receiving, storing, handling, processing and installing was 6 percent of the steel construction budget.

***Bilge Framing*** In a longitudinally framed ship, the longitudinals in way of the bilge radius are of high work content due to their shaping, twisting, closed angle fitting and cut-out collaring or chocking. The use of bilge brackets in place of the longitudinals is a productivity-improving alternative (Figure 14.68). Obviously, with computer aided lofting and NIC burning, the bilge brackets are easily produced. This approach also provides simpler and better control of the shape of the bilge shell plates. Obviously, before utilizing any of the structural details proposed, a complete producibility/cost benefit analysis should be performed by each shipyard to ensure that the selected detail is the best for their particular facility, equipment and methods.

### 14.3.4.2 Structural fittings

It is usual to group certain items which are either integrated into the structure, such as stem and stern frames, or connected to it, such as bitts, chocks, steel hatch covers, manholes, ladders and structural doors, into a category which is commonly known as Structural Fittings. Foundations are sometimes included in this category. Many of the items in this group were castings in the past and have been replaced by weldments, such as bitts, stems and stern frames.

There is considerable opportunity to apply design for production techniques to structural fittings. For example, when welded stern frames were first designed to replace castings, they were still designed as an independent item from the rest of the stern structure and many shipyards are still doing this. With modular construction there is no logic for this and the stern frame should be integrated into the stern block. This would significantly reduce the work content as the sternframe is effectively eliminated as a separate work item. The replacement of the stem casting by a weldment was already discussed, but it obviously requires the cooperation of the designer of the lines to be able to do so.

The traditional design of rudders results in high work content rudders. This can be reduced by simplifying the design through the following approaches:

- constant section throughout the depth,
- vertical leading and trailing edges,
- spade rudder instead of rudder supported by sole piece or horn, and
- horizontal bolting coupling instead of tapered stock and nut.

These concepts are shown in Figure 14.69.

Foundations for marine equipment are traditionally pedestal type made out of plate. They usually support only one piece of equipment. Even before advanced outfitting was developed, it was an obvious productivity advantage to integrate the foundations for multiple-associated equipment. The unitization, as it is called, of steering gears, hydraulic power plants, inert gas systems and purifier installations have been commonplace for some time. The use of standard foundations is obviously worthwhile due to reducing design, engineering and lofting effort and production fabrication and installation man-hours due to multiple runs and

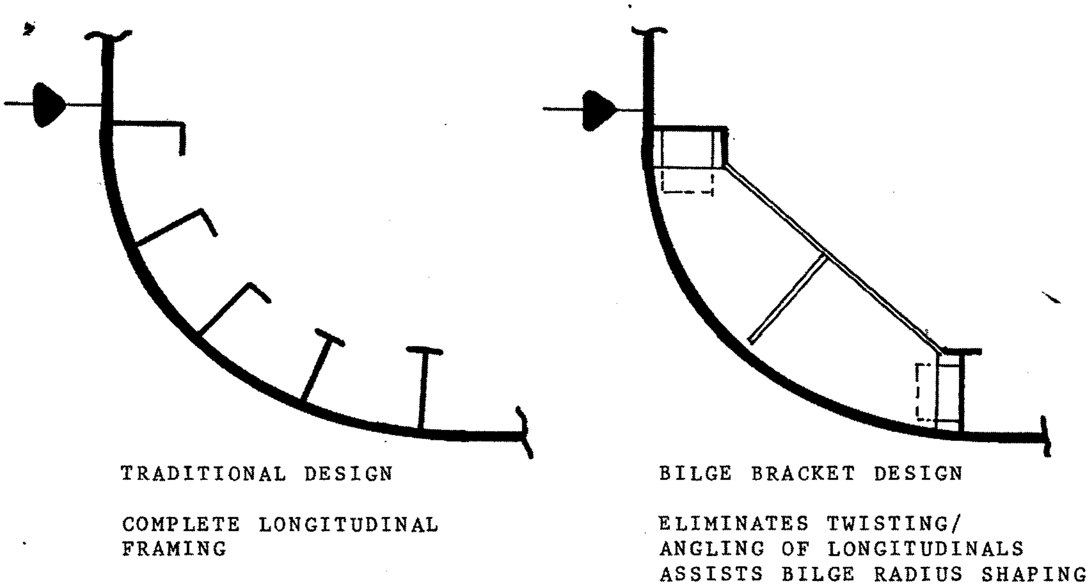


**Figure 14.68** Bilge Framing Alternatives

work familiarization. Foundation design for production depends on shipyard equipment and worker capability, but, in general, the following approaches have provided low work content design (Figure 14.70):

- minimize number of parts,
- minimize number of unique parts,
- foundation designer and equipment arranger must work together. Sometimes moving the equipment a few inches can significantly simplify the foundation design and construction with no adverse impact on the arrangement design,
- do not mix plate and shapes, that is, make the foundation completely out of either all plate or all shapes,
- standardize on a few structural shapes, such as angle, channel or square tube,
- run supports vertical. Do not slope supports,
- provide any required *back up* structure on the same side as the foundation, that is, integrate it with the foundation,
- eliminate fitting joints, maximize lapping joints,
- use sheet metal independent drip pans in lieu of built-in,
- group a number of small items onto a common foundation, and
- securing bolts must be easily accessible. Otherwise, use studs.

For the remaining structural fittings, the use of standards is an essential design for production approach. It is illogical to redesign and/or redraw items such as hatch covers, railings, structural doors, ladders, flag and ensign staffs, etc. for each new design.

One item that is surprising in its lack of standardization in many shipyards is manholes and their covers (see example in subsection 14.3.6.4). For some reason the cover and gasketing for the coaming, raised and flush types are not made the same. There is no reason why this should be so. It is the different parts of each type that should be designed to suit the standard cover and gasket. Obviously, not all of the possible structural fittings have been covered, but the intent should be clear from those that were.

### 14.3.4.3 Hull outfit

Hull outfit covers joiner work, insulation, furniture, habitability equipment, deck covering and painting. In some shipyards, it also covers deck machinery, hull piping and HVAC. The two latter items will be discussed separately in the following sections on PIPING and HVAC, respectively.

The major item of recent development in hull outfit that is in keeping with design for production is modular accommodation-units. The advantages of modular accommodation-units are, not surprisingly, similar to those for advanced outfitting units, namely:

- relocation of work from ship to shop, resulting in easier access, efficient material handling, cleaner and safer environment,

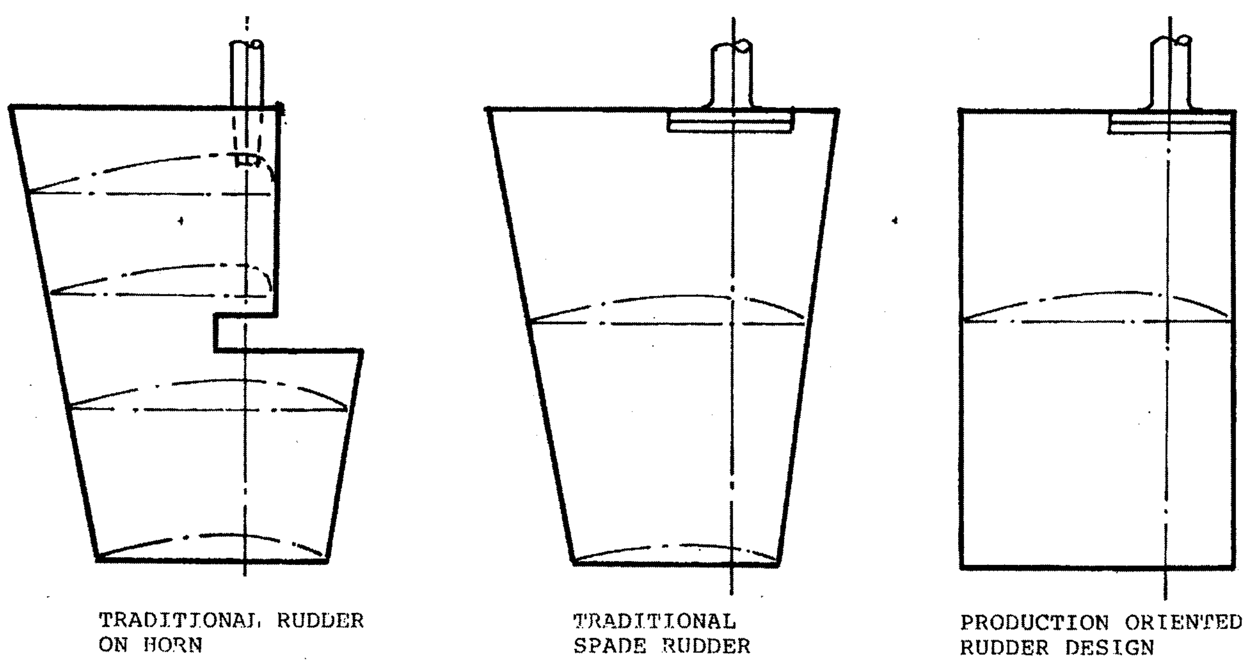


**Figure 14.69** DFP for Rudders

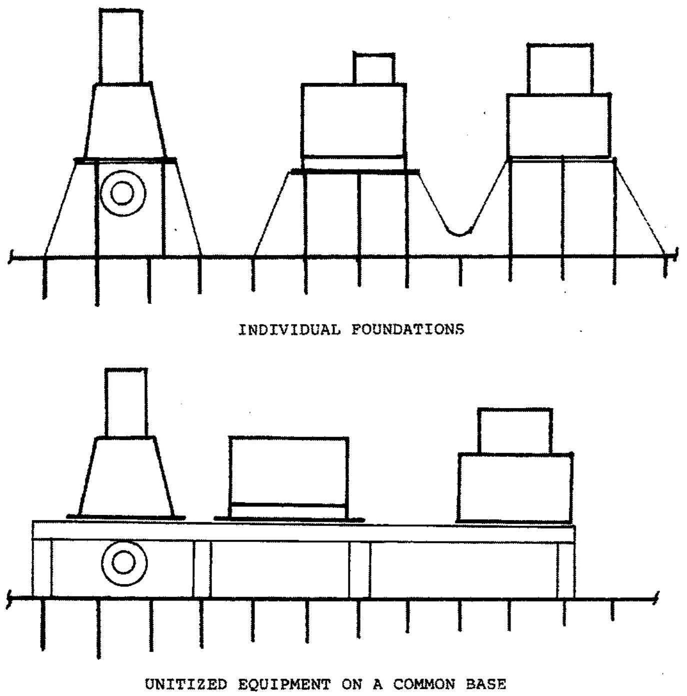


**Figure 14.70** DFP for Foundations

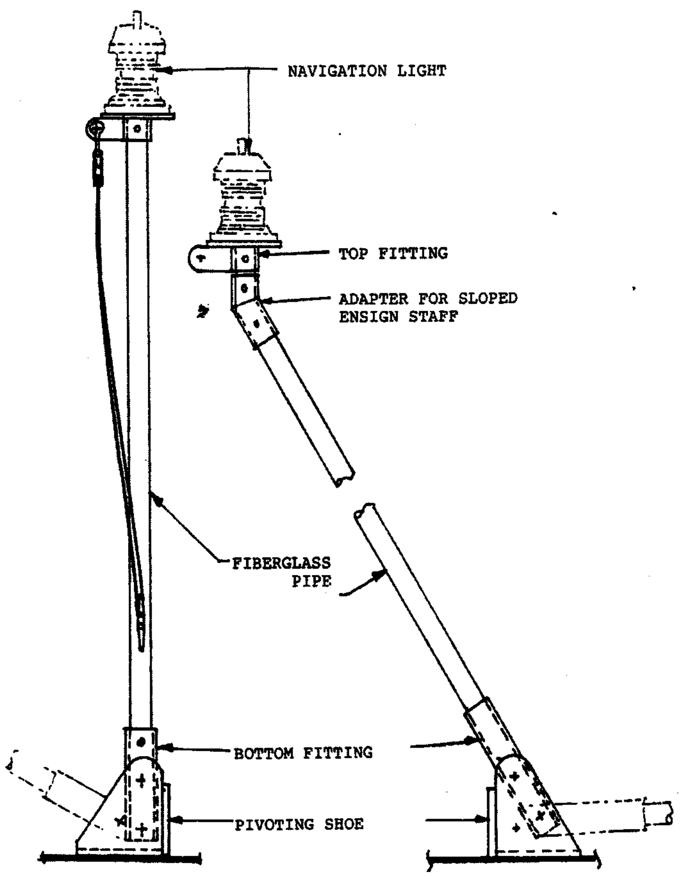


**Figure 14.71** Standard Flag Staffs

- possibility of assembly line techniques for multiple units,
- elimination of transporting many small items to ship,
- simpler material control,
- reduction in material scrap,
- shorter installation time onboard the ship,

Again, standardization is an essential design for production approach, not only for individual items but also for units such as modular toilets, modular furniture, complete cabins, galleys and storerooms.

A number of design for production ideas for hull outfit are (Figure 14.71 through 14.76):

- incorporate foundations for deck machinery into the equipment design and weld direct to the structure,
- use above deck slide or *A frame* anchor davit instead of hawse pipes (Figure 14.76),
- use modular accommodatiOn-umits. If not complete cabin units at least modular toilets, modular furniture and common outfitted joiner bulkheads,
- keep furniture off the deck. Support by joiner bulkheads, as this will eliminate sub-bases and their fitting to the deck,
- use modular galley equipment/walls,
- use carpet over bare steel in cabins,
- use trowelled in place deck covering in passageways, and
- use non-grinding terrazzo in galley and toilets.

Another idea that results in significant work content reduction, is to apply hull insulation to joiner linings and ceil-

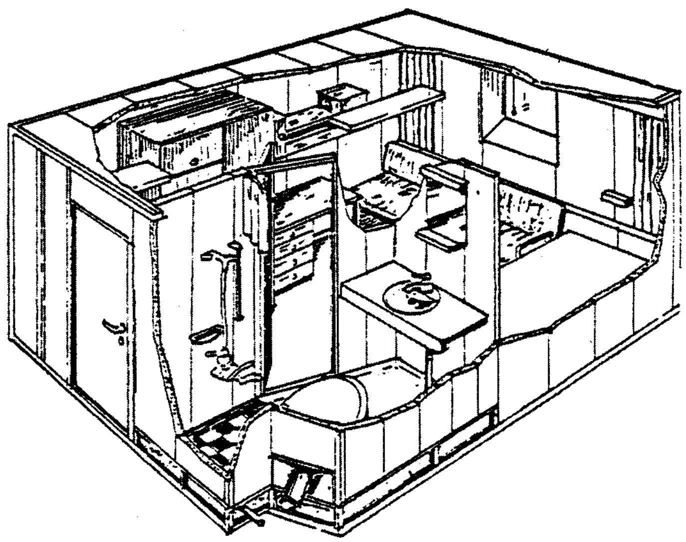

**Figure 14.72** Accommodation Cabin Module

ing instead of the inside surfaces of hull and deckhouse structure. This eliminates work effort for fitting insulation between and around frames and beams as well as cutting flaps for welded supports for vent ducts, piping and wireways. Many of the currently available modular accommodation systems use this approach, but it can be and was used by a shipyard in Sunderland, England in 1964 for traditional joiner lining and ceiling installations. As previously mentioned in discussing arrangements, service spaces should be provided adjacent to each toilet, laundry and other service locker, which can be accessed by easy removal of joiner lining/bulkhead panels.

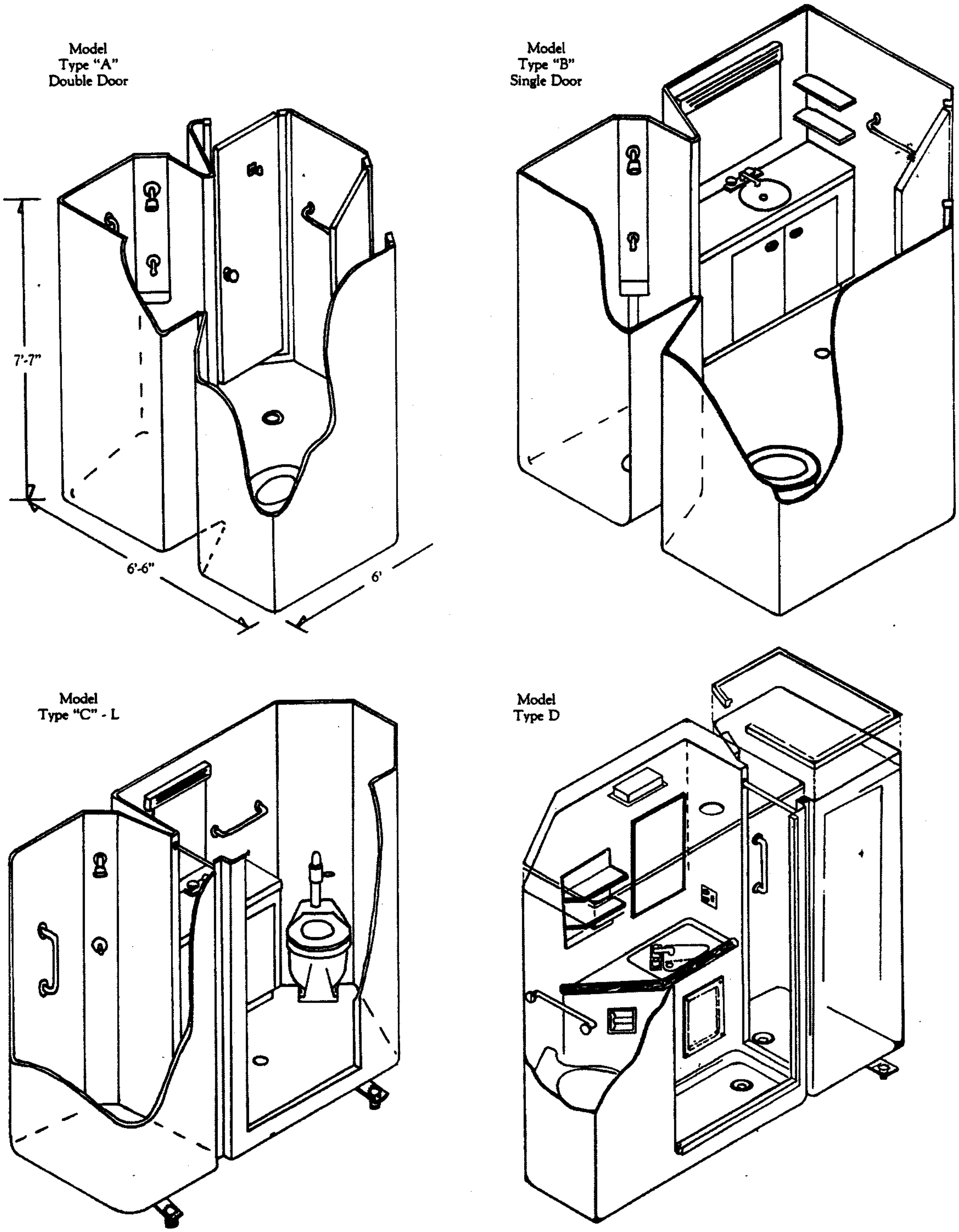


**Figure 14.73** Toilet Modules

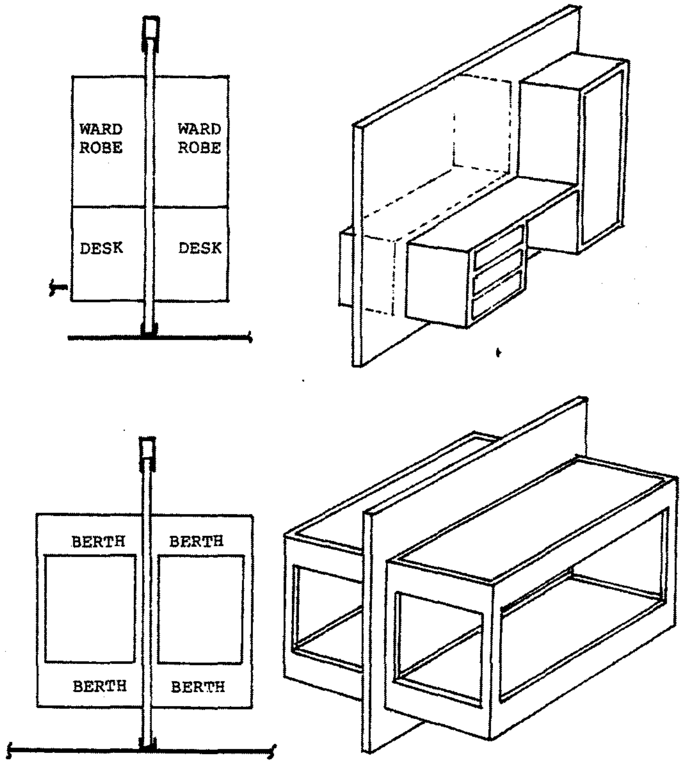


**Figure 14.74** Furniture Bulkheads

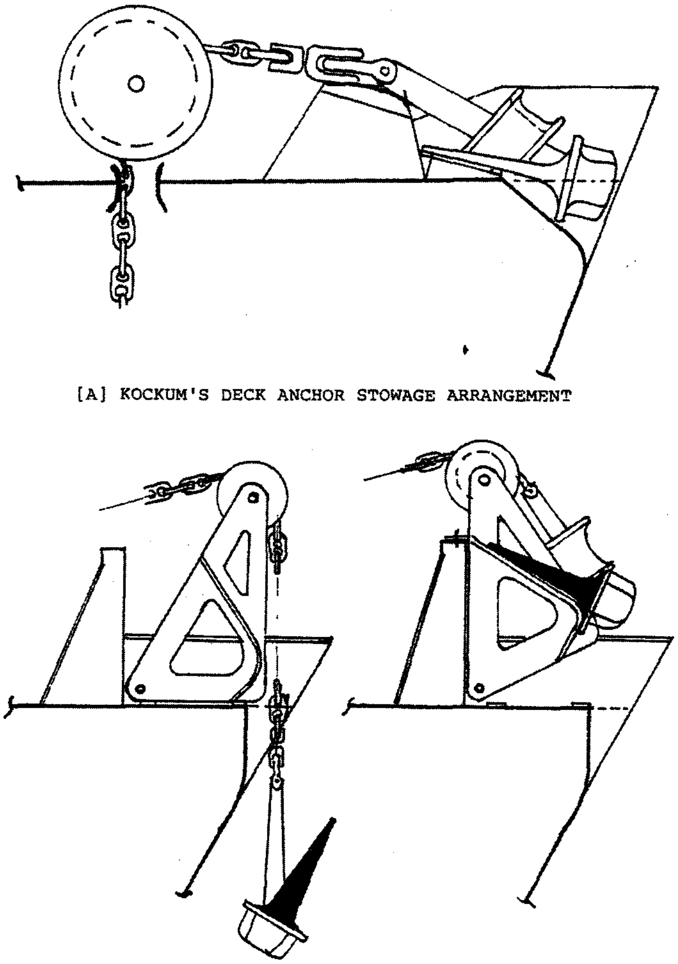


**Figure 14.75** DFP Anchor Stowage

### 14.3.3.4 Machinery

Very few shipyards today design and manufacture the propulsion and auxiliary machinery, which will be installed in the ships that they build. They will probably purchase the machinery from other manufacturers who specialize in the manufacture of the different machinery items. Therefore, the machinery design group is usually responsible for designing an integrated power plant from many *stock* or *standard* items of equipment available from many different suppliers. They may also be responsible for the design of the machinery space ventilation, gratings/floor plates and ladders.

The design of the machinery installation can significantly assist the ultimate goal of improved productivity by standardization. For example, foundations for propulsion and auxiliary machinery could be standardized for the equipment and different ship structural arrangements designed to suit the standard foundations. Some years ago, Det Norske Veritas attempted to standardize the arrangement of machinery spaces for different ship types. The idea was that all equipment associated with a given function or system should be grouped together and located in the same area for similar ship types. The idea is still a good one as it allows the familiarization of both shipbuilders and ship crews of similar machinery plants for different ships. By utilizing such an approach and assigning vertical and horizontal system routing corridors for the different systems, such as piping, ventilation and electrical wireways, the task of other engineering groups and production can be significantly simplified and reduced. Again, standardizing the system routing corridors can save considerable engineering and production man-hours.

Assembly and block breaks must be carefully developed between the machinery and hull groups to ensure that no major equipment or their foundations extend over the breaks as this will prevent installation of the equipment into the blocks before erection and joining.

***Machinery Arrangement*** Even with the recent trend to unattended engine rooms and complete automation, ship machinery plants will still have maintenance and overhaul work performed on it regularly throughout its life. While machinery manufacturers have applied much thought during design, for easy maintenance of their equipment, it often

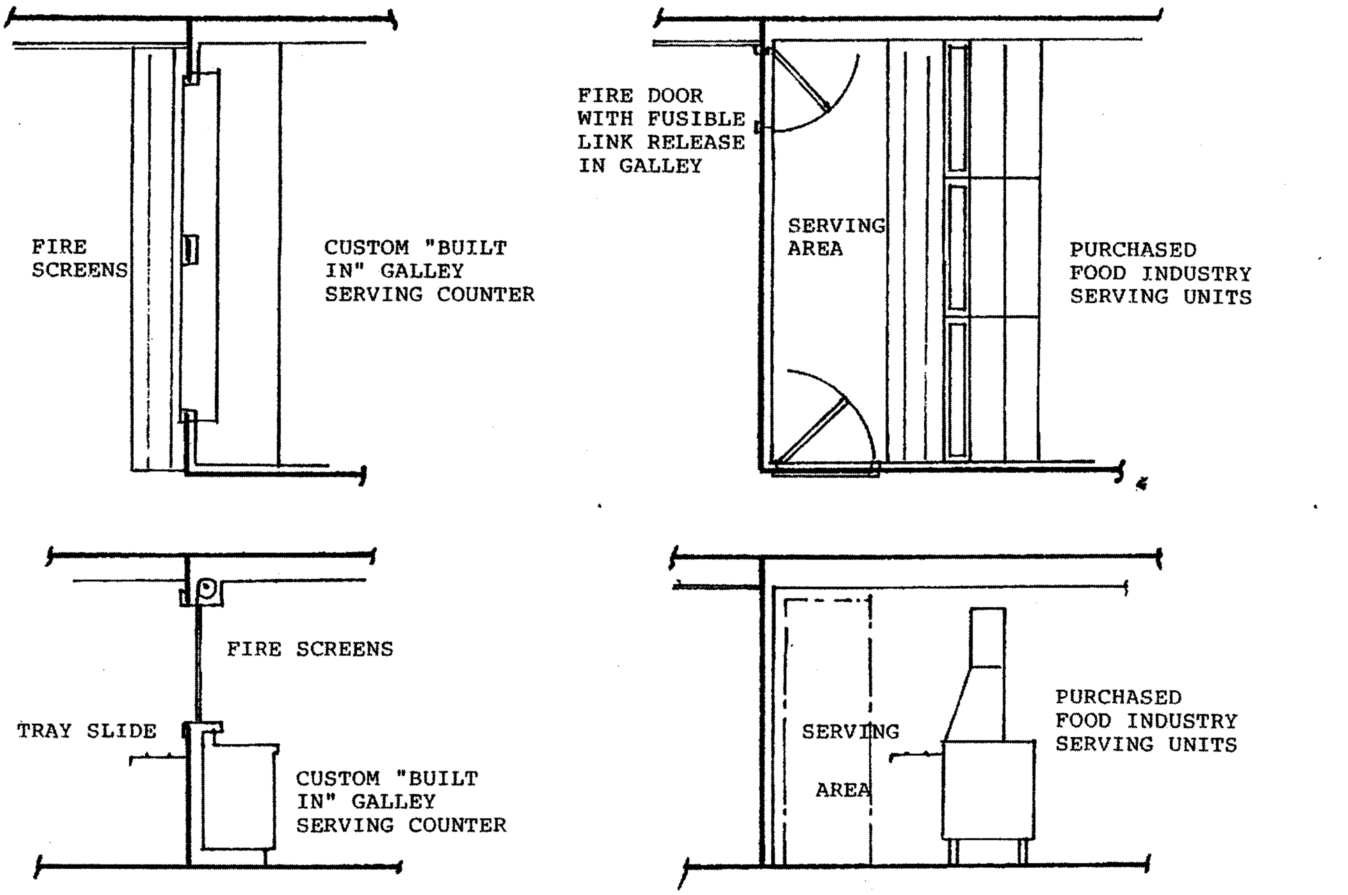


**Figure 14.76** Galley Arrangement Concept

seems that little thought is given by the ship designer in the arranging of the machinery. The recent introduction and application of Human Factors Engineering if applied correctly should change this. During Contract Design, efficient transport routes for spare parts and tools must be developed along with good working space for required equipment withdrawal and maintenance, lifting capability, stores and spares locations, etc. Floor plate level and the level of the machinery space flat/s should be determined to be the most efficient for maintenance work, without compromising normal operational requirements. The arrangement of machinery, equipment and systems should be designed for easy cleaning. With reduced engine room crews, less time is available for this function, which is normally very difficult due to the dirt which accumulates when fuel, oil and water mix. Proper design of drip trays under equipment and of draining and collection system for same can assist in accomplishing this goal.

The lifting and transportation of equipment and spare parts should be considered for all machinery and large equipment, not just the propulsion engine and gear. The manual chain hoist is still needed in most machinery spaces of cur-

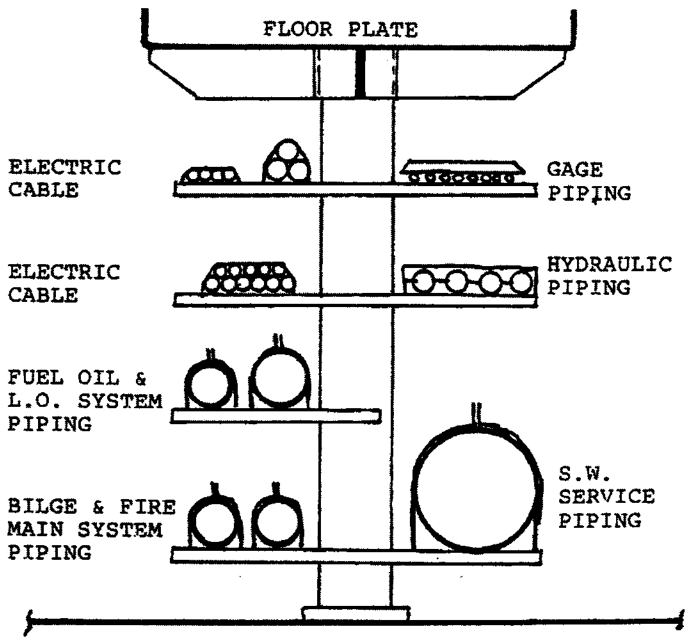


**Figure 14.77** Integrated Support Concepts

rent ships. With small engine room crews this is no longer acceptable.

The location of spare parts should be an integrated part of the machinery arrangement design process and not simply left to whatever space can be found when the ship is nearing completion. When designing the supporting distribution systems, a balance must be maintained between minimum equipment and multiple uses and the design, which would be best for operations and maintainability. Design for production should not be applied to the detriment of design for efficient operation and maintenance.

The machinery arrangement development obviously must take into account whether or not advanced outfitting is to be utilized. The equipment association list, the network and the final diagrammatic are the basis for the design of an advanced outfitting machinery unit. The arrangement of the equipment and the overall dimensions of the unit will be affected by the space available in the machinery space and the other equipment or units therein. It is, therefore, normal for the design of the unit and the arranging of the machinery space to be performed concurrently. Units should be arranged with the following points in mind:

- identical units for identical major equipment should be located identically (True Modularity),
- units should be located with both the major equipment and the system storage tanks in mind so as to provide both the best operational and least cost arrangement,
- completely forget the traditional concept of mounting equipment on bulkheads, unless all the unit equipment will be installed as a unit onto the bulkhead. The design of a unit must be developed from the concept of support from only one plane. Occasional braces can be allowed for high small plan area units,

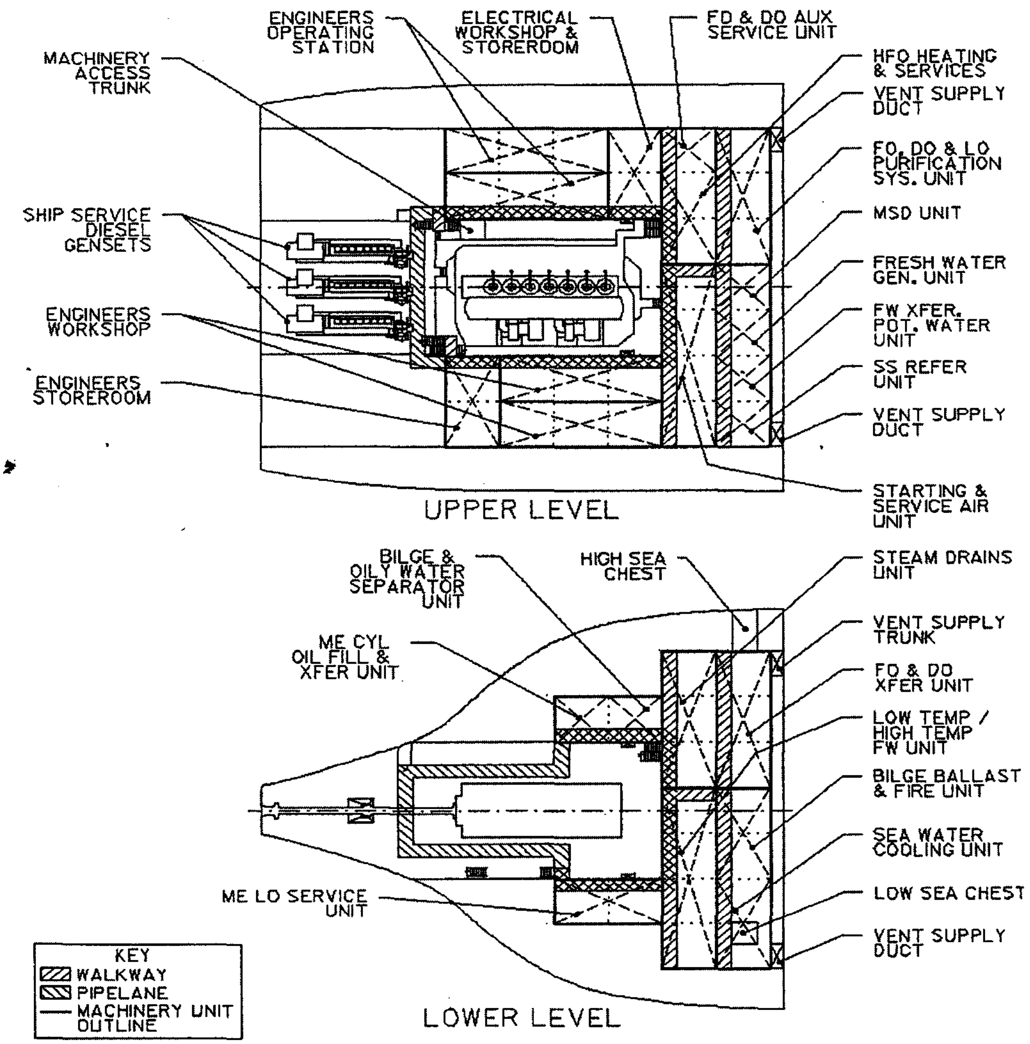


**Figure 14:78** Space Allocation