full scale (Fig. 3).
- Large amount of space required to store part templates after

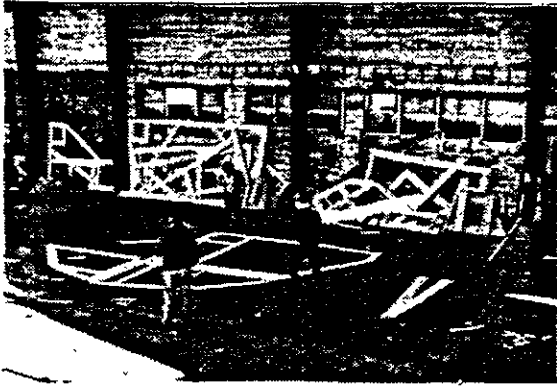


Figure 3
Traditional Layout of Tugboat Bulkhead

- 1 construction of first hull.
- 1 Time necessary to effect changes to hull form or parts once lines are down and vessel is lofted.
- 1 Eradication of old lines upon lofting of a new vessel.

In the late '50's and early '60's, various shipyards began to experiment with numerically controlled (NC) burning machines to cut steel plate. These machines had the potential to increase the accuracy of cut steel parts and decrease the manhours required to cut those parts. In those early times, coordinates defining the shape of a part were entered at the keyboard by hand utilizing offsets obtained from the loft floor. Currently, prices of NC burning equipment have put them within the reach of even small shipyards (Fig. 4).

With the advent of the NC burner came the ability to use scaled down versions of the hull lines. No longer was it necessary to use full scale lines to obtain part geometry and 1/10th scale lofting using manual methods became popular. It was then a simple matter to mechanically measure and record coordinates from 1/10th scale part templates and eliminate the keyboard entry of coordinates and NC code.

Computer aided lofting was an obvious outcome of automation of manufacturing systems. As numerically controlled manufacturing systems were developing, computers were also developing and it was only a matter of time until the two were linked, eliminating the traditional mold loft floor as the source of all vessel geometry information. Computer lofting has many advantages over full scale lofting. Storage of the hull form and part templates is a major consideration. No longer is it necessary to have large space allocations for template storage. Computer generated hull lines are also easier to modify to meet new requirements, or to effect hydrodynamic changes after test-

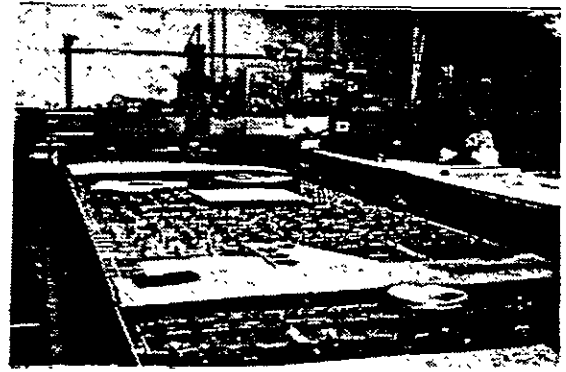


Figure 4
Typical Small Yard Burning Table
Courtesy MARCO

ing. There is no longer a necessity to remove an existing loft floor. The magnetic data base is easy to store and to duplicate, thereby reducing insurance risks.

Computer lofting can be broken into two major categories:

Hull definition and fairing

There are a number of hull definition programs currently available, both in the public domain and through private parties.

* Sophisticated systems

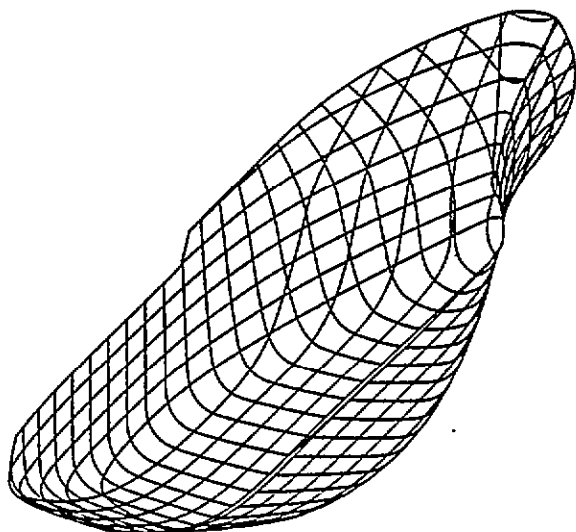
They are less labor intensive, demanding less input from the operator. They have the ability to automatically generate structure and shapes. They typically support design and analysis packages such as vessel hydrostatics calculations.

* Public Domain Software

The software available as public domain software can be a very cost effective means to do computer lofting. Typically, the programs demand powerful computer systems to run, thus requiring time sharing computer services or hiring a consultant. These programs can be very time consuming and labor intensive to use if compliance with an existing hull form is a necessity. Many of these programs also require manual integration with other design and analysis programs.

* Inexpensive fairing programs

These can be an excellent value if used to generate a hull from the preliminary design stage (Fig. 5). They are usually limited as to the



195' MOTOR VESSEL

Figure 5
Micro-Computer Lines Generation

complexity of hull forms that they can handle and therefore have limited application. They also require manual integration with other programs.

The proliferation of programs for micro-computers means that there is now software for generating developable surfaces and creation of foil shapes using standard NACA sections. True three dimensional shape manipulation is expected in the near future.

Part definition

Parts definition involves extracting shape information from the computer hull shape to define decks, frames, bulkheads, etc. These structural areas are then further broken down into individual parts. Where necessary the parts are developed into flat shapes and detailed with lightening holes, construction reference lines and piece numbers (Fig. 6). Once the part geometry is completely defined the manufacturing considerations of tool path and kerf can be added, resulting in a piece ready for nesting and NC cutting;

An advantage to parts definition by computer is the ability to check the accuracy of the parts and completeness of the structure before parts are actually cut. Because the pieces are assembled first on the computer, they can be checked for fit before they become parts. The greater accuracy leads to easier construction with less rework. The overall result is a less expensive, higher quality product.

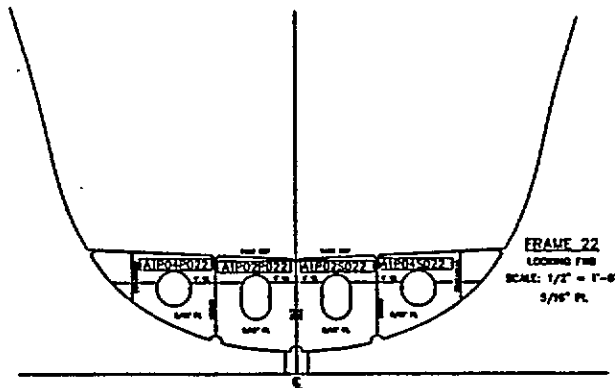


Figure 6
Computer Lofted Frame

The computer also gives the ability to track weight of materials, allowing analysis of module weights, increasing estimating accuracy, and giving greater control of costs.

More planning is required with computer lofting since each piece must be determined in advance. Thought must be given to a numbering system to identify parts as they arrive from the steel yard and their storage must be organized to ensure that the parts can be located when needed. If Zone construction is used in conjunction with NC cutting then the build strategy can be used as an organizational framework.

In its simplest form, computer lofting is accomplished in the same way as manual lofting. The same techniques and methods used by traditional loftsmen can be practiced on the computer. From development of shell plate to expansion of a cambered deck. The greatest power of computer lofting lies, however, in its ability to integrate a number of shipyard disciplines from structural design to steel fabrication to materials handling. The people producing the computer information must work effectively with the steel shop to create a producible design. Coordination is imperative for this technology to succeed.

ZONE OUTFITTING

The National Ship Research Program has identified several levels of shipbuilding technology (Ref. 4). The first is the traditional method described in the introduction above. The second is

Pre-outfitting, where blocks of the vessel are outfitted independently before final assembly but, the outfitting process is still developed from traditional functional detail design drawings. The third level is zone outfitting where vessel construction involves rethinking the building process as a series of interim products oriented around location in the vessel end/or skills required to produce the product. It is this level that we suggest small yards should be aiming for.

For most small yards, some steps towards zone outfitting can be found. A typical example is the separate construction of an aluminum deckhouse which is then attached to the hull (Fig. 7). The key is that aluminum work requires different skills than steel fabrication since the deckhouse is geographically distinct, the separate fabrication is logical. The deckhouse is treated as a separate interim product and could easily be produced by a subcontractor entirely removed from the yard. This interim product is small enough to be built in a covered shed and lifted by cranes.

Structural elements are traditionally the first area where zone construction logic occurs. Unfortunately, the zone logic proceeds no further. Small yards will assemble structural blocks into the hull and only then begin outfitting, yet outfitting productivity benefits tremendously from a zone approach. Why not outfit the deckhouse, its requirement for carpentry, extensive electrical work and ventilation, before lifting it into place on the hull? Physical obstacles such as limited crane capacity can be overcome; it is the mental shift to a new way of approaching vessel construction that is the real obstacle. Properly applied, the concept of zone outfit must pervade the entire process of constructing a vessel.

The usual construction process cannot accommodate this thinking. Let us outline the "normal" process:

- 1) Bid on a contract design - Few small yards have in-house design teams so they must bid on vessel work, either new construction or modifications, that have been designed by either the vessel owner or a third-party. Seldom is that contract design oriented around an explicit construction strategy.
- 2) Negotiate Contract with Owner - After a successful bid opening the yard will usually settle details of progress payments, schedule, and the design. At this stage, a yard may or may not propose some design or



Figure 7
Deckhouse for an 85 ft. Fireboat

equipment changes to improve productivity or material delivery.

- 3) Prepare Working Drawings by System - Usually the yard will prepare some working drawings to route systems and provide material takeoff. Some times this stage is omitted entirely on small vessels in the belief that additional engineering is an unnecessary extra cost. Where drawings are done they are grouped by function i.e., bilge and ballast system arrangement and details.
- 4) order Materials - During the bid phase the yard estimator will usually contact vendors of specified equipment for price quotes. Following a contract signing, orders will be placed for long lead items while the working drawings are being prepared. Short lead items will be ordered from a materials take off on the working drawings.
- 5) Phase Progress Payments - The yard will expect partial payment upon achieving construction milestones. A typical schedule might be as follows:

signing contract	20%
laying keel	10%
hull completion	10%
installing main engines	10%
installing deckhouse	10%
launch	10%
engine startup	10%
sea trials	10%
delivery	10%

This type of payment schedule is wrapped around level 1 construction and might result in a builder installing the main engines when the hull is only partially complete in order to get a payment.
- 6) Brace for omissions, Changes, and Delays - Since outfit is accomplished system by system, a competition for territory ensues, with resulting in-

interference end consequent rework. Should materials ordering have overlooked a part, the omission will not be discovered until the system is near completion, bringing a scramble to correct the situation.

The above narrative is not intended to imply that small yards turn out shoddy goods. On the contrary, small U.S. shipyards can perform the highest quality work in the world with exquisite craftsmanship. We contend that zone outfitting can maintain or improve quality while increasing productivity. The new approach would be as follows:

- 1) Negotiate Build Strategy into Contract - Since the build strategy is the foundation upon which productivity is based, it should become an integral part of the contract negotiations. By being up front about construction approach the yard end owner can agree to schedules, drawing reviews, end materials approval formats. The yard can push for minor changes in the design documents that will enhance producibility at no cost in quality.
- 2) Design end Schedule by Zone - using the contract drawings end the build strategy the vessel is divided up into a sequence of smaller pieces that can be treated as interim products. A logical assembly sequence is then used to create a detailed schedule, integrating materials ordering, drawing production, end fabrication milestones.
- 3) Phase progress payments to detailed schedule - As part of the contract negotiations, the payments can be tied to project milestones that are based upon a logical build strategy. The detailed schedule shows when money is needed for materials purchases end manpower. The vessel owner can accurately track yard progress, giving assurance that payments are being properly applied, while the yard can structure a more even cash flow.
- 4) Brace for Material Delays - Vendor supplied equipment can still be delayed, regardless of approach. but zone outfitting results in more accurate materials lists, end omissions or delays are caught sooner. By breaking the project into smaller separate pieces, the critical path becomes clearly defined and scheduling impacts can be accurately determined when material delays are encountered.

The benefits of zone outfitting have been alluded to above but deserve repeating. By breaking the project into

smaller units the work can be performed indoors with good lighting end ready hoist assistance. The work can be positioned to maximize downhand work end staging is minimized. Safety is improved which has insurance benefits end improves morale. Less rework is required which saves time end dollars. Additional engineering is required, as much as double, but added engineering cost is more than offset by decreased labor cost resulting in improved productivity (Ref. 5).

So much for generalization. We will now present some portions of zone outfitting that are applicable to small yards end the vessels they encounter. The three portions are on-unit assembly, on-block assembly, and standards.

Cm-unit assembly

We will define a unit as a collection of piping, equipment, wiring, end assorted structure grouped by common geography end/or function. One example would be to group bilge/ballast/fire pumps together with their associated manifolds, strainers, end motor controllers. Structural elements can function as pipe hangers or grating supports while also providing sufficient rigidity to allow the unit to be moved.

Design of such a unit must account for access during assembly, weight end attachment points for lifting, end access for installation on-board. All wiring end most painting should be completed before the unit leaves the assembly area.

The similarity between units end purchased pieces of equipment should be stressed. A steering gear hydraulic set, bathroom module (Fig. 8), or a generator can all be viewed as units for zone outfitting. In fact a yard may choose to treat custom units like purchased vendor equipment end have a subcontractor assemble them.

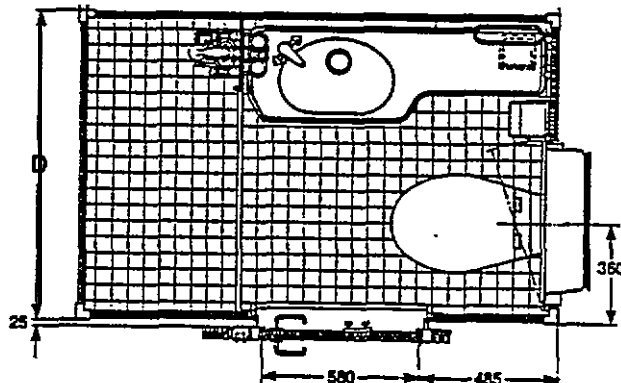


Figure 8
Modular Bathroom Assembly

On-block Assembly

A block is a major subdivision of the project consisting of structure and associated outfit. The block size is chosen on crane capacity and/or assembly logic. A typical example would be a lazarette section of a tug complete with steering gear hydraulics, motor controllers, rudder tube, lighting, and bilge piping. By careful selection of the erection seam, this block might be constructed separately without interfering with the shafting. Fig. 9 shows some partial outfitting of a block where large firemain piping is installed in the overhead of an fireboat engineroom before turning the block over.

Problems with block interconnections have been discussed in Ref. 6 but a few words appropriate to small yards are warranted. Many vendors offer fittings that are suitable to final connection of blocks, allowing for flexible joints or misalignment. The use of poured-resin chocks provides alignment margins for final machinery set-up. Judicious use of junction boxes or splices permit wiring to be installed in the blocks, reducing the time consuming job of cable pulling.

Standards

As stated in Ref. 7, 'A standard is an agreed upon published description of an item and/or procedure defining characteristics between specified tolerances. It normally represents a tried and approved method of doing something ... Widely used overseas, shipyard standards are a neglected productivity tool in small yards. Some yards have adopted steel and pipe fabrication standards for details but the use should be expanded to include outfit details and preferred vendor items. As mentioned in Ref. 6, a large yard could have over 4,000 standards. Their use benefits all departments of a shipyard from purchasing to design to the shop floor. using

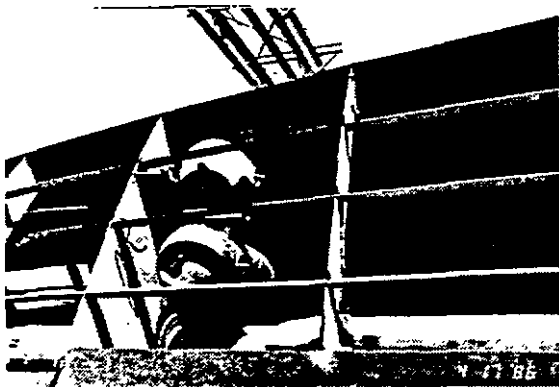


Figure 9
Partial Pre-outfitting

standards, like those shown in Figs. 10 11, provides for instant recognition of hours, cost, and connection sizes.

Standards should be seen as a quality tool, not just as a means of saving some dollars. In fact, the standards themselves have to represent good quality if they are to receive ready acceptance from the vessel owner and classification agencies. When a yard proposes a line of pumps that they have chosen as their standard, it must be presented as a savings in design and planning and not as a lower cost or cheaper type, even if it is. Adoption of existing standards such as ANSI, Mil-spec or MARAD is encouraged. Such standards present acceptable levels of quality that provide assurance to owner and yard alike.

Zone Outfitting, or Level 3 technology can be adopted by small yards profitably if the experience of larger firms is any guide (Ref. 8). The thoughts sketched above are a few, and not necessarily the best, ideas on the application of zone outfitting logic.

CONCLUSIONS & RECOMMENDATIONS

The U.S. marine industry has declined steadily in number of vessels, total tonnage of vessels, number of shipyards and labor force ever since the Second World War. The early part of this decade has been particularly tough on vessel types constructed by smaller yards. However, the march of progress has produced methods by which both small and large yards can improve their productivity and accuracy. The ideas presented in this paper have been selected by the Authors as ones that small yards might implement at modest cost. The expected benefits are summarized as follows:

- 1) Less labor hours expended.
- 2) An accelerated construction schedule
- 3) Safer working conditions
- 4) A more accurate, higher quality product.

Modest dollar cost has been emphasized throughout. Small yards cannot afford heavy capital investments in crane capacity, automated welding equipment, or expensive mainframe computer systems. All change however brings some cost; adopting the ideas in this paper will be no different. The cost will be in changing thought processes and work habits which means changing people. By judicious subcontracting of work, cross-training of staff, and introduction of the micro-computer as a tool, the small

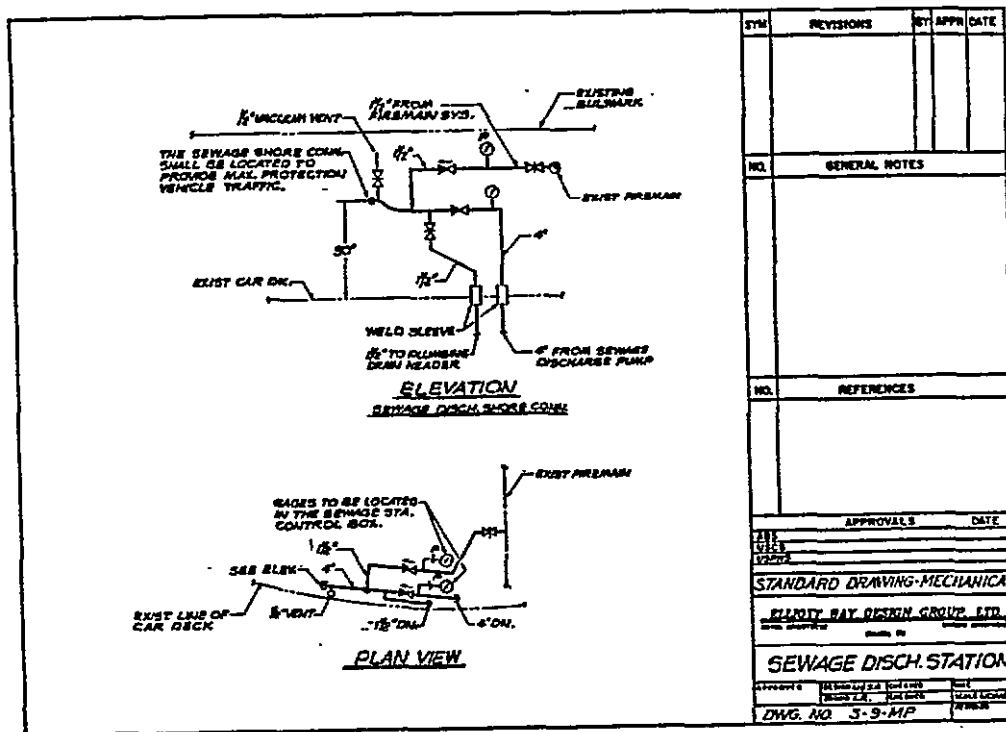


Figure 10
Standard Piping Detail Drawing

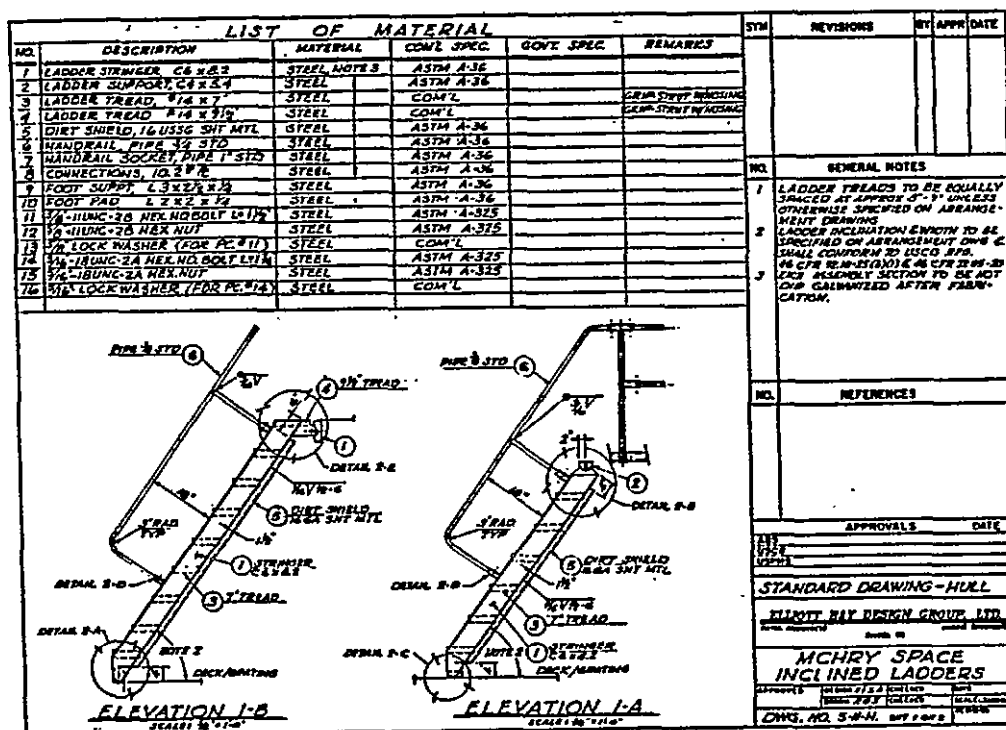


Figure 11
Standard Outfit Detail Drawing

yard can convince its staff that new ideas don't threaten the traditional skills of the shipbuilder, they build upon them.

As this paper was being researched, the lack of information on or for small yards became very evident. Published information on ship production has focussed on large yards, first on those performing new construction, and, as that dried up, on those overhauling naval vessels. It is time to address the special needs of small yards. The fact that small yards are a vital segment of shipbuilding is one that bears repeating, yet no one seems to have a clear vision of their abilities.

With that in mind, the Authors propose that a technological survey of small yards be undertaken with a scope similar to Ref. 9. Such a survey will reveal much about the ability of small yards to support the needs of the U.S. marine industry and ensure that old skills are polished by contact with new methods.

ACKNOWLEDGEMENTS

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Thermal Reclamation of Used Blast Grit

No. 10A

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ABSTRACT

Naval shipyards and other domestic port facilities generate thousands of tons of used blast grit annually and dispose of it in landfills. Also, there are thousands of steel bridges in the United States that are on a repaint maintenance schedule that requires grit blasting for surface preparation; this used grit also goes to landfills. However, for environmental reasons it is becoming prohibitively expensive to landfill used blast grit containing paint residues. The Institute of Gas Technology (IGT) has conducted test work to develop a process to clean blast grit to enable its recycling for reuse.

Essentially, IGT applied a transfer/adaptation of fluidized-bed calcination developed for the reclamation of foundry sand. This sloped grid fluidized-bed calciner affords processing advantages that include

pneumatic size classification of the reclaimed grit. In addition, the sloped grid reclaimer design facilitates ready removal of any tramp material feed or fusible lumps formed.

Four reclaimer feasibility tests were conducted with used blast grit from the Long Beach Naval Shipyard. The results of these tests revealed that the organic material component of the used grit was fully oxidized to carbon dioxide and water. Some of the metallic oxides of copper, zinc, titanium, and lead from the used grit were largely elutriated into a cyclonic-collector. The calcined (reclaimable) fraction from this test work amounted to approximately 95% of the used grit charged. The major oxide and organic component analyses conducted revealed no significant general chemical difference between the virgin and reclaimed grit. Based on these results, a commercial plant can be designed to provide a reusable grit yield in excess of 80% within the general size specifications.

SUMMARY

The U.S. Naval Shipyards produce about 100,000 tons of used blast grit annually and dispose of it in land-

In the near future it will become increasingly prohibitive - both environmentally and economically - to landfill used blast grit, which contains paint residue. Therefore, it is desirable for the Navy to develop a simple method to clean and recycle used blast grit.

The Institute of Gas Technology (IGT) has developed a fluidized-bed sand calciner for which this application seems suited. The calciner has a patented sloped grid (SG) design that enhances combustion of paint residues and promotes separation of reusable material from the used blast grit. This sloped grid design also facilitates the automatic removal of some tramp material from the calciner without interrupting the operation.

Preliminary calcination tests were conducted by IGT, at its own expense, with used blast grit from the Long Beach Naval Shipyard. These tests show that the paint's organic binders can be destroyed thermally, and most of the paint's inorganic oxide components, together with off-specification fine grit, can be removed selectively from the reclaimed grit. The data also indicate that about 80% of the used blast grit can be recovered at size and hardness specifications for new blast grit.

Therefore, the application of IGT's fluidized-bed calcining technology can reduce the quantity of new blast grit purchased and used grit disposal by approximately 80%. If the reported costs for the Long Beach Naval Shipyard are typical - \$100 per ton for new blast grit and \$150 per ton for used grit disposal - then the potential savings to the Navy are several millions of dollars per year.

INTRODUCTION

The U.S. Naval Shipyards generate about 100,000 tons per year of used blast grit from surface preparation of docks while being serviced in dry

The blast grit purchased can be slag from coal-fired power plants, copper smelters, or nickel smelters. During blast cleaning of ship hulls, the grit becomes contaminated with organic binders and zinc, titanium, copper, and tin compounds commonly found in marine paints. Currently the used blast grit is land filled, and in some states it is classified as a hazardous waste. As the availability of landfills diminishes the disposal costs for used blast grit will become

prohibitive. Therefore, it is desirable to develop an economical process to reclaim blast grit.

BACKGROUND

The Problem

The steel hulls of all U.S. naval vessels are provided with a protective coating to minimize damage from the harsh marine environment. These coatings provide corrosion protection and minimize fouling by marine life, in addition to providing a camouflage. These marine coatings consist of a binder and pigments. The binder is an organic film-forming liquid that converts to a continuous solid film upon drying after application. The pigments are finely dispersed solids that impart color, opacity, and corrosion inhibition. The pigments are oxides of metals such as zinc, titanium, copper, lead, etc. The coating also contains biocidal chemicals such as tri-butyl tin oxide (TBT) to minimize fouling by the growth of marine organisms.

The effectiveness of the protective coating on the naval vessels is significantly reduced in 2 to 3 years, after which a new coating is necessary. Before the application of a new coating, the vessel's hull has to be completely stripped of the old coating, including the removal of all rust, to attain a white-metal roughened surface profile. Today this is accomplished mainly through pneumatic blasting using crushed and sized slag, called grit, obtained from coal-fired boilers or copper and nickel smelters.

During blast cleaning, the paint and rust removed from the ship's surface accumulates in the used or spent blast grit (slag). Occasionally, material from other vessel servicing operations accumulates as tramp with the used blast grit. Because of this contamination and the generation of grit fines during blasting, the blast grit is not reusable and, therefore, must be disposed of or carefully discarded. Because it contains metals and organics from the paint coatings, the used blast grit is stockpiled on site or landfilled at special hazardous waste sites in certain states. This material is one of the major hazardous wastes generated in the eight Naval shipyards.

Managers of these shipyards, which collectively produce about 100,000 tons per year of used blast grit, have seen tipping fees at hazardous dump sites increase significantly; however, future Environmental

Protection Agency (EPA) regulations may restrict altogether the dumping of such waste. Therefore, naval shipyards are looking for solutions to this hazardous waste problem or at least a means to drastically reduce the quantity of hazardous wastes dumped.

Potential Solution

IGT has developed a versatile fluidized-bed sloped grid calciner (SG calciner) that may be well suited for the reclamation of used blast grit. The sloped grid design has evolved from development work for IGT's U-GAS coal gasification process. The SG calciner system has the following unique features:

A" intensive mixing of the' fluidized bed - all organic contaminants are completely destroyed

The capability to discharge tramp material that would accumulate on the surface of a horizontal grid

The countercurrent cooling of the discharged grit with a portion of the fluidizing air

The ability to separate by air classification the inorganic paint residue, which is liberated by calcining from the discharged grit

The capability of the process to use either natural gas or fuel oil

The capability to operate as a" incinerator for waste materials from other sources in a shipyard (for example, wastewater-oil mixtures, oil- or fuel-contaminated soil, etc.).

An SG calciner pilot unit has been operated to reclaim contaminated clay bonded foundry sand, in which it was able to 1) reduce the organic content of the sand to a very low level (0.2 weight percent measured as loss on ignition) and 2) remove most of the clay from the sand grains. To demonstrate the applicability, IGT processed 50 tons of sand in a pilot unit of 1 ton/h capacity for a major automotive manufacturer. IGT also participated in a" American Foundrymen's Society (AFS)-sponsored test work on thermal reclamation. From the IGT system, both of these programs yielded reusable sand.

Figure 1 shows a suggested prototype SG calciner system for blast grit reclamation. As the air enters the preheater, the air will dry the grit, which is then fed into the calciner by a metering screw feeder or

drag feeder. The grit will be heated to a temperature of 1200' to 1600°F by burning natural gas or oil directly in the fluidized bed. The organic content of the paint chips will be converted to water vapor and carbon dioxide, and the inorganic and metallic components will be elutriated out of the calciner with the flue gases. Bough particle sizing of the reclaimed media, free of paint residue and grit fines, can be achieved through adjustments in air flow to the discharge line from the calciner. Sensible heat from the calcined grit can be used to generate low-pressure steam and/or provide hot air for drying the spent grit. The cooled, reclaimed grit can then be stored for reuse. The majority of fines and inorganic paint residues can be removed from the calciner flue gases by a cyclone separator. A flue gas heat recovery system downstream of the cyclone can preheat the fluidisation and combustion air supplied for the calciner. The flue gases will then pass through a bag house for final dust removal before venting to the atmosphere.

By recovering energy from the hot grit media and flue gases, this proposed design is aimed at maximizing the overall thermal efficiency of the SG calciner system.

FEASIBILITY TESTS ON USED BLAST GRIT

Preparation

IGT conducted four tests in a laboratory (bench-scale) calciner to investigate the feasibility of using the SG calciner for reclaiming blast grit. The blast grit was obtained from the Lone. Beach Naval Shipyard. The two types of grit used by this shipyard are both from smelter slag produced during the refining of copper and nickel. The copper slag being black in color can be differentiated from the nickel slag, which is green. Virgin (unused) grit samples from both smelters and the used grit from the blast Cleaning operation were collected for these tests. The major chemical components of the grit are iron and magnesium silicate. To be able to evaluate the results of the calcining tests, IGT's analytical laboratory performed analyses (see Tables I and II) on the virgin grit and the used grit for metals content, major oxide components, and sieve size analyses.

The virgin grit contains about 5 weight percent less than U.S.S. Size 80 (Navy Spec.), whereas the used grit samples contained 15 to 20 weight percent below 50 mesh. The used grit samples contained a volume of about

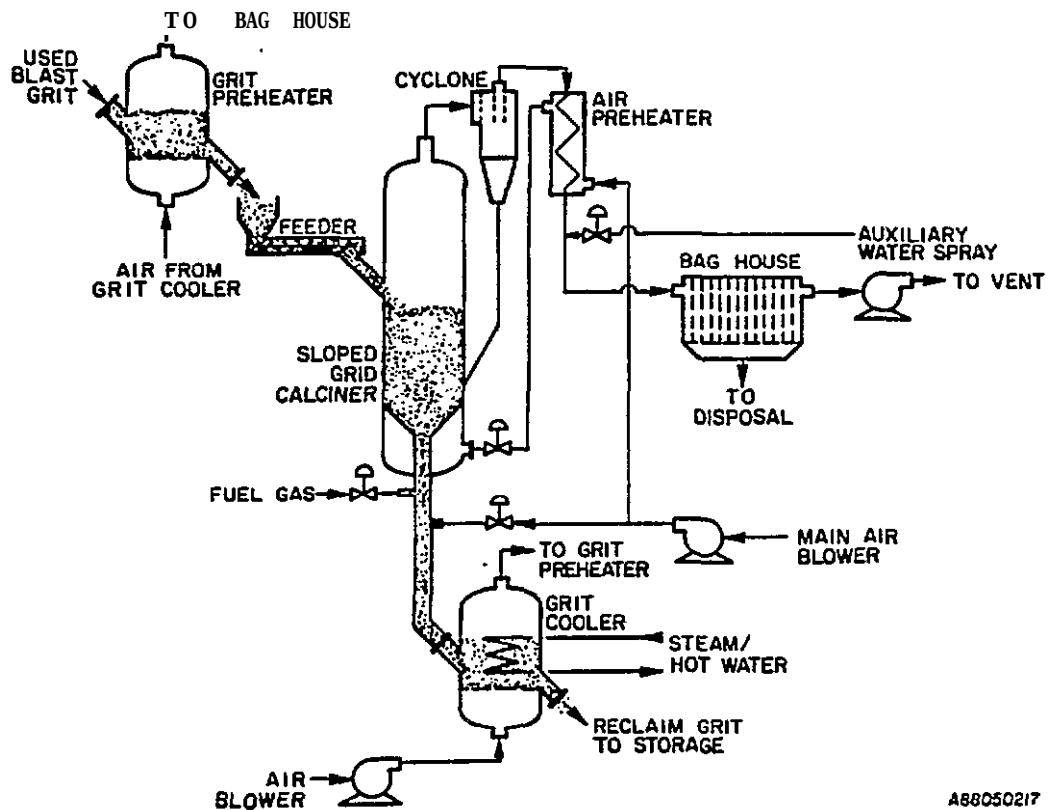


Figure 1. FLUIDIZED-BED CALCINER
FOR BLAST GRIT RECLAIM SYSTEM

Table I. LABORATORY ANALYSES OF VIRGIN GRIT

Metal	Virgin Grit, p p m	Major Oxides	Virgin Grit, w t %	Retained on U.S.S. Sieve No.	Virgin Grit, w t %
copper (CU)	980	Na ₂ O	0.45	6	0.0
Zinc (Zn)	3400	MG ^o	15.50	8	0.1
Titanium (Ti)	1900	^A 12.3	3.23	12	2.7
Barium (Ba)	590	SiO ₂	41.90	20	49.0
Chromium (Cr)	2900	P ₂ O ₅	0.12	30	25.9
Nickel (Ni)	2000	S O ₃	0.52	40	12.9
Lead (Pb)	840	K ₂ G	0.54	50	3.5
Tin (Sn)	160	C ₂ O	2.32	80	2.3
Arsenic (As)	210	TiO ₂	0.32	100	0.8
Cadmium (Cd)	8	Fe ₂ O ₃	30.20	200	1.8
Organics*	1000	Total	95.10	270	0.4
				325	0.4
				Pan	0.2
				Total	100.0

Bulk Density.
122.5

Moisture, wt % --

* Measured as carbon and hydrogen.

Table II: LABORATORY ANALYSES OF USED GRIT

Metal	Used Grit			Major Oxide	Used Grit		Retained on U.S.S. Sieve No.	Used Grit	
	1	2	3		1	2		1	2
	p	p	m		wt	%		Wt	%
Copper (Cu)	1000	--		Na ₂ O	0.35	0.30	6	0.2	0.03
Zinc (Zn)	3700	3700		MgO	20.60	20.70	8	0.1	0.2
Titanium (Ti)	1600	1400		Al ₂ O ₃	2.55	2.49	12	0.8	1.1
Barium (Ba)	790	670		SiO ₂	47.80	47.60	20	25.0	30.9
Chromium (Cr)	4000	3900		P ₂ O ₅	0.07	0.05	30	18.6	20.4
Nickel (Ni)	2700	2000		SO ₃	0.55	0.47	40	18.5	18.7
Lead (Pb)	320	320		K ₂ O	0.40	0.39	50	13.2	12.1
Tin (Sn)	120	130		CaO	1.30	1.32	80	12.0	9.8
Arsenic (As)	220	230		TiO ₂	0.27	0.23	100	3.1	2.2
Cadmium (Cd)	6	6		Fe ₂ O ₃	24.60	24.40	200	5.9	2.9
Organics*	5800	4900		Total	98.49	97.75	270	1.1	0.6
							325	0.7	0.2
							Pan	0.8	0.6
							Total	100.0	100.0

Bulk Density,
lb/ft³ **118.6 123.7**

Moisture. wt % **14.9 14.9**

* Measured as carbon and hydrogen.

1 weight percent paint chips and other tramp material. This contamination is illustrated by an organic content level 5 to 6 times higher for the used grit. To meet environmental concerns and Navy size specifications, the used blast grit must be dried, the organic materials removed, certain metals reduced in content, and the fines (<80 mesh) separated out.

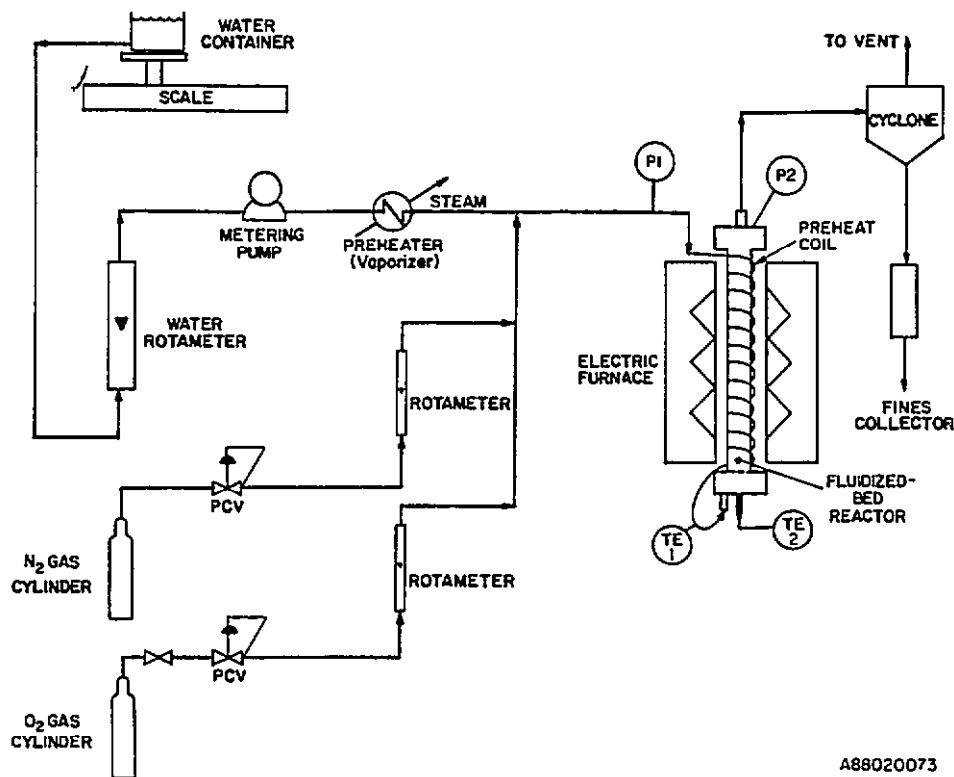
Description of the Tests

IGT's bench-scale fluidized-bed reactor used for conducting the feasibility tests is shown schematically in Figure 2. The reactor is constructed of 2-inch-diameter stainless steel pipe surrounded by an electric radiant coil furnace. The temperature within the reactor can be closely controlled by a variac over a range from 1000° to 2000°F. This is a batch fluidized-bed reactor having a flat plate gas distribution grid, instead of a conical grid typical of the SG calciner design. Air is forced through the holes in this flat plate to fluidize uniformly the grit charged. The outlet gas from the reactor passes through a cyclone before being vented. There is no provision for the combustion of natural gas and air within the reactor; instead the desired temperature is obtained through radiant heat from the electric furnace. The "air" used in these

tests was actually made from the proportional mixture of nitrogen and oxygen. As this unit has other test purposes relative to IGT's energy programs, a means for steam supply is available but was not used in these tests.

A total of four tests were conducted with the used blast grit in the 2-inch fluidized-bed reactor. A charged batch of grit was brought to the desired temperature both by the preheat coil fluidizing air and direct radiation from the furnace. Hot air, CO₂ and water vapor from the paint fine particles leaving the reactor passed through a cyclone where fines were separated and the gas vented.

In a typical test run, approximately 500 grams of the blast grit were charged to the reactor, which gave a fluidized-bed height of 6 inches. The heat-up rate to the preset temperature averaged 1.0°F/min. During this heat-up period the minimum superficial gas velocity (approximately 1.5 ft/s) was used. Once the fluidized-bed reached the preset temperature, the superficial gas velocity was increased to the desired level, and the test run was continued for 2 hours. The fluidized-bed contents were then cooled, removed, and weighed. The fines collected were also weighed.



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Figure 2. SCHEMATIC DRAWING OF A
2-INCH FLUIDIZED-BED REACTOR

The operating conditions for the four tests are given in Table III. Table IV illustrates the weight fractions of calcined grit retained in the reactor and carried to the cyclone.

Table III. TEST OPERATING CONDITIONS

Run No.	Test Temp, °F	Fluidization Velocity, ft/s	Test Period, h
1	1500	2	2
2	1200	2	2
3	1500	3	2
4	1200	2.3	2

Table IV. MATERIAL DISTRIBUTION

Run No.	Used Grit Wt, grams	Reclaimed Grit Wt, grams	Fines Wt, grams	Percent Reclaimed
1	534.5	493.3	30.8	92.3
2	535.5	513.5	16.4	95.9
3	537.5	512.7	19.0	95.4
4	535.9	504.5	26.9	94.1

Test Results

Visual observations of the calcined grit indicated that the discrete gray paint chips present in the used grit charged were converted

to a white material, most of which was present in the cyclone fines fraction. More of the white chips were found in the reclaimed grit from Test Nos. 1 and 2 than in Test No. 3 where the fluidization velocity was increased from 2 to 3 ft/s. The reclaimed grit was almost free of any inorganic paint residue. There was no visual color difference between reclaimed grit from tests at 1500°F and 1200°F.

To evaluate the results of the four calcining test, samples of the calcined grit and the cyclone fines were analyzed for the same criteria as were the virgin and used grit for metals and major oxide content plus sieve size distribution. These analytical results are shown in Tables V, VI, and VII. The same information on fresh grit and used grit is also listed to facilitate a ready comparison.

The analyses presented in Table V show that common constituents of paint - organics, zinc, barium, titanium, and copper - were removed from the grit and carried to the cyclone fines collector. The greater concentration of these metals in the fines fraction confirms that fluidized-bed calcining incinerates the paint chips and entrains the inorganic oxides to the fines fraction. The fines fraction also contains size

Table V. BLAST GRIT TEST RESULTS
OF METAL CONTENT ANALYSES

Metal	Virgin Grit	Used Grit		Test No. 1		Test No. 2		Test No. 3		Test No. 4	
		1	2	Reclaimed Grit	Fines	Reclaimed Grit	Fines	Reclaimed Grit	Fines	Reclaimed Grit	Fines
Copper (Cu)	980	1000	200	1100	5700	2000	6200	600	860	1400	11900
Zinc (Zn)	3400	3700	3700	3700	9000	3400	7200	2800	6800	3100	6400
Titanium (Ti)	1900	1600	1400	1000	4000	1100	5200	1000	4900	1000	4600
Barium (Ba)	590	790	670	360	4100	400	4400	290	4600	320	4300
Chromium VI (Cr)	2900	4000	3900	4000	3300	4000	3100	4400	3300	3800	3200
Nickel (Ni)	2000	2700	2200	1700	1800	2700	1600	2700	660	1400	5600
Lead (Pb)	840	320	320	300	480	310	550	240	440	300	510
Tin (Sn)	160	120	130	60	110	160	80	100	140	100	100
Arsenic (As)	210	220	230	92	170	130	220	160	210	220	170
Cadmium (Cd)	8	6	6	4	12	6	9	6	11	6	11
Organics*	1000	5800	4900	800	35400	900	2900	700	4100	700	42300

* Measured as carbon and hydrogen in the sample.

Table VI. BLAST GRIT TEST RESULTS
OF MAJOR OXIDE ANALYSES

Major Oxide	Virgin Grit	Used Grit		Test No. 1		Test No. 2		Test No. 3		Test No. 4	
		1	2	Reclaimed Grit	Fines	Reclaimed Grit	Fines	Reclaimed Grit	Fines	Reclaimed Grit	Fines
						wt %					
Na ₂ O	0.45	0.35	0.30	0.26	0.70	0.28	0.76	0.27	0.69	0.26	0.85
MgO	15.50	20.60	20.70	21.50	18.70	21.50	17.80	21.50	17.90	22.60	18.00
Al ₂ O ₃	3.23	2.55	2.49	2.66	3.27	2.65	3.48	2.72	3.27	2.70	3.19
SiO ₂	41.90	47.80	47.60	46.50	41.00	44.40	43.20	48.10	44.70	48.90	43.90
P ₂ O ₅	0.12	0.07	0.05	0.07	0.14	0.07	0.14	--	--	--	--
SO ₃	0.52	0.55	0.47	0.62	1.85	0.52	1.22	0.5	1.30	0.50	0.87
K ₂ O	0.54	0.40	0.39	0.34	0.54	0.35	0.52	0.36	0.51	0.34	0.51
CaO	2.32	1.30	1.32	1.27	3.19	1.40	3.78	1.26	3.37	1.26	3.44
TiO ₂	0.32	0.27	0.23	0.17	0.67	0.18	0.87	0.17	0.77	0.17	0.82
Fe ₂ O ₃	30.20	24.60	24.40	24.30	24.80	24.30	24.80	23.70	24.80	23.70	23.50
Total	95.10	98.49	97.75	97.69	94.86	95.65	96.57	98.58	97.26	100.43	95.08

Table VII. BLAST GRIT TEST RESULTS
OF PARTICLE SIZE ANALYSIS

U.S. Sieve No. Retained on	Virgin Grit	Used Grit		Test No. 1		Test No. 2		Test No. 3		Test No. 4	
		1	2	Reclaimed Grit	Fines	Reclaimed Grit	Fines	Reclaimed Grit	Fines	Reclaimed Grit	Fines
						wt %					
6	0.0	0.2	0.03	0.0	1.3	0.0	1.9	0.0	0.0	0.0	0.0
8	0.1	0.1	0.2	0.1	1.0	0.1	0.6	0.0	0.0	0.10	0.0
12	2.7	0.8	1.1	1.1	1.0	1.2	0.6	2.2	0.5	1.1	0.4
20	49.0	25.0	30.9	28.2	2.7	31.4	0.6	36.9	0.0	28.5	0.4
30	25.9	18.6	20.4	22.2	0.7	23.2	0.0	23.1	0.0	22.2	0.0
40	12.9	18.5	18.7	19.9	0.3	19.3	0.6	16.9	0.5	20.1	0.0
50	3.5	13.2	12.1	14.5	0.7	13.1	0.0	11.5	0.0	14.5	0.4
80	2.3	12.0	9.8	10.9	1.3	8.9	0.6	7.9	4.3	10.4	1.5
100	0.8	3.1	2.2	2.3	6.4	1.5	2.5	1.2	12.9	2.0	5.8
200	1.8	5.9	2.9	0.5	65.7	1.0	57.1	0.3	54.3	0.9	55.8
270	0.6	1.1	0.6	0.1	6.1	0.1	10.8	0.0	8.6	0.0	9.6
325	0.4	0.7	0.2	0.1	4.0	0.1	6.2	0.0	6.5	0.0	6.9
Pan	0.2	0.8	0.6	0.1	8.8	0.1	16.5	0.0	12.4	0.09	19.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Bulk Density, lb/ft ³	122.5	118.6	123.7	123.2	96.0	118.6	89.1	121.8	97.8	122.2	105.5
Moisture, wt %		14.9	14.9			--	--			--	--

degraded grit generated during blasting. The organic content of the reclaimed grit readily meets the low specification level of the virgin grit. The organic content of the fines is high in Test Nos. 1, 2, and 4, but not in Test No. 3 because the higher fluidization velocity of the latter test provided more intensive mixing thereby more complete combustion of the paint.

Table VI lists the analysis for major oxide components of the blasted grit. These data show that there is no significant difference in the general chemical analysis of the virgin, used, and reclaimed grit. The major oxide content of the fines, though, indicates that concentrations of Na_2O , SO_3 , CaO , and TiO_2 increased. Some of these compounds are paint components; others may have been volatilized at the calcining temperature.

The Table VII data on size distribution show that the reclaimed grit from all the tests is lower in fines (<80 mesh) than the used grit but does not meet the virgin grit specifications. Operating velocity limitations for the laboratory reactor prevented the use of higher fluidization velocities needed to remove sufficient fines so as to meet virgin grit size specifications.

However, a cursory observation of the data on Table VII reveals that a larger fraction of the fines collected exceeded the 100 mesh sieve size during Test Run No. 3 than in Test Nos. 1, 2, and 4. Test No. 3 operated at a 50% higher fluidization velocity than Nos. 1 and 2, and 33% higher than No. 4. A calciner can be operated at any velocity compatible with elutriation constraints, therefore, if required, a commercial unit can be designed at higher velocities to yield a reclaimed grit more closely approaching the virgin grit sieve size specifications.

There is another factor that relates heavily to the suitability of grit calcining for reclamation and reuse, that is, the hardness of the grit particles. Published Military Specifications¹⁾ list the capability for virgin grit to meet a No. 6 Moh Scale hardness qualification as whether or not it can scratch a glass surface. All evaluated samples met the 6 Moh Scale hardness criteria. Samples of each important size fraction were tested individually for hardness to cover the specification range. Further, within this size range both light and dark particles were tested to ascertain differences in hardness by a major oxide

constituent. Table VIII contains a summation of these hardness evaluation tests. A low-power microscope was used to obtain the photos that, in Figure 3, illustrate the scratch surface profiles obtained. Virgin grit, used grit, and calcined samples from this test work were analyzed per the above specification procedure.

Overall, the results of these preliminary fluidized-bed tests are promising in that used grit was calcined, thereby incinerating paint organics while entraining the inorganic residues to a cyclone collector. The laboratory bench-scale fluidized-bed reactor used for the tests is not a scaled-down version of the SG calciner; therefore, it would be quite beneficial to conduct a test in either of IGT's 8-inch-diameter SG fluidized bed or 36-inch-diameter SG fluidized bed. Both of these are continuous feed systems having significant fluidization velocity rangeability.

A test conducted in either of these units would provide not only design data, but also sufficient solids samples suitable for toxic metal and soluble metal components analyses.

Table VIII. GRIT HARDNESS EVALUATION TESTS

Sample	Scratching Microscope Slide Glass*			
	Virgin Grit**	Used Grit**	Calcined Grit	
			Run #1**	Run #2**
U.S.S. Sieve Size Range				
12 x 20	Yes	Yes	Yes	Yes
20 x 30	Yes	Yes	Yes	Yes
30 x 40	Yes	Yes	Yes	Yes
40 x 50	Yes	Yes	Yes	Yes

* Fisher Catalog No. 12-544-3: Dimensions 3 in. x 1 in. x 1mm.

** Overall, as well as light and dark particles separately.

TECHNICAL AND ECONOMIC CONSIDERATIONS FOR CALCINATION

The economics of reclaiming mineral abrasive blast grit appear very attractive based on these preliminary test results and cost information (1986) obtained from the Long Beach Naval Shipyard. Their cost for virgin grit is approximately \$100/ton, and their cost for landfilling the used grit is \$150/ton. The annual grit usage at Long Beach is approximately 8000 tons. The total cost of buying and disposing of the blast grit is therefore \$2 million.

Extrapolating these preliminary test results based on Table IX, approximately 80% of the used grit

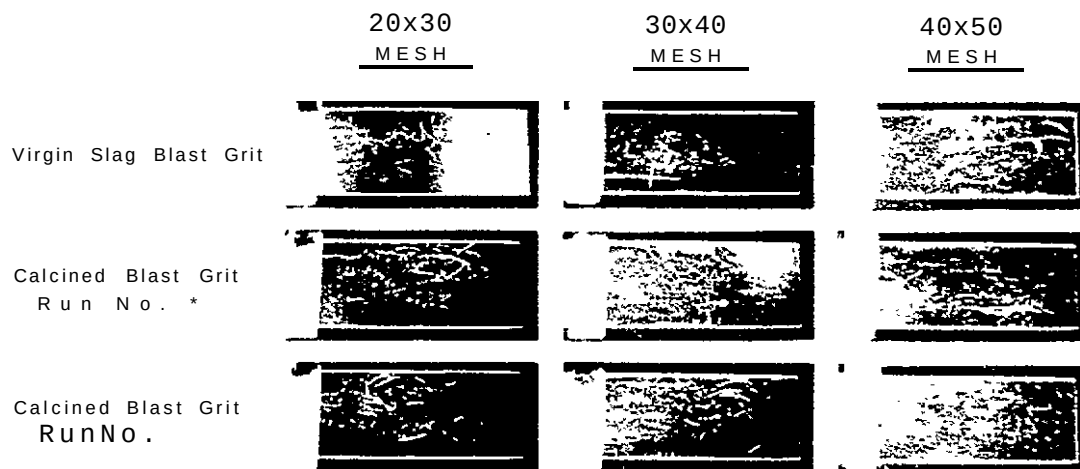


Figure 3. SCRATCH SURFACE 'PROFILES
OF THREE SAMPLES

Table IX. ESTIMATE OF RECLAIM GRIT YIELD

	Minus 40 Mesh Fraction in Reclaimed Grit	Minus 40 Mesh Fraction in Virgin Grit Wt %	40 Mesh Fraction in Reclaim Grit	Reclaim Grit Meeting size Spec's, grams	Net Spec. Grit Reclaimable,+ wt %
Test No. 1	28.5	9.4	19.1	399.1	74.7
Test No. 2	24.8	9.4	15.4	434.4	81.1
Test No. 3	20.9	9.4	11.5	453.7	84.4
Test No. 4	27.8	9.4	18.4	411.7	76.8

* Reference Table 7.

** Reference Table 4. Ex. $493. - (100.0 - 19.1) = 399.1$

Reference Table 4. Ex. $(399.1 / 534.5) 100 = 74.7$

charged to a calciner could be reusable. The balance (20%) less the incinerated organics has to be land-filled. The reclaim potential (R_p), based on this very preliminary data, then is given by -

$$R_p = 1 / (1 - r^{(2)}) \text{ where } r = 0.80$$

$$R_p = 5.0$$

The gross savings at a calciner would then be \$2,000,000 - $(8000 / 5.0) \$250 = \$1,600,000$ less the operating and amortization costs of an SG calciner system. Extrapolated on a similar basis to all the naval shipyards which use a total of \$0.000 to 100,000 tons of grit per year the gross savings available for installing and operating an SG calciner are

several millions of dollars per year. Obviously, the above economics are preliminary and based on rough assumptions about costs at various shipyards and the performance of the SG calciner. However, they do indicate a savings potential while simultaneously addressing a serious environmental problem.

So far no mention has been made of the capital and operating cost of an SG calciner grit reclaim system. The cost obviously depends on the details of how such a system would be integrated into a shipyard's normal operation and are very site specific. Several general considerations must be addressed before a calciner "size" relative to a yearly shipyard tonnage can be determined.

Those considerations are as follows:

1. Can the calciner be operated 24 hours per day?
2. Should the calciner be a permanent installation reclaiming an existing stockpile and keeping up with the daily blast grit usage rate?
3. Should the calciner be a transportable system reclaiming the stockpile, putting it in storage and moving on to another shipyard site?
4. How much of the overall system is part of grit "reclamation" rather than grit "handling"?
5. Must the reclaimed grit be blended with virgin grit to provide a uniform material for the blast cleaning operators?
6. How much and what type of tramp material is present in the existing stockpile, that is, are scaling screens and magnets needed?
7. Is storage capacity to be provided for reclaimed grit?
8. Is a covered vs. an open air facility preferred for stability of system capacity year-round?

CONCLUSIONS

Four reclaimer feasibility tests were conducted with used blast grit from the Long Beach Naval Shipyard. The results of these tests revealed that the organic material component of the used grit was fully oxidized to carbon dioxide and water. The major oxide and organic component analyses conducted revealed no significant general chemical difference between the virgin and reclaimed grit. Based on these results, a commercial plant can be designed to provide a reusable grit yield in excess of 80% within the general size specifications. Therefore, the application of IGT's fluidized-bed calcining technology can reduce the quantity of new blast grit purchased and used grit disposal by approximately 80%. If the reported costs for the Long Beach Naval Shipyard are typical, then the potential savings to the Navy are several millions of dollars per year.

REFERENCES

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24WP/PAP/sandpap



Formal Manufacturing Approaches to Modern Shipbuilding

No. 10B

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ABSTRACT

This paper describes how a formal manufacturing environment, as defined by the American Production & Inventory Control Society (APICS), compares to modern shipbuilding techniques. Formal manufacturing, through a product based build strategy, provides a framework for integrating contract scheduling, design development, material purchasing, inventory control, production capacity planning and production control. An understanding of formal manufacturing provides a foundation for understanding modern shipbuilding techniques.

INTRODUCTION

Shipbuilding is the physical transformation of material into a product that has value to a customer. In short, shipbuilding is manufacturing. In the authors' experience, however, the comparison between shipyards and other manufacturing businesses is down played. Manufacturing is often associated with products such as toasters, not at all comparable with a warship. Therefore, the body of knowledge associated with manufacturing management, Production and Inventory Management (PIM), is not generally applied to shipbuilding. This conclusion is typically based on two notions: ships are products which are much too complex and PIM is only applicable to identical products produced in great number.

There are differences between shipbuilding and other manufacturers, but they are of a more subtle nature. Many of the problems shipbuilders face are like those of any other manufacturing business. For example, people who order material for their operation (either purchased or fabricated) have limited knowledge of when it is needed, exactly how much is needed or both. Their experience is that the system is unreliable, so it pays to keep a few extra on hand. As a

result they tend to order more, earlier, Just-In-Case.

Meanwhile the people who fabricate the items like to build a lot of them. This seems to be the most efficient way to manufacture things, particularly if performance is based on manhour utilization. They never seem, however, to have enough room to store anything, so both the shop floor and storage areas are always clogged with material. In spite of the mountains of inventory, expeditors are often looking for something that is missing and needed right away. It might not have been made or it might be lost. The one person who knows for sure is usually on vacation.

These universal problems of manufacturing are the ones addressed by the practitioners of PIM, often with great success [1,2]. As a result many of the concepts of PIM are applicable to shipbuilding and merit study. One of the best sources of information on manufacturing management is the American Production and Inventory Control Society (APICS). This paper will introduce some of these concepts and compare them with modern shipbuilding techniques.

Formal Manufacturing

PIM starts by viewing manufacturing as a process which requires a control system. Like any control system, PIM requires the classic elements of planning, execution and control [3]. Planning is the process of goal selection and the development of steps to achieve the goal; execution carries out the steps, while control measures the results so that corrections may be fed back into the plan.

The planning process in manufacturing is a complex one ranging from capital acquisition decisions to which hole John Doe should drill before lunch. Yet all planning functions must answer the four questions basic to any manufacturing business (shipbuilding

Included). The question suggested by Wight are [4]

What are we going to make?
(And when?)

What does it take to make it?

What do we have?

What do we need to get?

All manufacturing businesses must answer these questions yet they do not do it in the same way. In the informal manufacturing environment, planning is performed in a disjointed ad hoc manner. Often much of the planning is left up to the production people on the "deckplates". The only guidance they receive from upper management is to do whatever it is they do faster and with fewer resources. PIM concepts describe, on the other hand, the formal manufacturing environment. Among its characteristic is that the planning process is well defined, coordinated from top to bottom and results in well defined goals. Planning is often organized by the time frame the it covers: long, medium and short [3]

Long Range Planning. Long range planning operates in the context of corporate strategy and capital acquisition [5]. The answers to the four questions describe the very nature of the company. They state what the basic products are and what facilities and equipment are necessary to produce them. Planning at this level is done in aggregate units that are appropriate for the manufacturer. An auto maker plans the rate at which passenger cars will be made; so many thousands per year. A shipbuilder could state the rate that it will deliver certain classes of ship such as so many tankers per year. If the type of market cannot be readily predicted then the Production Plan (the PIM term for the rate which sets the overall level of manufacturing output) can be stated in more universal units such as man-hours.

Medium Range Planning. Medium range planning further defines the Production Plan. Now the rate of production is turned into an actual schedule for specific quantities of specific items [6]. The planning horizon is reduced to approximate the longest cumulative lead time of the products. Depending on the nature of the business this schedule, called the Master Production Schedule (MPS)¹, is set in anticipation of sales, or only in

response to a specific customer order. The proverbial toaster manufacturer operates in a make-to-stock environment where, to be competitive, the customer never waits. Most American shipbuilders operate at the other end of the spectrum known as build-to-order where, in exchange for a custom built product, the customer waits through the entire design and manufacturing lead time.² Nonetheless, a schedule can be stated for the specific number and types of ships that will be delivered that year.

The MPS in a formal manufacturing environment is constrained by the Production Plan. A capacity analysis is performed against major facilities to insure that in aggregate the MPS is a feasible plan in line with the corporate goals [6].

One of the most important factors which distinguishes the formal from the informal manufacturing environment is the care with which the MPS is prepared. In the informal environment the MPS is often arbitrarily determined without consideration of its impact on all parts of the company such as Finance or Engineering. Further, the MPS is often set unrealistically high as many managers believe this acts as an incentive to drive production higher. When people realize that the MPS is unrealistic, it ceases to become a credible plan against which performance can be measured [7].

In the formal manufacturing environment the MPS is agreed upon by all divisions of the company as a realistic plan which achieves corporate goals. Then as conditions change the best trade off among goals can be made. For example, suppose Marketing has come up with a major potential sale. Based on the MPS, if the capacity for the new business is not available without seriously disrupting the plan then the new business might be turned away. An alternative would be to eliminate or delay some part of the old plan in favor of the new business. Another alternative could be arranging for increased capacity to handle both the original plan and the new business. This could be through extra shifts, subcontracting or overtime. In any case the MPS is not arbitrarily changed. Instead those responsible are required to make choices in a visible and consistent manner as constrained by capacity. This insures that all concerned parties can agree that the MPS is realistic, and that their performance can be measured against it [7].

1 In PIM jargon the MPS is always set in anticipation of sales. We will use it in the general sense of a medium level schedule for end products.

2 In between is the assemble-to-order environment. Here a unique product is assembled out of combinations of standard items.

Short Range Planning. Once the Master Schedule is set the plan can be taken to the lowest level, where day-to-day decisions are made. In formal manufacturing environment the short-range plan is defined through the lower level or interim products which make up the end product on the MPS. These interim products can be accurately defined regardless of whether the product is built once or one million times [8]. While this definition can be complicated by subtle interactions between process and product, the basic criteria is easy. What material does the mechanic need to perform his or her task? This material may be purchased or fabricated; it might be production support material that never leaves the job site; it might be material for the original design or for a change incorporated ten minutes ago. To the worker these distinctions are irrelevant; if he or she does not have the right material at the right time the job cannot be completed.

Not only is material quantity defined in the plan but so is schedule. Once the due date is determined for the end product due dates can be determined for the interim products which support it through back-scheduling. In this manner a schedule based priority can be set for the production or purchase of each interim product. This is Dependent Demand, the idea that the need for one interim product can be calculated based on the need for another [8].

The formal environment takes advantage of the product based plan to define and control the manufacturing process. Formal work authorizations are issued by schedule which direct that a specific quantity of an interim product is due on a specific date. The work authorization allows the picking of specific amounts of material to complete the job. In addition, process information recorded for each product can be provided with the work authorization. A complete package can be given to the mechanic with schedule, quantity, material definition and process all included [9].

Now that the formal plan is defined and execution authorized the loop can be closed by regular accurate status of the work authorizations. If status indicates that completion will be late or quantity insufficient the information can be fed back into the plan since all the interim products are linked together to show how they support the end product. Status information can be analyzed to see how it affects other interim products and potentially the end product itself.

The analysis may indicate that changes are necessary. These changes

are transmitted by re-scheduling the work authorizations either earlier or later. This insures that the mechanic is always working on the product that has the highest priority; the one which must be worked now to support the plan.

With a formal product based plan. detailed capacity analysis can be performed. By associating the capacity consumed by a particular interim product with the schedule for its production, an accurate capacity profile is developed. If the rough capacity analysis has been performed correctly at the higher levels the detailed plan will be achievable [3]. This is not to say that every day will be perfect. The dynamic nature of **manufacturing, guarantees day to day** problems. The higher level analysis, however, insures that the detailed plan will be, on average, realistic over time.

Informal Manufacturing

All manufacturing firms perform these short range planning functions or else product would never be shipped. The differences among them can be defined by the different way these functions are performed.

The informal manufacturer typically controls his interim products with little or no regard to dependent demand. In the make-to-stock world this means order points. When the on-hand quantity of an item drops below a certain point more are ordered, regardless of when they are actually needed based on the priorities derived from the Master Schedule.

The make-to-order manufacturer (like a shipbuilder) does not make large batches of identical items. However, if there is no clear picture of individual priority, items are often grouped together for manufacturing efficiency even though their actual use may be spread out over weeks or months. The orders are based on groupings thought to allow efficiencies in fabrication or ease of administration based on criteria like drawing organization (i.e., build all pipe piece on this drawing).

ONCE the order is prepared, it is launched or "pushed" onto the shop floor based on the earliest need date for a few of the items. Because of the size of the order, large lead times begin to build up as the entire order has to pass through any work center before the next large order can begin. For a typical Job Shop operation, products spend about 90% of their lead time in queue, waiting to be worked [7]. This gives rise to the practice of expediting. Based on current priority, some part of the order may be needed right away. The expeditor

identifies those items (because someone is asking for them) and "pulls" them ahead of the others. This practice quickly destroys the credibility of any schedule as the items without a champion now wait even longer. A worse situation occurs when there are too many expeditors. Now all the products are the meet important an impossible situation. As a result, planners often increased lead time, thinking that this will increase their chances of getting their product on time. Instead, orders are queued even earlier making the backlog larger still. Lead times increase and expeditors have to work even harder to break the log jam. This is because longer lead times mean less accurate orders. It is a simple rule of forecasting: the longer the lead time of the prediction, the less accurate it will be. Now a vicious circle builds up of lengthening lead times and increasing mistrust of the system [10]. The shop knows that if it keeps to the schedule someone will try to accelerate the order based on immediate need. When they do accelerate the order, most of it ends up being stored for weeks.

Building products ahead of need has other deleterious effects. They must be stored for longer periods incurring costs, and increasing the chances that the items will be lost or damaged. For Defense Contractors, there is the added risk that the product will become obsolete on the shelf as result of the continuous change required by the customer.

FORMAL MANUFACTURING MODELS

Formal manufacturing is a set of concepts. As such it manifests itself in different ways when applied to different industries using different technologies. We would like to discuss three versions of formal manufacturing: MRP II, JIT/Kanban, and the management techniques presented by the National Shipbuilding Research Program (NSRP).

MRP II

One method used by formal manufacturers is Manufacturing Resource Planning (MRP II). This technique takes the elements of the formal environment from the Master Schedule down through execution of the day to day plan and captures them on a computer. Figure 1 shows a block diagram of the major elements of MRP II. A note about terminology is in order. MRP II traces its roots to computerized inventory planning systems developed in the 1960's. These systems, dealing only with inventory, were known as Material Requirements Planning or MRP (often little MRP). As these systems were

integrated with other elements of formal manufacturing such as capacity and work authorization, they became known as Manufacturing Resource Planning (MRP II or "big MRP"). The inventory planning element of these larger systems is still called material Requirements Planning (little MRP) [11].

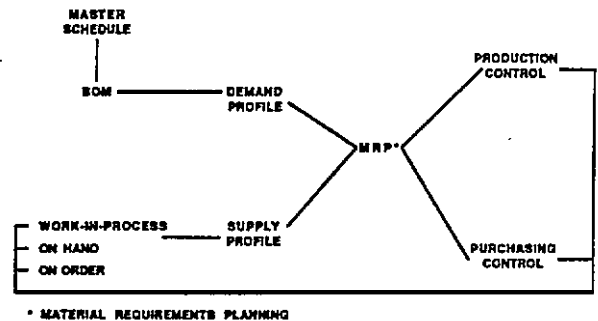


FIGURE 1
MRP II

Demand Profile. using MRP II, the Master Schedule is developed following the planning process already described. The definition of the lower level interim products is captured in a bill of material (BOM). This bill is not merely a list of material but instead captures a series of product and component relationships. It shows how raw stock and purchased components become interim products, which combine with other interim products (and more material) until finally the end product is reached. Figure 2 shows a simplified product structure for end item A. Here A is made up of fabricated items B and C and purchased item 1. Item B is in turn made up of products D and E. This structure can be made as elaborate as necessary to represent the manufacturing process. The only requirement is that the interim products at any level be defined in terms of the interim products at the next lower level. This definition is made strictly on the way the product goes together. It need not be based on organization or other design constraints [8].

In addition to quantity, schedule can be associated with the interim products. The amount of time necessary to build or buy each item combined with the product structure allows back-scheduling. Once the due date for the end item is determined (from the Master Schedule), start and finish dates can be calculated for all the interim products which support it. This process can be easily envisioned by turning the product structure on its side and noting its resemblance to a schedule network [8].

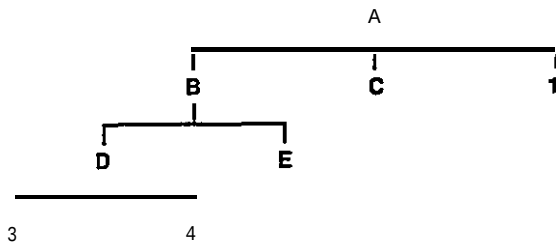


FIGURE 2
STRUCTURED BILL OF MATERIAL

Collectively, the Master Schedule combined with the product structure form the Demand Profile on Figure 1. This is a time phased view of the quantity of interim products needed to fulfill the Master Schedule.

Supply Profile. once an accurate Demand Profile has been calculated, it can be compared with existing inventory. The inventory records in the MRP II system contain both on-hand quantity and the schedule for receipt of committed purchase and manufacturing orders. With this information it is relatively easy to calculate what additional items are necessary to build or buy through time. This Supply Profile becomes the minimal plan to execute in support of the requirements captured in the Demand Profile.

The supply Profile is captured as a series of proposed orders. These are formal authorizations to either buy or build something. The manufacturing orders can be supplemented with process information, stored in the computer for each interim product.

Figure 3 shows a typical time phased inventory record contained in an MRP II system. Gross requirement show all known demand for the item across time based on the Demand Profile. Scheduled receipts show all known released orders to re-supply this item either purchase or manufacturing. The On Hand row indicates the levels of inventory that will be carried in each period based on the plan. Planned Releases represent the Supply Profile. the system's proposal for purchase or manufacturing orders that should be released to maintain sufficient inventory to cover the Demand Profile.

Feedback. The MRP II supply Profile can be modified to account for process or material constraints. For example, it may be desirable to build an item in multiples of twenty because that

is the quantity which consumes an entire bar of raw stock. The formal system shows the demand this month to be for five only; the plan, however, may be adjusted to supply twenty for efficiency's sake. By maintaining accurate status in the system, the fifteen extra items are known to be in inventory and available for future demands.

Building extra may sound suspiciously like the informal system. Suppose, however, that all has not gone well with the order. Perhaps the machine malfunctioned after making six parts and destroyed the remainder of the bar stock. Should a replacement bar be expedited? In an informal environment, the answer would probably be, yes, just "In Case". someone might attempt to do research but it will probably be difficult to find out when or if the other fourteen are needed. With an MRP II system, however, accurate Demand Profile is available so the question can be readily answered. Thus, with MRP II, one has the option to combine small orders into bigger ones. The information on exactly what is needed, is always available.

Similarly, other changes in order status will be reflected in the formal system. Information such as early or late performance as well as incorrect quantities bought or built is fed back to the system. Then appropriate, frequent adjustments can be made to the plan. This insures that work is being performed on the right product based on the most current information.

Feedback to the formal system allows the maintenance of both horizontal and vertical priorities. Vertical priority means that the priority of a product and the interim products which support it are linked. Thus, if item A (Figure 2) is re-scheduled by six weeks, the effect can be represented in the schedules for all the supporting interim products. This is an obvious result, though difficult to model on complicated products without a computer. More subtle, however, is the concept of horizontal priority. Here, if item D is unavoidably delayed, the priority for item E can be reduced as well. It is pointless to complete item E on time if it will end up in storage waiting for item D. This is particularly true if item E absorbs scarce capacity needed for another product with a new, higher priority. Accurate feedback of the formal system allows the situation to be recognized and appropriate action taken [8].

The Formal Manufacturer has learned that the key to managing capacity is to manage priority. In the informal environment, it is difficult to know

	1	2	3	4	5	6	7	8
GROSS REQ S		20		25		15	12	
SCHED RECEIPT			30					
ON HAND	23	23	3	33	8	8	- 7	-19
PLANNED RELEASES		7	12					

LEAD TIME: 4

FIGURE 3
TIME PHASED INVENTORY RECORD

which job in the queue is the most important. As a result, capacity may be squandered by working on something that is not needed; now, or ever [12].

JIT

Other formal manufacturing systems have grown up without the heavy use of computers. Perhaps the best known is the Japanese Kanban system; an implementation of the principles collectively called Just In Time (JIT).

JIT is a formal manufacturing philosophy which strives to eliminate excess inventory in two ways. First, lot sizes are cut to the bare minimum. Traditionally, large lot sizes are justified by the economy of maintaining the setup over a number of items. Under JIT, careful attention is given to the factors controlling setup cost at workcenters. Second, products in the JIT environment are only built if they are needed at that particular time. Workers will be allowed to stand idle rather than produce items not immediately needed [14].

Kanban. Kanban embodies these principles into a simple card controlled system. As implemented at Toyota, there are two kinds of cards: a production card and a move card [14]. When the schedule says that an end item should be built, a worker starts to use parts from a full container to which a move card is attached. As soon as parts are used the move card is removed and taken back to the work center which produced the parts. There a full container is waiting with a production card attached. Now the move card may be attached to the full container and the production card

removed. The move card authorizes transit of the full container to the next work station. The newly free production card authorizes production of exactly one container of the item. These containers are specifically designed to hold only a certain number (the authorized lot size) of the product. When this container is complete, the production card is attached to it. If no other loose cards exist, production stops at that work center. By regulating the number of cards and containers on the shop floor the system is completely controlled [14].

The Kanban system relies on repetitive manufacture of a few items. Even Toyota uses this system for only about 60-70% of their parts [13].

NSRP Model

We do not mean to imply that the shipbuilding industry has ignored the concepts of formal manufacturing. Over the last ten years, the National Shipbuilding Research Program (NSRP) has promoted the management concepts and techniques used by a number of overseas shipbuilders. These techniques represent an integrated, company wide approach to scheduling and controlling manufacturing through structured bills of material. Feedback mechanisms provide for the continual evaluation and refinement of strategy and execution. We highlight the match between NSRP concepts and formal manufacturing in greater detail in the following review.

What are we going to make? From a long term, or business planning perspective, shipyard organization and

goals are centered around the measurement of value added [15]. This aspect of the strategic plan is best understood in terms of a make/buy analysis. The cost of "making" or internally generating a product is compared to the cost of purchasing that same product. This comparison is made strictly on a cash flow basis. Those products which can generate a sufficient rate of return, or value added, are designated as "make" [5]. For the shipyards studied by NSRP, the functions chosen as "make" are [15]:

- o Design and component integration
- o Assembly, installation and testing of finished components
- o High volume fabrication, such as pipe piece manufacturing (where Group Technology can be applied to achieve efficiency)

Subcontracting is used to accomplish all other requirements; chiefly for low volume fabricated components. Beyond the value added criteria, subcontracting may also be used to minimize operating resources (i.e., to obtain special expertise or mitigate short term manning peaks) and to eliminate the drain on management resources required to keep a job shop environment running efficiently [15].

The beginning of product definition is material planning. Material planning establishes basic policies for classification, standardization, application, etc. These basic policies have three major goals;

- o to improve the efficiency of the Production work force by minimizing the amount of learning required from project to project.
- o to facilitate the design integration process by extending the applicability of previously developed design details.
- o to minimize the number and type of truly unique items in inventory when multiple classes of vessels are working simultaneously.

The principal mechanism to achieve these goals is the standardization of products. Three types of standards are developed [15]:

- o Vendor equipment standards, which provide a file of readily available engineering and design data without waiting for the negotiation

and Purchase Order cycle to complete.

- o Functional design standards, which detail common system, or sub-system characteristics using standard equipment.
- o Detail design standards, which indicate assembly and fabricated component requirements for installation of standard sub-system modules.

Group technology plays an important role in the development of the shipyard standards. From Production's perspective, the experience resulting from building a unique item must be captured, and be applied across as broad a spectrum of similar problems as possible. Further, the amount of time required to shift from production of a given component to any other component inhibits the overall efficiency of the operation. Therefore, production standards seek to reuse past designs and process data, as well as provide guidance for new designs which minimize planning and set-up delays. This concept has been most highly developed in the piping area, where pipe pieces are grouped into families according to common processes (i.e., straight vs. bent) [16].

In keeping with the "assemble-to-order" philosophy, the shipyard seeks to eliminate purchasing lead times from the overall contract lead time. This is accomplished through long term agreements with vendors, which essentially reserve vendor capacity for expected shipyard purchases. These contracts generally specify target quantities for purchase, with price adjustments for over or under runs [15]. Changes in the market place (such as the surge in construction of clean product carriers in the late 1970's and early 1980's, which influenced the average diameter and total footage of pipe per hull), can have a significant impact on the bottom line for the company. Market analysis, is therefore, a key input to setting target quantities and adjusting bidding strategies.

What does it take to make it? Once a contract is signed, a two pronged strategy of design development is followed. The first is aimed at supporting early purchasing activities to ensure all required materials are ordered in time to support the production schedule. Of primary importance is the creation of the Budget Control List [17], a complete list of material by commodity used as the basis for projecting design, production and material costs. Initial purchasing actions; requests for quotes,

negotiations on price and placement of purchase orders is authorized by this list [15].

The Budget Control List is compiled from the Material List by System (MLS), which, along with system diagrams, is the principal product of functional design [17]. As each functional system matures, often using standard modules for sub-system layouts, the MLS documents the complete estimate of material required for purchase. Each item listed on an MLS is allocated to a material ordering zone (a temporary product used for scheduling purposes prior to detailed product definition) where it will eventually be installed. Particular emphasis is given to long lead items which are individually identified and listed with exact quantities whenever possible. Short lead items are frequently estimated only by weight within material cost codes [17].

Close vendor relations are an important aspect of the approach to purchasing. In many cases, the use of vendor materials as shipyard standards reduces the purchasing cycle. Continual contact with the vendors, required to maintain the shipyard's standards, also permits maintenance of pricing and shipping data. Purchasing decisions can be made rapidly from this file data, and purchase orders can be placed immediately. Further, vendor performance in both quality and schedule is enhanced when existing vendor products can be used [15].

The second prong of the design development strategy supports the refinement of the product definition through detail design. Detailed product definition evolves through a two step process; (1) Translation of the basic product line into specific products for a given vessel, and (2) Definition of each product through detailed design and materials information.

Using contract documents, functional drawings and early sketches from detail design, Production translates the basic product line into a detailed build strategy. As previously mentioned, the starting point for this translation is material planning and shipyard standards. The standards describe the basic building blocks of integration; functional service packages (or units in NSRP terms), or common structural block configurations for a given hull type. But these standards only provide a framework for the detailed product definition or build strategy required for each vessel.

As the design effort shifts to detail design, a series of meetings, referred to as "C" meetings, are held

with the Production departments to aid in the development and communication of the detailed build strategy for each product [17]. The principal output of these meetings is a finalized pallet list for production. The pallet list forms the basis of a structured bill of material for the interim products of construction for the vessel. Each pallet represents a particular stage of construction for each product. It may be broken down simply by work center (on unit, on block, grand block, onboard), or may be broken down further by required work sequence (i.e., a pallet for each time a block is rotated to a new downhand position) [17].

Design develops for each pallet a Material List for Fittings (MLF), which details all the components for installation at a particular stage of construction. This list of components contains purchased items, subcontracted assemblies, items fabricated in-house (principally pipe pieces) and raw stock required for installation. The MLF is used to update material requirements from the original MLS, to budget and to control weight, and to kit material for the job site. The MLF defines the basic unit of work for scheduling and management purposes. For these reasons, the shipyards documented by NSRP consider the data systems for storing, sorting and collating MLFs as the most important systems in shipbuilding [15].

When the product definition has been standardized at a relatively high level, much of the design activity associated with defining the MLF can be focused on manufacturing problems. Reuse of previously developed technical analysis and design allows engineers and designers to devote time to manufacturing and producibility issues. Without existing details, technical staffs must spend significant amounts of time tracking down vendor data and accomplishing functional analysis. Time spent on these tasks tends to detract from producibility due to the pressures of schedule.

Each fabricated component shown on the MLFs, whether subcontracted or built in-house, is further supported by a detailed material list of the raw stock and purchased components required for fabrication. This is referred to as a Material List for Pipe (MLP) or a Material List for Component (MLC). When the detail design is complete, it is therefore possible to diagram a structured bill for the entire vessel, a somewhat simplified version of which is shown in Figure 4.

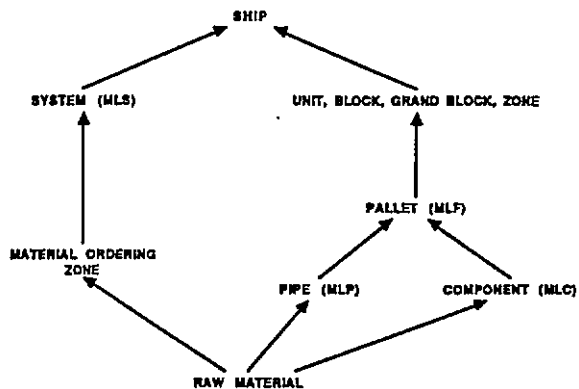


FIGURE 4
SIMPLIFIED BILL FOR VESSEL

When are we going to make it?

Production scheduling is approached on the basis of the length of the horizon required for a given schedule. Shorter horizons allow increasing levels of detail in the schedule data [18]. In practice this results in a hierarchy of schedules; long, medium and short. It is also appropriate to think of this hierarchy of schedules in terms of the structured bill of material; construction products, pallets, and components. For long term purchasing schedules, developed prior to the availability of the pallet breakdown, individual construction products are aggregated into material ordering zones. Each item listed on an MLS is then allocated to the material ordering zone where it will eventually be installed. The use of material ordering zones allows for flexibility in adjusting product schedules by providing a way to relate material to the schedule prior to detailed palletizing. This facilitates the initial negotiations for component delivery, especially for long lead items. It is expected that as design and schedule data evolves to increased levels of detail (i.e., MLPs and MLPs/MLCs), material delivery dates will be refined to prevent both shortages and inventory surpluses.

What do we have, or need to get?

Analysis of purchasing requirements is driven by a number of factors, including: owner requirements for unique items, item cost and lead time, surplus (if any), and the nature of long term purchasing agreements for common commodities. The material planning organization facilitates this analysis by classifying all items for purchase under the following scheme [15]:

- o Allocated materials (A) - requires specific purchase by contract. Used especially for high dollar, long lead items.
- o Stock materials (S) - required in high volumes across all contracts. Generally low cost items. Purchased based on historical supply vs. demand.
- o Allocated Stock materials (AS) - standard materials whose expense justifies purchase against specific hulls. A single purchase order across contracts may be issued, but periodically supply is balanced with demand to ensure zero surplus relative to the backlog.

Inventory control specialists will recognize this as a classic implementation of an ABC, or in this case ACB, material classification scheme. ABC classification categorizes materials on the basis of risk (usually measured through annual dollar volume). It relies heavily on Pareto's Law: a small percentage of the items in inventory accounts for the largest fraction of value. For example, "A" items may be only 20% of the total items, but account for 80% of the total value of inventory. They, therefore, receive the greatest amount of management attention [19].

Figure 5, a representation of a Nishijima Ledger, illustrates the method for analyzing the supply vs. demand requirements of Allocated Stock materials. Quantities currently on-hand plus projected receipts during each time period are compared to total requirements for a given item. Deliveries are expedited to prevent shortages, and de-expedited to eliminate surpluses. In short, supply is balanced against demand. Comparison of Figures 5 and 3 highlights the similarity of this process to Material Requirements Planning.

Using the material lists developed by Design together with the schedule data prepared by Production, the Purchasing organization places all Allocated and Allocated Stock material on order for discrete delivery dates. This includes any subcontracted components which may fall into these categories. Due to the use of long term agreements, some components may already have purchase price and terms negotiated with only specific delivery dates required. As detail material lists are made available, A, and AS materials on order are checked against requirements to ensure accurate quantities are being purchased. As more detailed schedules are made available, delivery dates are

Economical Ord. Q'ty				Material Name			Standard No.	
Standard lead time								
Month		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Q'ty in Stock								
Q'ty Received								
Purch- asing	Q'ty							
	Requisition No.							
Q'ty to be used	Ship No.							
	" "							
	" "							
	Margin							
	Misc. Use							
	Sub-Total							
Q'ty used	Ship No.							
	" "							
	" "							
	Margin							
	Misc. Use							
	Sub-Total							

FIGURES

NISHIJIMA LEDGER FOR CONTROL OF ALLOCATED STOCK MATERIAL

refined to maintain as close to just-in-time delivery as possible.

Approximately 30 days in advance of the scheduled delivery, responsibility for negotiation of delivery schedules with the vendor shifts from the buyers to the Production field expeditors responsible for scheduling pallets. This ensures that items arrive on-site precisely when needed, even though production schedules may shift slightly due to changing conditions on the Shop floor [15].

Additionally, for components fabricated in-house, the field expeditors may choose to subcontract as a means of level-loading fabrication facilities. Short term loading peaks are not handled by providing some additional capacity, or by shifting work earlier than required. Rather, the peaks are simply eliminated by meeting delivery requirements through subcontracting. This reduces capital requirements for tooling and storage, as well as the costs of idle capacity.

Control and Feedback. Feedback in this approach is an absolute requirement. The constant refinement of delivery schedules to match shop floor schedules can only be achieved if procedures are in place to apply the changes in a timely manner. This is the chief reason for shifting negotiation of delivery to the field expeditors. Further, in multi-hull contracts, production workers will inevitably discover required refinements to the detail build plan represented by the Grouping Of fittings within pallets. These refinements must be captured and fed back to Design. Typically this process is handled through a "D" meeting, held specifically to accomplish this review. The close scrutiny of both schedule and Plan is coordinated by a central group known as Production Control.

The Production Control organization is charged with coordinating all industrial operations through the integrated planning and scheduling of the entire shipyard. This

responsibility cannot be met without including control of material ordering and material stocks. In order to achieve the latter, the purchasing organization is part of Production Control. Basic responsibilities of Production Control include:

- Ž General Control - Profit plan, operations plan, manhour allocations, scheduling and consolidated material planning.
- Ž Purchasing - control of vendor and subcontractor relationships, procurement, value engineering delivery control.
- Ž Expediting³ - traditional warehousing functions of recording receipt and issue. control of 5 and AS inventories, material kitting (palletizing) and transportation, and control of scrap and surplus. Control of delivery within 30 days of scheduled production.

Production Control, therefore, Orchestrates the entire process, setting material policies and using structured bills of material together with construction schedules to define or re-define priorities for Purchasing and Production. Production and Design use the material policies to develop standards, hull build strategies and the structured bills. Delivery of purchased materials and the kitting of components is carefully controlled to minimize inventory and storage facility investment. Product lead times are much reduced over traditional shipbuilding approaches due to clear priorities and the highly focussed task definitions inherent in the use of structured bills. In short, the shipbuilders studied by NSRP practice formal manufacturing.

MODEL ANALYSIS

MRP II

MRP II systems are often thought to work only in repetitive manufacturing environments. In fact, they can work for any manufacturer where Dependent Demand can be defined. This feature makes these systems particularly attractive to shipbuilders. The maintenance of priority in Shipbuilding is difficult with any degree of accuracy using manual methods. There are just

³ Note, this is not the traditional definition of expediting described earlier. These expeditors never disrupt internal schedules.

too many interim products to track. MRP II makes use of the strength of computers; manipulation of large amounts of data. Since the data is captured in one place any changes are immediately visible to all users. This information can then be made available to anyone who needs it.

There are problems in supplying MRP II to shipbuilding. A full discussion of these problems is beyond the scope of this paper. Instead, we will present a partial list to suggest areas for further study.

Nesting. A toaster manufacturer has to nest parts onto plates and shapes of raw material. That is he has to decide what combination of parts can be cut out of a particular plate or shape. Since thousands of identical parts will be made, this pattern or nest can be set once and re-used.

A shipbuilder has to perform the same task but for thousand. of unique items, requiring many unique nests. Traditionally this has been performed weeks or months in advance based on high level schedules or other groupings. In a formal system, the nest itself would have to be managed as an interim product limiting the flexibility of the system.

Design and Construction Overlap. To reduce the total design and construction lead time, they are often run in parallel for the lead ship. This can limit the amount of time available to prepare the BOM in advance of construction. It also prevents a total ship view of the detailed plan until sometime after construction has begun.

Construction and Activation Overlap
To meet the schedules demanded by the customer, testing and activation of specific systems must begin before the ship is complete. As a result the definition of interim products becomes complicated when zone products must be integrated with system products that run through many zones.

Each of the problems described is solvable. Today major aerospace companies like Boeing and McDonnell Douglas are building products of equal complexity to warships using MRP II systems. We know of no technical reason why MRP II systems cannot be made to work in American shipbuilding.

JIT/KANBAN

The kanban system as stated previously works best in a repetitive manufacturing environment. This makes it inappropriate for many shipbuilding manufacturing problems.

While Kanban itself is not generally applicable to shipbuilding its principles are. Reducing setup costs increases flexibility in responding to changing priorities. Increased flexibility makes it easier to build only what is needed when it is needed. Both of these principles are worthy goals for shipyards.

NSRP

The NSRP model has now been with us for 10 years. In that time, it has proven to be a useful framework for major gains in shipbuilding productivity. Yet many people are still struggling to understand how to apply the details on the shop floor. Among the difficulties often cited are: lack of top management commitment and understanding, organizational differences, and the complexity of naval versus commercial construction. We believe it is time to re-examine the NSRP model in the context of other manufacturing systems. This results in the following conclusions.

The NSRP model is a form of formal manufacturing. It is, however, only a particular implementation optimized to support a specific business environment.

The NSRP model does not discuss the details of implementation on the shop floor. It presents a static picture of shop organization and planning, materials and subcontracting policies. No guidance has been given on ways to adapt the methods presented to a different business situation.

The NSRP model has been difficult to implement on warships owing to the volume and complexity of interim products as compared with commercial ships and because of the complex nature of the purchasing/inventory control process associated with government contracting.

We believe that these are all issues of education. By understanding the fundamental concepts of Production and Inventory Management, common industry practices can be re-examined as to their impact on efficient manufacturing. The NSRP model can be placed in context and analyzed for its strengths and weaknesses as compared with other formal manufacturing models. Through broader education, it is possible to begin sorting out where business, organizational or procedural changes are required.

Educational opportunities are available from a broad spectrum of industries outside of shipbuilding. The Aerospace and Defense industries are an especially valuable resource. Through

organizations like the American Production and Inventory Control Society, a vibrant discussion of manufacturing productivity issues is going on in our own backyards. It is time that shipbuilders joined the discussion.

CONCLUSIONS

Most discussions of shipbuilding productivity involve process improvement. Regardless of how efficient a particular process is though, it cannot contribute to the goal without having the right material at the right place at the right time. Nor does the efficiency of a process contribute to the goal if its output is wasted on the wrong product. These are issues not of process but of Production and Inventory Management. We have endeavored to show that shipbuilding, like any manufacturing business, must address these issues in order to be competitive.

ACKNOWLEDGEMENTS

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Discussion on Paper #10-B, " Formal Manufacturing Approaches to Modern Shipbuilding" by Paul C. Powell and Charles I. Zigelman.

by Howard M. Bunch, Member

Numerous studies have indicated that U.S. shipbuilding productivity is well behind that existing in Japan and in Western Europe.¹²³⁴⁵ The typical explanation for this disparity has been that "cultural" differences exist which give foreign industry, especially the Japanese, the ability to operate more efficiently. But now we find that even when the Japanese build factories in the United States they are able to outperform their U.S. competitors, and that cultural differences can be overcome. An example is the joint venture between General Motors and Toyota--the New United Motor Manufacturing Inc. (NUMMI) facility, located in Fremont, CA--. This operation has, with a minimum amount of capital and attention from GM, outperformed any other GM facility, including the expensive and

¹Jenks, A. and Lamer, J.E., "A Tanker Owner's Perception of Newbuilding Costs and Prices in Japanese, North European, and United States Shipyards 1971 to 1981. Paper No. C-i presented to a Combined Symposium on Ship Costs and Energy, SNAME, Sept 30-Oct 1, 1982.

²Arado, J., Chevron Shipping Co., Remarks before the California Maritime Academy Symposium, May 19, 1983.

³Levingston Shipbuilding Company, with IHI Marine Technology, inc., *Cost Accounting Final Report*, Maritime Administration, Technology Transfer Program, March 1980.

⁴Weiers, Bruce J., "The Productivity Problem in U.S. Shipbuilding", Journal of Ship Production, February, 1985.

⁵Bunch, H.M., "Comparison of the Construction Planning and Manpower Schedules for Building the PD214 General Mobilization Ship in a U.S. Shipyard and in a Japanese Shipyard," Journal of Ship Production, February, 1987.

highly automated Saturn operation.¹ Numerous other examples can be cited.

Examination of the factors relating to productivity have led to the conclusion that concepts, such as those described by Powell and Zigelman, are the major reasons for the differences. Implementation of the formal manufacturing concepts of Just-in-Time (JIT), Manufacturing Resource Planning (MRP II), and Group Technology (one of the central themes of the National Shipbuilding Research Program [NSRP]) does pay. Reductions due to the effective implementation of these concepts have produced the following results:*

Feature	<u>% Reduction</u>
Manufacturing costs	20-40%
Lead times	50-75
Work-in-process inventory	30-60
Quality costs	50% plus
Floor Space	30-60
Total manpower	20-50
Purchasing cost	5-10
New-product development lead time	20-50
Design engineering costs	10-20
Engineering changes	10-20

Other benefits, harder to quantify, 'have also been realized by the companies reporting the above-listed reductions.³ They include increased flexibility, better response to customer service needs, faster communications, and greater return on assets.

The contribution made by Powell and Zigelman is to indicate that the concepts, successfully applied in other industries, are also appropriate for U.S. shipbuilding. It is one thing for an academic, such as I, to make such a case; it is quite another for two professional persons (like Powell and Zigelman), located at one of this country's major shipyards, to make the argument. Academics are often looked upon as being "ivory-tower" and unrealistic; hence

¹ Lubben, R.T., Just-in-Time Manufacturing: An Aggressive Manufacturing Strategy, McGraw-Hill, New York. 1968. pg xi.

²Gunn, T.H., Manufacturing for Competitive Advantage: Becoming a World Class Manufacturer, Ballinger Publishing Company, Cambridge, MA, 1987. pg. 164.

³Ibid.

their arguments are often discounted and generally ignored.¹ But this paper doesn't have that problem because both authors are actively involved in developing and implementing the concepts they describe into the operations at Bath Iron Works (especially MRP II).

Because of their experience in concept emplacement, it would be helpful if the authors would discuss some of the implementation dynamics that have occurred during the process. Here are some questions that arose in my mind as I reviewed the paper:

1. What formal manufacturing concepts have been (or are being) implemented at their shipyard?
2. Can the various concepts be independently implemented, and if so, what is the order of implementation?
3. What have been the major problems of their yard's implementation, and how have they been overcome?
4. Does it appear that the savings evidenced in other industries will also occur in their implementation? If not, why not?

I thank the authors for their presentation of this -paper. The fact that an American yard has people in its organization who are actively considering² the concepts of formal manufacturing is an indication, within itself, that productivity improvements are being made. That is a reason for long-term optimism.

¹While that argument may be appropriate in some instances, it is more often incorrect. As a person who has been on both sides of the fence (industry and academia), I feel that industry would do well to pay more attention to what academics are saying, especially in the area of productivity improvement. The close link-up between academia and industry has been found to be one of the essential structural features of the Japanese system. And the Japanese managers themselves often point out this feature as one of their strengths.

*And who are also actively involved in the implementation of the concepts.



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Electroslag Surfacing: A Potential Process for Rebuilding and Restoration of Ship Components

No.11A

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ABSTRACT

With construction of new commercial ships in U.S. shipyards at an all-time low and Congressional appropriations insufficient to maintain a U.S. fleet of 600 ships, the priorities of the surviving U.S. shipyards are changing from that of shipbuilding to ship rebuilding, restoration and repair.

This paper presents a review of the international literature on the most recent developments in thick section surfacing by electroslag surfacing (ESS) using strip or wire electrodes. The advantages of this newly-developed technique from Japan are explained in comparison with the conventional surfacing processes, such as submerged arc surfacing (SAS). A number of innovations and applications in this area are introduced to emphasize the substantial economical advantage of strip ESS for ship repair and manufacturing.

ESS with strip electrodes is capable of overlaying a wide variety of corrosion and/or wear-resistant deposits on structural ship components with half the dilution level and twice the deposition rate of its closest competitor, SAS. Because of its significant economical merits, strip ESS has already become the dominant thick-section surfacing process in many industrialized countries, particularly in Japan, the Soviet Union and parts of Europe.

NOMENCLATURE

ESS -- Electroslag Surfacing
ESW -- Electroslag Welding
ESR -- Electroslag Remelting
SAS -- Submerged Arc Surfacing
SMAW -- Shielded Metal Arc Welding
GMAW -- Gas Metal Arc Welding

INTRODUCTION

The future requirement for new Ships forecast by the Association of West European Shipbuilders (1) implies over a third of the world's shipyard

capacity active in 1985 will have to close if it is to be brought into line with demand. The Japanese shipbuilders have tried to maintain their capacity to meet the predicted market upturn in the early 1990's. The south Korean shipbuilding industry has flourished since 1978, and a concerted sales drive is presently under way to utilize as much capacity as possible.

Unfortunately, international competition and foreign labor rates have put virtually all commercial shipbuilding contracts out of reach for U.S. shipbuilders (2,3). This has created a fiercely competitive environment for the dwindling U.S. Naval contracts. With construction of new commercial ships in U.S. shipyards at an all-time low and Congressional appropriations insufficient to maintain a U.S. fleet of 600 ships (4), the priorities of the surviving U.S. shipyards are changing from that of shipbuilding to that of ship rebuilding, restoration and repair.

Various surfacing processes have been utilized to repair and rebuild corroded or worn ship components. The near-future need for more economical repairing methods must be increasingly emphasized in order to remain competitive internationally. Surfacing by the Shielded Metal Arc Welding (SMAW) and Gas Metal Arc Welding (GMAW) techniques are labor intensive with little opportunity for innovation and improvement. For many years, SAS with strip electrodes was considered the most cost-effective method to overlay large components, such as ship propeller shafts, and now still prevails in the United States. The Japanese and Soviet shipbuilders, in particular, have developed highly cost-effective methodologies to rebuild large ship components using an innovative concept known as "Electroslag Surfacing". Strip ESS exhibits substantial advantages over strip SAS in the areas of "recess control, surfacing quality and economic productivity. It has completely replaced the less economical surfacing methods in

Japan and the Soviet Union, but has yet to be "discovered" in U.S. shipyards and manufacturing industries. In fact, except for the current program sponsored by the National Coastal Research and Development Institute at the Oregon Graduate center, virtually none of America's manufacturing and shipbuilding industries have benefited from this new technology.

Due to the relative newness of ESS, the terminology throughout the world varies. For example, ESS is commonly referred to as (1) resistance electroslag surfacing, (2) electroslag overlay welding, and (3) electroslag cladding. The "strip" term is often added into these terminologies because filler metals are commonly utilized in the form of strip material.

In 1980, Kawasaki Steel (5) of Japan first developed a reliable strip ESS process and registered several patents in the Western world. This technique rapidly spread throughout Japanese industries (6). Several western European countries also adopted this process and are commercially manufacturing standard ESS equipment.

For the last seven years, a great number of innovations in ESS have been developed. However, it is surprising that strip ESS had not caught on in American industries. In 1985, Forsberg of Sandvik Steel published the first article about this technique in an American journal (7). Since that time, the manual, semi-automatic and SAS methods continue to dominate virtually all overlaying applications in the United States.

The purpose of this study is to critically review the international literature on ESS and strip ESS. Of particular emphasis will be the flux chemistries and the electrochemical reactions that are associated with this processing innovation. The advantages of surfacing with the strip ESS method will be reported. Also included will be the results of preliminary studies on strip ESS for practical applications on ships currently underway at Oregon Graduate Center.

CHARACTERISTICS OF ELECTROSLAG SURFACING

Although the strip ESS process is new, the fundamental principle of ESS is similar to that of the Electroslag Welding (ESW) and Electroslag Remelting (ESR) processes. Heat is generated by ohmic heating of a resistive slag by the passage of an electric current through a strip electrode, which is continuously fed into the molten slag pool. Figure 1 shows a schematic diagram of the ESS process.

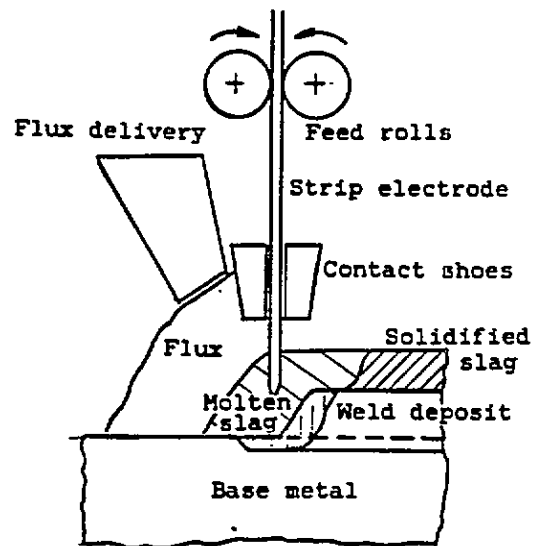


Fig. 1 Diagram of the Electroslag Surfacing process

Considerable differences in process detail exists between ESW and ESS. These include:

- (1) Welding position in ESW is vertical or near-vertical, whereas ESS is performed in the flat position;
- (2) The depth of slag pool and base metal dilution are substantial in ESW, whereas ESS requires only a shallow slag pool and produces low dilution;
- (3) The chemical composition of electrodes in ESW are usually similar to that of the base metal, whereas in ESS, they may (or may not) be substantially different; and
- (4) Travel speed in the ESS process is about 10 to 15 times greater than conventional ESW.

The process appearance of strip ESS is nearly identical to that of strip SAS, except SAS is primarily arc-functioning while ESS is generally arcless and produces heat by I²R (ohmic) heating of the molten slag. However, strip ESS exhibits a series of advantages over strip SAS in providing low dilution deposits, high deposition rates and better productivity.

The first important feature of strip ESS is low dilution in the deposits. In any surfacing process, a critical factor requiring precise control is the dilution ratio. The term, "dilution ratio", is expressed as:

$$\% \text{ Dilution} = B / (A + B) \times 100$$

where A is the cross sectional area of reinforcement of deposits above the

base metal surface, end B is the cross sectional area of the melted base metal below the workpiece surface. In terms of surfacing, it is necessary to keep low dilution levels because the surfaced layer has to maintain its desired inherent properties, like wear the Corrosion resistance. In SAS, the arc tends to penetrate more deeply and melt more base metal in comparison to ESS. For example, the strip SAS process typically produces a dilution ratio of 18% at a current density of 25 A/mm² (16.1 kA/in²), compared to approximately a 9% dilution ratio for the strip ESS process at 41 A/mm² (26.5 kA/in²) (8). Thus, the chemical composition of the overlay deposited by ESS will more closely resemble that of the filler metal.

The second important feature of ESS is its high deposition rate, which is a function of the current density. The use of a high current density in the SAS process will effectively make the arc hotter and stiffer, thus causing it to penetrate more deeply into the workpiece to increase the dilution ratio. On the other hand, the strip ESS process allows the use of almost double the current density to produce a much higher deposition rate while still maintaining a lower dilution level. This desirable combination of a high deposition rate and a low base metal dilution was the main incentive for Japanese industries to eliminate SAS in favor of ESS.

The third important feature of ESS is the feasibility of single layer deposition. By virtue of its low dilution and high deposition rate, surfacing can be most economically attained for the desired thickness of a corrosion or wear resistant layer with a designed chemical composition. Since the dilution level for strip ESS is almost half that of strip SAS, the strip ESS process can more likely eliminate the necessity for multiple layer deposits and result in greater cost effectiveness. Furthermore, thin overlays (about 3 mm or 1/8 in. thick) are far more advantageous by ESS because dilution decreases with overlay thickness for ESS but increases by SAS.

Further economical advantage is gained by the use of wide strip which deposits a greater surface area per unit time. Large strip widths (> 60 mm [2.4 in.]) are particularly more difficult to apply by SAS than ESS. In SAS process, the arc is struck at one corner of the strip and then starts traversing the entire width of the strip (5.9). The strip is consumed by the oscillatory movement of the arc across the strip. However, in ESS the strip is consumed uniformly across its entire width. This phenomenon is

illustrated in Figure 2 (5). The movement of the arc in SAS is not necessarily uniform and leads to inconsistent penetration and lack of fusion. For this reason, SAS has been limited to a strip width of 75 mm, whereas using strips as wide as 300 mm (11.8 in.) is not uncommon in ESS. A comparison between the strip ESS and SAS process is presented in Table I.

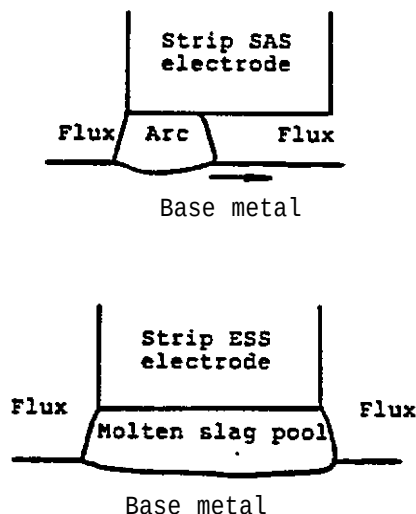


Fig. 2 Penetration characteristics of SAS and ESS

FURTHER INNOVATIONS IN ESS FROM JAPAN

External Magnetic Field for ESS

In 1980, Nakano and his colleagues in Japan (5) first developed an electromagnetic controlled strip ESS method called the MAGLAY process. During surfacing with wide strips (> 60 mm [2.4 in.]), the formation of undercutting and lack of fusion defects were found to be related to the flow pattern of molten slag and metal, which is driven by the electromagnetic force induced by the high values of the surfacing current. Electric current, flowing parallel from the strip to the bottom of the molten pool, makes both slag and metal move from the edges of the pool toward the center as illustrated in Figure 3. To counteract this force in the MAGLAY process, two direct current coils are mounted adjacent to the edges of the strip electrode resulting in counterbalancing magnetic forces. The use of an external magnetic field effectively (a) avoids undercut, (b) eliminates slag entrapment, and (c) produces a more uniform thickness of overlay.

The MAGLAY process was patented in both Japan and Europe, and adopted as

Table I Comparison between submerged arc surfacing and electroslag surfacing with stainless steel strip electrodes (6)

	SAS	ESS
Strip: dimension (mm)	60 x 0.5	60 x 0.5
carbon content (%)	0.015	0.015
Parameters: I (A)	750	1250
v (V)	26	24
v (cm/min)	10	16
Current density (A/mm ²)	25	41.7
Heat input (KJ/cm)	117	112.5
(KJ/cm ²)	19.5	18.7
Bead thickness (mm)	4.5	4.5
Dilution (%)	16	9
Deposition rate (Kg/h)	14	22
Flux consumption	0.65	0.5
Carbon content of single deposit layer (base metal: 0.18% C)	0.045	0.030

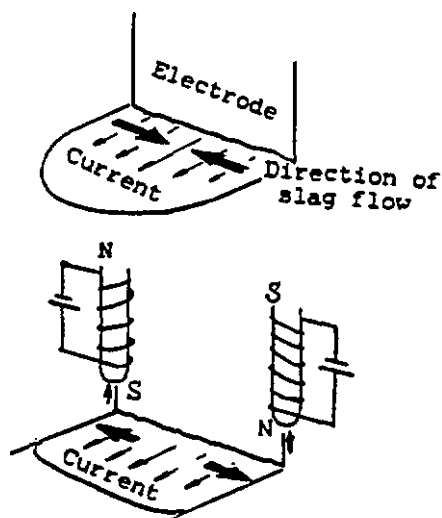


Fig. 3 Mechanism for eliminating undercutting by use of an external magnetic field (5)

the classical method of strip ESS in Europe and in many other countries. The strip-feeding head made by Soudametal (Belgium), which is now commercially available in the United States, employs a magnetic stirring device similar to the NAGLAY design.

"PZ" Arc-Facilitating Process

Strip surfacing at the Japan Steel Works also utilizes the electroslag mode of deposition but without the aid

of magnetic devices (6). Their process is called "PZ" and is illustrated in Figure 4. The important feature of

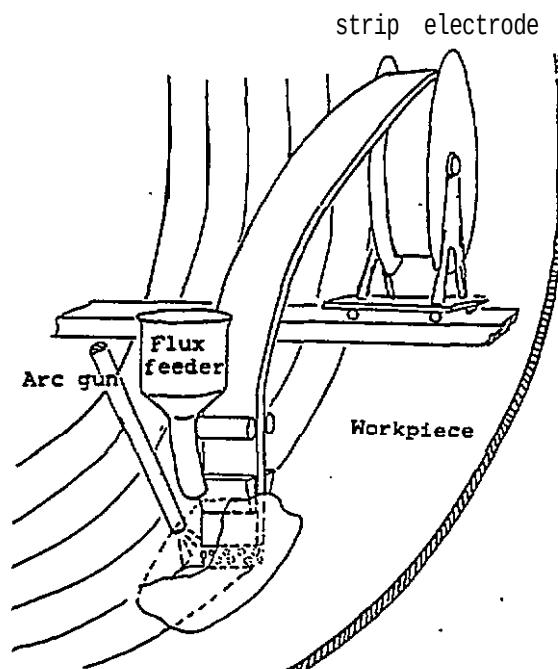


Fig. 4 PZ welding operation using 150 mm wide stainless steel strip (6)

this process is that an arc is always maintained at the strip extremities while most of the strip tip is still in the electroslag mode. The auxiliary arc facilitates bead tie-in and penetration, but avoids excessive dilution at the center of the bead caused by the Lorentz force. The 150 mm (6 in.) wide strips used in the "PZ" process provide a uniform overlay surface and a low dilution level in each bead.

"HS Process"

Kobe Steel Ltd. developed the high speed overlay welding technique called the HS Process (High Speed Strip Overlay Welding Process) which utilizes a strip that can be applied to an actual vessel even as a single layer process [10]. In terms of efficiency, the ES technique is claimed to utilize only a 75 mm (3 in.) wide electrode but competes attractively with the ordinary ESS process using a 150 mm (6 in.) wide electrode.

The key points of this technique are a high travel speed and a forward electrode inclination angle. Usually when the electrode travel speed exceeds 200 mm/min (7.8 in./min), the electrical transfer through the slag pool shifts from electroslag to submerged arc due to an increase in slag resistivity with decreasing slag superheating. The inclination angle of the electrode permits molten metal to enter the gap between the base metal and electrode and produces a buffer by preventing deep penetration into the base metal, and reduces the dilution of the surfacing layers.

INNOVATIONS IN THE SOVIET UNION

The ESS process is also widely used in the Soviet Union and Eastern Europe. A great amount of innovations were frequently reported in their technical journals. Although most articles are often lacking technical details, their basic designs and functions could still be reviewed.

Multi-Strip Feeding

The Paton Welding Institute started studies on ESS with two electrode strips in the late 1970's. This method was virtually unknown in the West but was widely used in the Soviet Union and the Eastern European countries (11-13). When two strips are arranged as in Figure 5, the molten slag may rise between the two strip electrodes and directly contact with air, causing considerable convectional agitation. Thus, the distance between two strips has become another important parameter to be taken into account.

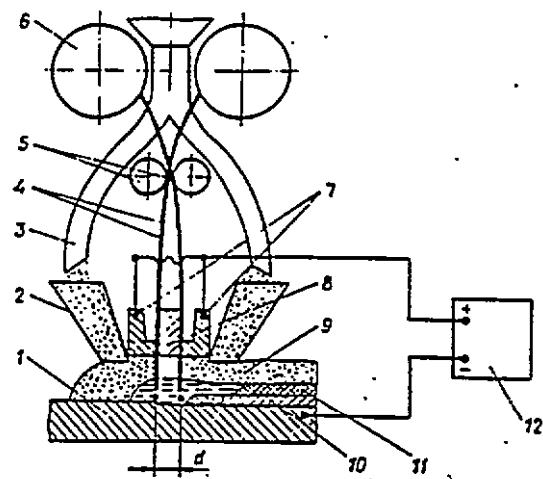


Fig. 5 Diagram illustrating deposition with two strip electrodes: 1) parent metal, 2) flux funnel, 3) flux feed guide, 4) strip electrodes, 5) feed roller, 6) spool, 7) current conducting jaws, 8) separator, 9) flux, 10) deposited metal, 11) slag, and 12) power source (12)

ESS with more than two wire electrodes has also been reported by V. Melikov (14). As many as 15 stainless steel electrodes (all 3 mm [1/8 in.] diameter wires) were simultaneously deposited over the entire width of the workpiece in the downhand position with artificial cooling. The low-carbon steel base plates were 70 mm (2.8 in.) thick, 500 mm (20 in.) long, and 340 mm (13.4 in.) wide.

A. Shyartser (15) claimed two hardfacing processes with a group of plate electrodes. In one case, the high Mn steel electrodes were deposited on worn dredger buckets. In another case, the high Cr casting iron electrodes were deposited on worn steel blades, as shown in Figure 6. The absence of cracks and formation defects made it possible to greatly increase the service durability of hardfaced components and reduce the production cost. For example, tests on the blades showed that their wear resistance was virtually identical to that of those blades hardfaced by brazing expensive alloys, whereas the cost of the former was almost a factor of 8 lower.

Plasma-Electroslag Deposition

A plasma-ESS method was reported by A. F. Batakshev et al. (16) to deposit high purity copper on low alloy carbon steels, as shown in Figure 7. The requirement of an auxiliary plasma is to counteract the high conductivity of the copper overlay.

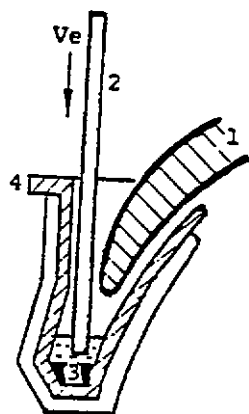


Fig. 6 The hardfacing of buckets: the diagram of the process 1) component, 2) electrode, 3) deposited metal, and 4) solidification mold (15)

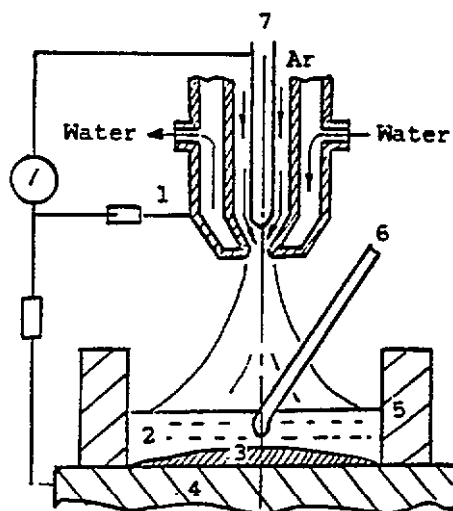


Fig. 7 Technological diagram of the plasma-ESS method (16): 1) plasma, 2) slag pool, 3) deposit, 4) base metal, 5) shaping/cooling device, 6) filler metal, and 7) electrode of plasma torch

In this process, the pilot arc is initially ignited in the plasma torch, followed by ignition of the plasma arc between the workpiece and the electrode of the plasma torch. A special flux is fed into the acting zone of the plasma jet. This flux contains elements with low ionization potentials (Ca, Na, Be, etc.), which increase the stability of the plasma jet due to a decrease in electrical resistance. The flux soon melts and forms a slag pool. When the base plate is heated to a sufficiently high temperature, the copper filler metal is fed into the slag pool, and the plasma torch and the mold are moved at the same time, resulting in the surface overlay.

The plasma ESS process provides a means to control the time dependence of heating the parent metal without the use of consumable electrodes. It also prevents contamination of the deposited copper. In a steady-state operation with the optimum parameters of 450-500A/55-60V and a 30-40 mm (1.4-1.6 in.) deep molten slag pool, the process could produce a 2-3 mm (0.1 in.) thick and 15-20 mm (0.6-0.8 in.) wide deposit in a single pass. The deposits of copper are free from pores, cracks and inclusions and contain no Si, W, Mn, and other commonly found impurities. The strength of bonding in the deposited metal is close to the strength of copper. The inventors (16) of this method claim that it could be used for repairing casting defects and hardfacing the surfaces of cutting tools.

Surfacing of Shaped Parts

A variety of examples could be found in the Soviet technical journals, reporting the use of ESS for the restoration of worn components having complex shapes. The surfacing of those shaped parts is performed by a modified electroslag welding process. A specially designed water-cooled mold is used to confine the molten slag and metal pool into the desired shape. Figure 8 illustrates the use of a shaped mold for surfacing the teeth of excavator buckets.

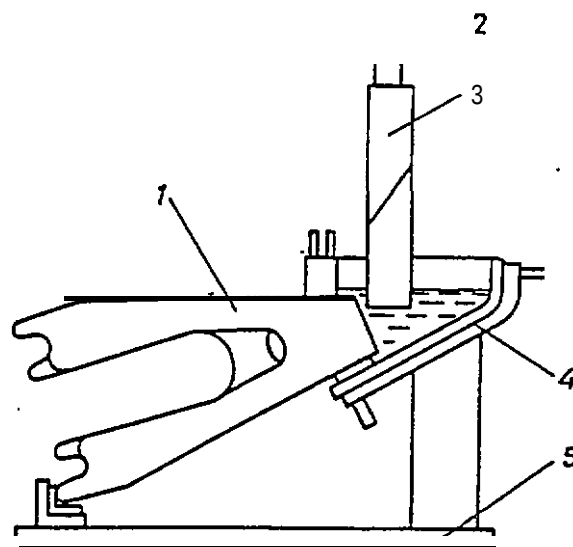


Fig. 8 Diagram illustrating the ESS of an excavator shovel tooth with varying chemical composition metal: 1) tooth blank, 2) standard head, 3) consumable electrode, 4) mold base, and 5) frame

As K. Valits indicated (17), to restore a complicated shape, the energy

of the melt must be sufficient to ensure both the transfer of the melt to the remote part of the mold end the complete fusion at that location. His experimental results verified that an increase in the voltage or the current density improved the quality of the deposited metal. However, when the current density was excessive, the slag pool could be "thermally saturated". The thickness of the deposited layer no longer increased, and the risk of short-circuiting was eminent.

For large-scale parts, the ESS operations were reported lasting more than 30 hours. To ensure a high quality of the deposited layer, the process must be stable and maintained without interruption. Stepanov (18) pointed out that the non-uniform adhesion of molten metal and the presence of a slag skull in long term ESS could cause rapid abrasive wear and local superheating in the tail part of the shaped mold. Thus, the inner surface of the mold has to be made of materials with high thermal conductivity and also high resistance to the action of molten slag and metal pools. In this case, copper and its alloys do not ensure the required thermal efficiency. He reported an application using a damping heat conducting layer in the solidification molds. The inner contact surface of the mold was made of a less thermally conductive alloy steel, followed by a damping heat conducting layer made of pure copper, and finally by the water-cooled structural steel base. This method provides proper control of the cooling rate of the deposited metal, and ensures a uniform temperature distribution in the molds.

Surfacing of Thin-Walled Components

Multi-electrode surfacing usually makes it possible to deposit, in a single pass, a layer of metal having the required thickness and width nearly equal to that of the components. Although its use for thin-walled components risks the possibility of burning through, a report from the Tashkent Institute of Railway Transport Engineers claimed the development of a successful example for the ESS of the friction wedge of the damper of wagons whose maximum wall thickness was only 5 to 6 mm (6 0.2 in.) (19), as shown in Figure 9.

In this process, nine electrode wires (each 3 mm [1/8 in.] in diameter) are deposited simultaneously, and an AC (not specified in that paper, but believed) power source with a hard external characteristic is used. The main parameters of this process include: 32 volts, an electrode feed rate of 0.51 m/hr (20 in/hr) and a surfacing speed of 1.8 m/hr (70 in/hr). A few factors

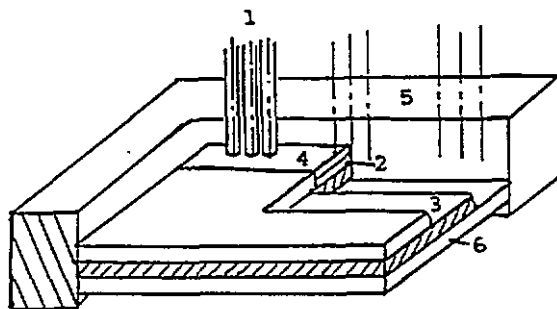


Fig. 9 Diagram of multi-electrode ESS of vertical surface of the friction wedge of the damper of a wagon: 1) axes of electrode, 2) slag pool, 3) metal bath, 4) flux, 5) copper shaping device, and 6) component (19)

are critical to prevent burn-through defects, including the slag pool depth, the electrode extension, and the stationary (without longitudinal displacement) feeding time of electrodes in the initial stage of surfacing for inducing the slag pool and the final stage of surfacing for filling the crater. By increasing the initial stationary feed time, the molten filler metal spread ahead of the electrode tip thermally protecting the base metal. A wear-resistant layer of 6-12 mm (0.24-0.47 in.) thick and 135 x 180 mm (5.3 x 7 in.) in size is reported being deposited in a single pass on the surface of mild steel.

surfacing Layers With Compositional Gradients

In many cases of service, the different portions of an individual hardfaced work piece experience different degrees of wear. The geometrical loss due to the uneven wear reduces its life prematurely. The rational solution to this problem is to make the working surface from composite metal, whose wear resistance changes gradually to accommodate the differences in the severity of wear at different locations on the workpiece. By producing a part that wears uniformly, the functional life of the part is lengthened.

Shyartser (20,21) developed a special surfacing process to provide a wear gradient for an excavator shovel, which is illustrated in Figure 8. In service, the abrasive wear on its rear face increased substantially from the tail end of a tooth to its apex. In order to extend its life, a prescribed variation in chemical composition of the deposited metal was obtained by depositing a special composite electrode which consisted of two dissimilar metals meeting along an inclined plane (Figure 10). In this case, the

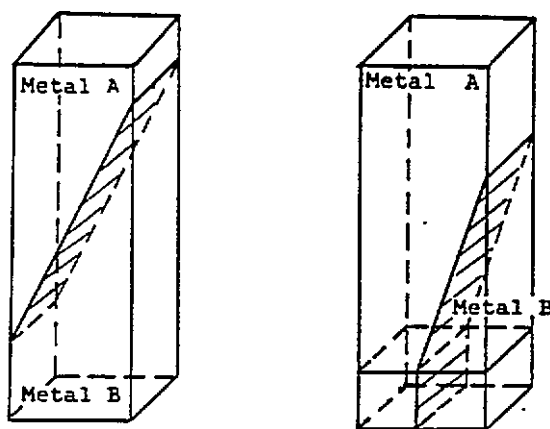


Fig. 10 Two composite electrodes designed to provide surfacing layer with compositional gradient (20,211

electrodes consisted of a high Mn steel and a high chromium iron. A calculation had to worked out for determining the combination ratio of electrode materials to obtain an overlay with the desired gradient in chemical composition. As illustrated in Table II, the surfacing deposits adjacent to the front face of teeth were a wear-resistant Cr iron, changing (towards the rear face) into a high Mn steel. In service, those hardfaced teeth maintained a consistent geometry (21).

Recently, Gulakov et al. (22) analyzed both the buffer effect of the weld pool and the element transfer from the base metal (or the previous deposited layer) on the final gradient of the chemical composition. They constructed a model of the molten surfacing pool and proposed ways of reducing the difference between the required and actual compositional

variation. A programming device was also designed to facilitate the gradient method of surfacing (23).

PROCESS DETAILS

Equipment

The strip feed rates required for the ESS process are within the ranges which characterize submerged arc wire welding and strip SAS. The equipment for strip SAS is essentially the same as that required for strip ESS (8), schematically illustrated in Figure 1. Thus, conventional DC constant voltage welding machines, capable of 1200 amps or more at 100% duty circle, can be easily converted to ESS by attaching a special strip feeding head. A few types of strip feeding heads are commercially available in European countries. Oerlikon provides a popular strip feeding head for strip electrodes in the width range of 50 to 125 mm (2 to 5 in.), which is made by Soudometal Company of Belgium.

The popular strip feeding head is basically an improved MAGLAY process device originally developed by Kawasaki Steel. The wheels and counterwheels provide pressure and guide the strip into the feeding nozzle. Both the pressure and the gap are adjustable to allow variation in the thickness of strips. A pair of magnetic solenoids are fitted along the sides of the strip feeding nozzle. The magnetic intensity of the solenoids can be adjusted separately by a control box to ensure the desired fluid flow characteristics of the overlay.

Direct current, constant voltage (DC-CV) power sources are recommended for ESS. Surfacing is always carried out using reversed polarity (the strip

Table II Variation in Chemical Composition and Mechanical Properties of Deposited Metal from the Front to the Rear Faces of Teeth Shown in Figure 8 (23)

specimen No.	Distance from Front Face mm (in.)		Content of %						HRC	Coefficient of Wear Resistance
			C	Cr	Mn	Si	Ni	Mo		
1	10	(0.4)	3.0	20	1.5	1.0	1.5	1.0	50	4.3
2	30	(1.2)	2.7	16	3.8	0.9	1.2	0.8	46	3.2
3	50	(2.0)	2.3	12	6.1	0.7	0.9	0.6	38	2.8
4	70	(2.8)	2.0	8	8.3	0.6	0.6	0.4	32	2.2
5	90	(3.6)	1.6	4	11.0	0.4	0.3	0.2	26	1.8
6	110	(4.4)	1.3	--	13.0	0.3	--	--	—	1.3

electrode is connected to the positive terminal of the power source) in order to ensure adequate fusion to the base metal. Since the optimal current density for ESS is around 40 A/mm², the output rate of power sources at a 100% duty cycle should meet the following minimum load handling requirements: 1250A for 60 x 0.5 mm (2.4 x 0.02 in.) strips; 1800A for 90 x 0.5 mm (3.5 x 0.02 in.) strips; and 2400A for 120 x 0.5 mm (4.7 x 0.02 in.) strips (8). In practice, such high current levels are usually obtained by connecting two power sources in parallel.

Flux Chemistry

The flow of electrons in a surfacing or welding process may take place either through an arc or molten slag depending on the relative conductivity of the medium through which the electrons pass. In strip ESS, it is very critical to establish stable ohmic (arcless) conduction of electricity through a shallow slag pool of only about 20 mm (0.79 in.) depth. Other factors which are essential in ESS are the wettability of the slag, the bead profile, the slag removal, the recovery of alloying elements, and the reduction of gas generating components.

To maintain a stable electrosag mode through a shallow slag, a special flux composition had to be developed. Such fluxes must provide greater electrical conductivity than would be needed for normal electrosag welding of the same plate material. Adding large quantities of fluorides, mainly CaF₂ and NaF and/or semiconductors, such as TiO₂ and FeO, can greatly raise the electrical conductivity of molten slag without risk of generating arcs. However, large quantities of TiO₂ in slag cause a deterioration in the detachability of the slag. Therefore, additions of fluorides are more preferable (8).

The level of electrical conductivity of slag is closely related to the fluoride content in the flux, as illustrated in Figure 11. The IIW (International Institute of Welding) Document XII-A-4-81 (24) described the effect of calcium and sodium fluoride additions on the electrical conductivity of the 3CaO-3SiO₂-Al₂O₃ ternary system, and indicated that when the fluorides were less than 40% (balance ternary), the submerged-arc mode prevailed; and when more than 50% fluorides, the electrosag mode prevailed. In terms of the electrical conductivity of the slag, this corresponded to a transition range of 2 to 3 n⁻¹cm⁻¹. Above 3 n⁻¹cm⁻¹, a stable electrosag mode is easily achieved. However, to restrict the generation of fluoride type gases (due to a reaction: 2CaF₂ + SiO₂ + 2CaO +

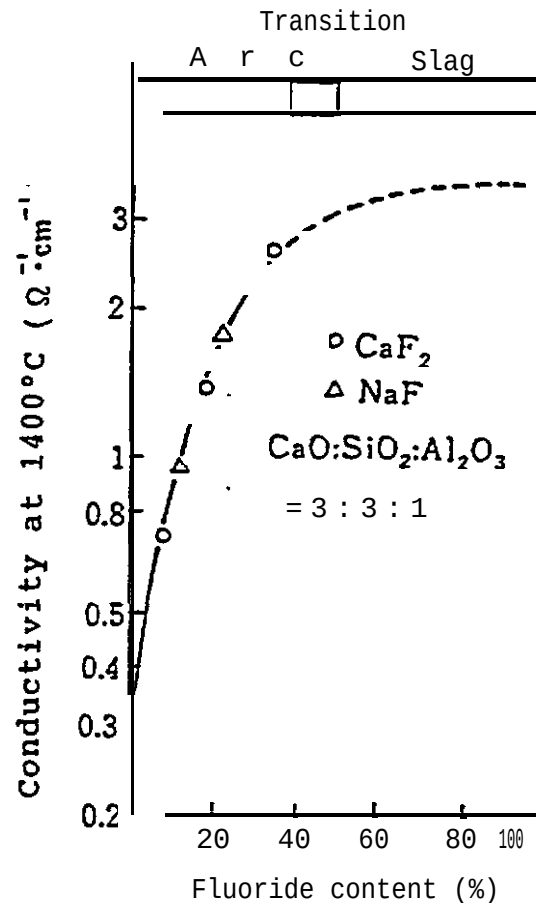


Fig. 11 Effect of fluoride content in flux on electrical conductivity and current conduction type during Strip ESS (24)

SiF₄), additions of CaF₂ were usually held at slightly less than 50%.

In Japan, fluxes for stainless steel overlays are principally supplied by Kawasaki Steel and Kobe Steel (6). The Kawasaki XFS-150 is a fused flux with an electrical conductivity of about 3 n⁻¹cm⁻¹ at 1700°C. It was patented in the United States in 1984 (25). The composition of Kawasaki's patented flux contains 50-60% CaF₂, 10-20% SiO₂, 5-25% CaO and 10-30% Al₂O₃ in a ratio of SiO₂/CaF₂ of at least 0.20 and a ratio of CaO/SiO₂ of at least 0.50.

In the Soviet Union, a series of fluxes were developed for ESS. The ANF series fluxes are of high fluoride contents (> 50%) and high electrical conductivities (26). The AN-series fluxes, which were originally used in ESW, are also used for the thick layer build-up. Their fluoride contents are below 25% and electrical conductivities are comparatively low (26). Some new fluxes were occasionally reported being

developed for certain special ESS processes (27). however, no concrete compositional information was presented.

In Western Europe, fluxes EST 122 and 201 are commonly used [8]. Some characteristic data of these two agglomerated fluxes are given in Table III. The flux EST 122 is specifically designed to be used for the depositions of all types of 300 and 400 series stainless steel strips. The flux EST 201 is designed for the deposition of the Ni-base alloys, such as 825, 600, 625 and 400 (7).

In the United States, the commercially available fluxes for ESS can be ordered through Sandvik Steel or Oerlikon, which are basically very close to those available in the European market. The Sandvik 375 welding flux is a universal flux for ESS (Table III). Its electric conductivity is 5 to 6 times greater than an ordinary submerged arc welding flux. It can be used to deposit corrosion-resistant cladding using 300 and 400 series stainless steel strip electrodes and certain hardfacing electrodes. Fluxes suitable for depositing nickel-base alloys are also available in the Sandvik series 17).

In a recent study (28) of ESS with stainless steel wire electrodes, fluxes of the CaF_2 - CaO - Al_2O_3 system were studied. It was noticed that at higher CaF_2 percentages, (i.e. beyond 70%), the process was once again that of arc conduction. As the percentage of the CaF_2 in the flux increased, there was a corresponding increase in the conductivity level. This, in effect, raised the current at the same wire feed speed, and gave rise to burn back problems. Hence, at higher CaF_2 percentages, arcing could be visible on the surface of the molten slag. On the

other hand, below 40% CaF_2 , the observed arcing was submerged-arc type as illustrated in Figure 12.

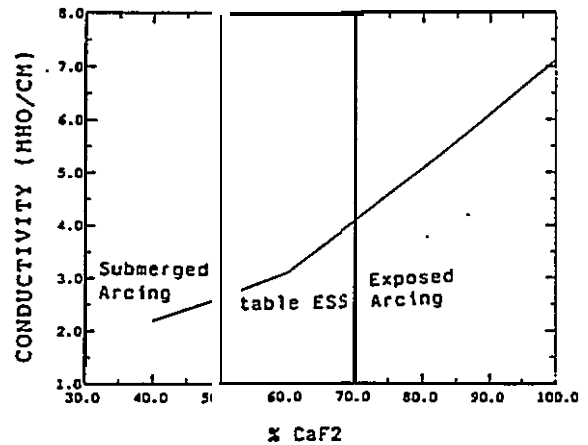
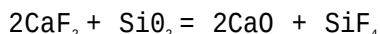


Fig. 12 Effect of CaF_2 content in flux on electrical conductivity and current conduction mode during wire ESS (28)

Usually, CaO , SiO_2 and Al_2O_3 are common additions for optimizing the conductivity level of a CaF_2 -based flux. The practice at the Oregon Graduate Center (28) indicated that optimizing the viscosity level of molten flux is of the same importance. Since conductivity and viscosity have an inverse relationship, adjusting the flux composition becomes a complex problem. SiO_2 is one compound which has a major influence on slag viscosity and slag flow (25). To maintain the desired viscosity, it is necessary to control a $\text{SiO}_2/\text{CaF}_2$ ratio of at least 0.2 and to avoid evolution of toxic gases like SiF_4 by the reaction:

Table III Fluxes Available From European Sources (7,8)

content	EST 122	EST 201	Sandvik 375
(%) Alkaline & alkaline earth oxides (CaO , MgO , K_2O , Na_2O)	50	50	50
(5) Amphoteric & alkaline earth oxides (Al_2O_3 , TiO_2 , ZrO_2)	25	25	25
(%) Silicon dioxide (SiO_2)	10 max	5 max	10
(%) Fluorides (expressed in F)	30	25	30
Flux density (kg/dm^3)	0.85	0.85	0.85
Flux consumption rate (kg flux/kg strip)	0.5	0.5	



In addition, as specified by the Kawasaki patent (25), the minimum requirement for CaO/SiO_2 ratio should be about 0.5 for stable ESS (Figure 13).

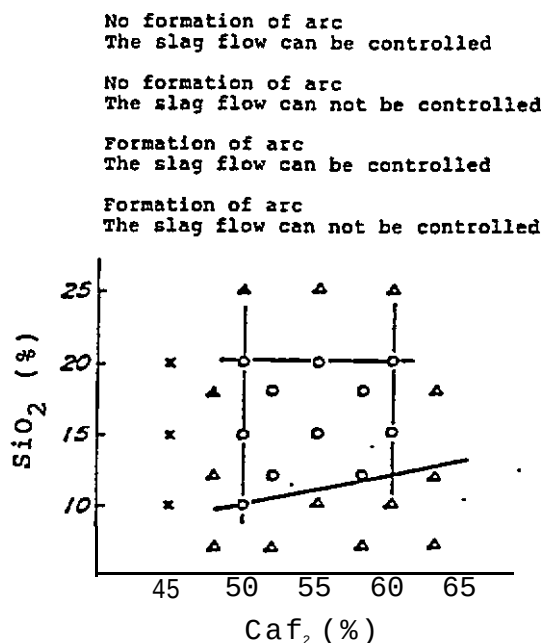


Fig. 13 Effect of CaF_2 and SiO_2 content on slag viscosity and process stability (25)

Fluxes can be either bonded or fused. The particle size of fluxes is generally controlled to 18/60 mesh, being smaller for SAS than for ESS (7). Because all fluxes are prone to moisture pick-up, they should be baked at 250-350°C (480-660°F) before using and held warm in the production area. Kawasaki claims that the ESS process is more tolerant of moisture pick up in the flux than the SAS process (6). However, the studies (28) have found that baking is necessary for the bonded fluxes because of their strong tendency to absorb moisture. Moisture in the flux induces porosity in the overlay, and this is especially severe when the alloy of the strip has a narrow temperature gap between its liquidus and solidus.

Strip Electrode Sizes

The thickness of the strip electrode is always expected to be thin enough to facilitate coiling into rolls, in order to conveniently feed cladding during ESS. The Japanese appear to have standardized the 0.4 mm (0.016 in.) thickness for all strip widths. This differs from the European practice where a 0.5 mm (0.02 in.) thickness is most common.

The ESS process favors the use of wide strip as long as the capacity of the power supply is adequate to provide 1000-2000 amps, typically. That is because, at a given layer thickness, the most marked effect of increasing the strip width is a decrease in dilution and penetration. Usually, the penetration of overlay deposits is always more accentuated at the sides of the bead. However, the relative importance of this localized higher penetration is lessened when (a) the strip width is increased, and (b) bead overlapping is considered (8). Strip widths of 75 mm (3 in.), 100 mm (4 in.), and 150 mm (6 in.) are most common in Japan; while widths of 60 mm (2.4 in.), 90 mm (3.5 in.), and 120 mm (4.8 in.) are more popular in Europe. In the U.S., through Sandvik Steel (7), a variety of strip electrodes are available commercially for ESS.

Voltage

Voltage is perhaps the most critical controlling parameter in the ESS process. In most ESS practice, the working range of voltage values is quite narrow, because of the shallow depth of the molten slag pool (5-10 mm [0.2-0.4 in]). Forsburg (7) reported that, for a fluoride-based flux, the stable range is usually 26-28 volts. When the voltage is below 24 volts, it is difficult to initiate the process, and the strip tends to stick to the base metal resulting in short circuiting. On the other hand, above 28 volts, the process starts arcing on the surface of the flux, and slag spatter becomes violent. Therefore, an accurate control in voltage is extremely important. Practices at the Oregon Graduate Center (28) found that the optimum voltage was closely related to the actual depth of the molten slag pool, and a stable ESS process could be performed at 22-24 volts. In addition, it was also shown (28) that an intentionally increased open-circuit voltage is beneficial to the initiation of ESS.

Even within the stable voltage range, fluctuations in voltage also affect the dilution, penetration and geometry of the surfacing layer as shown in Figure 14. By increasing voltage, the rising heat input increases the volume of base metal melted, thereby increasing the level of penetration and altering the geometry (width/thickness) of overlays. Nevertheless, the dilution level still remains essentially constant or only slightly decreases with increasing voltage.

Current

ESS has been reportedly used only with DC reverse polarity (electrode

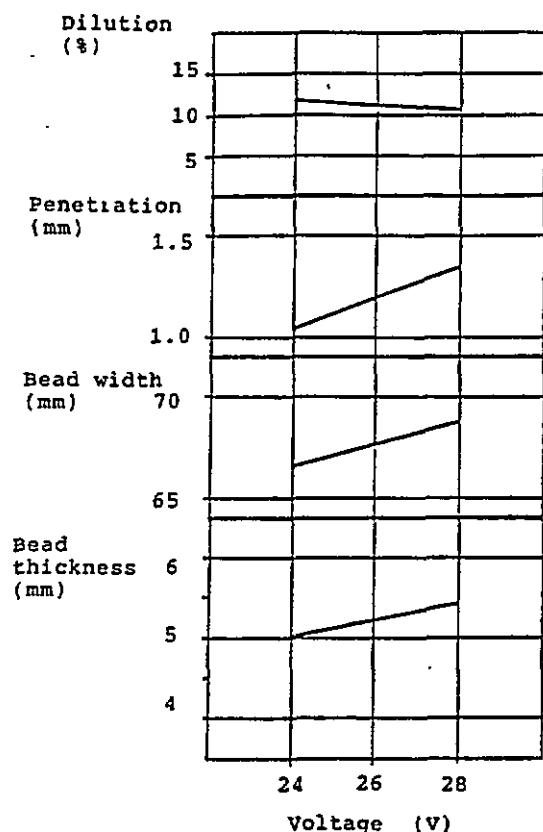


Fig. 14 Influence of voltage for strip electrode, size 60 x 0.5 mm at 1250A surfacing current and 150 mm/min travel speed (7)

positive). DC straight polarity results in an unstable operation at the normal working current density range for ESS, which is approximately twice that for the SAS process.

At a given voltage and surfacing speed, variations in the ESS current directly affects penetration, bead width and thickness, as shown in Figure 15. The dilution of surfacing layers is the result of two factors--the penetration into the base metal, and the thickness and width of the beads. Hence, the combined effects of both factors cancel each other, resulting in little change in the dilution.

Stable and quiet welding conditions can be achieved within a given range of ESS current. The optimum current density for strip ESS is around 40-45 A/mm² (26-29 kA/in²). At the higher values of current density, the amount of slag spatter increases and the depth of the slag pool has to be raised to stabilize the operation.

Travel Speed

At a given welding current and voltage, increasing the travel speed

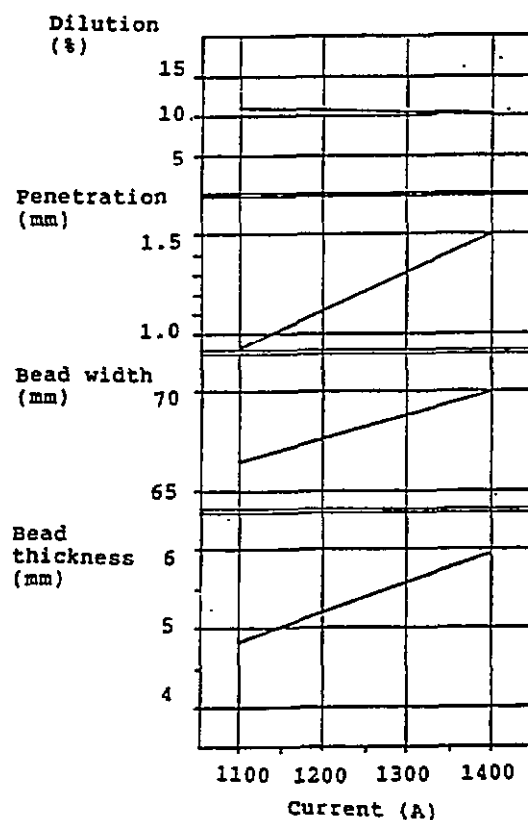


Fig. 15 Influence of current for strip electrode size 60 x 0.5 mm at 26V and 150 mm/min travel speed (7)

tends to increase dilution and penetration, while decreasing bead width and thickness, as shown in Figure 16. Increasing the travel speed in effect reduces the heat input and, thereby, decreases the electrical conductivity of slag. The ESS process can only be stable when sufficient contact area between the molten slag pool and the melting strip is maintained. An excessively fast surfacing speed may cause the strip to be in contact with cold flux or insufficiently heated slag, thus resulting in sporadic arcing and process instability.

In general, the travel speed should be optimized for both economy (fast speed) and an adequate thickness of surfacing layer (about 4-6 mm [z 0.2 in.]) (81). Excessive travel speed results in not only a bead thickness less than 4 mm, but also in the risk of the formation of undercutting. On the other hand, too slow a travel speed results in a bead thickness above 6 mm. Then, the wetting angles of beads become too steep and slag entrapment may occur at the overlaps. In general, the optimum travel speed range is about 160-200 mm/min (6-8 in/min), which results in about a 10% dilution level,

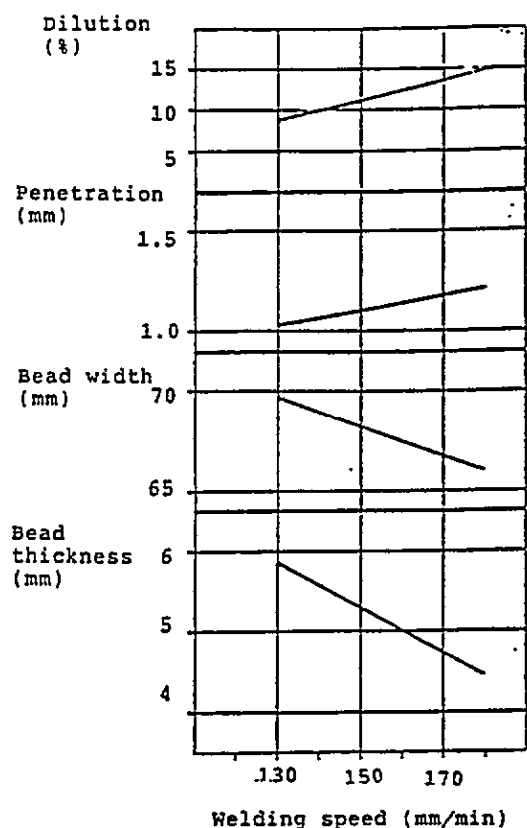


Fig. 16 Influence of travel speed for strip electrode 60 x 0.5 mm at 1250A and 26V (7)

and consumes about 0.15 kJ/mm² (96 kJ/in²) heat input (28).

Other ESS Parameters

The strip extension, i.e. the conventionally called "stick-cut" (the free length of the strip extending from the contact jaws to the slag pool), is not critical in this process. Usually it may vary from 25-40 mm (1-1.5 in) (7). However, the greater the strip extension, the greater will be the deposition rate for a given setting as in normal welding operations due to ohmic heating of the filler strip.

The depth of flux burden should just cover the strip extension or up to 5 mm over the extension length. Typical flux depth ranges from 30-45 mm (1.2-1.8 in) (7). If the flux is too shallow, arcing develops as the slag depth is less than the arc gap" for the given voltage and conduction through the slag is "open-circuited".

The limitation of parent metal thickness depends on the heat input during ESS and the width of strips used. Forsburg (7) reported that in order to ensure sound ESS with a 60 x 0.5 mm (2.4 x 0.02 in) strip, the

minimum parent metal thickness is 40 mm (1.6 in.). The minimum diameter of curved surface for ESS with the 60 x 0.5 mm strip electrodes is 250 mm (10 in.) for external surfacing, and 450 mm (18 in.) for internal surfacing. This is ideally suited for the rebuilding of ship propeller shafts. Practices at the Oregon Graduate Center (28) have found the above limitation was relatively conservative. For example, with a 60 x 0.5 mm strip, ESS could be performed on 25 mm (1 in.) thick plates.

QUALITY CONTROL

Stability of Process

Although economically desirable, the major problem associated with using a faster surfacing speed is the stability of the process. If the surfacing speed is excessive, the slag pool becomes cold and erratic submerged arcing will occur.

One possible way to avoid this trouble is to judiciously select an angle of inclination (downhill) for the base plate. This causes the molten slag and metal pool to flow slightly ahead of the strip, thus ensuring that the strip is in appreciable contact with the molten pool in spite of an increase in the surfacing speed.

The inclination angle of the parent metal also affects the dilution level of surfacing layers, as shown in Figure 17. It has been recognized that the downhill position slightly favors a decrease in dilution, which is sometimes important for the quality of microstructure of single pass deposits.

As mentioned above, the current and voltage of the ESS process can only vary within a narrow range. Maintaining optimum power parameters is very critical in order to continue a stable surfacing process. If disturbances in current or voltage can be monitored and recorded, a coefficient of stability could be used for quantitative determination, which has been used in the Soviet Union since 1962 (11,29).

The electrode inclination angle also influences the dilution, the width of bead and the thickness of overlay (7,8,10), as illustrated in Figures 18, 19, and 20. A greater electrode inclination angle (forehand) results in decreased dilution, wider bead and reduced thickness. In fact, the Japanese "HS" process (mentioned in the previous chapter) is based on this principle. When attempting to increase the surfacing speed for better economy, this geometrical parameter becomes extremely important. At a greater electrode angle, slag is pushed ahead of the electrode. Hence, care must be taken

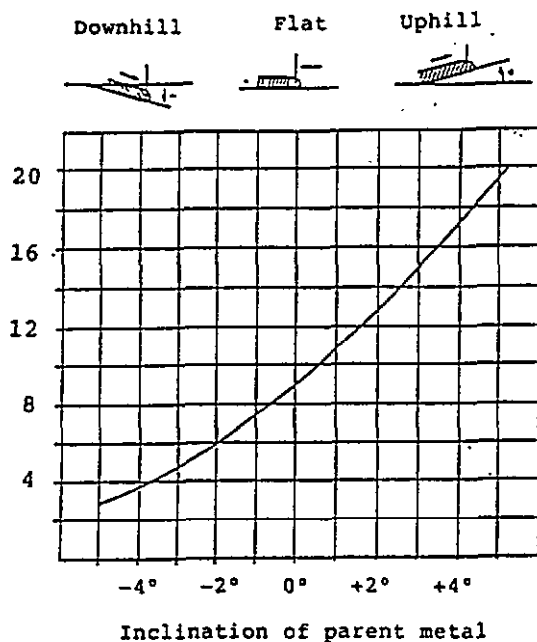


Fig. 17 Influence of inclination of base metal on dilution for strip electrode size 60 x 0.5 mm, 1250A, 26V and 140 mm/min travel speed (7)

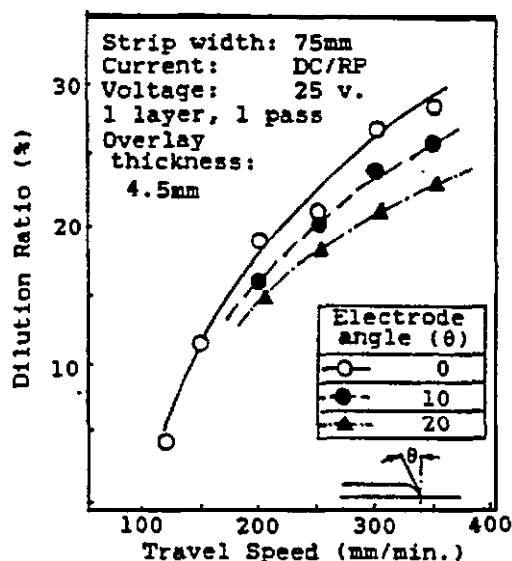


Fig. 18 Effect of travel speed on dilution (10)

when selecting the electrode angle, particularly when the curvature or the inclination angle of the parent metal is also being considered.

Residual Stresses

Surfacing stresses are principally induced by shrinkage of the overlay during solidification. These stresses may result in cracking, deformation,

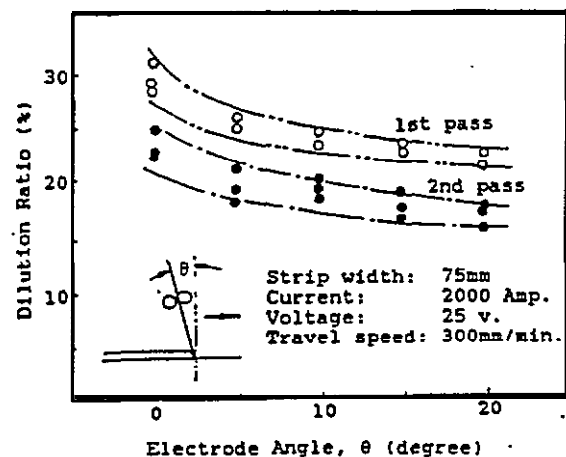


Fig. 19 Effect of electrode angle on dilution (10)

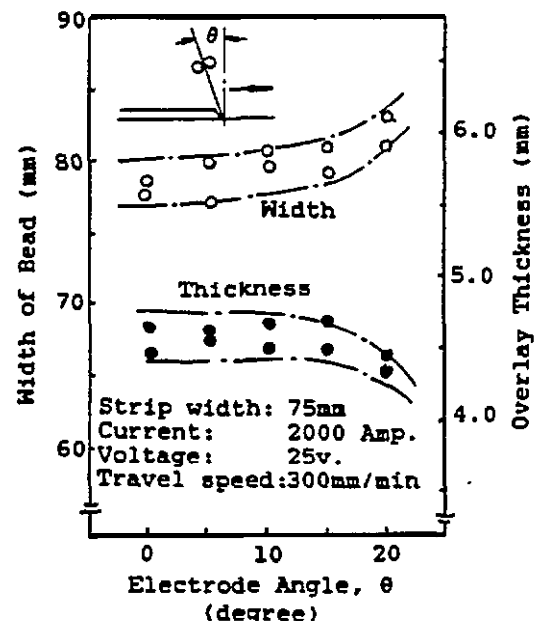


Fig. 20 Influence of electrode angle on the bead width and thickness (10)

disbonding and reduction in designed resistance to wear and corrosion, as summarized by Babiak (30,36).

The value of stress induced in the surfaced parts depends on the degree of solidification shrinkage, the difference in coefficient of thermal expansion between the filler metal and base metal, and the phase changes occurring in the surfacing materials. To simplify this complex problem, the residual stress developed in overlays can be classified in three categories:

- (1) Surfacing a massive part of soft steel with a nonhardening material. The surfacing layer and the

heat affected zone of the parent metal are stressed in high tension, whereas the parent metal in contact with the overlay is in compression (Figure 21). A good example of this case is the cladding of mild steels with a corrosion-resistant stainless steel coating.

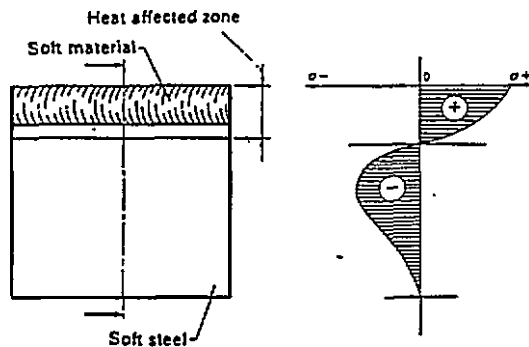


Fig. 21 Stresses in a component of low carbon steel alloy surfaced with a soft alloy (30)

- 12) Surfacing a mild steel with a hardenable
states are just opposite to those of case 1 as shown in Figure 22. Here the surfacing layer is in compression while the base metal is in a tensile state of stress. This situation is common for some hardfaced parts.

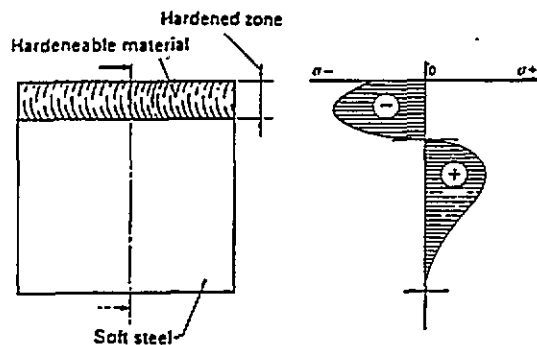


Fig. 22 Stresses in a component of mild steel surfaced with hardenable material (30)

- (3) Surfacing a hardenable steel with an austenitic alloy. The stress states can become very complicated (Figure 23). The surfacing layer is subjected to tensile state of stress. The hardened part of the heat affected zone is subjected to greater compressive stress. Below this hardened layer in the heat affected zone, tensile stresses

appear to be enhanced. In the part of parent metal farthest away from the surface overlay, the stress state becomes compressive once again.

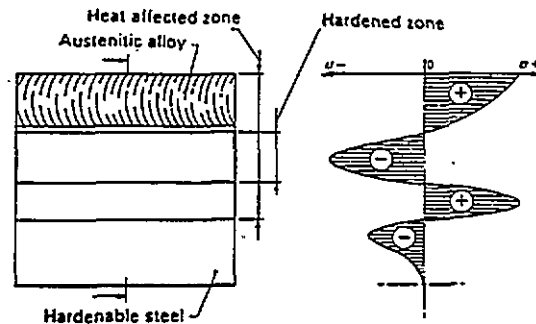


Fig. 23 Stresses in a component of hardenable steel surfaced with an austenitic alloy (30)

Blaskovic (13) reported measurements of stress in the ESS layers deposited by the dual strip method. It was shown that annealing (620°C/20hr + 650°C/10hr) eliminated the stress peak, but a tensile stress zone still remained.

The actual values of stresses depends on a variety of factors. Among them are the surfacing procedure, the consideration of the intermediate layer and the stress state of surfaced parts in service. To minimize the harmful residual stresses in surfaced work pieces, the following are recommended:

- 11) The proper selection of both the base metal and the filler strip materials to provide satisfactory metallurgical bonding and the desired chemical and mechanical properties;
- (2) The selection of process parameters, such as the travel speed, the heat input, and the number of passes to produce the required dilution, penetration and bead shape;
- (3) The possible application of an intermediate layer with transition chemical composition and properties having the strength and thermal expansion properties to buffer the undesirable metallurgical properties of a direct bond between filler metal and parent metal;
- (4) The cost-effective use of preheating for the parent metal only when necessary.

Disbanding Problem

Since the surfacing process may involve depositing a layer of material having different chemical composition and mechanical properties (particularly the thermal expansion coefficient) than those of the parent metal, bonding strength between the overlay and the substrate becomes an important metallurgical consideration. This can be critical when surfaced parts are designed for special environments, such as elevated temperature or high hydrogen pressure.

For example, consider the surfacing of steel with the corrosion-resistant austenitic stainless steel. Depending on the Cr_{eq}/Ni_{eq} ratio of the deposited layer, a dual effect is noticed:

- (1) Austenite grains may coarsen at the fusion zone between deposited metal and the base metal. This coarse grained austenitic structure, being lower in strength, is susceptible to disbonding. Furthermore, for applications in severe chemical or nuclear environments, diffusion of hydrogen to the grain boundaries also produces a weakening of the fusion zone structure, which once again leads to disbonding (31). To avoid this, it is desirable to limit the austenitic grain coarsening to 0.5%. The coarse grain percentage is defined as the length of the austenite grain boundary, which is parallel to the fusion boundary, divided by the length of the fusion boundary. To achieve this, a Cr_{eq}/Ni_{eq} ratio of at least 1.85 is used, according to the Kawasaki Steel European patent, as shown in Figure 24 (31)

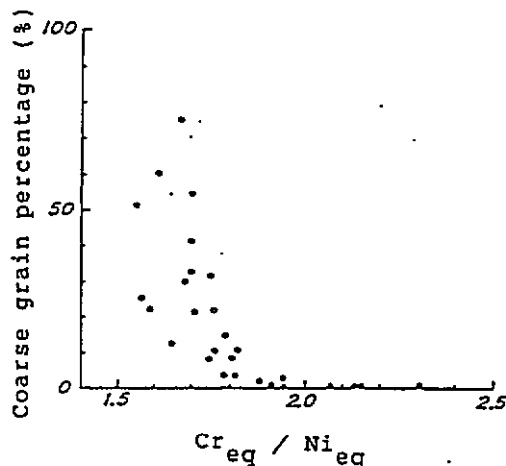


Fig. 24 Effect of Cr_{eq}/Ni_{eq} ratio on coarse grain percentage (31)

- (2) The percentage of delta ferrite present in the fusion zone is a function of the Cr_{eq}/Ni_{eq} ratio. Although, the presence of delta ferrite has a beneficial effect of preventing both hot cracking and precipitation of grain boundary carbides, it can also transform into the sigma phase at 500°C or above. The presence of the sigma phase leads to disbonding, as well. Thus, the acceptable level of the delta ferrite content is about 8 to 10%, and this is once again achieved by maintaining a Cr/Ni equivalent ratio of at least 1.85, as predicted by the standard Schaeffler diagram (31).

In Japan, a number of research projects were devoted to hydrogen-induced disbonding susceptibility in pressure vessels made of 2-1/4Cr-1Mo steel with an austenitic stainless steel overlay deposited by strip ESS. Tanaka (10) claimed that the Kobe Steel Ltd. HS process could improve the disbonding problem. This improved disbonding resistance was attained by a greater cooling rate and much finer grains near the interfaces. The HS process inhibited the development of coarser grains in the heat affected zone of the base metal, and might be effective in the prevention of under-clad cracking or cold cracking. The Japan Steel Works long-term studies (32-35) considered that the surfacing parameters hardly affected the disbonding resistance of surfaced parts. For example, austenitic/martensitic duplex structure provided the overlay layer with good disbonding resistance, which was obtained by modulating the process in a manner similar to the Kobe Steel "HS" process. They claimed the residual stress in the through-thickness direction at the bond between the first layer deposit and the base metal was smaller than that of the conventional ESS. The low residual stress provided an ESS technique that could produce overlays with good disbonding resistance.

APPLICATIONS OF STRIP ESS

Presently, strip ESS is entirely foreign technology, which has further widened the construction cost gap between the Asian shipyards and U.S. shipbuilders. However, utilization of this foreign technology and the substantial improvements in strip ESS anticipated at the Oregon Graduate Center will enhance the economic position of U.S. shipyards to rebuild worn, eroded or redesigned structural ship components, such as large propeller shafts, rudder horns, strut shafts, deeply corroded portions of the hull, hawse pipes and leading edges of rudder castings.

This process, though fully automatic, is also portable in the shipyard when a conventional land inexpensive) carriage system is used to mobilize the strip ESS system in remote locations. A typical carriage system can handle 1500 amps and can pull power cables 30 m (100 ft.) long while being either track or manually guided. These carriage systems have been commercially manufactured in the United States for many years for Submerged arc welding applications, particularly in shipyards.

CONCLUSIONS

Based on a computerized search of the international technical journals on the subject of electrosag surfacing, a critical review was performed and the following can be concluded:

1. ESS with strip electrodes is the most economical and productive method to overlay a wide variety of corrosion and/or wear resistant deposits on Structural ship components, such as propeller shafts.
2. The highest deposition rates combined with the lowest base metal dilution are characteristic of ESS with strip electrodes compared to conventional surfacing methods, such as strip SAS, GMAW and SMAW.
3. The dominant thick-section surfacing process in Japan, the Soviet Union and several European countries is ESS.
4. Neither U.S. shipyards nor U.S. manufacturing industries have adopted the ESS process. Conventional surfacing methods are still utilized in the U.S.
5. Technically, the key difference between the newly-developed ESS process and other similar processes, such as SAS and ESW, is the flux chemistry.

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THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

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Applying Group Technology (GT) to Increase Productivity in a Job Shop Environment No. 118

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ABSTRACT

Decreasing the high cost of small lot production in a job shop environment is a continual problem for shipyard shops supporting extensive repair and overhaul work. In the past, reducing cost in this area has been a desirable, but mostly unattainable goal. However, continued development of computer solutions to manufacturing problems utilizing Group Technology methods has made significant savings in this area possible.

BACKGROUND

Mare Island Naval Shipyard, located about 40 miles NW of San Francisco in Vallejo, CA is the oldest naval shipyard on the Pacific Coast. Established in 1854, Mare Island has a rich heritage that spans most of the Naval conflicts the United States has experienced. During its 134-year history, Mare Island workers have broken record after record in building and repairing naval ships. Yet, by the early 1980's it was apparent that past history was worth very little in the competitive business of a shipyard. In 1972, new construction had ceased, and then in recent years, with competitive bidding between private and public shipyards becoming a way of life for naval ships overhauls, new anxiety was introduced. Mare Island and the other public shipyards could no longer rely on the high quality of their work to guarantee overhauls. They would have to find a method not only to continue to produce quality work, but also to do it at a price competitive with private industry.

In October 1984, two general foremen from the large machine shop, in an attempt to find manufacturing methods more competitive with private industry, attended a Department of Defense, (DOD) sponsored workshop on Computer Aided Process Planning (CAPP), held at Brigham Young University in Provo, Utah. They left this workshop convinced that CAPP and the related

capabilities of Group Technology (GT) held the key to lowering cost and improving the productivity of the machine shop. Upon returning to Mare Island, they shared their findings with the machine shop superintendent, and he also became convinced that GT and CAPP held the key to lower cost.

IMPLEMENTATION-APPROACH

In January 1985, the Machine Shop Superintendent met with the head of Production Engineering and set in motion the implementation of GT and CAPP, into the Machine Shop operating scheme. A Group Technology (GT) team was formed consisting of (1) Machine Shop General Foreman, (1) Machine Shop Foreman, and (1) Industrial Engineer. None of these individuals had previous experience with GT or CAPP, so there were no preconceived ideas of what GT or CAPP should do for the shop. The team recognized that the Machine Shop exhibited job shop characteristics. Many "one of a kind" and small lots are produced, and the demand for a given part cannot be forecast until an order is received. The team was also aware that the average skill level of the machinists in the shop had been decreasing since new construction ceased in 1972. The task then was to learn how GT and CAPP could improve productivity in this environment. The first step taken by the team, was to become educated in the area of GT and CAPP. Society of Manufacturing Engineers (SME) seminars provided this education, giving the team a foundation of understanding on which to build a unique application, specifically designed to meet the needs of the large machine shop.

APPROACH

It is usually accepted by industry that a job shop has little potential for productivity improvement. High set up cost, small lot size and resulting high cost per part are characteristics of this environment. Most decisions concerning how to manufacture a part

are left up to the machinist doing the work, and historically, very little effort has been expended to find a more productive method. However, as the GT team learned more about GT and CAPP, they found that the current goal for GT based systems is to provide data and tooling that will allow economical production of parts in lot sizes of 1. I" parallel with formal training, a serious effort was made to find companies with a manufacturing environment similar to Mare Island who had successfully implemented GT and CAPP. Individuals associated with manufacturing concerns both inside and outside of the Federal Government exhibited a willingness to freely share their knowledge. The help that these people gave saved the team hours of work that would only have duplicated the efforts of others. Many of the people contacted were able to suggest additional referrals, and almost two dozen installations were visited, contributing valuable information to the team's investigation.

DEVELOPMENT

As the capabilities and possibilities of GT and CAPP were gradually learned, ideas and goals relating to Shop 31 began to take shape. The advantage and opportunity provided by coding of parts and grouping them into families was evident. If the GT program could search the coded parts and find enough parts manufactured in a similar way to form a family, then a standardized process plan could be developed for that family. Instead of starting from scratch each time a member of the part family was to be manufactured, the planner could start with the basic process plan and adapt it to the specific part required. This capability would require the installation of a GT system and an adaptive (variant) process planning system.

The team observed demonstrations of generative process planning systems during the formulative stages of the application concept for Shop 31. But they realized that a generative CAPP system that would automatically create a complete process plan based upon the descriptive features of a part would need access to complete data bases containing extensive machine tool parameter data, material data bases, tooling data bases and others. These data bases do not exist. It will take years to develop them. It is generally agreed that they should be developed, but until they are developed and until Shop 31 planners are ready for such an advanced system, variant process planning can be used to gain significant productivity gain.

ADDITIONAL REQUIREMENT

During the formulation of the plan for improving Shop 31, a significant problem surfaced that had little to do with GT or CAPP. Because two of the team members had extensive experience in the shop, they were concerned that the drawings issued to the machinists were not adequate for manufacturing the parts. Further investigation of this problem showed that it was even bigger than first suspected. Machinists were having to spend excessive amounts of time going to shop plan files verifying dimensions, tolerances, and material specifications. In many cases, the machinist would find it necessary to draw a separate sketch of the part to be made because the issued drawing was of such poor quality and because many dimensions often had to be transferred from a table to the drawing. What the machinist needed was a drawing containing only the part he was to manufacture with all necessary material tolerance and manufacturing notes. After considerable research, it has been determined that the best way to supply the machinists with the needed drawings is by electronically scanning the aperture cards that contain the required drawing information. This allows the drawing and notes to be viewed at a computer terminal, here a new single part drawing can be created by electronically cutting and pasting from the scanned input. The new drawing can then be stored, and at any time output to a printer, and then be issued to the shop floor with the process plan.

LONG RANGE - SHORT RANGE

As the overall needs in the shop continued to be defined, it became clear that both a long range and a short range approach had to be implemented in parallel. The long range approach could look 5-10 years ahead and be somewhat idealistic, but it had to accommodate the short range 2-4 year plan which had to correct the areas of the most serious problems. The short range plan had to be practical and achievable, providing a good foundation for future improvements. Four elements of the short range plan were finally defined. First would be a scanning and editing system to provide quality drawings to the machinists, second would be a Group Technology System to provide visibility of the entire scope of the parts being made, third would be an Adaptive Computer Aided Process Planning System, and fourth, retention of the current Machine Shop Tracking system (MSTS). MSTS monitors the location of a part as it passes through the shop. At first, these elements were discussed as individual systems

being networked together, but later it was realized that each of capabilities should be integrated into a single, expandable system. This system would be a first step capable of growing into tomorrow's requirements.

IMPLEMENTATION CONSIDERATIONS

In figuring budget calculations for this system, a payback time of 2 to 4 years "as calculated, depending upon the variables introduced. takes 18-24 months after procurement to install and implement such a system, and the initial cost is several hundred thousand dollars for the hardware and software alone. This resulted in two concerns. First, will it work? Are there enough similar parts in Shop 31 to establish part families and manufacturing cells? And second, how can enthusiasm for the system be maintained during the long procurement and implementation cycle?

The first concern was addressed by the team in two ways. First, following a suggestion obtained at a seminar they attended, the team chose at random 300 recently manufactured part numbers and obtained standard drawings of these parts. Each standard sheet of drawings contains several parts. The team then divided up the drawings and using "cut and paste" constructed "size individual drawings of each part. The individual part drawings were then visually grouped by shape, observing that the materials the parts were made of were at least similar. It was observed that more than 60% of the parts sampled exhibited significant similarities to one another, and in fact 7% of the samples were either identical parts or close enough to share identical manufacturing processes. This first effort provided full support for the original purpose of this project.

The second effort to prove the usability and effectiveness of the GT-CAPP System in the machine shop, involved purchasing an AT compatible computer and software package called DCLASS. DCLASS is a Decision Tree Management System (DTMS) that can be used for Group Technology and Computer Aided Process Planning as well as a variety of other decision-based applications. By purchasing DCLASS PC, the team is able to test the full scale capabilities of a large whole shop system at a fraction of the cost. Testing in GT, CAPP and Material Specifications continues to confirm the need and applicability of a large whole shop system to reduce production cost.

GETTING THE CELL BEFORE THE SYSTEM

In conjunction with confirming the applicability of a GT-CAPP system in the shop, the secondary concern for maintaining enthusiasm for the system over a long period of time had to be dealt with. It was recognized that displaying computer programs, sorting part drawings, and other relatively low profile activities do not provide tangible, interest grabbing, visible objects around to maintain enthusiasm. What was needed was a successful, operating cell right in the shop, but a cell would be the result of a GT system, not a forerunner to it. However, several occurrences made it possible to pursue not only one, but two cells for installation into the shop prior to the installation of the GT system.

The two cells are at opposite ends of the automation spectrum. The first cell, a "fastener cell" developed at Mare Island, utilizes only conventional machine tools. This cell was defined by the GT team using manual methods to establish a part family and is expected to be operational by April 1988. The second cell, a "RISIC CELL" developed (NBS), the National Bureau of Standards is totally automated and is designed to operate for full E-hour shifts untended. The RISK CELL is expected to be installed operational by October 1988. (see Figs. 1 & 2)

The efforts required to implement these two cells have been effective in creating and maintaining enthusiasm in management and on the shop floor and have helped focus attention on improving the overall way business is conducted in the machine shop. The only detrimental results from the cells is some confusion and extra explanation as to how the cells were defined without having a GT System in place. The team has to explain that the "Fastener Cell" is not based on an optimum part mix, but on a reasonable part mix determined by experience and limited vision of the various possibilities. It is expected that even though the cell was defined in a rather crude fashion, it will be effective in demonstrating advantages of cellular manufacturing. After the GT system is implemented, it will be possible to re-evaluate and optimize the part family.

The "RISIC CELL" was defined when the General Foreman on the GT team recognized the RISK parts as an "obvious" part family with 4 distinct parts manufactured in 12 different sizes. National Bureau of Standards, Automated Manufacturing

Research Facility (AMRF) was looking for such a family around which they could implement the automated cell technology developed over the last 5 years at the ARMF. However, the RISIC family will not be able to keep this cell loaded. The GT system will be needed to determine additional parts that should be in this family. In actual practice, the GT system will be used as the primary tool to conduct an ongoing evaluation of all manufacturing cells both operating and proposed.

business requires long term commitment and innovative ideas to adapt the rigid guidelines of the "expert" to the needs of one's own shop.

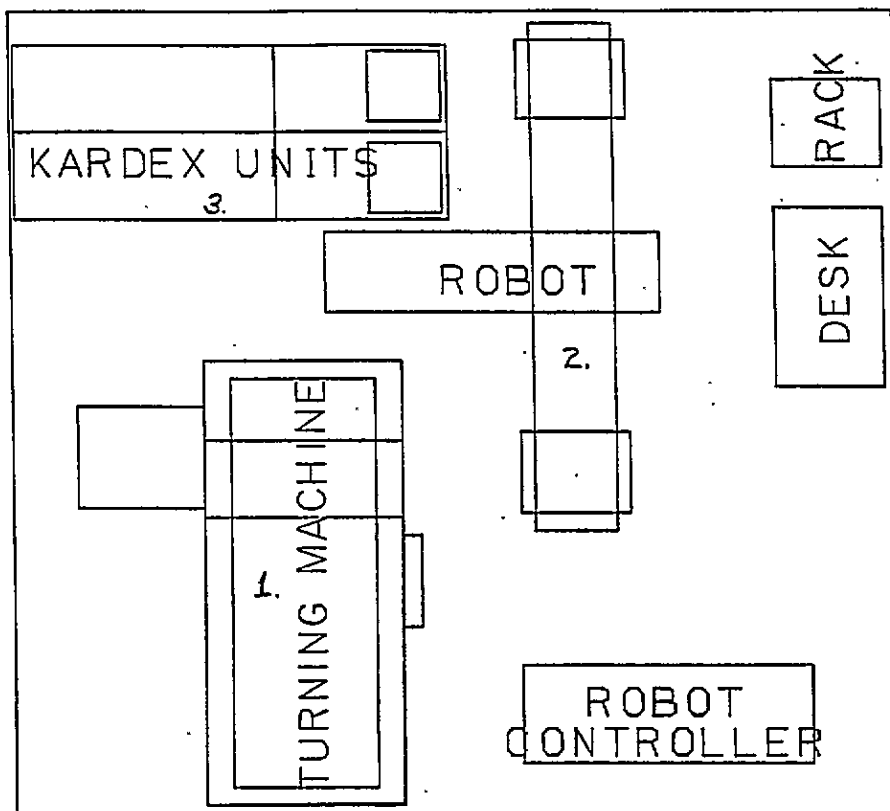
MOVING FORWARD

Introducing Cells onto the shop floor is time consuming, and it dilutes the effort of the GT team. However, it has provided additional "beneficial results" in maintaining the momentum of the project. To obtain computer equipment like the GT- System in the Naval Shipyard environment requires a ponderous mass of bureaucratic, dead end paperwork that takes months of effort for each step taken. tion, pressure to reduce spending at all levels has made the acquisition of funding a time consuming, difficult task. But, by being able to utilize the cells as visible results of the project, progress has continued to be made.

The current effort centers around purchasing and implementing the scanning and editing portion of the system. It is hoped that by summer 1988, this part of the system will be in place. At that time it is also anticipated that the main computer on which the system resides will be installed.

While the main computer is scheduled to be installed prior to October 1, 1988, funding for the GT and CAPP software will not be available until after October 1st. Once the system is operational with the capability to code parts, the part data base will begin to be built. The plan is to build this data base, part by part. It will take from 12 to 24 months before sufficient data will be available to start constructing useful part families. This method of building the part data base might at first seem to be inefficient, but investigation has shown that the data currently available is insufficient to establish any kind of part history. One of the benefits of this system that really isn't being considered in the economical analysis is that accurate shop history will be available for future decision making.

The work has only begun, although a lot of energy has already been expended. But the message is clear. To implement new technology at a level that changes the way a shop does



1. TURNING CENTER - WARNER SWASEY 12 inch with live tooling
2. ROBOT - WESTINGHOUSE, UNIMATE 6000
3. KARDEX UNITS - KARDEX MATERIAL STORAGE MODULES

FIGURE 1. "RISIC CELL" LAYOUT

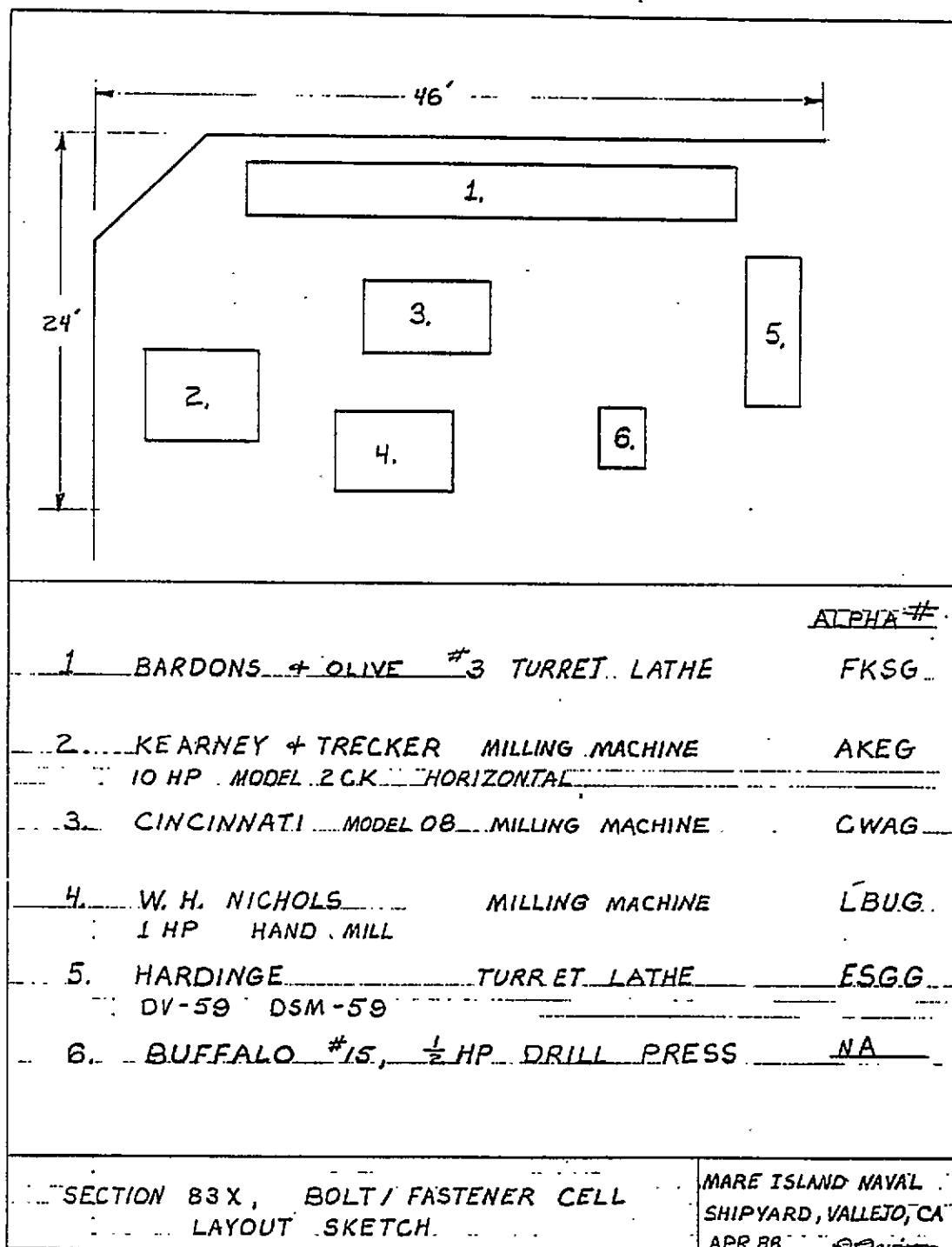


FIGURE 2



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Designing Partial Penetration Tee Joints for Naval Ships

No. 12A

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ABSTRACT

This paper reviews development of weld design equations which can be used to analyze beveled partial penetration tee joints. The method developed herein follows closely the development of equations for design of square edge partial penetration tee joints which was presented at the 1936 Ship Production Symposium. for U. S. Navy ship design, technical authority is vested in the Naval Sea Systems Command (NAVSEA). The published NAVSEA design criteria for partial penetration tee joints is so conservative that it is mathematically impossible to design a conventional 100 percent efficient partial penetration beveled tee joint. The alternate method for beveled joints outlined in this paper might be an acceptable replacement for the simple, though unduly, conservative existing design criteria with a more rigorous engineering analysis.

The alternate method for bevelled joints is similar to the alternate square edge joint design criteria presented in reference (1). Again, six probable conditions for failure are investigated. These are derived, from three probable locations (the weld throat or the intercostal or the continuous heat affected Zone boundaries) under two possible load directions (longitudinal or transverse to the weld). The corresponding equations used to design conventional square joint fillets are modified to account for the heat affected zone boundary changes due to the bevel geometry as well as for the fillet size.

The modified design equations developed in this paper are applicable to joints with balanced or unbalanced bevels. A sample implementation of the design equations using an electronic spreadsheet program on a Personal Computer are included. The proposed

design equations are compared to the existing U. S. Navy criteria.

Partial penetration welds are preferred to full penetration welds because they do not require backgouging. A backgouge is typically required for full penetration tee joints. This operation removes some of the weld root deposited on the first side, and generally cuts away a large amount of the base material on the second side. The base material removed must, of course, be put back by welding. This raises the cost to achieve a full penetration weld not only for the backgouge operation, but also by the cost of adding back the solid material which was removed during backgouge.

NOMENCLATURE

The terminology is in accordance with American Welding Society and applicable military standards. The important terms and abbreviations are explained below. See figure 1 for further clarification.

CONTINUOUS MEMBER- The member which continues through the tee joint.

INTERCOSTAL MEMBER- The member which ends at the tee joint.

AB- Angle of bevel

AH- Angle of HAZB. AH=AB for geometry

B- bevel depth

E- weld joint Efficiency: weld strength as a percentage of the strength of the intercostal member.

HAZB- Heat Affected Zone Boundary

S- Size of fillet leg

SNC- Ultimate Shear strength of the Continuous member.

SUI- Ultimate Shear strength of the Intercoastal member.

SWL- Shear strength of the Weld, Longitudinal direction.

SWT- Shear strength of the Weld, Transverse direction,

TC- Thickness of Continuous member

TI- Thickness of Intercoastal member

TUC- Ultimate Tensile strength of the Continuous member.

TUI- Ultimate Tensile strength of the Intercoastal member.

Z- land width; TI minus the right and left Bevel depths

ALTERNATE FILLET SIZING

There are two methods approved by the U.S. navy for designing square edge fillet welds for surface ships. The original method is documented in reference 4. The alternate square edge fillet design method was developed by Charles Jordan and Bob Krumpen of Newport News Shipbuilding (references 2 & 3) during the 1970's and 80's. NAVSEA authorized use of the alternate method for surface ship construction and repair.

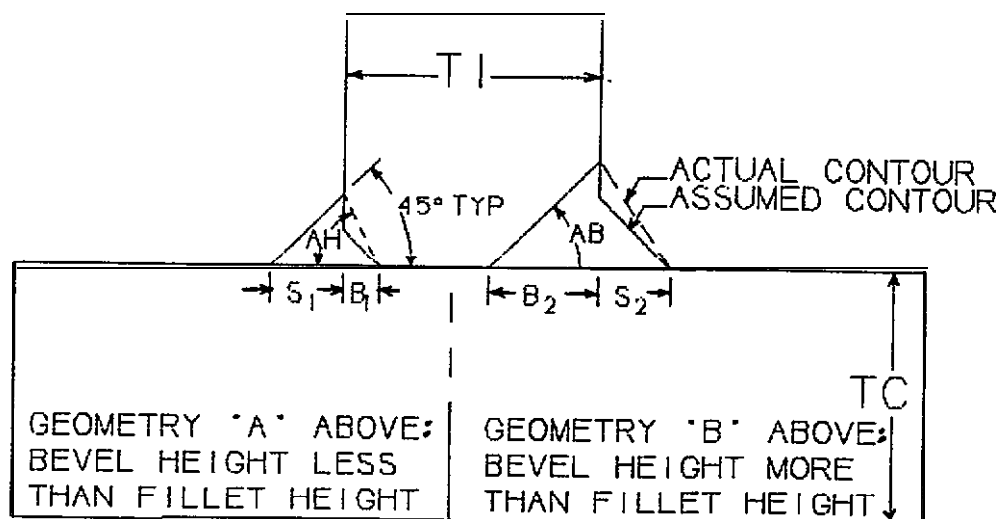
The proposed design method for beveled edge tee joints is an extension of the NAVSEA approved alternate method for determining minimum fillet sizes for square edge tee joints reported in reference 1. At the time of this writing, use of the Partial penetration beveled tee joint design method presented in this paper is under review by the Naval Sea Systems Command, U. S. Navy, and has not implemented at Ingalls.

DERIVATION OF METHOD

The derivation of the proposed beveled edge tee joint design equations exactly parallels development of the approved alternate square edge fillet sizing method. Two possible conditions of loading are considered; longitudinal (shear along the weld and transverse (tensile) to the weld. Shear across the weld (in the plane of the continuous member) is not considered in either method. The longitudinal shear loading would be typical of a beam and plate combination in pure bending. The transverse tensile loading would be typical of a stanchion or foundation.

Under each condition of loading, three possible failure locations (simplified fracture surfaces) are considered. Please see figure 2 for a pictorial representation of the three surfaces. The strength of each of the three planes is related to the strength of the intercoastal member by a design equation. The weld joint design is adequate when the weld strength equals the weaker member strength. A correctly designed 100%

FIGURE 1 : NOMENCLATURE



efficient weld must satisfy all six proposed design equations and will provide 100% of the strength of the weaker member under both loading directions. Throughout this paper, the intercostal member is assumed to be the weaker.

LOGITUDINAL SHEAR LOADING

Condition 1- Relates load capacity of weld throat to intercostal member load capacity under longitudinal shear loading. In this case the lengths of the right and left throats are calculated assuming a 45 degree angle of the failure plane. This angle was chosen to permit the proposed equation to remain compatible with the existing method. The 45 degree angle gives the shortest length of the throat ignoring convexity and production reinforcement. The weld capacity (weld longitudinal shear strength times the total throat failure plane length) is related by the required efficiency to the intercostal member shear strength using the following equation:

$$(1) TI < \frac{(SWL) (\text{total throat Length})}{(Sul) * E}$$

For geometry "A", where the bevel height is smaller than the fillet size ($B < S / \tan(AB)$),

$$(1A) \text{ throat length} = .707 * (S+B)$$

When ML this equation is identical to equation (1) of reference (1). When $B=0$, only geometry "A" is applicable.

The close parallel relationship of equations between the Proposed bevelled joint design method and the approved alternate Square edge joint design method shows that the proposed equations are an extension of the alternate square edge equations rather than a departure into radical new design theory. This factor should simplify and speed approval of the proposed equations based on Past approval of the alternate square edge fillet design equations.

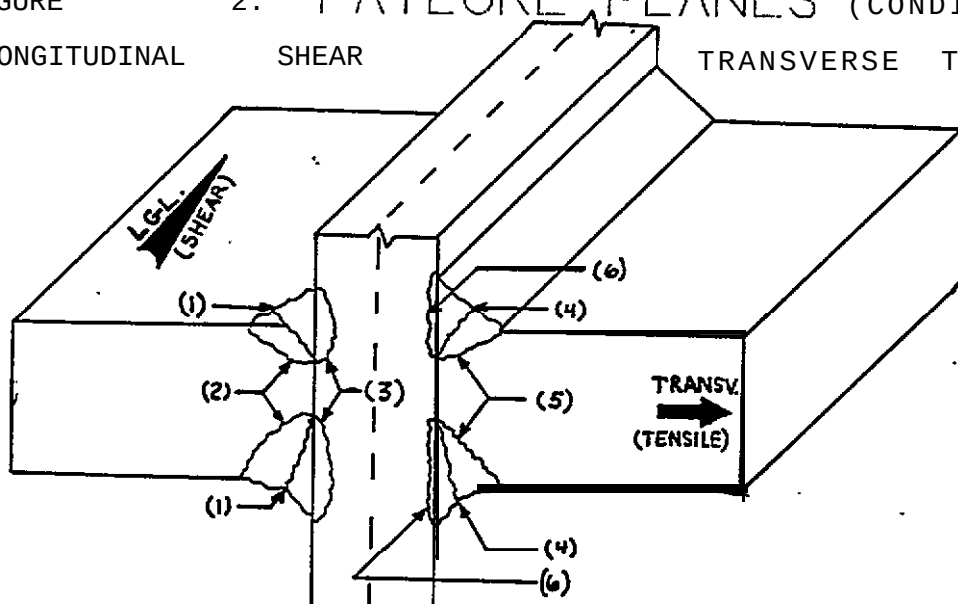
For geometry "B", where the bevel height is larger than the fillet,

$$(1B) \text{ throat length} = \text{SQRT}(SA^2 + BA^2)$$

Condition 2- Relates load capacity of the intercostal member HAZB (heat affected zone boundary) to the intercostal member load capacity under longitudinal shear loading. The HAZB of a steel weldment is also a possible failure location due to embrittlement, grain growth and thermal residual stresses. In the case of shipbuilding steels, the HAZ does not necessarily weaken the joint. The HAZB of an aluminum weldment is a likely failure location due to annealing and residual thermal stresses. In the case of aluminum ship design, the annealing effect is offset by use of the annealed material strength for design.

The strength of the weld is the intercostal member ultimate shear strength times the total length of the intercostal member HAZB. This is related by the required efficiency to the

FIGURE 2: FAILURE PLANES (CONDITION)
LONGITUDINAL SHEAR TRANSVERSE TENSILE



intercostal member shear strength using the following equation:

$$(2) TI < \frac{(\text{total intercostal HAZB Length})}{E}$$

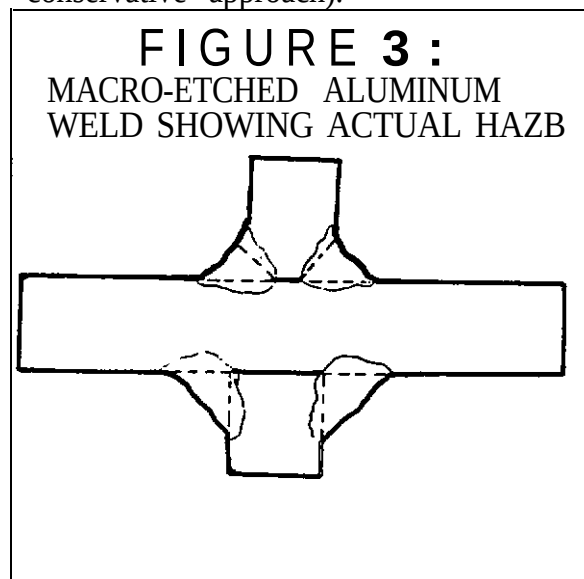
In developing the equations for fillet welds loaded in longitudinal shear in reference (1), the HAZB was assumed 10% longer than the length of the fillet leg to account for the penetration of the heat. Based on examination of macro-etched weld samples this was reasonably accurate. See figure 3 for an illustration of the HAZB in a partial penetration joint.

For geometry "A" only, the actual HAZB length is not easy to calculate. To permit development of simple equations, a very conservative assumption is used to estimate this HAZB length for the proposed design method. First, the HAZB is assumed to be the shortest distance between the top of the fillet leg and the root edge of the bevel (no credit for root penetration of fillet oversizing). Second, the 10% extension for heat penetration is not used. The 10% extension was used in references (1) - (3) to design square edge fillets. It was valid then, and would be valid for most, but not all, bevelled joint designs.

Thus for geometry "A" where the bevel height is smaller than the fillet ($B < S / \tan(AB)$),

$$(2A) \text{ HAZB length} = \text{SQRT}(SA^2 + BA^2)$$

When $B=0$, geometry "A" is applicable and it can be seen that this equation differs from equation (2) of reference (1) only by the 10 percent HAZB length increase which is not used here (due to conservative approach).



For geometry "d", the HAZB will always be longer than the shortest distance between the root and the fillet toe. Therefore, the 10% increase of references (1) - (3) is used. For geometry "B" where the bevel height is larger than the fillet,

$$(2B) \text{ HAZB length} = m$$

Condition 3- Relates the capacity of the continuous member HAZB (heat affected zone boundary) to the intercostal member capacity under longitudinal shear loading. The HAZB of the continuous member is also a possible failure location due to the same reasons as outlined in condition 2. The strength of the HAZB is the continuous member ultimate shear strength times the total length of the continuous member HAZB. This is related by the required efficiency to the intercostal member shear strength using the following equation:

$$(3) TI < \frac{(\text{Cont. mem. HAZB Length} * SUC)}{(SUI * E)}$$

The HAZB length is assumed 10% greater than geometric length. This assumption was used in references (1)-(3) and examination of macro-etched samples shows this assumption remains valid. For both geometry "A" & "B",

$$(3A) \text{ \& } (3B) \text{ HAZB length} = 1.1 * (S + B)$$

When $B=0$, this equation is the identical to equation(3) of reference (1).

TRANSVERSE TENSILE LOADING

Condition 4- Relates load capacity of the weld throat to the load capacity of the intercostal member for transverse loading across the weld throat. In this case the lengths of the right and left throats are calculated assuming a 45 degree angle of the failure plane to give minimum length. This is conservative because actual (and theoretical) failures show a failure Plane of about 60-70 degrees. The strength of the weld is the weld transverse shear strength times the total throat failure plane length. This is related by the required efficiency to the intercostal member tensile strength using the following equation:

$$(4) TI < \frac{(SWT * \text{total throat Length})}{(TUI * E)}$$

For geometry "A", where the bevel height is smaller than the fillet height ($B < S / \tan(AB)$),

$$(4A) \text{ throat length} = 707 * (S+B)$$

When $B=0$, this equation is identical to equation (4) of reference (1). When $B=0$, only geometry "A" is applicable.

For geometry "B", Where the bevel height is larger than the fillet,

$$(4B) \text{ throat length} = \sqrt{SA^2 + BA^2}$$

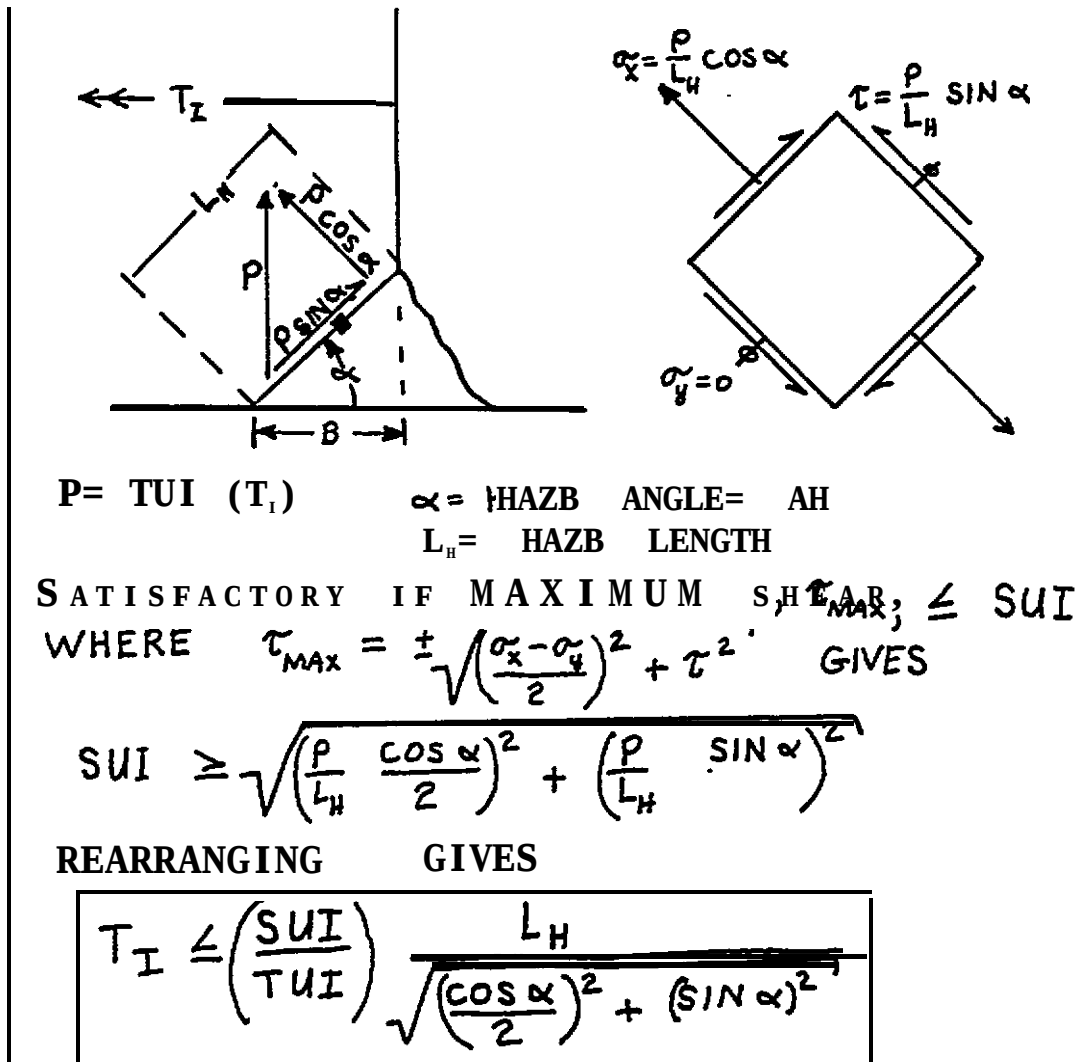
Condition 5- Relates the load capacity of the intercostal member HAZB (heat affected zone boundary) to the load capacity of the intercostal member under transverse tensile loading. The HAZB of the intercostal member is also a possible failure location due to the same

reasons as outlined in condition 2. When calculating the strength of the intercostal HAZB the directionality of the capacities must be considered. Mohr's stress transformation is used to calculate the maximum shear stress along the HAZB. When the geometry satisfies the equation below, the maximum shear stress will be less than the intercostal member ultimate shear stress. The derivation is shown in figure 4. The intercostal member HAZB capacity is related by the required efficiency to the intercostal member tensile strength using the following equation:

$$(5) TI < \frac{(I'_{\text{costal HAZB Length}} * SUI)}{E * \sqrt{((\cos(AH)/2)A^2 + \sin(AH)A^2)}}$$

A Mohr's transformation for principal tensile stress less than intercostal member ultimate tensile stress was

FIGURE 4: Development of equation (5) using Mohr's approach.



considered when developing the proposed design method. In the case of a balanced joint with a sixty degree bevel, this works out to a minimum bevel depth of (.29) T. This value is the same as the American Welding Society recommended design from page 157 of reference (6). However, the shear comparison is used for this paper so that when considering a square edge (B=0) Joint, equation (5) in this proposed method will match equation (5) of reference (1).

For geometry "A", where the bevel height is smaller than the fillet leg height ($B < S / \tan(AB)$),

$$(5A) \text{ HAZB length} = 1.1 * \text{SQRT}(SA^2 + BA^2) \\ \text{HAZB angle} = \text{ARCTAN}(S/B)$$

For a fillet where $B=0$ and $AB=90$, the proposed equation (5) is identical to equation (5) of reference (1).

For geometry "B" where the bevel height is larger than the fillet,

$$(5B) \text{ HAZb length} = 1.1 * B / \cos(AB) \\ \text{HAZB angle} = AB$$

Condition 6- Relates load capacity of the continuous member HAZB to the load capacity of the intercostal member under transverse tensile loading. The HAZB of the continuous member is also a possible failure location for the same reasons as outlined in condition 2. The strength of this HAZB is the continuous member ultimate tensile strength times the total length of the continuous member HAZB. This is related by the required efficiency to the intercostal member ultimate tensile strength times it's thickness using the following equation:

$$(6) TI < \frac{(\text{cont. mem. HAZB Length} * TUC)}{(TUI * E)}$$

Because the continuous member HAZB is loaded transversely (tensile), the HAZB length was assumed as the projected length. For both geometry "A" & "B";

$$(6A) \text{ \& (6B) HAZB length} = (S + B)$$

When $B=0$, this equation is identical to equation (6) of reference (1).

EXISTING DESIGN CRITERIA

The existing approved U.S. Navy method for design of partial penetration beveled tee weld geometry is published

in section 5.3 of reference (5). That criteria has several significant shortcomings. It is not as precise or accurate as the proposed method. Also, it usually requires excessively large welds in most cases, but could result in inadequate joints in other cases. Finally, the existing calculation method is applicable only to symmetrically beveled joints, even though unbalanced joint designs are permitted.

First, let us see an example showing now conservative the existing Criteria is. Examine the design requirements for HS steel ($TUI = 75 \text{ Ksi}$) welded with 7018 SMA filler ($SWL = 59 \text{ ksi}$). From section 5.3.1.1 of reference (4) we get the equation

$$(7) D = \text{Design Factor} = \frac{E(T) TUI}{(2 SWL)} \\ = (.635) T$$

When D is less than .707 inch (T less than 1.112 inch for this material combination), section 5.3.1.2.1 would control and require:

$$(8) B = D / 1.414 = (.449) T$$

If this equation were applied to a one inch thick intercostal member, the bevel depth required would be .449 inches, and the required fillet would be 1/2 inch. By contrast, the method proposed in this paper would only require a 3/8 inch fillet and bevel depth (both sides).

However, the weld calculated in equation (8) above would not be permitted because the land width above is .105 inches and the minimum land width permitted by note 1 in figure 23 of reference (5) is 3/16 inch. When the minimum required land width is substituted into the land width equation of section 5.3.1.3 of reference (4) as shown in equation (9), we find the minimum thickness of 1.84 inches is greater than the maximum thickness (1.112 above) for which equation (8) is valid.

$$(9) 3/16 = Z = T - 2 B = (.102) T \\ T_{min} = .1875 / .102 = 1.84$$

If we were to assume a member thickness of 1 1/4 inches, then section 5.3.1.2.2 would be govern because D is greater than .707 inches. B would be found using the following equation:

$$(10) B = \text{SQRT} (D * D - 0.25) = .616$$

This yields a land width of 0.017 inches which again does not meet the minimum

land requirement of reference (5). Thus, there is no valid solution by the published U.S. Navy design criteria for a 100% efficient partial penetration weldment of this material combination for this range of thicknesses.

However, it is also possible to use the published design method to design an inadequate joint. Let's examine the result of severely overmatching the filler to the steel. Assume a 3/4 inch thick mild steel ($T_U = 60$ ksi) intercostal member is welded to a thick HY-100 continuous member with 11018 SMA filler ($SWL = 87$ ksi). For this combination, $D = 0.259$, $B = .183$, $Z = .384$ and $S = B = 3/16$. It should be apparent that the heat affected zone boundary does not increase in strength when the filler metal does. From equation 4 we find this joint, although 100% efficient by the existing criteria, is only 89% efficient by the proposed method. The difference is that the existing criteria does not take into account the strength of the HAZB (which is a common failure location of partial penetration weldments), while the alternate method does.

One final note, the American Welding Society Handbook includes a simple approach to designing full capacity partial penetration tee joints shown on page 157 of reference (6). This design criteria recommends a symmetric design with a 60 degree bevel to a depth of $(0.29) T$ with a fillet of $(0.29) T$. This apparently was derived from a Mohr's stress transformation. This particular equation can be found if we require principal tensile stress at the bevel (HAZB) to be less than the intercostal ultimate tensile strength for transverse tensile load "P" in figure 4). One of the example applications of the proposed method included in this paper (third design example in Table 2) shows that the alternate method would recommend a depth and fillet of $(0.34) T$.

While the American Welding Society method from reference (6) is indeed simple, it does not account for longitudinal shear loading of the weld nor for possible variable mismatch between base material and filler metal. It is interesting, though, that there is no minimum land width recommended in this simple design method.

SELECTION OF MATERIAL PROPERTIES

It can be seen from the previous discussion that the alternate fillet sizing method requires material

properties not previously required to satisfy the standard method. The standard method from reference (4), equations (7) - (10), required tensile strengths of the continuous and intercostal base materials, and the longitudinal shear strength of the weld material. The proposed method, equations (1) through (6), requires, in addition to the above mentioned properties, the ultimate shear strengths of the continuous and intercostal base materials, and the transverse shear strength of the weld material. Based upon material test data and application of weld and metallurgical theory, NAVSEA has approved the use of some ratios to approximate the additional material properties.

First, the ultimate shear strengths of the base materials are related to their ultimate tensile strengths. For steels, NAVSEA has approved the conservative assumption that the ultimate shear strength is 75% of the tensile strength. For aluminum, NAVSEA has approved the assumption that the ultimate shear strength is 60% of the tensile strength. This results in the following equations:

$$(11a) S_{UI} = T_{UI} * (0.75 \text{ for steel})$$

$$(11b) S_{UI} = T_{UI} * (0.60 \text{ for aluminum})$$

$$(12a) S_{UC} = T_{UC} * (0.75 \text{ for steel})$$

$$(12b) S_{UC} = T_{UC} * (0.60 \text{ for aluminum})$$

The strength of HSLA80 (a modified A-710 steel recently developed for Navy applications) is not listed in reference (4), but NAVSEA has approved the use of HY-80 tensile strength to determine weld properties. This simplifies table design and appears to be conservative, based upon the slightly lower permissible design stress for HSLA80.

Second, the transverse shear strength of the weld is related to its longitudinal shear strength. For steels, NAVSEA has approved a ratio of 1.44. For aluminum, the approved ratio is 1.58. This results in the following equations:

$$(13a) S_{WT} = S_{WL} * (1.44 \text{ for steel})$$

$$(13b) S_{WT} = S_{WL} * (1.58 \text{ for aluminum})$$

NAVSEA has approved some significant changes in weld properties for use in design calculations. These changes are based upon various test programs undertaken since reference (4) was published. A list of the pertinent weld properties currently in use at Ingalls Shipbuilding and their sources are shown in table 1.

TABLE 1

WELD LONGITUDINAL SHEAR STRENGTH (KSI)

F. EILLER. NAVSHIP 0900 MIL-STD APPROVED
METAL -000-1000 1628 AT ISD

18	58.1	59	59
10018	71	N/A	7 8
11018	75.3	87	87
100S-1	N/A	83	83
5556	19.2	20	26; ref 7

SPREADSHEET ANALYSIS BY ALTERNATE METHOD

A Printout of a simple spreadsheet analysis is shown below. This "program" is a Lotus 123 template that allows the user to interactively change any of the variables and instantly see the result. The user can expand the template to develop an entire weld table, including fillets. This template is available from the author at cost of diskette & mailing. To run it you will need a IBM-PC compatible with a 5 1/4 inch disk drive and a Lotus 123 or compatible spreadsheet program.

TABLE 2: SPREADSHEET ANALYSIS BY LOTUS 123

PROPOSED METHOD FOR PARTIAL PENETRATION JOINT DESIGN

INTERCOSTAL		CONTINUOUS		WELD			
MATERIAL	HS	MATERIAL	HS	MATERIAL	E7018		
TENS. ULT	75.00	TENS. ULT	75.00	LGL SHEAR	59.00		← User input material properties.
SHEAR ULT	56.25	SHEAR ULT	56.20	TRANS	04.96		
SIDE A							
BEV DEPTH	0.3750	0.5000	0.5000	0.6250	0.0000		
ANGLE(DEG)	45.0000	45.0000	60.0000	45.0000	89.0000		← User input joint descriptions
ANGLE(RAD)	0.7854	0.7854	1.0472	0.7854	1.5533		
FILLET	0.3750	0.5000	0.5000	0.5000	0.5000		
GEAM A=1	1	1	0	0	1		← Find geometry type
EQN 1	0.5562	0.7416	0.7417	0.8395	0.3708		
EQN 2	0.5303	0.7071	1.1000	0.9723	0.5000		
EQN 3	0.8250	1.1000	1.1000	1.2375	0.5500		
EQN 4	0.6007	0.8009	0.8010	0.9067	0.4005		
EQN 5	0.5534	0.7373	0.9153	0.9224	0.4125		
EQN 6	0.7500	1.0000	1.0000	1.1250	0.5000		← Program solves equations for the joint designs. (inches thickness per side)
SIDE B							
BEV DEPTH	0.3790	0.5000	0.5000	0.0000	0.0000		
ANGLE(DEG)	45.0000	45.0000	60.0000	45.0000	45.0000		← User input joint descriptions
ANGLE(RAD)	0.7854	0.7054	1.0472	0.7054	0.76854		
FILLET	0.3750	0.5000	0.5000	0.5000	0.5000		
GFUM A=1	1	1	0	1	1		← Find geometry type
EQN 1	0.5562	0.7416	0.7417	0.3708	0.3708		
EQN 2	0.5303	0.7071	1.1000	0.5000	0.5000		
EQN 3	0.8250	1.1000	1.1000	0.5500	0.5500		
EQN 4	0.6007	0.8009	0.8010	0.4004	0.4004		
EQN 5	0.5534	0.7379	0.9153	0.4125	0.4125		
EQN 6	0.7500	1.0000	1.0000	0.5000	0.5000		← Program solves equations for the joint designs. (inches thickness per side)
CONTROL	1.0607	1.4142	1.4834	1.2103	0.7416		← control is least sum for each side for each load direction.
T (MAX) VS FFF							
	MAXIMUM	ALLOWABLE	INTERCOSTAL	THICKNESSES			
	FOR ABOVE	JOINT DESIGN	(VS. EFFICIENCY)				
100.00%	1.0607	1.4142	1.4834	1.2103	0.7416		
75.00%	1.4142	1.8056	1.9778	1.6137	0.9888		
60.00%	1.7678	2.3570	2.4723	2.0172	1.2360		
50.00%	2.1213	2.8284	2.9667	2.4206	1.4831		← Control equation determines table of maximum intercostal thickness vs. joint efficiency.
COMMENTS	3/8" BEV. & FILLET	1/2" BE. & FILLET	60 DEG. BEVEL	UNBAL-ANCED	SQUARE EDGE		

IMPACT FROM USE OF ALTERNATE METHOD

implementation of the alternate joint design method impacts cost both directly and indirectly. The savings are directly related to substitution of partial penetration for full penetration joints are primarily due to deletion of the backgouge. The real justification for the use of partial penetration welds is that circumstances exist where partial penetration welds are more economical than either fillet or full penetration welds while still meeting strength and service requirements.

Where do the savings come from? Because the minimum backgouge size is pretty large, there is significant savings because the oversize "hole" does not have to be filled in by weld metal. In addition, the extra cleanup of the gouged out material is not necessary. There are indirect savings because distortion is minimized (weld volume is less), and NDT is much less costly. For full penetration joints, there is an additional backgouge inspection plus random test gouges to verify. In some categories of structure, full penetration joints may require additional NDT (UT/MT/PT) not required for partial penetration joint designs.

The weld design changes made at Ingalls initially were part of an effort to reduce weld caused distortion. However, a very beneficial side effect of the distortion reduction is a significant cost reduction. Weld savings are passed on to the Navy by reduced bid estimates, and benefit the shipyard by increased competitiveness.

CONCLUSION

The alternate design method for partial penetration joint designs is a marked improvement over existing published navy design criteria. By comparison, it permits a more economical design for common material and filler combinations. It may also prevent unsatisfactory designs which could result from application of the existing criteria. One added benefit is that the alternate method is applicable to unbalanced joint designs. There is currently no published Navy design criteria for unbalanced partial penetration joint designs.

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Model Testing of an Oval Shaped Seal for Sealing of Large Gaps Between Mating Surfaces

No.128

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ABSTRACT

A pressure chamber was designed and manufactured in two parts which were clamped together at their flanges using a clamping ring and an "O" ring seal was used for sealing the gap between the mating surfaces. The clamping ring held the two flanges together while the chamber was pressurized with mixed gas. The internal chamber pressure caused the gap to widen (unseat with pressure) resulting in a final gap in which the "O" ring could no longer maintain an adequate seal. The "O" ring seal groove was designed with an undercut or dovetail groove to capture the "O" ring. The dovetail groove cross-sectional area was designed to accept 100 percent of the "O" ring area. The pressure chamber could not be taken out of service to redesign the mating connection and to accomplish the related production work. To solve this problem, an oval shaped seal was designed to fit into the existing dovetail groove, but with a greater standoff height to allow for the larger gap (See Figure 1).

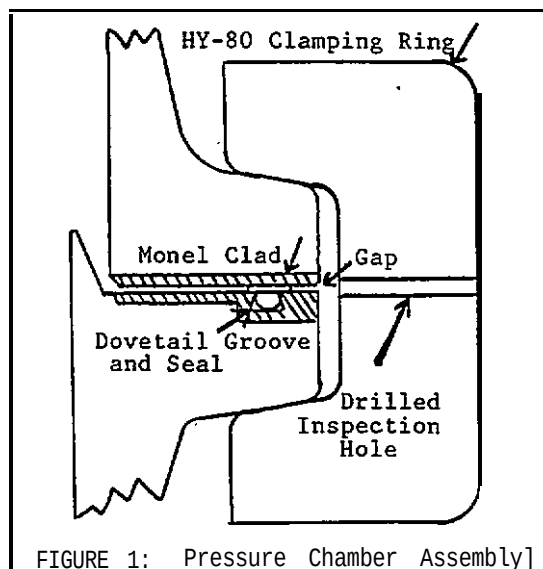


FIGURE 1: Pressure Chamber Assembly]

INTRODUCTION

The oval shaped seal cross sectional area was designed to be equal to that of the existing "O" ring. The oval seal was of a non-standard design and had no previous performance data. A test program was needed and developed to certify the seal for this application by (1) obtaining field data on actual gaps at the seal area of the chamber, (2) applying the field parameters to model testing. The material selected for the oval seal was EPDM Neoprene Military Specification MIL-G-22050 with a Shore A durometer hardness of 80. The criteria for material selection was based on (1) operating pressure, (2) operating temperature, (3) permeability (tendency of gas to diffuse through the elastomer), (4) service life, (5) static application and (6) extrusion resistance.

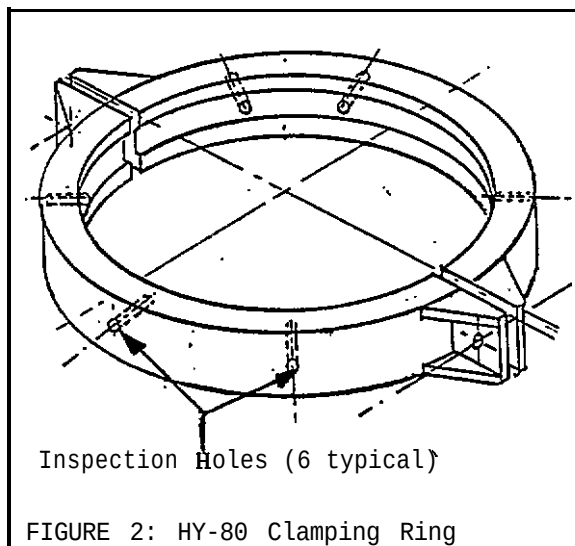
FIELD DATA

Actual field data was considered necessary to identify seal test parameters and criteria for model testing and seal certification for this specific application. Direct gap measurements of the pressure chamber were taken to (1) determine relative waviness/unevenness between flanges (measurements taken every five degrees circumferentially with seal and clamping ring removed), (2) determine gaps with seal installed before clamping (measurements taken every five degrees circumferentially), (3) direct measurements with clamp in position. The measurements for (1) and (2) could be easily obtained because the mating surfaces were exposed however, once the clamping ring was installed, the mating surfaces were obstructed and direct measurements were no longer achievable. This presented a problem as the maximum unseating gap occurred under internal pressure and this measurement was needed for correlation to model testing.

Direct Measurements With Clamp Installed

The solution to obtaining these measurements originated with a finite

element analysis of the HY-80 material clamping ring. The finite element model depicted internal forces and geometry of the ring. stress plots/contours were developed to determine stress gradient across the HY-80 clamping ring. As a result, it was concluded that six 3/8 inch diameter inspection holes could be drilled through the center of the 2-1/2 inch thick clamping ring without compromising safety of design (See Figure 2). The inspection holes were to be used for direct access to measure the actual gaps with clamping ring installed and system at full operating pressure. The rationale for inspection hole location was based on accessibility for drilling, expected areas of high deflection and the location of areas of greatest unevenness between mating flanges. The gaps were first measured with the system unpressurized and then fully pressurized to directly measure the increase due to unseating pressure. The gaps were measured by inserting a specially designed feeler gage through the inspection holes to directly measure gaps on the low pressure side of the oval seal.



Field Data Obtained for Model Testing

The field data taken demonstrated that without a seal installed, unevenness existed between mating surfaces ranging from 0 inch (metal to metal) to .009 inch. After the oval seal installation without clamping ring installed, gaps between mating surfaces ranged from .025 inch to .045 inch. With oval seal and clamping ring installed and no internal pressure, gaps measured from .020 inch to .040 inch. Under full pressure, the gaps measured through the inspection holes were .020 inch to .057 inch. The range of percent squeeze

of the oval seal under pressure are as follows:

<u>.051 Inch</u>		<u>.020 Inch</u>
.350	Seal Height	.350
-.222	Dovetail Groove Height	-.222
-.128	Seal Standoff Height	-.128
-.057	Max. Gap	Min. Gap -.020
.071	Squeeze	squeeze .108

% Squeeze = $.071 / .350 = 20\%$ Minimum

% Squeeze = $.108 / .350 = 30\%$ Maximum

It is to be noted that the commercial recommended squeeze for "O" ring seals ranges from 20-35 percent. (Reference Parker Hannifin Corporation O-ring Handbook ORD-5700.) ASTM recommends 25 percent squeeze for proper sealing.

Original "O" Ring Failure

As can be demonstrated from the above unseating gap data, the original "O" ring could not withstand full pressure without leaking due to improper squeeze of the "O" ring. This is attributable to the built-in surface unevenness plus the increasing gap due to unseating pressure. This can be best illustrated as follows:

Original "O" ring diameter .269 Inch Min.

Depth of dovetail groove-.222 Inch Max.

Standoff Height of "O" Ring .047

With 20 percent of the circumference of the chamber having an actual unseating gap of .040 inch to .057 inch, it is clear why the existing "O" ring would not properly seat under operating pressure.

MODEL AND TESTING APPROACH

Technical discussions were held in which it was concluded that for oval seal certification, a test fixture would be designed and manufactured with a 1/4 scale overall diameter (approximately 11 inches) yet maintain the full scale cross-sectional area of dovetail groove and oval seal (See Figure 3).

Test Fixture

The test fixture was designed of two flat circular shaped plates bolted together. Stress and deflection calculations performed indicated that the top and bottom plates to be constructed of HTS (high tensile steel per MIL-S-22698 Grade DH) plate of 1-1/2 inches and 2 inches thick respectively. The bottom plate would have machined in it, the dovetail seal groove, the oval seal and passages for filling and venting the assembled fixture (See Figure 4).

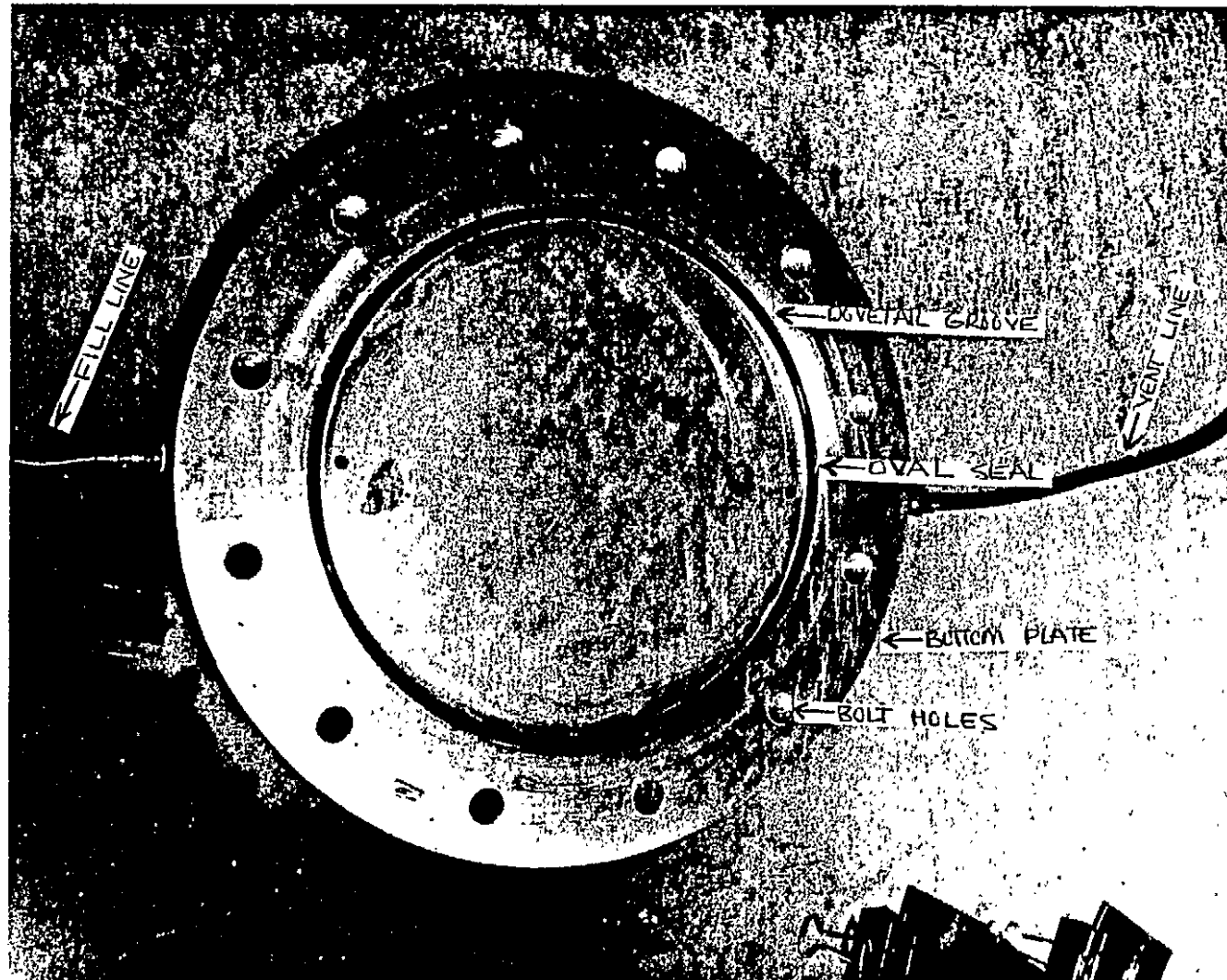


FIGURE 4: TEST FIXTURE BOTTOM PLATE

The plates would be held together by twelve attachment bolts and were designed to be 3/4 inch-10 UNC machine bolts Grade 8 per MIL-S-001222 (See Figure 5 and Figure 6). The bolts would be sequentially torqued to 185 ft. lbs to assemble the fixture for testing. The geometry of the gland seal area including surface finish, would be to the same drawing requirements as the full size pressure chamber. In addition, in order to directly view the seal shape at the smallest measured gap, a second top plate was manufactured of clear Plexiglas (per MIL-C-24449) that would mate to and accommodate the same method of attachment to the bottom steel plate.

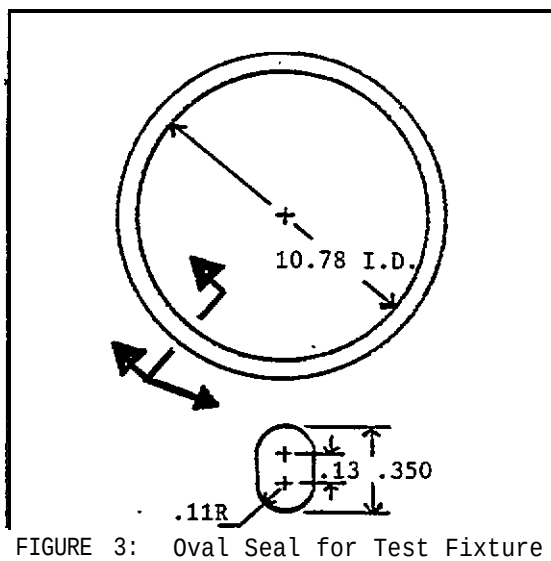


FIGURE 3: Oval Seal for Test Fixture

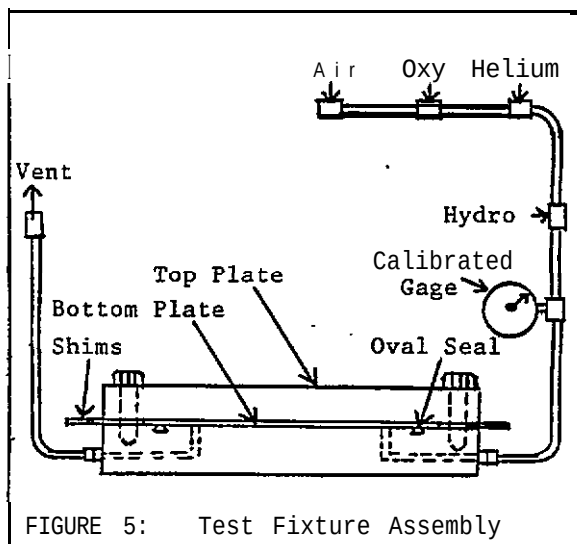


FIGURE 5: Test Fixture Assembly

Gap Control

Shims were designed to fit in-between the top and bottom plates and in-between the attachment bolts in order to directly control test gap. The shims were milled out of steel plates of various thickness from .002 inch to .064 inch.

Criteria for Model Testing:

Technical discussions were held on operational parameters from which the following test criteria was developed:

1. Initial Test Pressure = 1512 psig (1450 psig minimum)
2. A helium and oxygen mixture would be used for final testing.
3. Test temperatures = +140 degrees fahrenheit, -40 degrees fahrenheit.
4. Ten day pressurized hold test at each temperature extreme.
5. Acyclic, seal stiffness and visual compression test would be required.

MODEL TESTING

Hydrostatic Test

In order to determine the maximum gap the oval seal would hold for start of testing program, pressure and gap iterations were performed of the test fixture with oval seal installed. This was accomplished by internally pressurizing the test fixture with water and varying the gap (shim pack) starting with .080 inch gap and incrementally decreasing the gap (See Figure 7). At .075 inch gap, the oval seal in the test fixture held the full 1512 psig. Results were then verified by installing a second oval seal which sustained the same pressure at the same gap. The gap of .075 inch was then used to proceed with the remainder of the test program.

Low Temperature Mixed Gas Test

A new oval seal (Shore A Hardness = 79) was installed in the test fixture using the .075 inch gap previously determined by hydrostatic testing. The test fixture was placed into an environmental test chamber and subjected to -40 degrees fahrenheit (See Figure 8). Upon pressurizing the system with a 80 percent helium 20 percent oxygen gas mixture, leakage occurred at 800 psig. Upon disassembly investigation revealed that excessive fluorolube grease was present on the top plate's mating surface directly

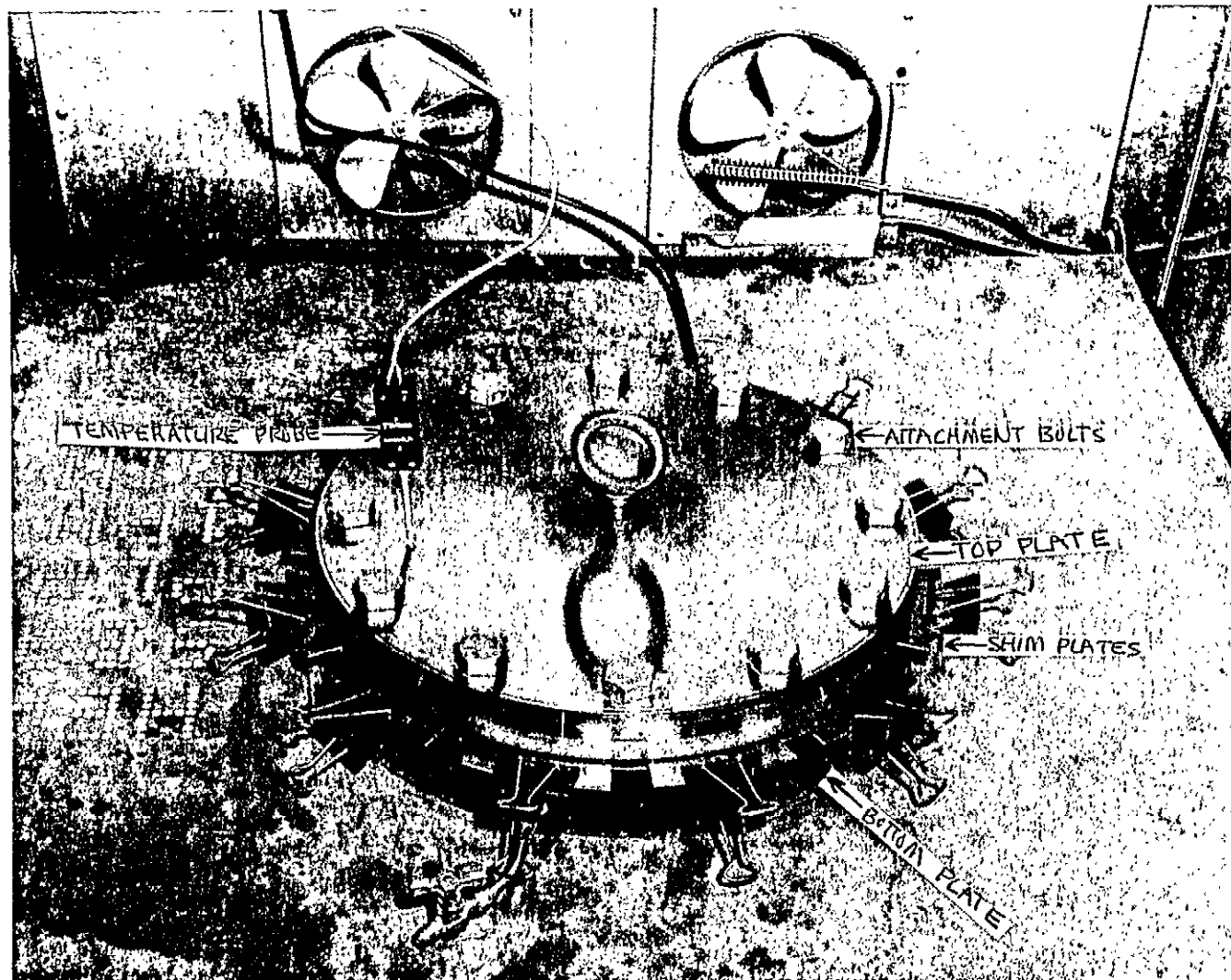


FIGURE 6: TEST FIXTURE ASSEMBLY

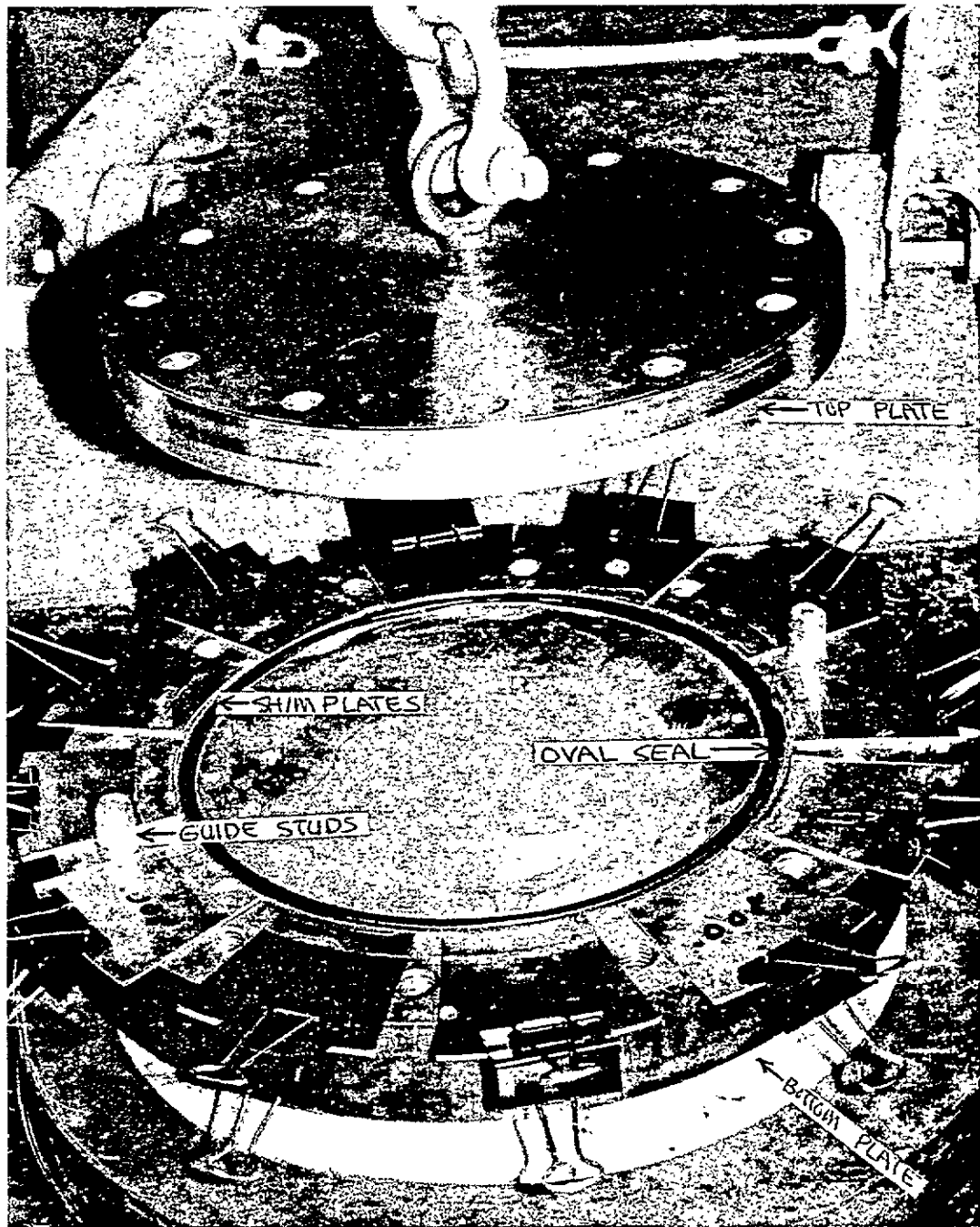


FIGURE 7: HYDROSTATIC TEST-FIXTURE DISASSEMBLED

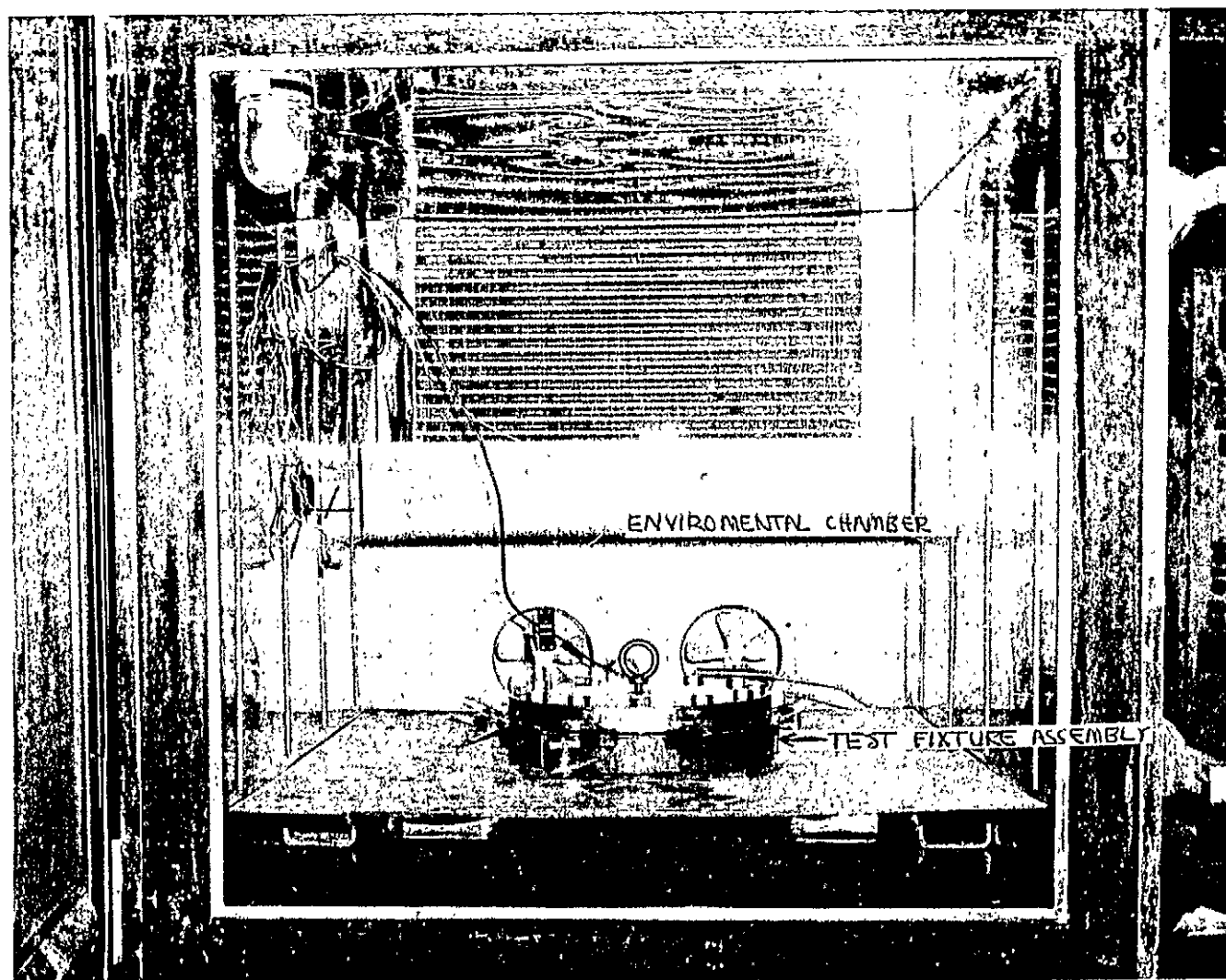


FIGURE 8: TEST FIXTURE IN ENVIRONMENTAL CHAMBER

above the oval seal, allowing mixed gas to leak by. The fluoralube grease was originally used to lubricate the oval seal for ease of installation into the dovetail groove. The excessive grease was wiped off, the fixture reassembled, cooled to -40 degrees fahrenheit and again pressurized. This time the pressure of 1512 psig was attained and then held for the ten day test period. Temperature and pressure were continuously recorded and checked every eight hours during the test period. Total pressure loss over the ten day period was 9 psig. At the completion of the ten day test, the test fixture was removed from the environmental chamber and disassembled. The oval seal was visually inspected and exhibited a slight amount of compression set however, there was no damage to the sealing surface and the oval seal was still considered serviceable.

High Temperature Mixed Gas Test

A new oval seal (Shore A Hardness = 79) was installed into the test fixture using the previously established .075 inch gap (shim pack). The test fixture was placed into the environmental chamber and heated to +140 degrees fahrenheit and the system pressurized with the 80 percent helium and 20 percent oxygen gas mixture. No pressure drop was encountered therefore the 10 day/240 hour hold test commenced. The test pressure and temperature was continuously checked every eight hours during the test period. At 184 hours (76 percent) into the test the pressure had dropped below the specified minimum of 1450 psig to a value of 1447 psig and make-up gas was added to restore the 1512 psig. The test was then continued to the ten day completion at which time the final pressure was 1492 psig. The pressure drop throughout the ten day test was linear and at a rate of -.36 psig/hour. The test fixture was removed from the environmental chamber and disassembled. The oval seal was removed and examined under 10X magnification. The oval seal had shown evidence of having taken a permanent set after being compressed and pressurized. Although the set was greater than noticed on previous oval seal tests, the oval seal did not exhibit major damage and was still considered serviceable. The pressure loss of 8.6 psig/day developed during the test was attributed to gas diffusion through the gasket as opposed to a seal boundary leak which would have steadily increased until system failure.

Cyclic Hydrostatic Pressure Test

A new oval seal (Shore A Hardness = 79) was installed into the test fixture at the previously established

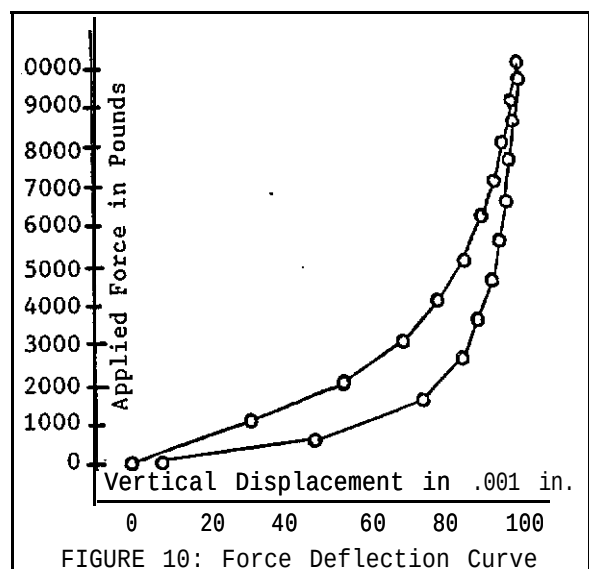
.075 inch gap (shim pack). The test fixture was subjected to 199 cycles of water pressure cycling from 0 psig to 1512 psig then back to 0 psig. Each 30 second cycle consisted of:

1. Eight second duration-increase pressure from 0 to 1512 psig.
2. Ten second duration-hold 1512 psig pressure.
3. Twelve second duration-decrease pressure from 1512 psig to 0 psig.

At the completion of the 200 cyclic testing, the pressure level was brought up to 1512 psig and held for ten minutes then returned to zero. The test fixture was then disassembled and the oval seal removed for visual inspection. Inspection revealed that the oval seal exhibited permanent set from being compressed, however, there was no evidence of cuts, nicks or extrusion and the oval seal was considered as still serviceable.

Stiffness/Load Deflection Test

A new oval seal (Shore A Hardness = 79) was installed in the test fixture which was then placed in a 60 ton hydraulic press. The hydraulic press held the test fixture plates together in lieu of the attachment bolts. Two dial indicators were positioned to monitor the relative movement between the upper and lower test fixture plates (See Figure 9). A compression load was then applied in 1000 pound increments from 0 pounds to 10,000 pounds then decreasing to 0 pounds. Dial indicator readings were recorded and plotted at each 1000 pound increment (See Figure 10).



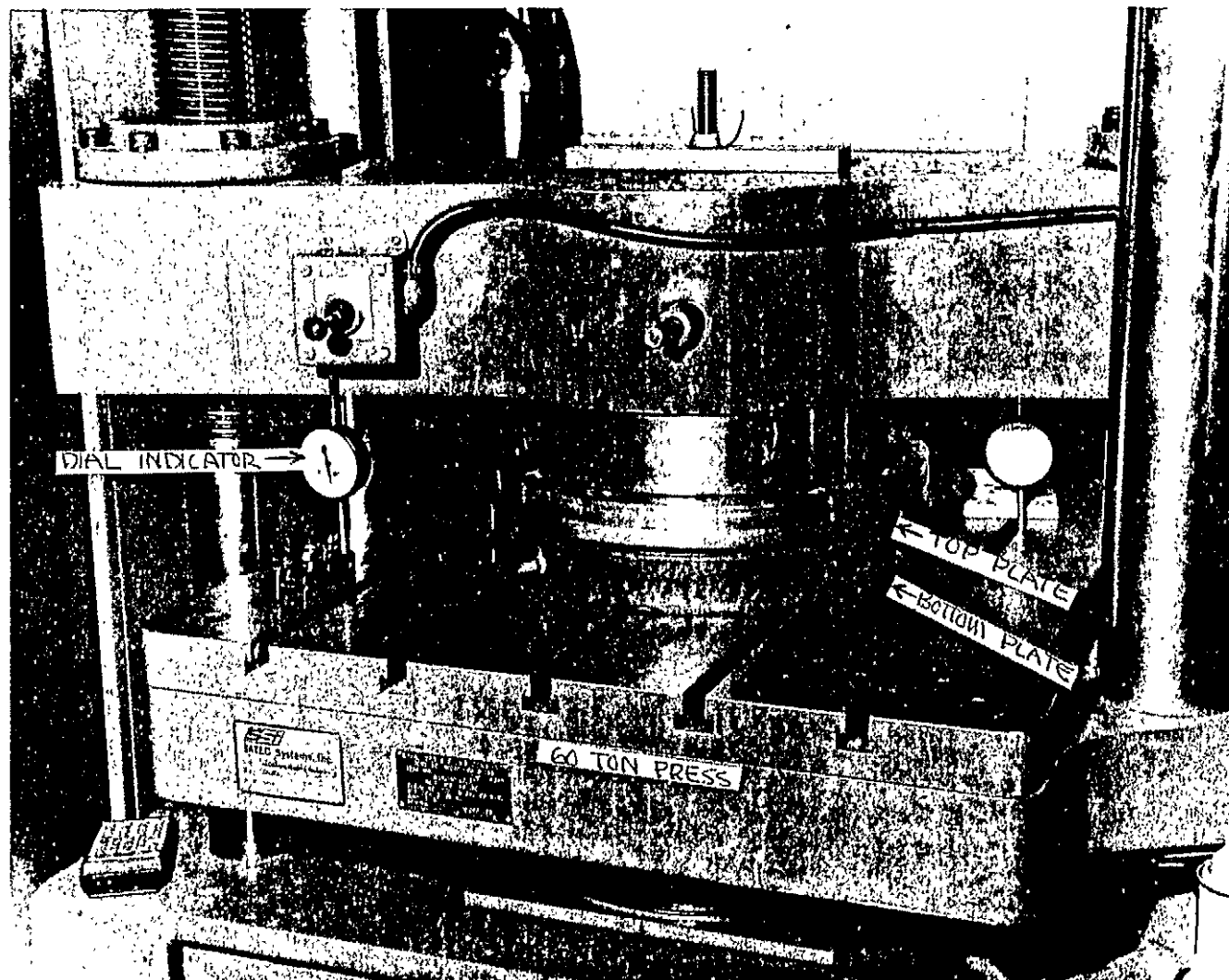


FIGURE 9: TEST FIXTURE IN HYDRAULIC PRESS

Visual Compression Test

A new oval seal was installed in the dovetail groove in the lower plate of the test fixture. The steel top plate of the test fixture was replaced with the 2-1/2 inch thick polished Plexiglas plate (See Figure 11). The shape of the oval seal was visually observed and photographed through the transparent plate. The attachment bolts were progressively tightened to reduce the gap between plates to .020 inch which corresponded to the minimum measured chamber gap. The final gap of .020 inch was fixed by installing shims between the plates. The behavior of the seal was observed and photographed through the transparent plate (See Figure 12). The results of the test indicate that when the gap is decreased the oval seal does not recede into the dovetail groove but deforms to a mushroom shape to seal the gap between the two plates. At the completion of the test, the fixture was disassembled. the oval seal was visually inspected and considered to be in satisfactory condition.

CONCLUSION

The oval shaped seal technically met the intent of the test program, therefore, it has been recommended for use in the full size pressure chamber. The pressure loss which occurred during the high temperature test was significant for the small volume (8 cubic inches) of the model test fixture but insignificant when scaled to the much larger volume (many cubic feet) of the full size test chamber. The following recommendations were imposed as a part of operational use of the oval seal:

1. Operational pressure not to exceed approximately 400 psig.
2. Operation pressure gap between mating surfaces not to exceed .060 inch (measured with special feeler gage).
3. Operational temperature envelope of -40 degrees fahrenheit to +140 degrees fahrenheit.
4. Replace seal after 200 cycles of use or after one year.
5. Visually inspect seal after every use.
6. Install oval seal in dovetail groove using a light film of lubrication.

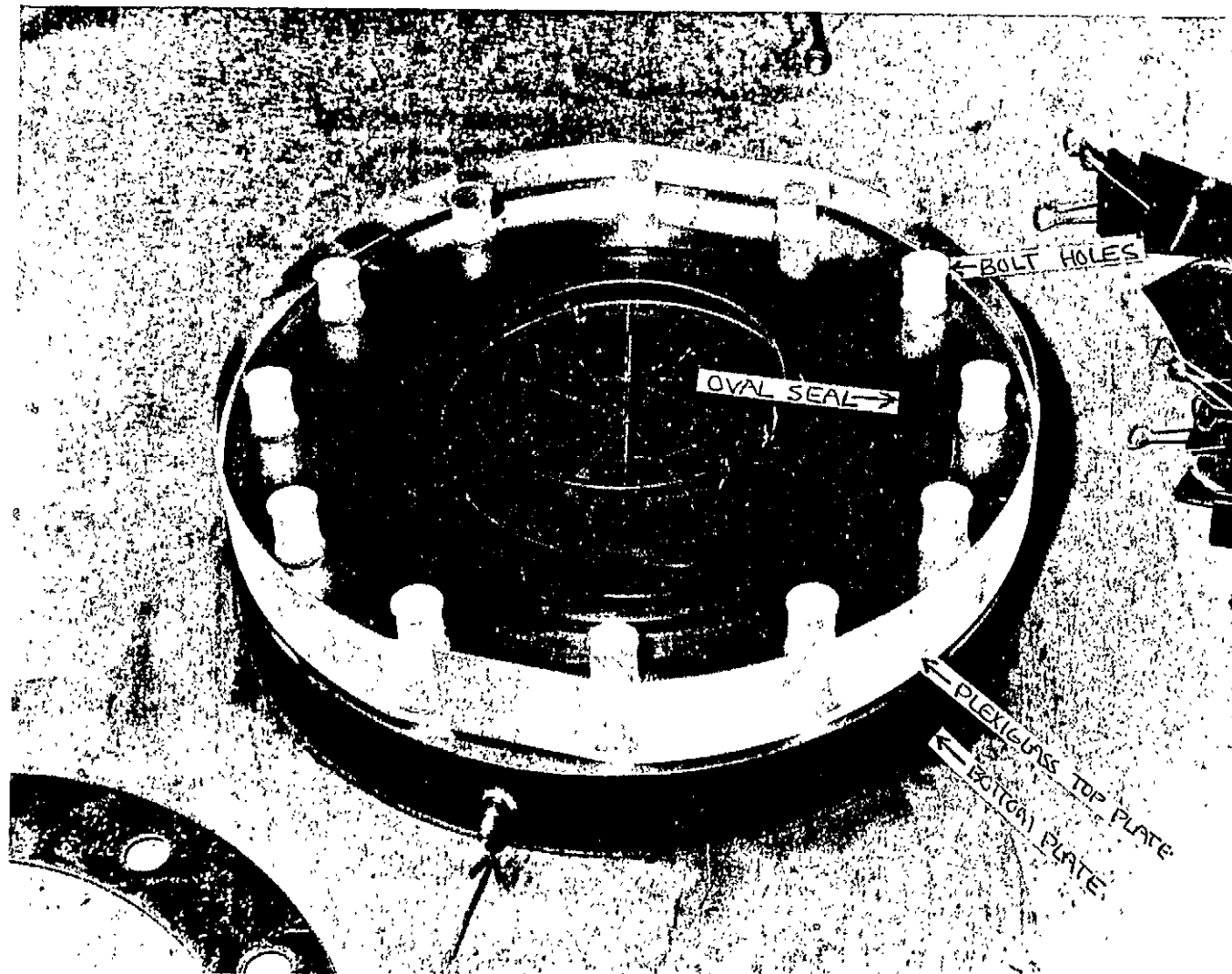


FIGURE 11: TRANSPARENT PLEXIGLAS TOP PLATE

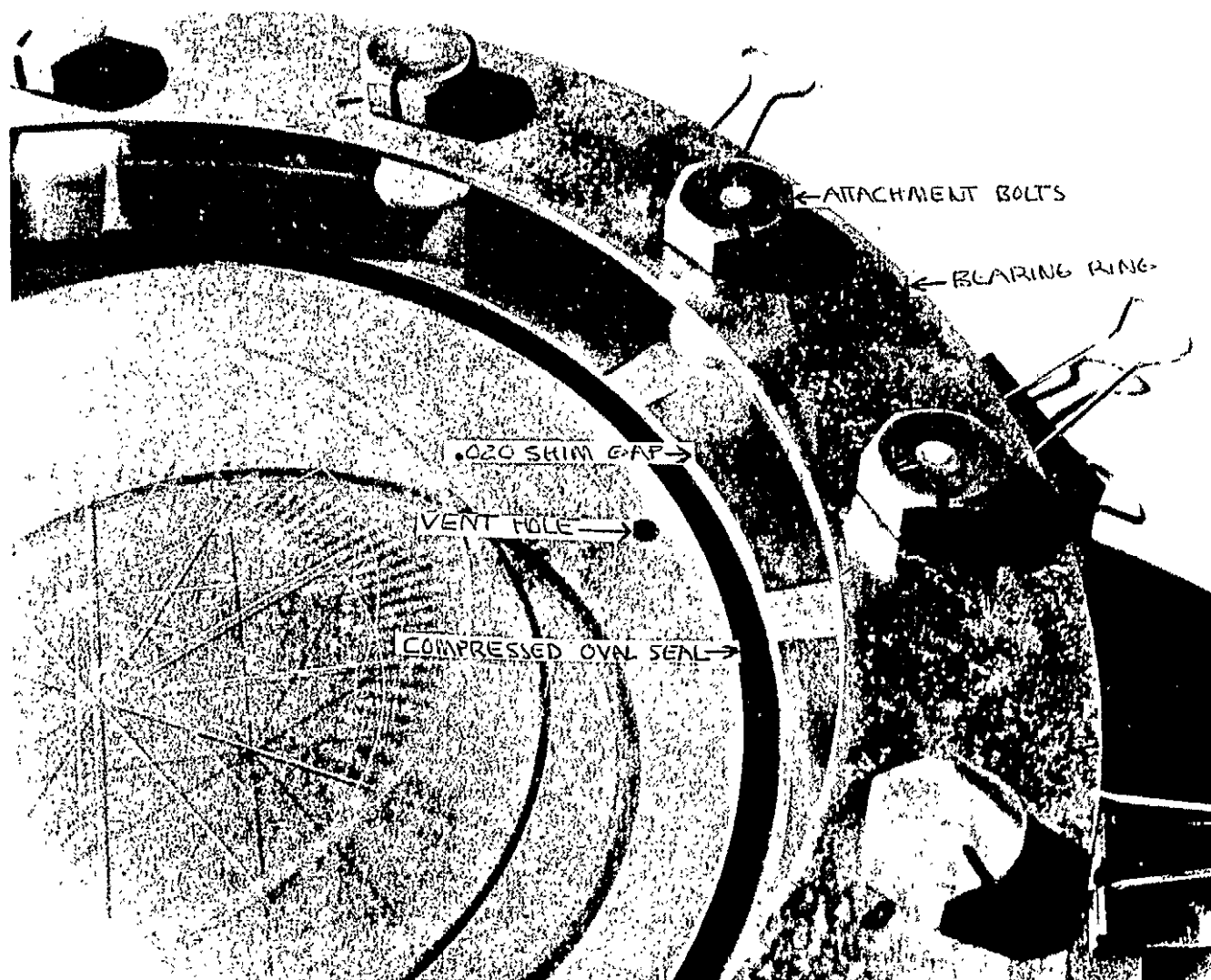


FIGURE 12: TOP VIEW OF COMPRESSED OVAL SEAL

Title: The Use of Computers in Advancing Group Technology

Author: Eric W. Stewart, Member

Discussor: I.D. Chirillo, Member

About 2-years ago, the president of a large U.S. shipyard noted. "No wonder that gone United Kingdom shipyards have very rapidly exploited the National Shipbuilding Research Program's disclosure of a product work breakdown structure (PWBS). They traditionally have many College-educated people in middle management." Quite aware of this resource, in 1982, Dr. Roger Vaughan, the Director of Productivity for British Shipbuilders, advised, "There is nothing like a PWBS in the U.K. As a matter of fact, there is nothing like a PWBS in all of Europe!" The, with a great sense of urgency, he initiated development of the computer applications describe in the author's paper. No equivalent development in mainland Europe or North America has come to my attention. Today, as the Deputy Chief Executive of Swan Hunter Shipbuilders Ltd., Dr. Roger Vaughan is a foremost user of the system he envisioned.

Certainly, the author is correct in noting that a PWBS does not fundamentally changed the "...continual iteration and refinement..." nature of the design process. But, it is important to add that design sequences change to reflect integrated hull construction, outfitting and painting. As a consequence of the integration, shipyards in the U.K. and in North America which have fully committed to a PWBS now routinely "se numerical-control machines for cutting all bulkhead and deck penetrations. In other words, outfit information is grouped to match the way structural information is grouped and both are produced in the same sequence per a common build strategy.

Also, the author is commended for warning that retraining people and coordinating the introduction of a different organization, is an awesome challenge. It is the organization of people

by specialities per product that simplifies the coding task because the various product groups "...do not have to understand the implications of a code beyond their use of that code".

Perhaps the most noteworthy passage in the author's paper is the one which advises that any computer system contemplated must be capable of supporting requirements during the transition from a traditional system work breakdown to a product work breakdown and must be capable of dealing with the various speeds at which individual shipyards or departments can assimilate change. These requirements for a flexible computer system were classified as no less than mandatory. Without it, managers attempting transitions to product orientation have good reason to be apprehensive.

The author listed 12 topics which he sees as forming the basis of an integrated system to support shipbuilding technology; half pertain to material. Subsequent descriptions in the paper also reflect the same emphasis which I agree is essential. But, does the system now maintain relationships between materials and man-hours required to process the materials? If not, is that capability being considered?

Production control through control of material is the essence of effective product-oriented operations. It becomes the driving force for a unique form of standardization which limits designers to a reasonable number of best alternatives for each item, according to corporate experience. It permits the use of statistical methods for, and decentralization of, man-hour budgeting and scheduling. During design, control of material also becomes a driving force for management by target.

Title: An Integrated CAD/CAM Network for Work Packaging Development and Database Management

Authors: LCDR M.S. O'Hare, USN, Visitor and LT M.J. Anderson, USN, Visitor

Discusser: L.D. Chirillo, Member

Those of us who are familiar with the psychology of the management of naval shipyards, recognize that the authors have described a tremendous undertaking, i.e., the zone-logic approach for a large part of the modernization of the aircraft carrier KITTY HAWK and simultaneous creation of "An Integrated CAD/CAM Network for Work Packaging Development and Database Management" to suit. Even the word "revolution" does not seem adequate. If the effort is sustained, the corporate culture of Philadelphia Naval Shipyard could become like that of the most successful U.S. corporations.

The first key factor listed is establishment of priorities based on a "war-time condition". As noted, the Under Secretary of the Navy and important agencies of two governments were involved in the approval process. All reacted in record time. Rarely is this sense of urgency applied to industrial matters in peacetime. Those of us who have experience as members of naval operations staffs, applaud. We understand how shipyards influence readiness. **To us,** cost overruns and schedule lapses are equivalent, to ships damaged or sunk.

Regarding the technical nature of the authors' paper, I am curious about provision for integration of outfitting and structural details. I recognize the suitability of the Computervision subsystem for detailing pipe runs but am not aware that it is used for structure. I recall seeing the structural-design output of Autokon being used as background for developing outfitting details with Computervision. But, when the developing outfit details suggested a structural change, the Computervision system at that time could not transfer changed structural details back to Autokon. An interface that permits transfer in both directions is necessary because effective utilization of Zone Logic Technology (ZLT) is dependent on integration of hull construction, outfitting and painting activities. Had the Hull Expansion Project for KITTY HAWK been implemented, this need would have been highlighted. But, there are other potential applications.

Recently, I observed a large-diameter pipe run which came through the overhead of a frigate passageway, turned 90°, curved toward the center of the passageway and went forward about 4-feet. It then turned 90° athwart, penetrated a

machinery-space casing, turned down 90°, and then sloped aft in the direction it came from. The pipe run had been routed around a bulkhead stiffener. I first thought, with integrated hull construction and outfitting, the bulkhead stiffener would have been shifted. I then thought, with CAD/CAM, it is practical to penetrate bulkheads and decks at other than 90° angles. Considering the case observed, the penetration would have been made at an acute angle to the vertical. The need for 4 large-diameter pipe bends would have been eliminated. I next thought, subject to certain requirements, the pipe could have doubled as the bulkhead stiffener. Such are the benefits of integrating hull construction and outfitting.

The scanner capability which is featured as part of the network for work packaging development and database management is a prudent investment. But, most drawings do not adequately reflect existing configurations in ships. This is a consequence of the traditional system-by-system approach wherein: pipes under 2-inches in diameter are field run, lots of interferences are resolved by first-line supervisors without notifying the drawing office and, even for submarines, drawings only approximately locate many components. It is also a consequence of preparing as-built drawings after a ship is delivered when other building projects have higher priority, and of inadequate drawing maintenance when ships are in service. Thus, a scanning capability of as-built arrangements in ships is also a requirement and will remain so for some years.

The U.S. Navy has sponsored development of a laser-scanning device to record as-built configurations. Evaluation is imminent. Panel SP-2 of the Ship Production Committee has proposed a marriage of "off-the-shelf" photogrammetric hardware, software and procedures. It is likely that the laser scanner will be found practical for short-range view and that photogrammetry will be more useful for capturing data in much larger fields of view, such as for surveying entire machinery spaces. Charleston Naval Shipyard has already productively employed a photogrammetric survey to produce detail drawings and numerical-control tapes as needed for manufacturing replacement gravity-type boat davits.

Provision of a "Remote PC Cluster" which permits KITTY HAWK personnel real-time access to the shipyard's planning and scheduling of zone/stage work packages is a major breakthrough. In naval ships, crews customarily perform a significant amount of work simultaneously with yard-managed overhaul work. With traditional system-by-system work packages, different work teams compete for access to work and claims that a ship's force disrupted yard work are common. Because of the real-time access and because of the logic shift for grouping information, i.e., system by system to zone/stage, KITTY HAWK can schedule its own work in a specific zone during a specific stage with much greater assurance that yard work will not be disrupted. On this account, there should be noticeable reductions in interferences and rework.

The benefits of the electronic and logic revolutions reported by the authors, are not unnoticed. I hope that the authors will continue to report on the savings as KITTY HAWK modernization progresses. I also hope they will give particular emphasis to the saving arising from the ceasing of charges immediately upon completion of work which is uniquely inherent in the use of zone/stage work packages.

Finally, no comment on benefits could be complete without acknowledging the contribution of the former Commander of Philadelphia Naval Shipyard, Captain W.F. Kerr, U.S. Navy. He made the bold decisions which set in motion the very impressive innovative approach for modernization work in KITTY HAWK knowing full well that the final tally of benefits will be long after his tenure as Shipyard Commander.

Title: Infusing Producibility into Advanced Submarine Design

Author: LCDR B.R. Brucker, USN; Member

Discusser: L.D. Chlirillc, Member

The author's paper is more evidence that a once sleeping giant has been awake for some time and is now applying tremendous resources toward furthering the application of zone logic in the U.S. shipbuilding industry. Those of us who introduced zone logic via the National Shipbuilding Research Program had at first only merchant-ship applications as examples. We were summarily told by traditionalists in the naval bureaucracy that warships are different. As the logic prevailed and applications for building surface warships became apparent, the traditionalists then responded, "Submarines are different". The author's paper confirms the advice given to us by Dr. H. Shinto 8-years ago. When asked if zone logic was more effective in outfit-intensive ships, he replied, "Oh yes. Particularly in...warship construction where the weapon arrangement is so concentrated within limited space." [4]

The types of SEAWOLF drawings described make sense, particularly because of the emphasis on use of Configuration Drawings for approval purposes. But, the breakdown of Sectional Construction Drawings "...into functional trade work packages called chapters" is reason to suspect that a modern product organization is not anticipated for the production phase. "Zone" is synonymous with "product" or "interim product". Until detail-design and production people are organized to specialize by product and are preoccupied with cost per product, zone-logic will not be fully exploited. Product organization as advocated by the management guru, Peter Drucker, should be studied. The product-trade concept currently being employed by Philadelphia Naval Shipyard for modernization and overhaul of the aircraft carrier KITTY HAWK, should at least be considered.

I wonder how many readers will detect the significance of the author's comment that, "The completion by a shop of a drawing chapter will indicate that a product has been built..." This is the inherent feature of zone logic which has virtually eliminated the practice of assigning charges to a work order long after the work described is completed. The latter is prevalent in traditional system-by-system operations and is a significant cause for inadequate corporate data.

The author notes that with zone logic, "The products needed...become the driving force in meeting schedules to provide design products..." Actually, each interim product should serve as a focal point for identifying all resources needed, not just design outputs. Also, there is another prerequisite for enhancing schedule adherence. Where interim products are classified by the problems inherent in their manufacture, reel end virtual work flows are organized. Then, with statistical methods as advocated by Dr. W. Edwards Deming, men-hour budgeting and scheduling are based on known probabilities for compliance. The driving forces are people responding to problems that are identified by statistical signals.

Regarding the post-design producibility review described by the author, it is suitable for SEAWOLF because design is being progressed to a great degree of detail before a building contract is awarded. Emphasis on the producibility review should continue for each follow boat and should be the responsibility of everyone in design, material and production departments. Without changing operational requirements or significantly impacting on provisioning documentation, there should be constant improvements in boat after boat related to the author's producibility issues supplemented at least by:

- o number of separate material items per boat,
- o total footage of all pipe,
- o number of all pipe pieces,
- o average pipe-piece length,
- o number of straight pipe pieces and pipe pieces that can be completely fabricated as straight and bent afterwards,
- o number of bent pipe pieces having other than 90° and 45° bends,
- o number of pipe pieces assembled in outfit packages,
- o number of pipe pieces assembled in sub-modules, modules, and sections,

- o number of pipe pieces fitted on board,
- o regarding pipe-piece precision, ratio of total number of mock, loose-flange, reworked, etc. pipe pieces to total number of pipe pieces,
- o total footage of all electric-cable runs,
- o total footage of electric cable pulled in sub-modules, modules end sections,
- o total footage of electric cable pulled

- o number of electric-cable ends connected in sub-modules, modules end sections,
- o number of cable ends connected on board,
- o accuracy in terms of mean values and standard deviations for pipe pieces, piece parts, sub-modules, modules, and erection butts and seams.
- o regarding steel yield, ratio of net weight to invoiced weight, and
- o regarding completeness of material pellets, ratio of missing number of line items to total number of line items.

I like what the author has written. His excellent paper is additional evidence of the growing awareness among mid-career naval officers of the power of zone logic to greatly improve shipyard productivity.

[4] When interviewed by I.D. Chirillo at the University of Michigan, October 1980. Dr. H. Shinto, now President of Japan Telegraph and Telephone Corporation, is a former president of Ishikawajima-Harima Heavy Industries Co., Ltd.

Title: Product Work Breakdown: An Essential Approach for Ship Overhauls

Discusser: Dr. Roger Vaughan,
Deputy Chief Executive,
Swan Hunter Limited; Visitor

Once again Lou Chirillo has hammered home a message with which we at Swan Hunter have total sympathy. The approach which he sets out is well known to us and is one which we have used for naval ship construction for a number of years. We have reorganized our management structure, our planning, labour costing; engineering functions and our labour agreements in support of these principles and confirm that it works. In fact I cannot now conceive of any other way of approaching the problem.

The difference between US/UK and Japanese shipbuilding is of course one of volume and this does present real problems in achieving sample sizes statistically significant for the application of statistical process control throughout the business. This is not an area where we would claim to be overly successful to date - it is not for the want of trying but it is taking us longer to get there than we hoped.

Material supply often presents problems because in general the US/UK supply industries also need to apply these principles. We do however define our materials in these categories Lou Chirillo sets out and again this has given us significant benefits as has the supporting computer based materials control system which we have implemented. We do believe in controlling projects by controlling materials.

I am glad that Lou has attempted to extend the principles to major ship refits and look forward to hearing how it went on the KITTY HAWK SLEP. This would be a further valuable experience.

The most important point to remember, however, is that we are really talking about changing management attitudes as well as behaviour. The technical content of PWBS is very simple but those of us who try to manage change effectively will know, logic is not sufficient to win progress. You have to excite, lead, cajole, persuade and train people. You also have to instill in them the recognition that thought is as important as action and that engineered quality means everybody caring about getting it right first time, right on time every time.

The people dimension remains pre-eminent.

Discusser: H. Sasaki, Senior Manager,
IHI International and
former Deputy Manager,
IHI Kure Shipyard; Member

This paper is very impressive because the author made the primary proposal for applying the product-oriented approach to ship overhauls. I would like to express my respect to the author, Mr. L.D. Chirillo for his innovative manner.

The product-oriented approach (or Zone-oriented) has recently become prevailing in U.S. shipyards, but there seems to still exist the craft-by-craft organizations and traditional supervisors having got used to the system-by-system method.

In the case of applying the product-oriented method to ship construction and overhauls, production planning, design engineering, material procurement and handling, manning allocation to work site and work instructions have to be synthetically organized. Should any one of them fail in its performance, the product-oriented method will not work.

The key to success in implementation of the new method is to achieve it first that all employees and union leaders are indoctrinated for recognizing the new method worthwhile and they agree to perform their duties with positive attitude.

Another key to success is seen in the statement that Avondale Industries Chairman, Mr. Bossier stated recently in a local newspaper of New Orleans:

"Avondale has two big advantages:

- It is the only major yard in the United States that is non union; non union status made it easy for Avondale to adopt to modular construction whose efficiencies require bypassing the craft-by-craft division of labor.

- It has been first with using Japanese method which he learned from IHI."

I do not intend to quote non union especially, but I believe that he made a big success by means of strong leadership of top management and more cooperation by employees and to transform Avondale from the conventional system-oriented and craft-oriented method to the new product-oriented method using multiskilled workers.

Paper No. 6B Discussions, Continued

Discusser: Roy H. MacGregor. Director
Industrial Engineering and
Planning Division,
Naval Sea Systems Command;
Member

This paper makes an important contribution by accurately describing the potential benefits to be realized from the application of product-oriented work management to the overhaul and repair of ships. Mr. Chirillo points out that the differences between ship construction and repair have little bearing on the effectiveness of product work breakdown techniques used to manage work in the two circumstances. In fact, the gains to be realized through application of the group technology methodology to ship overhaul and repair most likely exceed those realized on ships under construction; due to the fact that repair is a three-fold process, consisting of rip-out, repair, and re-installation.

Perhaps the most significant benefit to be derived from the product work breakdown approach is the forced integration of planning, design, industrial engineering and the production shops; groups that historically operate in relative isolation and with mutual mistrust. The benefits in productivity and cost reduction which can be achieved through the combined efforts of these different groups, each with their own area of expertise and understanding, is almost limitless. The paper clearly points out that integration and coordination of these efforts is a key ingredient in the successful application of the product work breakdown methodology.

The success of any work management system, including product work breakdown, is dependent upon an effective and disciplined planning and scheduling system. The product work breakdown structure facilitates the planning and scheduling process, but does not eliminate the need for it, and in fact will fail without it.

Finally, Mr. Chirillo emphasizes that successful implementation of this important innovation in the way ship overhauls are managed requires commitment and understanding at all levels, and a deliberate well-organized implementation plan. One of the most common failings as managers is our attempt to implement changes without adequately preparing those affected.

Product work breakdown represents a radical departure from the way in which shipyard work has been managed for the last few centuries. Cultural changes of this magnitude do not come quickly or easily. The time and effort invested in

developing a carefully thought out implementation plan, as well as training and developing those middle managers and supervisors who will determine the success or failure of the endeavor, will be returned many times over through the performance improvements which can be realized.

Mr. Chirillo is to be commended for his excellent treatise on a most timely and important subject.

Discusser: W.P. Keene.
Vice President - Operations,
Ingalls Shipbuilding; Member

I concur with the author's basic concept that the same product oriented approach utilized for new construction by many shipyards is also applicable to ship overhaul. However, the application of these concepts to overhaul work is often more challenging than to new construction. In new construction, a shipyard awarded a contract which includes the production design can adopt a product work breakdown structure from the start of the design phase to completion of the contract. All major surface construction shipyards in the U.S. are utilizing a product oriented approach for all new contracts. Some shipyards have progressed faster than others, but the forces of competition are accelerating those that lag behind.

It is unusual for an overhaul shipyard to have the design task for shipalfts and it is the area of complex rearrangements and upgrades that product orientation has the greatest payback. The overhauling shipyard has one of two options: redesign for optimum productivity or develop work packages which apply a product oriented approach. Redesign is normally cut off the question because of contractual or financial constraints. Therefore, the work planning process must normally be used. It should also be noted that most shipalfts are piece part system upgrades and/or change out and do not contain major sub-assembly possibilities.

I certainly agree in the value of establishing work groupings utilizing a zone oriented approach. However, system visibility must be maintained for test and completion scheduling. We have advanced our work package grouping techniques to offer the best of both zone

grouping end system orientation. Through the use of a sophisticated package breakdown technique during the pre-arrival planning period, we have developed a scheduling end management visibility system that is much more versatile than that used by most overhaul activities. These breakdowns include:

- a. Zone (propulsion, habitability, electronics, or compartment)
- b. Ship systems for production work
- c. Ship systems for test
- d. Major events
- e. Individual crafts involved.

We handle "open end inspect" by first utilizing our historic data base to order material that we have a degree of certainty to use. We then schedule the "open end inspect" work items to be accomplished as soon as possible in the overhaul so that the material may be obtained and the work appropriately planned.

The paper correctly emphasizes the importance of identifying all material including contingent material at the bid stage end refining budgets end schedules as material information becomes more definitive. It also states that a more effective material management approach which recognizes that material procurement and marshalling are production control functions. Our approach is not so different from that described since our production control organization has had the management responsibility for material support.

We have an extensive computer based system to track material requirements, ordering, receiving, end issue. Exception reports are provided to track new requirements end problem items. As we all recognize, the capability of computer systems is constantly improving so we are currently upgrading our management systems. This upgrade will improve the interaction between our scheduling, budgeting, end material systems end provide greater visibility for improved management of material as well as other overhaul requirements.

The paper correctly notes the deficiency which exists in the documentation of ship's configurations, however, we have an estimated rebuy rate of less than 5% due to incorrect component identification. This percentage varies from ship to ship depending on the ship's class end age.

The author uses the application of the product-oriented approach to the SLEP overhaul of the U.S.S. KITTY HAWK (CV 63) as an example. This application can be easily envisioned because of the very extensive refit effort involved. It may be pertinent to note some of the practical factors which influence the most effective application of the approach to a standard overhaul in a private shipyard. Some of these factors are:

- a. Design involvement
- b. Work package completeness
- c. Familiarity with class of ship
- d. Time between start of overhaul end contract award
- e. Type of contract
- f. Efficiency in negotiating growth end **new work**

All of these factors are either controlled by, or heavily influenced by, Government actions. None of these factors, by itself, preclude the application of a product oriented approach, but they certainly influence the efficiency with which it can be applied. As an example, if it is anticipated that the contract will be fixed price, most shipyards would be very reluctant to order contingent material until the work is identified end authorized.

As noted above, there are practical factors which influence the most effective application of the product oriented approach end these factors are dependent upon Government actions. It therefore should be apparent that the Government could reduce the cost of overhauls by optimizing these factors for the private sector. As an example, get the shipyard(s) involved in the design of shipalt packages so the product oriented approach can influence the design package. Also, increase the time between between contract award end start of overhaul by streamlining the bidding procedure or by allocations based on past performance. Most overhaul situations require a combination of approaches to suit the particular situation. Certainly a product oriented approach should be primary end only modified as the particular conditions demand.

Once again, Mr. Chirillo has produced an excellent paper which informs all of our industry of the status of product oriented technology end intensified our desire for further improvements in the application of this technology toward the overhaul and modernization of our fleet.

Title: Management Development for the Shipbuilding Industry

Authors: John A. McCarthy, Visitor and Jeffrey S. Geiger, Member

Discussor: Richard D. Chirillo, Visitor

During his career as a management consultant, Peter Drucker produced volumes on the nature of management and business organizations. He was the first to specifically identify the dependency of management development on corporate organization. His book, "The Practice of Management", written in the early 1950s, sparked the 1950-1970 revolution from functional to product organizations that occurred in American industries other than shipbuilding. [5]

Japanese shipbuilders also abandoned functional and adopted product organizations during the same period. Virtually all U.S. shipbuilding managers remain to this day frozen in archaic functional organizations and, for this reason more than any other, are outperformed by their Japanese counterparts. Read Peter Drucker's book. Then, study how Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) develops managers. The conclusion is inescapable that Dr. Hisashi Shinto not only read Drucker, but understood and implemented his ideas. [6]

Ask a traditional shipbuilder, "What is the most important thing in shipbuilding?" More likely than not, the quick response would be, "Experience!" But, when a senior IHI manager was asked the same question, after a thoughtful pause, he replied, "How to analyze." [7]

Learning by experience is valid, indeed it is vital. But, when effective analysis is not constantly applied to improve on experience, technology development stagnates.

In terms of logic and principles, the decades-long virtual stagnation of U.S. shipbuilding since the 1950s, has as its root, failure to adequately understand the management function, and how, in a modern industrial/business enterprise, to achieve that function.

There are two fundamental, equally important prerequisites for a middle manager who aspires to be an effective shipyard general manager:

1) Experience in Shipbuilding as a System

Real responsibilities as staff engineer, assistant shop manager, and shop manager in various shops for inherently different types of work, are essential.

2) Business Experience

It is not enough to have knowledge of shipbuilding as a system; it is also necessary to know how to manage the system as an economic entity.

The authors' paper addresses business experience. But, in a functional organization, business experience is peripheral and inadequate. In a product-organized shipyard, the shops are set up to produce specific interim products with emphasis on cost per product. Each shop is a microcosm of the shipyard. For example, design/production integration, work flow planning, manpower budgeting, and accounting are according to interim product. Promotion to shop manager is the first opportunity the organization gets to really evaluate an individual's economic performance, i.e., impact on cost per interim product. By heading a product-oriented shop, a middle manager is running a virtually self-contained business, an interim business.

The shop manager positions are absolutely necessary to separate business/generalists from functional specialists. In Drucker's words, "The number of functional managers must be kept to a minimum, and there should be the largest possible number of 'general' managers who manage an integrated business and are directly responsible for its performance and results. Young people, still young enough to assimilate new experience, must be placed in positions where they can be evaluated for business Performance." [8]

Commitment of shop manager and higher managerial positions specifically for management development purposes, is not mentioned in the authors' otherwise excellent paper.

[5] R.D. Chirillo, I. Inuki and I. Kobayashi, "Shipyard Organization and Management Development", Journal of Ship Production, May 1986, pp. 74-79.

[6] Dr. Hisashi Shinto is a former President of IHI and is now President of Nippon Telegraph and Telephone Corp.

[7] P. Mikami, General Manager, IHI International.

[8] Peter F. Drucker, "The Practice of Management", Harper & Row, New York, N.Y., 1954, p. 122.

Title: Initial Implementation of IHI Zone Logic Technology et
Philadelphia Naval Shipyard

Authors: Koichi Babe, Visitor; LCDR M.S. O'Hare, USN, Visitor;
James C. Schaff, Member; Takao Wads, Visitor and Soichi Kondo, Visitor

Discusser: L.D. Chirillc, Member

Although it took place 32-years ago, the scene is recalled vividly. All production supervisors were there, in those days shop masters, foremen, assistant foremen, quartermen, and leadingmen. The shipyard's theatre was also jammed with others, including the officers assigned to the planning and production departments. A representative of the Bureau of Ships (now Naval Sea Systems Command) was introducing a formal approach for planning and production control. The objective was to create corporate experience to supplement existing experience which, for the most part, was vested only in the production supervision.

At an opportunity for maximum effect, a leadingman stood end, with arm raised and fist clenched. shouted. "There will be no such system as long as I'm here!" While that attitude wasn't universal, it was prevalent. The approach was doomed. I often wonder, if the same zeal had been applied to improving productivity, would the long-gone Boston Naval Shipyard still exist?

Before the introduction of "IHI Zone Logic Technology" there were other innovations, most of which were trendy. The appearance and disappearance of the Navy's Zero Defect Program is a good example. The innovations did not address the foremost problem, i.e., people waiting for work because their supervisors were constantly reacting to the disruptive influences that are inherent in the application of system-by-system logic.

Zone-logic technology is not exclusively IHI's nor is it anything new. It consists of a number of disciplines that have been around for 30 to 70 years and that are well described in English-language textbooks. IHI's extraordinary contribution is having put them all together as a constantly self-developing flexible manufacturing system, and providing and reworking the system during the construction and/or overhaul of more than 3,000 ships and products other than ships.

Group technology was exploited during World War I. Statistical techniques for process control were first recorded in 1924. Product organization, as being applied in KITTY HAWK, is the subject of a book published in 1954. Unlike the trendy innovations, zone logic has a sound basis and proven track record. The

problem now is not the logic described by the authors. Instead, it is how to capture the cooperation of all of the key players. [4]

The other thing that is not new is the behavior of people who are confronted with change. In any large management group so challenged, there are:

- o those willing to cooperate who are capable of cooperating,
- o those who are sincere in their willingness who need special assistance to make the transformation, and
- o those who are "disbelievers, disinterested, dyed-in-the-wool traditionalists, or curators of ivory towers who constitute a threat to successful implementation". [5]

The letter have been encountered in all yards that have attempted to transform, even in Japan.

Obstructionist cannot be ignored nor dealt with passively. A plan and schedule for gradual transformation of a yard's archaic functional organization to a modern product organization is indispensable. The longer such commitment is postponed, the greater will be the adverse effects of acts or omissions by those determined to resist change.

The zone logic application in KITTY HAWK started with high-level backing, i.e., the Office of the Under Secretary of the Navy. Thus, that Office and naval-shipyard competitors have a common interest. The interest is sharpened by the private sector's skepticism concerning Navy evaluations of public/private shipyard competitions. Taking into account cost elements that the Navy had been ignoring, the General Accounting Office concluded that ship repair costs in public yards were 8% higher than in private yards. From the private sector's viewpoint, it is akin to playing football when the referees also manage the opposing team. A step toward a level playing field is a recent consequence. The FY 1989 Defense Appropriations Bill specifically addresses the issue by stating, "The Navy shall certify that successful bids include comparable estimates of all direct and indirect costs of both public and private shipyards.." [6][7]

The authors have provided an excellent end positive description of implementation of zone logic by a naval shipyard. While decentralization of man-hour budgeting end scheduling, statistical control end control through control of material, are not described, these aspects would surely come with continued application. What is truly remarkable is that the application in KITTY HAWK is very large in scope, is being managed by an ad hoc product organization, end is achieving for Philadelphia Naval Shipyard the distinction of leading all yards, specifically including private yards, in implementing zone-logic for overhaul and modernization work.

But, questions remain. What specifically is being done to overcome resistance to change? Do plans exist for extending the application of zone logic to other overhauls in the yard's backlog? Does a schedule exist for the gradual transformation of the shipyard's traditional system-by-system organization to a modern product organization? Do naval shipyards have time?

[4] Peter F. Drucker, "The Practice of Management", Harper & Row, New York, N.Y., 1954.

[5] John F. Kenefick, "Transfer of Photogrammetric Technology to the U.S. Shipbuilding Industry", U.S. Naval Shipyards' Structural Group Superintendents Workshop, 3-5 November 1987.

[6] LCDR M. S. O'Hare, USN end IT M.J. Anderson, USN; "An Integrated CAD/CAM Network for Work Packaging Development and Database Management", National Shipbuilding Research Program Ship Production Symposium, 24-26 August 1988.

[7] "Navy Evaluations of Public-Private Competitions to Tally All Costs", Inside Ship Repair, July 1988, p. 12.

Title: Formal Manufacturing Approaches to Modern Shipbuilding

Authors: Paul C. Powell, Member and Charles I. Zigelman, Member

Discusser: L. D. Chirillo, Member

This paper deserves a triple-A rating. The authors have connected what is currently recorded of the NSRP model to published descriptions of other formal manufacturing systems. "NSRP model" is the authors' name for that which the National Shipbuilding Research Program (NSRP) has published so far of the logic and principles employed by Ishikawajima-Harima Heavy Industries Co., Inc. (IHI), for managing shipyards.

Various aspects of IHI's approach have been studied. Most of the projects were conceived by Panel SP-2 of the Ship Production Committee. Related painting projects were initiated by Panel SP-3. As a singular feature of IHI's manufacturing system is constant self-development,, no one should believe that IHI's system has been completely described nor that IHI continues to practice everything as published by the NSRP over a period that now encompasses a decade. The value of that literature is its ability to stimulate thought as manifested by the authors' excellent paper.

The second such research project disclosed a product work breakdown structure which I have often called a Rosette stone. It enables people to understand that shipbuilding productivity could be greatly improved by applying a number of formal manufacturing systems that heretofore were regarded as being only suitable for mass production. The traditional belief that "shipbuilding is different" was challenged. Specialized experience along functional lines was, and is still being, pitted against generalized experience along product (interim product) lines that is coupled with ability to analyze. [20]

The authors identify a number of issues having to do with need to reexamine the NSRP model and cite that they "...are all issues of education." I agree totally. The need for pertinent education was recommended and outlined by the National Research Council 4-years ago specifically for senior managers, middle managers, first-line supervision and students. The same need, in fact "nothing less than massive education", was recommended to the Subcommittee on Merchant Marine at about the same time. I am not aware that there has been any Government or industry response commensurate with the sense of urgency conveyed with the recommendations. [21][22]

Without education there will be no general appreciation of the need for product organizations. Without product organizations and devotion of the organization to develop generalist managers, particularly to lead shops as long advocated by Peter Drucker, traditional functionally-oriented management can only dabble in implementing the NSRP model or any other formal form of manufacturing. "For want of a nail...."

[20] The National Shipbuilding Research Program, Product Work Breakdown Structure, November 1980, U.S. Department of Commerce, Maritime Administration in cooperation with Todd Pacific Shipyards.

[21] The National Research Council, Toward More Productive Naval Shipbuilding, National Academy Press, 1984, pp. 69-72.

[22] Record of the Hearings before the Subcommittee on Merchant Marine, Serial No. 98-57, 20 June 1984, p. 911.

Title: Product Work Breakdown: An Essential Approach for Ship Overhauls

I appreciate very much that Messrs Keene, MacGregor, Sasaki and Vaughan have taken time away from their impressive management responsibilities in order to address my opinions. The common element in their discussions about shipyard transitions to zone-oriented logic, is the need for leadership. I once wrote, "Leadership is not esoteric and undefinable. It is concrete, and so important that it demands continued expression by each and every officer". The same is no less important for shipyard managers. Perhaps, the SNAME Journal of Ship Production ought to adopt something equivalent to the Leadership Forum, a popular feature of the U.S. Naval Institute Proceedings. [11]

Pet Keene rightfully notes that "system visibility must be maintained for test and completion scheduling" and advises of work package grouping techniques to offer the best of both zone grouping and system orientation." Overhaul work on the main drive line is also something that would be best controlled with a system work package. Thus, managers are now faced with maintaining a traditional functional organization and regarding zone-oriented work packages as exceptions, or shifting to product organizations and treating system-oriented work packages as exceptions. While anything works among reasonable people, I sure agree with Pet Keene's statement, "Certainly a product oriented approach should be primary and only modified as the particular conditions demand." As he is "et the coal face" as they say in Newcastle, I would certainly trust his judgement in identifying the exceptions.

Also, Pet further serves this Symposium by identifying how effective application of the product-oriented approach for overhaul of naval ships is dependent on Government actions. He identified examples need to get shipyards involved in design of shipalt packages and increasing the time between contract award and start of overhaul. The latter is an inherent requirement of the zonal approach, i.e., much greater investment in planning, and design becoming, literally, an aspect of planning. Considering that many overhauls of naval ships are larger industrial projects than construction of most merchant ships, increased time and man-hours for planning is not an unreasonable requirement.

Regarding the need to get shipyards involved in design of shipalt packages, Panel SP-2 of the Ship Production Committee proposed a research project called "Information Required from Plan-

ning Yards to Support Product- (Zone-) Oriented Operations". Per suggestions by Puget Sound Naval Shipyard people assigned planning-yard responsibilities, the research would identify "data that should be in planning yard archives, date to be obtained by ship checks, and the level of design detail that planning yards should perform in order to avoid duplication of efforts by implementing yards." The proposal notes that now, planning yard "design work is done system by system without prior imposition of production-engineered strategies by implementing yards."

The Panel SP-2 proposal acknowledged that design work must often start before an implementing yard is designated and therefore described the following as a proposed method: "Planning yards would perform basic, functional, transition and work instruction design (zone/stage composite arrangement and details) only commensurate with ship operational needs and time available to an implementing yard. In the absence of a designated implementing yard to provide an overhaul strategy before the design process starts, a planning yard would, during basic design, begin grouping information in accordance with an implementation strategy applicable to a ship class. At first the grouping of information would be in a large-frame sense, in an intermediate sense during functional design, and finally in a small-frame sense corresponding to work package needs. Regardless of the design phase at which responsibility is shifted to an implementing yard the information so far grouped would be more suited to the latter's development of zone/stage work instructions."

Just imagine the man-hours that would have been saved had the design for the current RAST modifications of frigates been produced in accordance with the foregoing. Just imagine how communications would be facilitated if the U.S. Navy's Supervisors of Shipbuilding, Conversion and Repair offices were also primarily organized for zone orientation.

In behalf of industrial engineers, Roy MacGregor zeroed in on how "...the product work breakdown approach is the forced integration of planning, design, industrial engineering and the production shops; groups that historically operate in relative isolation and with mutual mistrust." Quite frankly, I didn't envision the "forced integration" of industrial engineering as neatly as Roy expressed it and I am grateful for the lesson. I have witnessed situations in traditionally operated shipyards

wherein advancing an innovation based on reducing cost per product was by no means enough to gain acceptance. In fact, as a first step it would have created a negative response. Instead, industrial engineers had to work politically in order to create a constituency even to just try an innovation, regardless of it having been thoroughly proven in other shipyards.

Consider the case advanced for an all-weather escalator that would lift workers from a graving dock floor. All shop managers were for it, but the industrial engineer's proposal was shelved because no shop would accept responsibility for maintenance of the escalator. Had the dry-dock work been product organized, even on an ad hoc basis, the product would have been converting a vessel which required docking to one that was docked. All of the various required trades would have reported to a common boss and the entire docking effort would have been treated as a single cost center. As the most conservative calculations indicated at least 4% savings in man-hours, the production engineer's initiative would have prevailed. Maintenance of the escalator would have been a cost willingly accepted by the "dry-dock shop" manager.

Hiroshi Sasaki is the senior IHI manager who advised the 1987 Ship Production Symposium that differences in "cultural and social" customs do not explain "...the gap in the productivity between shipbuilding industries in Japan and the United States." In his current discussion he proudly refers to the recent newspaper article which extols extraordinary success by the Chairman of Avondale Industries in a climate of shipyard closures and bankruptcies. Hiroshi cites as advantages the non-union situation and that Avondale was first to employ IHI methods. He then qualifies his opinion by inferring that such advantages would have meant nothing without the strong leadership of Avondale's Chairman, Al Bossier. [12][13]

I have further insight, based on verbal input, indicating that in the Spring of 1979 Al Bossier was told by a Vice President of Ogden Corporation, then owners of Avondale Shipyards, of the seriousness of the shipbuilding recession and that Avondale's then current methods would not enable the yard to prevail. At the same time there was growing awareness of the effectiveness of IHI methods without complete understanding of what they were. To make a long story short, Al "jumped in" before the end of 1979 and had more IHI consultants on board at one time, and over a longer period, than any other U.S. shipyard. Even in the non-union environment there was defective trade separation to some extent and certainly obstructionism

from management traditionalists. But Al Bossier's determination and leadership prevailed. All other U.S. shipyards had the same opportunity, specifically including those that are now closed or bankrupt.

Roger Vaughan's discussion is succinct. He strongly endorses the importance of material matters and advises that material supply industries have to address the same modern management principles that many shipbuilders are now applying. Regarding his comment about needing a greater backlog to achieve statistical process control, I suggest that application in the pipe shop for even one shipset of pipe pieces would be worthwhile.

But, most important, Roger expressed the imperative need to change the minds of managers. The way he said it and the way he urges that leadership be manifested are noteworthy. Traditional managers cannot reasonably expect labor to change unless they themselves change in both "...management attitudes as well as behaviour". Labor's challenge is reorded in Footnote [4], "If you do not like the way we are organized, change the way you organize work." Roger Vaughan met this challenge in a climate as difficult or more difficult than in any U.S. shipbuilding region. He succeeded only because he reorganized a number of things specifically "...including labour agreements in support of these (zone-oriented) principles...."

Again, I am very grateful for the discussions submitted.

[11] "See Comment and Discussions", U.S. Naval Institute Proceedings, March 1981, p. 15.

[12] Sasaki, H., IHI's Experience of Technical Transfer and Some Considerations on Further Productivity Improvement in U.S. Shipyards", Journal of Ship Production, May 1988, pp. 104/115.

[13] Hall, J., "Avondale learns from Japanese", The Times-Picayune, 3 August 1988, p. C-1.

Title: Affordable Technologies for Small Shipyards

Authors: Kenneth R. Lane, Member; Mark W. Siburg, Visitor and
John W. Waterhouse, Member

Discussor: L.D. Chirillo

The most impressive feature of the subject paper is the authors. They represent the Elliott Bay Design Group, but their paper demonstrates understanding of all of the higher order management functions, i.e., estimating, planning, scheduling, implementing and analyzing. Clearly, they understand that design is an aspect of planning, and implementation includes material procurement as well as production activities. To the best of my knowledge, theirs is the first such paper out of a design organization in the U.S. and elsewhere. It seems that Elliott Bay Management Group would be appropriate.

The paper is especially styled and written to cause very experienced and skilled small-shipyard managers and supervisors to pause and weigh the advantages of modern management methods. Most of the methods discussed were disclosed by the National Shipbuilding Research Program and are being implemented by some large shipyards in Canada and the U.K. as well as in the U.S. The authors' effort is valid because the wherewithal to produce an outfitted and painted block for a large ship is often the same for that required to produce a small ship of approximately the same displacement. Conversely, producing a number of small ships, even of different designs, often imposes the same problems inherent in producing blocks that reflect integrated hull construction, outfitting and painting for a single large ship. The question confronting small-shipyard managers who wish to adopt zone-oriented technology is, "How much of a large yard's infrastructure can be justified in a small yard?" Very little in my opinion, because design organizations that can demonstrate the authors' capabilities could fill the gap. There is precedent.

As a severe and prolonged shipbuilding recession exists worldwide, many shipyards have closed and some of the largest shipbuilding firms, including Ishikawa Jima-Harima Heavy Industries Co., Ltd. (IHI), made drastic cutbacks in capacity. Reduced operations meant that abilities to maintain constant self-development of their manufacturing systems were jeopardized. IHI compensated by entering the smaller-ship market in a unique way. An order for a 90-meter ethylene carrier was accepted. IHI performed all of the build strategy, design, significant material procurement, production control, inspection and

testing, and subcontracted the entire production effort to a small shipyard!

The message I received from the foregoing unique approach is: It is far more important to repetitively exercise planning capabilities with new challenges than it is to exercise production capabilities, for the purpose of continuing improvements in a manufacturing system. In this context, the collective building opportunities of 2 or 3 small shipyards could comprise the basis for a constantly self-developing manufacturing system if one design firm having planning capabilities were involved.