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THE PROGRESS OF PRODUCTION TECHNIQUES IN JAPANESE SHIPBUILDING

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A. INTRODUCTION

It is a pleasure for me to read a paper before you today on the progress of the production system in the Japanese shipbuilding industry. In speaking of this progress I am somewhat self-conscious, because I have been closely connected with it myself. However, to give you a better understanding of the history of this progress, I can think of no better way than to explain it by tracing my own technical remembrance. I shall be very happy if you would be generous enough to allow me to proceed with an explanation in this way.

In 1946, General Headquarters of the Allied Occupation Forces (hereinafter referred to as G.H.Q.) instructed the former Harima Shipbuilding Co., Ltd. in Aioi (hereinafter referred to as Harima) to refloat and scrap sunken naval vessels in the vicinity of Kure, where there was a major former Japanese Navy base, and to repair vessels under the repatriation program. For the purpose, G.H.Q. authorized the use of the shipbuilding and repair facilities within the former Japanese Navy base, which is the area now being operated by IHI as their shipyard and machining factory.

I was appointed by Harima as the Chief of the Refloat and Scrapping Section and simultaneously as the Deputy Chief of the Technical Department at Kure. I was thirty-five years old at that time. In those days, private shipyards were authorized only to engage in the construction of fishing boats, coastal service ships, or repair work on ships under the repatriation program.

While I was engaged in that business, the Korean War broke out in 1950 and the policy of G.H.Q. was substantially changed. Under this policy change, Japanese industries were stimulated and Japanese private shipbuilders were authorized to build new ocean-going vessels, most of which were financed and subsidized by the governmental special account established as a counterpart of the so-called GARIOA and EROA funds (Government Appropriation for Relief in Occupied Area fund and Economic Rehabilitation in Occupied Area fund). However, Kure was not authorized to build new vessels because Kure had been one of the Navy yards.

In the autumn of 1949, National Bulk Carriers, Inc. (hereinafter referred to as N.B.C.) approached the Japanese Government to lease the shipbuilding facilities of the former Kure Navy Yard for the construction of vessels for its own use. For the promotion of the economic restoration of the Kure district, which had been deeply depressed due to the surrender, the government formally authorized the application of N.B.C., in August of 1951. Thus, the Kure Shipyards Division of N.B.C. was born and a part of the Harima staff was transferred to N.B.C. I joined N.B.C. as the Japanese Chief Engineer and was concurrently in the position of representing the Japanese engineers working for N.B.C. This was the starting point of my involvement in new shipbuilding after the end of the War. Also, this was the starting point of the development of modern shipbuilding activities in Japan.

Before the end of the war, I had been engaged in the building of merchant vessels as a member of the basic design department until 1941, after that as a production planning engineer for the Navy between 1942/43, then as production superintendent at Harima Aioi Shipyard. In the autumn of 1944, the government decided to divert the shipbuilding engineers and facilities for the production of airplanes (small fighters) and I was also mobilized in January of 1945 for the purpose.

While I was analyzing in detail the complete sets of basic design drawings and engineering data for contemplated airplanes, which were supplied by the Navy, I noticed that engineering information and data issued by the engineering department were in full coincidence with the detail items for the production system. In other words, I was strongly impressed by the fact that all necessary information and data required for each stage of the production system, such as material flow, fabrication, sub-assembly, assembly, and final erection, were clearly described in detail sheets by breaking down the basic design drawings, which essentially deal with the finished product (that is, with the functional design of the airplane). Actually, this practice might have been a copy of the production system and the way of providing necessary information and data for production in the American automobile and aircraft industries.

The idea that such a production system might be applied to shipbuilding was implanted in my mind, and this became a guiding principle in my study to prepare for the day when new shipbuilding at Kure might be authorized. With the commencement of negotiations between the government and N.B.C., I started with several of my assistants to develop my idea, modifying the conventional shipbuilding system by introducing elements from the aircraft production system. Preliminary plans were developed, and these were deemed applicable for actual production by N.B.C. when negotiations with the government were finally successful.

It is my belief to this day that the initial appreciation and encouragement of our idea by Mr. Elmer L. Hann, the representative of the N.B.C. project in Kure and the leader of the shipbuilding engineers in the new N.B.C. Kure shipyard, was the starting point of the modernization of Japanese shipbuilding technology.

B. APPLICATION OF THE NEW SYSTEM TO HULL STEEL WORK

As its first application, the new system was applied to hull steel work, which was clearly divided into five stages, namely, mold loft, fabrication, sub-assembly, assembly, and erection. Each stage formed an organization consisting of a superintendent with the necessary staff, and was allocated the necessary area and facilities. Details of the work to be done at each stage were clearly documented, and all necessary information and data required for the work within each stage of production were provided. Based on these data and the master schedule of hull steel work which shows the sequence and timing of the erection of each hull assembly unit, each stage was managed under the responsibility of its own superintendent. In other words, each stage was regarded as an independent workshop. Manning or allocation of workers required for each type of job within each workshop was planned and executed under the responsibility of each superintendent.

The procedures required for this system have since been refined and computerized, and the way of production has been automated to a large extent. Consequently, the physical appearance of new shipyards in Japan are quite different from that of the early phase of N.B.C., but the basic criteria of the production system still remain unchanged.

At the outset, most of our energies were concentrated on maintaining the accuracy of the production schedule and the accuracy of geometrical dimensions of each piece and each unit at the earlier stages of hull steel work. Even though the actual techniques used for these ends were very primitive, yet we could achieve epoch-making reductions of the manhours required per ton of steel work of the first hull, a 38,000 DWT tanker which was the largest in the world at that time.

The next item we approached was quality control in welding. The quality of Japanese steel material at that time was not adequate to respond to manual welding rods imported from the United States and to the submerged arc welding technique introduced so that we were troubled by many problems. These problems were more diverse and frequent than can be imagined by engineers today. However, the weldability of Japanese steel material was rapidly improved by joint research of the staff members from both industrial and laboratory sides and most of the troubles were cleared up by 1954-1955. For this improvement, activities and joint research by the members of The Society of Naval Architects of Japan, The Japan Welding Society, The Japan Welding Engineering Society, The Japan Iron & Steel Federation, MOT and MITI, are deeply appreciated. And in some respects, this joint research work was one of the most important Japanese industrial improvements, not only for shipbuilding but also for the steel industry in general.

All data necessary for production at each stage were worked out manually. Apart from the low wage rate of Japanese labor at that time, the manual process was effective enough, and was actually more able to cope with the trial and error that was necessary before the system was improved and refined. This principle was followed in the application of the new system to the outfitting work, and also in the development of other new production systems.

At present, of course, the process itself is almost fully computerized. However, the accuracy of the production schedule for each piece and each unit during the earlier stages of hull steel work, and the accuracy of geometrical form, are still the underlying principles that permit the reduction of building costs and the rationalization of the entire production operation, including outfitting. In order to achieve these basic aims, it is absolutely necessary to resolve all problems within each production stage, and also problems at the interfaces between production stages. Those problems should be analysed, pragmatic and technical solution methods should be established, and then these should be applied so as to improve the production system partially or totally.

In order to achieve this process of production management, we appointed several veteran university graduates as team leaders, and organized separate working organizations for the production superintendent of each stage to pursue and trace the problems. Thus, we achieved the original plans, and arrived at effective, workable situations. Through this study process, new methods of production and rearrangement of production facilities were suggested. The accumulation of such improvements, together with continued innovations created from time to time in accordance with changes of the industrial environment around the Japanese shipbuilding industry, resulted in a modern form of shipbuilding technology quite distinct from the techniques of earlier days.

The bending of steel plates by line heating, gravity welders for contact fillet welding, etc., are some of the results of these early studies, and they are still widely used today.

C. APPLICATION OF THE NEW SYSTEM TO OUTFITTING WORK

The conventional outfitting system was to procure or fabricate outfitting pieces in accordance with a system drawing prepared to show the function of each system aboard the vessel, and to install and finish them aboard the vessel after the structural steel work was nearly completed. The task forces to undertake this work used to be organized under each foreman in the outfitting shop under the supervision of the shop manager.

At the start of the operation by N.B.C., the new system was rapidly applied to hull steel work, but the outfitting system was left untouched for some period. However, as the downward tendency of the learning curves of manhours required for outfitting was far less than that for hull steel work, we started to work out a completely new system for outfitting. The first thing I did myself was to go into the pump rooms and engine rooms of vessels under construction and stay there at least for one or two hours every day, because these areas were the most complicated zones to outfit and the greatest effects were expected by applying a new system to these areas.

The idea developed after several months of study was to finish the outfitting work zone by zone. In other words, it meant to divide the whole vessel into several zones and to prepare composite drawings for each zone by disintegrating conventional system drawings into predetermined zones and reassembling these disintegrated drawings zone by zone, regardless of system functions. Accordingly, the composite drawing for one zone included all such information as main engine, auxiliary machinery, piping, pipe bands, electrical cable, cable hangers, ventilation trunk, gratings, etc., so long as they were in the same zone. Procured material was put into separate pallets in accordance with the time when it was required in the production sequence and the zone in which it belonged. Such pallets were brought into the zones only at the proper time and place.

During the course of this change of the system, special emphasis was put on the adjustment of timing between conventional design (developing what functions each system of the vessel should have) and another type of design (preparing composite drawings for each zone, and data for material control, to be developed from drawings for each function in accordance with the outfitting schedule of the zones). The gap between the conventional and new system was so big that extraordinary energy and considerable time were required to persuade many engineer to follow the new system. However, as this zone-based outfitting system gradually materialized, such new ideas came forth as to install outfitting pieces on hull erection units while they were lying on the ground to eliminate difficulties in installing them after the erection of the hull unit. Particular zones having auxiliary machinery and complicated piping could be completed as one unit on the ground, then placed on board before overhead steel structures were installed. Thus, the effectiveness of the new system began to be appreciated among the engineers.

Over the course of time, the new outfitting system based on this idea was gradually expanded from engine rooms and pump rooms to cargo tanks, deck outfit and accommodation, and the system was nearly completed by 1956-1957. In working out this new system, my starting point for the idea was that every outfitting piece in every part of the vessel is, when completed, always accessible without the use of scaffolding. Accordingly, by completing otfitting work zone by zone as hull work advanced, no stage planking should be required for outfitting work, except in special cases. When I visited New York City for the first time in 1956, the production system used for skyscraper buildings was very impressive to me, and made me quite confident of my new method.

This method of outfitting was deemed to have been completed when we built two suction hopper dredgers with discharge booms, "Zulia," and "Icoa," from 1958 to 1961, for exploiting the Orinoco River in Venezuela.

By this time, there had been considerable change in the general concept among the N.B.C. staff regarding how to build ships. In essence, they had come to realize that the performance of any ship, and the cost to build it, depended not only on how the basic design department chose to provide the required systems for the vessel, but also on how the production engineering department chose to advance the outfit work from the commencement of the work order to the completion of the vessel. Thus, the traditional attitude among shipbuilding engineers, namely, that production control should be based on hull steel work alone, was completely thrown away. At this stage of progress, building costs at the Kure Shipyards Division of N.B.C. showed marked differences from those of other shipyards.

It should be emphasized that to achieve this system it is absolutely necessary to supply composite drawings for each zone and to supply material in a form ready for installation, in pallets, at the required spot on the ship or at any other work site, at the precise time required by the outfitting master schedule. This in turn is only possible by proper material control and work flow control in the fabrication shops, conducted and supported by proper activity of the engineering department. Here, material control eventually includes procurement of pipes, pipe fittings, sheet metal, electrical cables, and all other material as well as control of shop production schedules inside and outside of the shipyard.

D. TECHNOLOGY TRANSFER

In the agreement made between the Japanese Government and N.B.C. for the lease of the former Kure Navy Yard for the purpose of construction by N.B.C. of vessels for its own use, there was a clause, from the stand-point of technology transfer, that N.B.C. should open the door to Japanese shipbuilders visiting the yard and asking questions on technical matters. Accordingly many engineers from other shipyards visited Kure and stayed there for a long time to observe in detail the progress of the new production system discussed above, and to have earnest discussion with N.B.C. engineers. Accordingsly, the influence of the technical innovation at N.B.C. was gradually transferred to other Japanese shipyards during the nineteen-fifties.

Another factor which promoted this technology transfer was the mutual enlightenment between young engineers graduated from the universities and working for different shipyards. It had been the tradition among Japanese shipbuilders that they could open-mindedly discuss new techniques regardless of the keen competition between their companies.

In those days, The Society of Naval Architects of Japan organized sub-institutions for production technology and production control systems. The achievement was remarkable for all Japanese shipyard operations.

However, it was true that most of the people who were concerned with shipbuilding pointed out that N.B.C. was building vessels for its own use, and that there should be a basic difference in the relative difficulty of rationalization for shipyards building vessels for independent shipping companies, each under a different specification and supervisor. In any case, there had been much progress in other shipyards, too, when compared with the human wave tactics prevailing at the end of the war. By the early nineteen-sixties, all the Japanese shipyards had become fairly competitive with European shipyards in the efficiency of production and, accordingly, in the cost of production. In those days, Japanese shipbuilders, overcoming various difficult economic situations, became able to stand on their own feet by building considerable numbers of export vessels on a commercial basis, being supported by the finance system of the Export and Import Bank of Japan.

In 1962, N.B.C. ceased its activity in Kure and all of the staff members and facilities were transferred to Kure Shipbuilding and Engineering Co., Ltd., which in 1968 was merged with IHI. I worked for N.B.C. as the Deputy Chief until August of 1960 and joined IHI as General Manager of the Shipbuilding Division, following the merger of Harima with Ishikawajima Heavy Industry.

II. PROGRESS IN THE NINETEEN-SIXTIES

A. BACKGROUND

In November of 1960, the merger of Harima with Ishikawajima Heavy Industry was formally signed, and at that time I was appointed as the General Manager of the Shipbuilding Division of IHI. Since then I have been related with shipbuilding as one of the members of IHI. After the merger of Harima and Ishikawajima, major merging between big shipbuilding and heavy industry companies proceeded: three Mitsubishis merged into one, Mitsui with Fujinagata, Sumitomo with Uraga, Hitachi with Maizuru, IHI with Kure and Nagoya.

When I joined IHI, the new company owned two shipyards, one in Aioi and one in Tokyo. Aioi had already undergone its first modernization of facilities during the boom in shipping and shipbuilding circles at the time of the first Suez Crisis, and had a capacity for building vessels up to 100,000 tons deadweight. The Tokyo yard on the other hand had only undergone partial reconstruction of its facilities after the war, and had only a capacity for building vessels up to 40,000 tons deadweight. However, the Tokyo yard had been continuously building small numbers of defence vessels, such as frigates and escort vessels, and was equipped and trained to suit the building of such vessels. Accordingly, Aioi was superior in the productivity of hull steel work and Tokyo was superior in outfitting work. It was true that there was a large gap when compared with the productivity at N.B.C., but it was also true that the productivity was competitive with that of other Japanese shipyards. Starting from this stage, it was one of my principal responsibilities to upgrade the productivity to the level of N.B.C. and to make further improvements by taking advantage of the flexibility as a commercial shipbuilder.

In those days, Japanese shipyards had already become internationally competitive and about one-half of the new building tonnage was for export. However, the technical level of related industries was still backward and there were many technical problems in outfitting components, auxiliary machinery, etc. In this regard, N.B.C. had already been importing standardized machinery and outfitting equipment from leading manufacturers in the United States and these had been almost free from such troubles.

Japanese steel mills at this time had already undergone their first modernization and were in the second modernization stage; hence, there were no problems at all as to the quality and supply of steel material. As to the industrial environment in Japan as a whole, all heavy industries were exerting major efforts for expanded production. Competition between shipyards was intense, too, due to a hungry feeling peculiar to the Japanese. In order to earn dollars required for the expansion of the economy, most export orders were made on a very small margin of profit.

In the nineteen-sixties, the Japanese shipbuilding industry, supported by the progress of the related industries, achieved significant technical progress regarding the types of vessels to build and how to build them. Thus, we were able to continue quantitative expansion and qualitative progress during the first half of the nineteen-seventies. This history will be detailed subsequently.

For reference, the monetary exchange rate during these years was fixed under the Bretton-Woods Agreement, and financing systems by the Japan Development Bank for domestic owners and by the Export and Import Bank of Japan for foreign owners, according to the basic agreement between O.E.C.D. countries, were already in existence.

B. FROM MOLD LOFT TO ASSEMBLY OF HULL STEEL WORK

It can be said that the Japanese shipyards achieved the greatest innovations in every respect during the nineteen-sixties.

The progress of welding techniques as the basic element of production, together with the improvement of weldability of the steel material, caused remarkable innovations in the field of welding techniques in shipbuilding. The appearance of manual electrodes of iron-oxide type flux with a high melting point, in lieu of conventional cellulose type flux, made the wide application of gravity welders possible. Developments such as submerged arc welding machines, one-side welding machines, the introduction of various semi-automatic high-speed welding processes of the gas-shielded type, slag type butt welding for heavy plates, etc., took place one after another, and further progress became possible due to the improved geometrical accuracy of fabricated members by improved fabrication technique. In order to take full advantage of such progress in welding techniques, together with other means to improve accuracy of the geometrical forms, such as computerization of the mold loft, numerically controlled gas cutting, various forms of automation, etc., and to suit the change of painting systems, arrangements and components of facilities in mold loft, fabrication, sub-assembly, and assembly shops were substantially changed. Also in those days, techniques of templating for curved parts and techniques of bending plates, etc., were basically changed to suit the computerized loft work.

In addition to these changes, computerization and automation were further developed and taken into the production system, and conveyor systems and magnetic lifting took the place of conventional overhead cranes for the shifting of material. It is to be specially mentioned that the marshalling techniques used for heavy plate at steel mills were very instructive in this process.

It is to be noted that such techniques as were adopted in the latter half of the nineteen-sixties and in the first part of the nineteen-seventies are still being used today in each stage of production. This means that the changes were significant and also very reasonable.

In order to meet an increasing demand for ships, all the shipbuilders either reshuffled existing facilities or constructed new yards. This modernization of yard facilities, together with the progress of welding techniques and the introduction of computers, achieved rapid innovation with multiplicative effects on over-all productivity.

Increased output of production per unit area, improved accuracy of production, and punctuality in the production flow, substantially improved productivity during these ten years. This may be clearly understood from the fact that the labor requirement per ton of steel material from loft work to hull unit assembly was 12 manhours in 1970 against 18 manhours in 1960, while manhours for steel work in the erection stage changed from 19 manhours per ton in 1960 to 9 manhours per ton in 1970 in our Kure shipyard, for similar type tankers.

Our greatest concerns during these days were, as I stated before, to advance as much of the work as possible to earlier production stages, to maintain the accuracy of timing of the production at the earlier stages, and to maintain the accuracy of geometrical forms of the products, and this approach proved to be the proper way.

C. HULL ERECTION WORK

More accurate timing of the completion of assembled hull units and improved geometrical accuracy due to technical progress of on-the-ground assembly stages also made it possible to reduce net amounts of work in the erection stage. In addition, the introduction of new welding techniques such as electro-gas welding and consumable electro-slag welding reduced the interval between each hull block's delivery to the erection site and its completion.

Accordingly, it became possible to use one building berth as if it were two by pre-erecting the engine room part of the subsequent vessel, where the construction was most complicated, on the same berth before the launching of the first vessel, shifting the pre-erected engine room part to the proper position after the launching of the first vessel, and continuing the construction of the remaining portion of the hull very rapidly. This is the so-called "ship and a half" system of erection.

This system was very effective not only to shorten the overall period on the berth but also to flatten out the fluctuation of the amount of work load on all trades in the whole yard--especially to flatten out the imbalance of required numbers of workers just before and after the launching.

Such high-speed production of hull work definitely proved, in spite of its larger initial investment, that it was by far advantageous to build vessels in flat-bottomed building docks rather than on inclined berths. Newly constructed shipyards from this time on adopted building docks, and also many existing shipyards having slipways converted them into building docks, in spite of some unusual layout of the yard after the conversion.

The big difference between the construction of ships on slip-ways and in building docks is in the scaffolding which always causes worker hazards and problems during the erection stage. Besides, the launching of a large ship from a slipway is always risky and expensive.

D. SCAFFOLDING

As a result of study to reduce the amount of erection work, which was nothing but the repetition of erecting and finishing of units, by improving the accuracy of the hull units it has become possible to discover exactly what types and amounts of work are really required for fixing each erection unit into the hull. Accordingly, it became possible to know the exact types and locations of the staging to be attached to the hull units while they were still lying on the ground, and thus to keep scaffolding work during the erection stage to the minimum. This idea was rapidly adopted since it places special emphasis on safety. However, up to that time we could not eliminate the most hazardous job, dismantling of the internal scaffolding.

As to the vertical ship sides, it was possible to limit the work on the stage to butt and seam welding of the units only, and portable staging to travel fore and aft on the flat bottom of the building dock was designed. Two sets per side were enough for this purpose. In addition, it became possible to improve the accuracy of timing of the work on the stage by controlling the schedule of the shifting of these stages. Accordingly, this represented a significant advantage from the stand-points of both production control and safety.

As for the staging required for internal work, this problem took a fairly long time to solve. Net manhours for erection work required on internal stages had been reduced to such an extent that they were considerably less than those required for staging and unstaging, so we started a study to develop large movable work units with complicated mechanisms, first for tankers as it was believed that this application would be easier to develop and much more effective than in the case of bulk carriers.

Parts of the structural design, including the system of erection block division were changed to suit the work units. In addition, big changes in the erection sequences and techniques were required, and we asked for the cooperation of the workers by stressing that such changes were necessary from the viewpoint of safety. By installing on these work units heavy tools such as hydraulic jacks, automatic and semi-automatic welding machines, etc., which could hardly have been used before for internal erection work, amazing improvements in the erection work were achieved.

Based on this idea, staging outside of the fore and aft parts of the vessel was also largely changed. These changes were achieved during the early part of the nineteen-seventies. Later, work units for the hold parts of dry-cargo vessels were also designed, and are being used now with some modifications.

Thus, we could substantially reduce the labor requirements of erection work from the conventional value of 19.4 manhours per ton in 1960 to 5.4 manhours in 1970.

E. OUTFITTING WORK

As for the control system for outfitting work by zone as stated in the previous chapter, there was a big gap between N.B.C. and other Japanese yards, including IHI, in the early part of the nineteen-sixties. This was because the timely procurement of outfitting equipment was, until about 1960, a little difficult in Japan due to the backwardness of the related industries. Furthermore, other yards were somewhat reluctant to start the new control system, finding an excuse in the difference in relative difficulty between building vessels for their own use and building vessels to order for various owners.

At IHI, as the first step to procure necessary outfitting components on time and in the configurations required for zone contol, we started in the Aioi area to consolidate a group of exclusive and technically specialized sub-contractors. These sub-contractors were supplied with piece drawings showing the configuration just before palletization, as developed from composite drawings for each zone, together with the order list showing when and where such pieces were to be delivered. Teams were organized to advise the sub-contractors as to technical matters, to control the timing of delivery, and to take care of material supply for them so that the aims of zone outfitting could be achieved without fail.

For the outfitting of the most complicated engine room areas (consisting of several zones), pump room and accommodation (each consisting of two or three zones), composite drawings together with material lists only were issued; conventional drawings prepared for each function were handed only to engineers above the superintendent level. Accordingly, no other production activity could take place than that defined in the composite drawings. Due to inexperience, however, there was considerable confusion during the early period, but the new system was adhered to and promoted stubbornly for two years.

Improvements and amendments to the facilities in the fabrication shops were also made, and new organizations to control the pallet system for yard-fabricated and sub-contracted outfitting material were created.

Of course, team organizations of the workers were suitably altered from functional control to zone control. This necessitated a drastic change in the combination of worker skills in each team. Workers were retrained so that they could manage to do multiple jobs or at least tack welding and gas cutting in addition to their proper jobs. This change was possible due to the flexible attitude of the Japanese union.

Thus, we were able to develop a control system for zone outfitting, getting on the right track from the design department to the production department, but, as stated before, extra manpower was required in the drawing office to convert conventional drawings to composite drawings. At first, this extra manpower entailed added costs, but as the system took root, the reduction in outfitting manhours began to outweigh these costs. Finally, a great reduction in the overall cost was achieved.

As this control system became familiar to engineers and workers, any interference between the drawings and actual outfitting, better ideas for outfitting, etc., were fed back to the engineering department. Such data were accumulated as useful knowledge for the subsequent improvement of drawings, material control systems, safety guards, manpower efficiency, accessibility after the completion of the vessel, etc., and became a solid basis for the outfitting system as seen today.

Unexpectedly better ideas were also produced over the course of time by limiting, for instance, the angles of pipe bends to ninety and forty-five degrees only, reducing the number of stage planks for each zone, etc.

As these processes developed, a new big change appeared to improve mutual relations between hull work and outfitting work. It was the conventional system to arrange piping along the inside of shell, deckheads, bulkheads, etc., but the new idea applied to pumps, piping, and grating in the cargo pump room and to L.O. purifier systems in the engine room, etc., was to select the pump or the purifier as a core and to complete surrounding piping and outfitting in a high quality unit on the ground, independent of the hull structure. Thus, it was possible to reduce the overall cost to the minimum by placing these units aboard the vessel before the erection of the deckheads above them.

In cases when boilers and generators were to be placed on intermediate decks in the machinery space, it was the practice to arrange piping under the deck. This meant not only inefficiency in outfitting but also poor accessibility in maintenance. By installing piping on deck, together with the necessary grating for access, not only building costs but also repair and maintenance costs could be reduced. Many such improvements were achieved by the flow of imaginative ideas of the young engineers through the feedback system between the design and production departments.

At this point, foremen and leadermen were released from the burden of material location, which had consumed much of their efforts under conventional outfitting from system drawings, and they could then concentrate on quality control and increased production. This contributed to the efficiency of the whole outfitting operation, in terms of both ship performance and cost.

At this stage it was noticed that the application of the new system to engine rooms and pump rooms where there was the most stringent limitation of space was far easier to achieve than expected. By contrast, it took a long time to achieve similar benefits for outfitting on deck where there was little limitation of space. It was somewhat surprising to find that the apparent inconvenience of restricted work spaces produced the most marked improvements under the new system.

Of course at this stage each hull block, before erection, was considered as a zone. Accordingly, all outfitting components which could be installed on the block were attached to it on the ground. Thus, although building speed in the dock became high and the time required from keel laying to launching was drastically shortened as stated before, almost all vessels of the standard type could be delivered within one hundred days after launching.

In the latter half of the nineteen-sixties, the supply and quality of outfitting elements rapidly improved due to the general progress of the Japanese heavy industries and the increased amount of shipbuilding and petrochemical plant building. This accelerated the progress of outfitting both in quality and cost.

From the middle of the nineteen-sixties, with no excuses as in the days of N.B.C., other shipyards also started to change to the new outfitting system, and the productivity of all shipyards improved in the later part of the nineteen-sixties or in the early part of the nineteen-seventies. The following table show a comparison of total manhours required for outfitting work and combined hull and outfitting work for standard type tankers in 1960 and in 1970:

1960	-	150	MH per ton of outfitting weight
1970	-	120	
1960	-	50	MH per ton of total weight.
1970	-	30	

In this table, outfitting weight includes only items which are related rather proportionately to normal outfitting works. Excluded are painting and such heavy equipment as deck machinery, main engine, boiler, auxiliary machinery, generators, anchor and chains, etc. Manhours for painting work are not included in the above figures because painting practice changed drastically from 1960 to 1970.

Mutual relations between the expansion of related industries and this new system for outfitting eventually brought about standardization among the suppliers. The ratio of the inventory of material required for outfitting against the total amount required per month was greatly reduced and thus the yard's financial burden during the construction period was lightened.

III. PROGRESS IN THE NINETEEN-SEVENTIES

A. HULL AND OUTFITTING WORK

As I stated before, the Japanese shipbuilding industry, supported by the progress of related industries, had largely completed its framework of internal improvements by the beginning of the nineteen-seventies. Thereafter, more attention was given to detailed refinements of the underlying system.

By this time, design and production techniques had become relatively similar at most major shipyards with some differences in the details. At the same time, due to rapid economic progress, the wage rates of Japanese labor became nearly equal to those in advanced countries, and the manual engineering process described above was forced to give way to computerized processes, expecially for outfitting work and for hull work on the ground. As a result, at IHI, computer-aided design systems for hull and outfitting, called "Hull Total System" and "Seabird System," respectively, and material control by computer were introduced. This development is still going on, with the goal of improving the effectiveness of the computer as an aid in design and production.

During this period, two important research programs were undertaken in Japan. The first was the search for a system of determining the required scantlings of internal structural details. In this respect, international classification regulations could not effectively deal with the rapid increase in the size of vessels. During the latter half of the nineteen-sixties and the early part of the nineteen-seventies, various problems with hull structures arose everywhere in the world. A code substantially applicable to these problems was completed by joint research of the Society of Naval Architects of Japan, the Shipbuilders' Assocation of Japan, Nippon Kaijikyokai (NK, the Classification Society of Japan), and by the leadership of the Ship Bureau of the Ministry of Transport. The code standardized the external conditions used for the strength calculation of the internal structures, and improved the accuracy of the calculations.

The second major development was the remarkable progress of hydrodynamic research. Up until this time, there were only three laboratory tanks, two belonging to the Ministry of Transport and one to Mitsubishi. In the towing tank opened in 1966 by IHI, computerized model making techniques and computerized measuring systems were developed and the productivity of the towing tank was rapidly improved. To compete with this, other major shipbuilding companies were inclined to have towing tanks of their own, and Hitachi, Kawasaki, Mitsui, and Nippon Kokan now have their own towing tanks and laboratories for hydrodynamic research.

Although it has been only a short time since the start of research at these test tanks many useful results have been gained, largely related to the improved propulsion efficiency of vessels built in Japan since the early part of the nineteen-seventies. It is expected that there will be further progress in this field, accelerated by the competitive spirit between the companies. Expecially it is to be noted that there has been rapid progress in the study of hull stern forms, in conjunction with progress in the design of rudders and propellers.

IHI first developed at the beginning of 1961 the design of an economical hull form for large tankers with small L/B ratio but having a large bulbous bow. This achieved a remarkable cost reduction for a given deadweight by reducing hull steel weight while maintaining a given speed with the same horsepower. Since then ship forms with bulbous bows have become commonplace in the design of large and medium size ocean going ships of all types all over the world. In Japan in recent days this hull form is being applied even to ocean going fishing boats, expecting to save at least 25 per cent of fuel costs. Through the progress of research at these test tanks, the design of hull forms, which had long been done by trial and error, became possible by systematic processes with the aid of computers.

From the nineteen-sixties to the nineteen-seventies, the increase of tanker sizes from VLCC to ULCC and the development of very large high-speed container carriers were achieved in smooth technological steps, without revealing any technical defects. Joint studies of basic technical matters between the Government, universities, classification societies, researchers, and shipbuilders had contributed to this success.

B. PROPULSIVE MACHINERY AND POWER PLANTS

So far I have mentioned mainly the progress of steel work and hull outfitting, but I should refer at least briefly to the progress of propulsion machinery and power plants.

Until the middle of the nineteen-fifties, American shipowners still owned many mass-produced vessels built during the war. As these vessels were nearly all equipped with steam power plants, most of the engineering personnel had been trained in steam. In addition, as fuel prices were relatively low, it was difficult to recommend the adoption of Diesel engines for export vessels. However, as the superior fuel-consumption characteristics of Diesel engines became undeniable, as the internationally known types such as Sulzer, MAN and B&W began to be manufactured in Japan, and with increased horsepower per cylinder, Diesel engines became common as propulsion machinery. Influenced by this trend, rapid improvements were achieved and it became increasingly advantageous to adopt Diesel engines for almost all types of ships.

However, the requirements for high power for very large tankers and container carriers led to a considerable demand for steam power plants as well. Accordingly, progress in the design of boilers, turbines, and reduction gears, and the improvement of production techniques and accuracy enabled Japanese manufacturers to supply trouble-free power plants. Thus, IHI, Mitsubishi, and Kawasaki of Japan, as well as General Electric in the United States and De Laval in Europe, became the main suppliers of turbines and reduction gears for marine use. As for marine boilers, improved Foster Wheeler and Combustion Engineering types became the most common components.

Since 1967, IHI intended to introduce medium-speed Diesel engines as propulsion machinery for ships and thus to remove one of the defects of marine use of Diesel engines by designing a suitable propulsion system with the most efficient choice of propeller speed, through reduction gears. After many changes during the production of the "Freedom" class standard vessels, designs for "Fortune," "Freedom-II," "Friendship," and "Future 32" were developed, all equipped with medium-speed Diesels. About three hundred of these so-called "F-series" have been sold worldwide.

During this period, we finally succeeded, in cooperation with the licensor, in uprating power per cylinder from 500 HP to 1500 HP. The total number of such Diesel engines manufactured by IHI until today amounts to 642 sets, and the total horse power reaches 4,600,000 shaft horsepower. Needless to say, some of these engines are also being used in electric power plants on land.

As the market share of Japanese shipbuilding reached fifty per cent of the total world demand, the number of marine engines manufactured in Japan has naturally increased substantially. Every effort has been made to promote the advanced design of marine engines and related products, with the cooperation of the licensors. This effort continues today, even at a time of depressed shipbuilding markets.

Under the current international economic situation, fuel cost savings for the marine industry are most necessary. Possible improvements include lower specific fuel consumption for marine engines, more efficient propeller designs incorporating a review of optimum ship speed for the present economic environment, improved hull forms, introduction of more extensive waste heat recovery systems, marine engines based upon a new application of coal fuel, or gas turbines driving superconducting electric generators. All these and other schemes, are being seriously studied for application to a new generation of marine power plants.

IV. ECONOMIC ENVIRONMENT SURROUNDING JAPANESE SHIPBUILDING

Here I should like to describe the correlation between the Japanese shipbuilding industry and matters other than purely technical ones.

From the early part of 1950, a real restoration of Japanese shipbuilding began. This was because G.H.Q., after many changes of its policy, finally and clearly showed its new basic policy for Japanese shipping and shipbuilding, and authorized new shipbuilding. As an incentive for domestic shipowners, the government financed part of the building costs from the governmental special account arranged as a counterpart of GARIOA and EROA funds. The Export and Import Bank of Japan was founded in this year and a system to finance export vessels was established. This, together with the outbreak of the Korean War, expedited new shipbuilding for export. The bank, together with the Japan Development Bank established in 1951, have largely contributed to the prosperous development of Japanese shipbuilding. Incidentally, after the Korean War, shipbuilding in Japan experienced some hard times. For some of the export vessels built during those days a certain part of the building cost was compensated, depending on the level of ship prices, from the government "profit" due to the difference between the buying and selling prices of sugar imported from Cuba. Needless to say, the financial arrangements for export vessels by the Export and Import Bank of Japan have always been made in accordance with the agreement of O.E.C.D.

Japanese shipbuilding is believed to be one of the industries which most enjoyed the favor of the fixed international exchange rate from the middle of 1950 to the cessation of the Bretton-Woods system. Due to governmental restrictions, Japanese shipyards had to sign shipbuilding contracts in U.S. dollars. The shift from the Bretton-Woods system to the Smithsonian system, that is, from the fixed rate system to the free floating system, caused the Japanese shipyards to suffer from tremendous losses due to the unanticipated difference of exchange rates for the deferred part of the contract price, and were put into very difficult financial situations. However, due to an alleviating measure by the government through new tax regulations and with a large number of orders due to the shipping boom, Japanese shipbuilders could, until the first part of 1978, maintain full production without a breakdown in finance and without a reduction in the activity of the yard.

Due to the OPEC strategy of raising the selling price and limiting the production of oil, and international anxiety for the shortage of energy sources, with the rapid decline of the amount of sea transportation Japanese shipbuilders were subjected, from the middle of 1978 to 1979, to a severe depression.

Finally, in 1979, the Government designated shipbuilding as one of the most depressed industries and took remedial measures. Even under such relief measures, large shipbuilders who were not specialized in shipbuilding alone had to take such actions as the layoff of workers, etc., to cope with the depression. These workers who were laid-off due to the curtailing of business were in the same predicament as the workers from the medium and small-sized shipbuilders who had been specialized in shipbuilding only.

The first of the emergency steps taken by the government was to shut down thirty-five per cent of the existing physical shipbuilding facilities. For the shipbuilders who had been specialized in shipbuilding only and who desired to sell the facilities thus shutdown, a Facilities Buying Corporation was created by the government, and private shipbuilders were to buy these facilities.

The second step was to lend Japanese owners the necessary building costs of vessels up to a total of three million gross tons during the three years starting from 1979, and to compensate the interest for the loan, with the condition that they were to scrap the same amount of existing tonnage.

The third step was to facilitate the above scrapping by establishing an organization funded by the government and private industries for the purchasing of vessels to be scrapped and for financing the scrapping operation.

The fourth step was to designate certain cities and towns where shipyards were located as special districts to be taken care of due to the depression, and to provide further assistance in addition to ordinary unemployment benefits.

The fifth step was to organize a cartel to limit the production at the remaining facilities to thirty-five per cent of the annual production in 1976 and 1977. This cartel will, as of this date, be continued until 1981.

As a last step, under some special cases only, exceptional arrangements were made for specialized shipbuilders to prevent the undesirable breakdown of cash flow.

Parallel to the series of steps taken by the government, the management of each shipyard conducted long negotiations with the union to close part of the facilities, to reduce the number of workers, to reshuffle the personnel, to reduce organizations and to reorganize the financial structure, all to cope with the reduced production imposed under the cartel. Thus, with the full cooperation of the government, unions, and communities, the Japanese shipbuilders prepared themselves for the new economic situation.

At the present moment, the problem of the worldwide shortage of energy resources is still unsettled. Accordingly, the international economy is in a very serious condition, the political situation is in many ways unstable, and thus, there is little promise that the shipbuilding market will again become active in the near future. However within the share of the worldwide demand for vessels, Japanese shipbuilders now believe that they can maintain their international competitiveness, balance their finances, and survive until the time when the international economy may take a turn for the better.

V. HUMAN FACTORS

Most of the unions in the Japanese shipbuilding industry belong to the Japan Confederation of Shipbuilding and Engineering Workers Union. Some of the unions of medium and small-sized shipbuilders belong to the General Council of Trade Unions of Japan.

Originally, the Japanese unions were the house unions of the individual enterprises, rather than unions for each craft. These unions in turn organized larger groups to cover them. The house unions of most of the shipbuilders organized the Japan Confederation of Shipbuilding and Engineering Workers Union, which belongs to the Japanese Confederation of Labor, forming the basis of the Democratic Socialist Party. It is also a group member of the Internation Metalworkers' Federation-Japan Council. The union is more pragmatic than ideological, and its basic policy is to give precedence to productivity increases in all matters. As long as employment is maintained and improved working conditions are achieved as time passes, the house unions cooperate with management to obtain increased productivity. Throughout Japanese industry, most of the private unions, especially the unions of the larger companies, share the same guiding principles as the Japan Confederation of Shipbuilding and Engineering Workers Union.

Most of the young workers in the nineteen-sixties and almost all of the workers today have received twelve years of education and are qualified for the entrance examinations of the universities.

The racial uniformity and high educational level of the labor force are characteristics of the Japanese industry. This is one reason why innovations in the shipbuilding system could be achieved reasonably without wasting time. It is also one of the decisive factors in the high productivity of all industry in Japan.

In the middle of the nineteen-sixties, as explained before, the amount of shipbuilding was rapidly expanding and the international competitiveness was improving under the fixed exchange rate. On the other hand, however, the frequency and severity of labor accidents in the yard did not show a tendency to decrease. It could be said that the expansion and the competitiveness of the industry were based on the physical energy of the workers.

Even compulsory enforcement of the various measures for safety guards provided only a temporary improvement.

At IHI, we began a significant program of safety improvement when the new production system was instituted, and particularly after the retraining and reorganization of workers to suit the new system. It happened to be just at that time when questions of the quality of life and autonomy in the workplace were arising among the workers. As a concrete solution for such problems, five to eight workers sharing the same work space and doing the same or similar jobs were organized into so-called "small groups." This was in 1967. These small groups were neither military nor pyramid-like organizations of foremen, leaders, senior, and general workers. We gave the small groups places and times for free discussion about working facilities and techniques, especially about transportation facilities and the ways of shifting heavy items in their own workplaces, all from the standpoint of protecting their own bodies from accidents. Immediate steps were taken to remedy all problems identified by such studies in small groups, regardless of the expense required. We also organized a team directly under the production manager or yard manager to promote the activities of the small groups.

At the same time, special seminars were held for the foremen and the leadermen, who had responsibility for the workplace and the ability to give technical advice, to guide them in how to promote the small group activities. They were trained to take an advisory rather than an instructive stance in relation to the small group activities. Further, foremen and leadermen within the same yard were also grouped according to their types of jobs for the same purposes as the small groups among the general workers. Proposals submitted by these groups were considered with the first priority and every effort was exerted to improve working conditions as rapidly as possible. In order to promote the spread of good ideas, and to initiate the proposed improvements, general meetings for the announcement of new measures were held at least once a month.

At the start there were various inconsistencies, but the activity took root far earlier than had been expected. It was felt that the workers, who had previously had no way of realizing or instituting their own proposals and thoughts, had been given a voice in a very useful way. As stated before, almost all workers had a twelve year education, they had their own good sense, and their participation in the improvement of the production techniques and working conditions gave them greater satisfaction in their work. The results of this program of worker involvement exceeded our expectations.

As a result of these activities workplaces were cleaned up, all unnecessary items were removed from working spaces and everything was put into order according to the needs of the workers directly involved. It turned out that while realizing the workers' proposals a number of unexpected benefits appeared with the result that overall benefits far exceeding the expenses were gained.

Accordingly, there was a steady, long-term improvement of safety records, and the overall aims of safety management were finally realized. At the same time, there was a firm tendency towards improvement of both productivity and quality control. It took from two years in some yards to three years in others to obtain the full benefits. This movement was expanded to the whole company, and by 1972-1974 the effect of this activity was essentially complete.

Just before and after 1970, when there had been excited arguments about the division of market share between Japan and the countries of the European Community, the Japanese side, sponsored by the Shipbuilders' Association of Japan, invited various staff members from European yards to see the Japanese shipyards. Their first impression was, not to speak of the technological progress, the neatness and tidiness of the workplaces and the reasonability of the manning there. In these days the activity originated by IHI had spread to nearly all Japanese shipyards. For your reference, the curves of accident frequency as indicated by the number of workers injured due to accidents per million working hours, and the severity as indicated by the number of working days lost by accidents per thousand working hours are shown in Figure 1.

Essentially, productivity is the result of the combination of three elements: safety control, quality control, and efficiency control. The true aim of our starting small group activities was the improvement of productivity in terms of this wider meaning. At first, however, we emphasized the aspect of safety in order to eliminate unnecessary troubles with the

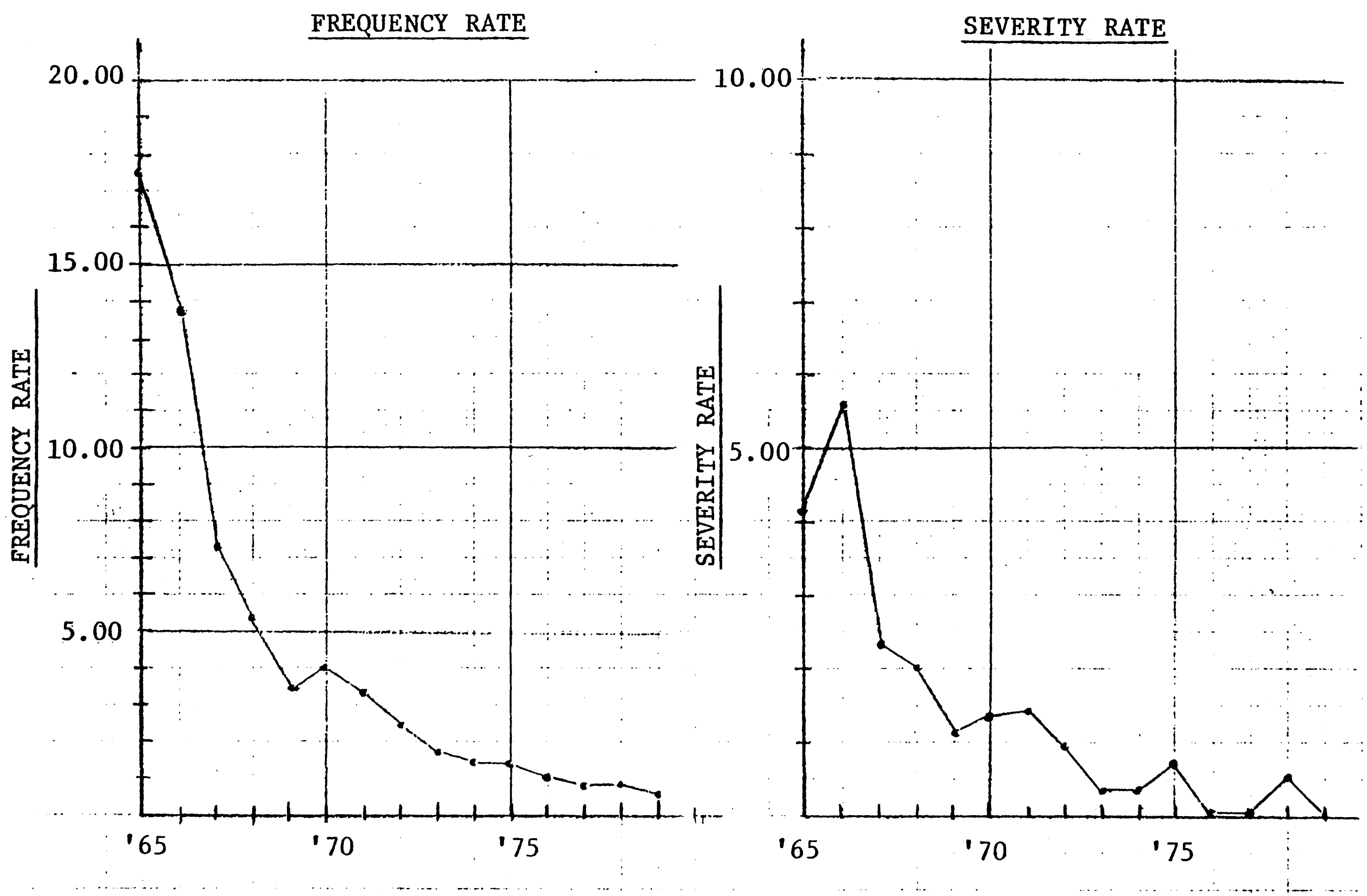

Figure 1. Accident frequency (worker injuries per million working hours), and accident severity (working days lost due to accidents per thousand working hours), versus year.

union rank and file. It is needless to say that we had explained the broader aim to the leaders of the union and had reached a consensus. In our industrial setting, safety control, quality control, and efficiency control are really the same thing, observed from different viewpoints. As the production circumstances and the reasonability of the movement of the workers therein improve, all three of these factors naturally improve, maintaining a balance between them. Accordingly, by first emphasizing safety, which is easily acceptable to the workers, and by leading the contents of their discussions tactfully to other aims in accordance with the progress of each group, long-lasting improvements of productivity can be expected. At the present moment, more emphasis is being placed on quality control.

This small group activity is being promoted voluntarily in all Japanese industries, and it is not an exaggeration to say that this is one reason for high productivity in Japan. Of course, the detailed way of leading this activity may vary in accordance with the type of industry involved, but this activity is very popular as the so-called "J.K. campaign," meaning voluntary management campaign. This example is one of the most peculiar features of the Japanese labor relationship.

VI. HISTORY OF MARKETING/BASIC DESIGN/PRODUCTIVITY

A. N.B.C. ERA

The management of N.B.C. as a shipping company with the added capability of new shipbuilding had been led by the superhuman Mr. D.K. Ludwig. The period when I was working as the Deputy Chief of the Kure Shipyards Division (1950-1960) was just the period when he was exerting all his efforts to expand his fleet amid the high growth of the worldwide economy. His basic idea then was to gain maximum economic results from the freight agreement based on the freight rate per ton of cargo from one port to another. For this purpose, he always aimed to build ships of maximum deadweight with optimum speed insofar as port conditions, building facilities, and design factors permitted. He built several vessels each of 38,000 DWT tankers, 45,000 DWT ore carriers, 60,000 DWT ore carriers, 87,000 DWT tankers, 100,000 DWT tankers, etc., successively, and these vessels were always the largest in the world when built.

From the viewpoints of freight rates, building costs, and fuel prices at that time, a speed of 16 knots was optimum for these raw material carriers. This speed was adopted for all large raw material carriers until the end of the nineteen-seventies without any reinvestigation. It was only after the rapid raising of oil prices by OPEC that this speed was widely restudied.

At any rate, at the very starting point of the expansion of the world economy during the nineteen-fifties, he succeeded in leasing a shipyard having the capacity to build vessels of more than 150,000 DWT, and in building up a fleet of large vessels at a speed no one could imitate. His foresight and courage should be highly appreciated in terms of his effect on the course of the expansion of the worldwide economy. It is also to be specially mentioned that during this period of rapid progress in shipbuilding techniques Kure Shipyards Division of N.B.C. was able to meet the rigorous marketing demands made by Mr. Ludwig as a shipowner.

B. AFTER 1960

When I joined IHI in 1960, 47,000 DWT to 60,000 DWT was the average size range of tankers and ore carriers in worldwide shipping circles. Supported by the successful records of the operation of large vessels by Mr. Ludwig, and by the rapid increase of the sea-borne movement of goods for the steel, aluminum, and petrochemical industries, the tendency towards increased size was most remarkable. During those days, IHI had always taken a leading position in the upward tendency in size, and this position was maintained until the outbreak of the second oil crisis.

Existing shipyard facilities were not adequate to meet this growth both in vessel size and in total tonnage, and a rapid expansion of existing shipyards and the construction of new shipyards took place in Japan and in Europe, several of which could even construct vessels of one million tons deadweight. Facilities at the loading and unloading ports were also improved during this period. However, due to the lack of development of basic theories for the design details of large tankers and ore carriers, various troubles with structural details were experienced.

Just before and after 1970, the extent of sea transportation of completed goods became increasingly large due to the development of basic industries, and existing vessels of the cargo liner type became unsuitable to meet shippers' demands both in quantity and speed. The container system was introduced. Due to the relatively low fuel cost, large and high speed container ships appeared, and container ports on the main trade routes of the world were rearranged rapidly. In Japan also many container carriers were built in response to this trend, but no great structural or hydrodynamic problems occurred, as Japan had already completed basic studies of these elements of ship design.

After the latter half of the nineteen-seventies, due to the rapid change in the pattern of the international oil trade, the economic superiority of VLCC's and ULCC's was reduced and a new demand for tankers from 60,000 DWT to 100,000 DWT and product carriers from 25,000 DWT to 35,000 DWT arose. Due to excess shipbuilding capacity as a result of the collapse of shipping since the second oil shock, these demands could be met without any problem. However, there was still a problem in arranging for special internal coatings for product carriers.

Being occupied with the building of industrial carriers and container carriers until 1977, the Japanese shipyards got behind in preparing themselves for the production of liquified gas carriers. This lag in the business side and in technical development and research is still evident to this day.

In the latter half of the nineteen-sixties, as a replacement for many old "Liberty" ships still in service at that time, IHI developed the design for "Freedom" type vessels with medium-speed Diesel engines, and began selling them as a standard-designed ship, with option clauses, a remarkable development in peacetime. Later, "Fortune," "Friendship," "Freedom Mark II," etc., the so-called "F series," were developed and are still being sold. About three hundred vessels of these types have been sold to date. For the development and marketing of these types, we owe much to Mr. G.T.R. Campbell of G.T.R. Campbell International, Ltd., marine consultants, of Montreal. The development of these types, as well as that of the SD-14, can be viewed as one of the memorable events in the history of marketing in shipbuilding.

C. BASIC DESIGN

Contracts for the building of new vessels are negotiated between the owner and the shipbuilder based on a preliminary design by the latter to meet the requirements of the former. The investment in any ship is a serious matter often affecting the destiny of the shipping company, and the requirements presented must take into account the shipbuilder's technical achievements accumulated during commercial negotiations with shipowners.

When a shipping company starts detailed negotiations with a specific builder (there are usually many processes to be followed before the technical and price negotiations start), the shipowner tries to be more competitive by taking advantage of the builder's technical potential, resulting in a combined engineering capability with the shipper. Accordingly, during the negotiation stage, the builder, standing on a common basis with the shipowner, must cooperate, as its social duty, with the owner in order to achieve maximum economic efficiency of the ship. Only this attitude can increase the competitiveness of the builder in the free market. This is a self-evident proposition, yet we often observe situations when the owner and the builder stand opposed to each other.

In order to attain satisfactory results in negotiating the performance of new vessels, it does not require undue effort if a program for the design is established as a module. Even for the modification of requirements by the owner during the course of construction, it is my own experience that the influence of accepting new proposals is far less than generally thought. Nonetheless, it is always advantageous not to disturb the building schedule, and to come to an agreement as soon as possible.

D. RELATION OF BASIC DESIGN TO PRODUCTION SCHEDULE AND BUILDING COSTS

The basic design activity of the shipbuilding company is the core of the vitality of the company. It is the fundamental significance of the existence of the basic design department to pursue the questions of what performance the vessel should have, and how and at what cost the vessel should be built. Thus, the basic design department should be at the core of the activity of the company. In this philosophy, and based on the experience of management in the Japanese shipbuilding industry, the marine consultant system so familiar in the U.S.A. is not very understandable. The existence of a shipbuilder with no such core for the development of basic technical progress is entirely beyond our comprehension.

When Harima Shipbuilding Co., Ltd. was merged into IHI in 1960 and when I was appointed as the General Manager of the Shipbuilding Division, the first thing I stressed was to realize my own thoughts in basic design. At that time, basic industries in Japan were in the midst of expansion, and I took the opportunity to place veteran staff members of the basic design department in direct contact with persons in the oil, steel, aluminum, petrochemical, and electric power industries. Thus, our basic design department was able to cooperate to an extent in the design and construction of factory wharves and loading ports abroad, contributing to the exploitation of the demand for larger vessels. This collaboration is still being carried on. In Japan, the managerial style of the major shipbuilders assumes the form of general heavy industries, and shipbuilding is only a part. In this respect, we are in a superior position with respect to specialized shipbuilders, and there have been many cases when we played a leading part during the engineering negotiations with the shipping companies.

On the other hand, for the purpose of raising productivity in the yard, design data issued by the basic designer can be inadequate, or even hazardous, unless it contains detailed information for the production control system. Expecially in cases when the issue of data is mistimed with respect to the production schedule, the data can be entirely without value. We have had just such bitter experiences when the design for an American owner was done by a consultant. It is our opinion that even when a consultant is employed, the consultant's activity should be confined to basic design which decides the performance and capability of the ship. All production design should be done in the yard. The consultant may check the drawings developed by the shipyard on behalf of the owner.

As I have indicated, the progress of hull construction and outfitting in each shipyard has had its own history, and each yard has, or rather should have, its own practice in the details of production procedures in accordance with its own history and present engineering ability.

Accordingly, any innovation, whether big or small, which may arise within the production process should be systematically reflected in the design details. Conversely, any new progress in the design stage should be incorporated in the production procedures. Thus, the progress of both basic design and the production system should advance in a mutual relationship. I believe that there will be no other way of progress than the systematic accumulation of technical improvement through such a dialectic.