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Development of the Automated Shipyard

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Development of the automated shipyard

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Modernization of shipbuilding helps supply less expensive and better ships, stabilize ocean freight and achieve smoother distribution of goods all over the world. Therefore modernization of the industry contributes to the steady growth of world economy. Among various aspects of modernization, the enhancement of employees' morale and preparation of favourable environment for them are particularly stressed. Steps for modernization so far taken by the Japanese shipbuilding industry are described, followed by a forecast of the development of various aspects of technology to be achieved by Japanese shipbuilders in the first half of the seventies. As shipyard layout and hull construction methods are closely related with automation and mechanization, the prevailing concepts of large shipyards in Japan are examined, and on that basis a suggestion is made with regard to a concept of shipyards in the 1980s.

1. Significance of the modernization of shipbuilding

In business enterprises of today, modernization serves as a powerful prime mover to the enhancement of productivity and competitiveness. Therefore the method of modernization is of utmost importance to each enterprise, and the plan for modernization is kept a top secret. For this reason, generally speaking, it is quite rare that each enterprise organization is uniformly modernized and having the same level of technology. Although Japanese shipbuilders are as keenly competitive with one another as in other industries in order to place themselves in a dominant position over others, they are less secretive about their modernization programme than other industries and exchange new techniques among themselves which eventually resulted in mutual improvement in productivity as well as reduction in costs. This friendly practice is a unique tradition of the Japanese shipbuilding industry, and is envied by other industries.

Meanwhile, ocean freight rates, though they fluctuate now and then in accordance with the demand and supply of ships and with the current international political or economic situation, are closely related with the shipbuilding costs in the long run. Modernization of the shipbuilding industry will therefore make it possible to supply the most economical and highest quality vessels, which will in turn help stabilize ocean freight and thereby contribute to the smoother distribution of goods throughout the world and to the steady growth of world economy. Herein lies the significance of modernization of shipbuilding.

2. Main features of the modernization of shipbuilding

The shipbuilding industry is facing many problems including the demand for ever increasing size of vessel and for various special-purpose ships which have to be newly developed, as well as problems on the shortage of manpower and the changing international monetary situation. The circumstances surrounding the industry are likely to continue to change in many ways in the future. In order to survive these difficulties, shipbuilders need sufficient management ability to give full play to their overall capabilities under a well established policy while keeping abreast of the international market trend. Major features of such management ability include:

(*a*) Securing capable employees…(fostering willingness to work, keeping good relations with unions).

(*b*) Advanced technology...(capability of developing new techniques).

(*c*) Outstanding ability to sell and control...(systematization of sales, purchasing and accounting).

(*d*) Remarkable capability of production control...(establishment of productive techniques and process control).

(*e*) Up-to-date facilities...(profitable automation and mechanization).

(*f*) High efficiency...(larger construction capacity).

(*g*) Excellent quality...(high quality control).

(*h*) Cooperation of related industries having high technical standards...(technical guidance, training and cooperation).

The most important among the above-mentioned factors is the morale of employees. Unless workers' morale is sufficiently high, high-quality and less expensive ships can never be built.

In managing a shipyard, therefore, it is vitally important to exert every effort to enhance the morale of its employees.

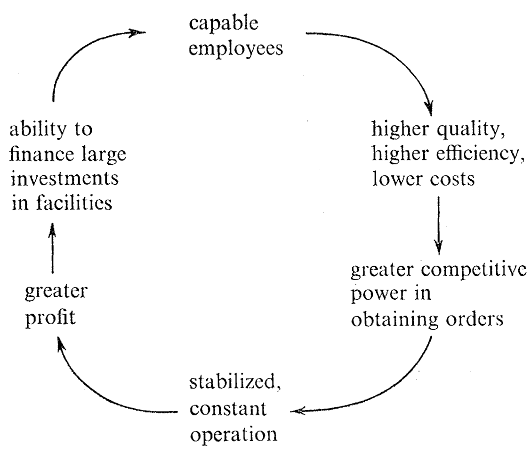
To achieve this purpose, it is necessary to make the shipyard an attractive environment in which they find it pleasant to work. Vital factors to such an environment are:

(*a*) stabilized operation – securing sufficient orders to avoid slowing down production;

(*b*) good human relations and safety of work – establishing favourable working environment;

(*c*) high wages – improving the standard of living.

By satisfying all these requirements, a shipyard, supported by excellent management, techniques and facilities, can be highly competitive and progressive.



3. History of the modernization of the shipbuilding industry in Japan

The shipbuilding industry developed ahead of other industries in Japan thanks to the technology imported from western Europe, particularly the United Kingdom. However, when World War II ended leaving the country in a devastated condition, Japan's shipbuilding industry had only obsolete facilities and found itself considerably behind west European shipyards both in technical standards and in productive capacity. It then began actively to absorb the advanced techniques of western Europe and at the same time to exchange information and techniques among all the interested circles including shipyards, research institutes and the academic societies. Meanwhile each shipbuilding company achieved modernization in the following respects within its own organization:

(i) *Improvement of production and control techniques*

Standardization of designs, construction processes and materials.

Implementation of a computerized system by which the quality and quantity of required materials are obtained at the designing stage and the order and delivery of materials planned accordingly.

Implementation of a computerized system by which the designing and construction processes for production planning are coordinated and the evaluation of results obtained.

(ii) *Research and development in the designing stage*

Development of economical hull forms and of mammoth vessels, research on the reduction of wave making resistance and on the calculation method of three-dimensional strength by a finite element method; development of automated ships, research on steel materials, and development of higher performance and larger output engines.

FISCAL YEAR	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
AMOUNT OF INVESTMENTS (£ MILLION)	24.8	24.2	29.0	43.6	43.8	35.2	51.7	55.5	48.9	61.1
TONNAGE LAUNCHED (10^3 tonnes)	1 799	2 183	2 367	4 085	5 363	6 685	7 497	8 583	9 303	10 476

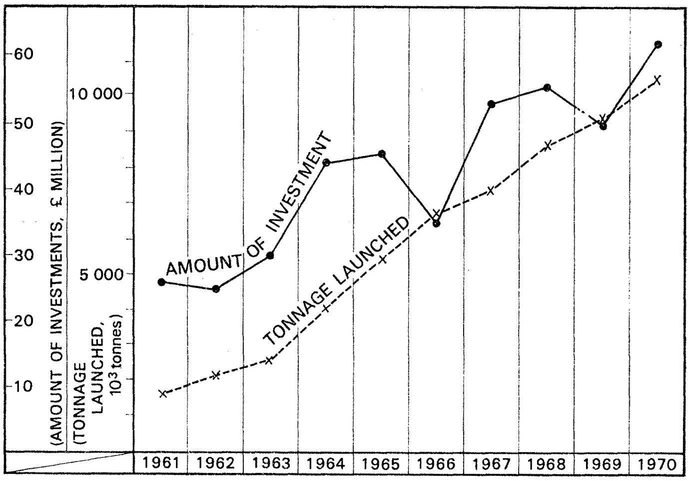


FIGURE 1. Trends in investments made by major Japanese shipbuilders in facilities for the past decade (£1 ≈ 800 yen).

(iii) *Modernization of facilities and construction techniques*

Steel material conveyance system, automatic drafting machines, e.p.m., automatic gas cutters, automatic welders, automatic pipe benders, ball launching system, various hull construction methods, afloat hull joining method, and new installation and/or expansion of conveyance equipment, assembly shops, cranes, building berths, docks, quays and engine shops. The scale of all above mentioned modernization measures is indicated by the enormous investments made by major Japanese shipbuilders in facilities over the past decade, as shown in figure 1.

(iv) *Improvement of working environment*

Bringing assembly work indoors, installation of movable roofs over block assembly shops, safety nets, sunshade tents, improvement of scaffolds, lifts, ventilation, supply of cool air, provision of body protectors, and establishment of safety control system.

(v) *Encouragement of in-service training*

One-year basic and practical training of new employees who completed a course at high school, mutual study in groups concerning the skill and manner and fostering of human relations with senior employees through a 'brother system' in dormitories.

(vi) *Establishment of cooperative relations with related industries*

Through guidance in inherent techniques, control techniques and value analysis, cooperative relations were strengthened with the result that the quality of materials became more uniform and delivery more punctual and reliable. For instance, the number of days in stock on an average has been reduced to 9 for steel and 14 for outfits, respectively. Furthermore, labour to handle materials, the area of stockyards and the interests on the funds to purchase them have all been reduced.

All such efforts on the part of management for modernization, coupled with the close co-operation of employees who are loyal to their companies as well as the management's endeavour to keep good relations with unions, have made it possible for the Japanese shipbuilding industry to achieve the present situation. Moreover, the contributions made by many university graduates who are recruited every year for the planning and implementation of such modernization programmes are particularly noteworthy.

4. Automation and mechanization of Japanese shipyards in the first half of the seventies

The shipbuilding industry is inferior in labour-saving equipment when compared with those of the automotive industry which is another assembly industry. Shipbuilders' investments in automation or mechanization account for only a small proportion of their total investment in facilities, and the objects of automation or mechanization are limited to rather easier aspects of the whole shipbuilding process.

In this respect, the shipbuilding industry of today should still be regarded as a labour-intensive industry. In other words, it also means that the industry leaves much room for automation in the future.

As a matter of fact, automation and mechanization utilizing hydraulic and control techniques have lately made rapid progress in the shipbuilding industry as a way to overcome manpower shortage. Therefore, when these techniques are fully utilized, the industry is expected to gradually change its pattern from labour-intensive to technology-intensive. The following account describes what elements of technology Japan is developing in line with the world-wide trend, as well as how it will develop them in the future.

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(a) *Development of automation and labour saving in each element of technology*

(i) *Automation and labour saving in the designing process*

(a) Technique in basic designing

While various calculations to determine basic performances and counting of costs to meet a specific requirement are already computerized, this process will be perfected to allow a designer, having a dialogue with his character display connected on line to a computer to take all relevant factors into consideration quickly and readily and thereby to workout an optimum design. As regards pudgy hulls, a method of indicating a hull form in numerical equations by which a lines drawing is automatically determined by feeding the computer with the desired deadweight, speed and principal dimensions, is now being developed. This method, when completed will dispense with tank tests except for confirmation of calculated figures. This will drastically reduce the time required for designing until a hull lines drawing is determined. This method may become applicable in future to other hull forms than pudgy hulls.

(b) Methods in detail designing

Various items of information determined in the basic designing stage will be stored in a data base and development into detail design will be carried out easily with the extensive use of aforementioned character display, graphic display and digitizer. As a result, the information which is converted into numerical data, can be directly utilized as on-the-spot input to numerically controlled machines.

(ii) *Automation and mechanization of hull construction*

(a) Fabrication stage

The use of computer-controlled cranes, already applied for steel plate handling, will become applicable to angle bars as well, making unmanned control of steel stockyards possible. This achievement will not only mean labour saving in the handling of steel materials, but also greatly facilitate the control of the ensuing fabrication process. Application of the numerically controlled steel plate gas cutting technique to angle bars is now under development and, when completed, it will drastically change the appearance of angle bar shops. At present sub-assembly is carried out manually on a conveyor, however the work will be done by the use of automated devices. Furthermore, as one of the measures to improve working environment, automatic welding devices in lieu of gravity welding, are under development for the main purpose of removing fumes as well as avoiding tedious jobs.

(b) Assembly of panel blocks

While this process usually takes place in a conveyor system, automation of the alinement and tack-welding for plate assembly is being developed.

Studies are being continued to improve one-side automatic welding of plates, which at present still needs partially subsequent rewelding.

There are two ways to fit and weld frames of hulls, the line welder system and egg box system as illustrated in figure 2.

In both systems, automation of the welding of frame to frame and of frames to plates has already been developed and is awaiting practical application.

To dispense with the collar plates at the slots where transverse and longitudinal members cross, a new method of inserting longitudinals through slits in transverses in an egg box system is now under development. This method will greatly contribute to labour saving.

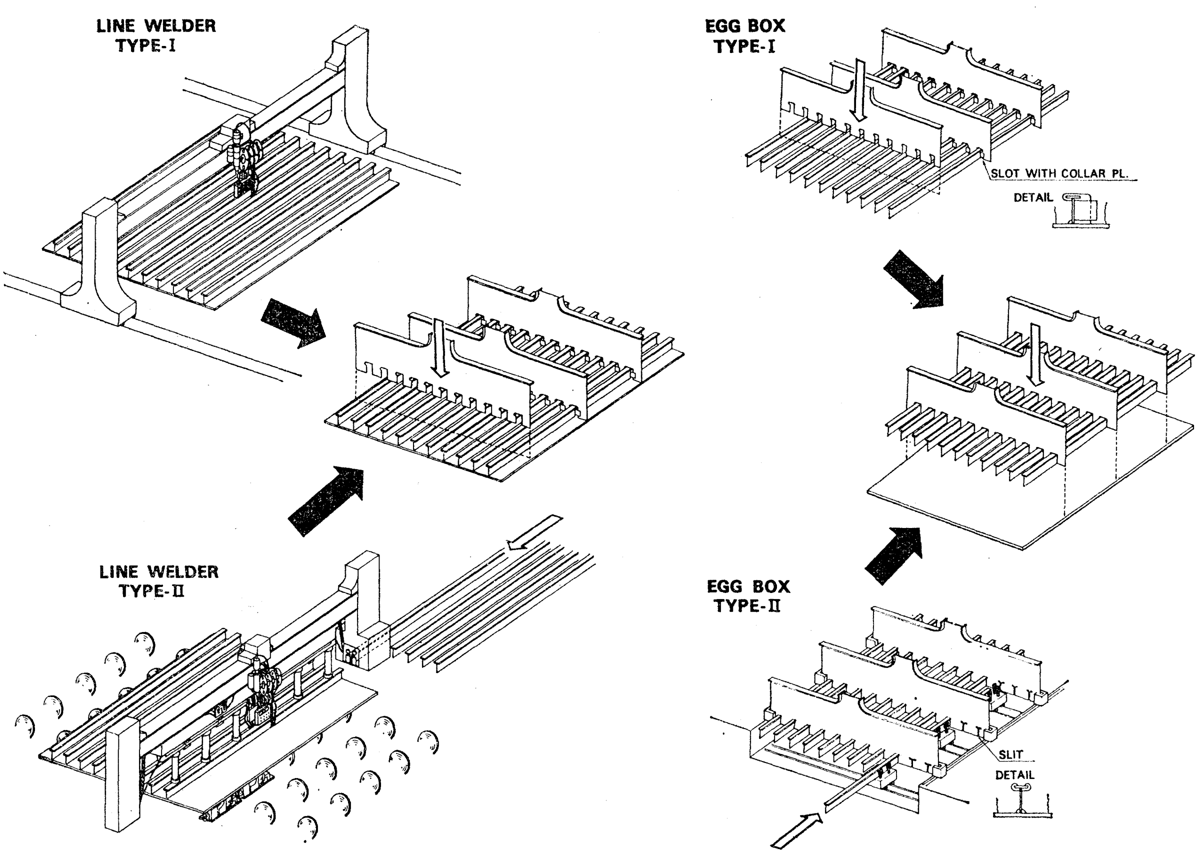

Figure 2. Line welder system and egg box system.

(*c*) Welding for curved block assembly

For automatic welding of curved plates, an automation system with rotating table and supporting jacks as illustrated in figure 3 is being developed, and automatic welding method for vertically inclined parts between frames is also being studied. However, these methods are not so easy as in the case of flat blocks and are likely to face considerable difficulty.

(iii) *Automation and mechanization of outfitting*

(*a*) Pipe shop

While pipes have become the only outfit item to be processed at shipyards, the whole process of straight pipes being taken off the racks, moving on conveyors, being cut into required lengths, fitted with flanges at specified angles and finally welded, is going to be automated. Of pipes to be bent, 60 % of them are fitted with flanges before bending. Large calibre thick pipes are easily bent by high-frequency heating method, and smaller calibre ones by numerically controlled benders. Control of subcontractor's products in warehouses, not standardized in size, is gradually switching to a computerized automatic system.

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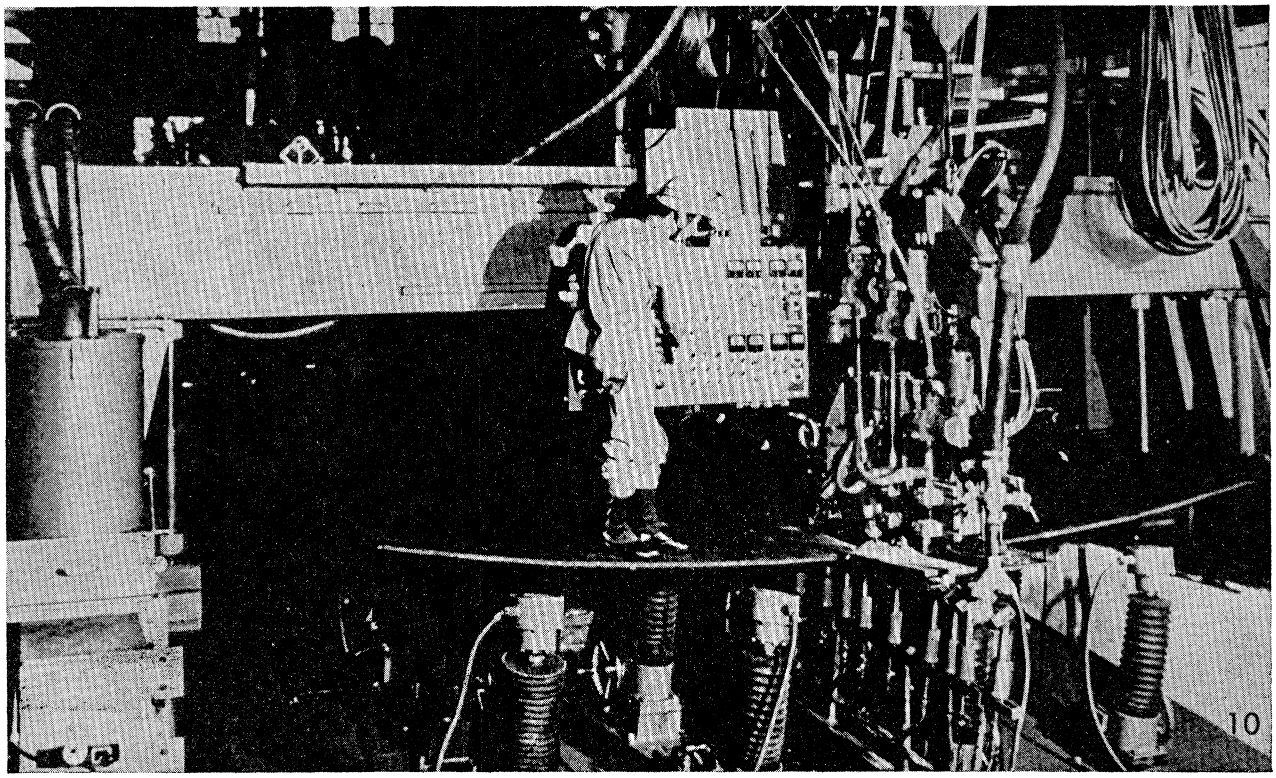

FIGURE 3. Assembling of curved skin plates using automatic rotating table and jacks.

(*b*) Advance outfitting

While advance outfitting is extensively practiced to do away with the inefficiency of on-the-spot work which still occupies a major part of outfitting operation, further improvement of efficiency is sought through unit and package assemblies. More recently, unit assembly of fuel burning system of boilers and the oil purifier plant systems is undertaken at subcontractors' factories. Mounting of the engine room deck after all outfits have been installed on it, is also being attempted.

(*c*) Superstructures

Although the traditional practice was for hull department workers to assemble superstructure bodies and for outfitting workers to furnish their interiors, the latter have come to be held responsible for the whole superstructure work.

While the module method of walls is coming into general practice, module method of unit rooms is also being developed. More extensive module method combining both these systems is likely in the future.

(iv) *Welding*

Submerged welding, gravity welding, carbon dioxide welding, non-gas welding and consumable electro slag welding (c.e.s.) are already in practical use. Recently, various developments, namely, improved versions of consumable electro slag welding, various oscillation welding method, magnet tracing method and contact bar submerged arc welding have made rapid progress, making it possible to automate nearly all the welding work in the holds. Examples are shown in figures 4, 5 and 6.

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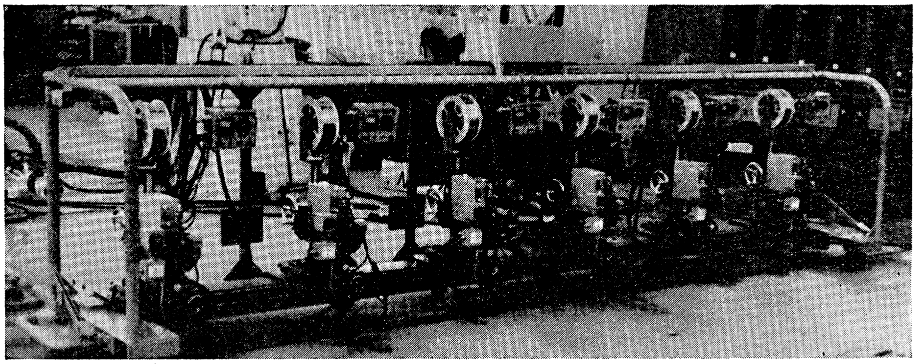

Figure 4. Deck longitudinal welding using multi c.e.s. welding (showing the welding equipment placed on upper deck, welding simultaneously several deck longitudinals under upper deck plate).

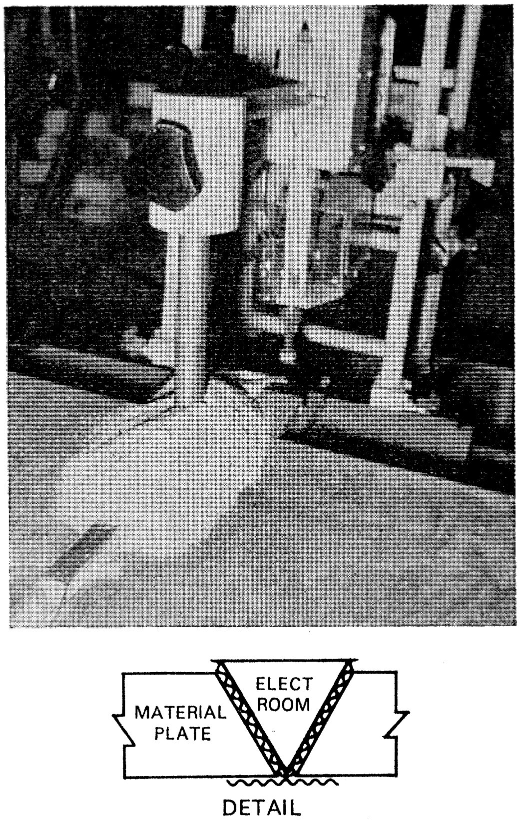

Figure 5. Welding butt joint longitudinals using c.b.s. (contact bar submerged arc welding).

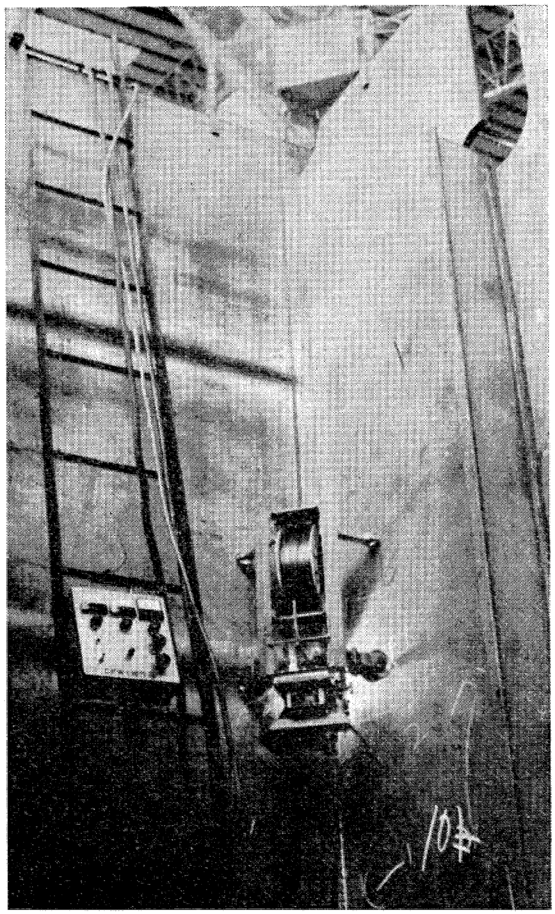

Figure 6. Vertical fillet welding by automatic oscillation without shielding gas.

(v) *Painting*

The method of surface pretreatment will be shifted from the mechanical process of shot blasting to a chemical treatment of spraying acid or rust-removing chemicals from now on. It is being studied whether to perform this operation after subassembly or after completion of hull blocks. The hand spraying method of painting, which is the current practice, may be replaced in the future by electrostatic spray or flow-on painting conducted after subassembly or completion of hull blocks, or by submersion of hull units or blocks in a tank of paint. Another treatment system under study is to pour paint into the ship's tanks to be coated. In any case, development of new paints themselves and the large quantity of paints to be stored still remain as problems to be solved.

(vi) *Production control*

In determining a production schedule at a shipyard, a preliminary plan is first prepared, followed by examination of the main production processes to check for inadequate points, and the schedule is then adjusted accordingly. Full computerization of this procedure with a program into which all the conditions of the main processes are incorporated is expected to be accomplished before long. The conditions of the main processes include bending operation at the fabrication shop, the square measure of the assembly shop, the limit of loading capacity per week on the building berth and the conditions of the quay. All such data are filed in advance in preparation for an optimum production schedule.

Although vouchers for materials to follow them from the designing and purchasing stages to the shops are prepared, they are not being sufficiently utilized.

A new system now being developed will make it possible to immediately grasp the needs of each stage communicated on line and to take proper measures. For instance, if an alteration is made in the designing stage, all relevant data in the purchasing department and the work at the shops will be supplied on line. Within the designing department itself, data on the existing vessels relevant to such alteration will be made immediately available.

In the shops, this sytem will allow the current situation regarding outfit components indicated on the pallet's control table, to be informed through on line at any time.

(*b*) *Recent changes of layouts and hull construction methods in Japanese shipyards*

The layout of a shipyard and the method of hull construction adopted by it, affect the productivity of ships as well as the above-mentioned elements of technology, and further determine the suitable mode of automation.

Therefore, in considering automation of a shipyard from now on, the selection of a layout and a hull construction method will be fundamental. As the construction plans of Japanese shipyards for large vessels seem to give a number of suggestions regarding these points, the historical changes in these two factors are described below.

All the shipbuilding facilities capable of constructing 100000 tonne dwt or larger vessels left in postwar Japan were for building large naval ships and were therefore obsolete. Construction of facilities to build large merchant vessels started in 1962 or thereabouts, to meet the increasing demand for such ships.

In western Europe at that time, Burmeister and Wain's Shipyard in Denmark had already completed its existing facility as the first shipyard equipped with a couple of 300 tonne goliath cranes. In Japan, new facilities for building large vessels at the Nagasaki Shipyard & Engine Works of Mitsubishi Heavy Industries, Ltd and the Chiba Works of Mitsui Shipbuilding & Engineering Co., Ltd were modelled after the Danish yard. The former comprised addition of a new building dock and cranes to the existing facilities, while the latter started as a repair yard. Intended from the outset as a yard specializing in the construction of large vessels, is the Yohohama Shipyard of Ishikawajima-Harima Heavy Industries Co., Ltd. Unlike older ship-

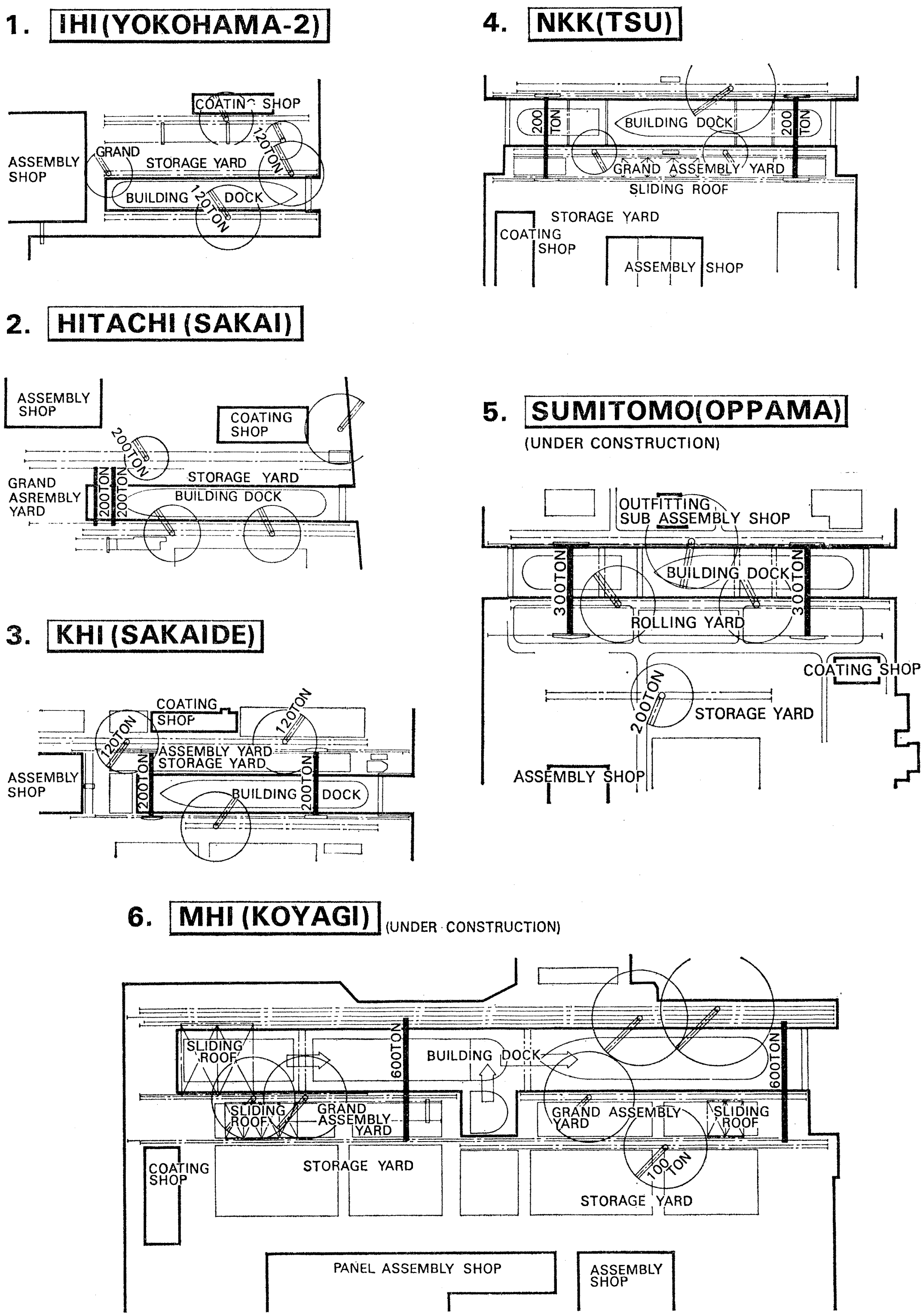

FIGURE 7. For legend see facing page.

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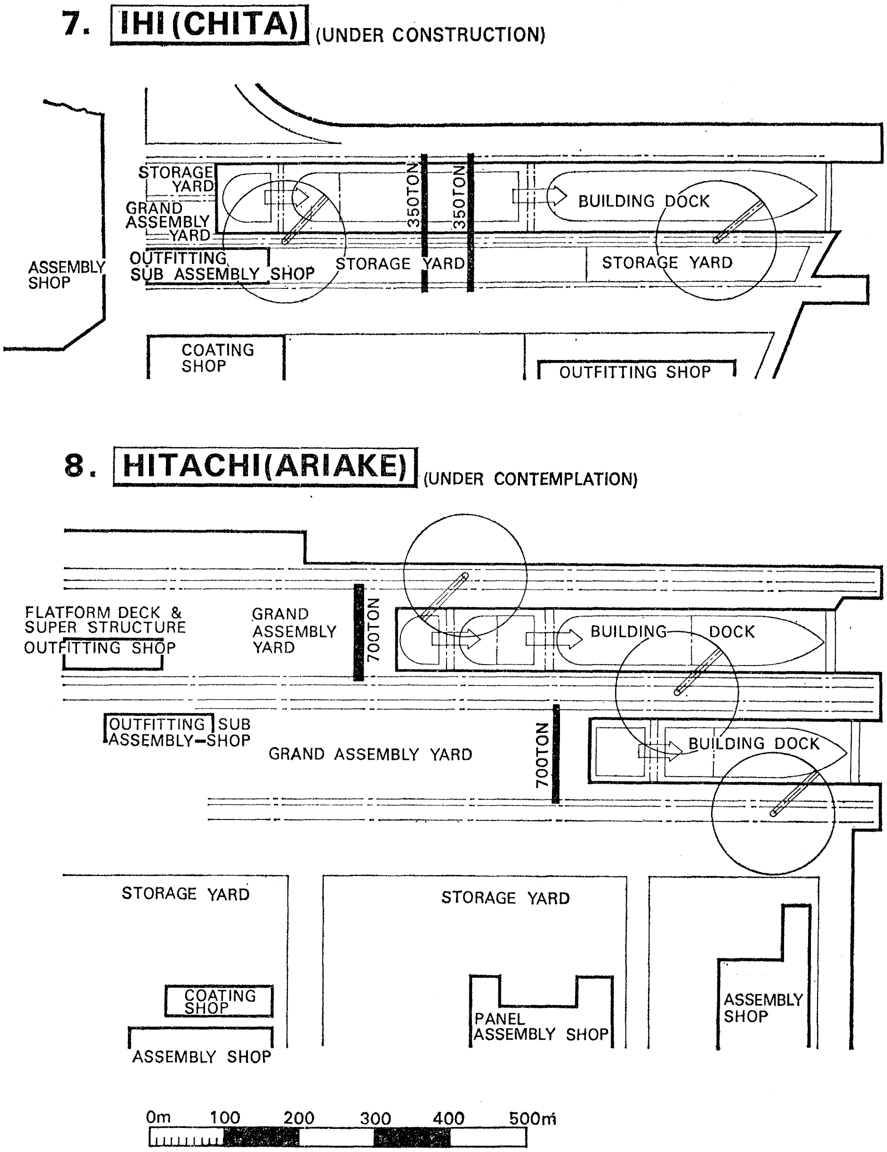

Figure 7. Progress of layout of very large sized shipyard in Japan.

yards where blocks were assembled outdoors on a small scale beside or in front of building berths, this yard as illustrated in figure 7, assembles large blocks for hulls under a shed adjoining an indoor fabrication shop and completed hull blocks are carried off by large trucks. As the Sakai Shipyard of Hitachi Shipbuilding & Engineering Co., Ltd which soon followed I.H.I.'s Yokohama yard, an indoor block assembly shop adjoins a fabrication shop as in I.H.I.'s case, as illustrated in figure 7. Hitachi's yard made some improvements, such as the indoor assembling of not only two-dimensional but also three-dimensional hull blocks and the setting of the leg span of goliath cranes wider than the breadth of the dock to allow blocks to be conveniently stored. Then came the Sakaide Shipyard of Kawasaki Heavy Industries, Ltd, where significant features include the partial advance outfitting system by which pipes are inserted into complete two-dimensional blocks about to be carried off for erection and an independent curved block assembly shop, separated from the shop where flat blocks are assembled.

While five large building docks were thus completed, the growth in the size of ships built there made it difficult to follow the initially planned construction system, i.e. that of building the stern part of the ship first and moving it afloat after the launching of the preceding ship. Moreover, the quantity of midbody blocks became too large to be stored in the stockyards already provided as indicated in figure 8. These circumstances are explained below in further detail.

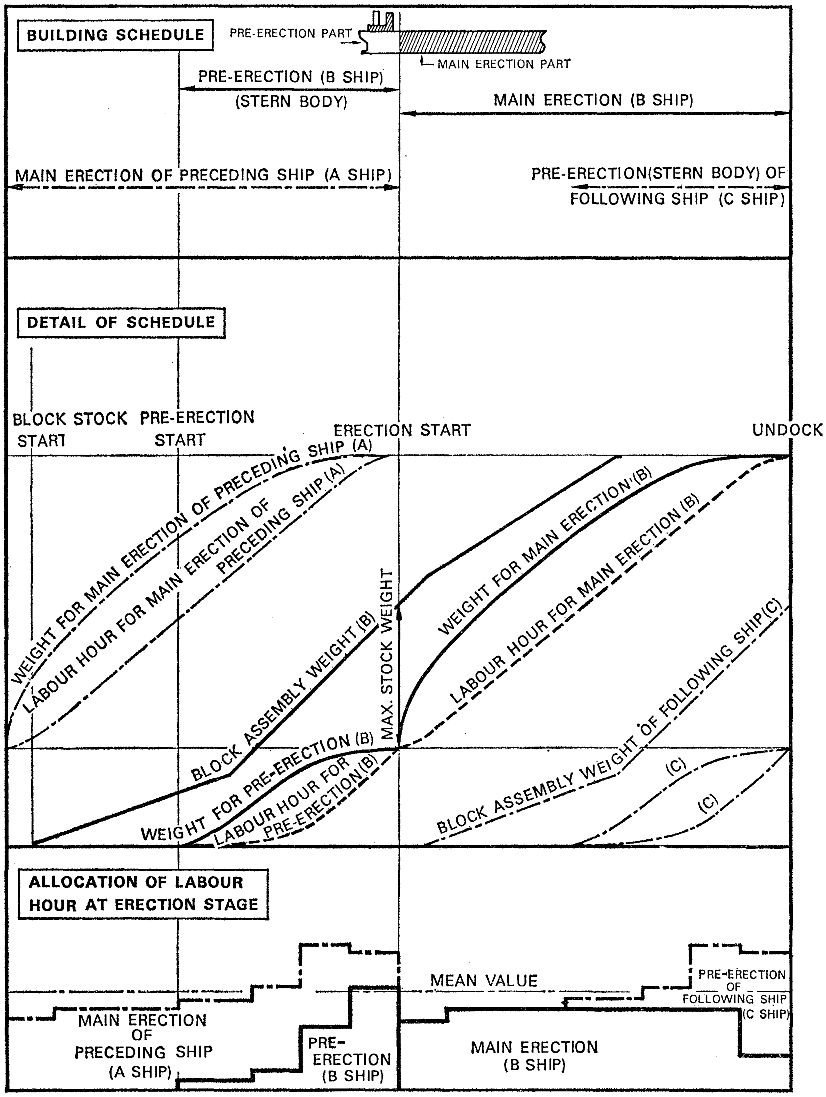

Figure 8. Stocked block weight and allocation of labour hour at erection stage when pre-erection method of stern body adopted.

(i) *Construction of stern part of ship*

Since the growth in ship size limited the length of dock available for the advanced construction of the stern body and made it difficult to move such a body afloat, it became necessary either to build only a part of the stern body or construct another dock specially for building stern bodies. Furthermore, while a minimum degree of finishing work was required before moving a stern body afloat, it coincided with the finishing of work on the preceding vessel which is to be launched, thus resulting in an inconveniently steep peak in the overall amount of work.

(ii) *Construction of midbody*

As the midbody is not build in advance, it became necessary, during the period between the completion of the erection of a ship and her launching, to stock many hull blocks for the next vessel. The quantity of such stored blocks proved comparable to the average monthly consumption of steel material in the dock. Therefore the cost of handling these blocks and the interest accruing during their storage became too large to be ignored.

Typical solutions to these problems were made by the Tsu Shipyard of Nippon Kokan Kabushiki Kaisha (N.K.K.) which was constructed in 1970.

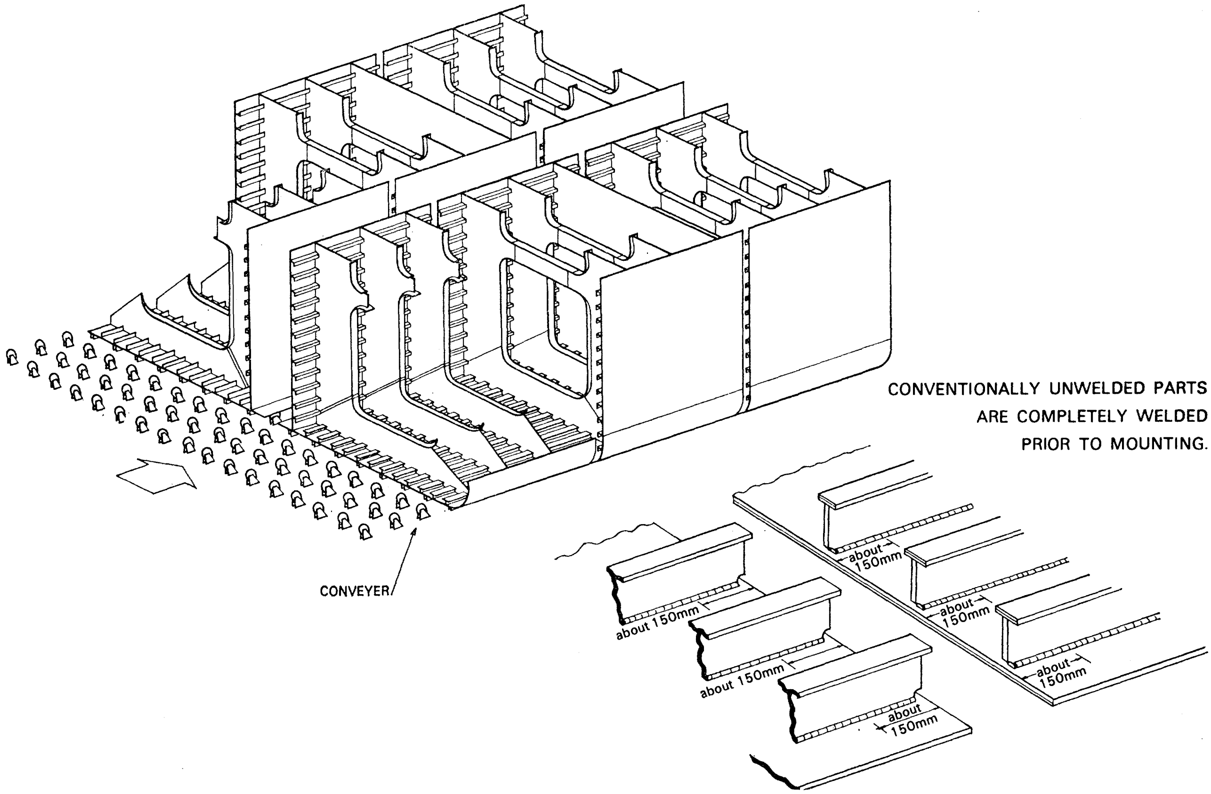

Figure 9. Rolling system.

This shipyard uses a canal dock system, which has an intermediate gate allowing construction of the stern and part of the midbody of a ship without being affected by the launching of the preceding vessel. Moreover, unlike the conventional layout of arranging the building dock and the fabrication and assembly shops on a single straight line, the dock and the shops in this shipyard are laid out in a T-shape, resulting in a shorter transporting distance between the block assembly shop or the outfitting shop and the building dock. It also simplifies the conveyance system.

The Oppama Shipyard of Sumitomo Shipbuilding & Machinery Co., Ltd which is currently under construction also follows the aforementioned N.K.K. system. Like the shipyard of Kockums in Sweden, the new yard also uses a rolling system by which side tanks are horizontally bisected and their bottom blocks and upper deck blocks are moved on a conveyor running parallel to the building dock. In case of the rolling system, unwelded parts which were necessary

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for adjustment at-the-spot in conventional methods are completely welded before mounting (see figure 9). The Oppama Shipyard has such other new features as a tunnel leading to the dock bottom for human traffic and material transport and a system of inserting longitudinal members during frame assembly.

Following Sumitomo's new yard is the Koyagi Works of M.H.I.'s Nagasaki Shipyard & Engine Works, scheduled for completion within this year (1972).

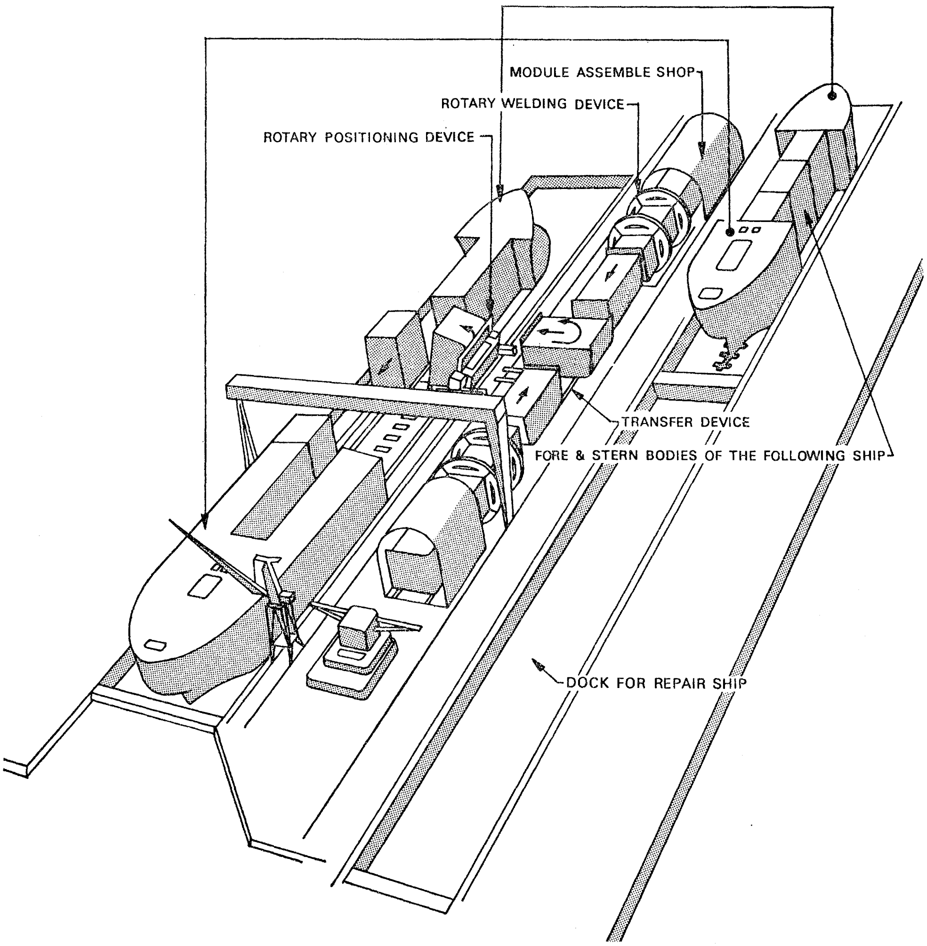

Figure 10. Rotas system.

This yard, where the work on the stern and midbody parts of a second ship is continued in an ordinary building dock instead of a canal dock and independently from the construction of the first ship, is characterized by the fixed location of every part of the work. In other words, the workers for that part of the work remain at the same place, repeating the same mechanized operation. For this reason, a side dock is provided for pre-erection of stern bodies. Sections, built by a pushing-out system as in the Arendal Shipyard in Sweden are given ample space for block erection, where the same work is repeated at the same place as stated above. The dock of this shipyard consists of the following four sections:

The side dock (for building stern body),
the fore dock (for building midbody),

the mid-dock (for joining stern body and midbody), and
the aft dock (for finishing outfitting work).

The dock is accordingly a long one, like that of the Atlantique Shipyard in France. Furthermore, fabrication shop and assembly shop of this shipyard are arranged sufficiently apart from one another to facilitate adjustment of the amount of work in each stage.

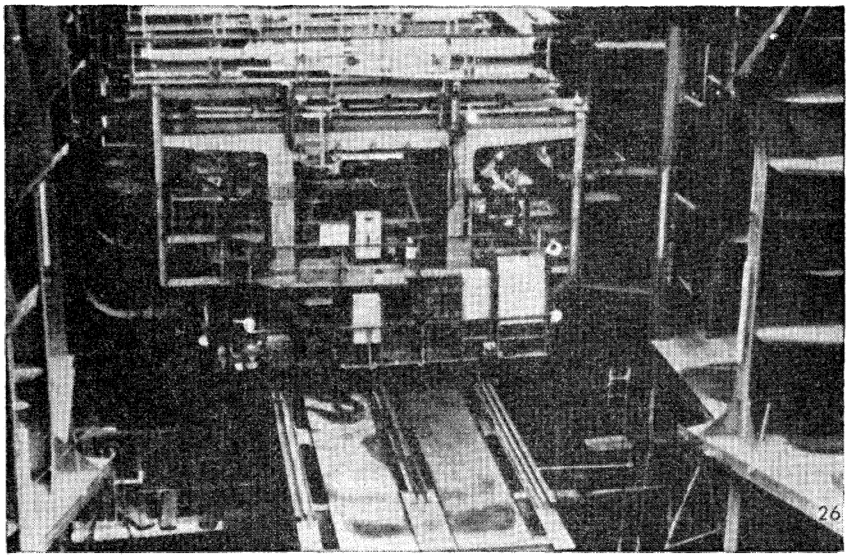

FIGURE 11. Hull construction work-unit for upper part.

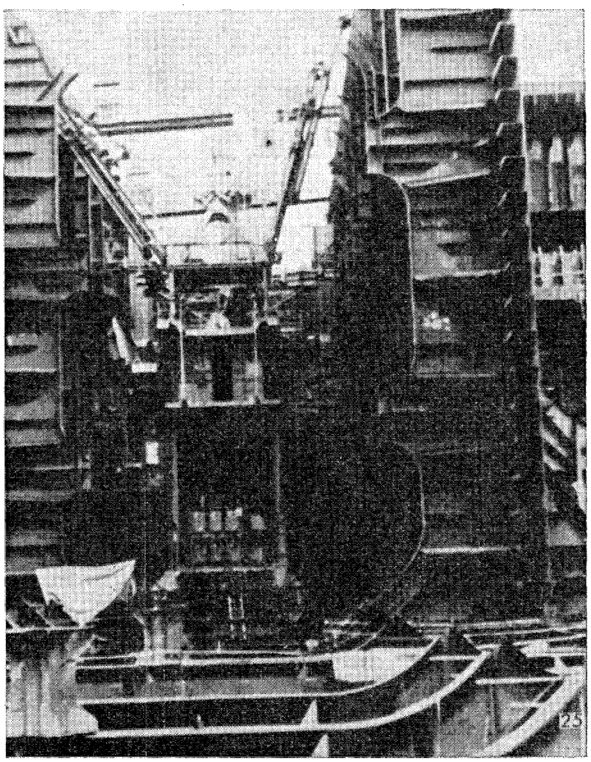

FIGURE 12. Hull construction work-unit for middle part.

At the Chita Shipyard of I.H.I. to be constructed next, the stern body is to be built in the fore part of the dock, and the midbody in the middle. They are then joined together and moved to the aft part of the dock.

At Hitachi's Ariake Shipyard scheduled to follow I.H.I.'s Chita, the midbody and stern body are again built in their respectively designated parts of the dock, but this yard has two separate docks arranged in parallel instead of in a straight line, and the midbody built in one of them is brought over to the other dock where the stern body is built and the two are joined together.

In all these three new yards, open-air outfitting work will be replaced by a complete block outfitting system using large outfitting units. At Chita and Ariake, special outfitting shops for blocks will be provided to perform all outfitting work under roofs. All the three shipyards will follow a system of erecting 400 to 1100-tonne two or three-dimensional blocks into engine room structures under goliath cranes. All the final outfitting work will be carried out in the aftmost part of the dock in every case. Thus Japanese shipbuilders have updated their yards by adding new ideas to what they have learned from the previously constructed shipyards.

Two noteworthy shipbuilding systems were revealed recently.

One is the Rotas system intended for building three dimensional blocks of side tanks at Mitsui's Chiba Works. As illustrated in figure 10, a three-dimensional block is firstly rotated with a set of jigs so that workers can assemble or weld it in a looking-down position as far as possible, then brought down to a building dock with a special device instead of a crane, and finally moved to its specified position by a bogie. This system, which makes it easy to construct the side tanks involving a lot of work without being affected by weather, has a promising future.

The other system is based on hull construction work-units, exemplified in figures 11 and 12 and is used for work within holds at the Kure and Yokohama Shipyards of I.H.I. The unit is a self-travelling machine, with hydraulic fitting jigs each specialized for a specific type of joint and an automatic welding device built into it. It proves highly efficient for work inside the holds. The use of such units has dispensed with dangerous fitting work and with scaffolds, thereby contributing to the modernization of shipbuilding operations.

5. Concept of shipyard in the 1980s

Automation and mechanization that are only partial in existing shipyards will become far more extensively applicable when the aforementioned elements of technology are further developed. However, the shipbuilding industry, viewed as a whole, would not fully qualify as a truly modern industry even if all such elements of technology were to be developed. In shipyards, while fabricating and assembling operations are performed indoors and increasingly modernized by numerical control and other means, all others are conducted outdoors, and are therefore, affected by weather. Such operations account for more than half of the total work. Thus, automating and mechanizing equipment, even though already developed, cannot be thoroughly applied for practical use. Future shipyards would accordingly have to transfer outdoor works to indoors. In this connexion, it would further become necessary to improve environment which is at present troubled by noises, sprays of paint, harmful fumes, poisonous gases, and drainage from shops.

Before entering further into the description with respect to the layout and facilities for a shipyard which would fulfill the aforesaid requirements, it is necessary to determine what kind of ships will be built at the yard.

In the 1980s, as many different kind of ships, both in type and size, will be built as at present, it is probable that the most prevailing type will be large tankers as it is today. Therefore the following description is concentrated on a shipyard which will build such large tankers.

It is needless to mention that all measures adapted to large tankers would be subsequently applied to smaller vessels step by step. The fundamental concept of modernization of the shipyard aims at (*a*) transference of as much outdoor work to indoor as possible, and (*b*) concentration of working procedure, both of which eventually will lead to the managerial end in view, i.e. a huge improvement of both working environment and of productive efficiency utilizing newly developed automated machinery and equipment.

(*a*) *Basic concept of the future shipyard*

(i) *Outdoor work to be brought indoors*

Whereas one of the common characteristics of existing shipyards for large tankers is their huge goliath cranes, this type of crane was installed for the first time in B. & W.'s shipyard more than a decade ago, followed by many more in other big shipyards all over the world. Along with the growth in ship size and increase in the quantity of blocks stocked, the leg span of such cranes has been gradually increasing, and the height has also been increased to clear ships' superstructures which are becoming ever taller. As long as such cranes are used, it would be impossible to build roofs high enough to cover them. To bring outdoor work in shipyards under roofs, an erection method and a shipbuilding process without goliath cranes would have to be invented.

(ii) *Outdoor work should be integrated into an unified shop to raise efficiency*

In existing shipyards, an advanced outfitting of blocks, grand assembly of two or three-dimensional large blocks and post-erection work are performed outdoors in scattered places, and not in a unified shop. It would be necessary to fully complete the hull blocks before erection and thereby dispense with the inefficient adjustment of joint parts after erection. On the other hand, although jobs are increasingly classified by stages of work, hull workers and outfitting workers still coexist in each stage. If a shipyard is planned taking all the above mentioned concepts into consideration, the working environment would be greatly improved, and the efficiency of outfitting work would be very much higher, resulting eventually in an enormous saving in manpower.

(*b*) *Layout of the future shipyard*

A proposed shipyard based on the above stated idea is illustrated in figure 13. It would have a shop for building midbody and another for fore and stern bodies, with a view to bringing outdoor work under roofs. Apart from the above shops the fabrication and assembly shops would be similar to those of the most up-to-date existing shipyards.

As this system will have two specialized shops as mentioned above for conventional erection work, no building berth or dock would be used, accordingly hulls would be built and completed on the same ground level as these shops. Consequently it would be necessary to float a hull when completed and this can be accomplished by an inclining system, sliding launching or a floating dock method. However, this yard would use the floating dock method which would be the safest and the most economical to float the large ships.

The reason why the direction of the transfer of hulls in this case is to be switched from longitudinal to lateral, as illustrated in figure 13, is that the stern body completed in the shop

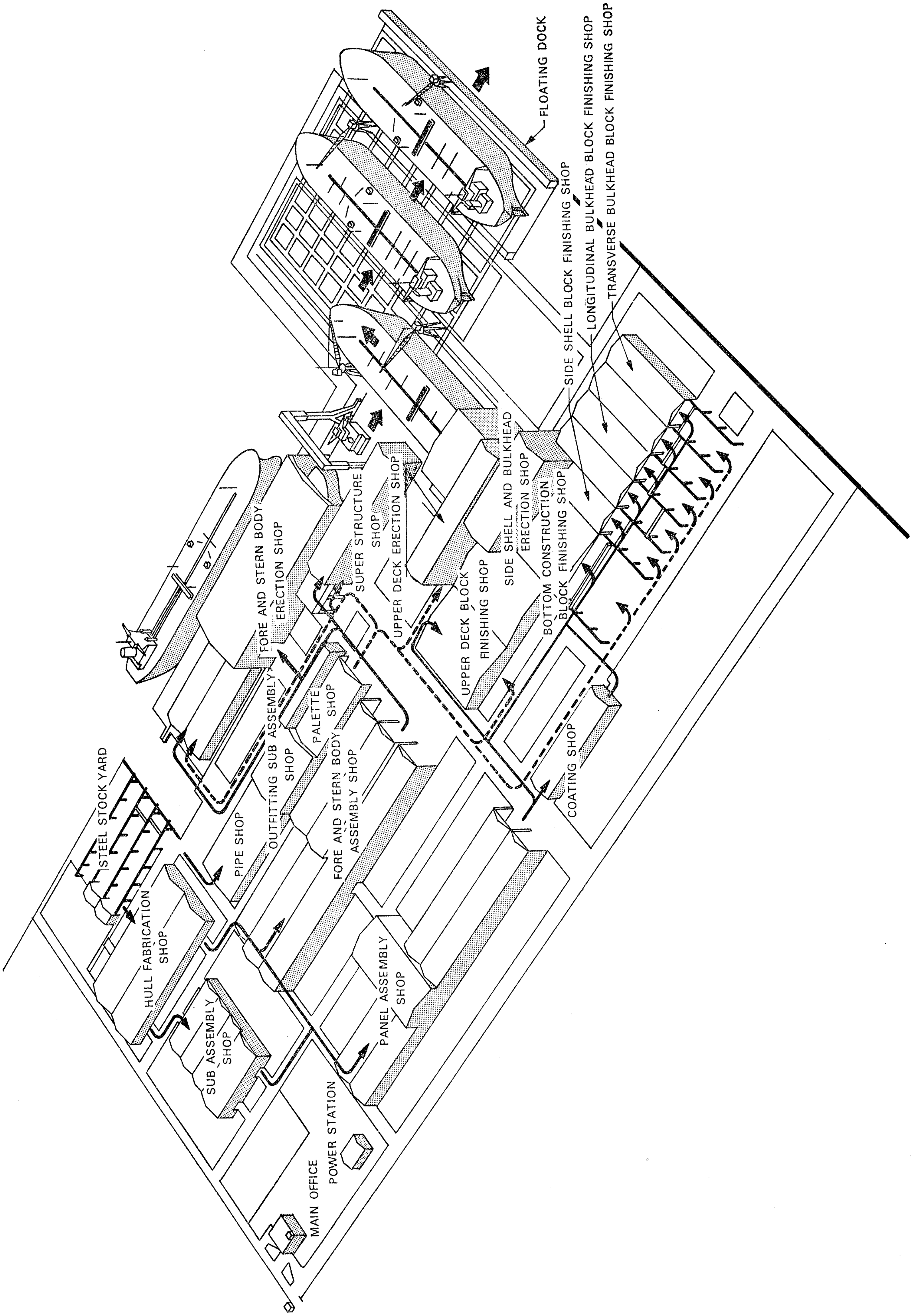

FIGURE 13. Proposed plan of a future shipyard.

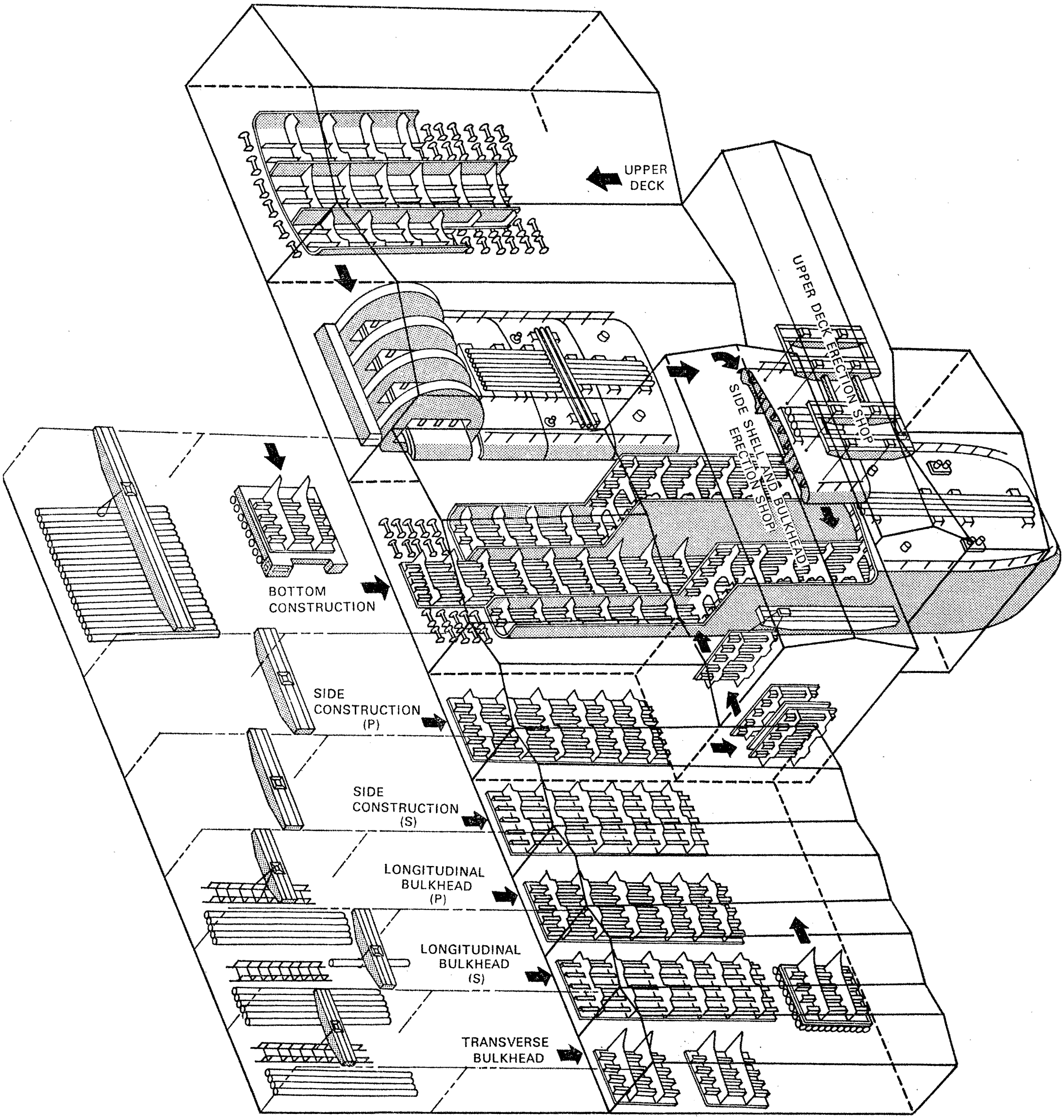

FIGURE 14. Finishing and erection shop of the proposed plan.

while moving in a lateral direction and joined to the midbody, could continue to be moved laterally. If a whole hull were to be shifted longitudinally from the beginning to the end and transferred into a longitudinally arranged dock, the movement of its stern body would have to be switched in the process from lateral to longitudinal, and accordingly the enormous weight of the stern body would have to be supported laterally at first and then longitudinally.

This would be difficult both in working operation and in facilities as far as large ships are concerned. Needless to mention, longitudinal transfer from the beginning would be no problem in case of smaller vessels.

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(*c*) *Construction of midbody parts*

Although a midbody is built in a specially allocated space in most of the recently completed shipyards, such space is not a unified shop as in case of the panel assembly shop. To transform such space into a shop, the blocks to be erected here would have to be supplied in complete forms from the block finishing shop immediately preceding this stage. Consequently, space for the construction of the midbody would consist of the block finishing shop and the erection shop adjacent to the finishing shop as illustrated in figure 14. The finishing and erection shops are separately discussed below.

(i) *Finishing shop*

(*a*) When blocks carried on trucks from the hull assembly shop are unloaded at the entrance of the finishing shop, they would be mounted on a moving conveyor and their positions are hydraulically set.

(*b*) The accuracy of the blocks would be thoroughly checked and adjusted.

While it is easy to check the accuracy of a block in relation to immediately adjoining ones on the conveyor, consistency with other blocks similarly assembled elsewhere would be checked and adjusted with a Laser beam or a fixed jig.

(*c*) Mounting of outfits

Outfits, collected at the entrance of the finishing shop would be mounted with small cranes installed in the shed. As the accuracy of this mounting operation would be as well maintained as that of the dimensions of blocks mentioned above, it would be completed in this shop. This would be a departure from the current practice of provisional fitting for adjustment and later, firmly fitted at the site.

(ii) *Block erection shop*

(*a*) Assembling method

Blocks completed in the finishing shop are erected and welded in this shop. Since blocks are built as precisely as machinery parts, there is no need to adjust their joints before being hydraulically positioned and automatically welded. Erection work is carried out in the shop with a crane for shell and bulkhead and in the other shop with cranes for fitting the upper deck, as illustrated in figure 14. In addition, there are small auxillary cranes travelling the length of the shop. Since shell and bulkhead would be fitted from a broadside, the hanging height of cranes can be minimized. Each crane would be equipped with a hydraulic hanging device, and the operator's cabin protrudes from the crane so that its hanging device could be watched by the operator. Installation of a block positioning device will be installed on the wall of the shed. Whereas the upper deck would be assembled in its full breadth in the aforementioned finishing shop as shown in figure 14, welding of its joints would be performed with a stationary automatic machine. Then the deck, going through a 180° reversing device, moves in a normal direction, to be equipped with all the outfits and erected.

The erecting cranes, though large in capacity, need not travel or hoist rapidly. Only one of the total four cranes would require the mechanism and driving motors as for a normal crane. The rest could be simplified as wheeled girders with hook and sheaves for hoisting. Bottom shell plates move from the beginning through a low-roofed building located on an extension line of the erection shop for large block assembly. The joints of the bottom shell plates in the total assembly work spanning the full breadth of the vessel, would be treated in the same manner as those of the upper deck, and their seams would also be put together with setting and welding devices provided specially for the purpose. Large-bore pipes would be fitted to the block with a pipe inserting machine now being developed, and a crane having a grab-equipped arm would be used for positioning the pipes.

(*b*) Pushing-out building process

As the pushing-out building process would make it possible to fix the position of each segment of work, special stationary devices for painting could be used for working on the joints of the outer surfaces of shell plates and decks as well as for painting the outside. While many ways of pushing-out the hull are conceivable, the least expensive and the most reliable one would be the 'spanworm style', a repetition of stretching and contracting movement on the berth, which is the same as the method already developed.

(*c*) Problem of sheds

When this pushing-out process was selected, it was confirmed that 50 m tall sheds spanning 100 m were sufficient even for super large vessels, and the design and wind tunnel tests of similarly large sheds have been completed without any particular problem. Naturally, the longer the shed as in this case, the lighter should the structural weight per square metre be. Nor would there be any problem with earthquakes which exerts less exterior force than wind pressure.

(*d*) *Construction of fore and stern bodies and superstructures*

(i) *Contruction of fore and stern bodies*

Even the current system which features extensive advance outfitting has not wholly eliminated the open-air outfitting work. To overcome this shortcoming, methods would have to be adopted such as packaged outfitting and outfitting of engine room deck block in the general outfitting shop where pipes, wires and auxiliaries are installed and then the deck is hoisted out by a goliath crane.

However, the limitations of shape and weight prevent such methods from being perfected as production methods. If the whole process, from the above mentioned outfitting to the completion of the stern body, could be accomplished in a shop provided adjacent to the building berth, efficiency will be remarkably improved. While this shop would be manned by skilled engine outfitting workers, hull department workers would also have to be highly skilled in hull construction which is likely to be complicated. However, if the engine room is composed of three-dimensional grid which is now being studied, common engine outfitting workers would be adequate to do the job. If, furthermore, the connexion of the shell and/or deck plates with the grid is made of linear web plate system which can easily match the above mentioned grid, engine outfitting workers would find no difficulty in this work. In assembling the shell plates and the upper deck which have web plate frames as stated above, blocks could be easily checked for exactness in the assembly shop before coming into this proposed shop. Test run facilities for auxiliaries would be so provided that tests could be almost wholly completed in the grid state. As the top and bottom joints of the bow structure would be checked in the stern and bow block assembly shop, grand assembly in this shop would be simple.

(ii) *Superstructures*

Assembled in a special shop adjoining the fore and stern bodies shop and transferred sideways, superstructures would be fitted by a travelling goliath crane within the stern shop. The crane would work in the following manner: it would go up without any load, then hoist the superstructure and, after the stern body is shifted under it, the superstructure would be lowered onto the stern body. When not engaged in this operation, the crane would be lowered and used for work within the stern shop or for unloading of main engines and related components to the yard from barges or vessels.

(*e*) *Hull assembly process*

Figure 15 illustrates the hull assembly process. As there is ample distance between the midbody shop and the stern shop, there would be no need for haste in joining the midbody and stern body. As each shop uses a hydraulic jig to keep the shape, the joining of each section can be carried out with accuracy. Between the joining stage and the floating dock, there is a spare stage, which could be used for ship conversion work as well as for adjusting the progress of shipbuilding work. While a concrete floor could be provided in the floating dock when a vessel is pulled into it, this floor could be dispensed with by using a special device.

(*f*) *Effect of modernization of a shipyard on its employees*

Some people are worried about possible adverse effects which the simplification of shipbuilding process would have on the morale of shipyard workers who find satisfaction and pride in acquiring skill through years of experience and practice. However, when other industries are being modernized through reduction in labour-consuming operations and by providing a safe working environment, it is doubtful that young people would prefer working in the shipbuilding industry than in other industries if it alone continues to remain a labour-intensive industry.

They would rather enjoy operating automated or mechanized systems in modernized shipyards, become interested in their mechanisms and receive technical training to improve themselves. They would also be attracted by the speed at which huge vessels are built in a short period, thanks to improved productivity. If shipbuilders thus, secure capable employees and try to raise their morale in favourable working environment, they can reasonably expect prosperous business.

Before closing the writer would like to call the reader's attention to the fact that each Japanese shipbuilding company desires very much to protect its industrial property rights with regard to the various technical developments described in this paper.

I wish to thank the Chairman and the Society for permission to give this paper.

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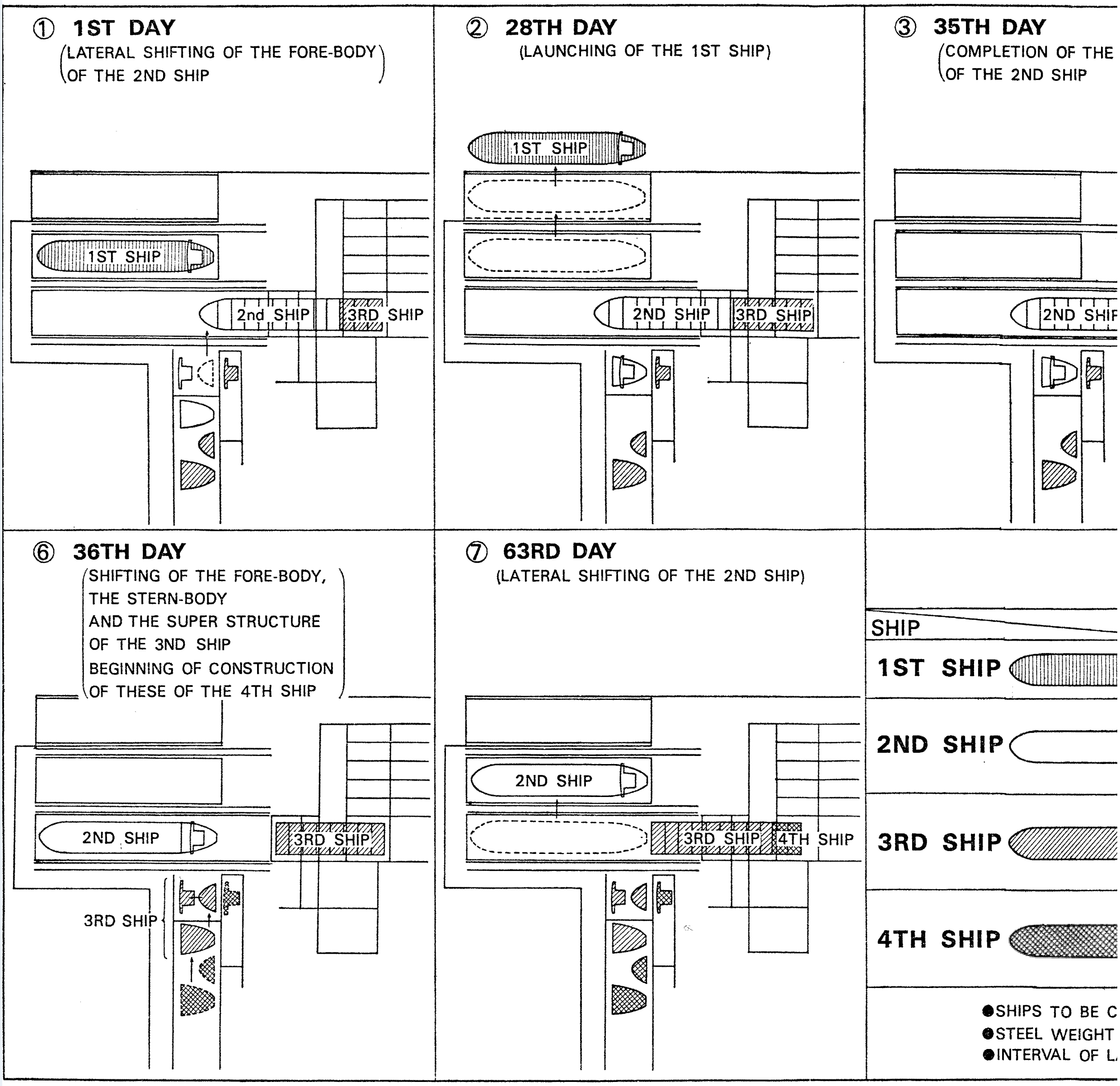
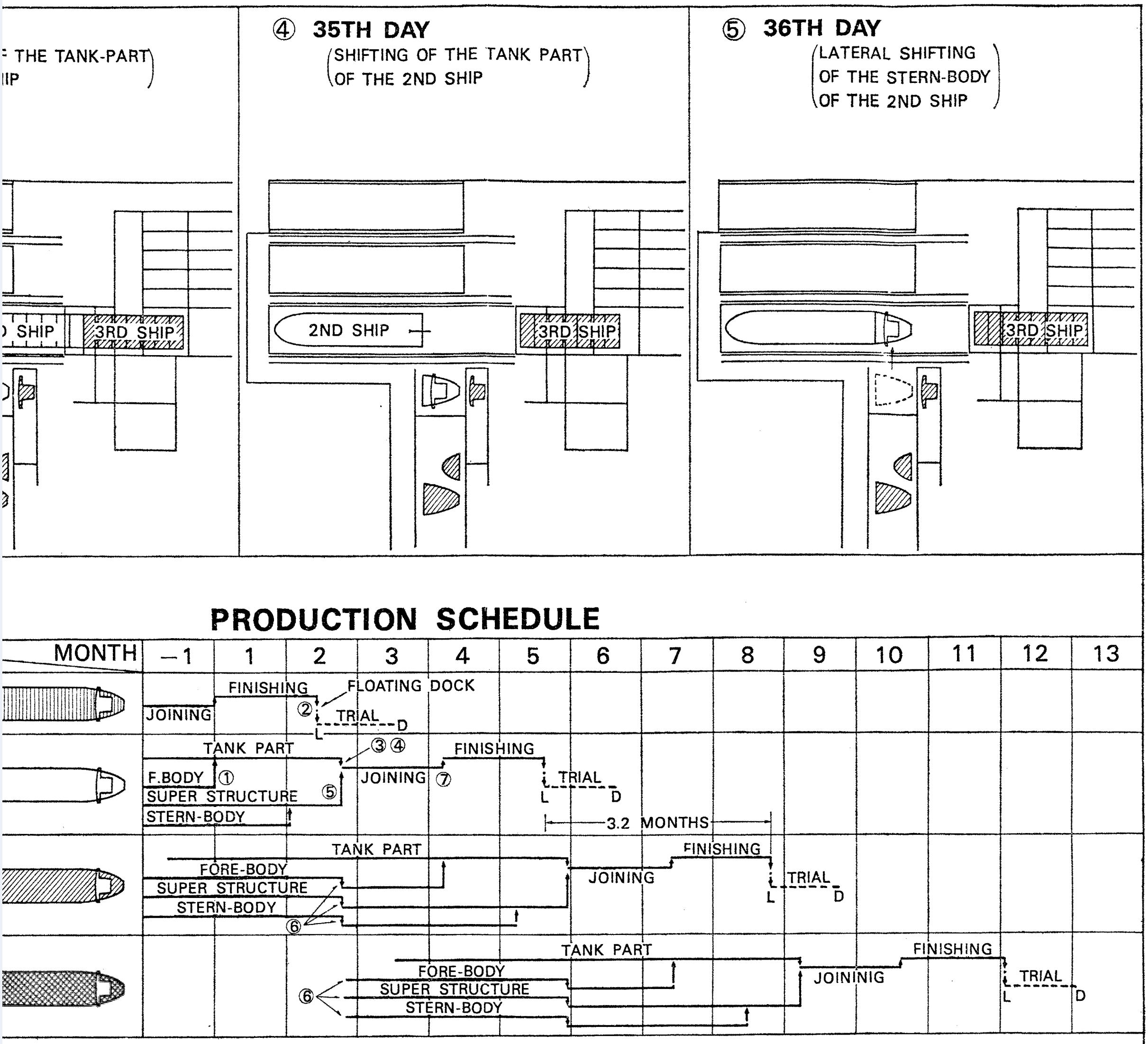


Figure 15. Building proces



BE CONSTRUCTED;500KDWT TANKERS
EIGHT TO BE CONSUMED ,20 000T/MONTH
OF LAUNCHING:3.2 MONTHS(63 WORKING DAYS)

●INTERVAL OF SHIFTING OF A TANK RING LENGTH:7 WORKING DAYS.
●NUMBER OF RINGS OF A TANK PART;9 RINGS

rocess at future shipyard.

(*Facing p.* 172)

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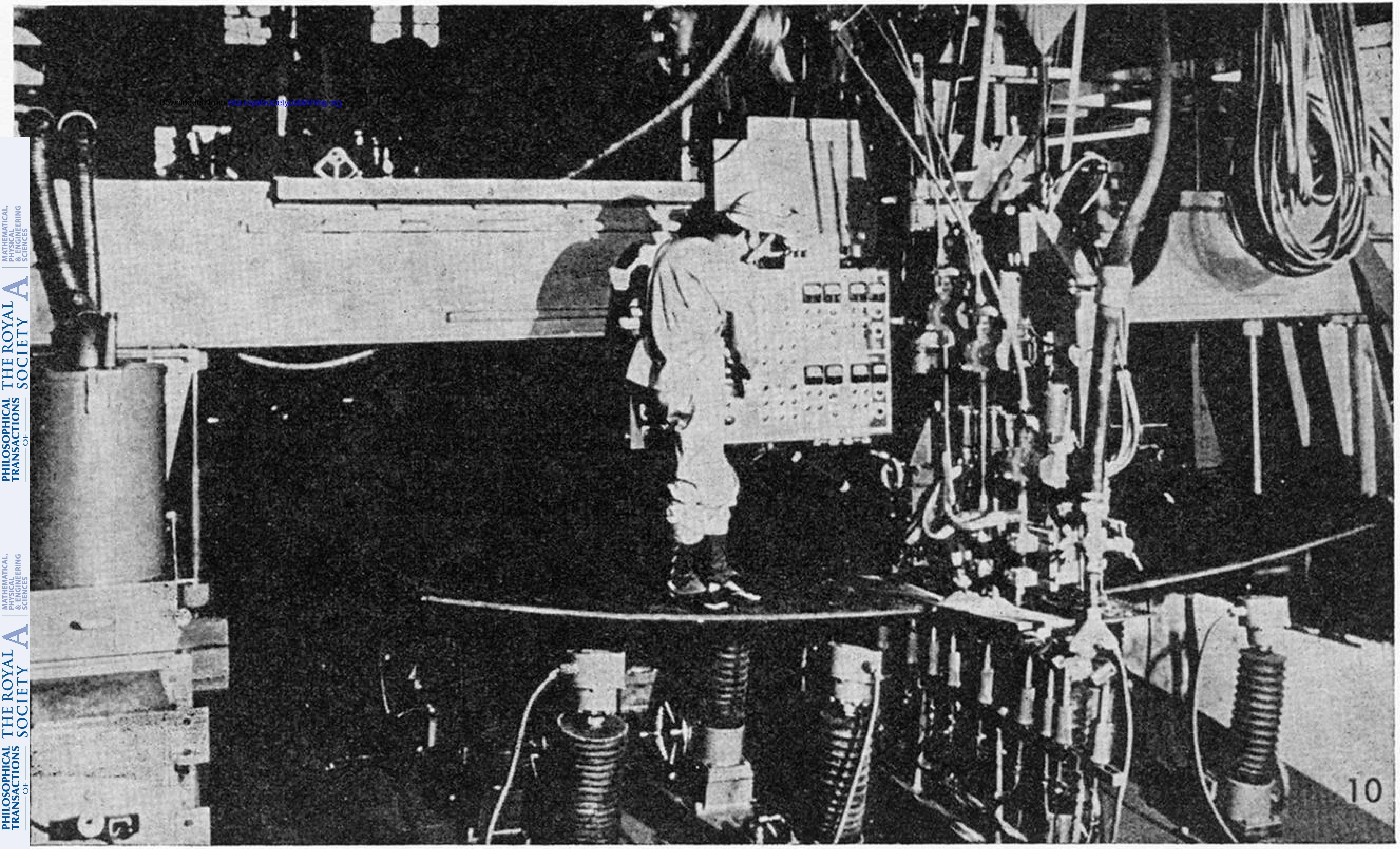


FIGURE 3. Assembling of curved skin plates using automatic rotating table and jacks.

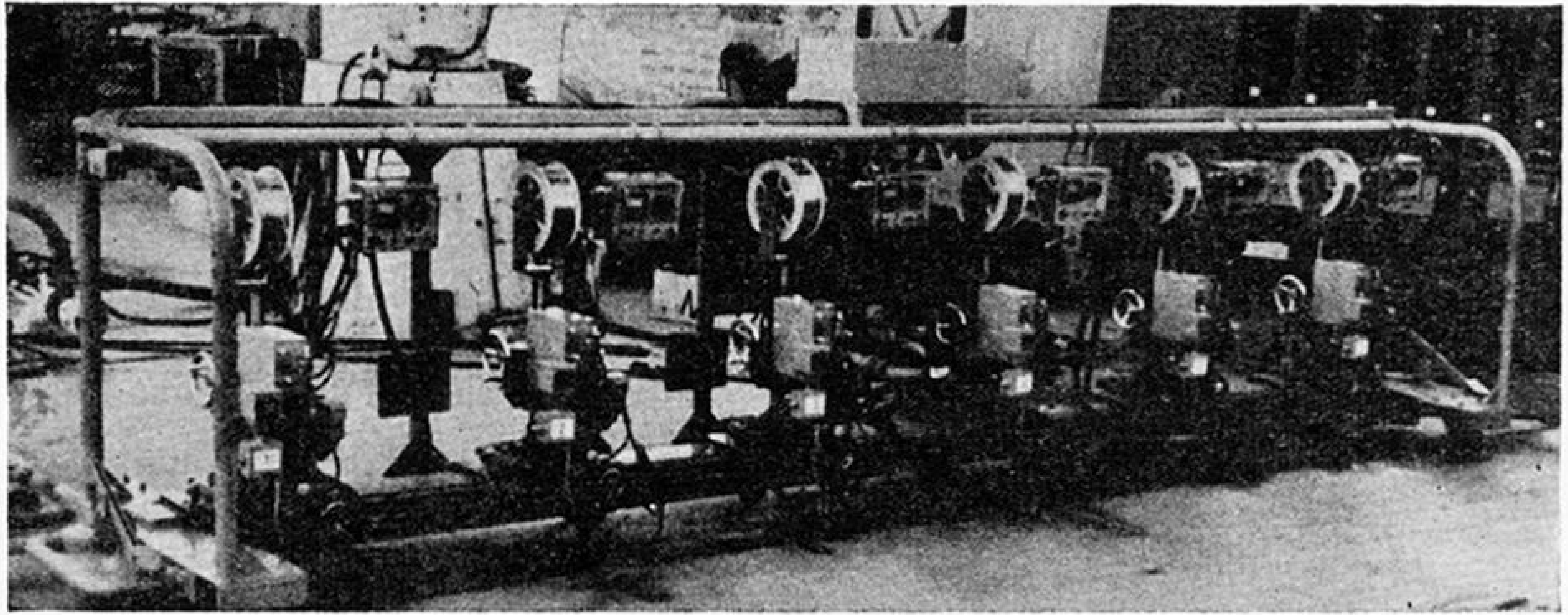
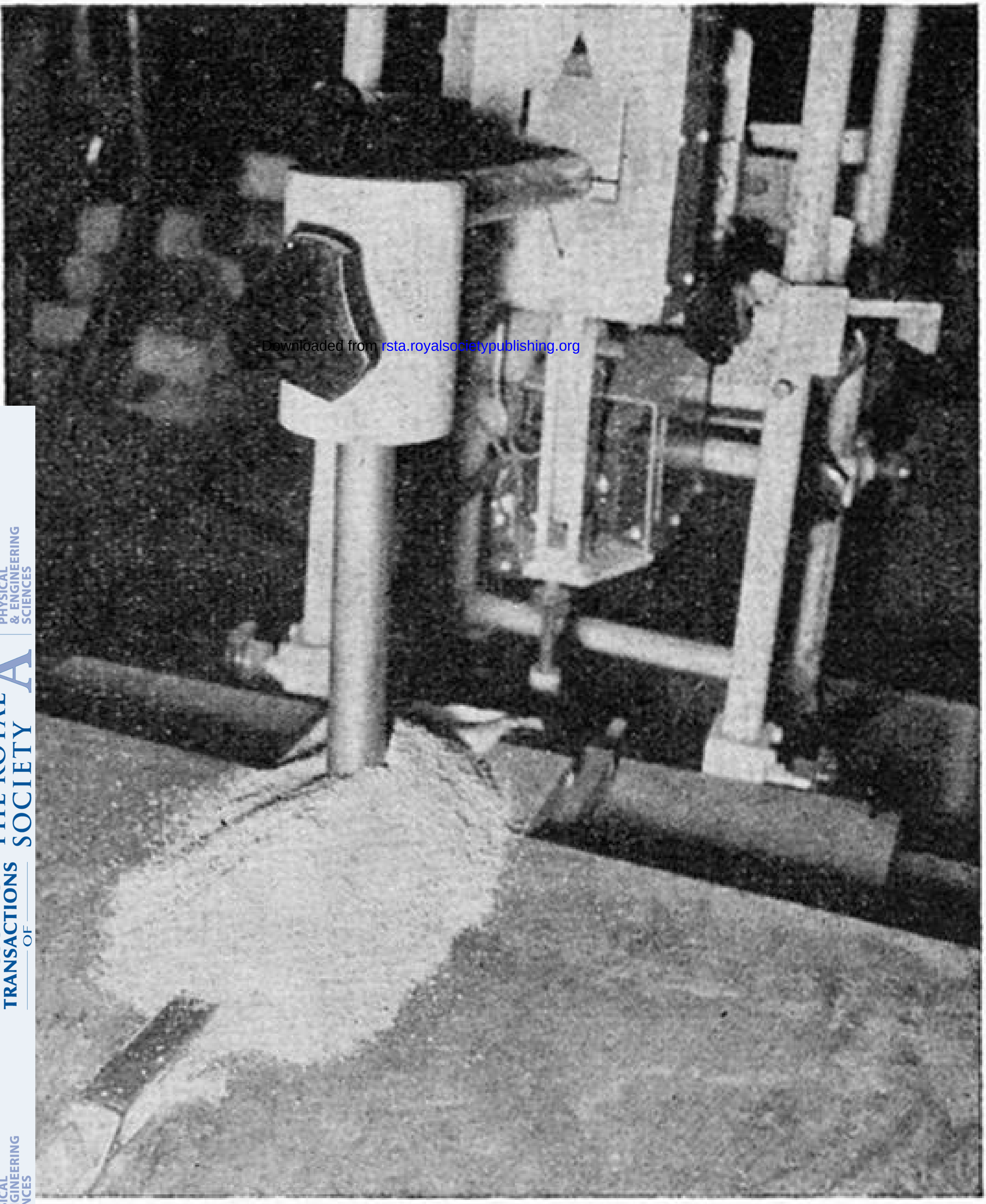


Figure 4. Deck longitudinal welding using multi c.e.s. welding (showing the welding equipment placed on upper deck, welding simultaneously several deck longitudinals under upper deck plate).



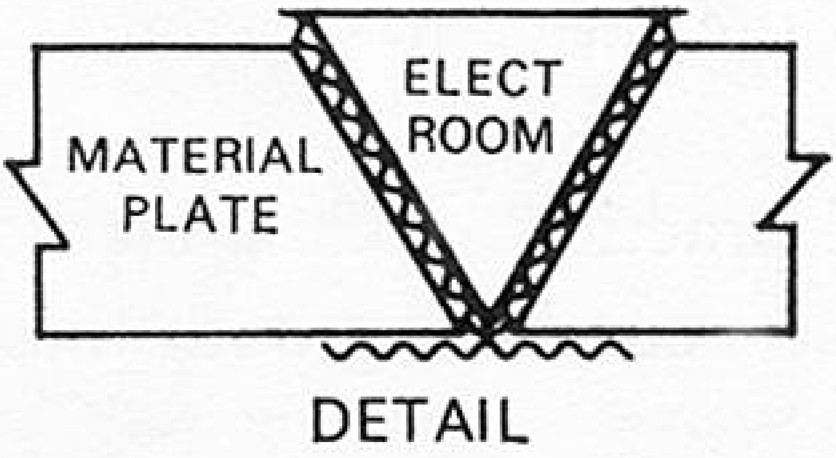


FIGURE 5. Welding butt joint longitudinals using c.b.s. (contact bar submerged arc welding).

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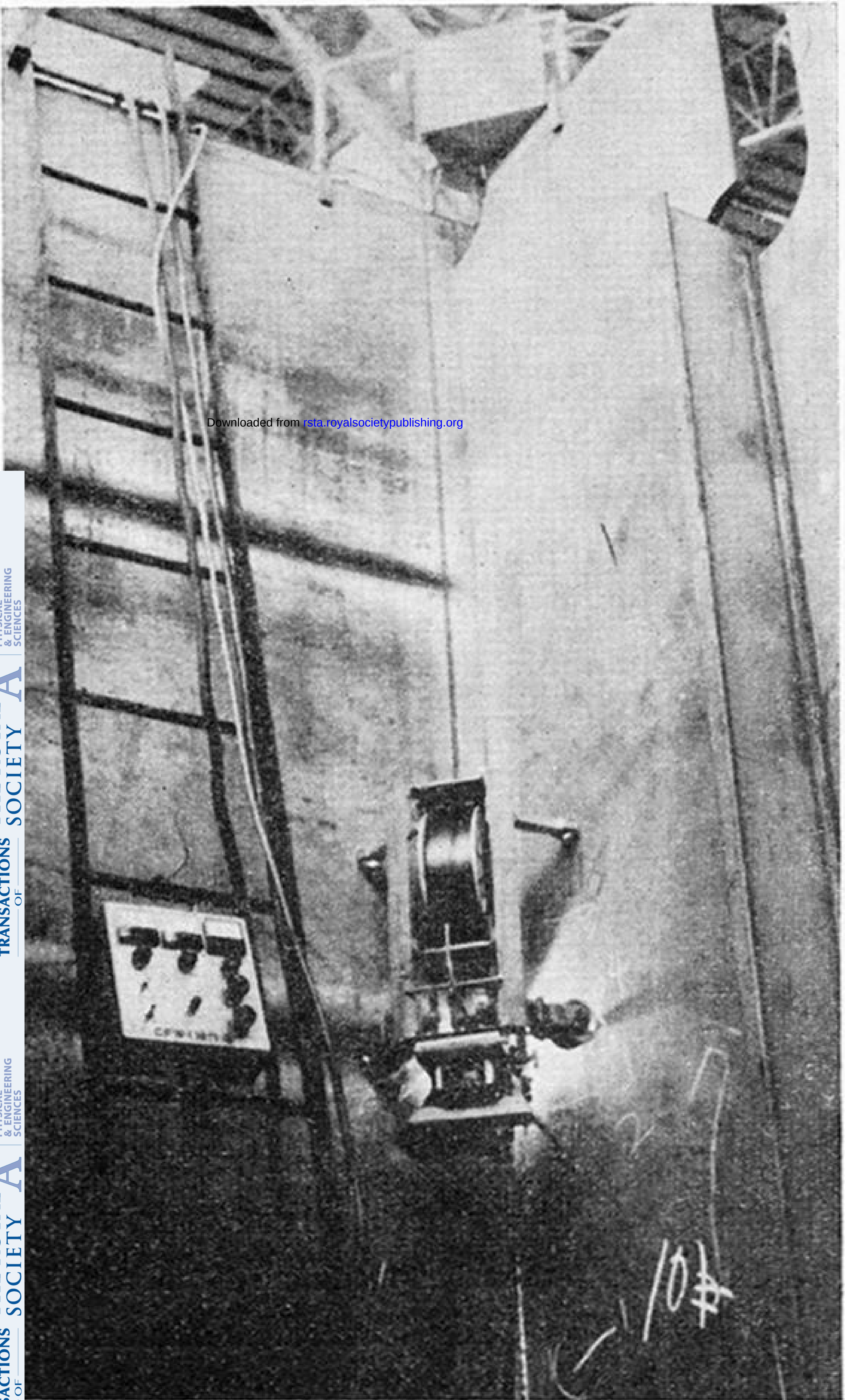

FIGURE 6. Vertical fillet welding by automatic oscillation without shielding gas.

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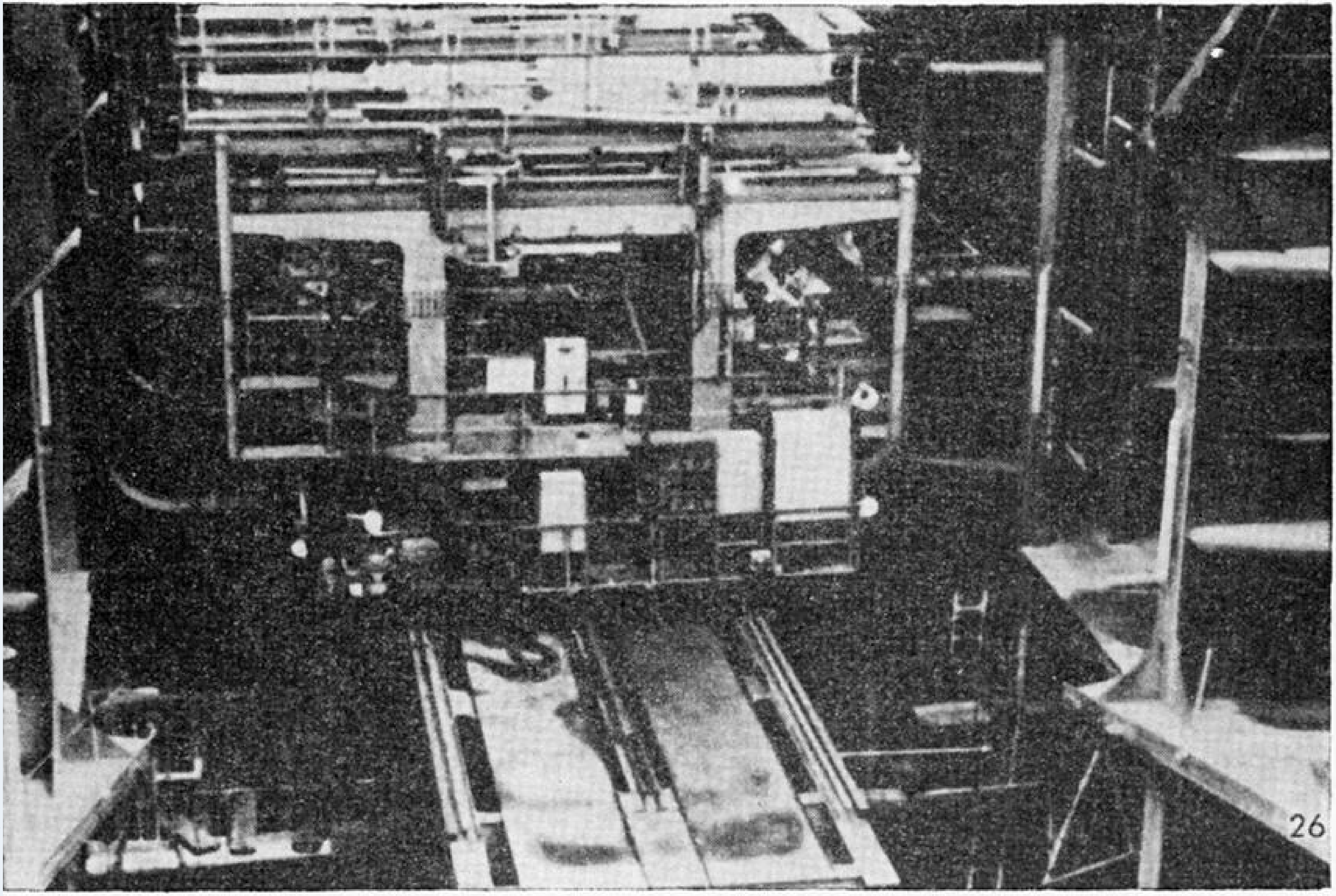

FIGURE 11. Hull construction work-unit for upper part.

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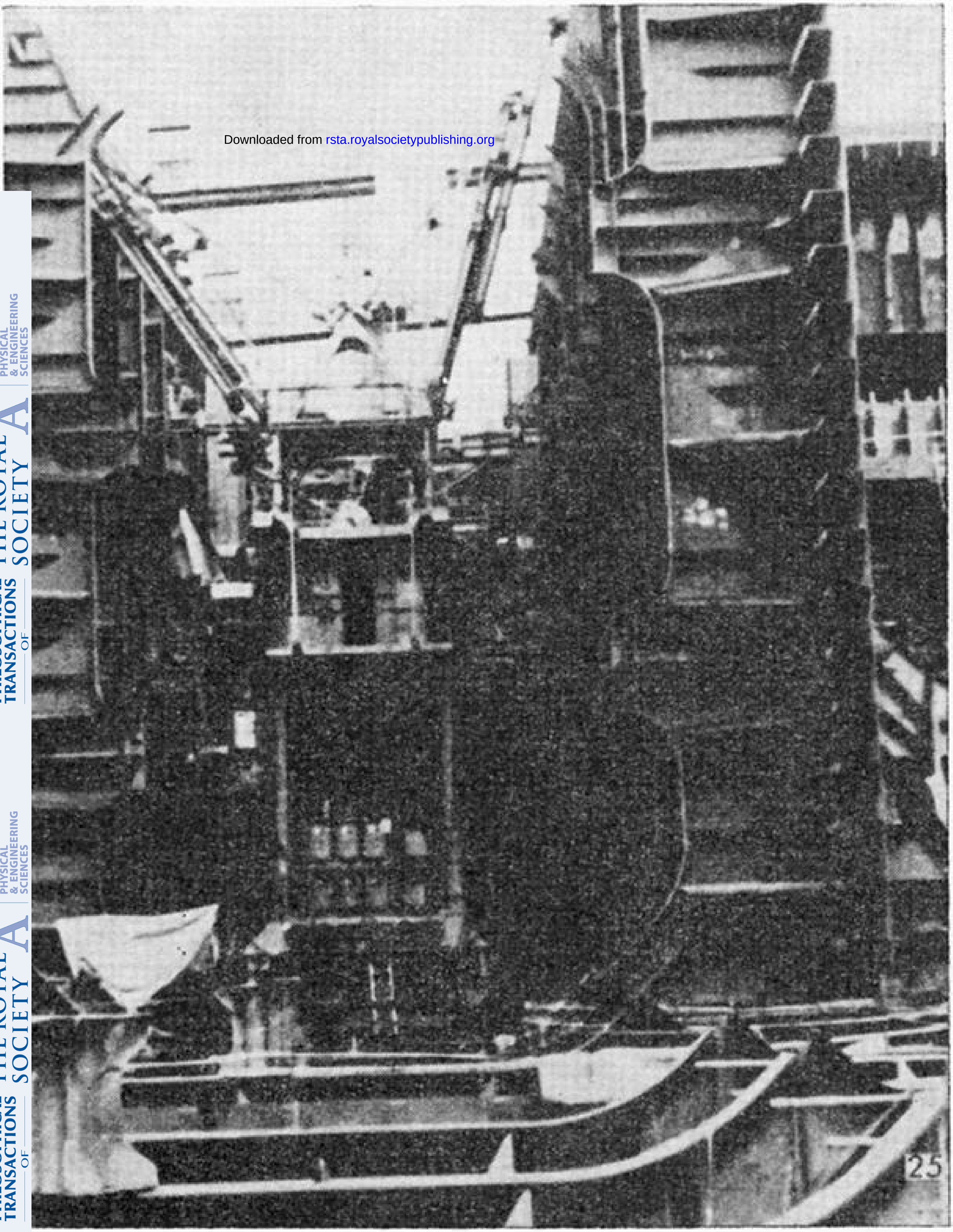

FIGURE 12. Hull construction work-unit for middle part.

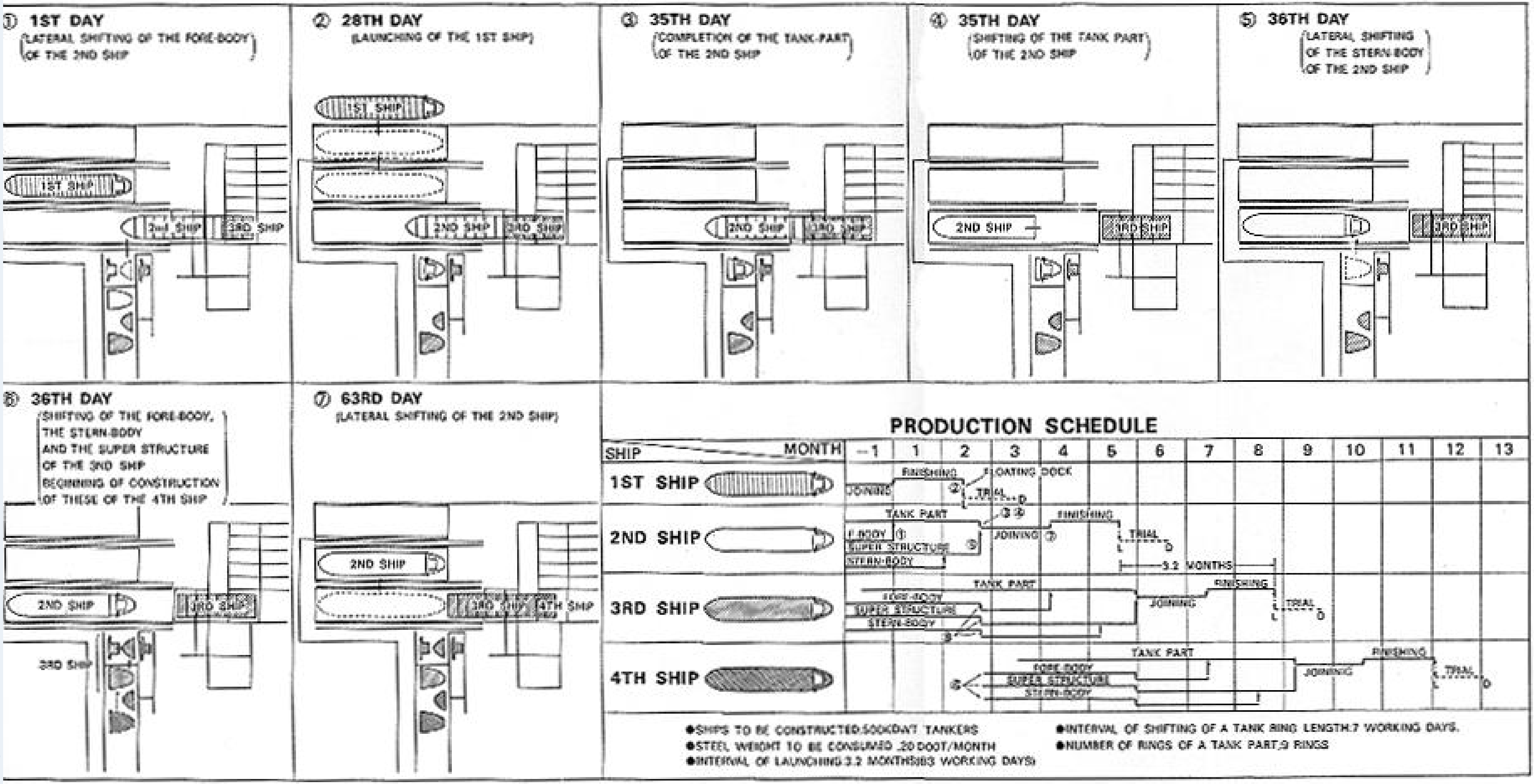

Figure 15. Building process at future shipyard.