CONTRIBUTIONS ON NEW HYDRODYNAMICS TEST FACILITIES
to be presented during the session on
FACILITIES AND INSTRUMENTATION

1. NEW MULTI-PURPOSE EXPERIMENTAL MODEL BASIN OF SUMITOMO

S.Nagamatsu
Hiratsuka Research Laboratory,
Japan

1. INTRODUCTION

In order to meet growing needs for offshore activities in shipbuilding market such as technical evaluation of mooring system, construction of offshore structure, development of subsea oil production system and etc., a new multipurpose experimental model basin has been completed at Hiratsuka Research Laboratory of Sumitomo Heavy Industries, Ltd. and has been in full operation since the spring of 1979.

The experimental model basin consists of two parts, seekeeping and manoeuvering basin (wide tank) and towing basin (long tank). One of the outstanding features of the basin is that two basins are connected each other through channels and water in the basin is circulated by current generators.

The main facilities of the wide tank (56 m x 30 m x 2.5 m) are a digital computer controlled X-Y carriage with a turntable, a wave maker of single flap type, current generators and two sets of wind generators (one is the axial fan type, equipped on land, the other the centrifugal type, temporarily suspended to the turntable). Utilizing these facilities, so many kinds of experiments can easily be performed under a specified sea state condition.

In the long tank (120 m x 6 m x 3.5 m), a digital computer controlled towing carriage and a plunger type wave maker are provided. This basin is mainly used for resistance and propulsion tests in still water and in waves.

The multi-motion carriage and the current generator are introduced briefly in the following, but as for other facilities please refer the ITTC catalogue of facility.

2. COMPUTERIZED PLANAR MOTION CARRIAGE (abbrev. CPMC)

The multi-motion carriage provided in the wide tank is usually called "Computerized Planar Motion Carriage". Main carriage (X-carriage) of CPMC runs in longitudinal direction and sub-carriage (Y-carriage) with a turntable which is suspended to the main carriage moves transversely along the 30 m length beam. These carriages and the turntable are completely controlled by 8 bits type digital computers in the control room, and they can trace arbitrary horizontal curve in three degree of freedom. One of the computers is utilized for a d ta aquision purpose during a test.

The CPMC at SUMITOMO has the following operation modes:

1. solo (running),2. obliquing,3. circular motion,4.pure swaying, 5. pure yawing, 6. combined motion, 7. tracking.

For instance, at free-sailing model test, tracking mode is applied. The CPMC accelerates a model and releases it when carriage speed becomes constant, then begins to track the model by sensing the relative deviation between the model and the carriage through a special TV tracker. Thus the ship path and speed can be obtained from the carriage location and the relative distance. This procedure is illustrated in Fig. 1.

3. CURRENT GENERATOR

One of the most important research works in offshore development is how to evaluate current effects on motions of offshore structure, mooring chains, dynamic positioning system and so on. In order to investigate these current effects, current generator system was introduced at Hiratsuka Experimental Model Basin.

The current generator, which consists of six ducted propeller units driven by DC motors and diffusers with punched metal plates, is installed behind the flap type wave maker, as shown in Fig.2.

The dimensions of current generator unit are:

length x breadth x height x weight:
2.4 m x 2 m x 5 m x abt. 5.5 tons;
DC motor power x revolution:
45 KW x 1750 rpm;
Impeller diameter 1.4 m
number of blades 3
blade section NACA 4409.

Each unit is operated independently and as the revolution of propeller is arbitrary chosen in clockwise or counterclockwise, reverse flow or a sort of eddy current can also be generated if necessary.

In the normal operation (clockwise revolution), water in the wide tank goes into the towing tank through a water channel and goes back to a large water storage chamber through the other channel. In the case, the flow in the wide tank curves toward the entrance of the channel. To prevent that and to run flow parallel with the basin wall, movable plate type guide vanes are provided in the basin. As a result of installing such reservoir, punched metal plates and guide vanes, the current velocity and velocity profile are desirable both in the horizontal and vertical planes (see Fig. 3). Being generated, the flow velocity in the long tank becomes about three times of that in the wide tank. In the speeded up flow in the long tank, a stationary flow pattern around a floating object can be observed.

4. CONCLUDING REMARKS

The above mentioned facilities were designed by Sumitomo Heavy Industries, Ltd., and the manufacturing of the X-Y carriage, the towing carriage and the flap type wave maker were also done, including the control systems of them.

Finally, main works carried out up to now in the Laboratory are as follows:

In seakeeping and manoeuvering basin:

motions in waves (container ship, catamaran, etc.);
mooring test in wave/wind/current (semisubmersible vessel, oil storage tank connected with riser, etc.);
manoeuvering test (captive and free-running, tanker, PCC, etc.).

In towing basin:

resistance/propulsion test (tanker, twin screw ship, etc.);
resistance increase test in wave (PCC, self-propelled barge, etc.);
propeller open test.

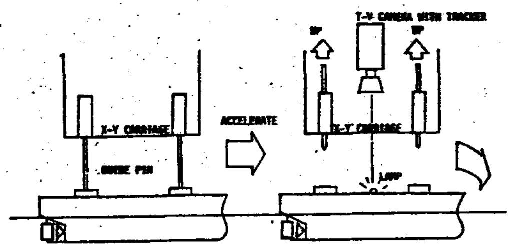

Fig. 1 Acceleration and tracking procedure

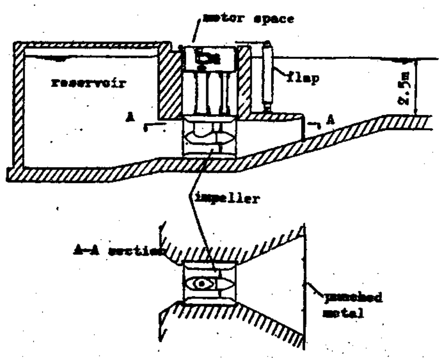

Fig. 2 Setting of current generator

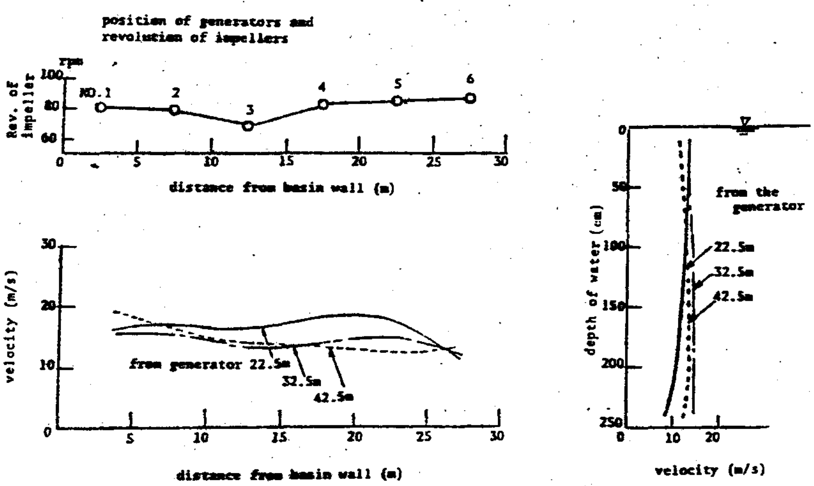

Fig. 3 An example of velocity distribution in horizontal plane (left) and in vertical plane (right)

2. THE OCEAN LABORATORY OF THE NORWEGAIN HYDRODYNAMIC LABORATORIES

E. Huse

Norwegian Hydrodynamic Laboratories,
Trondheim, Norway

GENERAL

Since around 1970, the Ship and Ocean Laboratory of the Norwegian Hydrodynamic Laboratories (formely the Norwegian Ship Model Tank) has performed a lot of model testing of platforms and other types of structures within the field of ocean engineering. Up to 1979 these tests were primarily done in the old towing tank with dimension 175 m long, 10.5 m wide and 6 m deep. In 1978 construction work started in order to expand and improve the laboratory facilities for testing offshore structures. The expansion has taken place in two steps.

The first step was a basin of 85 m length, 10 m depth and 10.5 m width. This basin was built as a direct extension of the old towing tank. It is separated from the old tank only by a dock gate and a wave beach. Both are hinged at the bottom and can be submerged to rest on the bottom. With the beach and dock gate down, the main towing carriage can travel in one stretch the full length of the two basins, which is now 260 m. With the dock gate closed and the beach in its upper position, the two basins can be operated separately. The new basin is equipped with a separate carriage to simulate current when testing offshore structures. It is also equipped with a hydraulically operated double flap wave maker, capable of generating up to 0.9 m high waves referred to regular waves. This basin became operational in 1979.

The second step in the construction of new laboratories is what is now called the Ocean Laboratory. This basin has been designed primarily for testing of offshore structures. However, with its dimensions and current and wave generating capabilities, it should also be suitable for certain types of manoeuvring and ship handling studies.

When building a new laboratory for ocean engineering work, an all-important consideration is that the facility must cover the needs not only for the immediate future, where the tasks may be more or less defined, but also for the more diffuse long-term challenges. Based on considerations of present and future requirements regarding testing of offshore structures, the following design aims were laid down for the new facility:

- It must provide a total environmental simulation including wind, waves and current, with particularly strict demands placed on the wave generating capability for the production of short-crested waves.

- It must provide space for the modelling of large complex systems and allow testing of a number of typical structures at significantly larger scale than available at existing laboratories.

- It must provide water depth variable from 0 to the largest reasonable depth considered for all oil exploitation in the next 20 years, with reasonable scale limitations.

- It must retain flexibility for future changes in measuring systems, instrumentation, computing equipment and basic facility equipment such as wave makers, current generators and wind batteries.

These design considerations have led to the Ocean Laboratory as described in the subsequent paragraphs.

MAIN DIMENSIONS

The main dimensions and lay-out of the Ocean Laboratory are as shown in the enclosed figures. Its main dimensions are:

Length	80 m
Width	50 m
Depth	10 m

The length and width given above are as measured from front of wave maker to intersection between wave beach and normal still water surface.

WAVE GENERATORS

The basin is equipped with wave generators along two sides. Along the 50 m side there is a hydraulically operated, double flap type wave maker. The design specifications of this wave maker are that it shall be capable of generating regular waves of a wave height at least 0.9 m in the period range from 2.4 to 2.8 sec. In the range of periods from 2.4 sec. down to 0.8 sec. the wave height falls off as determined by wave breaking. In the range of periods from 2.8 to 5 sec. the wave height falls off as determined by the given power of the wave generators. This wave generator is capable of generating only long-crested waves. The electrohydraulic control valves can accept any input signal for generating irregular as well as regular waves.

Along the 80 m long side of the basin, there is a second system of wave makers. This wave maker consists of all together 144 elements beside each other, each of them controlled independently of all the others. Each element is an electromechanically driven single flap unit. This system of wave generators has been designed primarily for generating short-crested waves. When generating long-crested, regular waves it is, according to design specifications, capable of generating a maximum wave height of 0.4 m at a period of 1.6 sec. (At the time of writing, January 1981, the laboratory is still under construction. The final performance of the equipment has thus not been measured, and one can therefore only refer to design specifications).

ADJUSTABLE BOTTOM

As shown in Fig.3, there is an adjustable bottom covering the whole area of the basin. The purpose of this adjustable bottom is twofold:

- It makes it possible to test models at any depth up to the maximum depth of the basin.

- The space underneath the adjustable bottom serves as a return channel for the current generating system.

The system for operating the adjustable bottom is as follows. The buoyancy of the bottom exceeds its weight, so that it will float up by its net positive buoyancy. There is a number of steel ropes fitted underneath the bottom, passing via trolleys at the bottom of the basin to jigger winches in a separate winch room. By means of the cable and winch system, the adjustable bottom will be pulled down to its correct position specified for each test.

There is a second mechanical system for holding the bottom rigidly in the specified position, preventing possible vertical motion due to wave action. This system consists of all together 30 steel columns fixed to the lower side of the adjustable bottom. These columns are about 10 m. long. They slide up and down in holes which go down to a depth of 10 m below the bottom level of the basin (see Fig. 3). At the bottom level of the basin, there are hydraulically operated clamps fitted. These clamps or brakes will, when engaged, prevent any vertical motion of the column.

CURRENT GENERATING SYSTEM

The current generating system is capable of generating current in any direction in the basin. According to design specifications the maximum current speed will be 0.2 m/sec. The design of the pump system is as follows:

There are all together 133 vertical tubes, about 5 m long, evenly distributed along all 4 sides of the basin. Fig. 3 indicates a few such tubes. The tubes cover the lower half of the basin's depth, and are connected to manifold tubes at the bottom level of the basin. Most of these vertical tubes are fitted with 4 nozzles, some of them only 3, pointing into the basin at right angles to the wall. Water is pumped out at high pressure, up to 10 bar, through these nozzles. The jets from the nozzles will transfer their momentum to the surrounding water, producing pressure gradients in the space underneath the adjustable bottom. This water will flow around the adjustable bottom through slots fitted in theadjustable bottom along the 3 sides of the basin. At the fourth side, where the double flap wave maker is fitted, the arrangement is shown in Fig. 3. There are 3 such slots along all 4 sides. The various slots can be opened more or less, or closed completely, by hydraulically operated guide vanes.

INSTRUMENTATION AND DATA PROCESSING EQUIPMENT

The main system for measuring model motions is an optoelectronic system described in a separate paper "3-Dimensional Position Measuring Systems" by Abelseth and Røtvold. Other physical quantities, such as forces, moments and accelerations, will be measured by commercially available transducers or by equipment specially designed for each test.

Data transmission from the model is by a wireless system designed by NHL. It is based on microprocessors for maximum flexibility. Maximum number of channels is 64, easily expandable to 192. It is full duplex with 8 control channels. Typical sampling rate with all channels in operation is 20 Hz. Maximum sampling rate at reduced number of channels is about 10 kHz.

The main building block of the data

acquisition and processing equipment is a Hewlett-Packard 1000 system with 384 kbyte memory, 20 Mbyte disc, graphic terminal, plotter, magtape unit, etc. Additional off-line analysis can be done on an in-house HP 3000 system or at the central computing facility of the University of Trondheim.

TIME SCHEDULE, BUDGET, FINANCING

The construction work for the Ocean Laboratory started in March 1979. According to the time schedule (at the time of writing) the construction work will be finished and all equipment installed by the end of March 1981. For the remainder of the year 1981 the activity will primarily consist in calibration work and other running-in activities.

The total budget for the expension of the Towing Tank plus the Ocean Laboratory with all equipment is about NOK 125 mill. According to present scheme the financing will be such that NHL receives about 80% of the investment as a grant from the government. The remaining about 20% of the investment will be obtained in the form of loans that will have to be paid back with interest on ordinary-commercial terms.

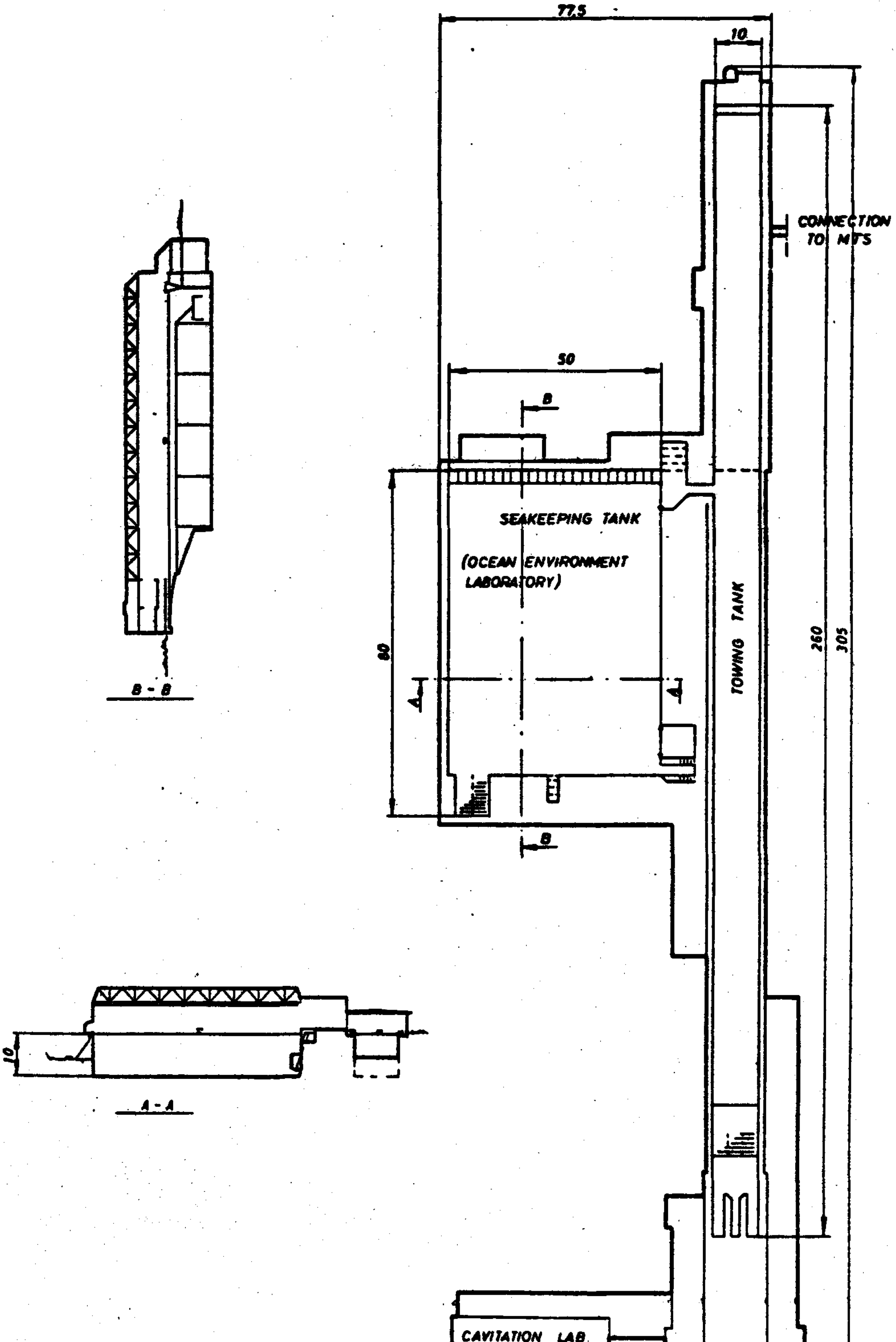

Fig. 1 General plan of the facility.

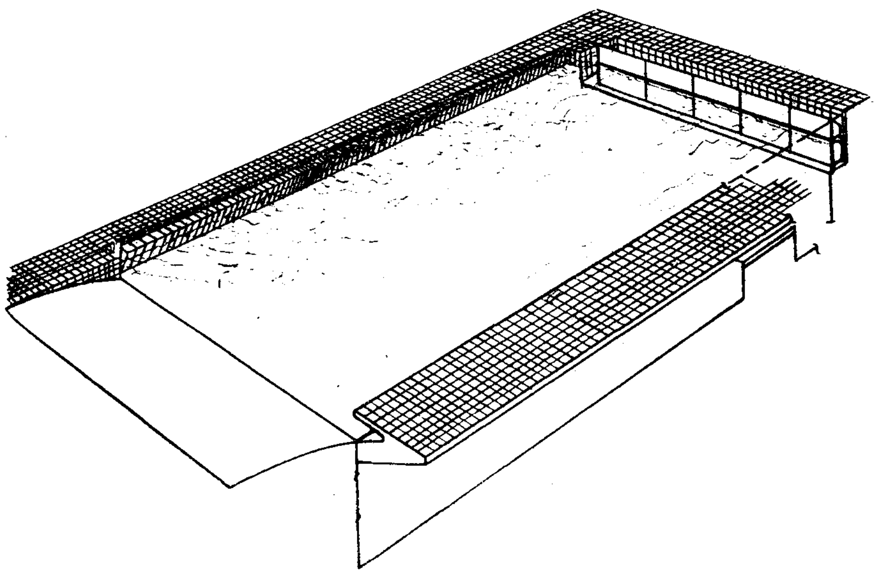

Fig. 2 General view of the wave generating systems.

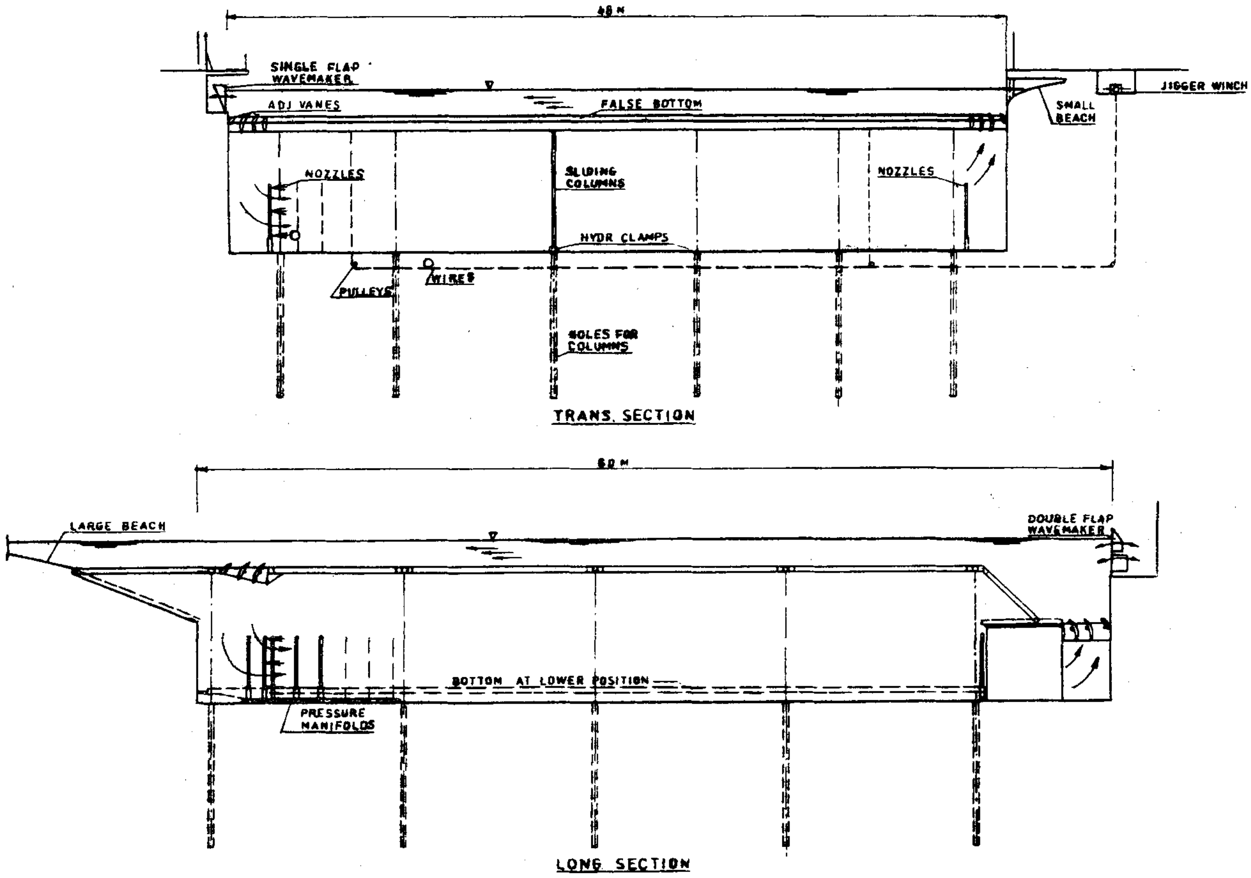

Fig. 3 The current generating system and the adjustable, floating bottom.

3. ICE MODEL BASIN OF SHIP RESEARCH INSTITUTE

H. Takahashi and H. Kitagawa
Ship Research Institute, Tokyo, Japan

INTRODUCTION

The industrial demands for reliable and satisfactory solutions of ice engineering problems have remarkably increased in the present decade. In response to them, an ice model basin was planned and is now put into service at Ship Research Institute. The new ice model basin is mainly intended to serve the industry and to provide data and information indispensable for solving technical problems of ice transiting ships which will be operated in the Arctic and other ice regions. The facility is also intended to conduct basic and applied researches on ice engineering problems.

GENERAL FEATURES

The building is a single storey, prefabricated construction, approximately 54 m by 25 m, containing five primary areas; a test basin, work shop, control room, offices, and machinery area for refrigerating system, as shown in Fig. 1. There is an observation corridor in a basement beneath the test basin.

An undiluted saline water tank is located apart from the main building.

TEST BASIN

The basin is 6.0 m wide, 1.8 m deep and 35.0 m long. At the northern end is a trim tank, 1.6 m wide, 0.9 m deep and 8.0 m long, which is through an insulated gate connected with the test basin. At the opposite end the wall is sloped and back up to an ice-crushing hopper. There is no separation between the cooling room and the ice-crushing hopper area. An insulated cover which is operated with a hydraulic system is provided over the stainless steel hopper.

The basin is of concrete, and the side walls are of reinforced concrete with steel fibre. The outer surface of the concrete basin is covered with polyurethanefoam, and the interior, which is exposed to ice and water, is additionally reinforced with fibre glass.

An observation corridor in the basement is provided to allow underwater viewing of ice phenomena during model tests, which also serves as insulation from relatively high underground temperature during the summer season.

The trim tank can be shut off from the test basin by insulating vertical slide doors above and under water and kept at a different temperature. There is no ice in the trim tank.

INSULATION

The insulating system consists of a coating with prefabricated polyurethane panels, which are covered with aluminum plates. The panels cove the ceiling and every side of the cooling room.

A water resistant polyurethanefoam layer insulates the floor, bottom of the test basin, and interior surface of the basement. The insulated trap doors separate the tank building from the work shop. Fig. 2 shows the structural arrangement.

COOLING SYSTEM

Refrigerating machinery for the cooling system is located at the machinery room. The foundation of the room is independent of the rest of the building. Two brine cooling systems are decided to use. One of them serves the ceiling coolers. It delivers a refrigerating capacity of 121,680 Kcal/hr at a brine outlet temperature of -48° C, in which trichloroethylen, $CHClCCl_2$, works as cooling brine. The system consists of three R-22 refrigerating machines of rotary piston type, Mitsui Esh Wyss ROTASCO RT-245. Ninety ceiling coolers are uniformly distributed over the whole basin, so that even temperature distribution can be expected, which will result in uniform ice thickness. The cooling room temperature can be varied between +15° C to -35° C.

The other system provides for the primary cooling of the supply water into the basin down to +2° C. Another R-22 refrigerating machine, ROTASCO RL-150 delivers 107,500 Kcal/hr at a brine outlet temperature of -15° C. This unit also serves as room coolers, to reduce the temperature of the trim tank room and the basement. Heating system for warming up the cooling room is also prepared.

COOLING PERFORMANCE

Cooling programme can be set up and memorized on a magnetic tape in compact cassette so that the cooling system can be switched on, operated and switched off automatically. No marked difference was found in temperature between the programmed and the measured. The lowest attainable room temperature is -35° C, in the summer. Cooling room temperature can be maintained between +15° C to -35° C and between +2° C to -25° C throughout with a maximum point to point temperature difference at any location 0.5 m above the water surface of ±1° C. Temporal variation of air temperature in any location in central region of the test room was found to be controllable to ±1° C.

Measured growth rate of ice was found to be fairly in good agreement with the predicted, for instance, of 2.3 mm/hr, where salinity of water was 30% and air temperature was kept at -20° C. In the salinity and temperature conditions, forced circulation of the air in the cooling room gave a marked increase in growth rate of ice as 3.0 mm/hr. However, this resulted in unfavourable increase of local differences in ice thickness. Two days later, since the cooling systems were switched on, daily ice growth through a night was found to be steady and constant.

TOWING CARRIAGE AND INSTRUMENTATION

Towing carriage has overall plan dimension of 6.40 m x 7.66 m with extension to carry the guide system, ice cutting and pushing devices. In principle it consists of two main transverse box girders carrying the driving motors and wheel assemblies connected by two vertical longitudinal apparatus girders which provide a working space for conducting experiments and placing dynamometers. The measuring bay in the center of the carriage is free from any cross-bracing above and below. The finished weight of the carriage with all the equipment and ordinally measuring devices is about 17 tons, which requires the installation of steel tracks of conventional section mounted on cast sleepers. Two driving systems, with wheels on rails and with gears on racks, are provided. The carriage speed is controllable from 0.1 to 2.0 m/s. The power supply to the carriage is made through a trolley system with heater. Spray system, breaking and pushing ice systems are equipped on the carriage.

Facilities can temporarily be set up to vary the ice compression, which works in a horizontal plane perpendicular to the direction of motion of the ship model. Thermisters, salinity probes and sonic probes for detecting ice thickness are provided in the test basin.

Various kinds of experiments in ice can be performed by making effective use of resistance, propeller and self-propulsion dynamometers, auto-piloting system, recording and analyzing systems.

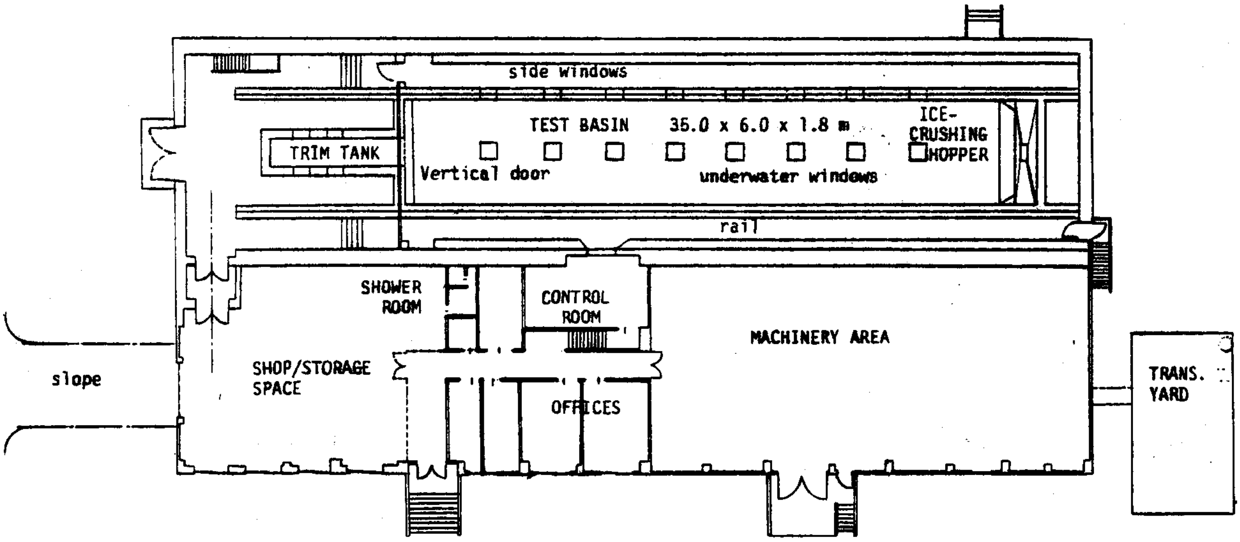

Fig.1 FLOOR PLAN

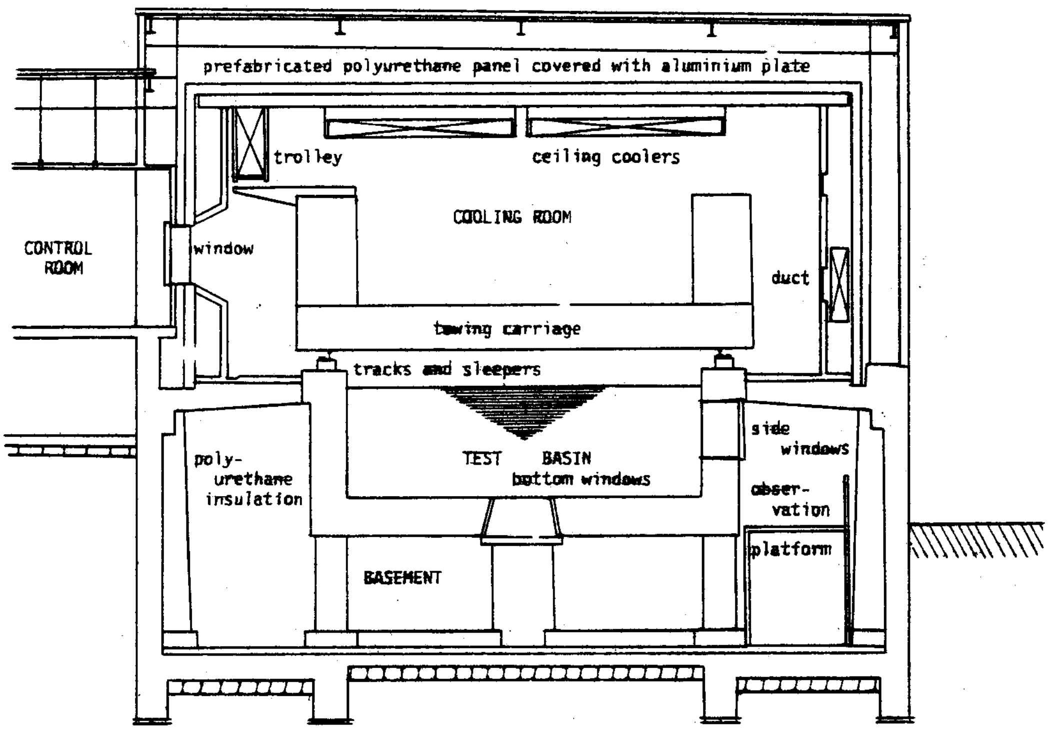

Fig. 2 TEST BASIN

4. THE AUTOMATIC SELF-PROPULSION TEST SYSTEM AT THE AKISHIMA LABORATORY

Y. Yamanouchi, T. Iwata and M.Abe
Akishima Laboratory, Mitsui, Tokyo, Japan

A new automatic self-propulsion test system has been adopted at Akishima Laboratory. In this system a model ship is towed by a self-balance type resistance dynamometer and the propeller revolution speed is controlled by an electric feed back loop connected with the dynamometer, which pickups the difference between the thrust delivered by the propeller and the identical model ship resistance at the self-propulsion point with skin friction correction. The concept of the total system is schematically shown in Fig. 1.

In Fig. 1 the torque motor is equipped at the pivot of the resistance dynamometer as a device to detect the unbalance force acting on the dynamometer. The torque motor as well as the ordinary damping devices, stands to the inclining moment of the balance by the signal delivered from the differential transformer which pickups the inclination of the balance. The electric output induced by the actuation of the torque motor which corresponds to the difference between the propeller thrust and hull resistance, is fed back to the propulsion motor controller to change the revolution speed of the propeller to make the difference toward zero. Here the transfer function of the balance itself is assumed as $1/(JS^2 + DS + K)$ and that of the motor controller as $Cn/(\tau S + 1)$. It is also assumed that the relation between the revolution speed of the propeller and the thrust delivered by the propeller is as follows,

$$T = A\rho VaD^3n + B\rho D^4n^2$$

where the transfer function of the self-propulsion dynamometer is not considered to simplify the system. The gain control and dead band are also added to make easy to control the system. Furthermore there exists the integrator to smooth the signal delivered to the motor controller.

Before realizing the system, several simulation studies have been carried out. Fig. 2 shows examples of the results of simulation calculation by using an analogue simulator for step and frequency responses of the propeller thrust. These response characteristics correspond to 15% step change and 7.5% periodic change of the model ship resistance, respectively. In this figure, it is seen that the optimum response is attainable by adjusting the gain control at the level of 0.035 to 0.020, and the thrust does not respond to the frequency above 0.2 Hz.

Fig. 3 shows two examples of the measured records at self-propulsion tests by this system under constant revolution speed of the propeller and under continuous feed back control. In the latter case the occurrence of the unsteady flow phenomena around the stern of a model ship is indicated on the record. Immediately after the clamp was open, the torque motor was acting to keep the balance of the dynamometer. At the middle of the record, the propeller revolution speed (N) was changed a little bit corresponding to the change of the side force (Ya) measured at the stern of the model ship, but the thrust (T) was stayed almost constant.

Ordinary restrained self-propulsion test have not necessarily been successful, because the strain gauge type dynamometer shows the poor performance in processing the disturbance of high frequency such as the vibration of the carriage etc. and on the other hand the balance type dynamometer is not suitable to absorb the surging motion of a model ship. Furthermore it seems to be difficult to improve the response of the motor controller and to adjust the gain for the individual model ship in usual cases. Such difficulties have fairly been removed in this system. The torque motor works as a spring to absorb the disturbance of high frequency and at the same time to restrain the displacement of the model ship. The low inertia propulsion motor is also helpful to keep the good response of the system. This type of electric closed feed back loop is far more essential in keeping the proper controllability for the different character of the individual model ship.

This automatic self-propulsion test system is usually used for the ordinary propulsion test method where a model ship is freely supported to run without operating the torque motor. Besides the continuous feed back control method by this system could be used for example when a model ship shows an unusual characteristics such as unsteady flow around the stern. However, it is considered whether such a kind of propulsion test has physical meanings or not. This is just the future problem given for us to be solved.

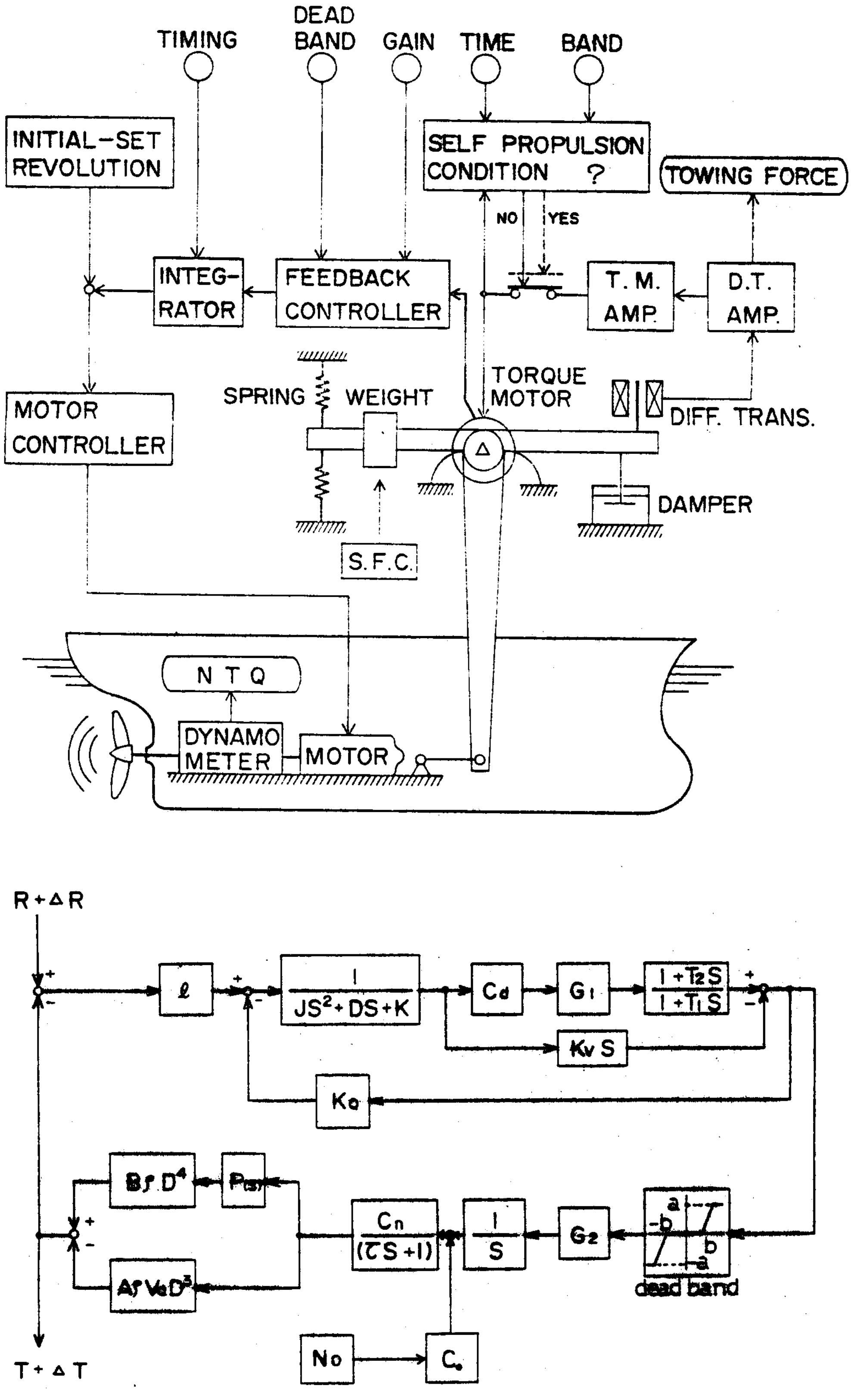

Fig. 1 Schematic Diagrams of the System

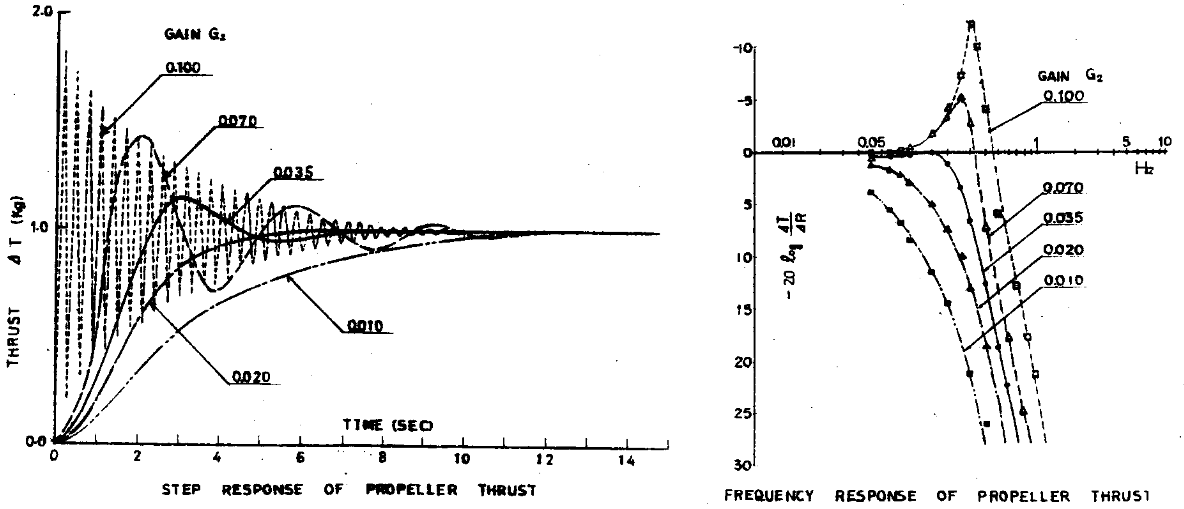

Fig. 2 Results of Simulation Calculation

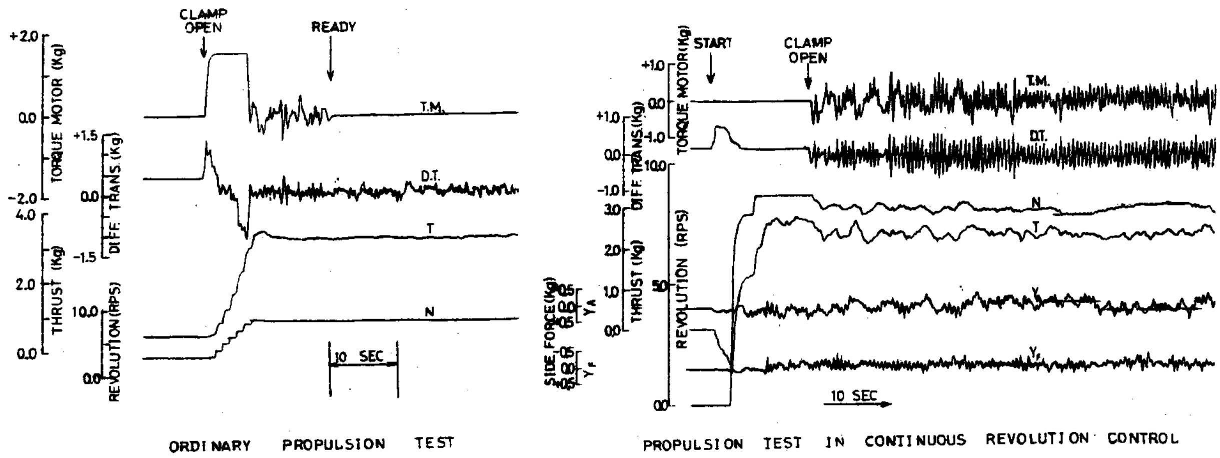

Fig. 3 Measurement Records of Self-propulsion Test

5. ACTIVITY OF CETENA IN THE FIELD OF NAVAL HYDRODYNAMICS

CETENA, GENOVA, ITALY

INTRODUCTION

The Italian Ship Research Center CETENA is an IRI Group society financed by Government with about three millions dollars per year.

CETENA carries on research on its own with an yearly expence of 1.5 millions dollars, whose about 0.5 millions dollars are income deriving from researches and services furnished to Shipowners, Shipyards etc.

About two millions dollars are employed by CETENA to support development and application research of National societies of ship and engine-building.

At present CETENA is organized into four departments, employing about sixty persons including twenty seven graduated.

Departments are:

- economic studies and advanced design;
- ship hydrodynamics;
- structural calculations;
- sea trials.

CETENA's activity in the research field of ITTC concern develops both under theoretic and experimental point of view.

INSTRUMENTAL FACILITIES FOR EXPERIMENTS

a) Sea Trials

For trials to be performed in full scale, CETENA is provided with a complete set of instruments enabling to measure data relative to:

- speed;
- power, thrust and propeller number of revolutions;
- manoeuvring characteristics;
- seakeeping;
- hull surface roughness;
- vibration and noise;
- exciting forces induce by propeller.

The most important devices relative to the experimentation field of ITTC interest will be briefly described in the following

Speed Sea Trials

For all new built ships speed sea trials requested by contract are performed by CETENA using the Raydist radiolocation system (as described in ref. /1/).

Up to present time CETENA has equipped and made ready four geographic areas with Raydist system (see Fig. 1) :

- North Tyrrenian Sea, with shore stations at Genoa and Leghorn covering up to 180 miles by day and 100 miles by night.
- Naples Gulf, with shore stations at Naples and Castellammare di Stabia, covering up tp 90 miles by day and 50 miles by night.
- North and Middle Adryatic Sea, with shore stations at S. Benedetto del Tronto and Ortona whose characteristics are similar to North Tyrrenian Sea installation and with temporary stations installed on request at Ancona and Pesaro, similar to those of the Naples Gulf.
- South Tyrrenian Sea, with temporary stations at Palermo and Milazzo, which are at present under revision.

The Raydist system requires an initial calibration, usually performed close to a well recognizable reference point at shore; starting from that moment control of ship position is continuous on the basis of the Raydist circular coordinates, called red and green lanes, with origin at the relative stations at shore.

Speed sea trials are performed running towards or away from one of the two shore stations so that, at the end of the course, speed can be easily calculated from the time elapsed in covering the measured run.

A more precise assessement can be made ashore, on the basis of recorded data of both stations.

The system enables to keep constant accuracy of measures, since it is possible to deduce the distance to be covered with respect to ship speed.

b) Power, Thrust and Propeller Revolutions Number

The number of propeller revolutions is recorded counting one or more impulses per revolution by means of electronic pickups.

For the measure of torque CETENA uses a torsiometer of its own make, based upon the measure of shaft torsional strain by means of electric resistance strain gauges.

The output of strain gauges bridge is then converted in an F.M. signal which can therefore be recorded without any contact with shaft; the signal in frequency is then integrated into an arbitrary time interval by a simple counting of all impulses occurred in the considered time span /2/.

Using Raydist system, power and speed data are available aboard just at the end of the test.

Thrust measurement is based upon the same principle and instrumentation set of torque measurement /3/, however is not considered a routine test, since it is needed a preliminar calibration of the instrumented shaft stump to record the unavoidable alignment errors of the axial strain gauges, as suggested in ref. /4/.

In the last five years speed-power tests have been performed for 93 ships and speed power and thrust tests for 4 ships.

Manoeuvring Tests

They always take place in the geographic areas equipped with Raydist system.

During trials ship position and speed, rudder angles, revolutions and power delivered to propeller are usually measured.

On request also special recordings can be performed, such as torsional moment on rudder stock, rate gyro, etc.

The usual tests for different load conditions and speeds include: pull-out and weave, Z test, circle test at maximum rudder angle and crash stop.

Data are recorded on punched paper tape and then elaborated aboard by use of a computer /5/.

CETENA is usually charged of compiling the IMCO booklet for each ship under investigation.

During the last five years manoeuvring tests have been carried out for 59 italian and foreigner ships /6/.

Seakeeping Tests

For seakeeping tests an instrumentation set /7/ has been made to record (see Fig. 12):

- wave height, by ultrasonic sensor;
- five ship motions (surge, heave, sway, pitch and roll), by a stabilized platform;
- accelerations and/or stresses in some preselected ship points;
- ship speed;
- power, thrust and shaft speed.

Data are recorded on magnetic tape and then analysed at CETENA by a Fast Fourier Analyser.

Hull Surface Roughness

Recordings are usually performed during dry docking in the following hull conditions:

- after washing;
- after sand blasting, if any;
- at the end of painting cycle, with measures at the end of intermediate painting steps, if requested.

Roughness measures are performed by the BSRA roughness analyser, using the standard technique recording the peak-to-valley maximum amplitude on a 50 mm standard length.

Using this system from 800 to 1000 roughness values distributed over 10/12 ship sections are recorded.

From these data mean roughness, standard deviation and roughness distribution in the various ship parts are defined.

At CETENA is also available an underwater roughness analyser.

Furthermore, in cooperation with Shipyards and Shipowners, have been started programs of systematic research to correlate roughness data to speed-power trials.

Exciting Forces Induced by Propeller

To measure the exciting forces produced by propeller both on shaft (bearing forces) and on hull (surface forces), has been made ready a complete instrumentation set, able to record:

- propeller blade position;
- propeller number of revolutions;
- torsional moment fluctuation on shaft;
- mean power and speed;
- added pressures induced by propeller at stern, using pick-ups housed into holes made on hull surface;
- vibration amplitude, measured on gland and at some characteristics ship points.

Experimental Equipment for Model Tests

As to instrumentation for model tests, are mainly to be mentioned the two following equipments, designed and setted up by CETENA itself:

- an instrument set to pick-up, record and analyse data, based upon micro-computer technique /8/;
- a six components propeller balance to measure and record fluctuating forces and moments induced by a propeller, operating in a non uniform hull wake. The instrument has been realized in cooperation with the CTO of Gdansk (Poland).

In model tests field can also be mentioned some researches carried out by CETENA on the following subjects:

- studies on large ships, with different propulsive solutions (single screw, ducted propeller, twin screw, twin skeg, overlapping propellers) /9/;
- systematic serie of single screw ships with high block coefficient /10/;
- experimental studies on large diameter - low revolutions propellers /11/.

Theoretical Research Developments

The main activities of theoretical research in Hydrodynamics concern seakeeping, manoeuvring and development of programs for design and verification of marine propellers.

The fundamental aspect of seakeeping theoretical research has been the set up f a quantitative criterion of ship design qualities based upon her geometric characteristics.

This work led to a very "merit rating factor" for any ship, related to the time percentage during which the ship is fully operational at various speeds, only depending on sea conditions statistically referring to a certain geographic area /12/.

A further information which can be drawn from this calculation program is the mean speed maintainable by the ship during the year or a single season, only depending on sea conditions.

Furthermore, up to extend forecasting procedures to all fields of designers interest, a calculation program has been setted up to determine the pressure distribution depending on ship motions and incoming wave effects.

The program can also be used for direct calculation of loads and transversal ship strength.

In order to complete the reliability check of theoretical predictions of motions, comparisons with international studies have been carried out: a cooperative research proposed by ITTC's Seakeeping Committee has confirmed both the good agreement between Italian and foreigner methodologies and those methodologies validity in th light of theoretic-experimental comparison.

Furthermore an experimental test on ship added resistance has been carried out with satisfactory results, by comparing theoretical values with model tank data, whereas as to operability limits an investigation has been carried on, based upon information given by the Board /13/.

Numerous full scale trials have been performed by CETENA, in cooperation with the Italian Navy, and by the Institute of Naval Architecture of Genoa, collecting a large amount of data, useful for a more complete check of theories and calculation procedures.

The second subject to be remarked regards the theoretical and experimental researches of large ships manoeuvring and control.

By now is available a data bank in which are collected the characteristic coefficients of standard manoeuvring tests, obtained by full scale trials on more than 100 ships of any type.

This data analysis has enabled both to go deeper into correlation between hull parameters and ship manoeuvring indexes and to build up an effective mathematical simulation model regarding both ship manoeuvrability and crash stop /14/.

The third subject concerns the integrated procedures of propeller and stern design.

As to development and final set up of design method has to be mentioned the definitive realization of a computer program based upon the lifting surface theory, enabling to tackle the problem of non standard camber values, related to any kind of chordwise load distribution and to any radial distribution of skew angle /15/.

This program application can be extended to any blade shape and to any load distribution.

Also on the base of lifting surface theory, computer programs for ducted and counter rotating propellers design have been setted up.

Finally, in order to check the behaviour of propellers operating in a hull wake, a computer package /16/ has been up to calculate:

- steady state operation characteristics, both at design and off-design conditions;
- steady and fluctuating load distribution on the various blade sections;
- steady and dynamic bending moment acting on blade;
- bearing forces;
- cavitation conditions, if any (type, extension and volume);
- surface forces, both in cavitating and non cavitating conditions.

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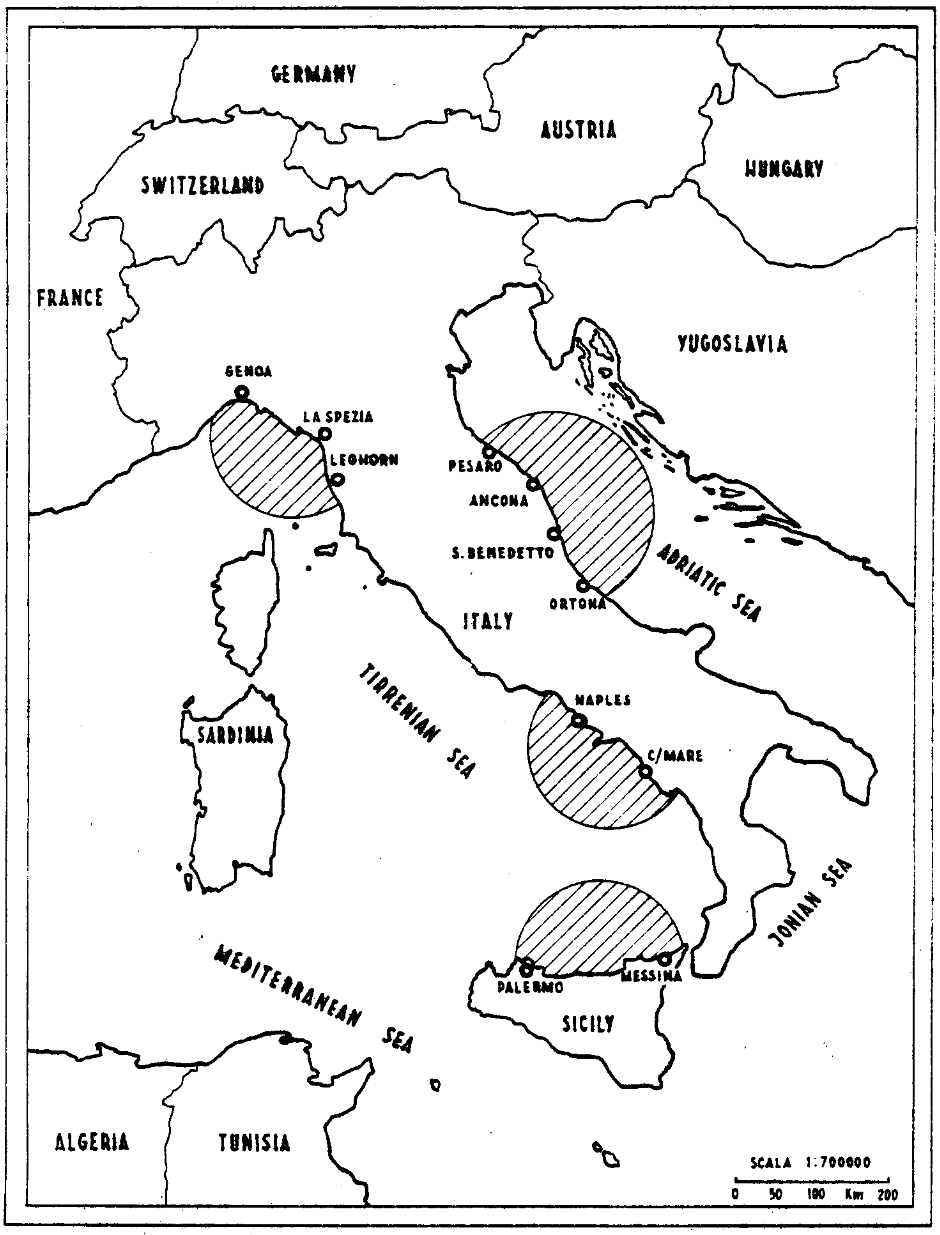

FIG. 1 _ AREAS COVERED BY RAYDIST SERVICE

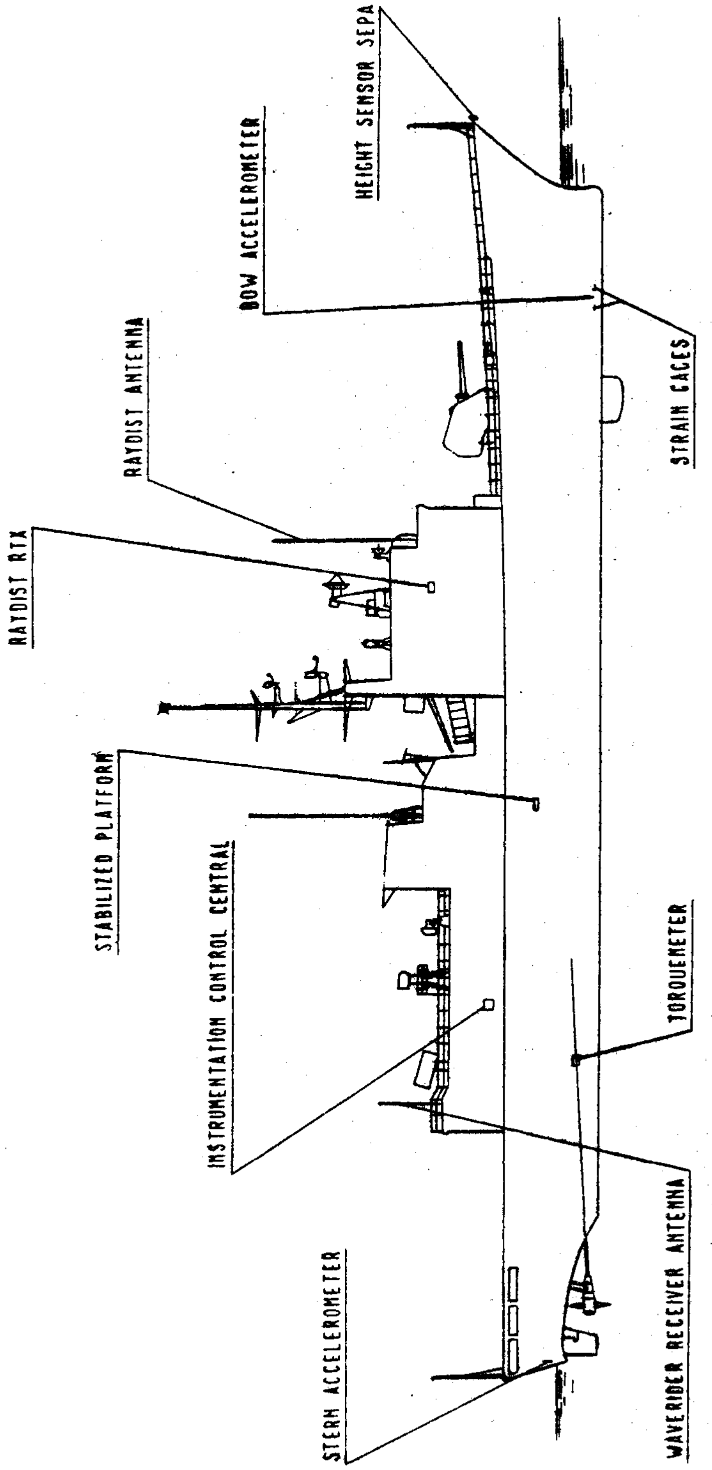
HEIGHT SENSOR SEPA
BOW ACCELEROMETER
RAYDIST ANTENNA
RAYDIST RTX
STABILIZED PLATFORM
INSTRUMENTATION CONTROL CENTRAL
STERN ACCELEROMETER
STRAIN GAGES
TORQUEMETER
WAVERIDER RECEIVER ANTENNA

FIG.2

6. THE SHIP MODEL BASIN OF NKK

Y.Yamazaki and N. Matsumoto
TSU Research Laboratories, NKK, Japan

1. INTRODUCTION

The chip model basin for NKK was established in November, 1977. The principal dimensions of the basin are 240 m x 18 m x 8 m. In the basin, the electric carriage for towing a ship model is comprised of a main part and auxiliary part, which were designed so, as to keep natural vibrations no lower than 8 HZ. The main carriage moves in the longitudinal direction of the basin. The Y Z carriage suspended from the box girder of the auxiliary carriage moves in the width direction and rotates around the vertical axis.

On one side of the basin, the wave generator is equipped to produce regular or irregular waves. In orde to increase the efficiency of the testing equipment, the laboratory automation was introduced into the system design for the purpose of achieving "reproducibility" and "instaneousness of primary analysis".

2. TOWING CARRIAGES

The main carriage and the auxiliary carriage are independently installed. When only the main carriage is used, the other is left on the wave generator side of the basin. The auxiliary carriage is used with the main carriage, both carriages are connected by couplers. The main carriage is of an independent motion at the constant speed, but being connected with the auxiliary carriage, the Y Z carriage can be moved in the X and Y direction and rotated around the vertical axis at the desired speed pattern.

The operational mode is one of position control (Y direction and around Z axis), circular motion control, oblique towing control, harmonic motion control (pure swaying, pure yawing, yawing with oblique angle, combined motion), tracking control and analog external input signal control. Operational mode, speed and acceleration are set from an operation control panel or from minicomputer's P I/C.

Taking into serious account the response characteristics, the controls of the X, Y and Z axis are based on the analog speed control by T.G.feedback signals, but as assistant controls integrating controls by the integrated valves of the P.G. outputs and differentiating controls aimed phase adjustment are also added. When the YZ carriage is driven as velocity is reversed, resulting gear backlash causes vibrations and accordingly where torque is small, a set of two motors on the Y and Z axis respectively have reverse directional torque applied thereto to impose antibacklash control. The block diagram of controls of carriages is shown in Fig.1.

3. TESTING SYSTEM

The hardware for this system is comprised of the testing apparatuses and the computer which gives instructions to the apparatuses. The software on the other hand consists of the program under which hardware is organically combined to execute testing and the procedures to carry out such testing. The flow of testing under this system falls into three steps, the pre-processor, processor & post-processor.

In accordance to the test requirements, necessary data are read out from the master file in the host computer and are used in the pre-processing and post-processing programs. The structure of the programs for the testing system is shown in Fig.2. The block diagram of this system's hardware centering around the equipment mounted on the towing carriage is shown in Fig.3.

In step 1, the host computer used, measured values are predicted and optimum ranges of amplifiers are chosen to keep high accuracy in test results by the pre-processor in accordance with the test plans. At the same time, in order that a plurality of conditions can be continuously measured while a ship model is underway, this program suitably combines test sequence with aims for highly efficient testing processes. The results are printed out as experimental instructions for an operator and the simultaneous output in a magnetic tape of instructions for the minicomputer.

In step 2, the minicomputer on the carriage starts the test processor and the processor performs the following stages. The processor reads the instructions from a magnetic tape. The operator decides the progress of each test using the display unit connected with the minicomputer in the conversational mode. A certain test condition is indicated from the above, and the testing apparatuses, including the towing carriages, a wave generator and others are set point controlled according to the instructions by the processor in the minicomputer. After one of the tests is started, data are measured and are primarily analyzed automatically. When one of the tests is ended, test results are recorded on the last half of the instruction tape. The remaining test condition is indicated to the minicomputer by the operator, and the process will be repeated.

In designing the test processor, the extendibility of the system and the flexibility of the routine testing were particularly kept in mind. The following five points characterize the test processor.

(1) At key points in the test processes, the operator's decision is called for in a conversational mode via CRT to proceed to subsequent processing.
(2) Collected data are immediately analyzed and the results are digitally displayed together with the preceeding results which are diagrammatically displayed, so that the operator can instantly judge whether the results are good or bad.
(3) The basin can be used effectively because the data can be continuously collected for many conditions, while a model ship is underway.
(4) In each test, additional items of measuring data can be collected in addition to predermined items of measurements.
(5) Combinations between the measuring amplifiers to be used and items of measurement can be freely assigned.

In step 3, the host computer is used to analyze test results in detail and prepare test reports.

4. TESTS PERFORMED

The following tests can be performed automatically by this man mashine testing system.

(1) Resistance test in still water or waves.
(2) Self propulsion test in still water or waves.
(3) Propeller open water test.
(4) Wake survey at propeller position.
(5) Wave analysis test
(6) Captive model test (Circular motion, Oblique towing, Large amplitude harmonic motion)
(7) Ship's motions measurement in waves.
(8) Behavior measurement of ocean structure with mooring lines in waves.
(9) Free sailing model test in still water or waves.

Besides the above routine testing programs, the general test processing program, which uses the minicomputer also prepares the data record and simple analysis.

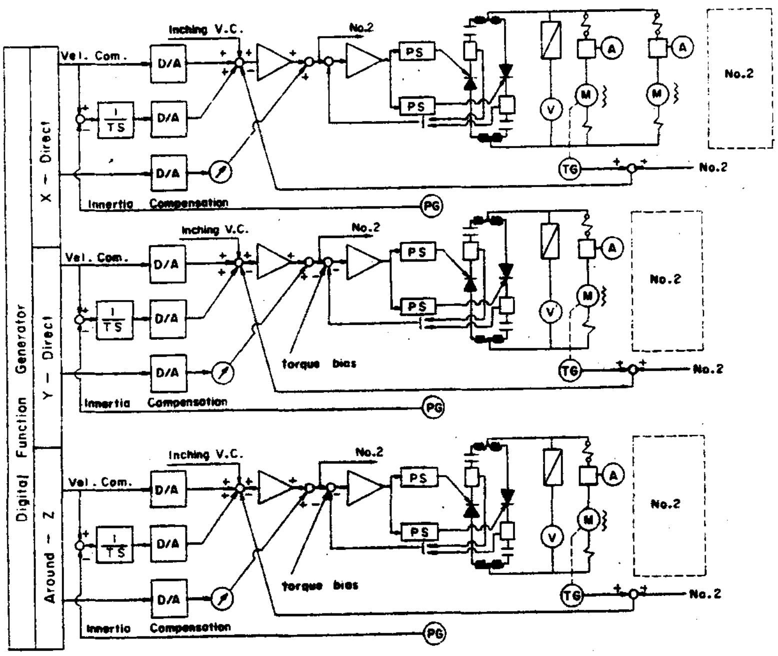

Fig.1 Block diagram of controls of towing carriages.

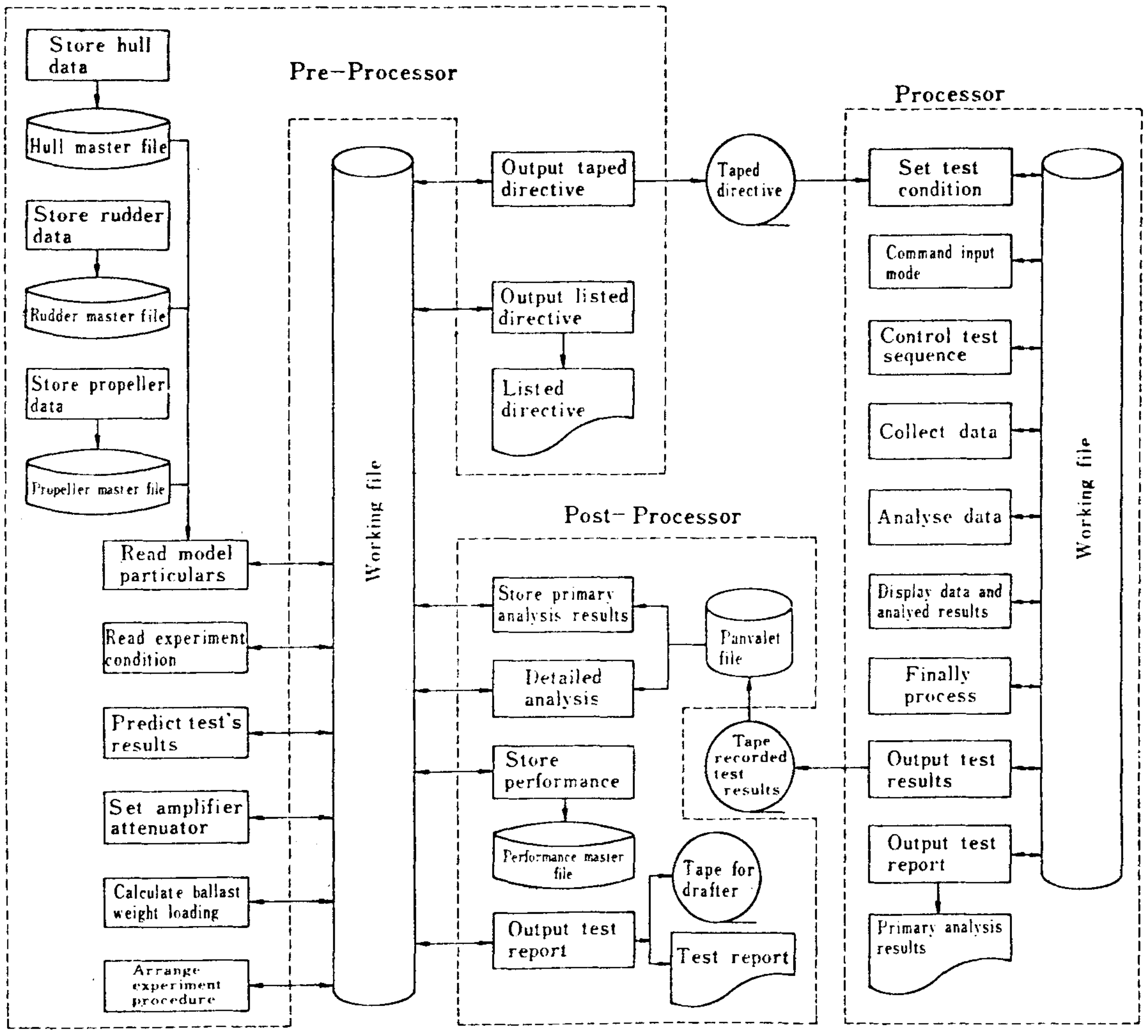

Fig. 2 Soft-ware system

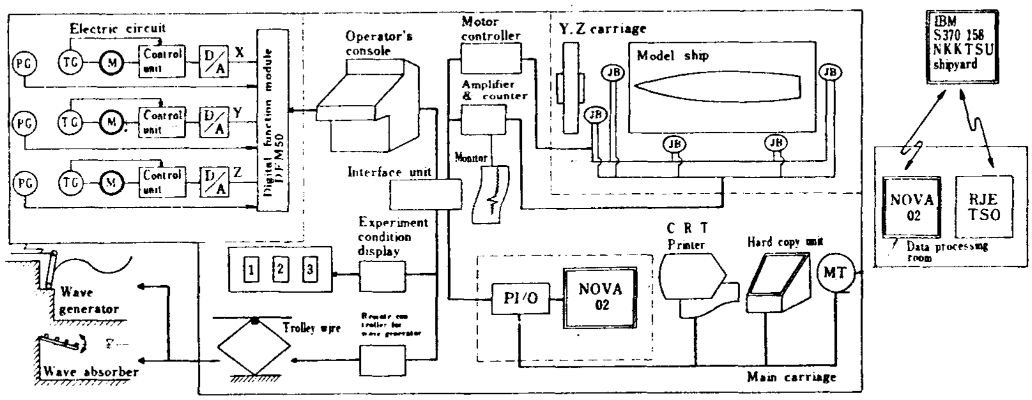

Fig. 3 ***Hardware block-diagram of test system***