Effect of admeasurement rules The application of the Admeasurement Rules has adversely affected the producibility of structural design for many years. Access holes in double bottom floors and girders, and to tanks have been restricted to 600 by 450 mm ovals. Lightening holes have likewise been restricted to 18 inch diameter, except in fuel tanks where 750 inch diameter holes are allowed providing they are strapped by installing a 40 mm wide flat bar horizontally across the middle of the hole.

This is an obvious work content increase that has no real design function. In the U.S., for small ships that benefit from being measured below 200, 300, 500 and 1600 Gross Registered Tons, various admeasurement reduction devices such as full depth plate floors on alternate frames, tonnage openings in cargo and accommodation spaces, and excess capacity of water ballast tanks all add significant work content to the ship.

The 1969 IMCO Tonnage Convention will eventually eliminate the unproductive additional labor and material cost for the larger U.S. built international voyage ships, as it does not allow any of the admeasurement reduction devices. By eliminating the tonnage reduction devices in larger ships, the ship designer will be free to utilize access and lightening holes to suit the shipyard's best approach to access for workers, equipment and material.

It is imperative that the arrangement designer be fully aware of the admeasurement method to be applied to the ship, and if it is the *new way*, to erase all *traditiona*l tonnage affected design details from the ship arrangement, and utilize instead details that improve productivity.

14.3.3.3 Structure

The design of ship structure is the process of applying rules and experience to integrate individual structural components into efficient and easily constructed subassemblies, assemblies, blocks and hull. Because it is a large part of the weight, construction man-hours and material cost, and also as it is relatively easy to design, more details are usually given for the structural part of a Contract Design than for any other discipline. Yet it is for the structure more than any other discipline that each shipyard must individually design to suit its own facility or else have its needs and preferences incorporated into the design during the preparation of the Contract Design. It is suggested that structural design, if prepared by a design agent for a Contract Design, be designated as *Guidance Only*, thus allowing the shipyard to utilize its own details. However, this has been proposed before (4,10) and it has not resulted in any change by Design Agents and Owners. In this situation, it is important that designers realize the impact of their design decisions.

Many ship structural designers use *Standard Structural Details*, which they may have *borrowed* from other designers in another shipyard. Or, for a naval ship, they may simply use naval ship standards, which are over 20 years old. Chances are that the decision to use a particular detail will be made without any regard to producibility requirements for the shipyard involved.

Remember that as there are a great number of connections between the structural components of a ship, the *best* design for one shipyard might not be the *best* for another. The *best* structural design detail depends on:

- block definition and erection methods,
- manual versus computer-aided lofting, and
- manual versus NIC cutting.
  - extent of automatic welding,
  - whether or not the shipyard has a panel line, and
  - facility and equipment.

However, the basic goal of Design for Production is to reduce work content, and the development of structural details should accomplish this goal. Before discussing some details, it is necessary to consider the selection of block boundaries.

Block definition When deciding block boundaries, a number of items must be considered, some obvious, and some not so obvious. These are:

- maximum block size,
- maximum block weight,
- block turning limitations,
- shell shape boundaries,
- access for workers and equipment required for joining blocks,
- extent of use of auto and semi-automatic machines,
- whether or not self-aligning,
- internal connection detail,
- framing method,
- plate straking direction,
- in line or staggered transverse breaks,
- maximum or standard plate/shape sizes,
- completion of adjacent spaces/tanks,
- blocking or shoring requirements,
- natural lifting points,
- use of *green* or stock material for fitting,
- large equipment arrangement and foundations to avoid overlapping block breaks, and
- design to eliminate plate or pin jigs.

The block boundaries should be located at natural plate butts and seams. Block breaks should be located to minimize erection work content.

14.3.4 Design for Production in Detailed Design

Design for Production in Detailed Design focuses on the preparation of design details that are production friendly and the use of production-oriented techniques to transmit and communicate design and engineering data to various users in a shipyard.

There are a number of production-friendly detailed design details that will be the same from shipyard to shipyard, but there are many more that will be unique to each shipyard depending on the ships to be built and the shipyard's facilities and capability. Therefore, the appropriate DFP for a given shipyard must be developed by the shipyard utilizing a team approach involving all departments involved in the decisions.

The Build Strategy Approach is a convenient way to accomplish this and it provides many benefits beyond the basic DFP. It is too late to begin DFP in the Detailed Design stage. Design for Production in Detailed Design builds on the Design for Production in Basic Design.

Keeping in mind that the detailed design stage is too late to apply the basic DFP, if it has been applied in basic design, then it is a natural extension for the design of the details of the product, in detailed design.

All functional areas are involved. Because structure is the major work content functional area in commercial ships it is always well covered. However, the DFP approach has to be applied to all areas consistently if the full benefit is to be achieved.

14.3.4.1 Structural details

The labor man-hours to construct the structure of a ship can be significantly reduced by proper attention to the design of the structural details. A number of structural details are examined in this context.

Stern Frame At one time most stern frames were designed as castings. This enabled complex shapes to be incorporated in the design, and also to provide an early-erected reference to build to when ships were constructed part by part on the building berth. A number of shipyards still fabricate the traditional stern frame. The widespread use of structural blocks necessitated the integration of the stern structural design. Therefore, the ship designer must select stern lines and propeller aperture shape to enable the stern block to be easily constructed and eliminated the need for separate and cast stern frames (Figure 14.51).

Block Breaks The basic guidance for block breaks was covered in DFP in Basic Design. In detailed design it is necessary to consider the details of the breaks.

Figure 14.52 through 14.54 show an approach for ship construction developed with DFP in mind. The layer con-

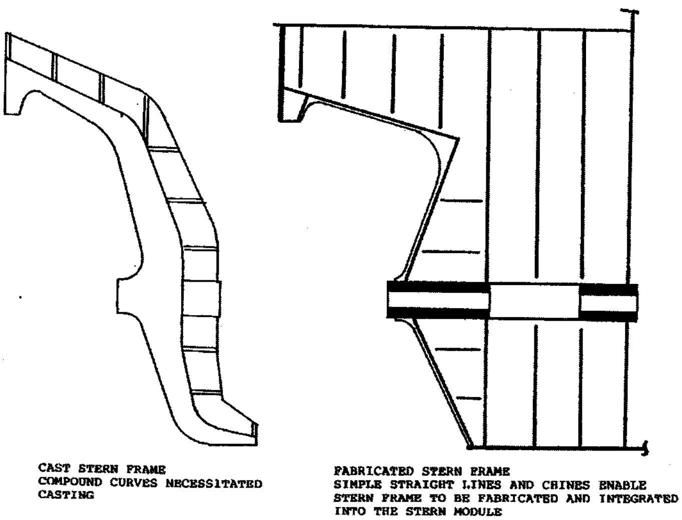


Figure 14.51 DFP Stern Frame Elimination

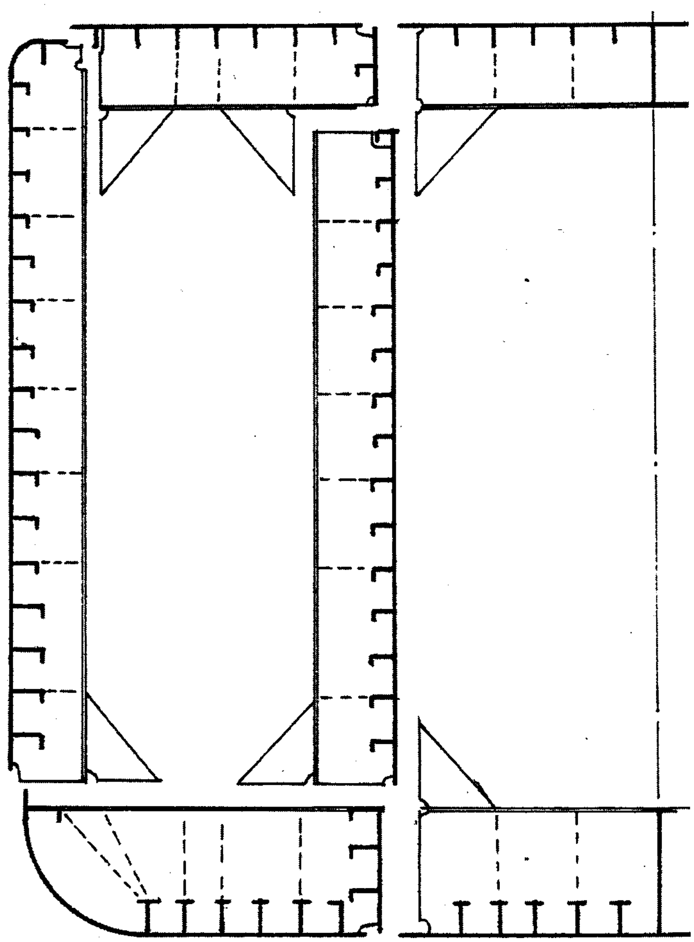


Figure 14.52 Layer Method for Tanker

cept can be applied to many ship types and in many locations. Its benefit is that the joining weld is a double fillet rather than a horizontal butt weld.

Figure 14.55 shows typical alternative approaches for the shell connections in way of block breaks and Figure 14.56 in way of block breaks in double bottom tanks.

Self-aligning Blocks Block breaks can be arranged to be either non-self-aligning or self-aligning. This is decided by the shipbuilder to suit erection preferences as shown in Figures 14.55 through 14.57.

Plate Straking The obvious goal for plate straking is to standardize the plates. A standard plate should not only be identical in size but also in marking, beveling, etc. (Figure 14.58), thus providing significant reduction in engineering, lofting and production man-hours. This can only be accomplished by locating the stiffeners and webs/floors in the same position on each plate. To do this, two options are use of special tooling cost effective and possible. One is to consider stiffener and web spacing to suit the maximum width and length of plates to be used. The other is to select plate width and length to suit the desired stiffener and web spacing. For example, if a shipyard desires to use a maximum plate size of 16 by 4 meters, the spacing of the stiffeners will be given by $4/n_s$ and of the webs by $16/n_w$) where both n_s and n_w must be whole numbers.

If, on the other hand, the shipyard wishes to use a stiffener spacing of 900 mm and web spacing of 3.5 meters, the 16 by 4 meter plate would not allow standard marking. The correct standard plate size for the desired spacing would be 14 meters in length and 3.6 meters in width. This example shows that when developing structural design, all the factors that can influence productivity, and thus cost must be included. It is pointless to spend time and money to standardize design and facilities and to lose much of the benefit by not understanding the impact of incorrect plate standardization.

Another problem not generally understood is the effect of shell plate straking on curved plate work content and material scrap. As previously mentioned in Subsection 14.3.3.1,

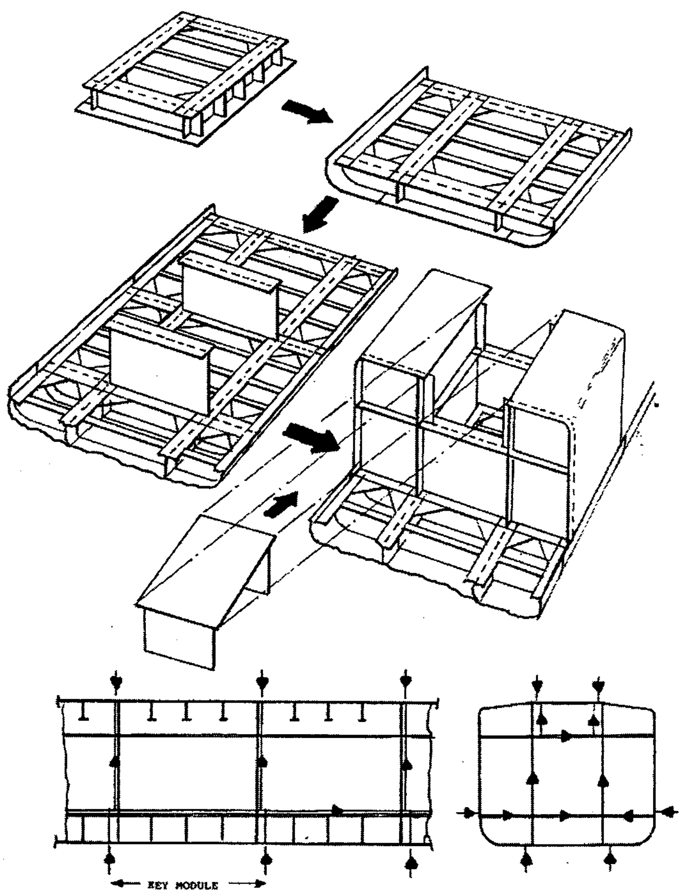


Figure 14.53 Block Erection Sequence for Layer Method Construction

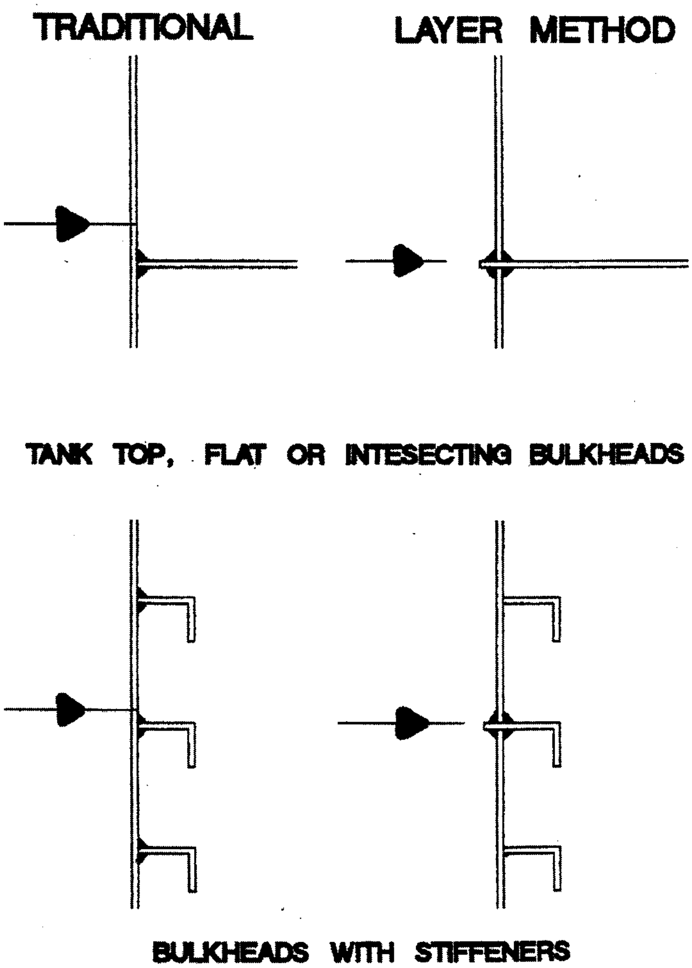


Figure 14.54 Details of Layer Method Joints

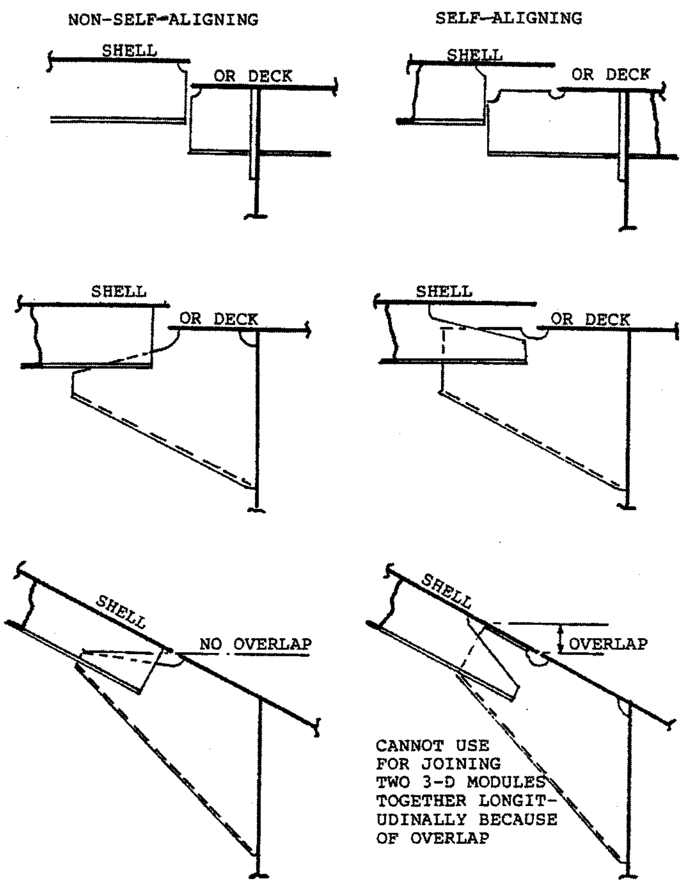


Figure 14.55 Shell Connect Alternatives in Way of Block Breaks

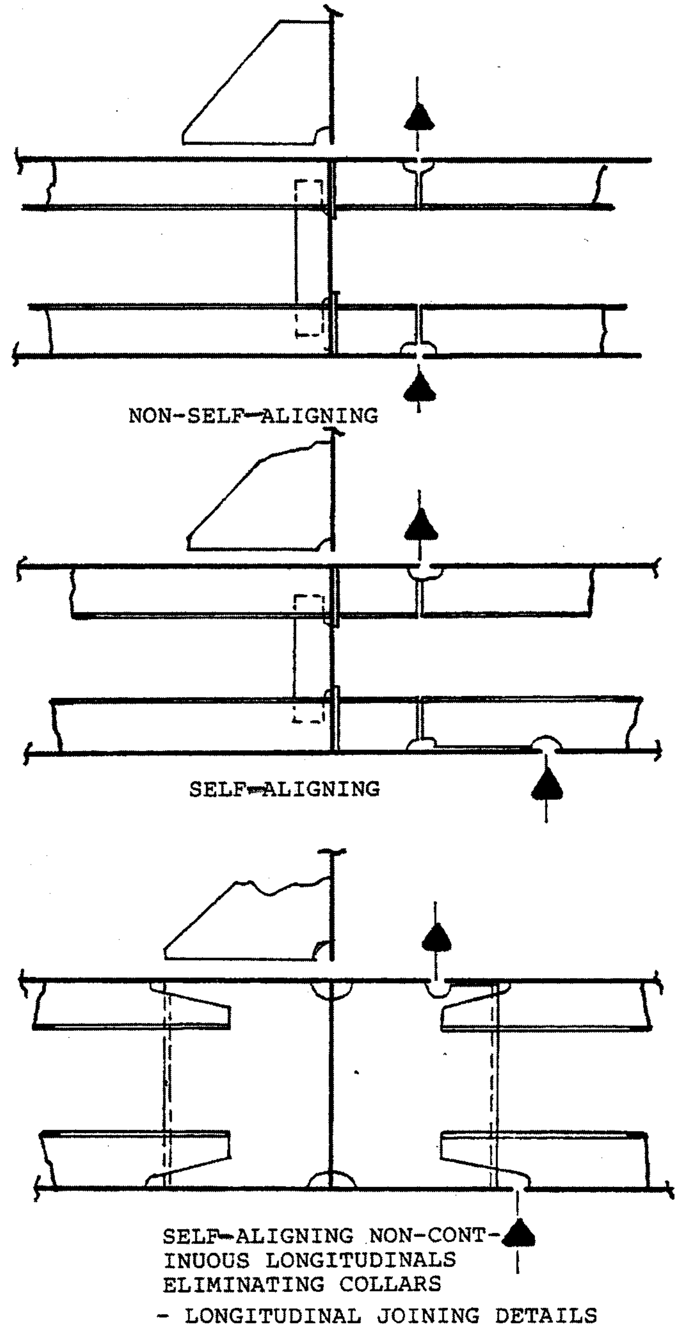


Figure 14.56 Block Break Connections in Way of Double Bottom Tanks

in the past straking was decided to follow the natural curvature of a ship as shown in Figure 14.59. Today, block construction has resulted in many plates having horizontal seems and vertical butts. This results in significant twist being introduced into the plate (Figure 14.59), and twist cannot be achieved by rolls.

Correctly applied, the number of different shell plates in the parallel body of a tanker or bulk carrier, can be as few as five. When this approach is applied to decks, bulkheads and tank tops, its impact can be a significant reduction in engineering, lofting and production man-hours. It also makes the use of special tooling cost effective and practical, as the extent of tooling will be small.

Another shell detail that involves extra work content is insert plates (Figure 14.60). This is because of the additional welding and chamfering of the insert plate. This can be eliminated by making the insert plate the full strake width, thus eliminating much of the additional welding. The chamfering can be eliminated by increasing the thickness of the plating surrounding the insert plate to that necessary to gradually build up to the required insert plating thickness in steps allowed by the classification society rules, without chamfering.

Many shell assemblies and/or blocks require plate or pin jigs to be able to construct them. This is an additional work content and by design it tan be eliminated. To do this it is necessary to either arrange flat structure, such as decks, flats and bulkheads, into the shell block so that they can be used as the assembly reference planes on which to set the internal structure and then attach the shell plates. Or else the internal web frames must be deliberately designed with their inner surfaces in a common plane for each block, in the

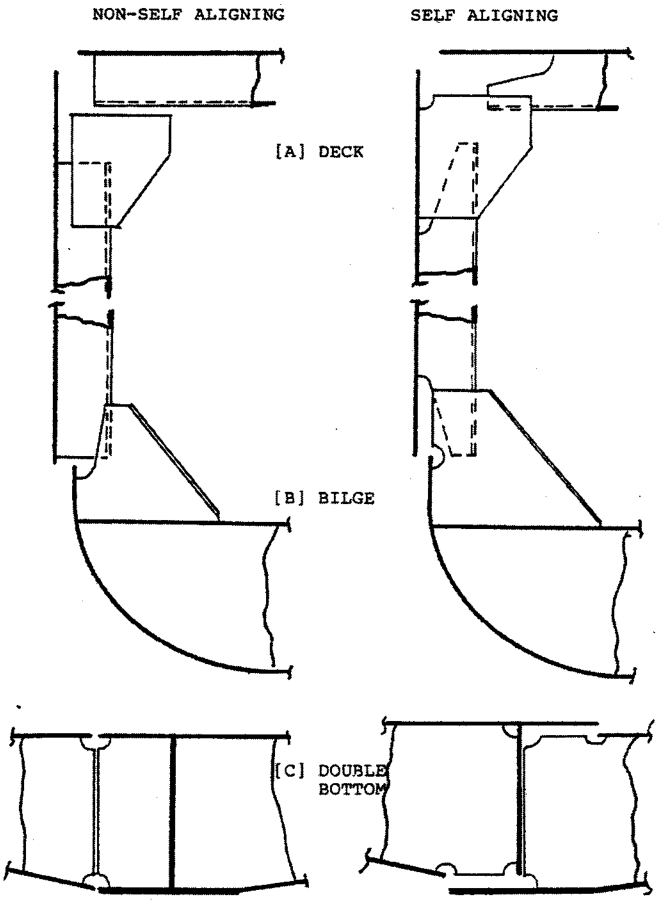


Figure 14.57 Block Break Alignment Considerations

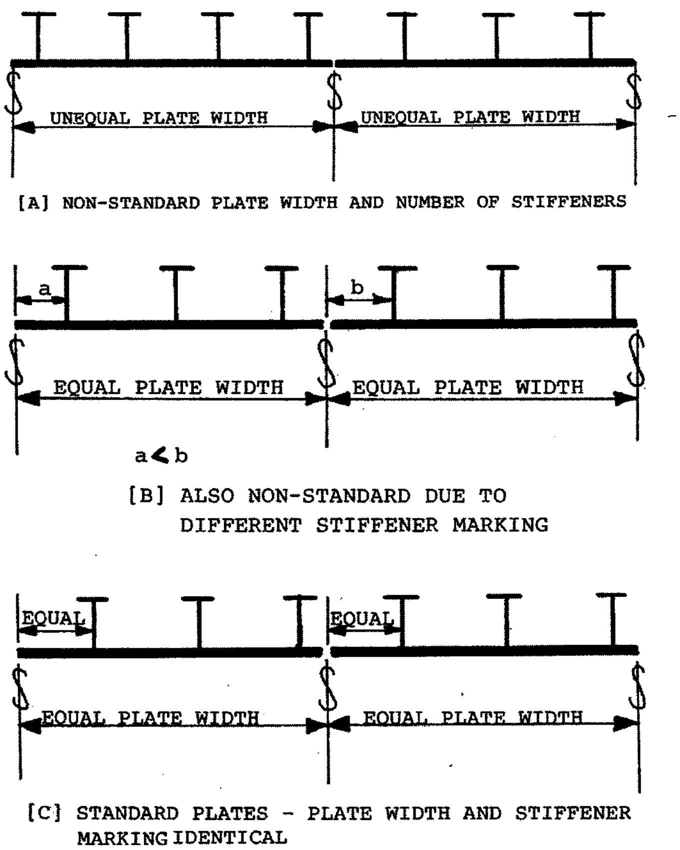


Figure 14.58 Standard and Non-standard Plates

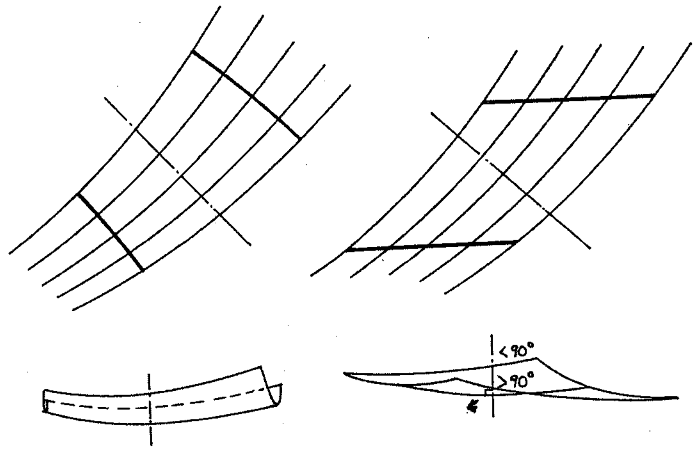


Figure 14.59 the Effect of Modern Shell Plate Straking

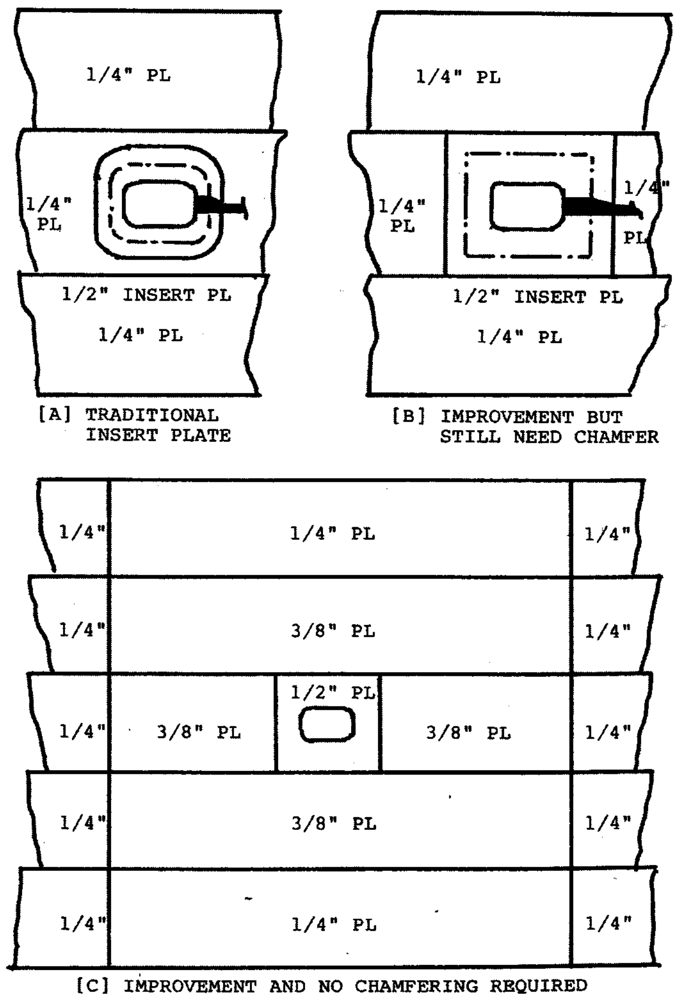


Figure 14.60 Shell Insert Plates DFP Considerations

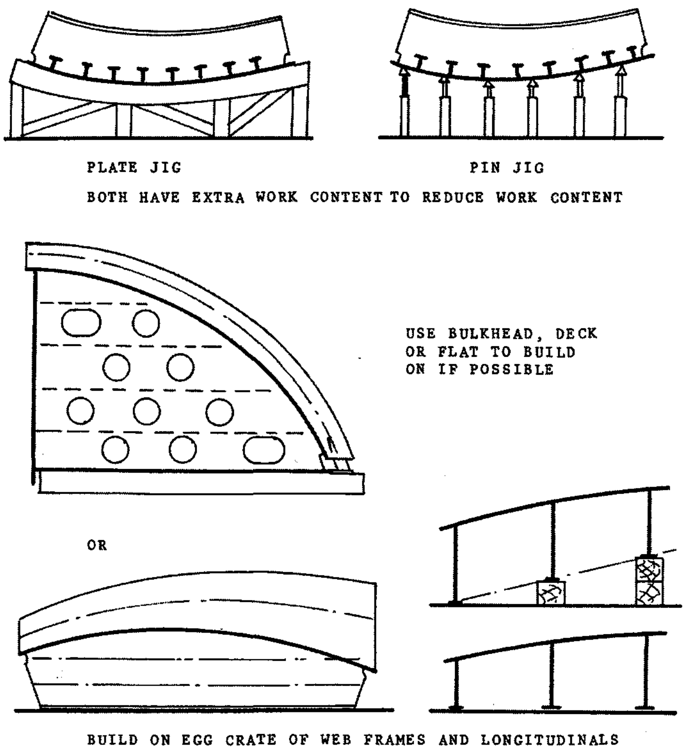


Figure 14.61 Curved Block Design for Production

same way that the upper surface and bevel angle of roll sets are used. These concepts are shown in Figure 14.61.

Cut-Outs The design of cut-outs for frames, longitudinals and stiffeners can also adversely influence work content, especially in naval work, where most of them at the shell must be chocked or collared. It is possible to eliminate cut-outs by slotting the floor, web or bulkhead, cutting away the flange of the frame, longitudinal or stiffener, and inserting a bracket to effectively maintain the sectional area of the frame, etc.

Corner cut-outs, snipes, drainage and air holes must take into account the construction methods and equipment that the shipyard intends to use. For example, if automatic or even gravity feed welders will be used, a detail allowing continuous fillet welding will be best, whereas for manual welding a complete edge cut detail may be better, especially if weld oil/water stops are combined in the detail.

The practice of making air holes smaller than drain holes in floors, girders, etc., is unnecessary and they should be made the same size.

Brackets There are many approaches to the design of brackets for frames, beams, longitudinals and stiffeners. In the days of the piece-by-piece erection of structural parts on the building berth, brackets were very simple. Even where shape was involved, they were fitted at the ship frame by frame. Figure 14.62 shows the evolution of some frame and beam brackets. Type (A) is a pre-computer aided lofting and NIC burning bracket. It was often sheared or burned from plate drop off or scrap and two standard sizes generally covered the complete ship. Standard II was used for shaped brackets and the excess material was simply cut off to suit each connection when joining frame to beam. Type (B) shows a bracket, which is practical only through the use of computer aided lofting and optical or NIC burning. As type (B) can be accurately cut, it can be used with advantage to align frame to beam and shell to deck. Type (C) is a bracket which utilizes the same concept as type (B) but attempts to eliminate the complex cutting of the ends of beams, frames, stiffeners, etc., required by type (B).

Its advantage is that as it is cut by N/C machine, all shaping can be easily accomplished and then the end cut on the frame, etc., becomes a simple straight cut. Its disadvantage is that as it is still used for alignment, it usually requires a larger bracket, thus encroaching on internal space. Another way to reduce the work content of brackets is to use thicker material and eliminate flanging or welding on a faceplate. This is allowed by classification rules.

Webframes Ships such as tankers and bulk carriers, and also some large naval ships, incorporate many web frames in their structural design. The usual design approach utilizes ring web frames with their many faceplates and web stiffeners. Figure 14.63 shows typical ring web frames and an alternative approach utilizing non-tight plate bulkheads in place of the ring web frames. The non-tight bulkhead web frame can be constructed for less man-hours than the usual ring web frame as it eliminates many differing parts including thick faceplates, which are often rolled to shape. It can also be constructed on a panel line with automatic and semi-automatic assembly equipment. However, in the case of coated spaces, the cost increase for the coating of the additional surface area must be taken into account. Where ring web frames must be used they should be simple in design without any curved inner contours or shaped faceplates (Figure 14.64). Also the faceplates should be located on one side of the web and not centered or even offset as a *tee*.

Access The location of access holes through the structure is important from the productivity point of view and must be considered for all positions of the assembly or block during construction and not only for the final ship attitude, as illustrated in Figure 14.65. It is a noticeable practice of many designers to center access holes in floors, girders, etc., making them difficult to use, and often requiring steps to be installed.

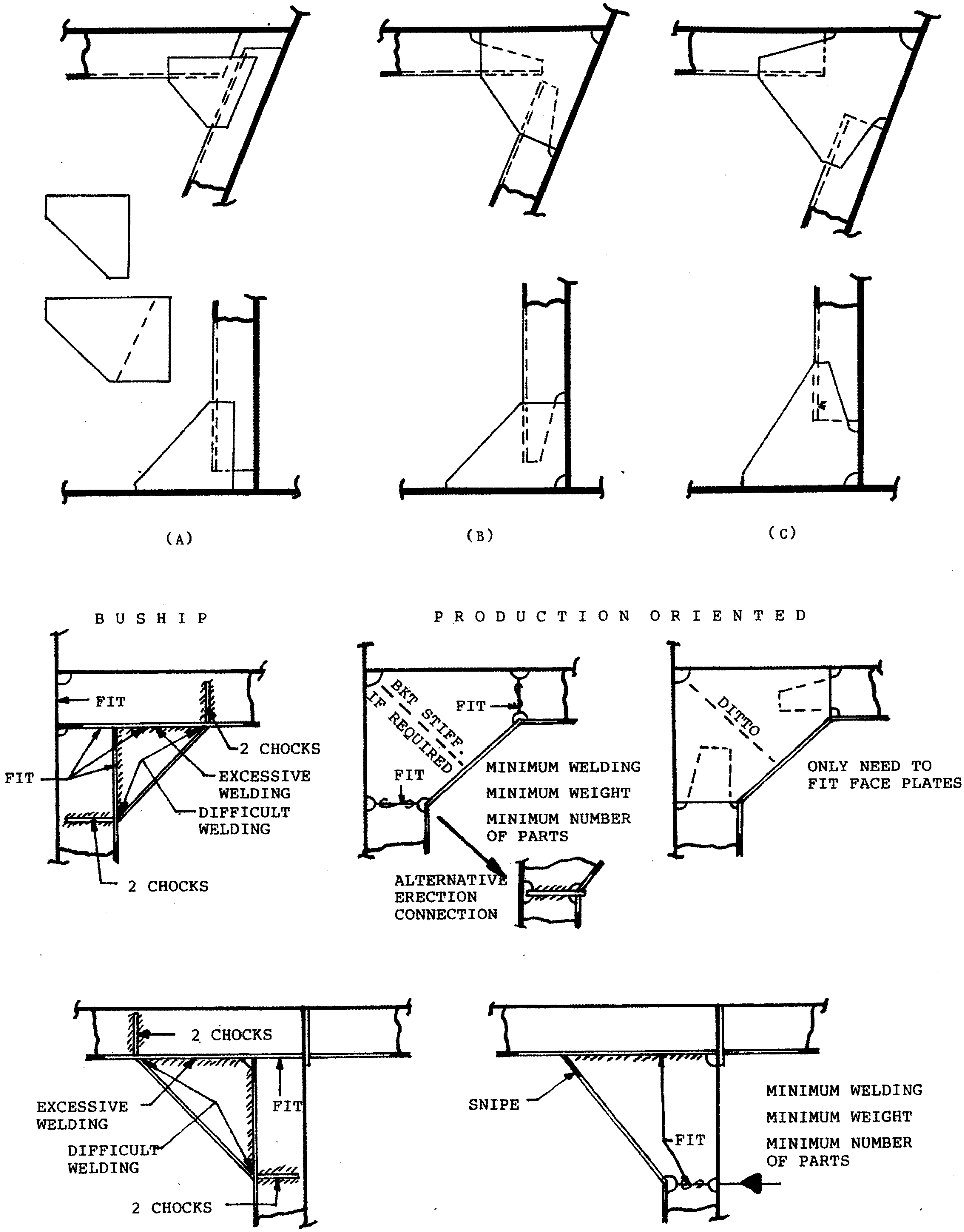


Figure 14.62 Typical Brackets

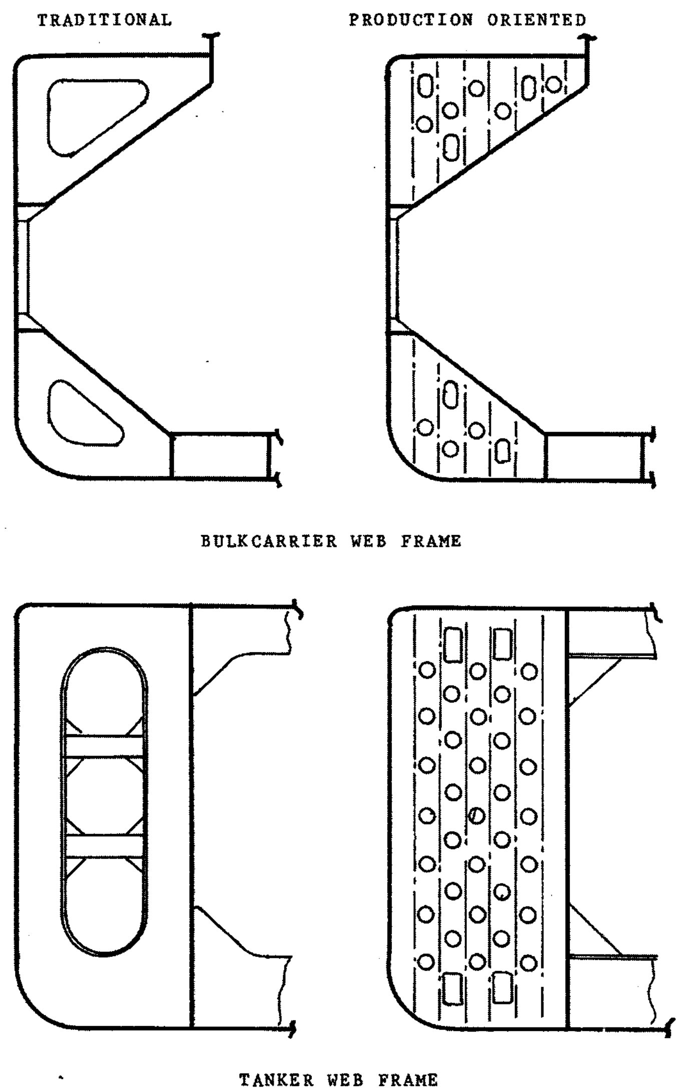
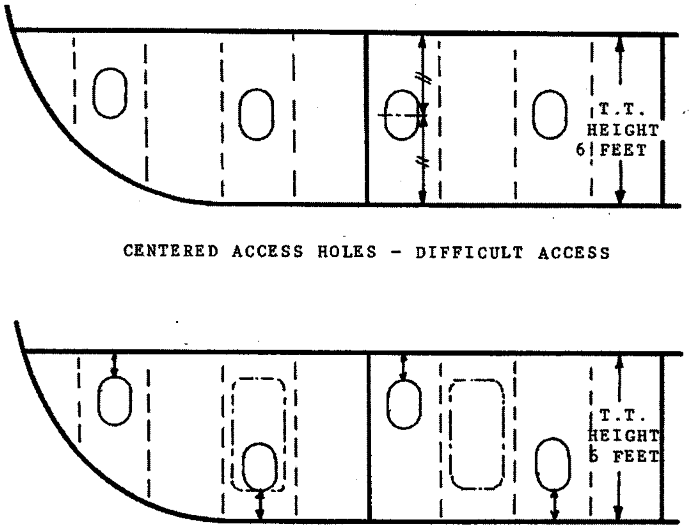


Figure 14.63 Web Frame Alternatives



ACCESS HOLES LOCATED FOR EASY ACCESS

* HEIGHT FOR EASY ACCESS WHEN CONSTRUCTING MODULE BOTH UPSIDE DOWN AND FINAL ATTITUDE

** CONCEPT OF USING ACCESS HOLES AS LARGE AS STRUCTURALLY POSSIBLE INSTEAD OF TRADITIONAL 23 x 15 INCH TONNAGE DICTATED TYPE

Figure 14.65 Location of Access Holes

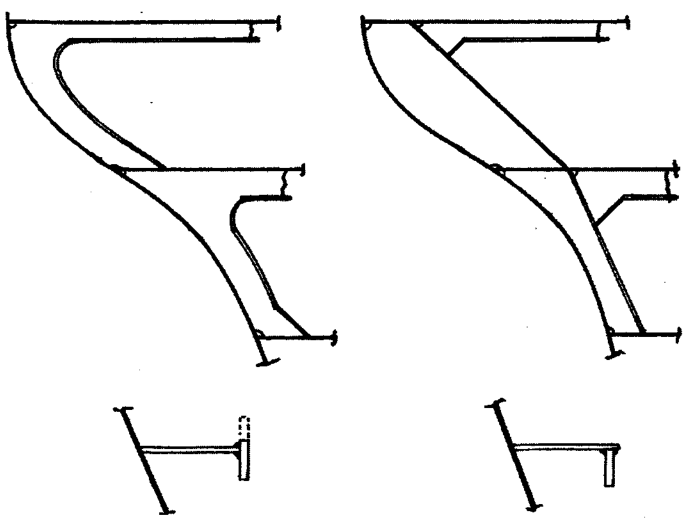


Figure 14.64 Web Frame DFP

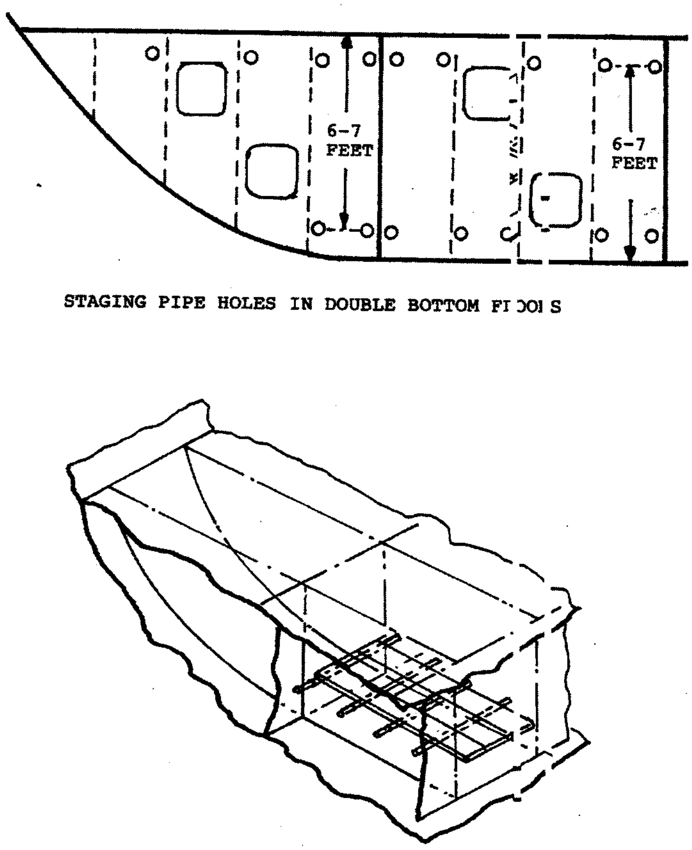


Figure 14.66 Designed-in Staging System

During the construction and for maintaining the ship in service, staging is required in many spaces. Integrating the requirements into the design as permanent features can eliminate this. For example, for staging, 40 mm diameter holes can be cut in floors, girders, web frames, deck transverses, etc., thr6ugh which 35 mm diameter staging pipes can be placed and staging planks laid across the pipes as shown in Figure 14.66.

This concept was shown in reference (9), which also showed the cutting of hand and toe holes in the structure to assist access throughout the ship. These staging and access holes can be efficiently cut by the automatic burning machine when cutting the plate. Permanent *built-in construction and access galleries* are also a possible way to improve productivity through improved and safer access.

Penetrations One area of significant work content faced by shipbuilders of naval and other sophisticated ships, is the cutting of penetration holes for pipe, HVAC and electrical systems. This must obviously be done for systems when they pass through bulkheads, decks and external boundaries but it is usual practice to see it also for deck transverses, girders and web frames. The need to penetrate the latter items should either be eliminated or they should be made easier to penetrate. It can be eliminated by the design of minimum depth members and the running of all systems inside of the members or if the members cannot be made smaller, by increasing the tweendeck height or width of the space to allow the systems to be run inside of the usual sized members. Members should be designed to be easily penetrated by systems. That is, the depth of the member can be increased and the web material cut away in a standard pattern, to allow the systems to pass through. Penetrations through bulkheads can be arranged in an insert plate as shown in Figure 14.67.

Scantling Standardization/Number Reduction In a recent Contract Design for a small 75 meter naval service ship, the original Contract Design utilized 12 different thickness of plate and 51 different shapes. Although one of the worst examples ever seen, it is, unfortunately, quite common for designs to be prepared without any regard to keeping size differences to a minimum. The shipyard reduced those to 4 plate thicknesses and 9 shapes during detail design with less than a 1 percent increase in steel weight. However, the man-hour savings resulting from the-easier

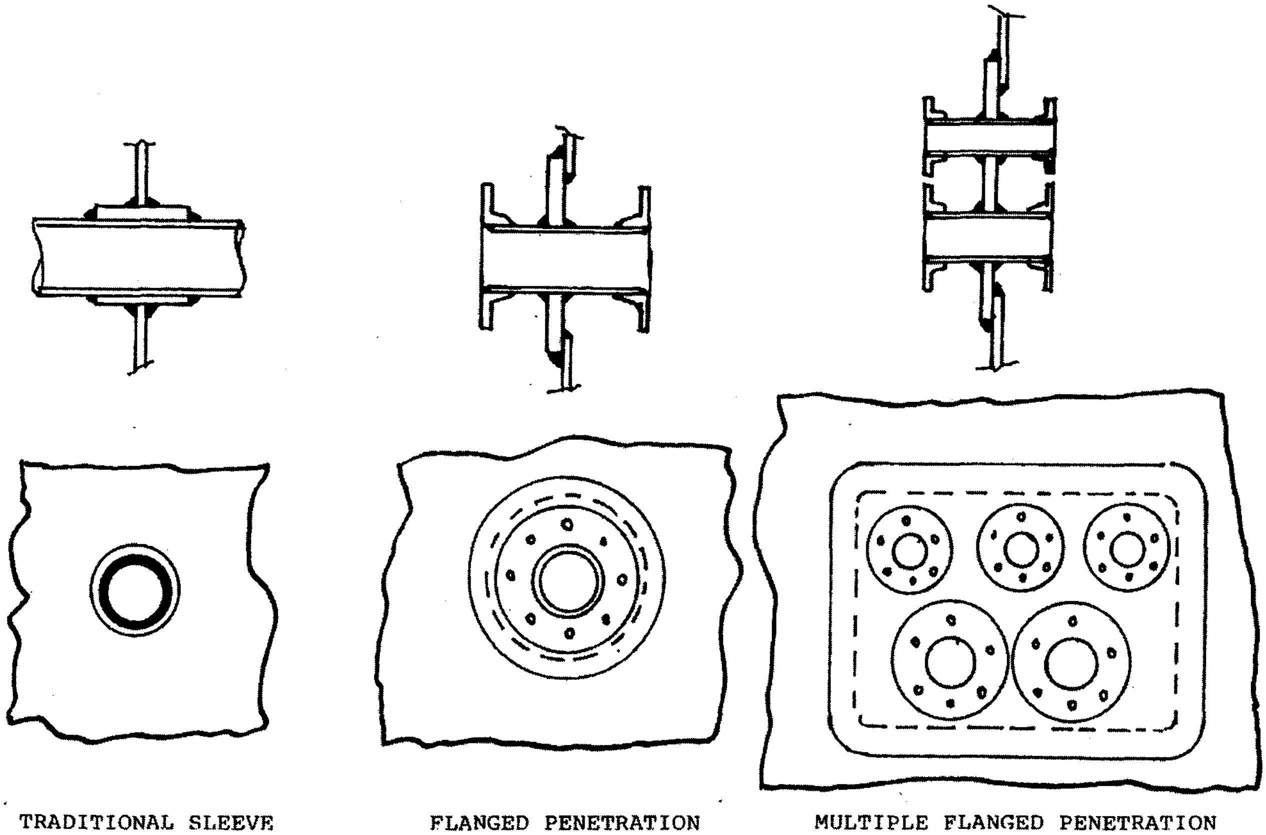


Figure 14.67 Pipe Penetration DFP Considerations