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by

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I. INTRODUCTION

It is difficult to give a clear definition of "super-large tanker." However, we can point out some notable features that can be found only in the construction of tankers larger than 100 or 120 thousand DWT. There is no great difference in structure between "super-large" tankers and smaller ones, as can be seen between tankers and general cargo ships. But the proportion of steel among different parts of the structure experienced a considerable change as tankers attained a large size, and this disturbed a balance among different production lines. Enlarged parts and structures also caused serious problems in production facilities, construction practices and safety.

To construct super-large tankers, we had to replace many small building berths by one building dock and switch from constructing many ships simultaneously in a long period to constructing one or two in a short period. Thus we have developed practices such as short-period-building method, general assembly method, and pre-erection method.

Those problems and solutions, however, may not be applicable to new yards, but proper only for existing yards such as Nagasaki, where we modified old facilities instead of constructing an entirely new yard for large vessels.*

II. HULL NET STEEL WEIGHT RATIO

The hull net steel weight (HNSW) ratio among different structures of large tankers is quite different from that of smaller ones. This difference disturbs a balance in production flow and brings about bottle necks in areas, facilities, and job shops.

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*Editor's note: Mitsubishi is now building a new shipyard in Nagasaki a few miles away from the old yard.

1. HNSW ratio of frames and longitudinals

Fig. 1 shows the HNSW ratio of frames and longitudinals of tank part blocks. The ratio increases almost linearly with ship size.

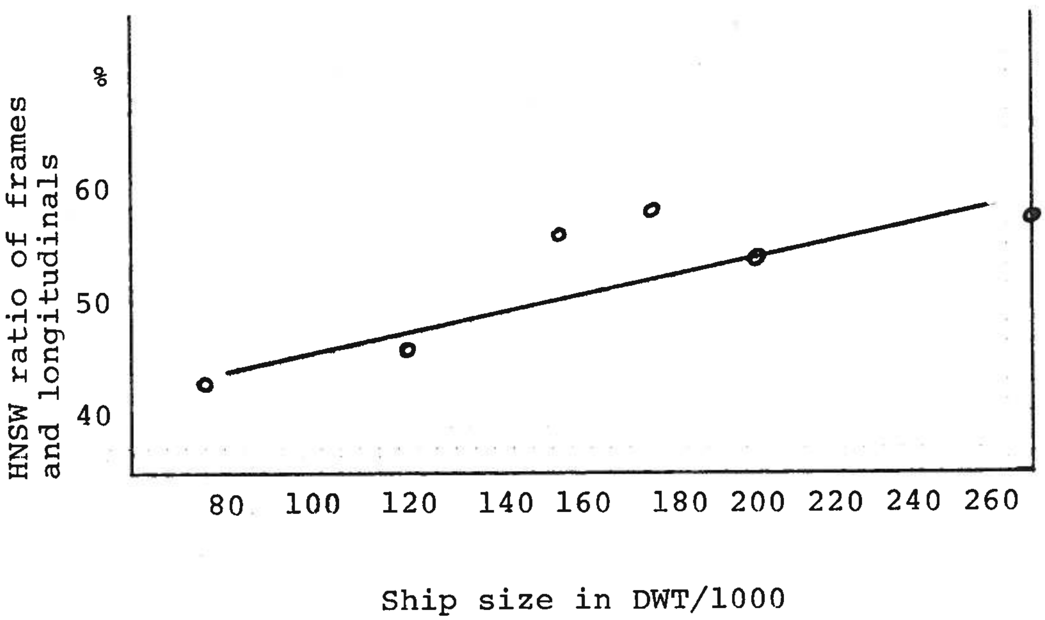


Figure 1

2. HNSW ratio among tank part, fore and aft part, and superstructure

Figure 2 shows the ratio among those structures. The increasing tendency of tank part HNSW is quite natural. The ratio of fore and aft part stays rather constant for the vessels larger than 120,000DWT. The effect of size is most remarkable on superstructure. Yards that have a specialized assembly area for superstructures may have scheduling problems.

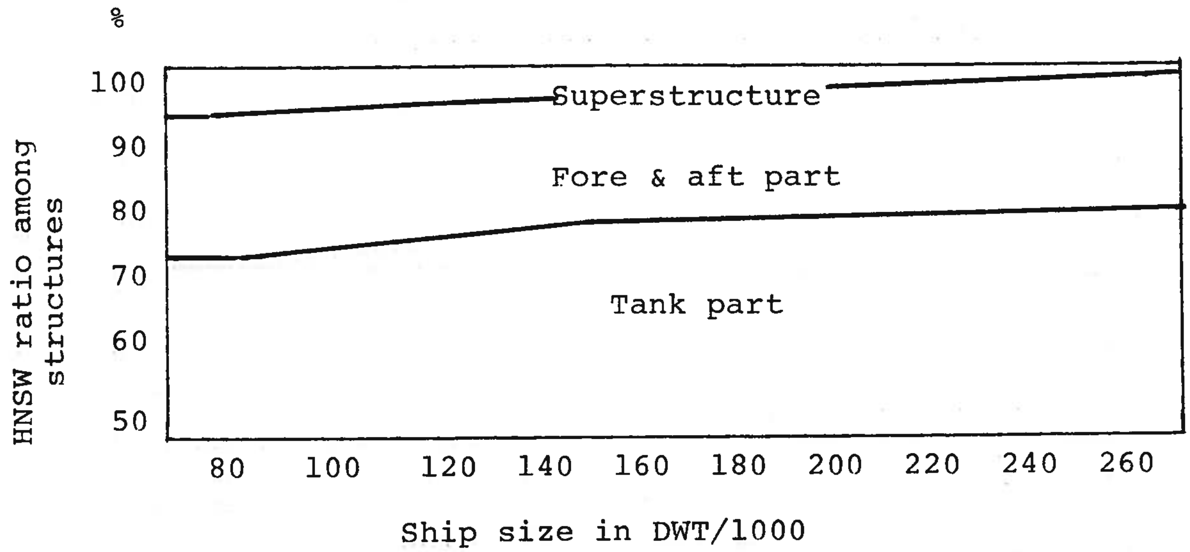


Figure 2

III. PROBLEMS IN PRODUCTION STAGES

1. Fabrication stage

Figure 3 shows the ratio among 4 jobs in fabrication stage, i.e., gas cutting, material handling, marking and bending. The importance of gas cutting increases with ship size, while the importance of marking and bending decreases.

Generally, the size of plates increases as the structural members become larger. In the case of Nagasaki, however, old facilities such as the shot blaster, straightening roller, E P M system, and gas cutting conveyors set strict limitations on the size of plates that can be processed.

These limitations have a great influence on gas cutting and sub-assembly to increase the amount of those jobs.

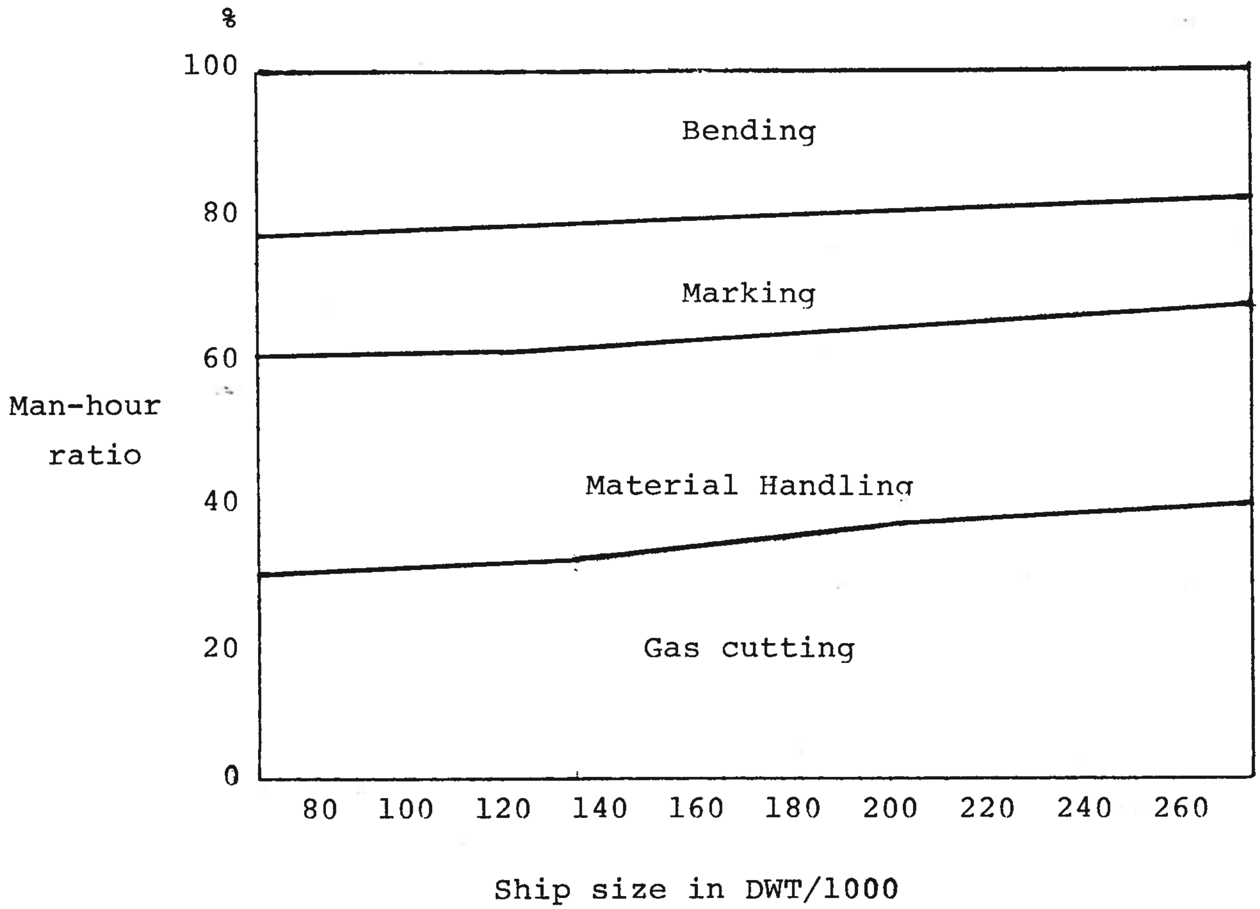


Figure 3

In gas cutting process, about 60% of all the plates are gas-cut on conveyors after E P M marking. Between E P M and gas cutting, there is a buffer area with the capacity of 100 plates. This buffer area enables workers to work without idle time in spite of such disturbing factors as the randomness of cutting time and plates that bypass cutting conveyors because of the limitations on plate width and weight. The adoption of U-shape, X-shape or J-shape grooves, because of the increase in plate thickness, also has unfavorable influence on cutting speed. The cutting process still has many problem areas, i.e., stuck cutting, improvement of gas cutting techniques, automatic cutting by N/C and so on. The face plates of transverse webs had a startling increase in thickness and width. For example, our 300 thousand tonner has a face plate as thick as 35 m/m (1.375 in.) and as wide as 1075 m/m (42 in.). It was too big for our ordinary presses, and only our bending roller was suitable for it. Sub-assembly of curved longitudinals is also a problem. Longitudinal frames of large tankers have become too big to be bent after being assembled into T-shape. Bending webs before assembly or cutting curved webs is the solution.

2. Shot blasting and primer coating

1) Shot blasting

The owners of super-large tankers often want their cargo oil tanks to be coated. The quality of surface preparation required for shot blasting has increased remarkably. The following are very important:

a) Removal of grease from the surface before shot blasting.
b) Selection of abrasives and their operating mix.
c) Control of projection.
d) Removal of abrasives.

Ordinary visual inspection is not enough. Sometimes we had to reduce the processing speed from 6 m/min. to 2 or 3 m/min. (23 ft/min. to 6 or 9 ft/min.) or to shot blast the plate twice. In such cases, the shot blasting machine became a bottle neck.

2) Primer coating

We had much more trouble with zinc silicate primer or zinc epoxy primer than with ordinary wash primer.

Zinc epoxy primer can be sprayed by the conventional airless sprayer, but zinc silicate primer chokes the nozzle with sediment. We solved the problem by developing air spraying apparatus with circulating unit and a nozzle washer as shown in Figure 4. It is difficult, however, to select a proper nozzle and spraying speed to get the proper film thickness at the given speed of the conveyor. When we use this apparatus, primer consumption is approximately 10% higher than that of manual coating.

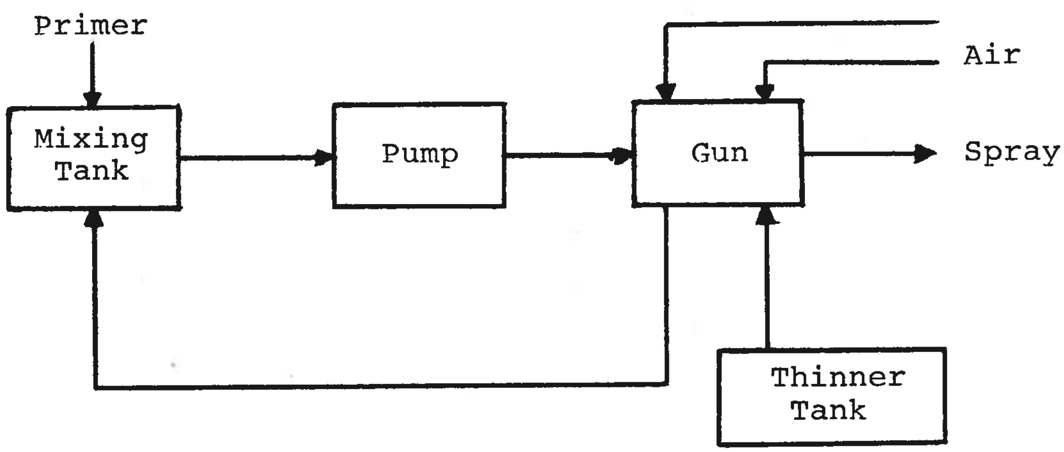


Figure 4

3) The effect of primer

Zinc-rich primer has unfavorable effect on one-side automatic welding and we had to cover the edge of the plate not to be coated. The harmful fumes in gas cutting and welding of zinc-rich primer coated plate is another trouble.

4) Problems of coating

Coating has many problems as shown below in both block coating and in-tank coating processes.

a) Block coating
   - Surface preparation before coating
   - Touch-up
   - Inspection
   - Intervals between coatings
   - Sheltering for blocks
   - Pin hole control
   - Film thickness control
   - Protection of coating
   - Setting and removal of scaffoldings for coating
   - Illumination, ventilation and control of temperature
   - Repair work and outfitting after coating

b) In-tank coating
   - Relation to airtest
   - Removal of scaffoldings
   - Fitting of steps, handrails and other pieces

3. Sub-assembly stage

The weight of sub-assembly work increases in the construction of large tankers as shown in Figure 5 and 6. Length of welded joints in sub-assemblies surpasses that of assemblies in tankers over 300,000 DWT.

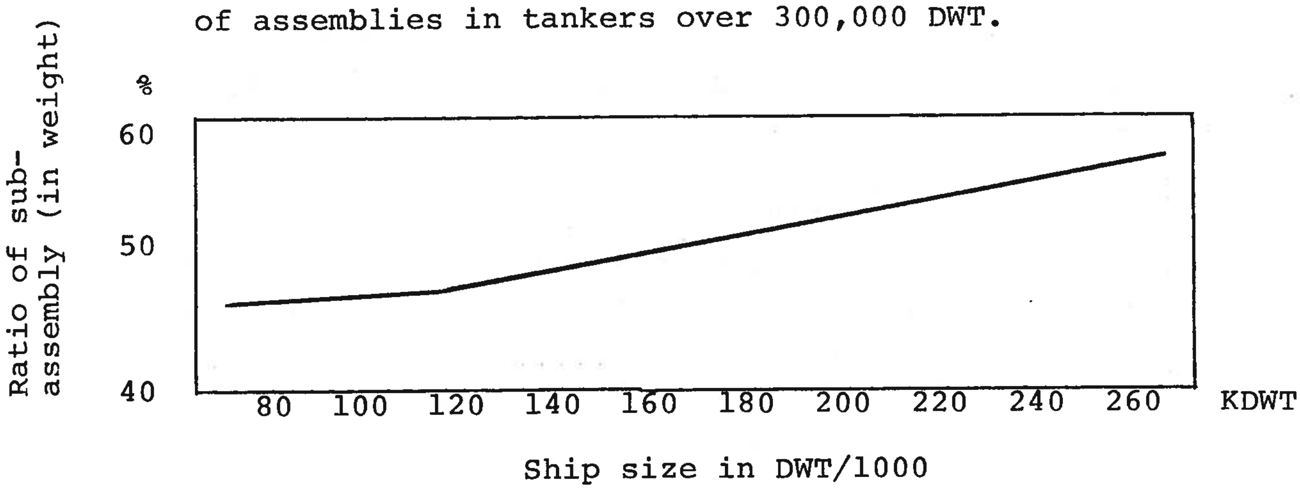


Figure 5

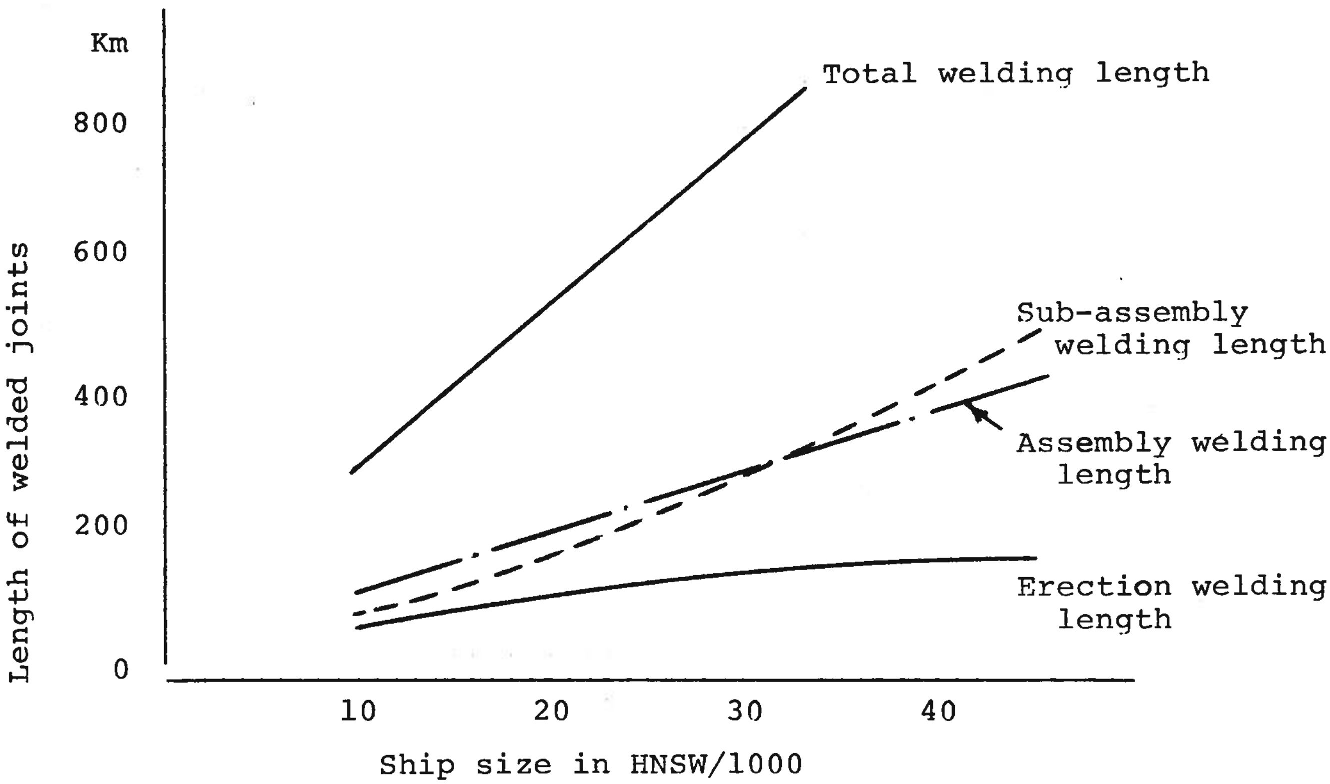


Figure 6

Enlarged sub-assembly parts bring about the following problems.

1) Increase of butt joints in web frames

This made it necessary to introduce "division of work" to sub-assembly stage, i.e., a specialization area for butt joint welding. And this promoted the introduction of automatic welding into the sub-assembly stage.

2) Increase of stiffeners

The number of stiffeners and the connection between stiffeners increases rapidly with the web frame size. This brings about a bottle neck in the sub-assembly stage because of the increase in vertical welding. Fitting stiffeners to both sides of the web frame is a partial solution of the problem. The average weight of stiffeners of web frames also increases with the web frame size as shown in Figure 7. The maximum weight of parts that can be handled manually is about 30 kg. (66 lbs). In the construction of super-large tankers, most stiffeners are too heavy to be handled manually. They need cranes or some other facilities.

Those sub-assembly problems mentioned above caused many troubles in facilities, e.g., lack of sub-assembly area, stock area, crane capacity, strength of jigs and so on.

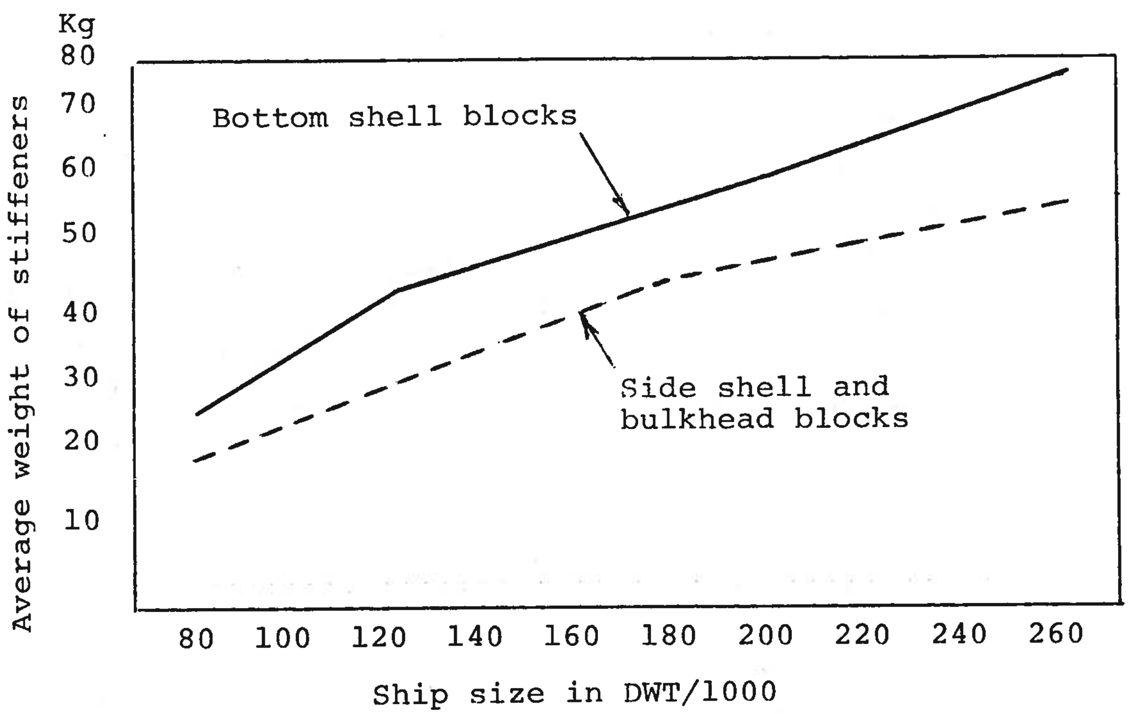


Figure 7

4. Assembly stage

1) Frame block

We assemble a flat panel block by getting a frame block and a panel together. And the frame block weight increases remarkably with ship size as shown in table 1.

DWT/1000 / Wt of frame block	80	120	175	200
30 T & above	0%	11%	74%	80%
Below 30 T	100%	89%	26%	20%

Table 1

The ratio of frame block weight to the total block weight is as much as 60% for super-large tankers, while in case of 100,000 DWT tankers, the ratio is 45%. The use of high tensile steel as "skin" plate develops this tendency. The unfavorable effect of increased weight of frame blocks is the lack of crane capacity in the frame block assembly yard. The limitation of crane capacity becomes more severe when we install cargo oil pipes in frame blocks.

2) Flat panel block

Steel plates are welded together into a panel by one-side automatic welding machines. The total length of joint welded since 1963 is over 200 km (120 miles). The performance of this method is improved by using multiple electrodes and improving back bead quality. We made a mistake at first in selecting the disc roller conveyor instead of the cylinder roller conveyor for panels. The disc roller conveyor damaged panels because of the heavy weight of blocks.

A frame block and a panel are assembled and welded by the gravity welding method. With the increase of longitudinal frame height in large tankers, the performance of gravity welding per worker decreases. The frame block method has the disadvantage of difficulty in balancing panel line and frame block line, and the limitations of gravity welding in performance and leg length, as well as the advantage in securing block form accuracy.

3) Curved shell block

Curved shell blocks of fore and aft parts are assembled into a larger block, which we call "general assembly block," from 200 up to 600 tons in weight. The size or weight of each curved block, therefore, does not necessarily increase with ship size. However, the increase of frame size sometimes made it difficult to set frames on shell because of the lack of crane lift. Also we had to reinforce the supporting jigs for curved plates because of the increase in block weight per block area.

When the vessel has twin screws and twin rudders, which ordinary size tankers seldom have, the structure of aft part becomes very complicated, using parts up to 60 m/m (2.4 in.) in thickness, with many narrow spaces.

5. General assembly stage

1) Meaning of general assembly

How to divide the whole ship into blocks, what shape of block of what size, through what processes to assemble, presents many interesting problems if we are free from existing facilities. We had almost no choice for this problem. We could only construct new facilities for erection stages, i.e., a building dock, some outdoor area adjacent to it, and cranes for erection. It was impossible to introduce a drastic change into already existing fabrication and assembly stage. We had to build medium size ships and super-large ships simultaneously through the common fabrication and assembly processes. To adopt a super-large block size, therefore, for super-large tankers was impossible. Even if it were possible, to adopt two different block sizes in one assembly stage would not have been an advantage for us from the point of smooth production flow. Thus, we adopted the block size of ordinary ships for super-large tankers and met the following problem.

a) To adopt an ordinary block size increases the amount of work to be done at the erection stage and as a consequence prolongs the construction period.

b) Positioning of overhanging shell blocks at fore and aft part has a difficult problem from point of safety.

c) The work at an enormous height increases with ship size at erection stage. We should notice the psychological effect of height to workers as well as the actual danger.

d) To apply an ordinary block size to the engine room, for example, of a super-large tanker means that outfitting of the engine room is to be divided into several blocks and the early-outfitting of the engine room is impeded.

As a solution of those problems, we adopted a general assembly method of assembling ordinary size blocks into a larger block.

2) Application of general assembly method

The area to be reserved as the general assembly yard is limited. We formulated some rules on what blocks the priority of general assembly should be given. The blocks that are to be assembled into general assembly blocks in our yard are as follows:

a) Center tank transverse bulkhead

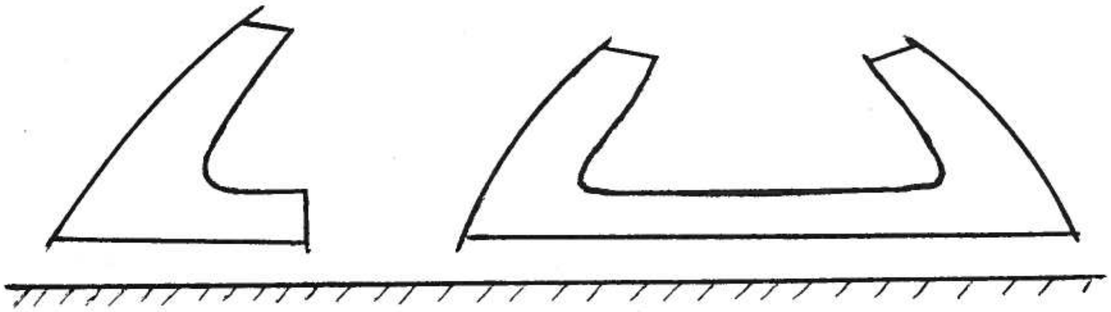
General assembly of center tank transverse bulkheads helps the fast development of blocks after the development of bottom shell blocks. Besides, a lot of construction and outfitting work at a height in the erection stage is shifted to the ground by this general assembly of the bulkheads. General assembly of longitudinal bulkheads has the same advantage as that of center tank transverse bulkheads. But the longitudinal bulkhead blocks are too many to supply to erection for a limited area of general assembly yard.

b) Upper deck of center tank

General assembly of center upper deck blocks which spread over from longitudinal bulkheads to longitudinal bulkheads is indispensable for a center-girder-less ship.

c) Curved shell blocks of fore and aft part

A general assembly block of curved shell is a combination of shell and deck as shown in Figure 8.



General assembly of this part is desirable from the point of safety, shortening construction period, and early outfitting.

Figure 8

d) Pump-room bottom shell and engine-room double bottom

The main purpose of this general assembly is to carry out early outfitting to those blocks as much as possible, i.e., as much as the crane capacity and general assembly period allow. Figure 9 shows the examples of those general-assembled blocks.

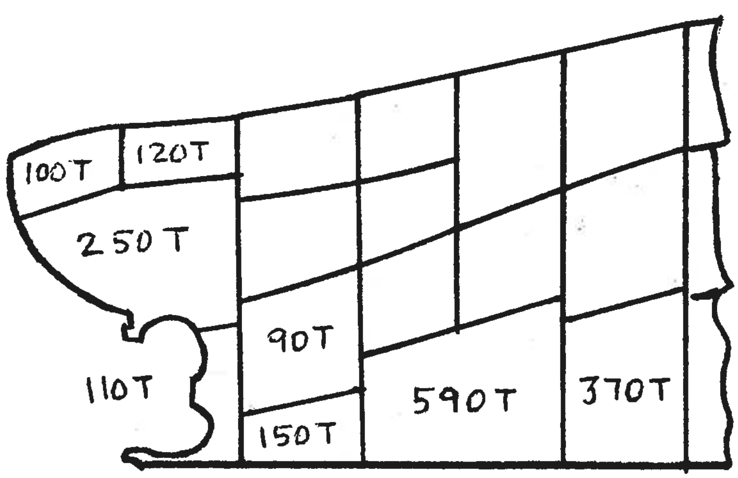


Figure 9

e) Superstructure

The main purpose of this general assembly is also early outfitting. The whole superstructure is assembled into one general assembly block. It is divided into two only when the strength is not enough for lifting in erection.

3) Problems in general assembly yard

One of the problems is the man-hours spent for preparing supporting jigs of general assembly block. Those jigs need to be accurate, strong, and sometimes very high. One of the solutions is the specialization of a general assembly area to assemble the same type of blocks by the fixed jigs. But the area of our general assembly yard is so limited that we have to use one area for different kinds of blocks,removing old jigs to prepare new ones. Another problem not to be neglected is the man-hours spent for fitting and welding lifting lugs. As the block size increases by general assembly, the number and size of lifting lugs increase, and as a consequence, man-hours necessary for fitting and welding lugs to blocks and reinforcement of blocks themselves increase unexpectedly. The large size of general assembly block compared to the capacity of general assembly yard makes it difficult to smooth the load for general assembly stage and so avoid idle time.

Many of those problems mentioned above come from the limited area of general assembly yard, which is peculiar to Nagasaki shipyard. Our solution, though it is not altogether satisfactory, is as follows. Such general assembly blocks as engine room doublebottom block, pump room bottom block, and superstructure, which need long general assembly period, are assembled in a place which is not an ordinary general assembly yard, a place which the erection cranes do not cover. After it is completed as a general assembly block, and outfitting is carried out, it is shifted to within reach of the erection cranes, and then lifted and erected. By doing this, i.e., separating long period blocks from short period blocks, we can give sufficiently early outfitting periods to those blocks. The presence of such long period blocks is very advantageous for smoothing the load in the general assembly stage.

4) Handling of general assembly blocks

a) Weight of tools for handling

As the weight of blocks to be lifted increases, the weight of lifting tools such as lifting lugs, shackles and wire ropes also increases remarkably. When the weight of those tools is too heavy to be handled manually, we have to take a certain countermeasure. For example, as shown below in Figure 10 and Figure 11, we use a pin with double-plate-lug instead of a shackle with single-plate-lug when the load to lug exceeds 40 T. The weight of a shackle for 40 T is 87 Kg, which is too heavy to be handled even by two men. But the weight of a pin shown in Figure 11 for the same load is only 25 Kg.* Table 2 shows the weight of tools for lifting blocks. The heavy weight of such tools makes it a difficult and dangerous job to handle them at a height.

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*87 Kg = 192 lbs
25 Kg = 55 lbs

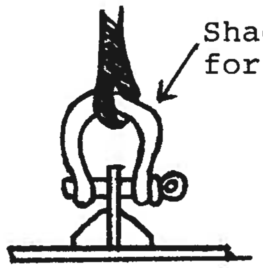

Figure 10

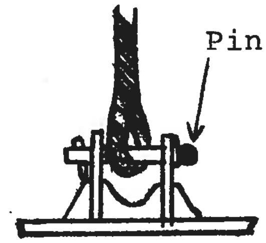

Figure 11

Tool			
Shackle	for 35 T	71 kg	156 lbs
	" 40 "	87 Kg	191 lbs
Pin	" 40 "	25 Kg	55 lbs
	" 80 "	71 Kg	156 lbs
Lifting lug	" 35 "	50 Kg	110 lbs
	" 80 "	130 Kg	286 lbs
Wire rope	" 40 "	14 Kg/M	9 lb/ft

Table 2

b) Reinforcement of blocks

When the load for a lifting lug of a block exceeds a certain limit, the reinforcement of structure around the lug is necessary. Such consideration is not necessary for ordinary size blocks. But in the case of general assembly blocks, the reinforcement is important. Figure 12 shows an example of reinforcement of a longitudinal block.

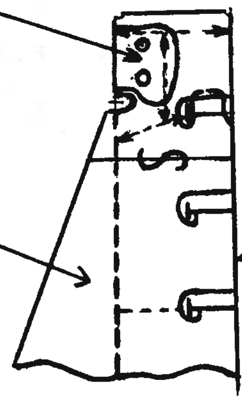

Figure 12

For a general assembly block of superstructure, not only the local strength around lifting lugs but also the total strength of the block is a problem.

c) Turning of blocks

Some general assembly blocks of aft and fore parts are assembled upside down at first, lifted when completed, turned over and then erected. In the process of turning over, the direction of load to the lifting lug varies and sometimes unexpected stress occurs. We should carefully study the stress on the lug and on the structure of the block in such process. A 1/50 or 1/100 scale model of the block is helpful to study the direction of load to lugs and the behavior of wire ropes in the process of turning over.

d) Erection of blocks

The more weight and size a block attains, the more accuracy is needed in the estimation of weight and center of gravity of the block. When the lifting lugs are located at the wrong places because of a wrong estimate, unexpected load on the lugs or wrong orientation of the block might result. And it takes a long time to erect a block that is hanging in a misaligned orientation.