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Modular Outfitting

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ABSTRACT

The concept of modular construction is not new in the manufacturing, construction, automotive , aeronautical or marine industries. This concept is presented from the initial stages of design ,and production, through ship builder s trials and operations. Through careful thought, engineering, and communications with all involved, from design, construction, and operation ensure a quality product with schedule reduction using modular outfitting. Each phase of modular outfitting is discussed to explain how it has effected, organizational issues, design issues, financial issues, production issues and life cycle or operational issues.

INTRODUCTION

Shipbuilders have become extremely competitive in the world market over the past 20 years. This has forced the ones who wish to remain in the business to continually improve designs, and production strategies. Thyssen Nordseewerke in Emden Germany has been faced not only with this external challenge but with internal constraints for a number of years and has developed a patented concept for modular construction of its engine rooms (see Figure 1).

This approach has provided the ship builder with a number of benefits and also some concerns. The major benefit has been schedule reduction on the slip-ways, on the order of 15 weeks. Quality of, and repeatability of units and modules have been positive, and training of apprentice workers more efficient. Organizational communications from all levels of the yard have seen positive improvements. Managerial measurements on performance and cost issues are now simpler to implement and perform. Another key area of improvement due to modular construction is the overall man hours per ship have consistently come down.

However there have been a number of teething problems. Two of the most pronounced problems are due to cost increases associated to initial design and production.

Costs of design increased as a result of the level of detail required for production and also from a higher level of complexity of primary and secondary structure of and within the units. The increased costs are also associated to the ship structure or the “nacelle” required to hold the units.

Production costs also increased due to the requirement for a new production factory and the transportation equipment required to move the engine room to the construction ways.

In the area of operations, the owners concerns for maintenance and obstructions due to the increased structural elements were addressed early in the design phase and a few were also corrected after a number of ships were produced. Early ships also experienced some vibration problems. Specific solutions, such as a hydrodynamic damping tank above the propeller, and attachment of the stack to the house, have virtually eliminated these past vibration problems.

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United States Patent [19]
Wilts

[11] Patent Number: 5,299,520
[45] Date of Patent: Apr. 5, 1994

[54] SHIP, IN PARTICULAR MERCHANT SHIP

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[73] Assignee: Thyssen Nordseewerke GmbH, Emden, Fed. Rep. of Germany

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[58] Field of Search .... 114/56, 65 R, 72, 73, 114/77 R

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U.S. PATENT DOCUMENTS

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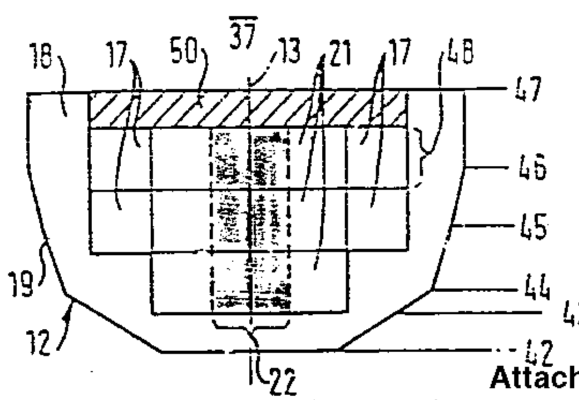
71292 4/1986 Japan .... 114/65 R

Primary Examiner—Jesus D. Sotelo
Attorney, Agent, or Firm—Nils H. Ljungman & Associates

[57] ABSTRACT

Ship, in particular merchant ship, with at least one large power plant such as a main propulsion engine (11) located in the ship's steel hull, around which there are the necessary auxiliary spaces, such as access spaces, bunkers, tanks, compartments, control rooms, workshops, control devices, distribution centers, pumps, hydraulic power plants, etc., characterized by the fact that the ship's hull (12), in the vicinity of the main power plant (11), has a nacelle (20) which is open on top, which is designed so that it becomes wider in steps from bottom to top and/or in the longitudinal direction of the ship (13), and is preferably free of bulkheads and platforms, that the height, length and width of the stepped walls (14, 15, 16) next to or under the main power plant (11) are of a specified modular dimension on the order of several meters, in particular 3 m, in at least one dimension, in particular the height, but preferably in two dimensions, and particularly preferably in all three dimensions, and at least a significant portion of the auxiliary spaces are located in rectangular containers or container frames (17, 21, 25) located next to, forward and/or aft of the main power plant (11) or on the stepped walls (14, 15, 16).

12 Claims, 17 Drawing Sheets



Attachment 14

Figure 1. United States Patent # 5,299,520

MODULARIZED ENGINE ROOM

Merchant shipbuilding in Germany is subjected to an ever increasing competitive pressure by Asian and East European shipyards. Therefore, each company is forced to develop massive cost reduction measures. Besides respective strategic and organizational measures, possible improvement potential in the sphere of direct production costs must be utilized. After having given attention to the cost reduction possibilities on the steel construction side, the shipyard has concentrated specifically on the reduction of the time-versus space relationship and the dependency of engine room outfitting on ship block assembly at the slip way. This consideration led to the modularization of large engine room sections into functional modules. Further the modular technology supports the shipyard target in saving man-hours. Consequently the overall production costs have been decreased. These activities reduced the cost of the total vessel by about 30 percent.

The main contributors to achieving this were as follows:

- Building series of ships,
- Purchasing equipment and material in cooperation with other shipyards,
- Concurrent engineering with vendors,
- Value analysis of the design material and the limitation of the design drawings to the absolute minimum necessary,
- More subcontracting to non-shipyard expertise areas,
- Pre-outfitting,
- Standardization, and
- Modularization.

Customary Pre-outfitting

During the building of a vessel, the dependency of ship sections on outfitting often exists and has an important impact on construction times and production hours. The desired high degree of outfitting requires that ship sections remain in the outfitting areas for a longer period of time. Converting this to local schedule change often leads to a disturbance in the global schedule. A common bad practice in the development of proper scheduling for modular outfitting was that sections were delivered without pre-outfitting. As a result of this, an increase in the number of production hours were experienced. Another reason is that shipyard crane capacity limits pre-outfitting, therefore the weight of the ship section is also limited by existing crane capacity.

Advantage of Modularization

The biggest advantage of modularization is proven by the separation of the construction area and time between shipbuilding and outfitting activities. It is very important that early in the project phase it must be determined what areas of the ship can be modularized. This results in the development of engine room modules whose interfaces are clearly defined. This is in order to allow independent construction between shipbuilding, the engine room module outfitting, arrangement of the functional modules and further outfitting within the machinery space. This allows independent production activities with minimum interference to other shipbuilding activities. As a result, only on the slip-way do the engine space modules meet with the ship hull.

This independence has the following advantages:

- Parallel design of shipbuilding and outfitting,
- Parallel production of shipbuilding and outfitting,
- Less disturbance in ship's hull production,
- Less slip-way time,
- Comfortable and faster outfitting of modules in hull,
- Reduction of transportation time,
- Easier to subcontract from cost effective suppliers,
- Reduction of construction time due to standard modules and arrangements, and
- Easier work in nonmodularized area in the empty engine room.

As a practical result the erection of the engine room at the slip-way consists of two space modules, port and starboard, and the main engine and three smaller modules in front of the main engine between it and the forward engine room bulkhead. The erection of the engine room modules within the ship is accomplished within two days.

Modularization Applications

Between 1991 and 1996 thirteen hulls were built in series with modular engine rooms (hull numbers 501-513).

The engine room area was determined to account for 40 percent of the production hours and ship cost. It was therefore determined that standardization and modularization of the ship would yield the most benefits within this space.

In 1991 with the series (starting with hull 501) of 1500 TEU container ships the shipyard decided to replace piping and pump groups by completely assembled and preoutfitted functional modules as follows:

- Low temperature cooling water module,
- High temperature cooling water module,
- Sea water cooling module,
- Separator module,
- Lubricating oil module,
- Fuel oil module, and
- Starting air and control air module.

In the past the dependency of production on installing a large number of individual function units that were difficult to install has been replaced by a much more manageable number of modules on this series of ships. The final outfitting of some functional modules, including generator and air compressor flats is still done on the ship.

The two individual space modules (port and starboard sides) consist of a frame structure where all equipment is tight (bolted and welded), piped to, and wired with the other individual units. These individual units are stacked into two large space modules, comprised of 8 individual units per port and starboard side. This effort is completed within the engine room factory. These two large space modules fit within the engine room, one on the port and one on the starboard side of the main engine . The maximum total weight of each engine room space module (8 per space module) is approximately 80 tonnes (88.19short tons). The individual module unit dimensions are 12m x 6m x 6m (39.37ft x 19.69ft x 19.69ft). The large space modules contain 60 percent of the engine room machinery equipment. Again there are currently 8 individual module units per ship side (port/Starboard) and 3 in front of the Main Engine giving a total of 19 individual module units.

DEVELOPMENT OF HANDY SIZE 1700 TEU CONTAINER SHIP. (see Figure 2)

This concept of modular outfitting is not restricted to one series of vessels but can be expanded to other larger and smaller series of ships. Not only is the engine room optimized for modular construction but other areas of the ship have also been selected for this type of construction and is discussed below with respect to costs and technical design effort.

The analysis of the building cost (see Figure 3) forced the shipyard to the conclusion that the vessels need to be divided into four major construction blocks.

- Deckhouse,
- Bow,
- Mid-body, and
- Engine Room.

Shipyard goals for this project were as follows:

- The reduction of the total costs by 20 percent or more,
- Reduction of the onboard outfitting by at least 60 percent,
- Significant reduction of time, approximately 30 percent between order and delivery,
- High quality of the product,
- Achieving higher flexibility by creating new methods and standards,
- Reducing manning costs through automation,
- Reducing fuel costs,
- Reducing maintenance costs,
- High endurance,
- High reliability,
- High economic life span,
- Easy repair and upgrading of the main engine, and
- Fast and efficient design process.

A conventional design begins with the lines plan, the steel drawings follow. At this point the detailed engine room drawings can be developed for arrangement of systems and functional units within the engine room, and space allocated for maintenance and operations of the engine room machinery. Construction follows the same pattern. Due to the differences in tolerances between shipbuilding and outfitting, much of the expensive outfitting work typically has been done in late stages of construction on the slip-way and after launching. To shorten the total building time, parallel design and construction are necessary. Therefore, new design methods and construction strategies to replace these conventional methods are needed. The parallel design and construction of engine rooms is only possible when the space for the engine room is defined and the interfaces are simplified. This can be achieved by using a modular design of functional units which have standard dimensions. These functional units must be transportable. This allows the construction, outfitting and testing of the space modules before they are loaded onto the ship in parallel and most importantly, outside of the ships critical path.

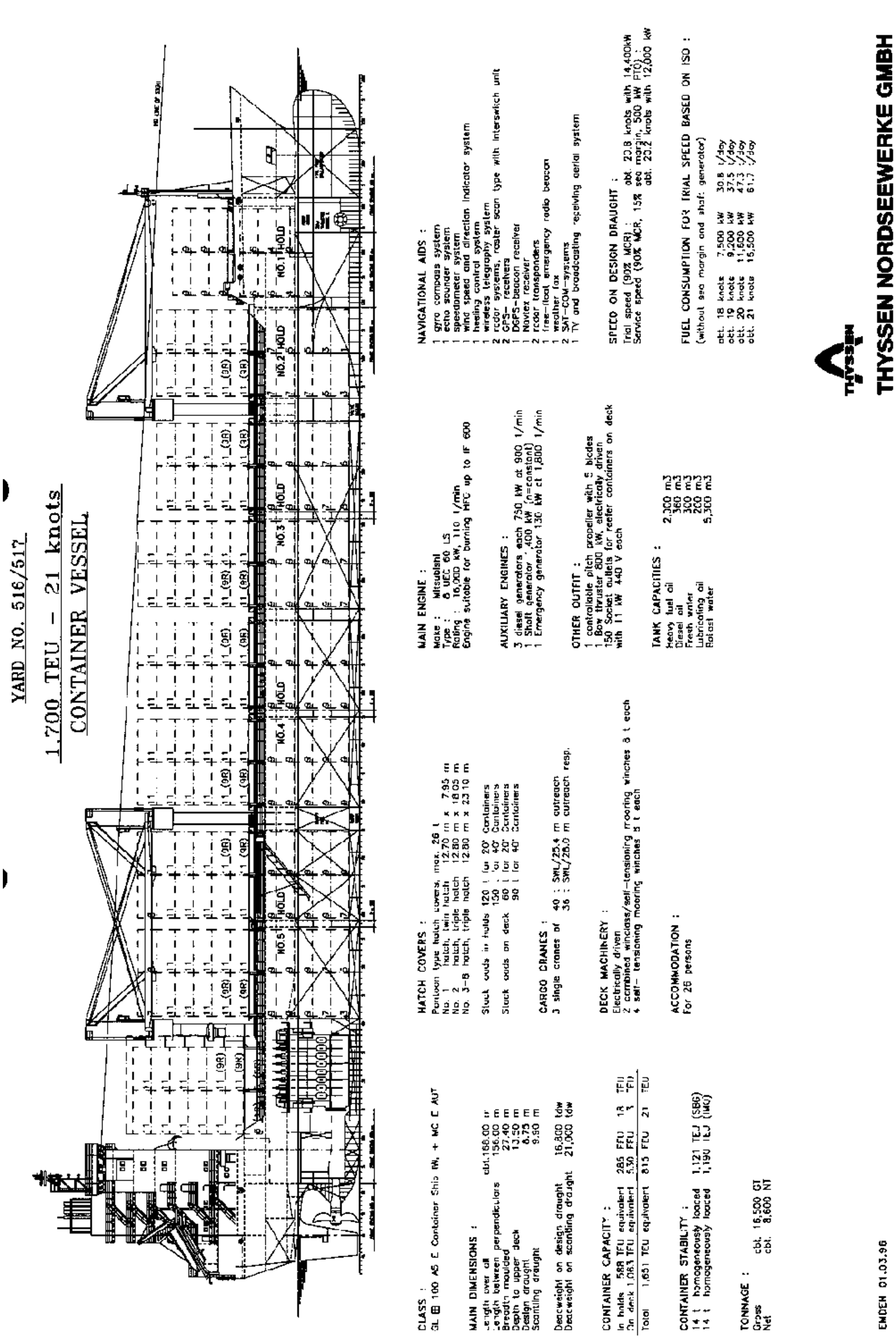
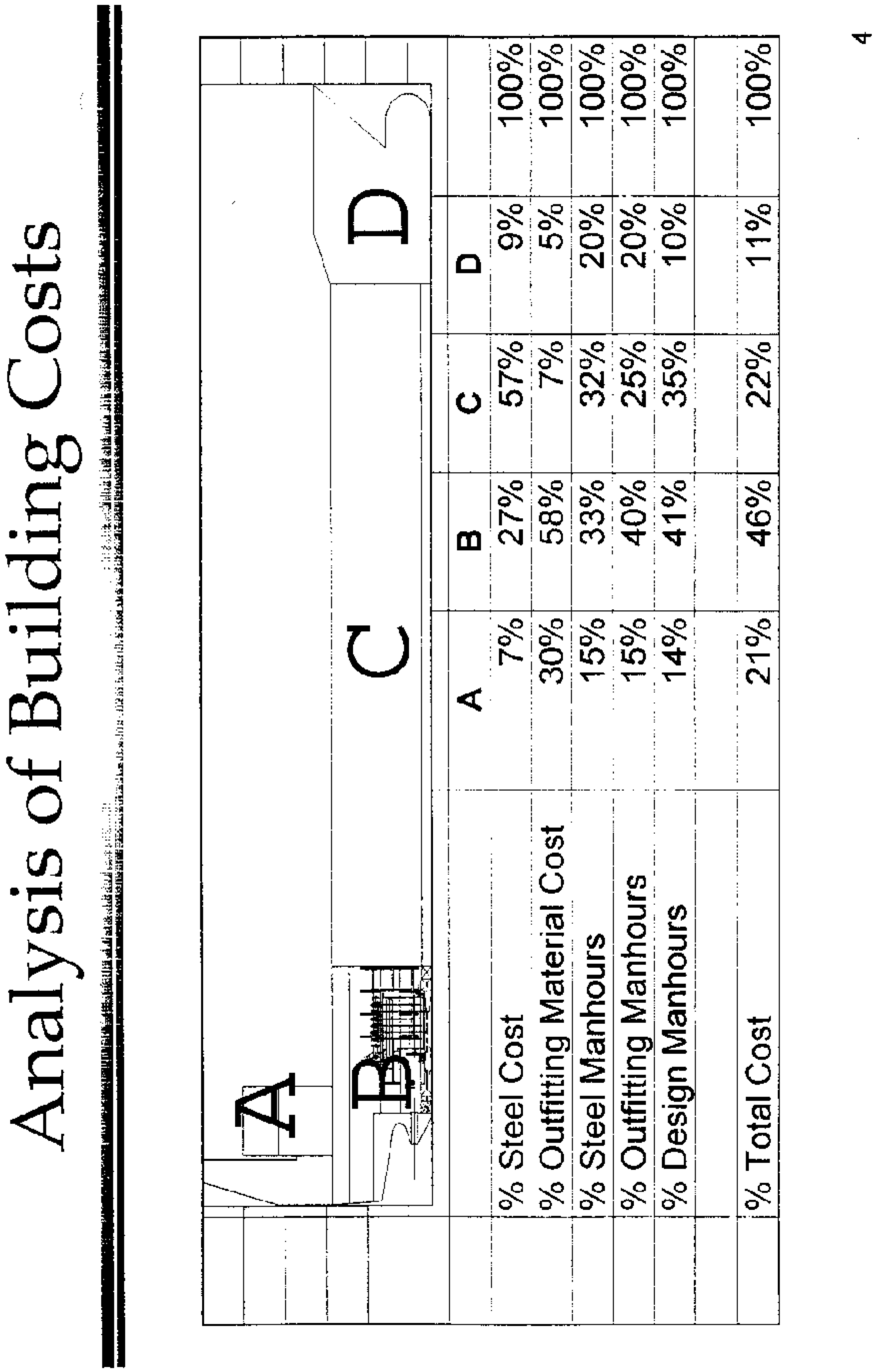


FIGURE 2

Figure 2. 1700 TEU Container Ship



	A	B	C	D	
% Steel Cost	7%	27%	57%	9%	100%
% Outfitting Material Cost	30%	58%	7%	5%	100%
% Steel Manhours	15%	33%	32%	20%	100%
% Outfitting Manhours	15%	40%	25%	20%	100%
% Design Manhours	14%	41%	35%	10%	100%
% Total Cost	21%	46%	22%	11%	100%

Figure 3

Figure 3. Analysis of Building Costs

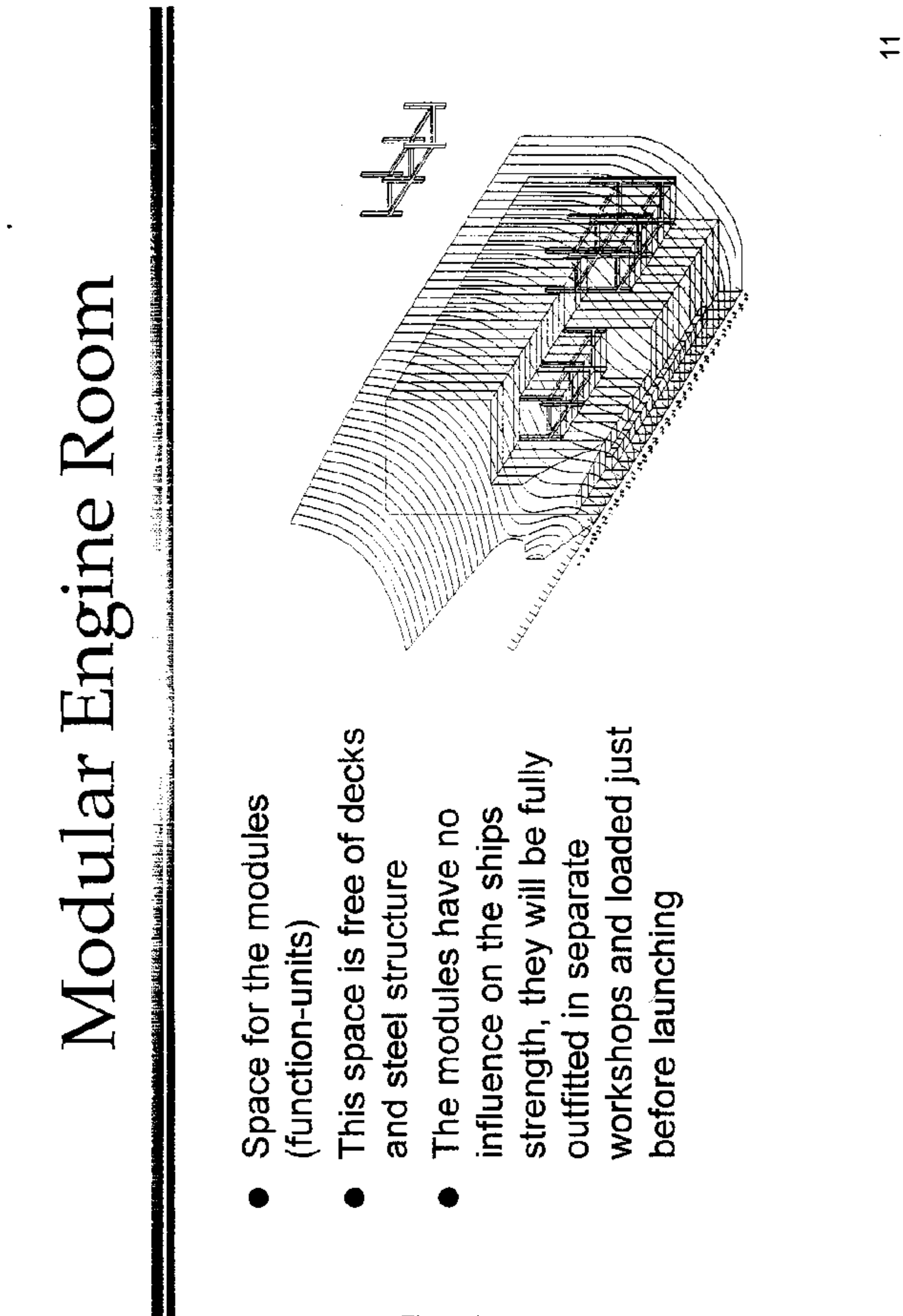


Figure 4

Figure 4. Modular Engine Room

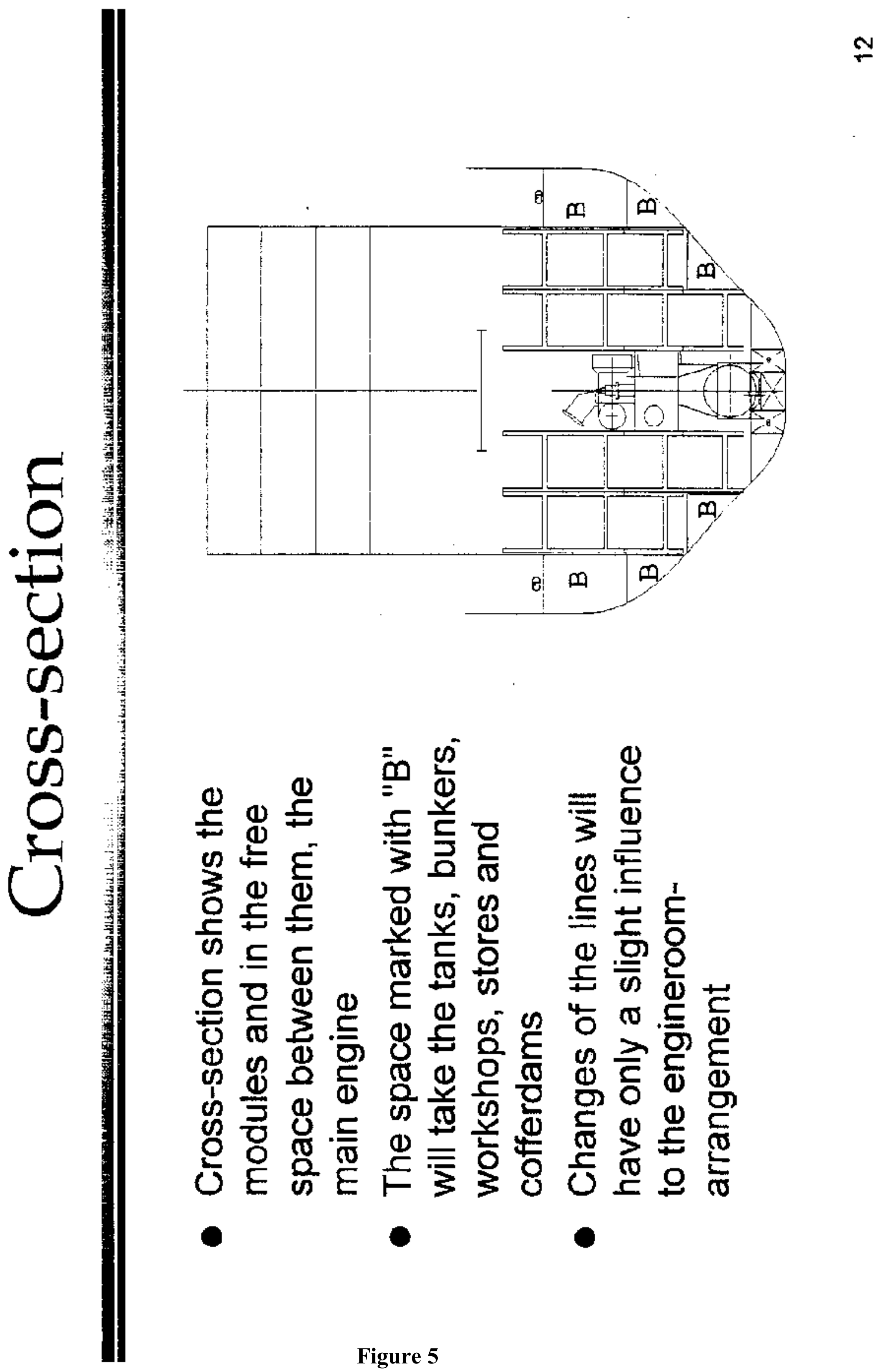


Figure 5

Figure 5. Cross Section of Modular Engine Room

Engine Room Space for the Functional Modules (see Figures 4 &5)

Under this approach the main engine room space on very different types of ships, particularly merchant ships, differ only slightly from one another. For example; the engine room forward bulkhead is generally 3 m from the main engine. The engine room compartment has been designed with vertical and horizontal walls and does not include bulkheads, frames and platforms. The Ship hull or "nacelle" in the engine room area contains usable spaces such as tanks (fuel/water), compartments and the workshop.

Engine Room Equipment

The system engineering group defined the equipment that have the best opportunities to be modularized and locations with respect to other interfacing systems. An example drawing of the HFO fuel system is shown in Figure 6.

The modular standard containers or individual unit modules, with dimensions of 3m x 3m x 6m (9.84ft x 9.84ft x 19.69ft) are connected together in the engine room factory, pre-assembled, pre-outfitted and tested. The space modules (port and starboard) are pre-outfitted outside the ship hull in parallel with the construction of the hull and introduced into the steel hull from the top of the engine room hold. Only the power supply (power, control, sensors) and piping connections to the main engine are installed on board. As a result, the 1700 TEU container ship engine room consists of the following individual unit modules:

- Engine control room,
- High temperature fresh water cooling system,
- Low Temperature Fresh Water cooling System,
- Sea water system consisting of sea water cooling, fire fighting, bilge and ballast pumps,
- Generator sets,
- Integrated ventilation system,
- Sewage system,
- Integrated cable ways,
- Potable water system including evaporator,
- Fuel oil separators included heaters, pumps, and sludge oil tank,
- Refrigeration and air condition system,
- Starting ,working and control air system,
- Integrated fire fighting system, and
- Lube oil system.

The preferred standard dimensions of the engine room individual unit module has been divided into two different spaces in the vertical direction. The upper portion has a height of approx. 2 m (6.56ft) so it can be accessible to standard persons in the 95th percentile range. Pipes, cables and other components are located in the lower part, which can be approximately 80 cm (2.63ft) high.

Foundations for the equipment are suspended and bolted to the frame tubing of the following dimensions, 200mm x 200mm x 10mm (7.87in x 7.87in x .39in).

The design of the engine room space and individual unit modules includes only right angle bars therefore interfaces between them can be predetermined to an accuracy measured in millimeters.

MODULAR SYSTEMS AND STEEL STRUCTURE

All space modules are connected to the hull but are not a part of the ship structure, they are structurally uncoupled. By being structurally uncoupled they are not required for hull stiffness and are separated from main engine, shaft and propeller forced vibrations. The space modules replaced previous engine rooms designed with tween and platform decks. The engine room space is similar to the container ship cargo hold concept. The engine room is a hold for the machinery space modules. The transverse strength of the engine room without tween decks and pillars does not create any problem due to the relatively wide fuel oil wing tanks (see figures 8 & 9) The structure has been designed according to German Lloyd Classification Society (Germanischer Lloyd).

The global vibration behavior of hull and superstructure was investigated using a three dimensional finite element model and the coupling effect between hull and superstructure was investigated. The vibration behavior of the engine room structure without tween decks has been found to be as good as the behavior of previously constructed conventional engine rooms.

Module Support

Similar to the container cargo hold, the engine room is equipped with foundations and horizontal supports for modules (see Figure 10). Due to the shape of the ship's aft body, aft modules can not be mounted directly onto the inner bottom. Special foundation structure is necessary (see Figures 11 & 12). The foundation structure is loaded vertically only. Horizontal supports are arranged according to the unit module decks. In the transverse directions the modules are supported by the ship wing tank structure and in the longitudinal direction by platform decks aft of the modules and the forward engine room bulkhead.

HFO Heater

- The HFO Heaters together with the Pumps, dearator and viscosimat, including all measuring points, the piping and wiring, are mounted together with the separators and sludge tank in one module

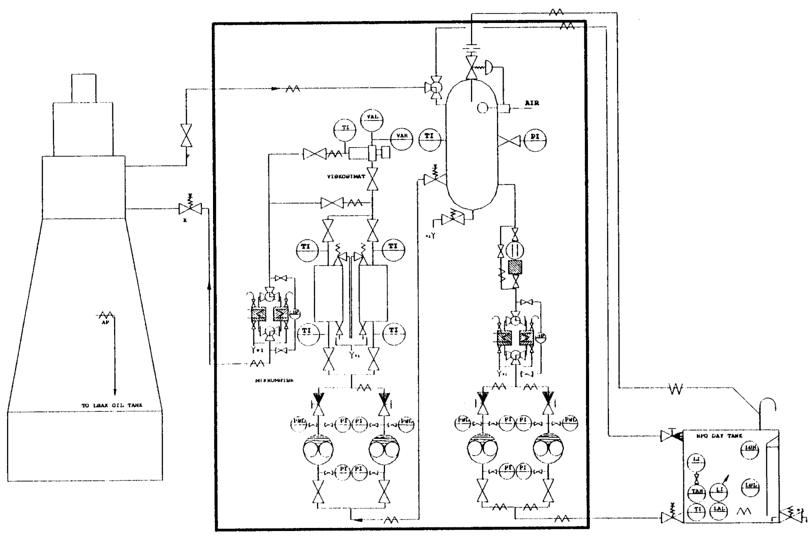


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Figure 6. HFO Heater System

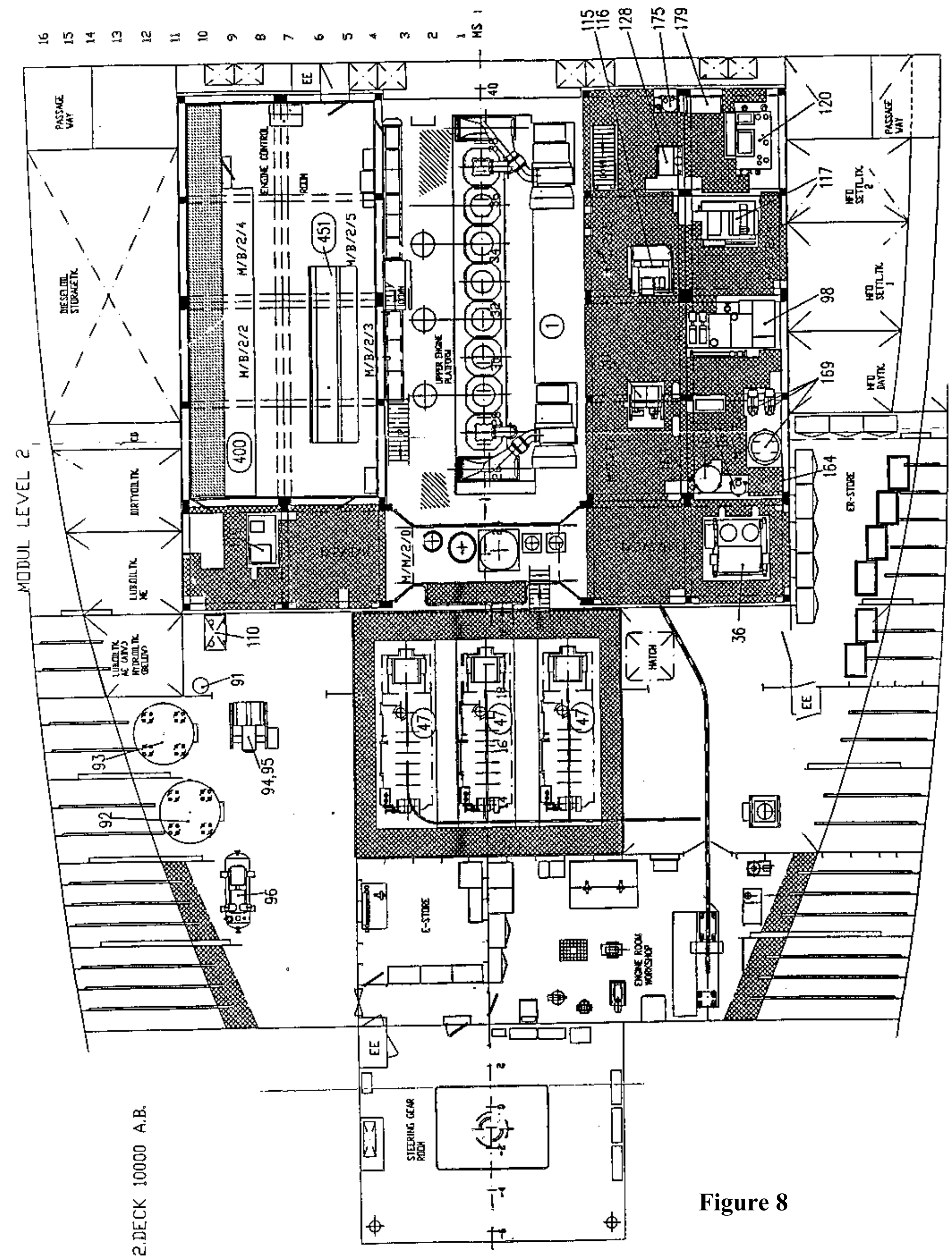


Figure 8. Plan View of Engine Room w/ Wing Tanks

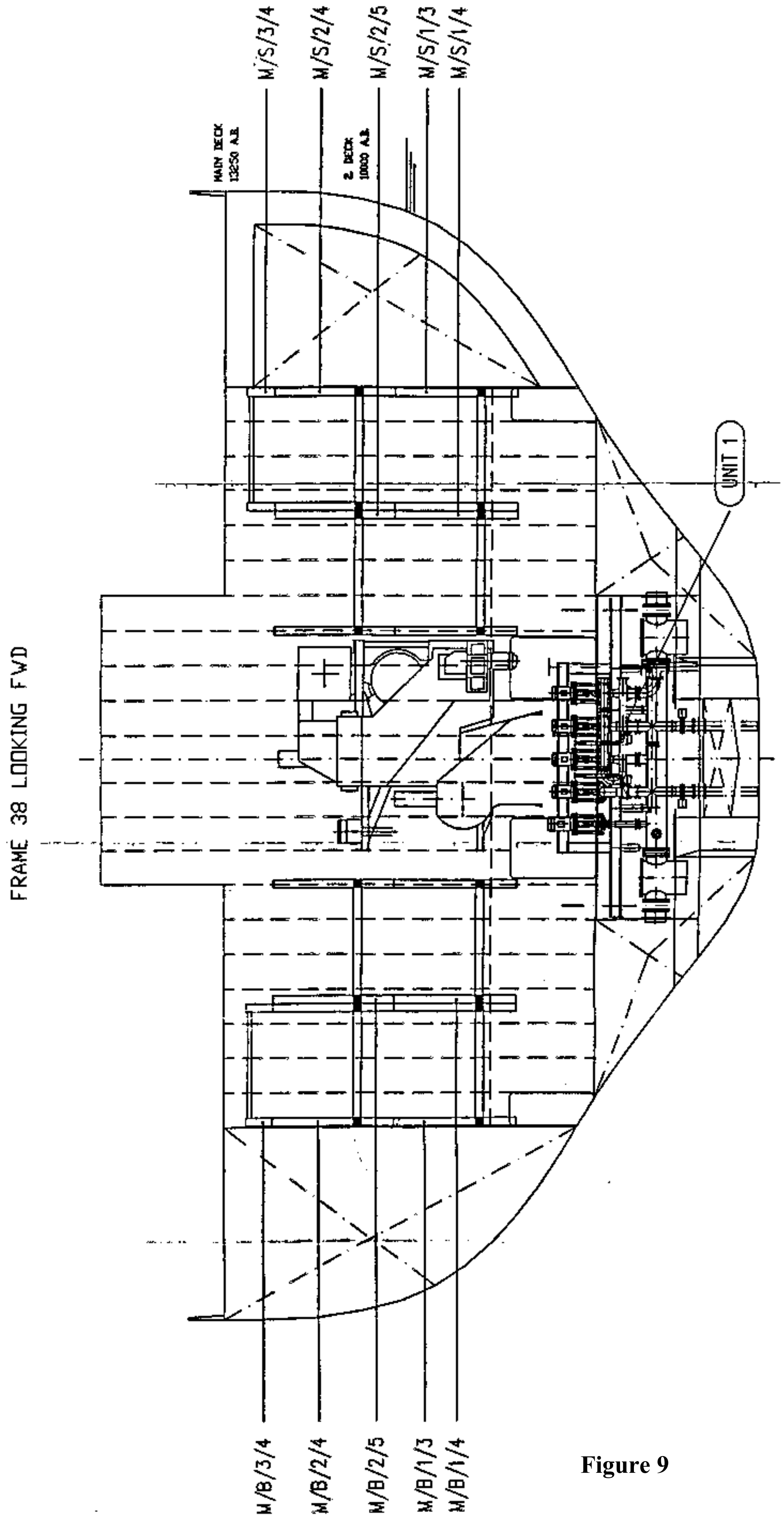


Figure 9

Figure 9. Section View of Engine Room aft Lkg fwd

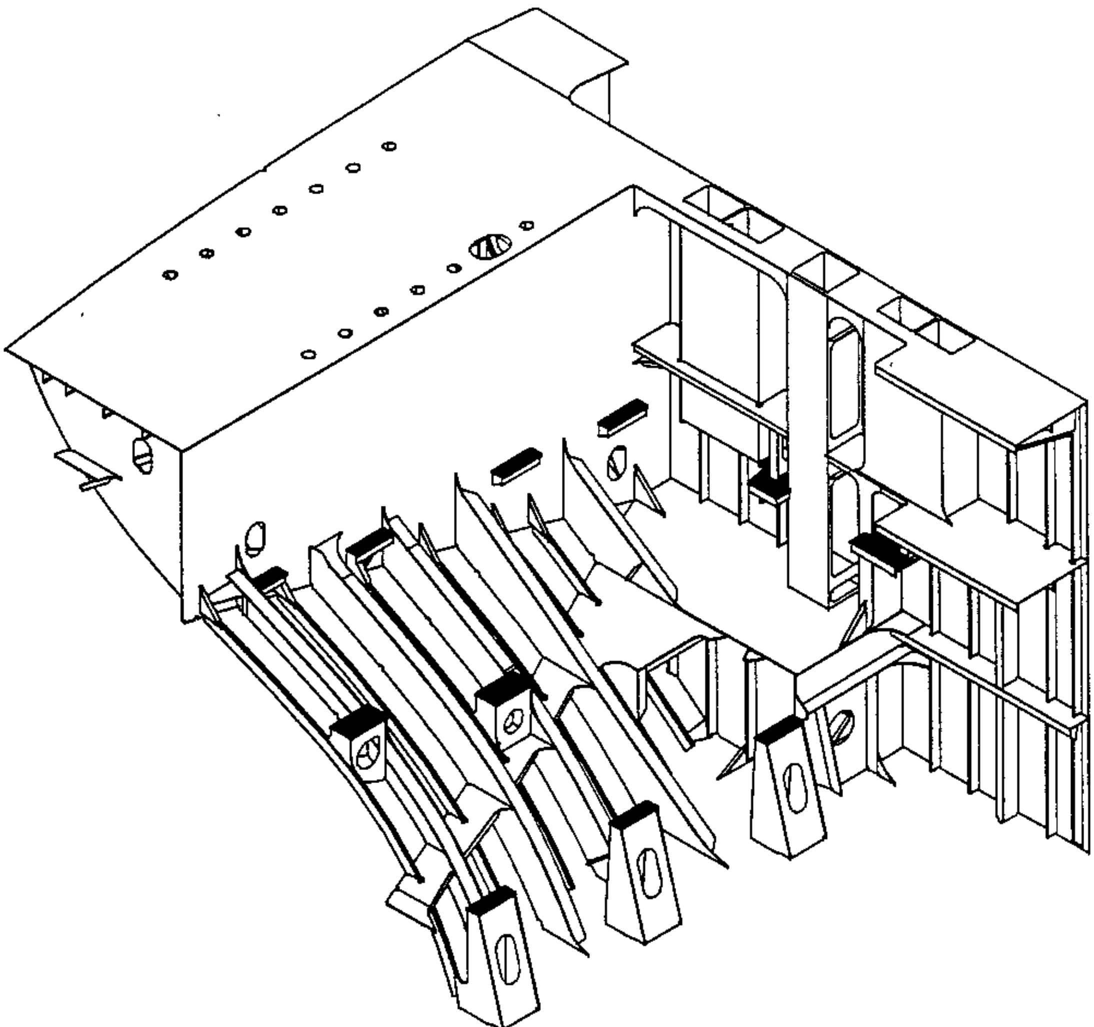


Figure 10

Figure 10. Supports for Modules

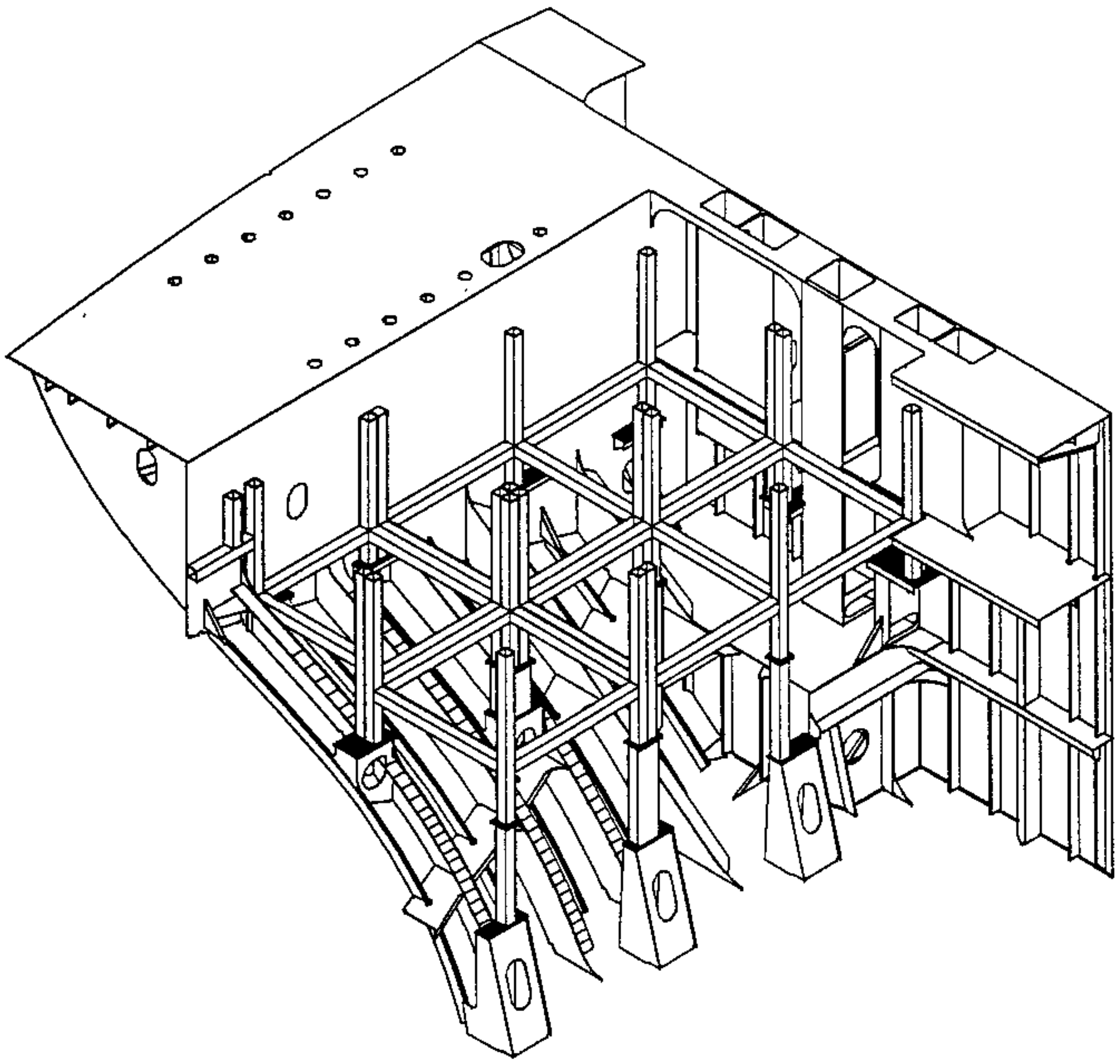


Figure 11

Figure 11. Modules Attached to Foundations

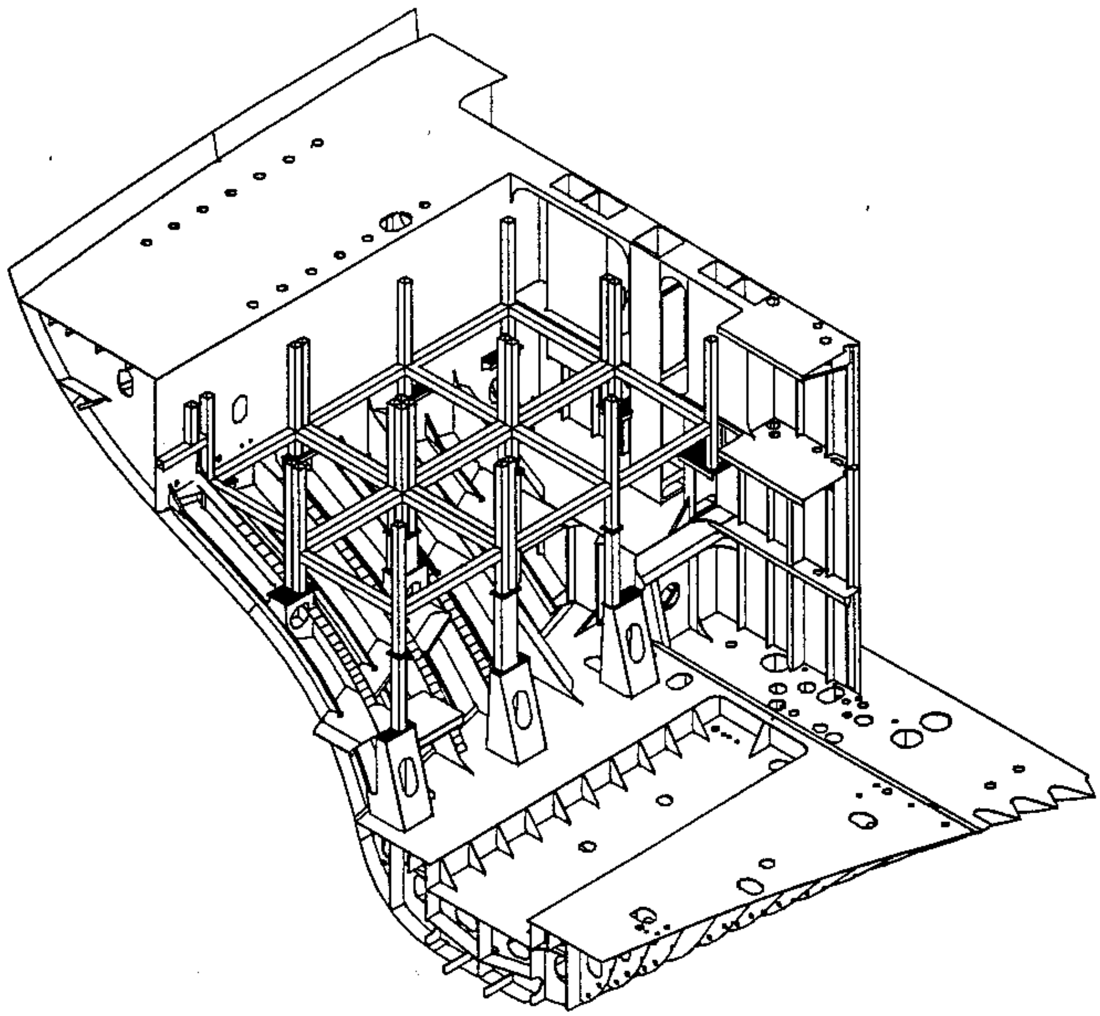


Figure 12

Figure 12. Further Detail of Modules w/ Foundation

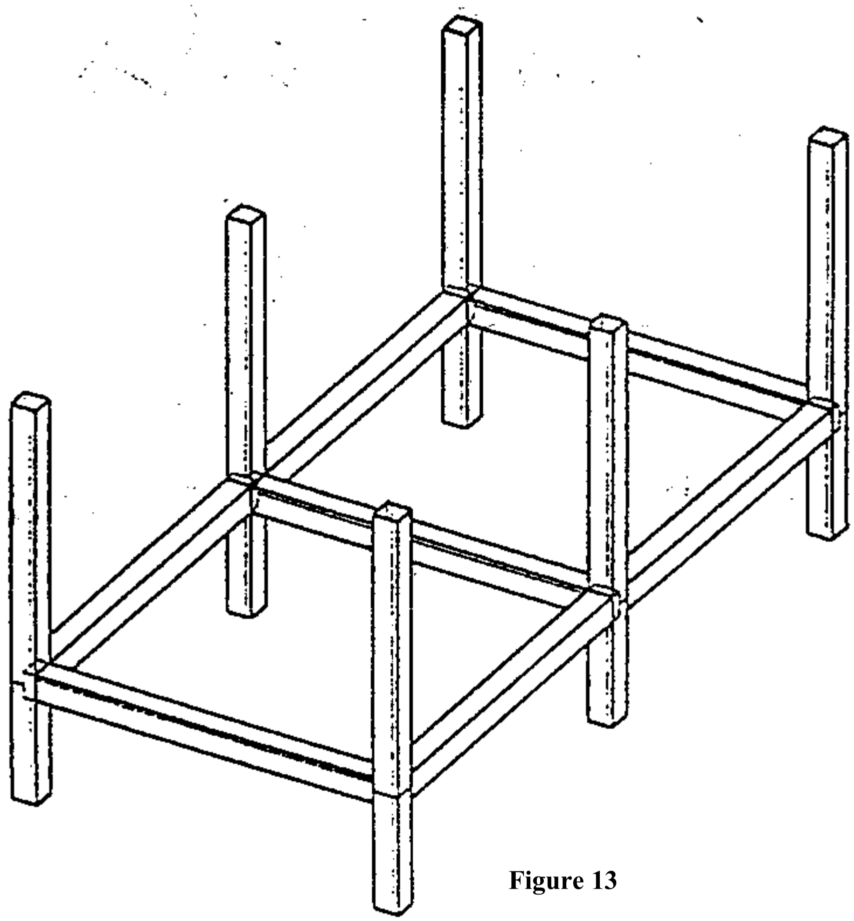


Figure 13. Standard Module Frame

The Frame Type Module (see Figure 13)

The standard module deck consist of open horizontal frame, 6m x 3m (19.69ft x 9.84ft) with two longitudinal and three transversal girders, six support pillars, reaching 2 m (6.56ft) above and 1 m (3.28ft) below the module deck. All structural frames are made of rectangular tubing 200 mm x 200 mm x 10mm(7.87in x 7.87in x .39in).

The maximum module weight as built for shipyard hull numbers 505/510 to 513 was as follows:

Basic frames	2.1 tonnes (2.3 S tons)
Outfit supporting structure	4.2 tonnes (4.6 S tons)
Outfit and equipment	7.7 tonnes (8.5 S tons)
Total	14.0 tonnes (15.4 S tons)

This represents 0.43 tonnes/m2 (0.47 S tons/ft2) equally distributed. The outfit supporting structure is represented by beams and clips that are necessary for nearly all fittings and for walk way platforms.

The Vibration and Strength of the Frame Modules

The static strength of the modules structure was not a problem. However the vibration behavior of the modules structure is a major design factor. The vibration has been investigated carefully, in all cases especially in area of heavy fittings. For example the plate cooler units. The natural frequencies were calculated by means of three dimensional finite element beam models. The models covered the basic frames, additional support beams and masses of the main fitting components.

The excitation frequencies of hull numbers 505/510 to 513 were as follows;

- Propeller first harmonic 6.7 Hz
- Firing of the main engine 11.7 Hz
- Module design frequency 13.0 Hz

Vibration problems did not exist in the structure of the modules.

LESSONS LEARNED

Representatives of the U.S. Navy's Mid Term Sealift Ship Development Program (MTSSDP) Producibility Task made two Product and Process benchmarking trips to Thyssen to investigate the factors that allow this German shipbuilder to be globally competitive and to further understand the benefits and possible weaknesses of modular outfitting. These benchmarking trips were applicable to the Engine Room Arrangement (ERAM) project whose goal is to produce world class ship propulsion machinery design concepts, to the Generic Build Strategy (GBS) project from a design/production standpoint; and to the Product Oriented Design and Construction (PODAC) cost model project.

A major lesson learned was that engineering, design and build processes make up an integral part of each companies strategy for competitive success. Top management at Thyssen was forthcoming in explaining how forecasting, marketing, financing, product development, production and customer support were concurrently planned and executed. Available literature on shipbuilding concentrates on business issues and does not explain how the engineering processes need to be factored in, thus it is important to gain first hand knowledge from the shipyard.

Thyssen is a Naval constructor which fills in the lows of military contracts with commercial work. This is offered as lesson for a number of U.S. shipbuilders who are in a similar situation and would like to smooth the highs and lows of business with different product lines.

The shipyard is counter-balancing their extremely high labor rates with the most producible designs. The focus of the first visit was to understand their patented modular engine room design which almost completely pre-outfits standard sized units that are landed onboard after block erection of the entire ship including the stern. The second visit was made to participate in shipbuilder sea trails and verify operational constraints. We were specifically concerned with possible vibration problems due to the extra primary and secondary structure. This could become a complex "source, path, receiver" relationship for vibrations generated by the propeller, shaft line, and/or main engine.

By the time of our second trip for sea trails, The shipyard had evolved the design concept one step further to be, lighter, more producible, less expensive, and with similar schedule reduction. This latest concept comprises four platform modules, each of which is half of the engine room height and breadth. This new concept will be utilized on their next generation container ship series. This ship a 2500 TEU vessel is shown in figure 14.

Sea trials were two days in the North Sea on hull no. 512, the M/V *San Fernando*. This 1,500 TEU container ship was the 10th in a series using the original smaller engine room modules. A similar modular machinery design by another shipyard from the 1970's resulted in vibration problems to secondary systems such as pumps and electrical panels. Therefore our concern was that the shipyard's engine room design, although highly producible, may be operationally deficient from the machinery vibration standpoint. We independently took vibration measurements which showed that vibration severity numbers, both structure and rotating equipment, were well below classification society and ISO guidelines for a ship in ballast condition.

The ship performed without incident (except the sewage system became overloaded by 50+ people onboard) throughout all trial requirements.

The combination of the slow speed main engine with the controllable pitch (CP) propeller is the most efficient combination for container ships of this type and size. Not only does this combination allow the Main Engine to run at optimal conditions (85-90% MCR) giving the highest efficiency, but the CP propeller gives great flexibility in maneuvering and in running the engine at dock side when testing engine after overhauls, etc. This combination gives benefits such as reduced NOx with engine running under optimal conditions. The ship also utilizes a shaft generator throughout the entire range of the operation profile thus reducing the electric load on the 2 service diesel generators.

The design appeared to adequately address the area of human factors and ergonomics. Operations and maintenance issues have been thought through with adequate lighting, overhead cranes and chain falls, good ventilation and good ingress and egress routes for both humans and equipment. The machinery space was open and was not interfered by the modules and unit frames.

CONCLUSIONS

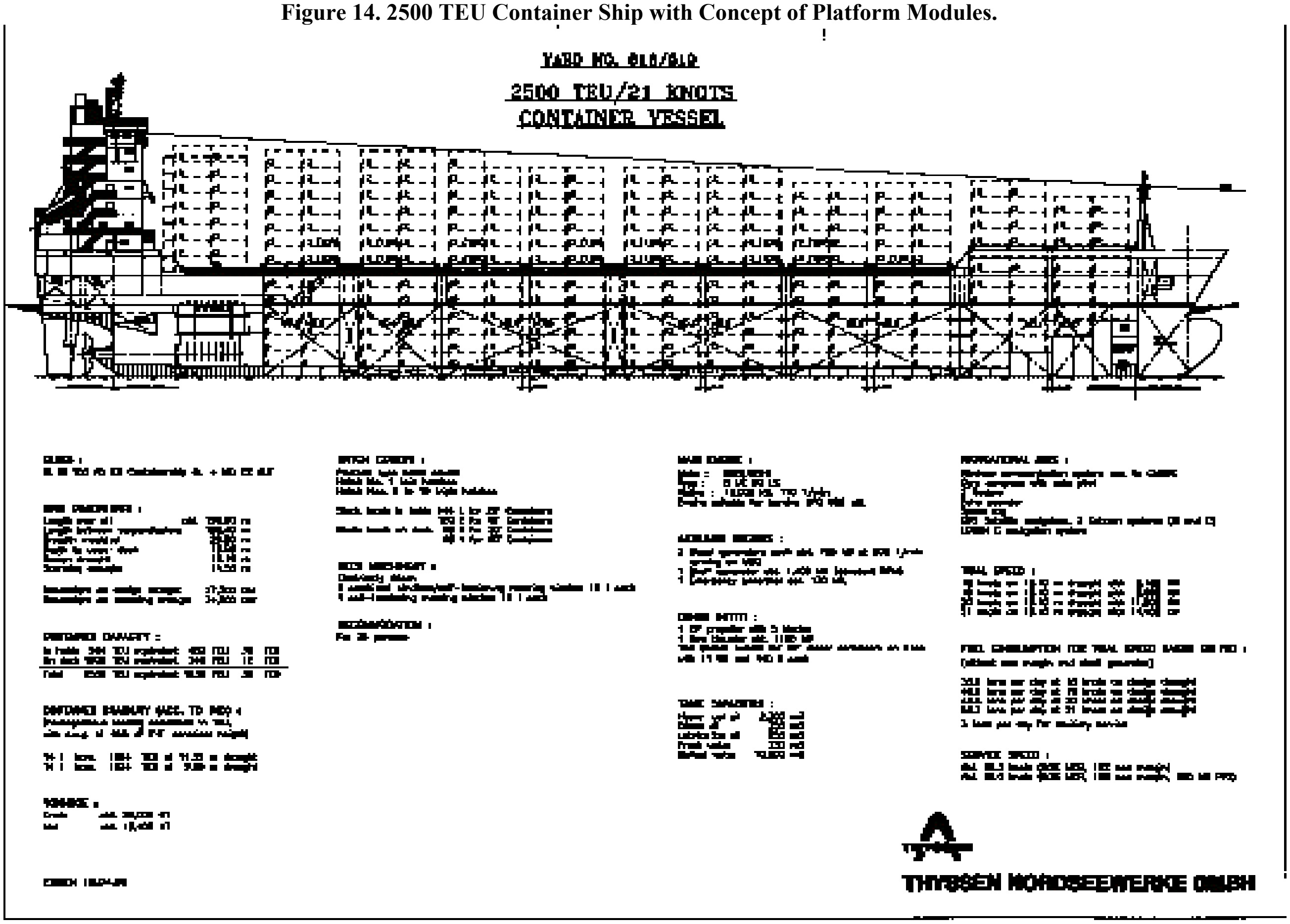
The shipyard part of Thyssen group and a subsidiary of Budd Industry USA can be used as an example of a model for US Shipyards in transition. This transition from a total government or Navy economy to a combination of market and government economy due to diversify work can be a product balance that not only meets the Military needs but those of the Maritime industry as a whole. The shipyard's approach of 1/3 military, 1/3 commercial, and 1/3 other allows them to fill the gap in the production and design work.

Cooperation with other shipyards in the world such as Mil Davie in Quebec, Canada and Yang shipyard in China expands their market base and share in the profits.

The overall concept of modular construction has allowed commercial ships to be built at lower cost to the yard, and shorter time frame for the owners. The concept also allows the yard flexibility with subcontracting. A number of suppliers provide excellent quality and less expensive units than can be built within the yard. As an example the yard subcontracts from Poland the House-superstructure. This very large unit is fully outfitted, beds, sheets, to soap in the showers as a turn key unit and is supplied to the yard by barge after the engine room is outfitted.

The shipyard has developed a modular design that meets and exceeds the classification society standards, but most importantly customer requirements thus ensuring an exceptional product for their commercial customers. Finally they have gone one further step through the development of a flexible private ship financing in order to meet shipowner freight rate requirements and profits. Lastly and most important the shipyard is meeting Germanys marine and shipbuilding needs which allow an maritime industrial nation to keep its independence.

Figure 14. 2500 TEU Container Ship with Concept of Platform Modules.



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