Annual Review

Marine Engineering Progress in 1989 *

This report gives a summary of the major developments achieved in marine engineering technology in Japan and abroad in 1989, prepared by the Editors Committee of MESJ based on the manuscripts written by the chairmen and members of the research committees.

Each section gives an objective summary of researches, indicates the data showing the present technical level and improvements in production and performance of marine equipments, and introduces new products worthy of special attention.

In writing these articles, the authors specially intended to make only a very brief statement concerning advances in the field of fundamental engineering, to make reference as much as possible to the previously published journals of the related societies for research papers and technical informations, and to restrict the introduction of individual products and achievements only to the most representative ones.

The authors express their deep gratitude to the companies for providing them with informations required in compiling this summary.

Contents:

1. General

1. Trends

In 1989, it was a year that was light for shipping and shipbuilding industries which were suffering from a long structural depression.

The profit of the five major shipping companies in the semiannual settlement was improved by the increase of cargo movement, the rise of irregular service and tanker markets, the effect of management rationalization and the good fortune of a drop in the Yen-US. Dollar rate.

In shipbuilding industry, the improvement in settlement was shown by the increase of ship order number and the recovery of ship price.

Concerning topics on the sea, the All Japan Seamen's Union approved the "MARU SHIP KONJO" which both Japanese and foreign crew work together on a Japanese flag ship, formally for the oceangoing ship faced with flagging out quickly.

The regulation of double bottom and double hull for oil tanker is under investigation.

Dry cargo trade volume was with prosperous continuance for ore, with steady chartering demand for grain, with stable growth for coal, and reflected the business upturn. The cargo volume

![Fig.1.1 Trends of Ships Completed](image)

* Translated from Journal of MESJ, Vol.25, No.7.
In North American container service was increased and the freight rates were getting good. In Europe container service, the state of affairs grew worse for many ships. The tanker market was getting better and the WS (world scale) of spot rate for UL, VLCC recorded 102.5 last year.

2. Ships completed 2)

587 ships of 2,000 Dwt and above were completed worldwide in 1989. This totalled 21,917,367 Dwt according to the Motor Ship. This showed an increase of about 15% in number, and an increase of 31% in tonnage compared with 1988. It stopped the tendency of a decrease in number and tonnage.

The figure 1.1 shows the number of ships completed the average Dwt per ship, the average main engine output per ship, and the average main engine output per 1,000 DW.t, for the past ten years.

The average Dwt per ship increases compared with 1988, the tendency towards larger ships has continued since 1983.

3. Propulsive engine type 2)

In 1989, a total of 705 engines amounting to 5,085,864 KW was installed in 587 ships of 2,000 DW.t and above in the world.

The number of engines increased by 48, and the output also increased by 15.4% compared with those in 1988 (508 ships 657 engines 4,405,362 KW).

The average was 1.20 engines per ship with 8,664 KW. 371 low-speed diesel engines totalling 3,573,433 KW were installed in 371 ships. Low-speed diesel engines supplied 70.3% of all propulsion requirements in completed ships as compared with in 1988 (72.6%).

4. Ship completed by country 2)

Japan retained the largest shibuilding nation in number of ships completed worldwide and also took first place in Dwt. 195 ships with 8,583,875 Dwt were completed in Japan. South Korea took second place in both number and Dwt. 75 ships with 6,712,697 Dwt were completed in South Korea.

Both countries (Japan and South Korea) shared 46.0% in number and 69.8% in Dwt completed in 1989. They had 48.6% in numer and 70.2% in Dwt in 1988. Other countries where Shipbuilding output of 400,000 Dwt and over was completed were Yugoslavia, Brazil, Taiwan, Italy, The Federal Republic of Germany and Denmark.

Yugoslavia and Brazil increased their completed tonnage twice as much as compared in 1988.

5. Ship types completed 3)

According to Lloyd's Annual 1989 Summary, which contained an analysis by ship type completed for all self propelled ships of 100 gross tonnage and above (excluding wooden vessels), compared with 1988 the tonnage of oil tankers in 1989 showed an increase of 881,900 grt to 5,013,200 grt and all Increase share to 37.9% of tonnage completed in 1989. Bulk carriers increased by 1,590.6 grt to 3,885,700 grt and represented 29.4% of all tonnage. Included in the above total was 4,170,000 grt of combined bulk/oil type ships. General cargo ships decreased by 715,000 grt to 1,180,000 grt and shared 8.9% of all tonnage. Container ships totalled 1,247,000 grt, 225,000 grt less than in 1988.

6. Ships on order in Japan 4)

Ships on order in Japan accounted for 267 ships of 8,258,000 grt during 1989. This was 57.1% increased in number and 78.7% increased in tonnage compared with 1988.

The above figures were of ship construction permits issued by the Ministry of Transport (Ships of 2,500 grt and above or of 90m length and above).

The total consisted of export ships of 7,677,000 grt which were supplied 3,795,000 grt more than in 1988, and domestic ships of 579,000 grt 7161,000 grt less than in 1988. In terms of the type of ships, oil tankers increased to 4,150,000 glt drastically from 1,862,000 grt in 1988. General cargo ships rose to 4,054,000 grt from 2,760,000 grt.

7. Other 1989

7.1 New generation 125,000m3 LNG ship

Three LNG ships of 125,000m3 for Northwest Australia Project were delivered. This project supplies 6 million1ts tonnage natural gas per year from the offshore field of Dampier in Northwest Australia to Ausralia and J apan.

The first ship for ALSOC (Australian LNG Ship operating Company Ltd.) and the second ship for NYK (Nippon Yusen Kabushiki Kaisha)
were constructed in Nagasaki Shipyard & Machinery Works of Mitsubishi Heavy Industries, Ltd. (MHI). The third ship for MOL (Mitsui OSK Lines) was constructed in Chiba shipyard of Mitsui Engineering Shipbuilding Co., Ltd. (MES).

Moss spherical tank type was adopted for the cargo tank. Special features of this ship are of 4 tanks, combination of low boil-off rate and forcing vaporizing system, only gas burning boiler and integrated automation system.

One set of 23,300 ps at 76rpm of Mitsubishi marine steam turbine for the propulsion and two sets of 40.4t/h at 61.5Kg/cm²g, 515 deg. C of Mitsui two drum boiler were adopted.

7.2 Opening of Oceangoing passenger ships
Two oceangoing passenger ships, "FUJI MARU" for Mitsui O.S.K. Lines, Ltd./Mitsui O.S.K. Passenger Line, Ltd. and "M/S OCEANIC GRACE" for Oceanic Cruise Ltd./Showa Line, Ltd. entered service in April.

The 603-passengers and 23,500 grt "FUJI MARU" was completed at Kobe Shipyard & Machinery Works of Mitsubishi Heavy Industries, Ltd. (MHI) and was designed with Japanese passengers principally in mind for medium distance and staff training cruises. Main propulsion comprises two MHI 8UEC 52LA engines, each developing 10,700ps at 133 rpm, in a two-engines two shafts arrangement. She has two highly skewed CPPs, one bow thruster and one pair of fin stabilizers and she gets 20.0 knots for normal cruising speed.

The 120-passengers and 5,050 grt large yacht cruiser "M/S OCEANIC GRACE" was completed at Tsu Works of NKK Corporation (NKK). Her propulsion Arrangement is of two, engines two shafts, each driver by Wartsila VASA 16V22HF rated at 3,530 ps x 1,000 rpm. She has two CPPs, one bow thruster and one pair of fin stabilizers and has 1,810 knots normal cruising speed.

7.3 Off-center Propeller Ship
NOPS (NKK Off center Propeller Ship) which was designed to arrange the propeller offcenter of starboard side was completed at Tsu Works of NKK Corporation (NKK) and was delivered to Nippon Yusen Kabushiki Kaisha (NYK).

This ship was the 230,000 DWT ore carrier "ONOE MARU" and she saved 14% energy compared to the conventional ships adopting NKK-SURF (Swept back Up thrusting Rudder Fin), wake gain fin and high efficient propeller.

In NOPS, the propeller and the rudder are 10-15% off centered to the starboard side from the ship center. And at the sea trial, there proved no trouble about its design of shafting, maneuverability and vibration etc.

7.4 Energy-Saving VLCC
The more energy-saving VLCC compared with the ordinary ships was completed at Ariake Works of Hitachi Zosen Corporation. This ship has achieved energy-saving adopting SSD (Hitachi Zosen Super Stream Duct) for ship propulsion performance and in addition, the very low fuel rate main engine of 114.5g/ps.h of B&W 8S80MCE with high efficiency turbocharger and drastic derating.

7.5 New Generation High-Speed Passenger Vessel of SWATH type
New generation high speed passenger vessel of SWATH type (Mitsui SSC type) "Seagull 2" (560 grt, 410 passenger) was completed at Tamano Works of Mitsui Engineering and Shipbuilding Co., Ltd. and delivered to Maritime Credit Corporation/Tokai Kisen Co., Ltd. Her design is based on the actual ship performance of motion with a fin control system, speed in waves and turning ability in addition to the invaluable data of "Seagull 1" constructed in 1979. And she has many special features with the largest accommodation space in this class, well controlled fin stabilizer system, the bow thruster, four-engines two shafts arrangement and in line arrangement of the main engines, gearboxes, shafting and propeller with a rake.

7.6 High speed fully submerged hydrofoil passenger craft
The first Kawasaki jet-foil of high speed fully submerged hydrofoil passenger craft "TSUBASA" (170 grt, 280 passenger) was completed at Kobe Works of Kawasaki Heavy Industries Ltd. (KHI) and delivered to Maritime Credit Corporation/Sado Steamship Co. Ltd. in March.

The water jet thrust force generated by the gas turbine driven water jet pump create a service speed of about 40 kts at sea with 3-4m wave height.

7.7 Training Sailing Ship Launched
The training sailing ship "KAIWO MARU" was completed at the Uraga Works of Sumitomo Heavy Industries, Ltd. in September. She is of a
2,556 grt, four masted bark type and two-engines two-shafts, and she has two sets of 1,500 ps main engine (low noize type). The ship is propelled by two variable pitch feathering propellers (FPP) which reduce wave resistance while sailing.

JG-MO for machinery part automation is applied and the CRT for monitoring/alam and the data-loggar are provided for students.

7.8 Contra-rotating Propellers

IHI has been developing contra-rotating propellers (CRP) for the large commercial ship from 1984. From December of 1988 to January of 1989, the conventional propeller and CRP was examined in turn to fit to the bulk carrier "J UNO" (37,000DWT) in order to compare the performance. As a result, the ship fitted with CRP saved 15% energy compared to the ship fitted with the conventional propeller.

From September of 1988 to August of 1989, MHI installed the contra-rotating propeller on the car carrier "TOYOFUJI 5" (4,177 grt) and tested concerning the maneuverability, shafting and energy saving. The results showed energy savings of an average of 13.5R6 (Max. 17%) 

7.9 Others

Duty of Double Bottom and Double Hull. The "Oil Spill" problem came to be argued much more internationally since the crude oil spill accident happened off the coast of Alaska in the USA on the 24th of March, 1989

In November of 1989, the "Oil Pollution Act of 1989" which compelled the double bottom or double hull to ships entering American ports was passed by the House of Representatives in the USA. Hereafter, in the case of the adoption of this resolution, all oil tankers entering American ports are obliged to have a double bottom within seven years and a double hull within fifteen years. And in the future, the countermeasure for the prevention of an oil spill and for the removal of an oil spilled is planned to be investigated.

Also, the international conference, the international cooperation for technical development., the exchange of information for oil accident and the investigation for influence estimation are planned in IEA. Start of "MARU SHIP KONJO"

The All Japan Seamen's Union decided the adoption of the "MARU SHIP KONJO" under the conditions of a minimum of nine Japanese seamen's embarkation and with the exception of the special ships such as LNG and LPG ships.

Reference

1) Nikkan Kajii.Tsushin Co. Ltd.. Marine .90 1,2
2) The Motor Ship, March 1990
3) Lloyd's Register of Shipping, Annual summary of Merchant ships Completed 1989

2. Diesel Engine

2.1 Production in the world

Ships (2,000 Dwt and above) completed in the world in 1989 were 587 in number and 21,917,367 in Dwt in total and the shipbuilding industry had been on the upward trend continuously from 1988. By country, Japan built 195 ships and 8,583,875 Dwt placing in the first place, and Korea built 75 ships and 6,712,697 Dwt giving priority to relatively large ships, placing in the second place. It means that Japan, who resigned her first place on the base on tonnage to Korea in 1988, recovered it. Anyway, total ships built in Japan and Korea were 46% in number and 70% in tonnage of all ships built in the world.

The production of diesel engines (low speed and medium to high speed) which were installed on these ships are shown in Table 2.1, quoting from the Motor ship. The production of MAN B & W type is 2,263,994 kW (44.52%), placing it in the first place continuously from 1988 and it

<table>
<thead>
<tr>
<th>Table 2.1 Total production by type</th>
<th>(Low speed and medium-to-high speed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine design</td>
<td>No of ships</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>MAN B &amp; W</td>
<td>213</td>
</tr>
<tr>
<td>Sulzer</td>
<td>146</td>
</tr>
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<td>Mitsubishi</td>
<td>71</td>
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<tr>
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<tr>
<td>Wärtsilä</td>
<td>21</td>
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<tr>
<td>SKL</td>
<td>18</td>
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<td>MaK</td>
<td>22</td>
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<td>Hitachi</td>
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<td>IHI</td>
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<td>Dalian</td>
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<td>Hanjin</td>
<td>8</td>
</tr>
<tr>
<td>Doosan MMW</td>
<td>6</td>
</tr>
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<td>Akita</td>
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<td>NJ</td>
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<td>Mitsubishi</td>
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<td>Franck</td>
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<td>16</td>
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</table>
increases to the amount move than that in 1988 of 1,900,108kW (43.13%). Though Sulzer type could hold the second place, its production is 1,569,183 kW (30.85%) and decreases to the amount less than that in 1988 of 1,405,098 kW (32.9%). Mitsubishi type is 375,944kW (7.39%), placing it in the third place and increases to the amount more than that in 1988 of 298,300 kW (6.77%). Pielstick, Wartsila, SKL and MaK follow them.

Tables 2.2 and 2.3 show breakdowns of the above which are also quoted from the Motor ship. when looking at low speed engines in Table 2.2, their share in output in total production slightly decreases from 72% to 70.2%6. The production of MAN B & W type increases from 52.8% in 1988 to 1,908,805 kW (53.42%), placing it in the first place. The share of Sulzer type decreases from 37.88% in 1988 to 1,288,684 kW (36.06%), placing it in the second place, though it increases number of engines and output. Mitsubishi type increases from 9.32% in 1988 to 375,944 kW (10.52%), Placing it in the third place.

When looking at medium-to-high speed engines in Table 2.3, the production of MAN B & W type is 355,189 kW (23.48%) still keeping the first place and is slightly superior to Pielstick type in the second place which produced maximum number of engines of 56 and 344,394kW (22.77%) including licensees. Sulzer type in the third place is 280,499 kW (18.55%) and followed by Wartsila, SKL, MaK and GMT.

The average tonnage of ships of 2,000 Dwt and above built in 1989 was 37,388 Dwt and it exceeded the average tonnage in 1988 of 32,180 Dwt. Thus ships had been on the trend toward larger size and it is thought that this trend will be kept even in 1990 by taking account of the predictable replacement of VLCC.

### Table 2.2 Production of low speed engines by type

<table>
<thead>
<tr>
<th>Engine design</th>
<th>No of ships</th>
<th>Total Built by</th>
<th>Built by licensee</th>
<th>kW</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>MAN B&amp;W</td>
<td>173</td>
<td>173</td>
<td>908</td>
<td>908</td>
<td>53.42</td>
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<tr>
<td>Sulzer</td>
<td>127</td>
<td>127</td>
<td>84,844</td>
<td>84,844</td>
<td>36.06</td>
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<tr>
<td>Mitsubishi</td>
<td>71</td>
<td>71</td>
<td>375,944</td>
<td>375,944</td>
<td>10.52</td>
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<tr>
<td><strong>Totals</strong></td>
<td><strong>371</strong></td>
<td><strong>371</strong></td>
<td><strong>375,433</strong></td>
<td><strong>375,433</strong></td>
<td><strong>100.00</strong></td>
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</table>

### Table 2.3 Production of medium-to-high engines by type

<table>
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<tr>
<th>Engine design</th>
<th>No of ships</th>
<th>Number of engines</th>
<th>Total Built by</th>
<th>Built by licensee</th>
<th>kW</th>
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<tr>
<td>MAN B&amp;W</td>
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<td>5118</td>
<td>355,189</td>
<td>355,189</td>
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<tr>
<td>Pielstick</td>
<td>33</td>
<td>58</td>
<td>344,394</td>
<td>344,394</td>
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<tr>
<td>Sulzer</td>
<td>19</td>
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<td>M'stan R'ston</td>
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<td><strong>8</strong></td>
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<td><strong>5.72</strong></td>
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<td><strong>Totals</strong></td>
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<td><strong>334</strong></td>
<td><strong>232</strong></td>
<td><strong>1,512,431</strong></td>
<td><strong>100.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

### 2.2 production in Japan according to the statistics by Nippon Kaiji Kyokai

According to the statistics by Nippon Kaiji Kyokai, 239 sets of diesel engines were installed on 217 newly built ships of NK class in 1989 and the total output was about 1.55 million PS. In comparison with 1988, the number and output of engines increased by 61 sets (34.3%) and 70,000PS (4.8%) respectively. The breakdown of total number of engines of 239 sets showed 140 sets and 1.31 million PS for the two-stroke type, and 99 sets and 0.24 million PS for the four-stroke type. Average unit output for the two stroke type was 9,346 PS and decreased by 3,758 PS (28.7%) in comparison with 1988, and the same for the four-stroke type was 2,430PS and increased by 732 PS (43.1%). On the two stroke engine, the trend toward high output since 1986 changed remarkably and, on the four-stroke engine, the trend toward low output which had been continuing for a long time stopped.

Table 2.4 shows the classification of the output of main engines which were installed on newly built ships of NK class.

### 2.3 Study in the Ship Research Institute of the Ministry of Transportation

(1) Study on adiabatic diesel engine

When raising the temperature of the combustion chamber and the gas temperature at the end of compression stroke by insulating the combustion...
chamber with heat insulating material (ceramics), the influence of high temperature on combustion, engine performance and the reliability of heat insulating material had been investigated. It has been found that the gas temperature in the combustion chamber rises by from 200°C to 250°C at the beginning of combustion by insulation in comparison with that in a previous metal combustion chamber. It has also been found that the surface temperature of the combustion chamber rises by about 300°C in comparison with previous engines when using material with superior insulation ability (e.g. zirconia). Such a tendency has been shown that, in the combustion chamber of such high temperature, the quantity of fuel oil burned in the early stage becomes less, combustion duration becomes longer, fuel consumption deteriorates, and the densities of nitrogen oxides and smoke become higher, since fuel oil with good ignitability ignited too early and the ingress of fresh air into fuel jets is impeded by gas already burned. Contrarily, it has been found that even on fuel oil with deteriorated ignitability (emulsifying fuel) which does not allow smooth operation in a non-insulation combustion chamber because of its two late ignition and the increase of fuel oil burned in the early stage, smooth operation is made and combustion duration is shortened, and the densities of nitrogen oxides and smoke are considerably lowered due to the promoted ignition of fuel oil in the combustion chamber of high temperature. Fig. 2.1 shows an example of the relation between the quantity of water added and the density of exhaust gas when emulsifying fuel burned in the adiabatic engine.

The heat resistance of ceramics and its compatibility with various metallic materials, and the change in exhaust gas energy has been investigated. When material with excellent heat resistance is used at the place where a thermal load is high, there are some problems for practical use, since thermal stress is excessively large and cracks may occur. Various design changes to reduce thermal stress (cavity parts have been divided into two or three elements) have been made and their effects have been examined, but satisfactory effects have not been obtained. Exhaust gas energy

<table>
<thead>
<tr>
<th>Output (PS)</th>
<th>Two stroke engine</th>
<th>Four-stroke engine</th>
<th>Total output (PS)</th>
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<tbody>
<tr>
<td></td>
<td>Number of ships</td>
<td>Number of engines</td>
<td>Number of ships</td>
</tr>
<tr>
<td>Min. ~ less than</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>40,000~</td>
<td>2</td>
<td>2</td>
<td>83,200</td>
</tr>
<tr>
<td>35,000~40,000</td>
<td>3</td>
<td>3</td>
<td>82,050</td>
</tr>
<tr>
<td>30,000~35,000</td>
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<td>2</td>
<td>47,890</td>
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<tr>
<td>5,000~6,000</td>
<td>1</td>
<td>1</td>
<td>38,794</td>
</tr>
<tr>
<td>4,000~5,000</td>
<td>1</td>
<td>1</td>
<td>65,096</td>
</tr>
<tr>
<td>3,000~4,000</td>
<td>1</td>
<td>1</td>
<td>35,237</td>
</tr>
<tr>
<td>2,000~3,000</td>
<td>1</td>
<td>1</td>
<td>4,000</td>
</tr>
<tr>
<td>1,000~2,000</td>
<td>1</td>
<td>1</td>
<td>2,200</td>
</tr>
<tr>
<td>700~1,000</td>
<td>1</td>
<td>1</td>
<td>14,040</td>
</tr>
<tr>
<td>500~700</td>
<td>1</td>
<td>1</td>
<td>4,090</td>
</tr>
<tr>
<td>300~500</td>
<td>1</td>
<td>1</td>
<td>868</td>
</tr>
<tr>
<td>~300</td>
<td>1</td>
<td>1</td>
<td>1,520</td>
</tr>
<tr>
<td>Total</td>
<td>154</td>
<td>140</td>
<td>1,308,371</td>
</tr>
</tbody>
</table>
the improvement in thermal efficiency can be expected by utilizing it effectively.

(2) Study on combustion of fuel droplet in high temperature air flow

The relation between the ignition delay of a fuel droplet in high temperature air flow and air temperature has been investigated with a single fuel droplet suspended on a quartz fiber as a fundamental model of the combustion process of fuel spray. The ignition delay of mixed fuel of diesel oil and heavy oil is approximately equal to that of diesel oil for the mixing ratio of heavy oil up to about 25%, but it increased with the increase in heavy fuel content for the mixing ratios above 25%. It has been clarified that the time difference in ignition delay between diesel oil and heavy oil decreases as air temperature rises.

Fig. 2.2 shows an example of the relation between the mixing ratio of diesel oil and heavy oil and the ignition delay using air temperature as a parameter.

2.4 Development and production by domestic manufacturers.

2.4.1 Akasaka Diesels Ltd.

(1) Development of A45 type

Akasaka Diesels Ltd. sells the A series engines of direct reversity type and the K and T series engines with reversity gears or reduction and reversing gears as major products in the four stroke field. It has developed the A45 engine developing 4000PS which was the biggest engine of the A series in 1989.

This engine retains features of the A series engines such as long stroke, low speed and high reliability, and improves its specific fuel consumption by the rise of P max, adoption of a high-efficiency turbocharger, reduction in friction resistance around pistons, improvement of the fuel injection system, etc. To prevent excessive system oil consumption which is apt to occur on four stroke large sized engines, this engine prevents oil from going up by adopting chrome plated liners of a mechanical pit type made by diamond grinding stones and suppresses the evaporation of lubricating oil as little as possible by preventing cylinder liner walls from being exposed during a heat release period. Fig. 2,3 and Table 2.5 show its sectional drawing and principal particulars respectively.

(2) Development of equipment to prevent dew condensation in holds
Domestic steel carriers have such a trouble that dew condensates on steel materials and rusts them during transportation due to the difference between inside and outside temperatures various preventive measures have been applied, but nothing has succeeded so far.

Akasaka Diesels Ltd. has developed equipment to prevent dew condensation utilizing surplus charging air of the main engine and made on board tests in cooperation with Nittetsu Transport Service Co. Ltd. This test obtained good results.

This equipment dehumidifies and heats surplus charging air, which is produced by modifying the operating conditions of the turbocharger, and sends a large quantity of dried hot air to holds with a blower after mixing the above mentioned charging air with air in holds. This hot air controls the humidity and the temperature in the holds and prevents dew condensation. Though a large quantity of heat is consumed, it is produced by utilizing waste heat and so no energy cost is needed. Fig. 2.4* shows its outline.

(3) Production of marine engines in 1989

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-stroke UE engine</td>
<td>35</td>
</tr>
<tr>
<td>Four-stroke low speed engine</td>
<td>98</td>
</tr>
<tr>
<td>Total</td>
<td>133</td>
</tr>
<tr>
<td>Power</td>
<td>365,900</td>
</tr>
</tbody>
</table>

2.4.2 Daihatsu Diesel Mfg. Co., Ltd.

Daihatsu Diesel Mfg. Co., Ltd. has developed the following two models in compliance with the market demands for high speed, high output, high reliability.

(1) 12KD 16A

This engine is a Vee-configuration of the 6DL, DK-16 engines (vertical type) and has been developed making good use of experience and service results of these engines.

Low vibration and low noise have been realized at high speed and high output conditions by having laid stress on the rigidity of the main bearing part and the engine foundation part in the development stage.

1. The rigidity of engine body is improved by making the frame with high-strength cast iron and by casting the air duct in the frame.
2. The main bearing caps are strongly fixed with bolts having large diameters from both sides. This construction ensures the highly accurate concentricity and the parallelism of the crankshaft during operation.
3. Engine vibration is extremely small thanks to the highly reliable Gaislinger damper fitted on the free end of crankshaft and the sufficient dynamic balance of moving parts.
4. In the performance aspect, good performance over whole range from low loads to high loads is maintained by adopting the high pressure

Table 2.5 Principal particulars of A45

<table>
<thead>
<tr>
<th>Type</th>
<th>A 45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. continuous output</td>
<td>PS 4000</td>
</tr>
<tr>
<td>Engine speed</td>
<td>rpm 210</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>6</td>
</tr>
<tr>
<td>Cylinder bore</td>
<td>mm 450</td>
</tr>
<tr>
<td>Stroke</td>
<td>mm 880</td>
</tr>
<tr>
<td>Mean piston speed</td>
<td>m/s 6.16</td>
</tr>
<tr>
<td>Brake mean effective pressure</td>
<td>kgf/cm² 20.41</td>
</tr>
<tr>
<td>Maximum cylinder pressure</td>
<td>kgf/cm² 135</td>
</tr>
</tbody>
</table>
injection system with single cylinder

* Refer P.P. 133.

### Table 2.6 Principal particulars

<table>
<thead>
<tr>
<th>Type</th>
<th>For generator and for general power source</th>
</tr>
</thead>
<tbody>
<tr>
<td>12DK-16A</td>
<td>V-type, water-cooled, direct injection type, four-stroke diesel engine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of cylinders</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder bore</td>
<td>m</td>
</tr>
<tr>
<td>Stroke</td>
<td>m</td>
</tr>
<tr>
<td>Engine speed</td>
<td>rpm</td>
</tr>
<tr>
<td>Fuel to be used</td>
<td>MDO</td>
</tr>
<tr>
<td>Brake power</td>
<td>PS</td>
</tr>
<tr>
<td>m</td>
<td>1500</td>
</tr>
<tr>
<td>Brake mean effective pressure</td>
<td>£</td>
</tr>
<tr>
<td>m/s</td>
<td>1.52</td>
</tr>
<tr>
<td>Mean piston speed</td>
<td>Mpn</td>
</tr>
<tr>
<td>Direction of rotation</td>
<td>Until clockwise looking from flywheel side</td>
</tr>
<tr>
<td>Supercharging system</td>
<td>Supercharging by exhaust gas turbine (with intercooler)</td>
</tr>
<tr>
<td>Starting system</td>
<td>Compressed air or electric starter</td>
</tr>
<tr>
<td>Firing order</td>
<td>A-bank</td>
</tr>
<tr>
<td>Engine dimensions</td>
<td>B-bank</td>
</tr>
<tr>
<td>Overall length</td>
<td>m</td>
</tr>
<tr>
<td>Overall width</td>
<td>m</td>
</tr>
<tr>
<td>Overall height</td>
<td>m</td>
</tr>
<tr>
<td>Engine weight</td>
<td>kg</td>
</tr>
</tbody>
</table>

**Note:**
- October (35)
- 96
- 1990
- Annual Review

fuel injection pumps and by optimizing the intake air and exhaust gas system and the shape of combustion chamber.

Table 2.6 and Fig. 2.5 show its principal particulars and sectional drawing of this engine respectively.

(2) 6DK-26

This engine has been developed aiming at the world's highest power rate (Pme x Cm) level of 216 and laying stress on reliability. After fundamental tests and endurance tests of independent parts were conducted, a demonstration test has been made using a test engine.

Major features of this engine are as follows.

1. This engine is light and its specific weight is 5 kg/PS.
2. Thanks to the large diameter of the crankshaft, no damper is necessary.
3. Engine vibration is small thanks to the lightweight hanger type crankcase with high rigidity.
4. Engine noise is low thanks to the double-wall construction around the combustion chamber by
making the intake air manifold and the

Table 2.7 Principal particulars

<table>
<thead>
<tr>
<th>Type</th>
<th>Vertical water cooled, four-stroke, single acting, trunk piston type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>6 DK-26</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>6</td>
</tr>
<tr>
<td>Cylinder bore</td>
<td>mm 260</td>
</tr>
<tr>
<td>Stroke</td>
<td>mm 270</td>
</tr>
<tr>
<td>Engine speed</td>
<td>rpm 1200</td>
</tr>
<tr>
<td>Mean piston speed</td>
<td>m · s⁻¹ 10.8</td>
</tr>
<tr>
<td>Max. cylinder pressure</td>
<td>kg · cm⁻² 150</td>
</tr>
<tr>
<td>Brake mean effective pressure</td>
<td>kg · cm⁻² 20.00</td>
</tr>
<tr>
<td>Max. continuous output</td>
<td>PS 2300</td>
</tr>
<tr>
<td>Power rate</td>
<td>kg · m · h⁻¹ 216.6</td>
</tr>
<tr>
<td>Specific fuel consumption</td>
<td>g · PS · h⁻¹ 145</td>
</tr>
<tr>
<td>Direction of rotation</td>
<td>Clockwise, taking from flywheel side</td>
</tr>
<tr>
<td>Starting system</td>
<td>Compressed air</td>
</tr>
<tr>
<td>Overall length</td>
<td>mm 3950</td>
</tr>
<tr>
<td>Overall width (Max. width of foundation flange)</td>
<td>mm 1120</td>
</tr>
<tr>
<td>Height</td>
<td>mm 2640</td>
</tr>
<tr>
<td>Weight</td>
<td>kg 11600</td>
</tr>
</tbody>
</table>

Fig. 2.6 Sectional drawing of 6DK-26

small by casting the main lubricating oil pipe and the main cooling water pipe into the crankcase.

5. Inspection and maintenance work becomes easy thanks to a hydraulic device for the inspection of main bearings together with large crankcase doors.

Table 2.7 and Fig. 2.6 show its principal particulars and sectional drawing respectively.

2.4.3 Diesel United. Ltd.

Diesel United, Ltd. (DU) was established on 1 October, 1988 amalgamating diesel engine departments of Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) and Sumitomo Heavy Industries, Ltd. (SHI). After a preparatory period for over one year, this company has been consolidated and are now producing engines actively. Furthermore, DU Technoservice, Ltd. (DUS), which is an engine service company established by the above, started its business in April 1989 and thus DU has established its organization for engine service,
(1) Technical matters to be noted specially are as follows.

The shop test of the 7RTA 72 (17,200 PS @ 66rpm), which is the first engine of RTA 72 type (Fig. 2.7), has been made and its performance (specific fuel consumption 121.0g/PSh at 90% load) and reliability has been verified as expected.

The shop test the 6RTA72 (21,000 PS @ 89rpm), which is the second engine and a power up version (its output and speed are increased by 6.6% and 3.8% respectively.), has been made and good results (specific fuel consumption 119.3 g/PSh at 90% load) were obtained. Furthermore, the first engine of RTA84C type is now under manufacture. This type was developed on the basic of its predecessor the RTA84 type to meet high-speed and high output ships such as container ships and the shop test of its first engine will be started in January 1990. This is the first engine in the world.

On the other hand, the PC40L engine has been up rated by 9.1% in output from 1650 PS to 1800 PS and by 2.9% in engine speed from 350 rpm to 360 rpm. The first engine is the 9PC40L (16,200 PC @ 360rpm) for main engines of a large sized ferry (two engines and two shafts) and good results of both performance and reliability have been obtained. An elastic support is used for this engine to improve the comfortableness of this ship. This elastic support supports the engine with 48 pieces of rubber being fixed with an angle of 48 degrees in relation to the seating surface of the engine. For this, the oil sump has special structure with higher rigidity (Fig. 2.8).

Torsional vibration of the main engine is absorbed by the combination of an elastic coupling and an universal coupling on the power transmitting shaft. It has been found through the measurement of vibration at a shop test that solid born sound can be reduced by 25 db on the average (Fig. 2.9).

(2) Production of marine engines in 1989
Sulzer type low-speed engine RTA type
16 sets, 335,000 PS
SEMT type medium-speed engine PC type
12 sets, 125,000 PS
Total
28 sets, 460,000 PS

2.4.4 Hanshin Diesel Works, Ltd.
(1) Engines developed in 1989
1. 6L35MC engine 4560 PS
Hanshin Diesel Works, Ltd. has manufactured and sold the Kawasaki-MAN B&W S26MC engines under the technical cooperation with Kawasaki Heavy Industries Ltd. Since 1987. In addition to this type, this company started manufacturing the L35MC engines in 1989 and its first engine was completed and forwarded in November.

The principal particulars of this engine are cylinder bore 350mm, stroke 1050mm, engine speed 200rpm, output of six cylinder engine 4560PS,
brake mean effective pressure at full load 16.9 kgf/cm² and specific fuel consumption 132 g/PSh.

2. LS28L engine 1600 PS

This engine is a long stroke type of the LH series which enjoys a good reputation. It aims at lowering its engine speed for a direct-coupled engine which does not need any reduction gear by lengthening its piston stroke, and reducing its specific fuel consumption by raising maximum cylinder pressure and improving thermal efficiency. The principal particulars of this engine are cylinder bore 280mm, stroke 530mm, engine speed 380rpm, output of six cylinder engine 1600 PS, brake mean effective pressure at full load 19.35 PS, brake mean effective pressure at full load 19.35 kgf/cm², maximum cylinder pressure 15 kgf/cm². Its performance at full load is good, i.e. specific fuel consumption is 134 g/PSh and exhaust temperature at cylinder outlet is 366°C. (Fig. 2.10)

(1) Annual production
   Total number of engines 200 sets
   Total output 371,820 PS

2.4.5 Hitachi zosen Corporation

(1) Development of the newest Hitachi Zosen-Sulzer 14ZAV40S type diesel engine

At the end of January 1990, 35 sets of Sulzer ZA40S type engines have already been put into service the first engine was completed in Europe in 1987. Hitachi Zosen Corporation developed the Hitachi Zosen, Sulzer 14ZAV40S for a ferry as the first engine in Japan.

(a) Features

The ZA40S type is a highly reliable engine with low vibration which has the following features and most suitable for ferries and cruisers in particular.

- Rotating piston of unique design an highly economical lubricating oil consumption
- Low vibration thanks to high rigidity of single piece engine frame integrating column and cylinder block
- Excellent operating performance at low speed and on heavy fuel oil thanks to high compression ratio specification
- Excellent speed increasing ability thanks to single pipe turbo charging system

(b) Principal particulars
   Number of cylinders: 4
Cylinder bore/stroke: 400mm/560mm
Brake mean effective pressure: 22.57 kg/cm²
Max. continuous output/
Engine speed: 12,600 PS/510 rpm

Fig. 2.11 shows the mechanism of the rotating piston which is one of features of this engine and Fig. 2.12* shows engine performance according to propeller law.

(2) Production of marine diesel engines from January to December, 1989
23 sets of only B&W type propulsion engine were produced.
Its total output was 318,460 BHS.

2.4.6 Kawasaki Heavy Industries Ltd.

(1) Development of Kawasaki-MAN B&W 9L50MC
Kawasaki Heavy Industries Ltd. completed the two-stroke low-speed type 9L50MC engine (number of cylinders 9, cylinder bore 500mm, stroke 1620mm, max. continuous output 14600 PS at 141 rpm, brake mean effective pressure at MCO 16.28 kgf/cm²) as the main engine of HOKKAIDO-MARU (pure trailer ferry I19 units). This ship was put into service in March, 1989.

Medium-speed four-stroke geared diesel engines with low engine heights have traditionally been used for the propulsion systems of large-sized ferries servicing in the greater coasting area in Japan. A direct-coupled propulsion system with a two stroke low-speed engine has been adopted for these ships for the first time thanks to the good reputation of various features of the MC type engines such as high reliability, low fuel consumption and ease of maintenance. Since there are limitations of height on main engines of ferries, the cylinder bore has been limited to the 500mm class and necessary output has been obtained by increasing number of cylinders. For this reason, this nine cylinder engine has newly been developed beyond the standard output range of this type.

(2) Production of marine propulsion engines in 1989

<table>
<thead>
<tr>
<th>Type</th>
<th>Sets</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-stroke</td>
<td>14</td>
<td>259,910 PS</td>
</tr>
<tr>
<td>Four stroke</td>
<td>2</td>
<td>5,400 PS</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>265,310 PS</td>
</tr>
</tbody>
</table>

2.4.7 Kobe Diesel Co., Ltd.

(1) Kobe Diesel-Mitsubishi UEC LA & LS types

Engines manufactured by this company were on the trend toward large size and 65% of total production were six cylinder engines.
The 6UEC 60LS (14,400PS/100rpm) and 8UEC 60LS (19,200 PS/100 rpm) equipped with Mitsubishi MET-SD type turbochargers are now under manufacture. This type of turbocharger has been developed to comply with high supercharging.

(2) Production of marine propulsion engines in 1989

<table>
<thead>
<tr>
<th>Type</th>
<th>Sets</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>UEC-LA</td>
<td>16</td>
<td>118,200 PS</td>
</tr>
<tr>
<td>UEC-LS</td>
<td>7</td>
<td>82,200 PS</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>200,400 PS</td>
</tr>
</tbody>
</table>

2.4.8 Makita Corporation

(1) Development of Matsui-Makita M31M type
Makita Corporation has decided to manufacture the M31M type low-speed diesel engine, which was designed by Makita, in Matsui Iron Works Co., Ltd. in the name of Matsui-Makita diesel engine under the technical cooperation with Matsui Iron Works. Its principal particulars are

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>310mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>550mm</td>
</tr>
</tbody>
</table>
Number of cylinders: 6  
Engine speed: 340 - 355rpm  
Output: 1,600 - 2,000PS  
Brake mean effective pressure: 17.0 - 20.4kgf/cm²

* Refer P.P. 133

Fig. 2.13 shows its sectional drawing.

(2) Production of marine engines in 1989
27 sets and total output 111,220 PS

2.4.9 Matsui Iron Works Co., Ltd.
(1) Development of Matsui-Makita M31M type
Matsui Iron Works Co., Ltd. has developed and manufactured the Matsui Makita M31M type diesel engine under the technical cooperation with Makita Corporation (See Fig. 2.13)
(2) Development of ML626 type
The ML626 type engine has been developed. This is an engine wholly modified on the basis of MS25 and 26 types whose total production was one hundred and several tens sets in the past. Its principal particulars are:
- Cylinder bore: 260mm
- Stroke: 480mm
- Number of cylinders: 6
- Engine speed: 330 - 410 rpm
- Output: 700 - 1,300 PS
- Brake mean effective pressure: 12.5 - 18.7 kgf/cm²

This engine has various features such as low fuel consumption by raising maximum cylinder pressure up to 135 kgf/cm². Single piece frame construction integrating the cylinder block and the crankcase without using tension bolts, and compact design incorporating the intake air chamber and the main lubricating oil pipe in the frame. Fig. 2.14 shows its sectional drawing.

(3) Production of marine propulsion engines in 1989
50 sets and total output 56,400PS

2.4.10 Mitsubishi Heavy Industries Ltd.
(1) Development of new engines
In 1989, the S4M3F-M25, S6M3-MTK, S4BB-M35-3 and S6A3-MTK type engines were developed and brought to market to comply with the demands for high-speed, high-powered and lightweight engines for small-sized fishing boats, leisure fishing boats, sightseeing boats, etc.
(a) The S4M3F-M25 engine has been developed targeting small trawlers and drag net trawlers under the regulation of number of horse power 25 according to Fishing Vessel Law. It is a non-supercharged engine equipped with a secondary balancer and its principal particulars are:
- Number of cylinder: 4
- Cylinder bore: 105mm
- Stroke: 135mm
- Output: 113 PS
- Engine speed: 2,800 rpm
- Weight: 630 kg
- Brake mean effective pressure: 7.6 kgf/cm²
- Mean piston speed: 12.6 m/s
(b) The S6M3-MTK engine has been developed as a compact, light weight and high-powered engine to comply with the demand for increasing the speeds of ships such as 5-ton class fishing boats, sightseeing boats, marine taxis, etc., and its principal particulars are shown in Table 2.8.
This engine has various features such as compactness and light weight thanks to the use of aluminum for many parts together with loose fit liners and a reversing gear developed for the exclusive use of this engine, high power of 460PS (brake mean effective pressure 19.2 kgf/cm², power rate 214 kgf/cm² m/s) thanks to the adoption of a self-made high-performance turbocharger and its best matching with the engine, high pressure injection and the optimization of combustion chamber. Its specific weight and specific output per unit volume are 2.2kg/PS and 256PS/cm³ respectively. As a measure to reduce the thermal load of the engine, the uniform temperature distribution around the combustion chamber has been ensured by using the piston with cooling cavity and the jet-cooling of the space between valves of the cylinder head. Figs.2.15 and 2.16 show its performance and sectional drawing.

(c) The S4BB – M35 - 3 engine has been developed targeting small trawlers and drag net trawlers under the regulation of number of horse power 35

<table>
<thead>
<tr>
<th>Table 2.8 Principal particulars of S6M3-MTK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>Assortment of work</td>
</tr>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Number of cylinders</td>
</tr>
<tr>
<td>Cylinder bore × stroke</td>
</tr>
<tr>
<td>Total stroke volume</td>
</tr>
<tr>
<td>Continuous rated output</td>
</tr>
<tr>
<td>Number of horse power according to Fishing Vessel Law</td>
</tr>
<tr>
<td>Maximum service output</td>
</tr>
<tr>
<td>Brake mean effective pressure</td>
</tr>
<tr>
<td>Mean piston speed</td>
</tr>
<tr>
<td>Dimensions</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Fig. 2.15 Performance of S6M3-MTK

Fig. 2.16 Sectional drawing of S6M3-MTK

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according to Fishing Vessel Law. It is a non-superecharged engine with improved performance equipped with a secondary balancer and its principal particulars are

<table>
<thead>
<tr>
<th>Engine speed</th>
<th>2,200 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>1,000 kg</td>
</tr>
</tbody>
</table>

(d) The S6A3-MTK engine has been developed as a compact, lightweight and high-powered engine targeting 15 ton fishing boats, sightseeing boats, launches, etc. This engine has realized maximum

<table>
<thead>
<tr>
<th>Output</th>
<th>140 PS</th>
</tr>
</thead>
</table>

Table 2.9 Principal particulars of S6A3-MTK

<table>
<thead>
<tr>
<th>Model</th>
<th>S6A3 MTK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assortment of work</td>
<td>Light work</td>
</tr>
<tr>
<td>Type</td>
<td>Vertical, water cooled, four stroke, turbocharged engine</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>4</td>
</tr>
<tr>
<td>Cylinder bore</td>
<td>123 nlm</td>
</tr>
<tr>
<td>Stroke</td>
<td>150 mm</td>
</tr>
<tr>
<td>Output</td>
<td>140 PS</td>
</tr>
<tr>
<td>Weight</td>
<td>1,000 kg</td>
</tr>
</tbody>
</table>

(d) Table 2.9 and Fig. 2.17 show its principal particulars and appearance respectively.

(2) Production of marine propulsion engines in 1989

(1) Low-speed two stroke engine

Mitsui Engineering & Shipbuilding Co., Ltd.
1. Completion of world's most powerful engine 12K90MC

Mitsui Engineering & Shipbuilding Co., Ltd. has completed Mitsui-MAN B&W 12K90MC (cylinder bore 900mm, stroke 2,550mm, engine speed 90rpm, brake mean effective pressure 16.5 kgf/cm², number of cylinders 12, output per cylinder 5,360 PS) in October, 1989. This engine has the biggest unit output in the world and will be installed on a container ship.

2. Completion of large size short stroke 10K90-MC-C

MAN B&W announced large size, short-stroke, low speed type two stroke K90MC-C and K80MC-C engines in 1988 as propulsion engines for high speed ships.

The first engine of these types 10K90MC-C (900, 2,300, 104, 16.5, 10, 5,590) was started in October, 1989 in this company and delivered to a shipyard in November after a performance test over a month.

(2) Medium-speed four-stroke engine

One set of the self-developed 8L42MA (420,450, 600, 20.5, 8,850) has been delivered to a domestic chemical plant as a generating engine for continuous use. The uprating type L42MB engine (420, 450, 600, 23.5, 975) with increased brake mean effective pressure by 15% has been developed.

(3) Production in 1989 (unit power: 100 PS and more)

43 sets and total output 744,940 PS

(including land engines for generating use and exported engines)

(4) Turbocharger

The production of the Mitsui-MAN NA type turbochargers has been increased for the S.L.K
MC/MCE and K-MC-C type engines and its cumulative number of sets in 1989 was 457. Types produced are NA70, 57 and 48.

(5) Development of double-layer cylinder liner

Fig. 2.18 Double-layer cylinder liner for S70-MC

Research and development have been conducted on the cylinder liner for which measures are desired most to realize high powered engines with starting valve control system which can freely control the opening and closing timing of starting valves to improve the starting and reversing capability of engines. This equipment has been installed on the NKK-SEMT-Pielstick 8PC40L engine on board.

(2) Production in 1989

Medium-speed engine (NKK-SEMT-Pielstick type)

<table>
<thead>
<tr>
<th>Type</th>
<th>Sets</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>S70MC</td>
<td>13</td>
<td>134,940</td>
</tr>
<tr>
<td>K90MC</td>
<td>16</td>
<td>274,880</td>
</tr>
</tbody>
</table>

Low-speed engine (NKK-SULZER type)

<table>
<thead>
<tr>
<th>Type</th>
<th>Sets</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC2 6</td>
<td>8</td>
<td>77,300</td>
</tr>
<tr>
<td>PC40</td>
<td>2</td>
<td>24,000</td>
</tr>
<tr>
<td>RTA58</td>
<td>2</td>
<td>30,240</td>
</tr>
<tr>
<td>RTA84M</td>
<td>1</td>
<td>19,700</td>
</tr>
</tbody>
</table>

They are broken down as follows.

Type Marine propulsion engine Land engine

<table>
<thead>
<tr>
<th>Type</th>
<th>Sets</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC2 6</td>
<td>8</td>
<td>77,300</td>
</tr>
<tr>
<td>PC40</td>
<td>2</td>
<td>24,000</td>
</tr>
<tr>
<td>RTA58</td>
<td>2</td>
<td>30,240</td>
</tr>
<tr>
<td>RTA84M</td>
<td>1</td>
<td>19,700</td>
</tr>
</tbody>
</table>

2.4.13 Niigata Engineering Co., Ltd.

(1) Development of new types

(a) 6MG46HX

This engine has been developed by organically combining technical know how accumulated over many years and various simulation calculations on the basis of abundant experience on Niigata medium-speed engines. It is the largest bore engine among the high powered, highly supercharged and four-valve type HX series engines. Its principal particulars and sectional drawing are shown in Table 2.10 and Fig. 2.20 respectively.

This engine has been developed with the

<table>
<thead>
<tr>
<th>Table 2.10 Principal particulars of 6MG46HX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated output</td>
</tr>
<tr>
<td>Rated engine speed</td>
</tr>
<tr>
<td>Cylinder bore</td>
</tr>
<tr>
<td>Stroke</td>
</tr>
<tr>
<td>Brake mean effective pressure</td>
</tr>
<tr>
<td>Mean piston speed</td>
</tr>
<tr>
<td>Power rate</td>
</tr>
<tr>
<td>Max. cylinder pressure</td>
</tr>
</tbody>
</table>
assistance of Japan Shipbuilding Industry Foundation.

The specific fuel consumption as low as the level of 120 g/PSh, the ability to digest heavy fuel oil of 700 cSt and the reduction in environmental pollution to comply with the regulation of NOx emission have been realized by optimizing the compression ratio, rate of explosion, excess air ratio and injection system of this engine. For this, this engine has been designed for the maximum cylinder pressure of 180 kgf/cm².

The structure and material of each major component have been optimized by FEM analysis and its rigidity has been confirmed with a component tester. It has also been confirmed on an actual engine that its thermal and mechanical stresses are low enough.

Ease of maintenance and inspection has been ensured thanks to its simple construction and hydraulic tools.

The efficiency and durability of the turbocharger have been improved by employing the high performance Niigata-MAN B&W type.

(b) 6M26HT

This engine has been developed on the basis of the Niigata low-speed, four-stroke, two-valve type 6M-AT engine, which has a production record of more than 1,200 sets, by making the best use of the development technology of this company. It is the smallest bore engine among the high powered, highly supercharged and two-valve type HT series engines. Its principal particulars

<table>
<thead>
<tr>
<th>Table 2.11 Principal particulars of 6M26HT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated output</td>
</tr>
<tr>
<td>Rated engine speed</td>
</tr>
<tr>
<td>Cylinder bore</td>
</tr>
<tr>
<td>Stroke</td>
</tr>
<tr>
<td>Brake mean effective pressure</td>
</tr>
<tr>
<td>Mean piston speed</td>
</tr>
<tr>
<td>Power rate</td>
</tr>
<tr>
<td>Max. cylinder pressure</td>
</tr>
</tbody>
</table>

Fig. 2.19 Macro/micro structure II of double-layer cylinder liner for S70MC (magnification 100) (at the position 50 mm below the upper surface of raw material of liner)

Fig. 2.21 Sectional drawing of 6m26HT
and sectional drawing are shown in Table 2.11 and Fig. 2.21 respectively.

Retaining the design principle of the HT series, the 28HT and 38HT engines have adopted hanger type structure with high rigidity. This structure enables the maximum cylinder pressures of these engines to be raised up to 150 kgf/cm² and the specific fuel consumptions to be reduced down to 139 g/PSh. It also enables the use of heavy fuel oil of 380 cSt.

Thanks to the same simple construction and hydraulic tools as those of the HX series, this engine has ensured ease of maintenance and inspection work. The efficiency and durability of the turbocharger have been improved by employing the high-performance Niigata MAN B&W type.

(c) 6NSDL

The 6NSDL has been developed aiming at an engine better than the 6NSD type in terms of fuel consumption, weight, compactness, output and reliability. The 6NSD is a leading engine among the Niigata high-speed NS series engines which were developed two to three years ago and about 300 sets of this engine have been delivered. Table 2.12 and Fig. 2.22 show the principal particulars and sectional drawing of the 6NSDL engine respectively.

This engine has realized tough operation over whole load range thanks to its piston stroke which is the longest among engines of this class.

This engine also has realized specific fuel consumption as low as 146g/PSh by improving air flow, swirl and the exhaust system which are already used on 6NSD, and by a longer stroke and a high fuel injection pressure.

The reliability and durability of this engine have been improved by adopting ductile cast iron pistons in place of aluminum pistons to cope with high loads.

(2) Production in 1989

It is shown in Table 2.13.
(1) Development of CX series

The market demands for lightweight and high performance (6CX-ET, 6-110X125, maximum service output 350 PS/2,700 rpm, and 4CX-ET, 4-110X1-25, maximum service output 230 PS,/2,700 rpm) by making full use of state-of-the-art technology and new developing techniques applying CAE and CAD on the basis of the CH series engines which had been leading the market of propulsion engines for small-sized fishing boats since the development of this series in 1977. Table 2.14 and Figs. 2.23 and 2.24 show principal particulars, sectional drawing and appearance respectively. As can be seen in them, these engines feature low specific fuel consumption, lightweight, high output, compact design with low height.

The CX series engines have ensured ideal combustion condition and realized high combustion efficiency and clean exhaust thanks to the direct injection system enabling maximum injection pressure higher than 100 MPa, which has never seen on engines of this class, by making the fuel injection equipment more powerful; the rising of maximum cylinder pressure up to 15 MPa while keeping sufficient reliability thanks to its lightweight and high-strength design by FEM analysis; and sufficient air quantity in the high load range thanks to high, efficiency turbochargers well matched with engines. These have also ensured sufficiently long overhaul intervals thanks to the cooled pistons which have abundant service results and the dry liners with specially treated surfaces.

These engines also pay attention to the functions of ships. The foundation flange is properly positioned, and the turbocharger, air cooler, and heat exchangers are installed below the top surface of the bonnet in order to lower the height of the engine room as much as possible to ensure enough space for the bridge and good working environment on the deck. Marine gears of an angle drive type and a V-drive type are prepared. By using them, the horizontal installation of an engine has become possible and the freedom of positioning an engine has been enhanced, and thus these marine gears greatly contribute to the optimization of hull construction design together with the compactness of engine itself. Engine noise is low thanks to the rigid cylinder block and oil pan though these are high speed and high powered engines. Thus they have reduced the vibration and noise of ships together with the adoption of elastic suspension (option).

(2) Development of GMY series

The GMY series engines (1GMY, 2GMFY and...
3GMFY) have been developed as propulsion engines for small fishing boats and leisure fishing boats smaller than one ton. Table 2.15 and Fig.2.25 show principal particulars and appearance respectively.

They are special swirl chamber type small-sized high-speed engines which have been developed for small-sized fishing boats on the basis of the GM type engines which are well-established inside and outside Japan as auxiliary engines for yachts.

Table 2.15 Principal particulars of GMY series

<table>
<thead>
<tr>
<th>Model</th>
<th>1GMY</th>
<th>2GMFY</th>
<th>3GMFY</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-B×S</td>
<td>1.72×72</td>
<td>2.72×72</td>
<td>3.72×72</td>
</tr>
<tr>
<td>Maximum service output</td>
<td>7×3200</td>
<td>14×3200</td>
<td>21×3200</td>
</tr>
<tr>
<td>Number of Horsepower according to Fishing Vessel Low (Adjusted)</td>
<td>5(3)</td>
<td>11(6)</td>
<td>16(10)</td>
</tr>
<tr>
<td>Combustion system</td>
<td>Special swirl chamber type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling system</td>
<td>Sea water cooling</td>
<td>Fresh water cooling (Fresh water is cooled with sea water)</td>
<td></td>
</tr>
<tr>
<td>Starting system</td>
<td>Electric start: Hand start through chain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed reducing and reversing system</td>
<td>Mechanical clutch (Wet, single disc and mechanical type)</td>
<td>YY-6 hydraulic clutch (Wet, multiple disc and hydraulic type)</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>Electric type 143</td>
<td>Electric type 143</td>
<td>Electric type 143</td>
</tr>
<tr>
<td>Chain type 95</td>
<td>Chain type 135</td>
<td>Chain type 145</td>
<td></td>
</tr>
</tbody>
</table>

These engines can offer fishing boats the most suitable working environment by adopting the high-and-constant-temperature fresh water cooling systems, intake air silencers and water cooled manifolds though these are small-sized engines; by the exhaustive adjustment of the balance of reciprocating parts; and by preparing hydraulic clutches (with trawl equipment for dead slow running).

Fig. 2.24 4CX-ET

Fig. 2.25 IGMY engine

Fig. 2.23 Sectional drawing of 4CX-ET

(3) Development of engines for pleasure boats

Demands for high-powered engines are getting stronger to obtain the high-speed performance of pleasure boats. In response to the market demands
inside and outside Japan, this company has developed two types of engines developing 90 and 160 PS for inboard-out drive type pleasure boats.

Table 2.16 shows their principal particulars.

<table>
<thead>
<tr>
<th>Model</th>
<th>Unit</th>
<th>4JH2DTZ</th>
<th>4LHDTZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder bore × Stroke</td>
<td>mm</td>
<td>82×86</td>
<td>100×110</td>
</tr>
<tr>
<td>Total stroke volume</td>
<td>l</td>
<td>1817</td>
<td>3,455</td>
</tr>
<tr>
<td>Nominal output</td>
<td>PS/rpm</td>
<td>72/3500</td>
<td>140/3200</td>
</tr>
<tr>
<td>Maximum service output</td>
<td>PS/rpm</td>
<td>90/3800</td>
<td>160/3300</td>
</tr>
<tr>
<td>Direction of rotation of crankshaft</td>
<td></td>
<td>Counterclockwise (looking from flywheel side)</td>
<td>Counterclockwise (looking from flywheel side)</td>
</tr>
<tr>
<td>Combustion system</td>
<td></td>
<td>Direct injection</td>
<td>Direct injection</td>
</tr>
<tr>
<td>Fuel oil to be used</td>
<td></td>
<td>Gas oil</td>
<td>Gas oil</td>
</tr>
<tr>
<td>Lubricating oil to be used</td>
<td></td>
<td>Class CD</td>
<td>Class CD</td>
</tr>
<tr>
<td>Cooling method</td>
<td>Fresh water cooling (Fresh water is cooled with sea water)</td>
<td>Fresh water cooling (Fresh water is cooled with sea water)</td>
<td></td>
</tr>
<tr>
<td>Dry weight</td>
<td>kg</td>
<td>215</td>
<td>300</td>
</tr>
<tr>
<td>Size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall length</td>
<td>mm</td>
<td>766.8</td>
<td>888</td>
</tr>
<tr>
<td>Overall width</td>
<td>mm</td>
<td>554</td>
<td>630</td>
</tr>
<tr>
<td>Overall height</td>
<td>mm</td>
<td>643.5</td>
<td>726</td>
</tr>
<tr>
<td>Use</td>
<td>Exclusive use for pleasure boats</td>
<td>Exclusive use for pleasure boats</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.16 Principal particulars of engines for pleasure boats

(4) Production in 1989

Production of marine engines (unit power: 100 PS and more) in 1989 was as follows.

- Number of engines: 4
- Output (PS): Total 2.5
  - Propulsion engine: 90 PS
  - Auxiliary engine: 150 PS

The author wishes to express his thanks to persons concerned.

As mentioned in this paper, the production of marine engines has continuously been on the upward trend this year. The author expects that this trend will continue further in the future.

[S. Morita]

### 3. Steam Turbines

#### 1. Main Propulsion Turbines

Mitsubishi Heavy Industries, Ltd. completed and delivered five units of main propulsion turbines in 1988.

Marine Engineering Progress in 1989

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Among five vessels which have been installed with these turbines three LNG carries for the North West Shelf Project of Australia and one LNG carrier of BADAK, Indonesia are already in service and are operating satisfactorily at present. The last one vessel is scheduled to be in service in 1990.

Furthermore, three units of main propulsion turbines are under construction at present as main engines for LNG carriers for the North West Shelf project of Australia.

It is expected that the demand for main propulsion turbines for LNG carriers will further continue.
2. Auxiliary Turbines

In succession to 1988, generator turbines for turbine ships were manufactured also in 1989.

Cargo pump turbines and generator turbines for diesel ships both decreased in number.

Shinko manufactured and delivered two units of generator turbines for turbine ships and nine units of generator turbines including five units of mixed pressure turbines for diesel ships.

Mitsubishi Heavy Industries, Ltd. Manufactured and delivered five units of generator turbines for diesel ships of which four units were mixed pressure turbines.

Generator turbines delivered for turbine ships in 1988 have already been installed onboard four LNG carriers and have been operating satisfactorily.

Like main propulsion turbines, the demand for generator turbines for LNG carriers seems to continue further. On the other hand, in view of the increasing demand for building new oil tankers, the demand for cargo oil pump turbines and generator turbines for diesel ships is expected to grow to some extent.

[Shigehiro Takada]

4. Gas Turbines and Turbochargers

4.1 Gas Turbines

4.1.1 Main propulsion engines

Aero-derived gas turbines of marine use have logged fine operational record for their advantages as main engines of a naval vessel, a high speed boat, etc.

In Japan, Japan Defense Agency (JDA in short) is proceeding with the program using gas turbines as main propulsion engines of escort vessels since 1977 fiscal year and new vessels have entered in service, successively. Total number of gas turbine powered ships, including in constructing or in planning is thirty two (32) and number of installed gas turbines, including spare engines, exceeds 100 sets. In 1989, the second, third and fourth ship of 'Asagiri' type DD vessel 'Yamagiri', 'Yuugiri' and 'Amagiri' using four Spey gas turbines (COGAG) were constructed at Mitsui Engineering and Shipbuilding Co., Sumitomo Heavy Industries Ltd. and Ishikawajima Harima Heavy Industries Ltd. (IHI), and these three ships have entered in service. The propulsion system including gas turbines were manufactured by Kawasaki Heavy Industries Ltd. (KHI). One new DDG escort vessel that JDA decided to construct in 1988 fiscal year is now being designed and constructed. This ship is a new escort ship with an Aegis system installed, which propulsion machinery is twin propeller shafts and COGAG type with four GE-LM2500 gas turbines. The propulsion system including gas turbines are manufactured by IHI.

Hovercrafts MVPP-5 powered by one set of IHI-IM100 gas turbine and jetfoils powered by water jets with Allison-501K gas turbines are in service at civil sea lines. A license agreement of this jetfoil is connected between Boeing Co. in USA and KHI, and the seventh domestic ship is being constructed at KHI. In Japan Maritime Self Defense Force, torpedo boats are successfully in service, which propulsion machinery is CODOG type with each two of IHI-IM300 gas turbine and diesel engine.

As to small high speed boats, in addition,
vessel of JDA and the operational record exceeds three million hours in marine use. Further, US Navy is proceeding with a research of intercooled and regenerative cycle (ICR) for practical use, in which RR-Spey or GE-LM1600 gas turbine is used in base engine.

In Royal Navy (RN), two ships of Type 22 frigate and one ship of Type 23 frigate were constructed at Cammel Laird, Swan Hunter and Yarrow shipyard respectively, and entered in service.

In Netherland Navy, eight ships ‘M’ type of frigate are constructed or planned. The first ship will enter in service in 1990. As the propulsion plant, CODOG type with each two of Spey gas turbine and diesel engine is introduced.

4. 1.2 Auxiliary generating engines

One or two sets of MIA-02 gas turbine (1,000 kw), which has been originally developed by KHI, are installed on each ‘Hatsuyuki’ type DD vessel (total 12 ships) or each ‘Asagiri’ type DD vessel (total 8 ships), respectively. Further, one set of MIA-02 is installed on each ‘Abukuma’ type DE vessel (total 6 ships to be decided) which construction was started in 1986 fiscal year. In 1989,NIIA-02 gas turbines for one ship of ‘Asagiri’ type DD vessel and two ships of ‘Abukuma’ type DE vessel were manufactured and delivered to shipbuilders. Two sets of MIA-05, which also has been developed as a power-up type by KHI, are installed on each ‘Hatakaze’ type DDG vessel (total 2 ships).

As to IME 831-800 (400kw) introduced as an OEM agreement with Garrett Ltd. by Shinko Engineering, Ltd., three sets are on each ‘Ishikari’ type DE vessel (total 3 ships) and one set on each observation ship AGS (total 3 ships) and all are in service.

[Toshiaki Iwamoto]

4.2 Superchargers

Major papers on super-changers presented in the 18th CIMAC 1989 in Tientsin, China were Further Development of the BBC Turbochargers for large Diesel Engines (ABB), Exhaust Gas Turbochargers for High Efficiencies and Pressure Ratios (MAN B&W), Developments of Middle-Size Turbochargers, RH-3 Series, with Mixed-Flow Turbine for Marine Engines (IHI), Development of MET-SR-VG Turbocharger Driven by Radial Flow Turbine with Variable Geometry Nozzle (MHI).

Ishikawajima-Harima Heavy Industries Co., Ltd. put the VTR 564E type on the market in December, 1989 as the first model of VTR 4E series high efficiency type superchargers. Super-changers of VTR4E series have been improved of the gas dynamic performance extensively on the basis of superchargers of VTR 4/4A series. On the other hand, as the demand for radial turbine type superchargers has steadily been increasing in recent years and a firm demand exists in the range of Larger output, the company is now engaged in development of superchargers of RH 3 series which will cover up to 2,500 ps. In 1989, the company manufactured 1,700 units of VTR type superchargers and 1,500 units of RU/RH type superchargers, or about 3,200 units of superchargers in total for marine use.

In order to respond to the requirement for superchargers for higher pressure ratio and for higher efficiency as a result of the increasing demands for main diesel engines for higher output and for lower fuel consumption as well as for use of turbo compound systems in recent years, Mitsubishi Heavy Industries, Ltd. Completed the development of MET-SD series superchargers in October, 1989. Super-chargers of this series can be utilized for a pressure ratio greater than 3.5 and having been adopted on two-stroke cycle and four-stroke cycle diesel engines, the high performance has been well proven and appraised. The company manufactured 160 units of MET type super-chargers in 1989 in total.

Mitsui Engineering & Shipbuilding Co., Ltd. manufactured a total of 60 units of MAN B&W NA/TO7 series superchargers in 1989 including 8 units of NA 48 type, 30 units of NA 57 type and 22 units of NA 70 type.

Kawasaki Heavy Industries, Ltd. commenced production of superchargers of MAN-B&W NA type about nine years ago and has manufactured 215 units by the end of 1989 financial year. For effective use of exhaust gas energy and for improvement of reliability of main engines, turbochargers of the high performance type NA/T series have become the
principle type products nowadays in place of turbochargers of the conventional NA/N series. The

company installed high efficiency superchargers for turbo

principal type products nowadays in place of turbochargers of the conventional NA/N series. The

compound system on a new vessel built by the company and the vessel entered service early in 1989. During the period of approximately one year since then, the superchargers have been operating satisfactorily without any aging deterioration in efficiency. In 1989, the company manufactured a total of 16 units of superchargers consisting of 10 units of NA 48/T type, 4 units of NA 57/T type and 2 units of NA 70/T type.

Niigata Engineering Co., Ltd. has been responding to the requirement for higher output of diesel engines in recent years by utilizing turbochargers of MAN-B&W radial turbine type NR/R series (four models), NA 34/T type and NA 40/T type as the principal models. Turbochargers of NR/R series have been installed as a standard on HX series high output high supercharged four stroke cycle medium speed diesel engines of a class of maximum combustion pressure of 150 kgf/cm² which were developed in 1988 by the company. The superchargers have been in actual operation at high pressure ratios and have been appraised for the high reliability. In 1989, the company manufactured a total of 527 units of superchargers consisting of 151 units of NHP series, 365 units of NR/R series and 11 units of NA/T series.

[Toshio Kato]

5. Boilers

1. General

The number of marine boilers produced increased in 1989 consecutively to 1988 with the bottom in 1987. A trend of increasing capacity is seen in auxiliary boilers.

Main boilers for LNG carriers for the North West Sheif Project of Australia and for Indonesia owners manufactured in 1989 subsequently to the previous year.

From the technical aspect, successively to 1988, research and development were advanced in 1989 for energy saving, human power saving, use of low grade fuel oil, treatment of waste oil and for gas only firing, heavy oil only firing and gas/heavy oil mixed firing in main boilers and auxiliary boilers.

2. Number of Units Produced

Table 5.1 shows the record of production of marine boilers in seven years since 1983 as summarized from the statistics issued by the Ministry of Transportation.

The decreasing trend in number of production was terminated with the bottom in 1987. During a half year period from April to October, the total number of boilers and exhaust gas economizers produced increased to 253 units in 1989 from 218 units in 1988. This increase is particularly noticeable in auxiliary boilers.

3. Major Trend

3.1 Main Boilers

Subsequently to 1988, Mitsui Engineering & Shipbuilding Co, Ltd. manufactured and delivered two main boilers (40.4 T/H x 61.5 kgf/cm² x 515) for an LNG carrier for the North West Sheif Project of Australia in 1989.

Mitsubishi Heavy Industries, Ltd. Manufactured and delivered two main boilers (45 T/H x 61.5 kgf/cm² x 515) for an LNG carrier for Indonesia. These boilers are designed for burning shingle fuel of either gas or heavy oil and also
mixed fuel of these two.

Under the circumstance of increasing demand for energy, the environmental problem has become important more and more and LNG has been highly appreciated as a clean energy. There are many LNG development programs including the Alaska Project at present and construction of LNG carriers has been actively planned. It is expected that the demand for main boilers will further continue at a high level.

3.2 Auxiliary Boilers

The number of auxiliary boilers manufactured was 139 in the period between April and October 1988 and was 174 in the same period in 1989. The number is increasing and the average capacity is also increasing as a result of increase in number of large auxiliary boilers for oil tankers. It is estimated that about 43 units of two drum water tube type auxiliary boilers were produced in 1989. This increase is considered due to an increase in construction of VLCCs.

Ishikawajima-Harima Heavy Industries, CO., Ltd. commissioned two gas firing auxiliary boilers (35 T/H x 16 kgf/cm²g saturated) for a FPSO (floating production storage and offloading) barge for Australia. These auxiliary boilers have been operating satisfactorily burning natural gas only.

Mitsubishi Heavy Industries, Ltd. also received an order for two gas firing auxiliary boilers (10 T/H) for an floating storage and offload crude oil barge and is now manufacturing these boilers.

There was no particularly remarkable achievement in technical aspect, however, the Boiler Committee of the Society continued an investigation on the problems related to burning of waste oil in auxiliary boilers following the effort made in 1988 and summarized a proposal for design, outfitting and handling of waste oil burning systems for improvement of reliability on the basis of informations and opinions obtained in response to questionnaires sent to those who have been directly concerned about the subject.

It is expected that more VLCCs will be constructed and the demand for auxiliary boilers for oil tankers will increase in 1990. Under the circumstance Osaka Boiler Mfg Co, Ltd. is developing vertical high pressure smoke tube boilers (10 - 30 T/H x 18 kgf/cm²g).

3.3 Exhaust Gas Economizers

Ishikawajima-Harima Heavy Industries, CO.,

Among exhaust gas economizers manufactured in 1989, only about ten units were of large size for turbo-generator plants as in 1988 and the rest were of small size for auxiliary steam supply. The reason why the number of large size exhaust gas economizers stayed small was for the overall reevaluation of the exhaust gas economizer turbo-generator system. The increased maintenance typically due to external fouling has now become one of the key factors to govern the economy of this system together with the effect for energy saving.

With a high efficiency exhaust gas economizer turbo-generator plant, the so-called third generation exhaust gas economizer system 1), heat is recovered to a range of low temperature and the overall plant efficiency is improved remarkably. However, as a result of lowering exhaust gas temperature due to the improvement of main engine efficiency in addition to the trend of burning fuel oil of more inferior quality in main engines, there have arisen problems of increased soot formation and heavier fouling of externals of exhaust gas economizer heating surface under the condition of reduced speed operation, etc. Such conditions which are severer than in the past have led us to be confronted with serious problems such as soot fire, acid dew point corrosion, etc. and studies have been in progress on these problems. Based on the result of investigation carried out in 1988 on practical needs concerning exhaust gas economizers, the Boiler Committee of the Society summarized a proposal for design, outfitting and handling of exhaust gas economizers for improvement of reliability.

Reflecting the bad effect of external fouling of exhaust gas economizers due to higher heat recovery down to a low temperature range, the proposal is made to suggest that the feed water temperature should be taken not lower than 120~130°C at the preheater inlet and the exhaust gas temperature should be taken not lower than 140~150°C at the economizer outlet on the design point.
6. SHAFTING

In 1989, development of new products and research for prevention of marine pollution, reduction of vibration and noise, energy saving, and etc, were much performed. JAPAN DOVER developed new type sealing system for stern tube "AIR GUARD 4AS" with the purpose for prevention of oil leakage outboard, sea water leakage inboard, and improvement of durability of sealing ring. This sealing system can prevent oil leakage outboard and sea water leakage inboard by supplying air into the chamber between #0/#1 seal rings.

In addition to the above, pressure difference between air chamber and oil chamber is always kept constant for various draft by controlling the oil pressure between #1/#2 sealing rings automatically. (The automatic pressure control can be achieved by detecting the air pressure in air tank corresponding to draft by air relay.)

KAWASAKI HEAVY INDUSTRIES developed a new type system "Damp Tank" to reduce vibration and confirmed its effect on a car carrier. "Damp Tank" installed above a propeller is a tank containing and water air absorbs the pressure fluctuation induced by a propeller. According to the results of sea trial for sister vessels, vibration level on the vessel with "Damp Tank" is improved.

As the results of the above, the durability of sealing rings is improved.
35~45% less than that of the vessel without "Damp Tank"

KAWASAKI HEAVY INDUSTRIES measured the propeller cavitation noise of a supporting ship "NATSUSHIMA" which is installed a controllable pitch propeller (cpp) for various combination of propeller revolution and blade angle.

On the measurement results, it was found that there are some combinations of propeller revolution and blade angle which minimige propeller noise.

The method to estimate the minimum of cavitation was established based on a 3-dim-

Ensional bucket diagram by the propeller lifting surface program.

It was found that the value estimated by the method well agree with the measurement results.

NKK adopted the method that sterntube bearings were fixed by the epoxy resin.

The method is that stern tube bearings are fixed to the stern frame by pouring epoxy resin into the space between stern tube bearings and stern frame after alignment of stern tube bearings.

Boring of a stern tube at building slips can be eliminated by adopting of the above method, and saving of working time can be much expected.

References
3) Nozawa, K., Fourth International Symposium on Practical Design of Ships and Mobile Units (1989-1-0)

F. Morimoto

7. Auxiliaries and Equipments

1. Pumps

1) Ebara Corporation installed the submerged motor pump in the LPG carrier which was built by Mitsubishi Heavy Industries for Yuyo Steamship Co., Ltd. This pump was developed succeeding the development of submerged motor pumps for a LNG carrier, and its features are to employ the spiral-typed inducer in consideration not only of loading/unloading but of stripping. This is to employ TEM (Thrust Equalizing Mechanism) to get the accurate balance of axial thrust, to lubricate the ball bearing with the pump delivery fluid to get safety operation, and to employ a supply line of methyl alcohol to prevent the locking phenomenon of the rotary part by freezing of water in LPG. In addition to that, the electrical feed through which isolate air side and the inner side of the LPG tank, uses the ceramic tube whose surface is metalized and brazed to both conductor and flange with a fitting of nickel cobalt alloy, so that the thermal effect to this part can be eliminated and mechanical reliability has been improved.

2) A small, robust and powerful axial piston pump has been developed by Volvo Hydraulics-uk. The pump operates at a maximum continuous pressure of 350 bar creating a displacement of 95cm3/rev. Minimum continuous speed is 500rev/min, with a maximum of 2900rev/min. The design of this pump is aimed to produce very low noise level, specific attention has been given to power/weight ratio and this unit is said to be ideal for many marine uses.

3) An advanced type of compact and powerful fire pump has been developed by Smit Fire and Loss Prevention, the Netherlands. This pump unit is coupled to dual hydraulic motors, which act as prime movers for two high-capacity submersible pumps and holds Lloyd's Certification to work in a gas hazardous environment. This unit is equipped with 456 KW diesel engine for driving hydraulic pump. It can be transported by air and is sufficiently sturdy to be handled by fork-lift.

2. Purifiers
1) Alfa-Laval KK introduced the LOPX separation system which is specifically designed for cleaning of lubricant oil for diesel engines. The main benefits of the LOPX separation system are:
   * Continuous optimum separation efficiency, as there is no water seal interfering with the disk stack.
   * Continuous monitoring of the cleaned lube oil and the system oil with respect to water content.
   * Fewer man-hours as there are no gravity discs, no alarms for broken water seal, and improved cleanliness of bowl.

   The design of the LOPX is based on the FOPX separation system for fuel oil first introduced in 1983. The layout of the LOPX is shown in Fig. 7-1.

2) Yamamizu Co., Ltd. has developed the low-quality fuel oil treatment equipment for the large sized marine diesel engine. This equipment, called Hope System, consists of the rotary typed filter and the device which can decompose and disperse the muddy sludge in the fuel oil, and separates the catalysts such as silica and alumina from the fuel oil and then atomizes the combustible asphalt into particle less than 5 micron in size. The treated asphalt is mixed with the fuel oil and is supplied for the combustion. This equipment has been improved on the Hope System for diesel generators through solving the problems issued by the results on the actual usage for 4 years.

**Reference**:
4) Shipbuilding and Engineering, Vol.23 (1990)
   [Takashi Nakamura]

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**8. Deck Machineries**

1) A new approach to windlass design could provide a reliable means of using the anchor to stop a large disabled ship in an emergency, according to the findings of study carried out at the University of Manchester, UK.

   According to the Amoco Cadiz disaster in 1978, in an emergency situation such as in the case of a large ship like VLCC drifting without engine power or steering in adverse weather conditions, the disabled ship frequently causes disasters, so the ship must be stopped by any way. As one of the ways, the University of Manchester carried out a study which made clear an effect of the energy absorption of a large ship in motion, and in order to realize it, the redesign of the windlass

   [Takashi Nakamura]

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300,000-ton VLCC drifting at 25 knot possesses kinetic energy of about 250 MJ and absorption of this energy is needed to stop the drifting. This energy would be equivalent to heating 4 tons of oil through about 301°C. In a paper presenting the results of this work, a windlass system is proposed in which the required energy conversion is achieved during paying out of the anchor cable by throttling the output of a positive displacement hydraulic pump/motor set, driven by the gypsy. On this system, when an anchor is used to execute an emergency stop, the resulting tension in the anchor cable is prevented from rising above the safe value by relief valves on the pump/motor set which limit pressure output to a predetermined level. Thus, if the limiting tension is reached, the anchor draws out more cable through the windlass until the tension decreases. In order to realize such a windlass system, the interaction of wind and currents and the change of anchor cable tension with time on the drifting ship should be needed to clear. According to the study, the dynamic hull behavior is simulated under the hull conditions responded to the interaction of wind and currents with the catenary effects of a constant anchor cable force, and as a result, the authors have obtained the range of the wind and the current velocities in which the anchor system can stop a drifting ship with and without an arrester, and have proposed the new anchoring system. The proposed anchoring system consists of one or more positive displacement pump/motor sets coupled to a windlass and arranged to pump fluid around a closed circuit through pressure relief valves. A secondary hydraulic circuit includes a power pack to provide high pressure oil with which to drive the motors for normal anchoring operation. A control valve in the high pressure oil line enables the gypsy to be rotated in either direction. If the anchor cable attempts to drive the gypsy, as in an emergency stopping operation or perhaps when lowering the anchor, a shut-off valve closes automatically and the cable is then controlled by relief valves. Changes in the oil volume during heating and cooling are accommodated by the accumulator.
2) The container crane recently has been required to expand the power, the speed and the efficiency for highly efficient container services. From the viewpoint of this requirements, Kawasaki Heavy Industries, Ltd. has produced large container cranes ("Super" container cranes). These cranes have features which are to apply to super-large container carriers (Over-Panamax size), to have the sway-prevention mechanism for hoisting container and the sag-prevention mechanism for hoisting wire, and to have adjusting functions for the height and span of column.

NKK Corporation has developed the monitoring system including operation guidance for container cranes. The features of this system are to have functions of the monitoring and the diagnoses, OA, such as making reports of operation and works, and information of maintenance. According to the functions, the data concerned with failures and operations can be restored to a computer set in an office building, and the data also can be informed to operators. In consequence of the data collection at the office, the cycle time of the crane operation has been improved so much.

Ishikawajima Harima Heavy Industries has developed a computer aided monitoring system with the function of the diagnoses of control system for container cranes. The features are to be able to diagnose failures by analyzing the data offered from a speed control network and to aim at establishing an intelligent container crane based on the control of operation and maintenance functions aided by computers.

References:
4) Ishikawajima Harima Engineering Review, No.2,(1989)

[Takashi Nakamura]

9. Fuels and Lubricants

1. Oil Situation

The Institute of Energy Economics, Japan held a symposium under the theme of "How to respond to the new energy situation-Demand, security and global environmental questions" on December 7th and 8th, 1989 and brought forward several problems concerning how to cope with the trilemma of economic growth, energy and environment as the core issue.

Particularly, as for the prospect for demand and supply, a study report entitled "The international oil situation is entering a new phase. - Does oil cycle repeat?" was presented. It was pointed out in the report that the recent international oil situation after 16 years from the first oil crisis in 1973 was similar in its nature to the situation in 1970s. At the same time, the paper presented the view that there was a high possibility for oil supply to become tight and for oil price to rise towards 1990s due to the hovering low price of crude oil in recent years and the international oil situation was entering into a climbing phase. According to the report, the present situation is similar to that in 1970s and has factors such as 1) unexpectedly high rate of increase in oil and energy demands, 2) large increase of demand for OPEC oil due to the stagnation in oil production in non-OPEC countries, 3) rapid increase of oil import by the U.S.A., 4) increasing interests in environmental problems and delay in energy development, etc.

Furthermore, the report analyzed that new trend concerning such international oil situations was brought about as a result of the oil demand being turned to increase due to the hovering low price of crude oil and the global active business market since 1986 and at the same time, investments for searching and developing oil and for developing alternative energies being kept low. The report said that the price of crude oil which had been hovering low since 1986 was likely to enter an upturning cycle on a full scale in early 1990s.

With respect to the short term prospect for next one to two years, the report analyzed that it would
be unlikely to have the oil price raised substantially as oil producing countries with the gulf countries as core nations were still having a strong will for production increase and that the price of OPEC crude oil would continue to stay in the range of US$ 15~20 per barrel. The report further pointed out that although the crude oil production capacity of OPEC countries was said to be about 30 million barrels per day, investment for development was kept in most oil producing countries and oil fields had not been well maintained, therefore, the present production capacity which could possibly be maintained had been considerably lowered to about 25~26 million barrels per day.

On the assumption that the oil demand in the free world will increase by about two percent every year in the future, the report estimated that the demand for OPEC crude oil would reach 27~28 million barrels per day in 1995 from 21.5 million barrels per day in 1989 as production in non-OPEC countries could not be expected to increase. On the basis of such estimation, the report emphasized that in the medium and long term views, the key to determine the trend of crude oil price in the future depended on to what extent the OPEC countries with the gulf oil producing countries as a core would expand their oil production capacity. The report estimated here that the rate of operation for crude oil production in OPEC countries would be raised to about 90% in 1995 from 83% in 1989 and the right feeling for oil supply would become stronger.

In addition, the report further states that 1) if opinions to impose heavier taxation on energy come up to the surface in order to respond to the global environmental problems, incentives to OPEC countries to make investment in expansion of oil production capacity will be lost and as a result, it will very likely become a pressure to raise crude oil price and 2) for the necessity to cope with the environmental problems, it is very likely that the demand for natural gas will sharply increase all over the world and the natural gas price will rise considerably and as a result, it will bring about a shift in demand from natural gas to oil causing the oil price to go up.

If the situation moves in such direction, the international oil market will be changed greatly from the buyers' market in 1980s to a sellers' market in 1990s. As to when the oil price really turns to rise, many organizations are estimating that it will be sometimes after the middle of 1990s, however, the report is pointing out that there is a strong possibility to have the turning point advanced to the first half of 1990s. According to the report, there is a strong possibility that the OPEC oil price which has been in the level of US$ 15~18/barrel will rise to an upper limit of US$ 25~30/barrel in around 1992-3.

Under the circumstance, it is necessary that measures for fuel saving should be further planned for ships and adequate measures should be considered to make ships to respond to extensive changes in fuel oil quality.

2. Marine Fuel oil

The price of marine fuel oil differs greatly for ports. For fuel oil having a viscosity of 380mm2/s at 50°C, the price was US$ 69~88/ton in January, 1989 1) but was US$ 82~110/ton in October, 1989 2) showing a rising trend.

The demand for marine heavy oil is the world excluding communist countries is estimated to increase to 116million tons in 1994 from 101million tons in 1988.

With respect to standards for marine fuel oil, the task to revise ISO 8217, BSMA l00 and CIMAC Standard have been in progress as reported in the 1988 Annual Review. BSMA l00 will be revised to the same standard as ISO 8217, however, the CIMAC Standard will be revised to be a different standard from ISO 8217. The newly revised CIMAC Standard will include the standard for grades of distilled oil as ISO. In this standard, MX is a gas oil for cold districts, DA is the ordinary gas oil and DB and DC correspond to A oil in Japan. According to the CIMAC Standard now under the process of revising, the sum of the content of Al and Si is specified to be less than 80mg/kg, however, this figure is provisional and is considered to be further reduced in the future, presumably to less than about 50mg/kg.

The method to determine content of Al + Si is stipulated in IP 377.

In connection with testing methods, a test method to accelerate deterioration of fuel oil which becomes necessary for stability tests is stipulated in the IP proposed method BA.

With respect to environmental protection, the MEPC (Marine Environmental Protection Committee) of IMO is requesting to make ISO Standards compatible for future revisions in connection with environmental protection. Responding to this request, it is considered that the contents
of sulphur, sediment, ash, residual carbon, etc. will be affected. It is predicted that use of fuel oil with a sulphur content of less than 1% m will be compulsory in ports and further, there is a possibility that the sulphur content in fuel oil burnt at the open sea will be reduced from the present value of 5% m or less to probably about 3.5% m or less. Therefore, it is predicted that ships will consume more fuel oil with a sulphur content of less than 1% m and will probably be required to be provided with MDF tanks of larger capacity. Furthermore, when changing over fuel oil there may arise unstable conditions due to mixing of fuel oil, therefore, it will become necessary to take some measures against formation of carbon sludges.

As a problem on safety and sanitation, an attention has been called to the possibility that H₂S in certain kinds of residual oil may be accumulated in tanks to a level dangerous for safety. With respect to this problem, a note is being included in a report to be issued by the CONCAWE (Oil Companies European Organization for Environmental and Health Protection).

With respect to the relationship between flash point and storage oil temperature, it has been considered safe because the space above oil surface will probably be in a non-flammable range if the storage oil temperature is more than 10 °C lower than the flash point. However, a question has been raised if this judgement is reliable. The OCIMF (Oil Companies International Marine Forum) is now preparing to issue a CONCAWE report on matters requiring special attention in connection with flash point in storing and handling fuel oil to shipping companies and ship operating companies.

For testing flash point of marine fuel oil, the Penski-Martens closed method is commonly adopted, however, when this method is applied to residual oil, there have been cases where a result of repeated tests shows a deviation of more than 50 °C. Under the circumstance, IP is in the process of revising the standard for testing methods at present.

Among various papers on marine fuel oil published in 1989, there are papers on changes in marine fuel oil and a summary of the trend of marine fuel oil quality. The issue of protection of atmospheric air pollution has become a matter also applicable to ships. From this viewpoint, studies on combustion have become necessary and there are papers on summary report on the trend of combustion technique, examples of studies on droplet burning by differential thermal analysis and development of an engine combustion analyzing system by personal computers. A paper was also published to introduce trends and countermeasures for NOx. NOx is related to the ignition characteristics of fuel oil and papers were presented on an new approach to the ignition mechanism and on a summary for effects of low cetane index on combustion. As a measure for reduction of NOx, the results of investigations on emulsion fuel were also reported.

For studies on combustion, various methods for analysis of fuel oil become necessary. In this connection, a report was presented on analysis of carbon distribution and structural group of fuel oil by calculation. An experimental result was reported on the effect of cylinder temperature and pressure on ignition delay. The level of NOx in exhaust gases from stationary internal combustion engines in Japan is desirable to satisfy the required level at least with a fuel oil with the cetane index of 40 considering that DMB of A oil is of a cetane index of greater than 35 in the ISO standard. Dealing with the fundamental of combustion, there are papers on combustion efficiency of residual oil, characteristics of soot formation and decomposition, a simulation method for heat release rate and fuel distribution and combustion of diesel engine spray.

In connection with changes to heavier fuel oil and changes of fuel oil in quality, there were papers on measures which had to be taken for combustion chambers as data for design of diesel engines and a measure for improvement of exhaust valve high temperature corrosion resistance by means of heat pipe cooling. For evaluation of various measures, it is very convenient if wear of piston rings and cylinder liners can be measured in a short time and a wear evaluation technique was reported.

A paper was also presented to report that a very good result was obtained using TiN coating to prevent wear of fuel oil injection pump plungers by catalyst in fuel oil.

In order to cope with changes of fuel oil to become heavier in density and more inferior in quality, it is insufficient only to change designs and materials for engines and it is necessary to respond to such changes with the entire fuel oil system including installations for fuel oil treatment.

On such a viewpoint, the CIMAC Recommendation was issued as a guidance for overall measures against heavy fuel oil treatment and fuel oil purifiers and fuel oil filtering.
techniques in recent years were reviewed.

3. Lubricants

The demand for marine lubricating oil in the world excluding communist countries is estimated to reach 1.1 million tons in 1990 and then to increase about three percent every year to reach 1.25 million tons in 1994.

There has been no change in quality of marine lubricating oil from what was reported in the 1988 Annual Review. The performance of engine oil can hardly be judged only by the level of total base number and it is essential to judge the performance by brands.

Papers presented in 1989 on the basic field of marine lubricating oil are an explanation on adhesive wear and abrasive wear, a report on fundamental characters and mechanism of corrosive wear and an interesting report on a calculation formula designed to estimate cylinder linear wear from the sulphur content in fuel oil, the total base number of cylinder oil and feed quantity of cylinder oil and on the fact that the result of calculation using this formula nearly coincided with the actual wear in engines. Furthermore, there are notes on the fundamental characters and mechanism of fretting wear, action mechanism of wear preventive additives and improvement of wear resistant characteristics by improvement of surface quality.

The item most important for lubrication of marine engines is wear of cylinder liners and piston rings and there are many papers on this subject. These papers are a report on present status of cylinder linear wear of low speed diesel main engines onboard ships, a note to explain how important it is to take countermeasures in an early stage by detecting abnormal conditions in lubrication and wear during operation and also to explain about development of necessary monitoring methods as an important subject, an introduction of materials and surface treatment methods for cylinder liners and piston rings to improve anti-wear performance and on a study on combinations between cylinder linear material and piston ring material to actualize low wear in medium speed diesel engines and on a finding that if the cylinder ring face pressure is excessively raised, the cylinder oil consumption can be reduced in a short term, however, eventually increases further as a result of increase in wear rate and uneven wear.

With respect to generator engines, there is a paper which presents an interesting report to explain that engines being taken with measures against use of inferior fuel oil such as chrome plating on piston ring grooves, hot water circulation at an adequate temperature, suction air heating at low load, etc. have less wear in cylinder liners and piston rings even when burning C oil having a viscosity of 380 mm²/s at 50°C and that the quality of fuel oil is related to the consumption of engine oil. There are also a well summarized paper on cylinder oil for low speed diesel engines and a report which explains clearly the range of fuel oil that can be managed by cylinder oil and describes the difficulty of cylinder lubrication. According to this report, it is highly desirable to establish a method to automatically control temperatures at various parts of engines adequately depending on operating conditions of engines by adopting electronic techniques as well as a method to confirm distribution and spray conditions of lubricating oil on cylinder walls in real time.

A paper on a ferrographic method was presented as a powerful tool to find problems and to investigate causes of these problems on lubrication.

Other papers presented are a report on the result of basic study on tribology of marine low speed diesel engines and tribology for improvement of quality and reliability of machinery and parts for marine use.

References
1) The Motor Ship, Jan., 1989
4) Ise, H., ibid., Vol. 24, No. 5 (1989-5), P. 8–13
5) Imai, K., ibid., Vol. 24, No. 8 (1989-8), P. 4–5
6) Shiode, K., ibid., Vol. 24, No. 8 (1989-8), P. 11–20
10. Nuclear Power

1. Research and Development by the Japan Atomic Energy Research Institute (JAERI)

1.1 Nuclear ship "Mutsu"

(1) Research and development by "Mutsu"

The basic policy which shall be carried out by JAERI on the research and development of nuclear ship "Mutsu" was announced by Japanese Government on March, 1985. The government policy also showed the research plan and procedure required for the development of nuclear ships.

The research and development with "Mutsu" (construction of new home port at Sekinehama, reactor inspection and tests, experimental voyage and decommissioning) is proceeding based on the policy and the schedule shown in Table 10.1.

(2) Reactor inspection by opening the reactor cover, hull inspection in floating dock and function test prior to start up

Reactor inspection by opening cover, and inspection and maintenance of reactor, control system and primary cooling system piping were performed at Sekinehama port. The work of the reactor inspection consisted of opening cover work, inspection and maintenance of main equipment and restoration work. The work of reactor inspection
started on August, 1988 and finished completely on
October, 1989. Some control rods and fuel rods
which had small pitting corrosions were replaced
new ones and a detailed inspection was made on all
of the rods to confirm the soundness.

Hull inspection was performed in a floating
dock on June and July, 1989 as shown in Figure
10.1 and no abnormalities could be found.

Function test prior to start up operation was
started on September, 1989. Operation and function
of machineries and equipments of all systems of the
plant are testing. The completion of the test is
scheduled before April, 1990.

(3) Research and development in physical year 1989
Power rising test and the test operation at sea
is started on March, 1990. After the tests, there are
plans to perform experimental voyage for about one
year. The aim of this voyage is to obtain the data
base related to the effects of vibration, rolling and
pitching, load variation, etc. on the reactor under
the oceanic environment.

1.2 Design study for Advanced Marine
Reactor2)
It is expected that nuclear ships could
contribute widely to the advance in marine
transportation system and exploitation of marine
resources when the conditions for the practical use
were satisfied in the further. Then the Japanese
Government decided that the research and
development for advanced marine reactors should
be proceeded steadily with taking long-sighted
views.

Based on the basic policy of the Government, in
order to establish the concept of the reactor which
fits to the demands from the future marine uses,
the trial design studies for the advanced marine
reactors, which are smaller in size, lighter in
weight and more simplified, safer and more
automatic in system than the existing reactors,
have been proceeding from 1983.

Practical design and evaluation studies for the
following two marine reactors which are supposed to

Fig. 10.1 Hull Inspection in Floating Dock

Fig. 10.2 Concept of MRX

(62) Marine Engineering Progress in 1989
Bulletin of the M.E.S.J., Vol. 18, No.2 123
be realizable in near future are conducted in
physical year 1989 based on the studies from 1983
to 1988.
- Advanced Marine Reactor MRX (thermal output 100MW, shaft horsepower 30,000ps)
- Ultra Small Reactor for Deep Sea DRX (thermal output 2MW, shaft horsepower 300KW)

In addition to the design and evaluation studies, development of nuclear ship engineering simulator which analyzes numerically the overall system of nuclear ships is under development.

This simulator is used for marine reactor development as an efficient tool.

(1) Advanced Marine Reactor X (MRX)

The conceptual sketch of MRX is shown in Figure 10.2. Its features are as follows.

- All the components of primary cooling system including the control rod driving mechanism are contained in the pressure vessel in order to reduce the possibility of the large scale of LOCA occurrence and accidents of control rod releasing. It also can simplify the safety system.
- The wet containment is applied to make it possible for the reactor core to be kept under water level and the decay heat to be removed by the passive cooling, even if LOCA would occur. It also can eliminate the secondary-shielding to the great extent.
- Long time passive cooling of reactor core is made by the passive cooling system which consists of the emergency cooling system and the containment cooling system. The emergency cooling system cools reactor core down by natural circulating coolant in containment when the emergency valve is opened. The containment cooling system cools the coolant in containment.

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**Fig. 10.3 Ice Breaker with MRX**

**Fig. 10.4 Concept of DRX**
by heat pump which contacts to the atmosphere. In physical year 1989, design study of 60,000ps icebreaker (Figure 10.3) which has two MRX was conducted.

(2) Ultra small reactor for deep sea (Deep Sea Reactor X, DRX)

The conceptual sketch of DRX is shown in Figure 10.4. Its features are as follows.

- The containment is wet type which contains both of reactor and generator (a set of steam turbine and dynamo).
- Steam piping lines are in the containment so that the pressure of deep sea cannot effect on the lines even if pipe rupture would occur.
- Turbine surrounding water is used for an emergency cooler and it can simplify the cooling system.
- the reactor core can be kept under water level even if LOCA would occur.

DRX can be utilized for deep sea researching submarine which can be in depth of 6,500m (Figure 10.5).

2. Other Research and Development

At Ship Research Institute3), Ministry of Transport, accident analysis of nuclear ships, evaluation of crack arrest behavior in reactor pressure vessel, research related to safe transport-ation of returning radio active wastes, computing codes for the safety evaluation of shielding, safety evaluation of destruction dynamics on reactor elements have been done continuously.

Furthermore they started the studies of man-machine interface system and reliability analysis GO-FLOW method4).

In addition, experimental study to clarify the effect of acceleration in the vertical direction on the critical boiling heat flux has been continued, cooperated with J AERI.

Tokyo University of Mercantile Marine has conducted the experimental study of pressure oscillation of vapor condensation in containment watery.

Reference
1) Gensiryokusenno kenkyuukaihatu (Research and Development of Nuclear Ships), (1989), JAE RI
2) Hakuyouronon Kairyoukenkyuu (Design study for Advanced Marine Reactor), (1990), J AERI
3) Papers of Ship Research Institute, No. 26, (1989)

[T. Takamasa]

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<table>
<thead>
<tr>
<th>Principal Items</th>
<th>Immersion Depth</th>
<th>Thermal Output</th>
<th>Shaifhorse Power</th>
<th>Inner Diameter of Pressure Resisting Globe</th>
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11. Automatic Control

1. General

The market of shipping and shipbuilding industries is considered really recovering and great changes were brought about in 1989 as an integrated result of the recent trend in number of crews which governs the extent of ships' automation and of the new development made in relation to automation.

One of the events was that the mixed crew system was approved for ships owned by shipo-wners in Japan together with reduced crew systems for modernized ships. At the end of 1989. The pioneer experimental ships started their test operation aiming at an eleven-men crew system as the final target and seven ships had been in test operation by the end of July, 1987. Furthermore, as third stage comprehensive test ships, D stage experimental ships newly started test operation in May, 1989 for modernization with a thirteen-men crew system. Including these ships, the number of modernized ships in Japan now reached 184. On the other hand, however, ships flagging out of registration in Japan have still been increasing to become flag-on-convenience vessels with mixed crew, therefore, mixed crew ships are now recognized to prevent this tendency.

Japanese people have now begun to be interested in marine cruise as a result of diversification of means of spending their leisure time and the year of 1989 is now remembered as the first year of building passenger boats on a full scale in Japan after the end of World War II. Following the commissioning of "FUJI MARU" of Mitsui OSK Passenger, Ltd., many passenger boats are planned to be built one after another. Although not of a Japanese flag, "CRYSTAL HARMONY" ordered by N.Y.K. Line to Mitsubishi Heavy Industries, Ltd. has been launched and is now under outfitting. She is scheduled to enter service in June, 1990.

Beginning with the large scale sea pollution accident caused by crude oil spillover from the tanker "EXXON VALDES" in March, 1989, the need for oil pollution regulation was suddenly advanced in the U.S.A. and both Upper and Lower Houses adopted respective bills to extensively modify regulations for design and operation of ships in the U.S.A. The major contents of both bills consist of measures for accident prevention, design of oil tankers and plans and measures for pollution clearance. Particularly, it has been decided that the bill regarding design of oil tankers would be studied by the U.S. Academy of Science by the end of 1990, however, it is planned to obligate tankers to be designed with a double bottom/double hull construction. With such a construction being introduced, the progress of discussion is being watched with a keen interest as a guideline to show future measures for prevention of oil pollution including navigation aid apparatus which will be useful for prevention of grounding and collision.

The research and development of element technologies for highly reliable and intelligent ships were being conducted by the shipbuilders' circle in the ship building Research Institute of Japan and were finalized in March, 1989. A part of the result was tested by the training ship "SHIOJI MARU" of the Tokyo University of Mercantile Marine. Systems tested were the automatic mooring and unmooring system, grounding prevention system and collision avoidance system. As these systems are useful as navigation aid devices for prevention of accidents, it is expected that the result of testing these systems will be practically applied for new navigation systems as soon as possible.

It should be also worth mentioning that the replacement ships for the oceanography research ship "HAKUHO MARU" of the Oceanography Research Laboratory, University of Tokyo was completed in May, 1989 at Mitsubishi Heavy Industries, Ltd. as a state-of-art research ship with world leading research facilities.

As for new products, various products utilizing AI and fuzzy theories were introduced and are expected to be used as tools for improvement of quality in the future.

2. Navigation System

As a result of technical development of electronic devices including LSI, a remarkable advancement has been achieved to make computers to have a higher performance and to gain move popularity. In the field of personal computers, for example, following the appearance of lap-top type computers, book type computers have been made available and the appearance of palm-top type computers has further accelerated the trend to smaller size and higher performance.
computers. In addition to such achievement made by utilizing the emerging technology, it was particularly striking that small size mass-produced units of global positioning system (GPS) were made public one after another.

These units will be mass-produced for use on cars and are expected to become attractive also in price.

The number of satellite networks will reach 24 in the beginning of 1991 and it will become possible to receive positioning data in twenty four hours a day all over the world.

Because of the high accuracy of positioning performance and the reliability, the GPS, when made available for actual application, will have a strong impact on various navigation systems in view of the development of high reliability intelligent ships and electronic chart D indication system (ECDIS) in recent years.

With respect to products of new development, Kawasaki Heavy Industries, Ltd. announced a new optimum navigation system. The first unit was installed onboard a container ship of Kawasaki Line commissioned in 1988.

This system has functions for navigation calculation, optimum speed allocation, optimum route finding, performance logging, ocean data indication, etc. and is also made capable of communicating with Ocean Routes Co. ashore.

3. Engine System

Mitsubishi Heavy Industries, Ltd. announced the new development of a condition monitoring system called MEDIC. This system is provided with special sensors such as cylinder pressure sensors, F.O. injection pressure sensors, piston ring monitoring sensors, exhaust value acceleration sensors, etc. and is to output the result of diagnoses. The system makes diagnoses of the condition utilizing fuzzy theories on the basis of data obtained by these special sensors and other process sensors. This is a main engine diagnosis system which has materialized an idea in the past. The first unit is scheduled to be installed for trial purposes on a VLCC which will be commissioned in May,1990.

Ishikawajima-Harima Heavy Industries Co., Ltd.

announced the development of an optimum power control system for main engine driven generator plant of thyristor inverter type. The first unit was installed on a VLCC delivered in 1989.

Hitachi Shipbuilding & Engineering Co., Ltd. announced the development of a start-up operation failure diagnosis system for main diesel engines which was to utilize artificial intelligence.

Mitsui Engineering & Shipbuilding Co., Ltd. introduced electronic governors for B&W S-MC type engines. The company reported that electronic governors had become to be used more and more as electronic governing by micro computers had been found effective as a measure to stabilize speed control of main diesel engines which were designed for an extremely long stroke and for lower revolutions.

4. Cargo Handling System

Construction of replacement vessels of VLCC became active in 1989. In such a situation, the requirement for cargo handling monitoring and control system has been changed in view of the importance of safety in operation and monitoring by CRT has also become to be adopted gradually.

Mitsubishi Heavy Industries, Ltd. completed and delivered crude oil floating storage tanks for Kamigoto Oil Storage Barge Co., Ltd. in October,1989. The cargo handling monitoring and control system for these tanks are to perform the same operation as that for handling cargo of ordinarily tankers, however, are designed for management and control accuracy of a level several degrees higher and are provided with hardwares of duplicate construction to improve reliability and safety. It is expected that these techniques will be applied to VLCCO in the further.

5. Ocean Technology

In connection with ocean technology, Ishikawajima-Harima Heavy Industries Co., Ltd. Announced the development of diagnosis system for underwater structures by television images.

Mitsubishi Heavy Industries, Ltd. also announced the development of manipulators useful for deep sea survey and underwater operation. Furthermore, Kawasaki Heavy Industries, Ltd. reported the development of varivec propellers (variable vector propellers) for ocean robots.

The varivec propellers are capable of changing the direction of thrust force in three dimensions and the thrust force in a wide range by changing the pitch of propeller blades.

[C. Furukawa]
12. ELECTRONICS

As remarkable advance of electronics for the marine technology in 1989, we can point out the following terms, that is, completion of "Hakuho-maru", is ., the ship for studying on the ocean at May, 1989, the real service of the submersible "Shinkai 6500", and then performance of the sea test based on the results of" the high auto-operating system of ships" developed by Japan shipbuilding committee using the training ship "Shiojimaru" of Tokyo University of Mercantile Marine.1)

On the other hand, for these few years, it might be said that the fuzzy theory has attracted the attention of the marine engineers, since we can find out lots of articles on the fuzzy theory and its application in the marine journals.

1. Application of fuzzy theory to marine technology

The symposium of " The fuzzy theory and its application to the ship operating system " sponsored by the electric technical standing committee of this society was a great success. This fact suggests that the fuzzy theory has been very popular2) and in particular become of major interest lately to the marine engineers. Even in this journal3), articles of the fuzzy theory can be seen ,and today, as its application to the marine technology, we can pick up such terms as the strength evaluation of the ship's shell2), the ship auto-navigation fuzzy expert system4) and so on, but there are few applications to the engine system or propulsion system. Consequently, we will wait for future research and development of the fuzzy system for the marine engineering.

2. Trend of electronics for marine engineering

In this journal, there were comparatively many papers on electronics and its application to the marine techniques and especially the term "mechatronics" was used considerably. For example, we point out the names of articles, say "The classification society's aspects to mechatronics"5), "proposal for practical engine mechatronics of marine diesel engine"6) and so on. Although it might be limited to an electronic governor7)8) system for the main diesel engine system, but from now on, the mechatronic technique will be applied to the each system in the marine field. From this journal of special issue9) on "Present and Future of Ship Automation", we can judge that such trendy becomes more and more strong.

On the other hand, in order to install in the ship "Hakuhomaru", many kind of devices and subsystems were developed newly.10) Moreover, the system of the submersible "Shinkai 6500" itself is very interesting, and the new system11) which can communicate between the two ships, i.e. "Shinkai 6500" and her mother-ship "Yokosuka" and their relationship was attracted the attention of the people concerned. In addition, as already stated, the test results of the high reliability and intelligent ship began to be appeared in the Bulletin of the Society of Naval Architect of Japan12) which suggests us a lot of informations on the concepts of the new ship coming soon.

As the miscellaneous topics, we can indicate the following terms, that is, the devices for designing the optimal navigation equipment installed at a container ship13), the modification of the electronic control method and technology applied to the marine system14) and the concept and design of the cockpit type of the console for operating or maneuvering ships15). These standing questions have been studied continuously and even now are still very important and difficult ones, and they also are the subject for a future study.

3. Others-Fields of research on electronics-

As already stated, in journals of the other fields, many kind of the fuzzy theory and its applications were appeared frequently, and this tendency also was found to be in journals of the basic research16)-18). In addition, in the field of control theory, the robust control which focuses on $H_\infty$ control has been developed and recently its achievements might become a center of attraction19).

On the other hand, in the field of electronic communication, the satellite communication20), future optical communication and processing technologies21) seem to be the most important problems. These new technologies also will be applied to the marine engineering soon and become key technology in the ships.
REFERENCES

1) For example, Tokyo shinbun (1989/11/26).
13) Ship Group, Kawasaki Technical Review, No. 104 (1989), p. 120.

13. Electric Equipment and System

1. Trends

The development made in connection with power electronics was a remarkable achievement in 1989. On the other hand, electric engineers made efforts also to develop new systems such as hotel service equipments for passenger boats in 1989.

Among many ships delivered in 1989, particularly noticeable were the 6,500 meter submarine survey ship, the oceanography research ship for the Ocean Research Institute, University of Tokyo, passenger boats, etc. The success of experiments carried out onboard actual ships as a part of the project for intelligent ship system was suggestive of the future development.

2. Electric Source and Electric Power

The main engine overhanging type 3,500 KW shaft driven generator unit manufactured by Nishishiba Electric Co., Ltd. was a remarkable marine electric equipment.

The generator unit is for a container ship built by Mitsui Engineering & Shipbuilding Co., Ltd. and consists of a 12P - 78/110 rpm - 405 V - 7.8/11 Hz - 4,140 KVA generator, a 4P - 1,800 rpm - 450 V - 60 Hz - 5,500 KVA synchronizer, an externally excited inverter type shaft driven generator control board, etc. This unit is one of the largest class in the world and is to play a role in making power electronics technique popularized for ships.

Japan Foundation For Ship Building Advanced has been engaged in research and development of superconductive magnetic propulsion vessels which utilize electromagnetic power for propulsion since 1985 and has been working on a schedule to have sea trials of an experimental ship with a length of about 22 meters in 1990. The DC power unit for superconductive magnetic propulsion experiments is under production by Nishishiba Electric Co., Ltd.

The unit consists of a 2,000 KW generator of 6 P - 370V(Max.473 V) - 0.95 pf - 90 Hz, two 900 KW rectifiers of DC 450 V (Max. 600 V) - 2,000 A, two ripple reduction reactors of DC 2,000 A - 0.75 mH, a control board, etc.

Unusual equipments which are now under production by Mitsubishi Electric Corp. for the 6,500 meter submarine survey ship are an oil sealed cage type induction motor, an oil immersed inverter, an oil immersed switchboard and a non-fuse breaker to be used being immersed in insulation oil under a deep sea pressure in an oil immersed equalizing pressure type container.

The cyclotron converter type electric propulsion system has already been used for passenger boats, however, is now studied positively for new passenger boats.
3. Instrumentation and Automation

Rationalization of ships' operation has been strongly required in recent years. Under the circumstance, real time operation and fleet control systems have become to be adopted. These systems are to realize an integrated shore/onboard management by unifying information from shore and ships. Systems used for this purpose are the centralized engine room and deck part control and monitoring system and the shore/ships data communication system. The latter system is making use of onboard operation management networks and IMARSAT marine satellite communication networks.

In order to rationalize operation of ships, systems to closely examine energy saving and human power saving are newly being introduced in relation to navigation. The optimum navigation planning unit of Kawasaki Heavy Industries, Ltd. is an example. This unit is to achieve reduction of fuel oil consumption while reducing time and effort required for navigation planning by integrating functions for navigation calculation, optimum speed allocation, optimum escape route finding, etc. upon receiving information on weather and sea conditions from Ocean Root Co.

"HAKUHO MARU" built and delivered by Mitsubishi Heavy Industries, Ltd. in May, 1989 for the Oceanography Research Laboratory, University of Tokyo played an important role in development of the optical data link system. The ship is equipped with an onboard data processing system which utilizes optical data link system and optical laser network with a navigation automation unit as a core.

A part of the result of studies for high reliability intelligent ships was tested on actual ships. The result of these studies had been expected to further advance automation. With the success of this experiment, it is expected that the items studied for the intelligent ships will be applied for practical use from now on.

4. Electric Installation on Passenger Boats

Construction of passenger boats has been actively underway and many projects for building passenger boats are further being planned. Many electric facilities which were not installed on ships built in the past are now required for passenger boats. This new development is providing many electric engineers with fields of activity and many techniques which are different from what have been used so far have become necessary.

Electric propulsion is adopted in many cases as explained in the paragraph for electric source and electric power.

For illumination, special illumination and apparatus such as large scale illumination control units, stage illumination units, laser light units, etc. are necessary for large halls, restaurants, etc. A sense for interior design is necessary for selection of equipments and for judgement on illumination effects.

Sound and image systems are indispensable for entertainment on passenger boats. For example, television systems are required to have the function of mini-wired radio stations which are capable of not only handling re-transmission of on air broadcasting but also handling sound and image information altogether.

BGM broadcasting equipments are also important to produce unique atmosphere of passenger boats and apparatus for discotheque and film projection are also necessary.

For telephones, multi-functional automatic telephone exchange networks are installed. These networks must have several channels for circuits of marine satellite communication, ships radio, shore radio, etc. respectively.

In addition, various systems are required including a POS key card system for onboard cashless service, for improvement of customer service such as passenger location service and for management of stocks, etc.

From safety aspect, address type fire sensors, escape route indication lights, emergency alarm broadcasting facilities, etc. are necessary.

As explained in the above, electric facilities are used everywhere onboard and electric cables are needed in an enormous quantity. Therefore, multiple communication systems which utilize optical fiber cables and coaxial cables have been adopted and are further being investigated.

5. Standardization Activity

There were many activities for standardization including activities of JIS/JMS and participation in international conferences such as those of IEC. These activities were promoted by Japan Marine Standards Association as a core.

Representatives from Japan participated in the following two international conferences on marine electric subjects held by IES in 1989:
14. Offshore Engineering Machinery

1. Outline

The level of crude oil price in 1989 was unstable although stayed at about US$20 per barrel, therefore, the oil and gas production industry in the world was still sluggish for uncertainty of profitability.

In addition, crude oil spill out accidents occurred to the sea in the U. S. A. one after another and there have arisen possibilities for increase of cost for production by regulations being imposed more strictly from the environment protection point of view. This is inevitably a negative factor in promoting production of oil and gas.

On the other hand, however, research and development for TLP tension leg platform have been steadily in progress for production of oil and gas in seabed of a medium depth.

Developments are steadily being advanced in the field of deep sea survey and observation. The deep sea submarine vessel "Shinkai 6500" and the supporting vessel "Yokosuka" were completed and "Shinkai 6500" achieved a diving to a depth of 6,527 meters.

Furthermore, various scientific technologies related to unmanned submarines, underwater robots, underwater acoustic apparatus, high static hydraulic pressure resistant electronic devices, marine biotechnology, etc. are being advanced year by year.

Although water front development projects were much talked about, the development of equipments for utilization of offshore space was not done as much as expected and stayed inactive in general.

2. Record of Construction

For construction of offshore engineering equipments, questionares were sent to member companies of the Society. The record of construction in 1989 is summarized in Table 14.1 based on the responses to the questionares. No drilling rig was constructed for production of oil and gas, however, an FPSO (floating production storage & offloading unit) was constructed after a long interval.

Underwater equipments, work ships, work platforms, measuring and searching equipments, leisure equipments and others were manufactured presumably also by other shipyards and manufacturers not registered as member companies of the Society, therefore, the record summarized here should be considered only for reference. A submersible sightseeing boat is included in the record showing a new trend.

3. Record of Order Received and Future Prospect

The record of orders received in 1989 is shown in Table 14.2. Although there is a prevailing feeling that the market related to oil and gas production has left the cloudly condition of a time, orders received were only for three projects. It is hoped that demands will increase by stabilization of crude oil price and activation of the market.

On the other hand, there were new orders received for a fishery survey ship of the newest design and a floating ice sight-seeing ship as a facility for ocean leisure. The demand for equipments related to leisure industry is steadily growing.

Oceanographic surveys are actively being
**Table 14.1 Record of Construction in 1989**

<table>
<thead>
<tr>
<th>Category</th>
<th>Customer</th>
<th>Content</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil-gas Production</td>
<td>BHP Petroleum Pty., Ltd.</td>
<td>FPSO (238.5m x 39m x 21.4m) Crude oil production capacity 30,000 BPD oil storage capacity 139,000m³</td>
<td>HHI</td>
</tr>
<tr>
<td>Underwater equipment</td>
<td>Japan Marine Science and Technology Center</td>
<td>Manmade submarine survey ship &quot;Shinkai 6500&quot; Max. depth 6,500m ROV (0.8m x 0.52m x 0.36m) MAX. depth 150m UV (1.5m x 0.75m x 0.45m) Autonomic submarine Submarine launcher Optical fiber communication used between vehicles</td>
<td>MHI</td>
</tr>
<tr>
<td>Kanto District</td>
<td>Construction Bureau</td>
<td></td>
<td>Mitsui</td>
</tr>
<tr>
<td>Production Technology</td>
<td>Research Laboratory, Univ. of Tokyo</td>
<td></td>
<td>Sumitomo</td>
</tr>
<tr>
<td>Japan Marine Science and Technology Center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work ship &amp; Work platform</td>
<td>Fukada Salvage JV Kubota, Ltd.</td>
<td>Cement plant ship (140m x 36m x 8.7m) Stabilized control within 0.2 degree Elevating type platform Offshore breeding feed monitoring Crane ship (100 tons) with spud Working water depth 38m Grab dredger (Self propelled 200m³ 38m x 10m x 2.8m) Unloading ship (93m x 28m x 3.5m with 16m backhoe)</td>
<td>Sanyoassy</td>
</tr>
<tr>
<td>Ministry of Fishery, Sri Lanka</td>
<td></td>
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<tr>
<td>Aoki Marine</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Leisure equipment</td>
<td>Japan Underwater Sight-seeing</td>
<td>Small hovercraft One man riding 32PS Two men riding 30PS Submersible sight-seeing boat Passenger / Diving depth 50m Simulation theater (On moored floating vessel)</td>
<td>MHI</td>
</tr>
<tr>
<td>Nagasaki Holland village</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Measurement and survey equipment</td>
<td>Osaka Industry and Technology Test Laboratory</td>
<td>Water quality automatic measuring buoy (Botanical plankton dissolved iron, etc.) Grab vessel work management system (Dredging bed profile measurement by sonar) Stratum survey unit (For various soils in sea bottom, 5-step frequency changes) Portable wave height meter (Data memory for 45 days maximum, for one year installation) Marine resources survey system (Sonars: Two kinds, four frequency fish quantity detection) Multi-narrow beam sonar (For sea bottom profile survey)</td>
<td>Furuno Electric Furuno Electric Furuno Electric Furuno Electric Furuno Electric Furuno Electric</td>
</tr>
<tr>
<td>Shikoku Kenko</td>
<td>Pentz Ocean., Arika Suisa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 3 Harbour Construction Bureau</td>
<td>&quot;HAKUHO MARU&quot; of Oceanography Research Laboratory, Univ. of Tokyo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisheries Test Laboratory, Iwate Prefecture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>Kansai Electric</td>
<td>Wave power electric generator unit (Max. capacity: 1kw, pendulum type) Hinge for mooring buoy (For low temperature) Submarine support vessel &quot;YOKOSUKA&quot; (195m x 16m x 7.3m with reduction measures for underwater radiation noise and propeller generated direct noise and solid transmitted noise) Water bus (Low noise and low vibration)</td>
<td>Hitachi</td>
</tr>
<tr>
<td>IMODCO, BHP</td>
<td>Japan Marine Science and Technology Center</td>
<td></td>
<td>Kobe steel</td>
</tr>
<tr>
<td>Meitetsu Kanko</td>
<td></td>
<td></td>
<td>Kawasaki</td>
</tr>
</tbody>
</table>


"Shinkai 6500" is most representative of submersible equipments. The demand for periodical continuous fixed point observation is considered to become more important and it is hoped in this connection that the development of underwater acoustic technology, etc. will be made more actively. Projects such as those for water front development, etc. are the field where the shipbuilding technology can expectedly be utilized, therefore, it will be necessary for shipbuilders to made plans of their own and to exert their best effort for materialization.

[H. Hara]
**Table 14.2 Record of Orders Received in 1989**

<table>
<thead>
<tr>
<th>Category</th>
<th>Customer</th>
<th>Content</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil-gas Production</td>
<td>Petronious ELF Japan National oil Corp. JAPEX offshore ltd.</td>
<td>FSO (230m × 39.5m × 22.7m, 125,000 DWT) FSO (256.5m × 60m × 30m, 275,000 DWT) RPTS (180m × 30m × 15.5m, 33,200 DWT) Basic design Iwafune offshore deck module (oil: 1,400 kgs/day, gas: 600,000m³/day)</td>
<td>MHI MHI NKK</td>
</tr>
<tr>
<td>work ship and work platform</td>
<td>Harbour Bureau, Osaka City</td>
<td>3m³ grab/mixed jet pump dredger (With spud 31m × 11m × 26m)</td>
<td>Sumitomo</td>
</tr>
<tr>
<td>Leisure equipment</td>
<td>Dobto Kanko Kaibatsu</td>
<td>Floating ice sight-seeing ship (Ice breaker type: 41m × 10m × 4.8m, continuous ice breaking capacity: 0.5m, passenger: 430)</td>
<td>NKK</td>
</tr>
<tr>
<td>Measurement and survey equipment</td>
<td>No. 4 Harbour Construction Bureau</td>
<td>Wave observation buoy (Water depth: 40m, wave height: 2.4m, wind velocity: 60m/s) Accumulated sand monitoring apparatus for water gate (Monitoring of accumulated sand by travelling sonar) Stratum survey unit (Detailed survey of remaining sand layers)</td>
<td>Mitsui Furuno Electric Furuno Electric</td>
</tr>
<tr>
<td>others</td>
<td>Fishery Agency Yoshiida Gami</td>
<td>High technology fishery survey ship (90.2m × 35m × 9.2m) provided with newest observation equipment, LAN, etc.) 20m³ grab dredging machine (Motor driven, constant digging depth, horizontal grab control)</td>
<td>Mitsui Sumitomo</td>
</tr>
</tbody>
</table>
Fig. 2.4 Cargo hold demister system

Fig. 2.12 ZA40S Perform. Curve(900PS/Cyl × 510rpm Propel. Charact.)