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The Influence of Integrated CAD/CAM Systems on Engineering for Production Methodologies in Shipbuilding

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ABSTRACT

This paper discusses the influence of integrated CAD/CAM systems on engineering for production methodologies in shipbuilding, using the European, and particularly the Spanish, experience as an example. While traditional methods of ship production are ill-suited for today's international shipbuilding arena, approaches such as engineering for production can provide significant improvements to a shipyard's competitive edge, using concepts such as simple and repetitive modules; enhanced work organization; and transitioning, as the ship design matures, from a 'systems' perspective to a perspective of 'workstations and zones.'

CAD/CAM, as adapted for shipbuilding applications, can serve as a catalyst and a tool to implement engineering for production methods. Examples of this actually taking place can be found in European shipyards. Such shipyards have, for example, recognized the strength of the integrated CAD/CAM product model, which contains ship design and production information in a single product data base and serves as a resource to all levels of shipyard personnel during the design and production of a ship. Engineering for production has been greatly advanced in the Spanish shipbuilding industry with its adaptation of the integrated CAD/CAM approach. A particular case in point, illustrating the dramatic improvements possible, is a Spanish shipyard using an integrated CAD/CAM system.

In many cases, the successes of European shipyards in using integrated CAD/CAM systems may be directly translatable to the U.S. shipbuilding industry, with resultant improvements in U.S. competitiveness

NOMENCLATURE

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
HVAC	Heating, Ventilation and Air Conditioning
NC	Numerical Control
PC	Personal Computer

INTRODUCTION

U.S. shipyards, in their present efforts to become competitive in the world shipbuilding market, are seeking ways to increase productivity in the design and production of ships. Practically speaking, this means reducing ship design and construction schedules and costs. One important tool that may be used to reach this end is the engineering for production methodology. Engineering for production has been in use for some years and is continuing to be improved. This paper will address one aspect of that improvement: the use of integrated CAD/CAM systems.

The paper is set in the context of the U.S. shipbuilding industry. While the discussion is relevant to shipyards of all sizes, an attempt is made to highlight the smaller and medium size U.S. shipyards, that is, those yards with fewer than 1,000 employees. The reasons for this are as follows:

- smaller and medium size yards are a focus of this year's Ship Production Symposium,
- many discussions of engineering for production and integrated CAD/CAM systems are not directed at the smaller and medium size yards,
- smaller and medium size yards stand to benefit from the use of engineering for production that is enhanced by integrated CAD/CAM systems,
- smaller and medium size yards often do not realize that this type of technology can be practically applied to their operations, and
- smaller and medium size yards form a significant part of the U.S. shipbuilding industry, as shown in Figure 1 (In the U.S. there are 29 yards with 250-500 employees, 13 with 500 to 1000 employees and 12 with over 1000 employees).

This paper is organized into the following sections:

- Engineering for Production Methodologies describes the development of the engineering for production concept and cites an example of its implementation;
- Integrated CAD/CAM Systems reviews the evolution of shipbuilding CAD/CAM, summarizes today's state of the art and provides an overview of the use of CAD/CAM in U.S. shipyards;
- CAD/CAM's Influence on Engineering for Production shows the common thread between CAD/CAM and engineering for production and describes the extent of CAD/CAM's influence; and
- Conclusions relates Spanish experiences to the U.S. shipbuilding industry.

ENGINEERING FOR PRODUCTION METHODOLOGIES

Development of Engineering for Production

Engineering for production was developed to help correct some of the inherent inefficiencies in traditional shipyards. Examples of these inefficiencies include the

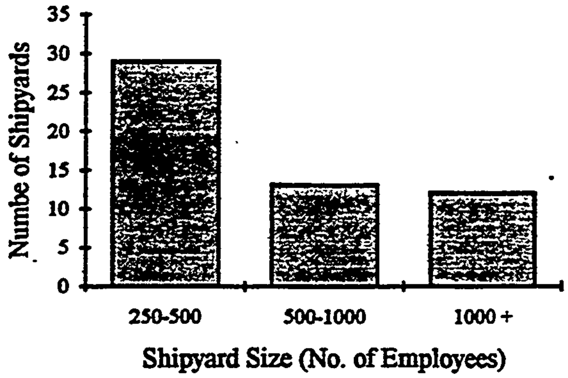

Figure 1
Distribution of U.S. Shipyards by Size

following: lack of up-front procurement definition; separate departments and shops; a lack of horizontal and vertical communication; different definitions in different sectors of a shipyard of 'the design' and 'the build plan'; and the need for a large amount of rework during construction.

Engineering for production may be defined as a method to apply group techniques and interim product techniques to one-off products like ships." From the very beginning of the design process, the focus is placed on the end use of the engineering product. That end use is to help define the production of the ship. For example, the emphasis is not on systems (e.g., the structure) but rather on zones. The perspective is that of those who must produce the ship; the result of engineering must be a tool that the ship production personnel can use.

Spanish Shipyards' Approach to Engineering for Production

In the mid-1980s, after the second oil crisis, the Spanish shipbuilding industry was in deep trouble. Still reeling from the effects of the first oil crisis, this industry had fallen from a production level of over 600,000 gross tons in 1975 to under 100,000 gross tons in the middle to late 80s. The industry took strong action, including learning from the Japanese and from the research of the National Shipbuilding Research Program. One part of the Spanish yards' multi-faceted approach toward recovery was to adapt 'design for production integration,' the first three elements of which are listed below (Gutierrez, 1992).

- Establish a stepped process for the definition of the vessel with coordinated advancement of the design, planning and material management.
- Reorganize the structure of the technical offices according to the zone-per-stage principle and improve the quality of contract design.
- Improve the relationship between technical offices and production, procurement and planning departments.

Early results of the Spanish effort show promise, including a reduction in lead time while simultaneously improving accuracy of planning, and an increase in overall productivity (Gutierrez, 1991).

INTEGRATED CAD/CAM SYSTEMS

Evolution of Shipbuilding CAD/CAM Systems

The evolution of CAD/CAM systems in the shipbuilding industry has taken place in a short time span with respect to the present age of industrialized shipbuilding. Table I illustrates this point. While the birth of industrialized shipbuilding can be set in the middle of the last century, well over one hundred years ago, the birth of shipbuilding CAD/CAM can be dated from the early 1970s, less than a quarter of a century ago. Another point that this table makes is that CAD/CAM is increasingly becoming a capability not only of the big yards but of the medium and small yards as well. The table illustrates the trend from main frame computers to local area networks and workstation and PC hardware coupled with integrated software. Software on modern systems may include a single database, which facilitates the construction of a product model (a key ingredient for using CAD/CAM to enhance engineering for production).

The table shows the evolution of shipbuilding CAD/CAM in general; not every shipyard evolves through each of the steps of the process. Also, as can be seen in the results of a survey by the authors (summarized in a following section), a number of U.S. shipyards do not yet possess the computing capabilities of the '87-94' row of Table I. For

YR	HARDWARE	SOFTWARE	END USERS/ COMPUTING POWER
1972-78	Big computing centers. Main frames. Punched cards and alphanumeric terminals.	Independent applications. Sequential files. Batch processes.	Big shipyards. High computing level.
79-86	Medium computing centers. Midi/Mini computers. Alphanumeric terminals and graphic terminals.	Integrated applications. Medium level independent databases. Interactive processes.	Big and medium shipyards. Medium computing level.
87-94	Local area networks. Workstations. X-Terminals PCs.	Fully integrated applications. Single database. Interactive graphic processes. Open systems.	Big, medium and small shipyards. Low computing level.

Table I
Evolution of Shipbuilding CAD/CAM Systems
(adapted from Garcia, 1994)

them, obtaining a modern CAD/CAM capability can represent not just an evolutionary step but a quantum leap.

CAD/CAM Today

A number of ship design CAD/CAM systems are available on the world market, including AutoSHIP, FORAN, HICADEC, HULLTECH, IMSA, NAPA, NAVSEA CAD-2 and TRIBON. The systems, or at least the modules which comprise the systems, have evolved over a period of years and are still being improved. While different systems focus on different aspects of CAD/CAM, they typically may include elements such as concept/basic/detail design, lofting, NC cutting and input to production robots. Recent development trends include further integration through product models, enhanced communication with third party programs, increased user friendly interfaces, and the extension of program capabilities into earlier stages or design and later stages of production (Ross, 1993). In addition, today's systems typically keep pace with the computer hardware industry, with its ever increasing computing power packaged in smaller and smaller machines. Thus, a program that needed a midi to function adequately several years ago may run today on a workstation or even a PC.

CAD/CAM in U.S. Shipyards

A number of U.S. shipyards have at least some components of a CAD/CAM system. Some of the larger yards have systems that have developed in house; the smaller and medium size yards have systems developed by third party vendors. A recent survey conducted by the authors provides insight into this subject. The survey was conducted during July and August of 1994 and included a mail-out and follow-up phone contacts to U.S. yards that have 250 or more employees. Of the 54 yards contacted, 20 (37%) responded. The responses provide insight into the present and near-term planned use of CAD/CAM in U.S. shipyards.

Figure 2 shows the percent of responding shipyards in each category (i.e., 250-500, 500-1000 and 1000+ employees) which use or plan to expand or replace their CAD-capable hardware, such as a Unix network, a PC network or a stand-alone PC. The results from 'responding shipyards' are used in this and the following charts. This may not reflect the trend in all of the U.S. shipyards of that category, since not all yards responded to the survey (for example, suppose there were 25 yards in a category, 10 responded, and of those 10, 8 presently used CAD hardware. Then the chart would indicate that 80% of the yards in that category use CAD hardware). Also, while certain yards may either 'presently use' or 'plan to expand or replace', other yards may both presently use and plan to expand/replace CAD hardware. Thus, the results of present and planned are independent and their sum, for a given yard size category, may exceed 100%.

The results indicate that all yards in the 500-1000 employee category presently have CAD hardware and 75% plan to expand or replace CAD hardware in the future. Next highest in present ownership are the 250-500 employee yards and the 1000+ employee yards (both 75%). 38% of the 1000+ yards have expand/replace plans, followed by 25% of the 250-500 employee yards.

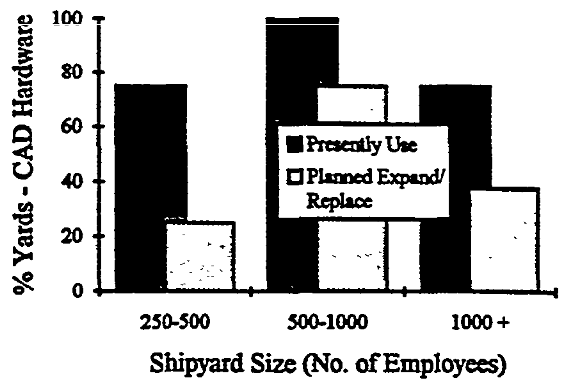

Figure 2
Use of CAD Hardware by U.S. Shipyards

Figure 3 shows the percent of shipyards with presently installed or planned CAD software such as GHS, Fast Ship, or SHCP. The 500-1000 employee yards again lead, with 100% for present and planned use. The 250-500 employee yards follow with 38% present and 63% planned, and then come the 1000+ employee yards with 38% present and 38% planned expansion/ replacement of CAD software.

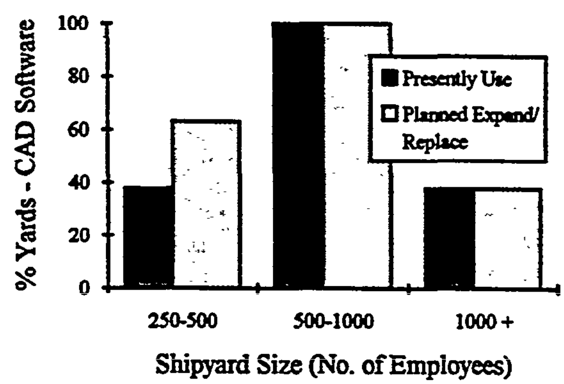

Figure 3
CAD Software in U.S. Shipyards

Figure 4 shows the percent of shipyards with presently installed or planned steel production software, such as ShipCam, SPADES, or AUTOKON. In this case, the trend is completely driven by the size of the yard: the larger the yard, the higher the commitment to steel production software. Of the 250-500 employee yards, 13% presently use and 25%

plan to expand or replace steel production software. For the 500-1000 employee yards, the percentages are 50% present and 50% planned (the same yards). For the 1000+ employee yards, 63% presently use and 63% (a slightly different mix) plan to expand or replace this type of software.

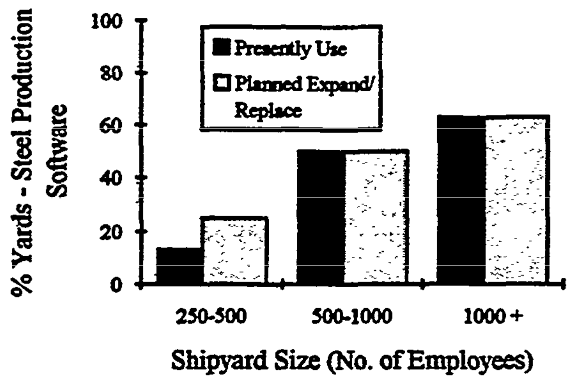

Figure 4
Steel Production Software in U. S. Shipyards

Figure 5 shows the percent of shipyards with presently installed or planned drafting software, such as AutoCad, Microstation, or CADAM (not to be confused with CAD/CAM). For present use, the trend is dependent on shipyard size: 63% of the 250-500 employee yards presently use this type of software, raising to 75% in the 500-1000 employee yards and 88% in the 1000+ employee yards. For planned expansion or replacement, the 500-1000 employee yards lead (75%), followed by the 1000+ employee yards (38%) and then the 250-500 employee yards (13%).

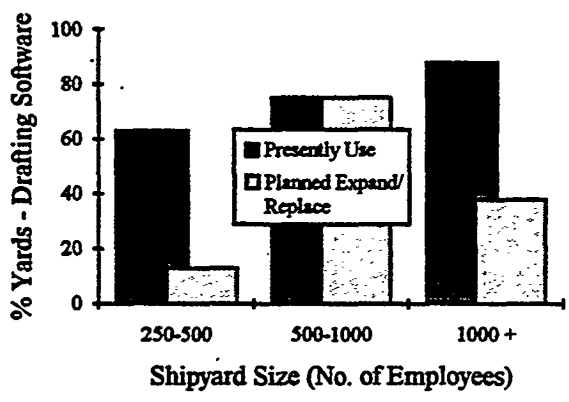

Figure 5
Drafting Software in U.S. Shipyards

Figure 6 shows the percent of shipyards with presently installed or planned piping, HVAC or electrical design software, such as CadMatic, CSA or RAMP. The 1000+ employee yards lead in present and planned (50% present, 63% planned), followed by the 250-500 employee yards (25% present, 50% planned), and then the 500-1000 employee yards (25% for both).

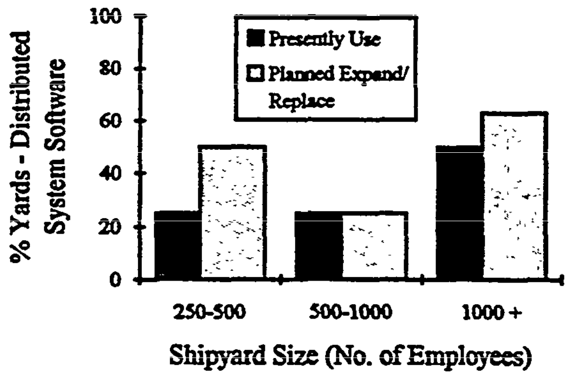

Figure 6
Distributed System Software in U.S. Shipyards

Figure 7 shows the percent of shipyards with presently installed or planned CAM facilities, such as numerical cutting or robotic welding. The 500-1000 employee yards lead in present use (100%), followed by the 1000+ employee yards (88%) and then the 250-500 employee yards (25%). All of the 500-1000 employee yards had plans for future expansion or replacement, followed by 25% of the 250-500 yards and none of the 1000+ employee yards.

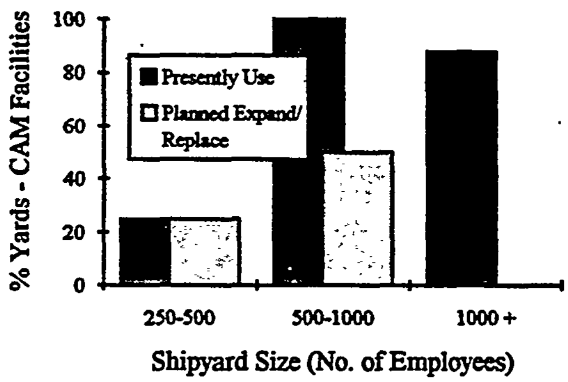

Figure 7
CAM Facilities in U.S. Shipyards

Finally, Figure 8 shows the shipyards' preference for UNIX or PC computers. Since this was an either-or choice, the totals add to 100% except in cases where yards did not state a preference. The results show that PC computers are by far the first choice, having been selected by 75% of the 250-500 employee yards, 75% of the 500-1000 employee yards and 75% of the l000+ employee yards. UNIX systems were preferred by none of the 250-500 employee yards, 25% of the 500-1000 yards and 13% of the 1000+ yards.

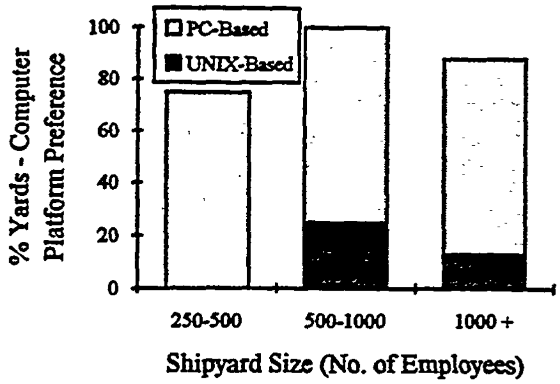

Figure 8
U.S. Shipyard Computer Platform Reference

From this survey, the authors concluded the following:

- The response rates to the survey are considered sufficiently high to establish general CAD/CAM trends in U.S. shipyards with 250 or more employees,
- These shipyards are committed to ***CAD/CAM persently and as part*** of their planned acquisitions,
- The interest shows by yards in all yards in all three size categories in CAD/CAM extends to all types of software and hardware addressed in the survey, and

. PCs are preference above UNIX computer platforms.

CAD/CAM's INFLUENCE ON ENGINEERING FOR PRODUCTION

using CAD/CAM to enhance the effectiveness of engineering for production is not a new idea. It was well articulated by Lamb in 1986 when he recommended computers "be used to develop data such as a full-size

1986). The idea of such an enhancement ,was also part of the

elements of their design for production integration plan were presented above. The forth element was to "Develop CAD/CAM applications to support information flows and to produce the required graphic and written information (Gutierrez, 1991)."

To define the influence of integrated CAD/CAM on engineering for production, one may first look for a common thread between integrated CAD/CAM and engineering for

the concept of integration. Integration is a dominant trend in

concept Integration is also a dominant theme in engineering

for production, which after all, is integrating engineering into the production process.

Given this
influence that integrated CAD/CAM systems have on

measured by the ability of integrated CAD/CAM to help realize the integration goals of engineering for production. This ability is one of the strong points of the better integrated CAD/CAM systems. Those systems can have significant

Significantly enhanced the yard's engineering for production methodology, as discussed below.

This privately owned shipyard, founded in 1924, is located in Valencia, Spain and presently has 800 employees

projects are shown inTable IL. This shipyard is proactive in

YR DEL	NAME	TYPE	TOTAL LENGTH (m)	DEAD WT (tonne)
1992	Crown Jewel	Luxury Cruise Ship	165	1800
1993	Crown Dynasty	Luxury Cruise Ship	165	1800
1993	Las Palmas de G.C.	Ferry	116	2650
1993	Sta Cruz de Tenerife	Ferry	116	2650
1994	Mar Almundena	Asphalt Carrier	121	9435
1995	(Car Ferry)	Ferry	153	3070

Table II
Recent Ship Construction by Unión Naval de Levante (Adapted from Poblet, 1994)

methodology (which it labels 'production oriented design') and enhancing its CAD/CAM capabilities. Regarding production oriented design the ultimate aim is to drastically cut production costs through increased efforts in design and layout. Significantly, the tool that the shipyard views as **making this possible is CAD/CAM. On the personnel side, the shipyard is increasing training in the use of computers.** In-house staff are developing software, often in conjunction with software system suppliers. Also, efforts are being made to enhance communication between computer systems used for management and those used for design and production.

This shipyard has a CAD/CAM capability which has evolved into a comprehensive system Figure 9 shows the system's growth as exemplified by the increasing number of workstations. As reflected in this figure, the computer was **introduced to the yard in 1984, with significant growth every** year since. The shipyard is encouraged by the results of

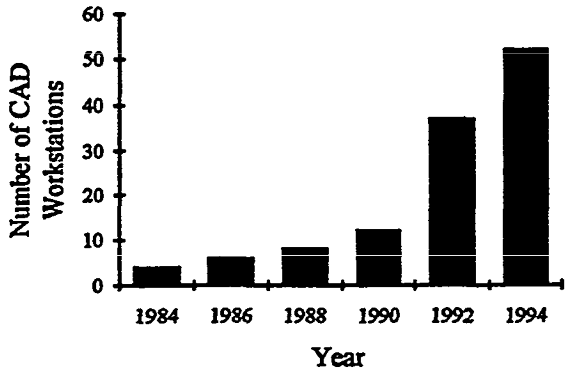

Figure 9
CAD Workstation Evolution at Unión Naval de Levante
(Adapted from Poblet, 1994)

implementing and enhancing CAD/CAM and points to the following improvements:

- Dramatic decrease in design time (e.g., 8 people working 6 months vice 21 people working 18 months to develop steel construction drawings),
- Decreased engineering time (e.g., in carrying out hydrostatic calculations by computer instead of by hand),
- Ability to quickly conduct what-if studies at the early stages of a project, and
- Ability to automate NC cutting of nested piece parts from steel plate.

A particular area where CAD/CAM has been implemented at the shipyard, with a corresponding influence on engineering for production, is piping design and production. Traditionally, piping design was conducted through the use of 2-D drawings, a plastic model, isometric drawings and, in the pipe shop, templates and manual checking. With the traditional approach, very little premanufacturing was carried out. Now the approach has been changed, radically enhancing how design information is developed and then relayed to the shop. With the present approach, the design is developed exclusively by CAD/CAM. Design information is provided to the pipe shop in the form of 'spools,' which contain only what is relevant to the piping and its associated valves and accessories. The spool includes on a single sheet of paper the drawing of the particular pipe with the geometry information and a list of materials as shown in Figure 10 (following page).

The transition from the traditional method to the use of CAD/CAM and spools is being carried out during the design of several ships. As each new ship is produced, the proportion of piping designed by CAD/CAM has increased. That is, instead of relying on manual methods (without intervention of any CAD system), automated methods were used, including mixed 2D (CAD drawings; construction information gathered manually), mixed 3D (design with CAD model; construction information gathered with integrated CAD/CAM model), and complete reliance on an integrated CAD/CAM. This is illustrated by Figure 11. As shown in that figure, the machinery piping in *Crown Jewel* was designed almost exclusively by manual methods. With *Las Palmas* and *Mar Almudena*, proportionally more use was made of CAD/CAM, until with the Car Ferry (presently under construction), most of the piping design is through CAD/CAM.

CONCLUSIONS

Much of the technology cited in this paper has been developed in the U.S., some of it through the sponsorship of the National Shipbuilding Research Program. The U.S. shipbuilding industry is accustomed to hearing how Japan learns, uses and benefits from our technology. The Spanish have learned, used and benefited as well, and their example may be more appropriate for use in the U.S. The Spanish shipbuilders brought themselves back from the doldrums, just as the U.S. shipbuilders want to do. And part of their success is by understanding and enhancing the role of CAD/CAM in engineering for production.

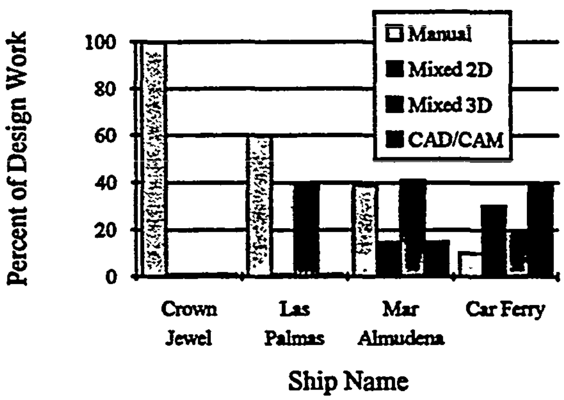

Figure 11
U.N.L. Design Approaches for Selected Ships
(From Poblet, 1994)

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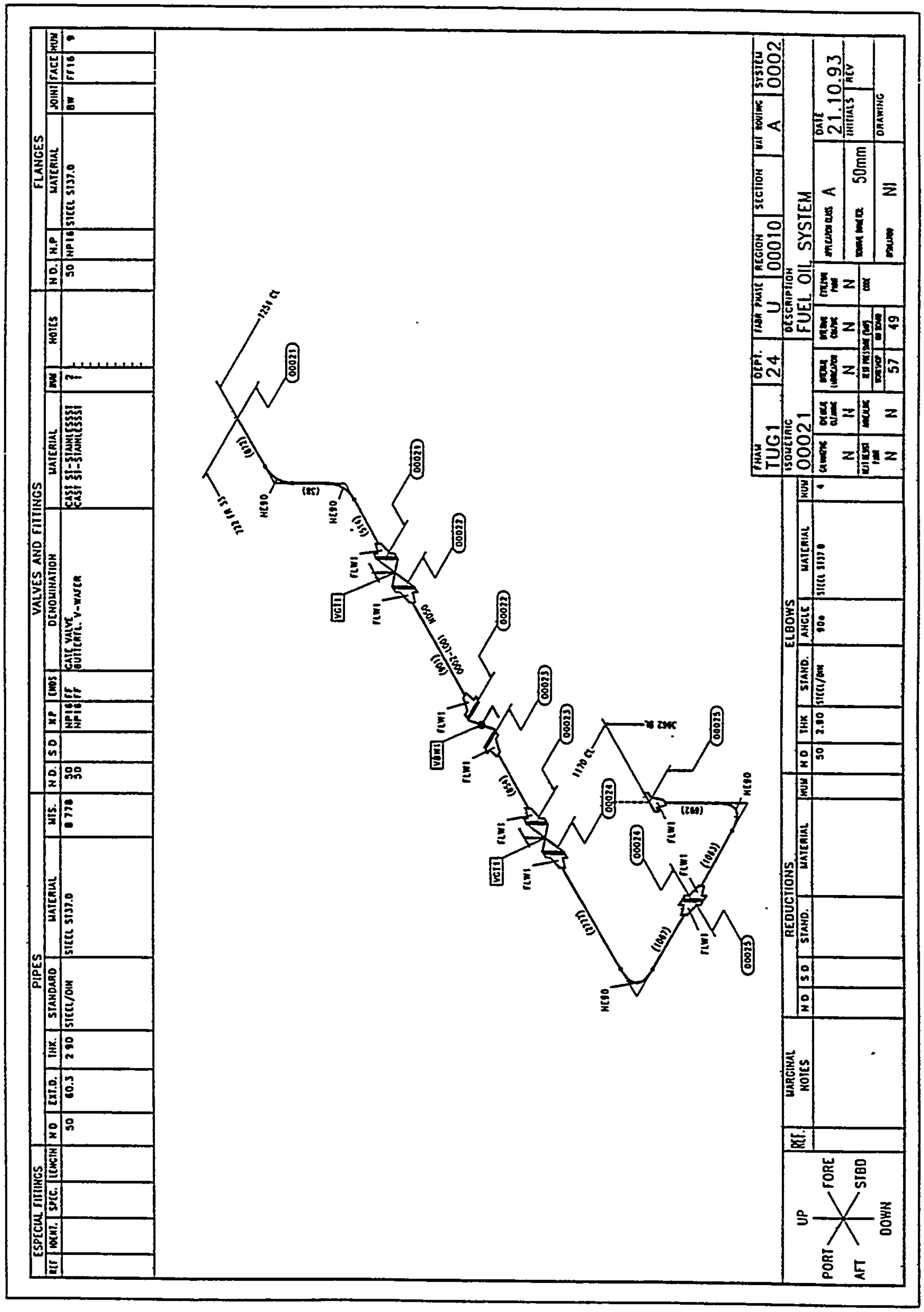

Figure 10
Typical Pipe Spool

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