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From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Japanese Model Basins.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, dealing with Target S-83(N) of Fascicle S-1 of reference (a), is submitted herewith.

2. The investigation was accomplished by Captain R.B. Lair, USN, Captain J.M. Farrin, USN, Commander N. Hancock, RCNC, and Lieut. P.F. Markstrom, USNR. The report was prepared jointly by Captain Lair and Lieut. Markstrom.

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SUMMARY

SHIP AND RELATED TARGETS

JAPANESE MODEL BASINS

Japanese model testing basins are located in MEGURO, TOKYO, at the Naval Research Institute, where all naval model testing was conducted; at MEJIRO, TOKYO, at the Communications Ministry's Ship Testing Laboratory, where only merchant ship testing has been conducted; and at NAGASAKI, where the Mitsubishi Heavy Industries have conducted their private work on merchant ships.

The facilities available for model testing vary greatly at these three institutions. The Navy's laboratory at MEGURO was, before being bombed and burned, quite complete as to equipment. It contained three completed basins and one under construction. There was a large propeller cavitation tunnel, a large maneuvering pond, a stability testing tank, a circulating water channel, as well as numerous wave makers, pressure testing vessels, and complete model making equipment.

At MEJIRO there are two medium size model basins, a cavitation tunnel, and the necessary equipment for making ship and propeller models.

The facilities at the Mitsubishi plant at NAGASAKI consisted of one obsolete basin and one completed in 1943.

Considerable bomb and fire damage was done to the installations at MEGURO and NAGASAKI. However, from what remains of all these facilities, it is quite apparent that the Japanese leaned heavily, in all their design, on the Germans and British. Their tanks are all quite similarly constructed and follow the Hasslar design. Their carriage and self-propulsion dynamometers were made by Kempff and Gebers. The Navy's basins at MEGURO were by far the most up-to-date, but even these were only comparable to the basin at the Washington Navy Yard.

In general, the list of current work being done at MEGURO reflected also a certain backwardness as evidenced by the elementary work on propeller cavitation and mine sweeping gear. In direct contrast, however, was the very complete and interesting model turning test pond at MEGURO, the research on bow rudders for capital ships, and the quite extensive program on high-speed boat forms.

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REFERENCES

Location of Target:

Naval Research Institute, MERGURO, TOKYO.
Ship Testing Laboratory, Communications Ministry, MEJIRO, TOKYO.
Mitsubishi Heavy Industries Testing Laboratory, NAGASAKI.

Japanese Personnel Assisting in Gathering Documents:

T. IZUBICHI, former Director of Model Basins, MEGURO, TOKYO.
H. SHIBA, Test Engineer at Ship Testing Laboratory, Communications Ministry, MEJIRO, TOKYO.
S. AKASAKI, Professor of Naval Architecture at Osaka Univesity.

Japanese Personnel Interviewed:

T. IZUBUCHI, former Tech. Rear Admiral and Director of Model Basins MEGURO. (20 years of model basins experience).
A. KATAYAMA, former Tech. Rear Admiral and Head of the Fourth Section (Ship Construction) of the Navy Technical Department.
T. KONDO, former Commander IJN, and Head of the Resistance and Propulsion Section of the Model Basins at MEGURO. (Graduate, Imperial University, TOKYO.)
T. NAKAYAMA, former Captain IJN, and Chief Propeller Designer of the Navy Technical Department. (Graduate of Imperial University, TOKYO.)
H. SHIBA, Test Engineer at Ship Testing Laboratory, Communications Ministry, MEJIRO. (Graduate of Imperial Univesity, TOKYO.)
H. IKEGAMI, Chief Test and Operating Engineer of the Self-Propulsion Tests and Cavitation Tunnel at MEGURO. (No technical education other than 30 years experience at MEGURO.)
S. AKASAKI, Professor of Naval Architecture at Osaka University.

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(A) List of Documents Forwarded to David Taylor Model Basin.

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INTRODUCTION

An early investigation of Japanese model basins, made in November 1945 by Capt. J. M. Farrin, USN, brought to light the rather extensive facilities of these laboratories. While it was believed that few if any startling innovations would be uncovered by further investigation, it was felt that a complete report on these institutions, their capabilities, current projects, and methods would be of interest and value in arriving at a better understanding of the Japanese scientific mind.

The Meguro Basins were visited on several occasions and the former Director and his principal assistants were interrogated.

The net total of information obtained was just what these officials chose to remember. While no official documents could be found, the stories told by these men were checked as carefully as possible with other officials of the Navy Ministry. The list of current work being undertaken at Meguro was verified at the Navy Ministry.

A visit to the test basins at Mejiro was more productive. Mejiro was intact but not operating, for lack of fuel. At this laboratory the equipment, such as carriages, resistance dynamometers, and self-propulsion equipment were all available and were examined. A complete test report, which had been compiled in August 1936 for a merchant ship, was obtained. The principal interest of the two portfolios composing the report lies in the procedure followed in making the tests and the presentation of the results rather than anything unusual in the model itself. It was stated on three separate occasions that the same test methods were used at all three of the establishments.

The model basins at NAGASAKI were very badly burned out and no additional information was received from this source.

THE REPORT

Part I - MEGURO BASINS

A. Organization.

Among a number of departments directly responsible to the Navy Minister was one known as the "Navy Technical Department." A integral organ of this department was the "Naval Technical Research Institute." The Institute was composed of the following sections: General Affairs, Chemical Research, Applied Physics, Material Research, Naval Architecture, Experimental Psychology, Medicine, and Accounting. The Naval Architecture Section carried on the model basin work. Vice Admiral TOKUNAGA was Director of the Institute, and Technical Rear Admiral Tatsumi IZUBUCHI was in charge of the Naval Architecture Section which was divided into four main groups, viz., (1) resistance and propulsion, (2) maneuvering, rolling, and stability, (3) strength, and (4) model workshops.

B. Facilities.

On 15 May 1945, three bombs fell on the Institute. The bombs apparently were incendiary, because the damage done was the result of fire rather than exlosion. The buildings covering the large basin, stability basin, model making shops, and high-speed basin, which was under construction, were twisted and destroyed beyond restoration. This is true also of the equipment within these buildings. However, the concrete basins were not seriously damaged because the water within the basins acted as an insulating medium. The water is still in place and the bottoms of the basins are strewn with debris.

Figures 1 and 2 are views of the remains of the large basin showing typical fire damage to the installations. The other facilities are operable. These include the medium basin, small basin, water tunnel, circulating tank, and maneuvering pond. At the present time no work is being done at the Institute, and no attempts or plans are being made to salvage the buildings or equipment.

The large basin, built in 1930, is 280 meters long, 12.5 meters wide, and 8 meters deep. The effective length is 265 meters, there being space at the starting end to float models waiting to be tested, etc. The carriage was a Dr. Gebers' design with Ward-Leonard speed control. The basin and equipment were enclosed by a light steel frame structure covered by a corrugated steel roof. The roof contained no skylights. Light was admitted through windows located at the top of the concrete walls supporting the roof, running continuously for the entire length of the building. A wave maker was located in the finish end. The basin structure was built on piling in the absence of bed rock. Fresh water was used and no attempts were made to guard against marine growth, it being stated that marine growth did not offer any problem as it did not occur. The water was replenished only because of leakage and evaporation. The statement was made that in this way the water was completely changed every two years. This process has been used since the basins completion in 1930. Wave dissipaters were located along the sides of the entire basin. The dissipaters consisted of wooden boards set at an angle of about 10 degrees with the horizontal and extending several inches into the water. The boards were suspended by metal straps which hooked over the top of the wall. The track was surface ground and leveled by means of a floating measuring device, i.e., the water surface was used as a reference plane for making measurements. Tracks, unlike those at the Taylor Model Basin, were laid directly upon steel track supports deeply embedded in concrete as shown in figure 3, and shimmed into correct position. Releveling took place every three years.

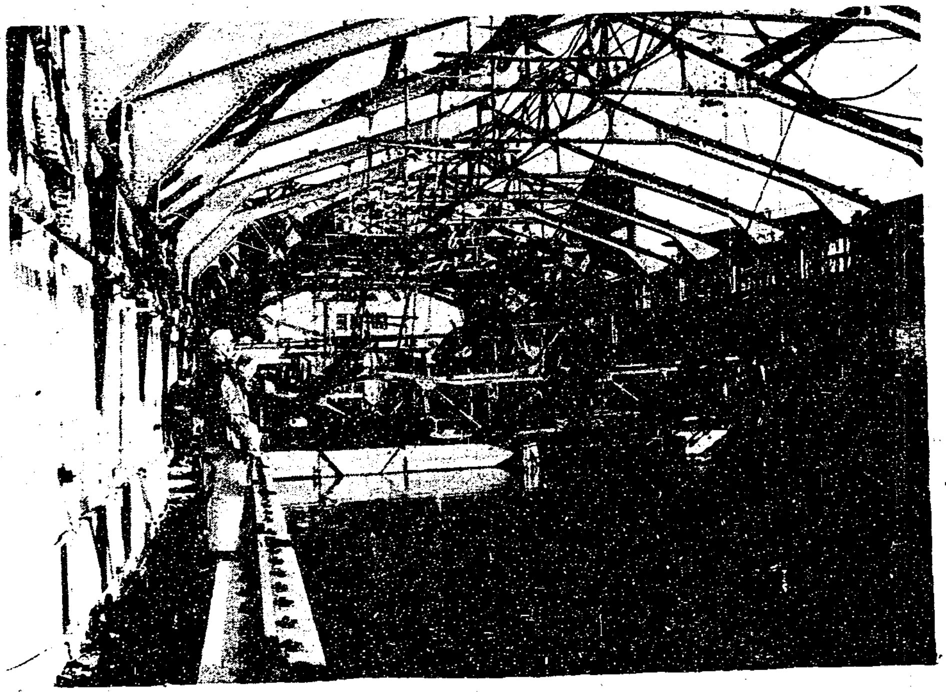


Figure 1
STARTING END, LARGE BASIN AT MEGURO, TOKYO

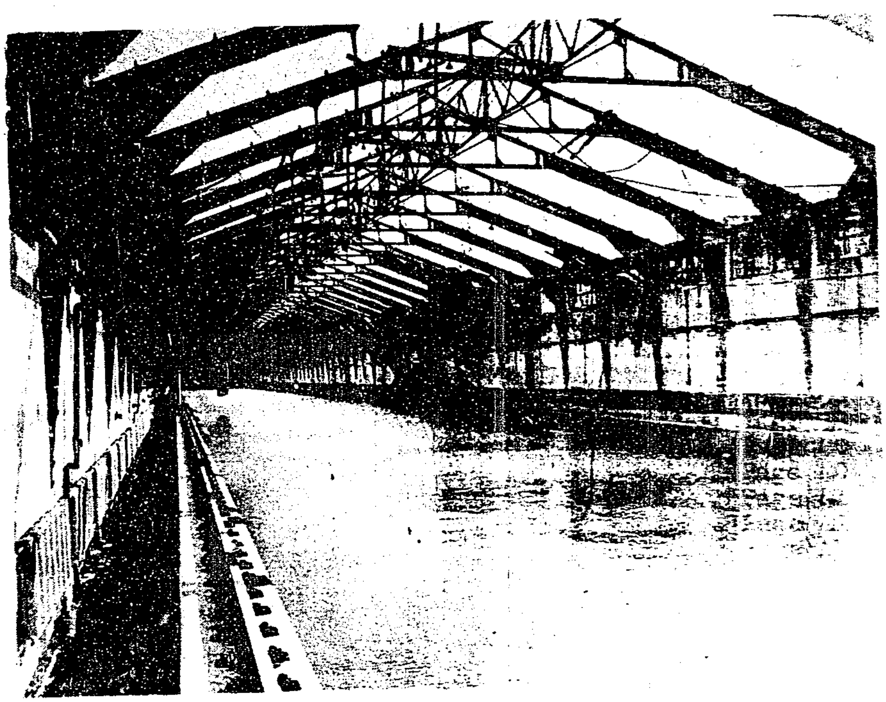


Figure 2
FINISH END, LARGE BASIN

The carriage was built in Japan. It was constructed of the conventional angle iron, rivet joint truss, and was powered by four 25 hp electric motors. Each motor was connected through a gear box to one of the four drive wheels. The carriage weighed 25 metric tons, and could attain a maximum speed of nine meters per second. At the time the carriage was being designed by Dr. Gebers, Admiral IZUBUCHI and Mr. IKEGAMI, who was in charge of all model making and cavitation tunnel tests, went to Germany to consult with Gebers.

Paraffin models were used extensively in this basin. Sizes varied up to a maximum of eight meters, but for the most part 6.5 meter models were used.

Water temperature ranged from 15° to 25°. However it was stated that no deformation occured at higher temperature.

Cleaning of the tank, replacing the carriage, and installation of new rails would make this basin operable.

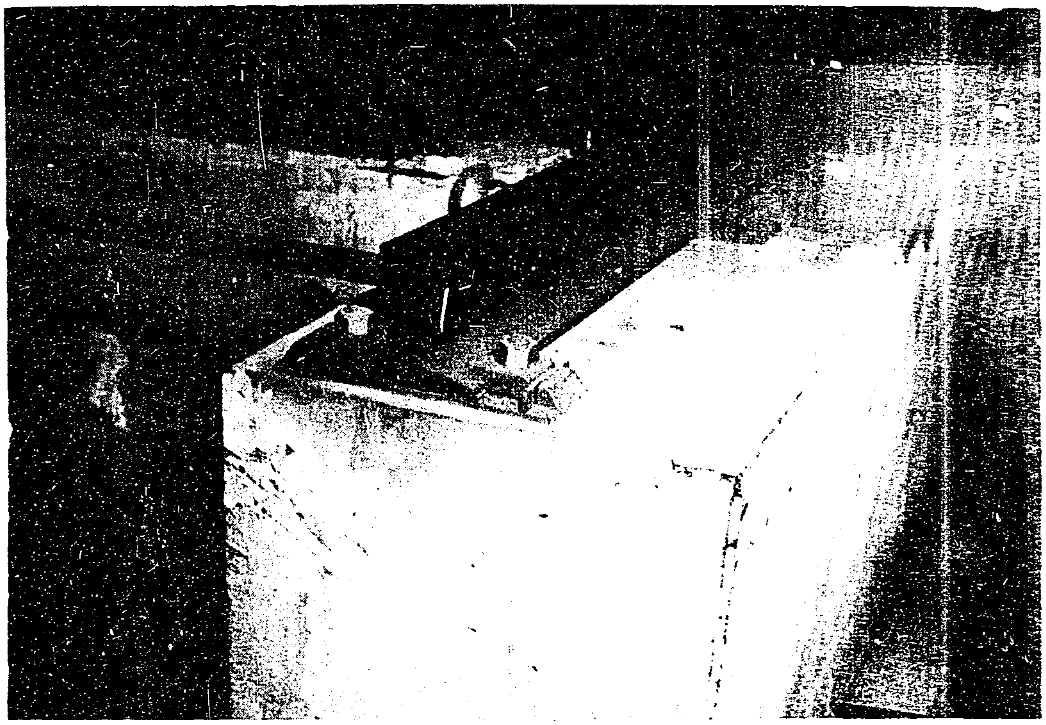


Figure 3
RAIL SUPPORTS, LARGE BASIN

The high-speed basin was in the process of construction when the bombing occured. It was adjacent to and parallel with the large and stability basins. The walls and bottom were of concrete placed on piling. It was 380 meters long, six meters wide, and three meters deep. Both the basin and carriage, which was also under construction, were designed in Japan. The water supply was to be the same as the large basin, i.e., replacing only the loss of water caused by leakage and evaporation, and making no attempts to combat any marine growth which might occur.

Construction had reached the stage of track laying part of which had been accomplished at the time of the bombing. The tracks were being laid in the same manner as in the large basin and were to be surface ground. Figure 4 illustrates in detail the track support used.

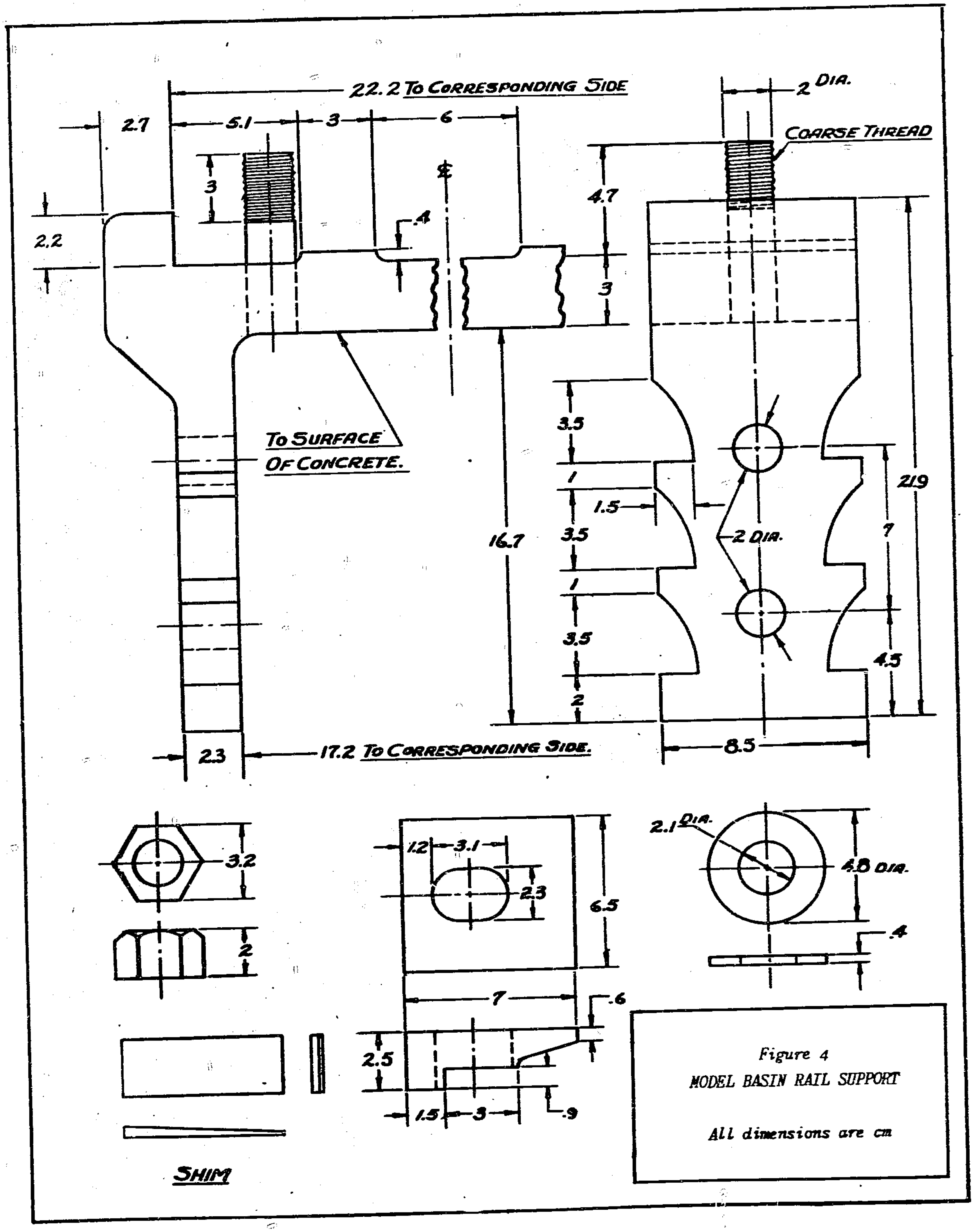


Figure 4
MODEL BASIN RAIL SUPPORT

All dimensions are cm

The carriage was to be built of steel with rivet joint connections. It was designed to have a maximum speed of 20 meters per second, and was to be powered by two a.c. electric motors having a total output of 100 kw. The power from these two motors was to be transmitted to the two forward wheels by gears. An electronic speed control was to be used, and the carriage was to weigh ten metric tons.

The entire basin and equipment were to be enclosed by a corrugated steel roof supported by light steel trusses. Concrete walls with window spaces located at the top were to support the roof trusses.

Unfortunately the plans for this basin and carriage, according to Admiral IZUBUCHI, had been destroyed at the time of the bombing. As in the case of the large basin, water acted as an insulator and protected the basin from fire.

A wave maker also was planned for this basin.

The medium basin, built in 1937, was designed by Mr. IKEGAMI, and is concrete on piling 108 meters long, 4.5 meters wide, and 3.5 meters deep. It is closed by a wooden roof supported by light steel frames which rest on concrete walls. Figures 5 and 6 are views of this basin.

Fresh water is used, and as in the other basins, only the leakage and evaporation loss is made up.

Wave dissipaters of the same construction and shape as used in the large basin, but proportionately smaller, are installed along the basin sides.

The carriage tracks were laid in the same manner as on the large basin. However, the weight per linear foot is less.

The carriage was designed by Mr. IKEGAMI and built in 1937. It is powered by two 10 kw electric motors. Each motor supplies power to the fore and aft wheels on one side of the carriage through gear boxes and shafting, the motors being located at the forward corners of the carriage. Speed control is by the Ward-Leonard system. A maximum speed of four meters per second is obtainable. This basin does not have a wave maker.

The small basin is 39.6 meters long, 1.8 meters wide, and 0.9 meters deep. It is enclosed by a wooden roof supported by light steel frames resting on concrete walls. Figure 7 shows a view of this basin.

The track is secured by the same method as used in the other basins. Leveling was accomplished by float type measuring instruments. Fresh water is used in the basin and is not changed or treated. Make-up water only is added.

The carriage is a very light wooden frame structure drawn by a 1/4 inch steel cable running along the side of the basin wall and driven by a 19 hp direct current motor. This cable system can give the carriage a maximum speed of 2.8 meters per second.

A small wave maker is located in the finish end.

Special research only is carried on in this basin.

The stability basin is in line with the large basin and separated from it by a distance of 7 meters. It is 80 meters in length, 12.5 meters in width, and 4 meters deep. There are no wave dissipaters along the basin walls.

A wave maker is located at one end and is powered by a 100 kw direct current, constant speed motor supplying power to two Waterbury variable stroke pumps.

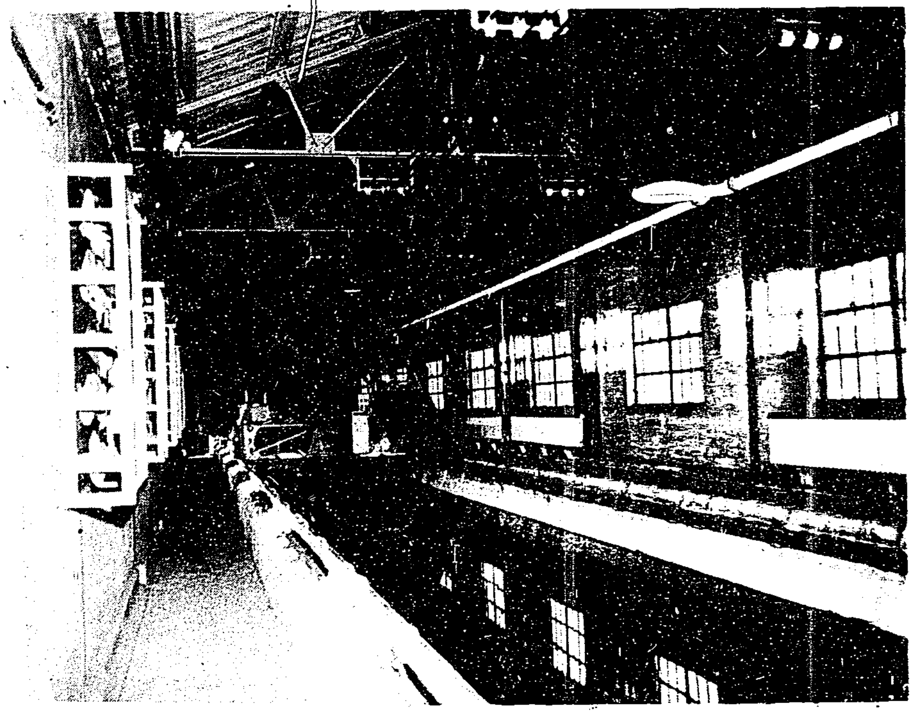


Figure 5
STARTING END, MEDIUM BASIN AT MEGURO, TOKYO

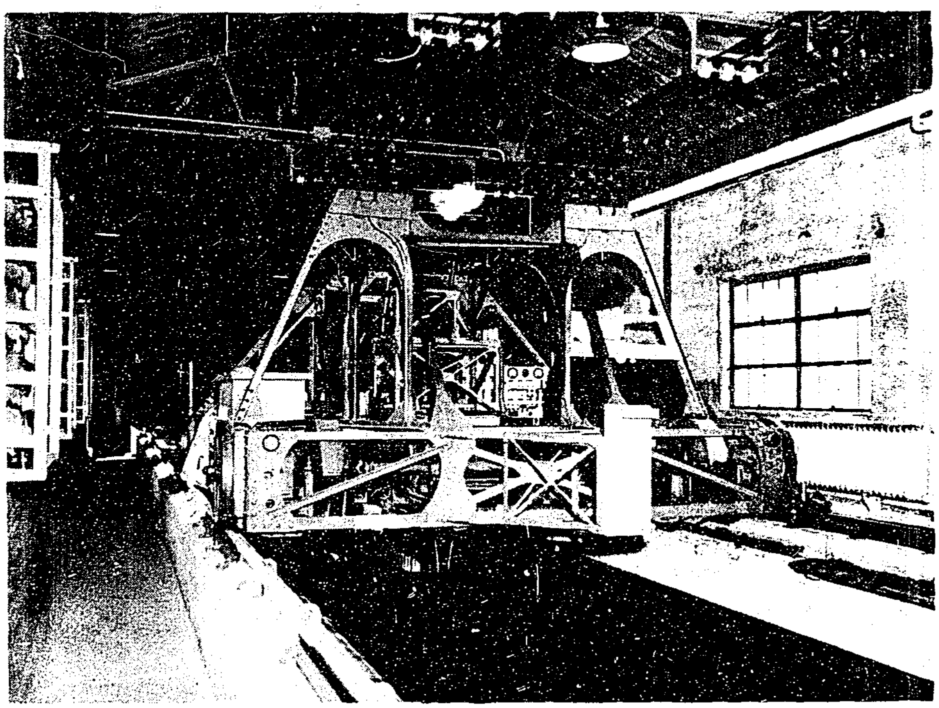


Figure 6
MEDIUM BASIN CARRIAGE

These pumps, through a gear train and crank, cause the vertical plate wave maker to oscillate. The crank has a maximum throw of 50cm, and wave heights of 300mm can be obtained.

As in the other basins, fresh water is used and make-up water only is added.

A rather large observation carriage spans the width and can be located at any point along the 80 meters of length.

The same building that enclosed the large basin also enclosed the stability basin. This building was destroyed.

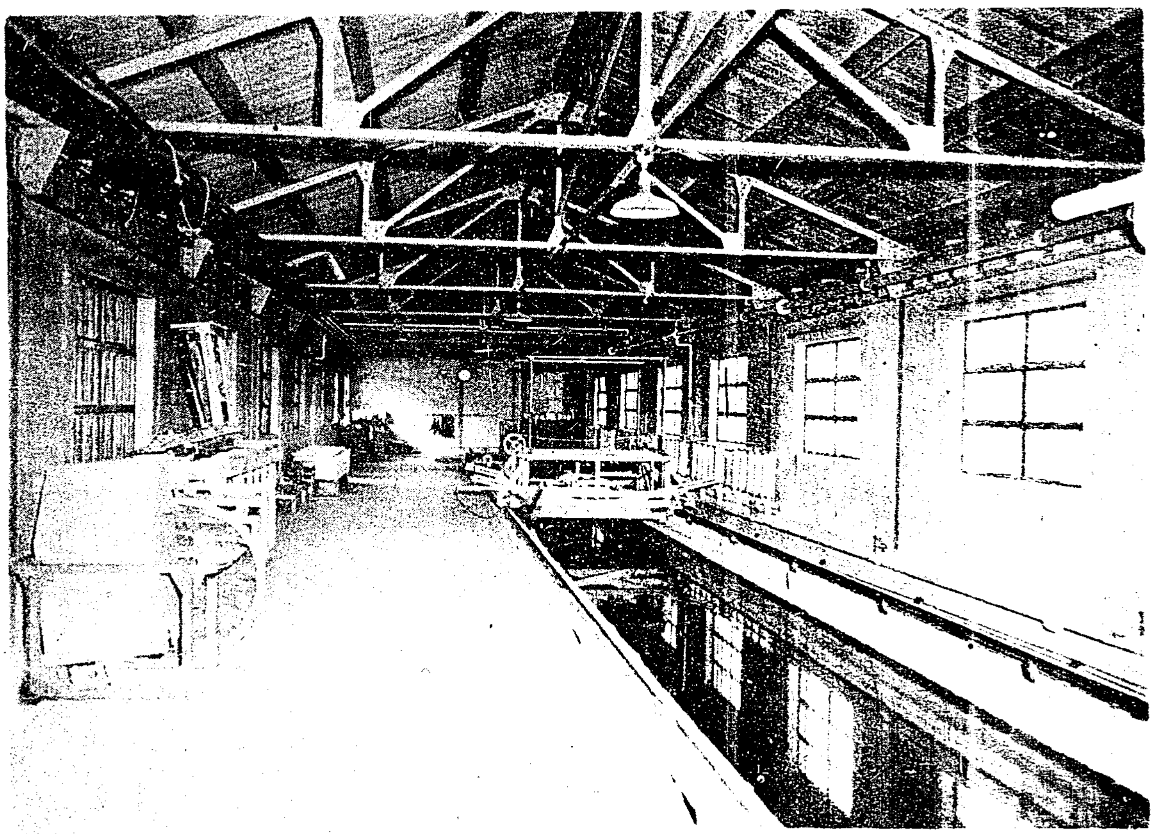


Figure 7
SMALL BASIN AT MEGURO, TOKYO

The circulating water channel at MEGURO was a small steel horizontal flow channel of square cross-section measuring 600mm on the side. The test section was open at the top (the remainder of the channel was closed) and was about 1½ meters long. The channel was designed by M. KANEKO of the Model Basin staff and was completed in 1922. A maximum water speed of 3.5 m/sec could be obtained. Practically the entire side walls of the test section were glass, permitting excellent visibility of the model.

The principal use of the channel was to measure the lift, drag, and torque on rudder models, but it had been used upon occasion for open water testing of propellers. The model propellers used were of 120mm diameter.

For more than two years now this equipment has lain idle as the maneuvering pond was used for rudder testing, and open water propeller test were carried

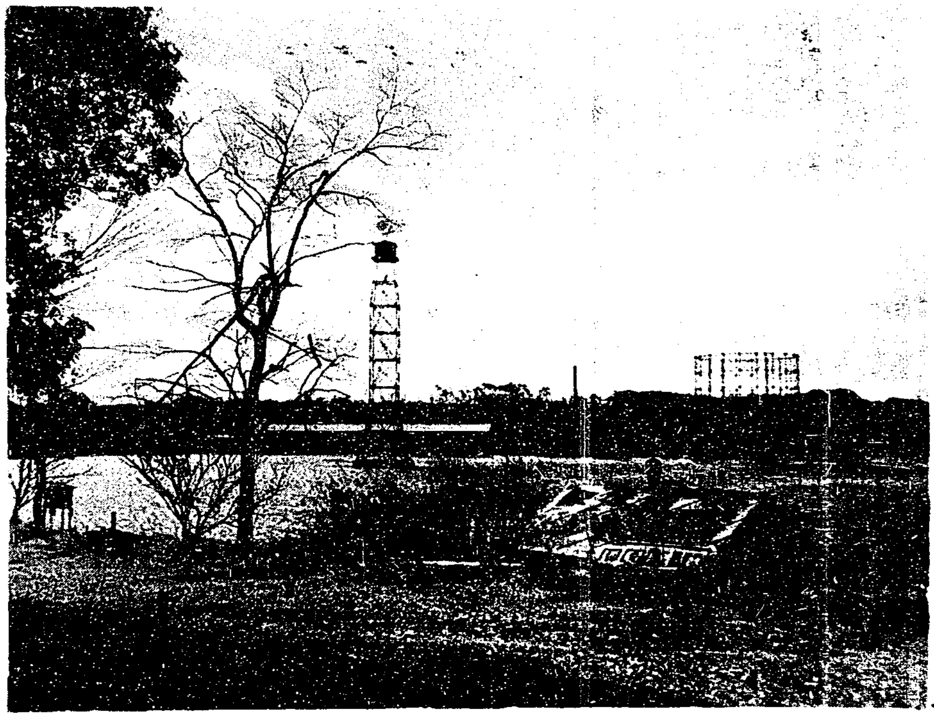


Figure 8
MANEUVERING BASIN AT MEGURO, TOKYO

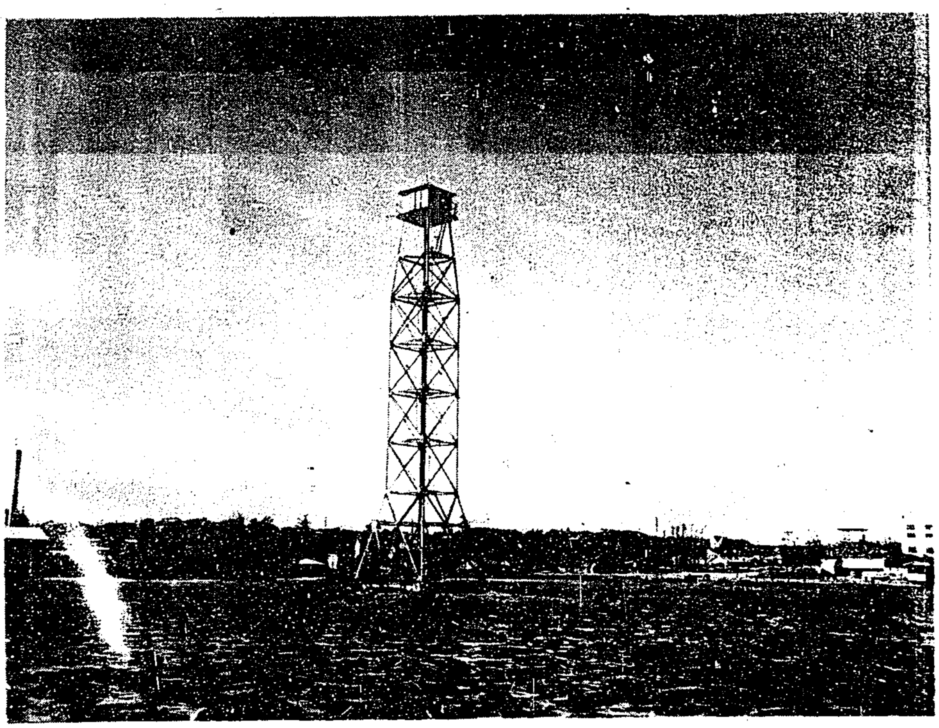


Figure 9
PHOTOGRAPHIC TOWER AT MANEUVERING BASIN

out in the medium basin.

The maneuvering basin at MEGURO is a small lake, generally circular in shape, having in its center a steel tower from which visual and photographic observations of the model could be made. The lake is 150 meters in diameter and the water depth varies from 3 to 3½ meters. The observation tower has an instrument house at the top, 28 meters above the surface of the water. This house is also fitted as a dark room.

Figures 8 and 9 are views of the basin taken from the approximate shore line in the direction of the model testing basins. Less than a quarter mile separated these two facilities.

Along the shore line was a small marine railway for handling the models in and out of the pond and at two other points on opposite sides were light crane facilities and landing floats. A small crane and landing platform were provided at the base of the observation tower. The instrument or observation house contained a glass box camera approximately one meter square in the center of the floor and a special wide angle lens was mounted in its center and projected through a peep hole in the floor. The lens, ground in Germany, was a special one covering an angle of 135°.

For daytime testing a timer was employed to open the camera shutter once each second and in this way the path of the model was recorded on the very large negative employed. This was apparently the first method of use, but according to Professor AKAZAKI, the designer, it was not too successful. It was found much more satisfactory to conduct the model turning tests at night. For this work a single light was mounted at the bow and stern of the model and a timer flashed these lights on simultaneously once each second. In this case the same negative recorded the path of the model in tiny points of light in pairs. The camera shutter remained open all during the run.

Models for turning and maneuvering trials were built of wood and self-propelled by storage battery. The rudders were hand operated by a man seated well forward in the model. Another operator was seated well aft and handled the rheostat speed controls. The exact size of the model was dictated by the ballasting requirements. Figure 10 illustrates a model which was approximately six meters long.

A rudder angle indicator was installed and the propeller RPM were recorded on a drum by counter and chronometer. Motor input was also measured. It was stated that a model could be run about four hours on one charge. No actual test data were obtained. Professor AKAZAKI did, however, produce a series of papers on model testing on rudders, turning, and maneuvering which has been assigned NavTechJap Document Number ND50-1290 and forwarded to the Taylor Model Basin. Included in these articles are a description of the maneuvering pond and the test methods employed, and a comparison of model and full-scale turning tests on two vessels.

C. <u>Models</u>.

Paraffin models were used quite extensively. They were cast in one of three molding boxes which were located in the model workshop. After being cast and allowed time for solidifying the models were placed in a cutting machine, keel up. Waterlines were cut by cutters controlled by templates and a pantograph arrangement. Figures 11 and 12 illustrate the casting mold and profiling machine, respectively. After the water lines were cut, sections were faired in by hand. The method is the same as used by the British.

The maximum size model used was eight meters. However, the majority of models were 6.5 meters. It was planned to used models of four meters length in the new high-speed basin. Wooden models were used in the small basin and the maneuvering basin. These models were 1.5 and six meters long, respectively.

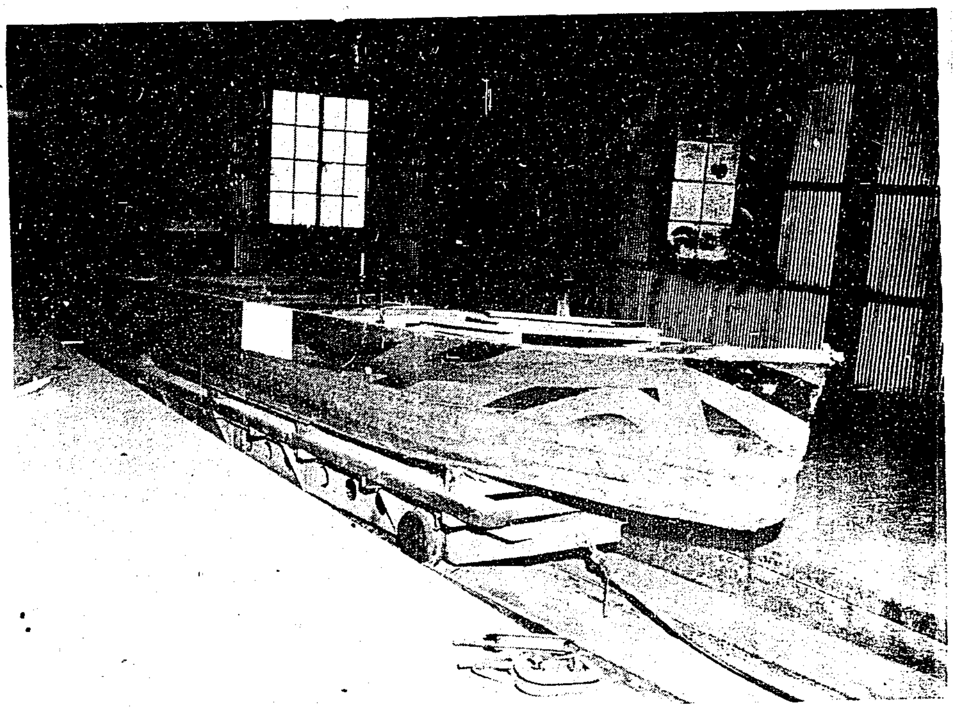


Figure 10
SELF-PROPELLED MODEL USED IN MANEUVERING BASIN

Figure 11
MODEL CASTING MOLD, MEJIRO, TOKYO

Mr. IKEGAMI expressed the opinion that paraffin models were quite satisfactory and seemed to feel that they were as good as wood models for basin testing.

Rudder and strut models were made of steel, being machined as far as possible to shape and hand finished to size. These, as well as the propeller models were polished to give a smooth finish.

Propeller models used were made of two materials, depending upon the test to be made. Manganese bronze models were used in the cavitation tunnel. These were 250mm in diameter. Propellers that were used in the open water tests conducted in the medium basin were cast in metal of the following composition: 15% lead, 67% tin, 10% bismuth, 5% antimony, and 3% copper. They were cast in clay and the pressure faces machined and finished by hand, while the suction faces were finished entirely by hand.

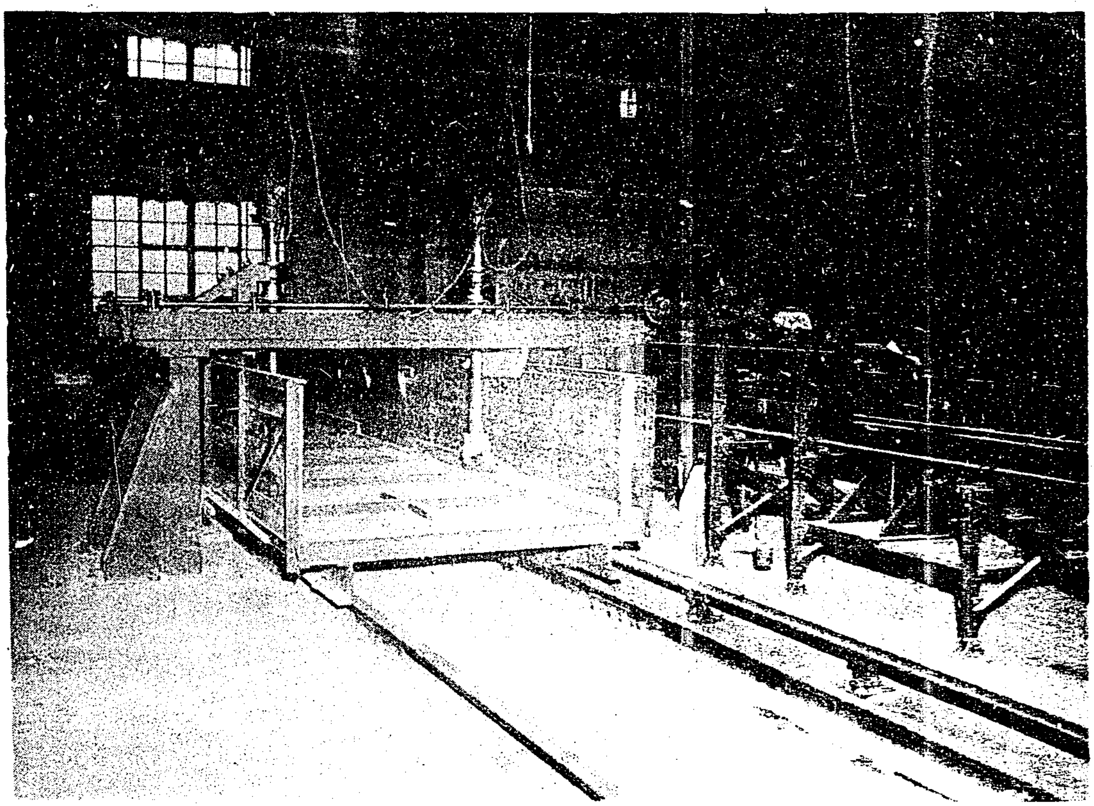


Figure 12
MODEL PROFILING MACHINE, MEJIRO, TOKYO

Steel plate ship models about seven meters in length were used in the stability basin for making flooding experiments. These models were quite similar to the ones used at the Taylor Model Basin for the same purpose.

D. Current Projects.

Although the Director reported that all records and test data had been destroyed by fire, the following list of research and test projects has been obtained from him and his principal assistant in naval architecture, Comdr. KONDO. The list has been checked at the Navy Technical Department and is believed to accurate.

1. Model Basin Test.

Ship form, resistance, propulsion and turning tests on models labeled 2nd, 3rd, 4th, and 5th complementary designs. All test results, models and plans have been destroyed. These "complementary designs" represented the various construction programs starting with the second in 1928 and ending with the fifth in 1943.

2. Model Stability Tests for BB NAGATO.

Tests has been made for various conditions of underwater damage and counter flooding. No information could be obtained on the results of these tests. The model used is still in the stability tank. It is approximately seven meters long and made of sheet metal. Its construction is very similar to the metal stability models used at the Taylor Model Basin.

3. Emergency Rudders.

Model tests were conducted on two types of bow rudders, both retractable, and one type of floating rudder. One of the bow rudders was a standard spade rudder, but the design was unsatisfactory because the turning effect was small. The second bow rudder design consisted of twin rudders housed in the bow but not rotatable. They were set at an angle of 30° to the keel on either side with the trailing edge out. Turning was accomplished by lowering the rudder on the side opposite the turn desired. These rudders were satisfactory in model test, but none had actually been installed. The rudder was about one-third the size of the main rudder, of hydrofoil section, and of standard spade shape. In model tests turning circles twice normal size were obtained. The floating rudder consisted of a large plate of faired section towed just awash about one-third ship length from the stern. A towing bridle was attached to its leading edge and two guide cables were attached to the trailing edge. Control of the rudder was obtained by hauling in on one or the other of the guide cables until the rudder had planed into the desired position on the quarter. Reports differed as to whether or not any of these floating rudders had been used. However, it was generally conceded that they were not satisfactory.

4. Anti-Rolling Tanks.

Stability tests of Frahm tanks had been made, but no information on the results could be obtained.

5. Buckling Stress of Submarine Pressure Hulls.

Several hundred model tests of sections of submarine pressure hulls had been made. An empirical formula and a family of curves for determining the buckling stress had been experimentally developed. This information is covered in NavTecJap report, "Characteristics of Japanese Naval Vessels, Article 1 - Submarines", Index No. S-01-1, although no actual test data could be obtained. Four papers reporting the results of pressure hull tests have been forwarded to the Bureau of Ships under NavTechJap Document Numbers ND50-1143, ND50-1144, ND50-1145 and ND50-1146.

6. Bending Tests of Box Girders.

A series of 50 models were tested using different riveted corner angles, etc., but no information could be obtained on the results of the tests.

7. Stress Distribution on a Ship in a Seaway.

These tests were made on a steel model towed in the large basin in waves. The model, eight meters long and representing a section of destroyer construction to scale, was tested. Hand strain gage readings were taken at various points on the deck, maximum and minimum readings were taken, and various speeds and waves were used. Analysis of the data was not complete at the end of the war and could not be obtained.

8. Experiments on Underwater Protection.

Caisson tests in model size were conducted varying the size of the explosive charge, the distance of the charge from the model, and the liquid loading of the model. The caissons had two torpedo protection tanks, the inner one being left empty. The best results were obtained with the outer tank 70% full. Full-scale tests were conducted to check scale effect and it was reported that the model test results were confirmed.

9. Form and Power of Submarines.

Completely submerged self-propelled tests of submarine models as well as tests in the surface and awash conditions were conducted, but the accuracy of the test results is very much questioned. Two methods of conducting the submerged tests at MEGURO had been used. In the first method attempted the model was very accurately ballasted, after all the self-propulsion drive had been installed, so as to give the model neutral buoyancy at approximately one meter submergence. The model was then attached to the carriage by a faired strut which incorporated a quick release mechanism for releasing the model after it was up to speed. The Director stated that this method had been discarded as unsatisfactory and had been replaced by their present system. This consists of a pair of faired struts pin-joined to the model forward and aft. These struts were also pinned to the carriage, but were permitted two to three degrees of motion in the longitudinal direction.

The self-propulsion dynamometer was a very compact unit of the self-recording type. A record of propeller RPM as well as thrust and torque was made on a drum similar to the larger dynamometers used in the surface tests. The principal difficulties encountered in this submerged testing were maintaining the tightness of the model and the proper adjustment of the propeller revolutions to ship's speed. Preliminary surface runs were made to obtain the rough curve of motor input to propeller RPM and this was corrected by an arbitrary amount to make an experimental curve for the submerged runs. The model self-propelled tests in the surface and awash conditions were conducted in the same manner as used at the Taylor Model Basin.

10. High Speed Boat Forms.

The purpose of this project was to determine the most efficient high-speed boat form for the SHINYO, or suicide boats. (See NavTechJap Report, "Japanese Suicide Craft", Index No. S-02). The desired displacement was about 15 metric tons, speed 40 knots, and shp 1500. The test of some 60 model hulls of round bottom, Vee bottom, and single step type resulted in the derivation of the following empirical formulas:

For Vee-bottom hulls:

$$V = 1.88\ L^{0.8} D^{1/6}$$

For round-bottom hulls: $V = 1.876\ L^{0.9} D^{1/6}$

Where V is skimming speed in knots
L is length of boat in meters
D is displacement in metric tons

No correlation was obtained for the step type hulls and, after three trials, this part of the project was abandoned. By similar testing it was found that the optimum length to beam ratio was between 4.81 and 4.85 and that the center of buoyancy was 0.394 L from the stern of the hull for the speed range of 40 to 50 knots. A typical comparison of the three hull types is given in the following tabulation.

HIGH SPEED BOAT FORMS
COMPARISON OF SPEED AND RESISTANCE

	Round Bottom	Vee Bottom	Single Step
Length, meters	19.00	16.70	16.50
Displacement, tons	15.00	15.00	15.00
Max. beam, meters	3.00	3.68	3.80
Mean draft, meters	0.59	0.60	0.63
At 20 knots	167.9 EHP	160.5 EHP	221.0 EHP
At 30 knots	437.6 EHP	364.0 EHP	368.0 EHP
At 40 knots		570.0 EHP	430.0 EHP
At 50 knots		956.0 EHP	582.0 EHP

The Director presented his personal work book on this project, in which he was much interested. In this record and in two pamphlets also obtained may be found the hull lines and a portion of the test results on many of these models. These three documents have been forwarded to the Taylor Model Basin, identified by NavTechJap Document Numbers ND50-1291, ND50-1292, and ND50-1293.

11. Flooding Calculations for Merchant Ships.

All data had been destroyed.

12. "Sea Bus" Form.

The "Sea Bus," or tank carrying ship, (usually called SB boat) suffered severely in its original form from pounding in heavy seas which caused buckling or tearing of the plates of the upper deck.

The purpose of this project was to determine by impact test on a series of models, the best form of the bow and the spacing of the twin keel. The impact on the models was measured by a piezo-accelerometer when the models were (1) dropped into water from various heights and (2) when the models were run in waves. The series of tests was incomplete at the end of the war, but two results stood out. First, in a heavy sea the farther apart the twin keels were, the greater were the chances of buckling and second, tested in waves, the farther apart the keels were placed, the more nearly the resistance approached that of a single keel design. It is believed that the war ended before a compromise design could be secured. A short paper describing these tests and showing some results has been forwarded to the Taylor Model Basin, identified by NavTechJap Document Number ND50-1294.1.

13. Dynamic Forces on High-Speed Boat Bottoms.

This project was a companion test to those carried out on the "Sea Bus", and embodied the impact testing of 17 models of high-speed boat forms by accelerometer when dropped into water from various heights. An illustration of each hull form with such information as had been analyzed by the end of the war has been forwarded to the Taylor Model Basin identified by NavTechJap Document Number ND50-1294.2.

14. Propeller Cavitation.

Theoretical cavitation studies had been made on numerous metals to determine their resistance to this form of erosion. The methods used were very similar to U.S. methods. In one set of tests a magnetostriction device was used while another series was conducted using a water hammer. Aside from the fact that the Japanese proved to themselves that cavitation erosion is not a chemical action, they also found that a smooth, highly polished surface resists erosion better than one that is rough. It should be borne in mind that propeller cavitation erosion was not a serious problem in the Japanese Navy since their propellers were designed to absorb full power before the cavitation range was reached. This was done by a sacrifice of maximum efficiency at full power. In almost all of their propeller designs the Japanese used a very wide blade with an ogival section. Considerable washback of the leading edge near the blade root section also tended to prevent cavitation. It was difficult to obtain an accurate answer on the Japanese propeller series work. One series which was conducted by Mr. Hayashi IKEGAMI at MEGURO is tabulated below:

Propeller diameter	250mm
Blade form	elliptical
Number of blades	three
Blade cross section	ogival
Water Speed	6m/sec
Effective slip	15-45%
Vacuum	60, 65, 70, 75, 77.5, 80, 82.5, 85
Pitch ratio	0.7, 0.8, 0.9, 1.0, 1.1, 1.2
Developed area ratio	0.4, 0.5, 0.6, 0.7, 0.8

A second series consisted of wide tip blade form, three bladed design, having varying blade cross-sections. The pitch ratio (1.1) and the developed area ratio (0.8) were held constant. Five sub-series were run as follows: (a) varying the location of maximum blade thickness, (b) varying the starting point of washback on the leading edge, (c) varying the amount of washback on the leading edge, (d) and (e) same as (b) and (c) on the trailing edge with the optimum washback at the leading edge maintained.

15. Sweeping Gear for Pressure Mines.

Two devices were developed, a flat plate about six feet wide by four feet long towed at an angle of attack of 11°, and a six foot cylinder, one foot in diameter, which is towed horizontally. These were to be used in conjunction with a magnetic sweep. A full scale test of the flat plate was a failure, but the Director attributed this to the magnetic impulses being poorly timed. The cylinder was considered better because of greater towing stability but was not tested. The Japanese determined that a negative pressure of six grams per square centimeter was required to actuate the mines. (See NavTechJap Report, "Japanese Minesweeping Gear and Equipment", Index No. S-28.)

16. Form of Towed Depth Charge.

No tests were made of this proposed anti-submarine device.

17. Prevention of Propeller Noise (Singing).

Fundamental research in propeller singing was carried out in a small tank one meter square in which blades of flat sheet metal were rotated. Steel, cast iron, aluminum, bronze, brass, and even celluloid were tested. Further test of propellers up to 500mm in diameter were made in a five meter square tank. A 35 hp motor rotated these propellers up to speeds of 1200 RPM. Although none of the test results are available, the conclusion was reached that fining the trailing edge would in most cases cure the singing. Although this became standard practice on naval and merchant ships mechanical damage to these fined edged proved to be a large and continuing problem. Admiral IZUBUCHI stated that on some merchant ships it had been found necessary only to fine the trailing edge for a short distance between the o.6 and 0.8 radius. This reportedly stopped the singing on relatively slow turning propellers.

18. Use of Resin in Pastes for Plywood.

No information was obtained other than the fact that a soy bean resin paste was found to be best.

19. Form of BB YAMATO Class.

The tests for this class were apparently the most important item on the list of projects submitted. The body plan and offsets for YAMATO have been included in NavTechJap report "Characteristics of Japanese Naval Vessels, Article 3 - Surface Warships Hull Designs", Index No. S-01-3.

Admiral IZUBUCHI was very proud of his work on YAMATO and claimed to be the designer of the special bulbous bow which he stated produced a saving of about 20% in the hull resistance at full speed over the model with a conventional bow. A great many tests were conducted on YAMATO, including a twin skeg design which was very poor, showing a 30% increase in resistance at top speed. Three different model sizes - four, six, and eight meters - were employed to insure that no scale effect would be evident in the results. It was found that a six meter model could be used safely. Some 50 tests, including approximately 10 different propeller designs, were subsequently conducted before the final design was reached.

20. Flooding Calculations for Merchant Ships.

No information available.

21. Strength of Wood Ships.

Various keel and frame fastenings were tested. A joint was found which gave 60 percent the strength of the intact wood.

Part II - MEJIRO BASINS

A. Organization and Facilities.

As previously stated, the Naval Research Institute at MEGURO confined its activity to naval vessels. To investigate problems relating to commercial vessels the Japanese Ministry of Communications operated an establishment known as the TEISHIN-SHO Tank in MEJIRO, TOKYO.

The testing equipment other than the basins proper, and the testing method used in working up results at this basin were identical with those used at the Navy Ministry basin at MEGURO.

The basins have not suffered any damage from bombings as was the case at MEGURO, and at the present time are operable but virtually at a standstill.

Mr. SHIBA, Engineer-in-Charge of the basins, was interrogated and was present during an inspection tour of the facilities. He is a graduate naval architect, having obtained his education at Tokyo Imperial University.

The establishment consisted of one large and a second smaller basin. A rather small machine and ship model shop were combined in one room adjoining the large basin. Propeller models were made in a separate building nearby. Generally speaking, the testing equipment looked quite run down, but still capable of conducting tests with a reasonable degree of accuracy.

The large basin, built in 1930, was made of concrete, 200 meters long, 10 meters wide, and 6 meters deep. Pieces of ordinary bevel siding as used in house construction were laid end to end floating on the water surface along the tank walls to act as wave dissipaters. Also, at the beginning end of the tank were six wave dissipaters placed side by side across the width of the tank. Inspection of Figure 13 will indicate how they were located.

Each one was made of a series of 10.2 pound steel plates of about one square meter area placed on top of each other, with approximately 5cm spacing between plates. They had a very slight slope into the water and were held in position by several angle bar brackets.

A wave maker capable of producing waves 300mm in height was located in the finish end of the tank. It was a caisson-like structure made of flat plate and hinged at the bottom. The top was oscillated by power supplied from an electric motor driving through a gear train, crank, and eccentric. The track was installed in the identical manner as in the large basin at MEGURO. Fresh water was used and only make-up was added. No treatment was made.

The carriage and equipment was of the same design as the large carriage and equipment used at MEGURO Basin except that a propeller dynamometer similar to that used on the medium basin at MEGURO was also contained on the carriage along with the towing dynamometer. The maximum carriage speed was six meters per second.

The high speed basin was built in 1937 but because of budget limitations, the tank desired could not be built. A compromise was reached which resulted in constructing the tank in three sections: an accelerating section, a measuring section, and a decelerating section. The dimensions are given in the following table:

	Accelerating Section	Measuring Section	Decelerating Section
Width	4.5	8.0	4.5
Depth	2.4	4.15	2.4
Length	60.0	105.0	35.0

(All dimensions are in meters.)

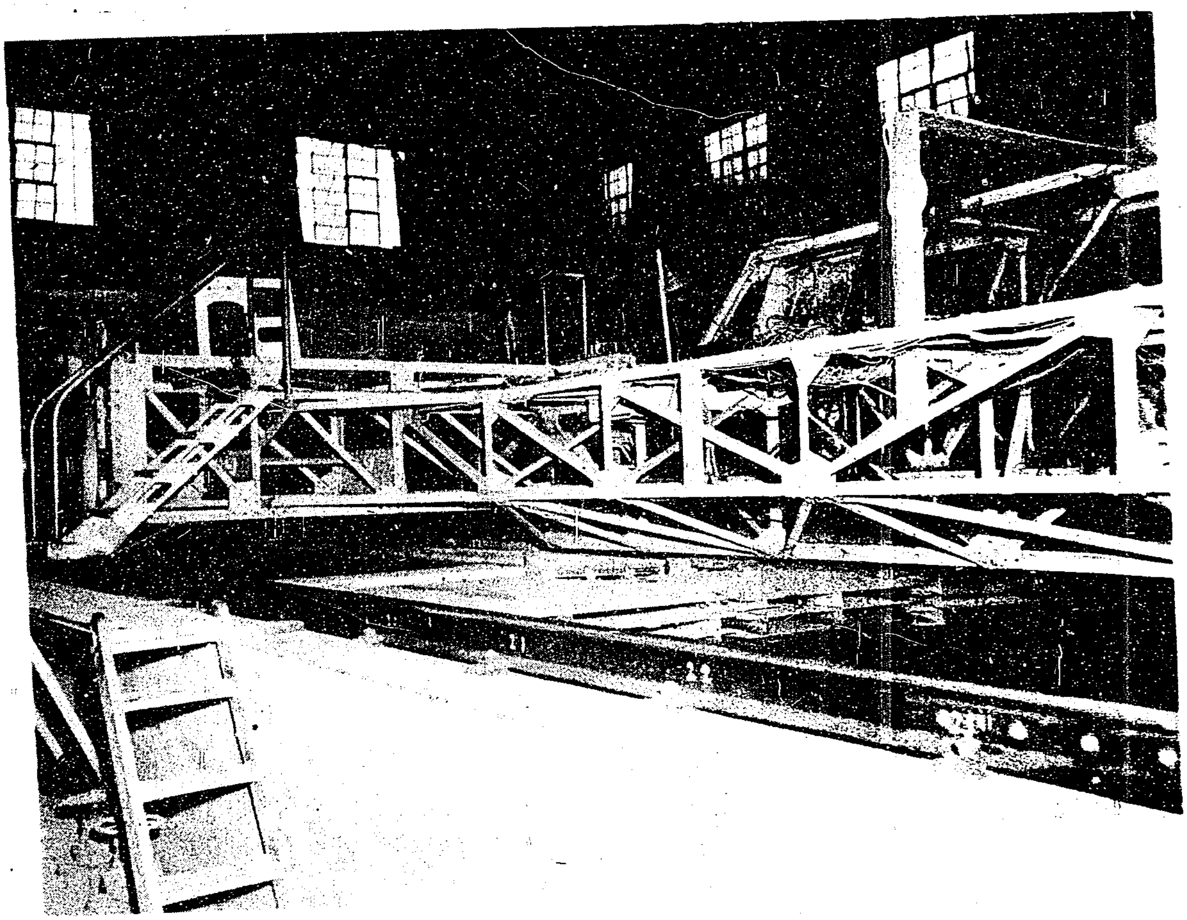


Figure 13.
LARGE BASIN CARRIAGE AT MEJIRO, TOKYO

By constructing a reinforced concrete overhanging wall from each side of the measuring section above the water surface the span of the carriage was held to five meters, rail to rail, and at the same time the width of the measuring section could be maintained at eight meters. By this method a smaller carriage was required and in turn less power needed to obtain the desired maximum speed of 12 meters per second. The carriage weighed six metric tons, and the power was supplied by four 10 kw motors. Speed was controlled by the Ward-Leonard system. Hand braking was employed which caused brake shoes to clamp against the sides of the rail. Owing to the inefficiency of the braking system, the carriage actually was never used above the speed of seven meters per second.

Tracks were located on track supports embedded in the concrete and were adjusted vertically by shims located between the supports and track. Lateral adjustment was made by bolts which pressed against the sides of the rail and were held fixed by set screws. Figure 14 illustrates this method of adjustment.

B. Models.

Six-meter paraffin ship models were used in both of these basins. These models were made in the same way as those used at MEGURO, and as illustrated in Figures 11 and 12. The process and composition used in making propeller models was also the same.

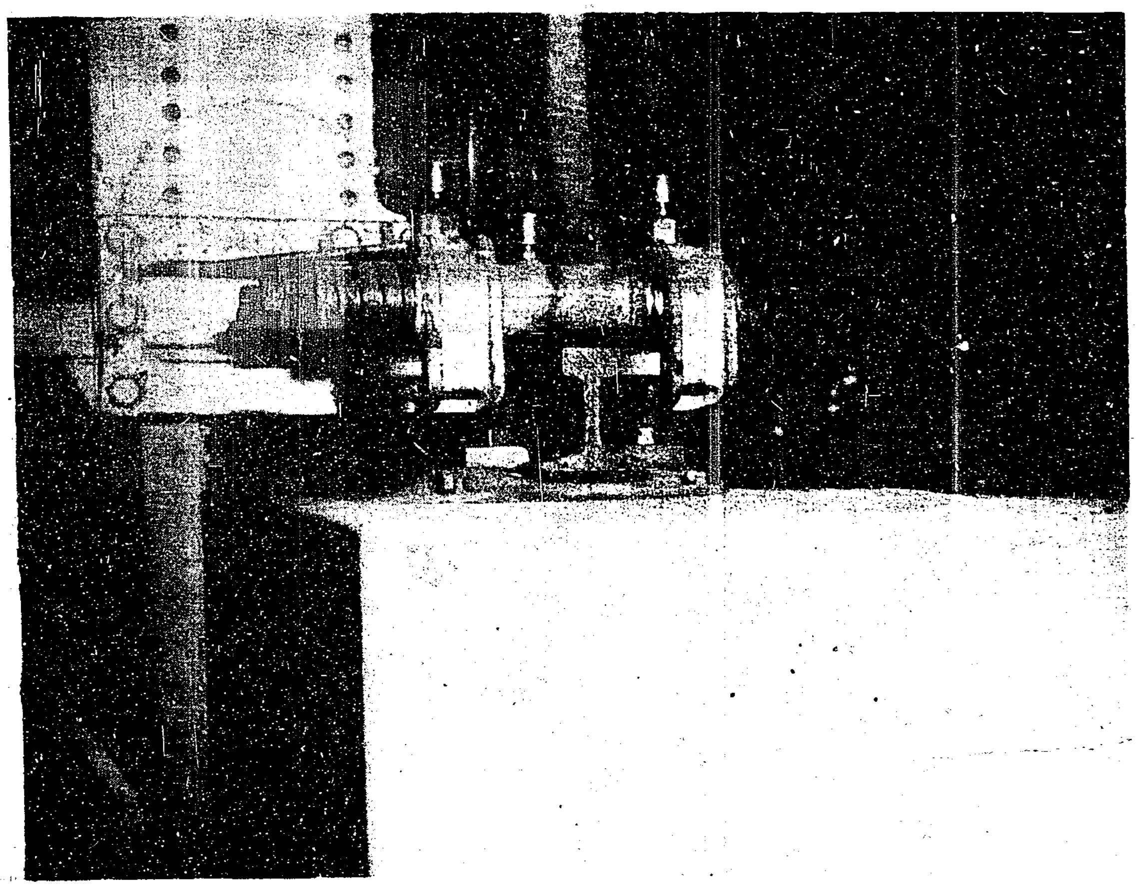


Figure 14

RAIL SUPPORT AT MODEL BASIN, MEJIRO, TOKYO

C. Current Program.

During the years 1943 and 1944 no work was carried on at this basin, for lack of qualified personnel. It is believed that the basin was maintained as a standby to be used in case of emergency.

At the present time the personnel employed are chiefly for the general repair and upkeep of the basin facilities. Some few technical people are occupied in the design and testing of an 84 meter steel cargo ship, hull, and propeller, and the design of a propeller for a small wooden cargo vessel.

PART III - NAGASAKI BASINS

A. Organization and Facilities.

The Mitsubishi Company started tank testing in 1908 at a now discarded tank which was 131.1 meters long, 6.1 meters wide, and 3.7 meters deep. About 1935 the directors of the Mitsubishi Company decided that the above basin and its equipment was not good enough for modern practice, and plans were made for a new basin to be constructed in Nagasaki. Work was started just prior to December 1939 and was completed in July 1943. By November 1943 the equipment from the old basin had been transferred and work at the new basin was started. The design and drawing offices, however, were retained at the old basin.

The Mitsubishi basins were subsidized by the Japanese government and a portion of the work done there was for the Japanese Navy. However, no close liaison was maintained with the TEISHIN-SHO Tank at MEJIRO, TOKYO.

The new basin was located on the northern boundary of the area destroyed by the atomic bomb dropped on Nagasaki in August 1945. It was a single continuous tank, one section being 126 meters long, 6 meters wide, and 3.6 meters deep expanding into a larger section 14.4 meters long, 12 meters wide and 7.2 meters deep. Figure 16 shows a view of these basins looking toward the large end, and Figure 15 is a sketch of the layout. A carriage operated over each section with a maximum speed of four meters per second for the small section and eight meters per second for the large. The carriage over the small basin could run only the length of the small basin, while the second carriage could run the full 270 meter length of both basins.

The model basins were a part of the Mitusbishi Research Division, which was directed by Mr. HORIKOSHI. Responsible to Mr. HORIKOSHI for the operation of the basins was Mr. AOYAMA. Mr. AOYAMA had two senior assistants, Mr. MURATA, who was in charge of experiments, and Mr. TAGUCHI, who was in charge of design work and analysis of test data. Both Mr. HORIKOSHI and Mr. TAGUCHI were interrogated.

At about the midlength of the basin and on the northern side is a smaller building separated from the main basin building. It is in this smaller building that a well-equipped model workshop was maintained, with facilities for all types of model manufacture (see Figures 17 and 18). A monorail crane was used to transfer the models from the casting mold to the cutting table and to the basin model dock. The latter are located at the junction of the two basin sections and are formed by an extension of the sidewalls of the smaller section into the larger (see Figure 15).

A third Building also located on the northern side of the basin houses the 3300 volt motor-generator power supply.

The basin was constructed of reinforced concrete, as were the walls, which supported arched steel trusses. The roof was covered with tile, lighting being provided by windows located in the upper half of the walls and placed continuously along the length of the building. Tracks were laid in the same manner as at MEGURO and MEJIRO.

The small carriage was of wood box girder construction and carried a resistance as well as a Fronde pulley type propeller dynamometer. This carriage is shown in its present wrecked condition in Figure 19.

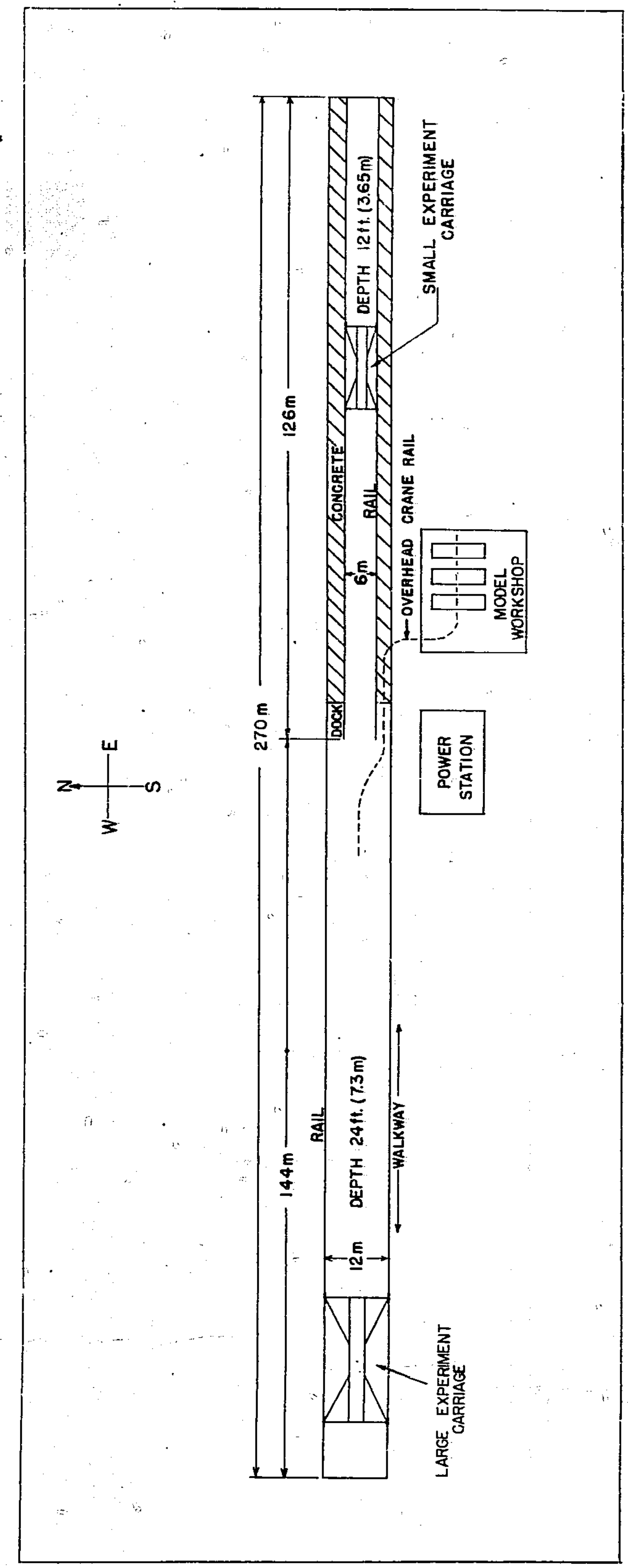


Figure 15
LAYOUT OF NEW MITSUBISHI TANK AT NAGASAKI

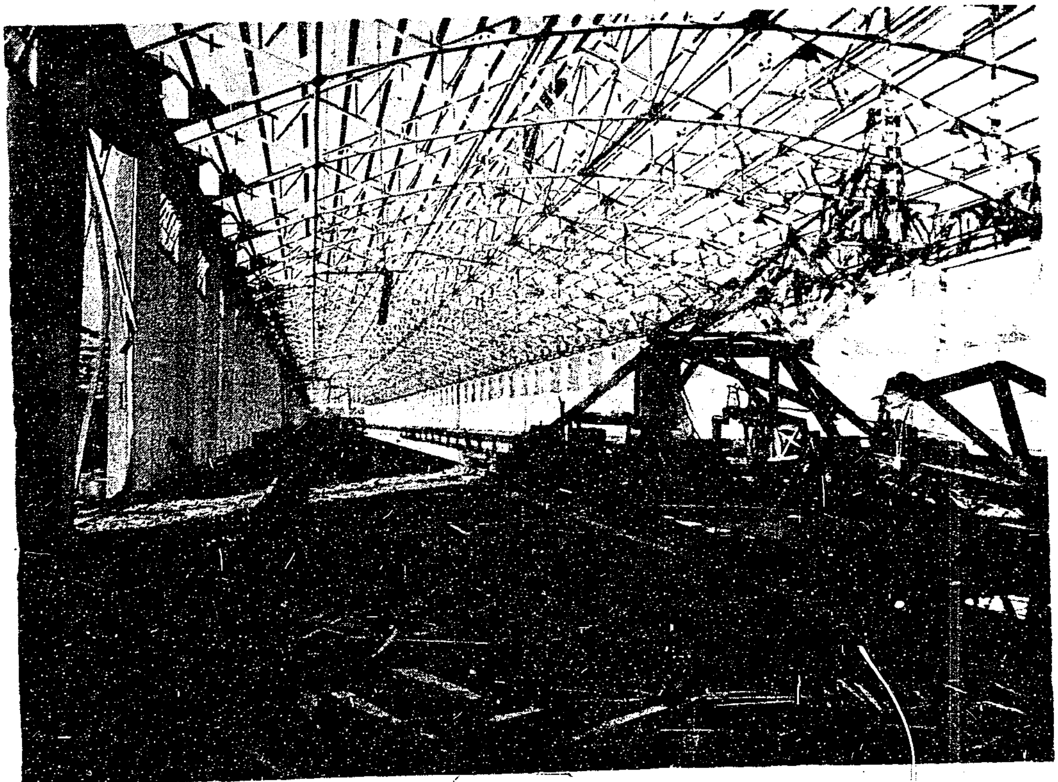


Figure 16

MODEL BASIN AT NAGASAKI

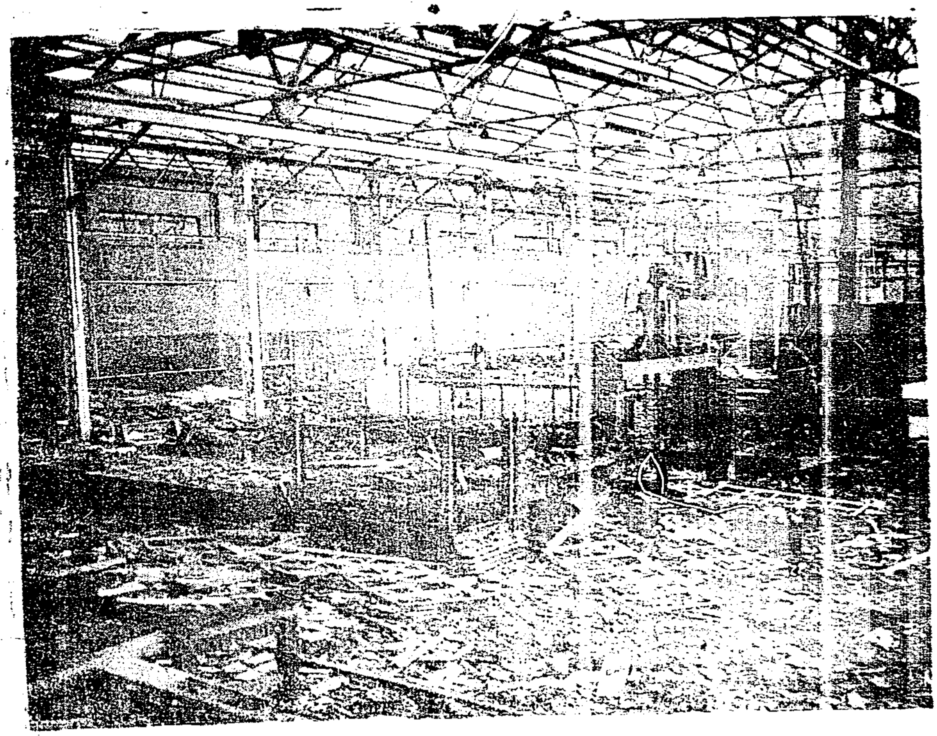


Figure 17

MODEL WORKSHOP AT NAGASAKI

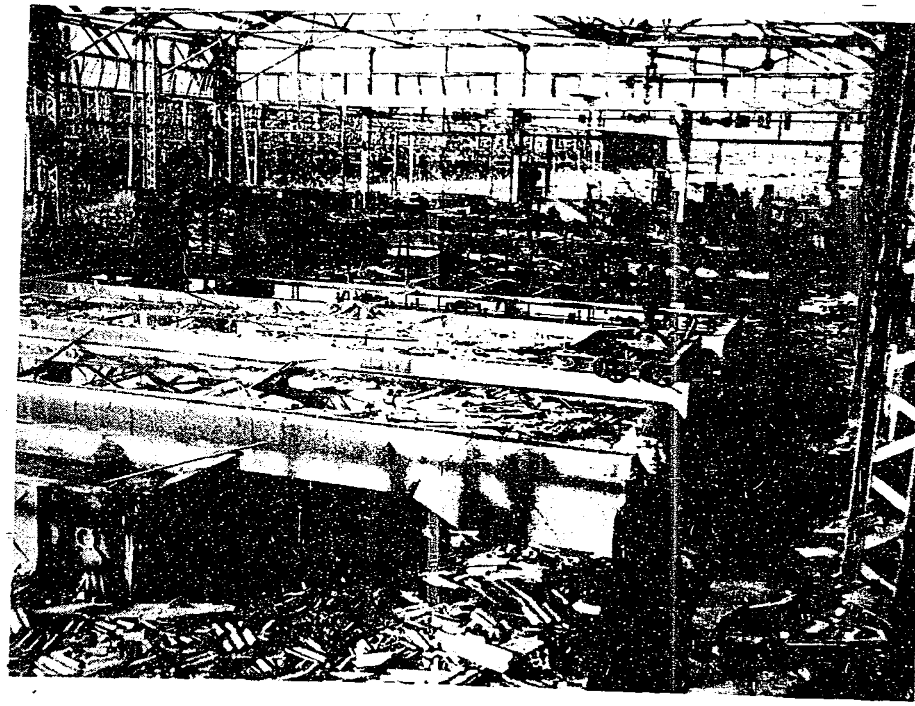


Figure 18
MODEL WORKSHOP AT NAGASAKI

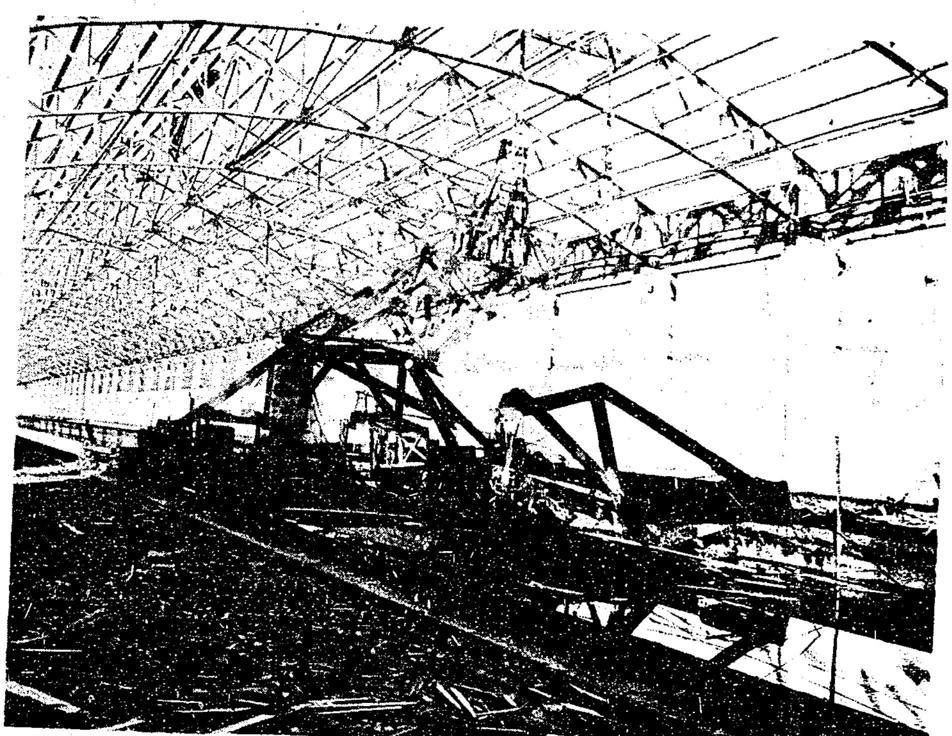


Figure 19
SMALL CARRIAGE AT NAGASAKI

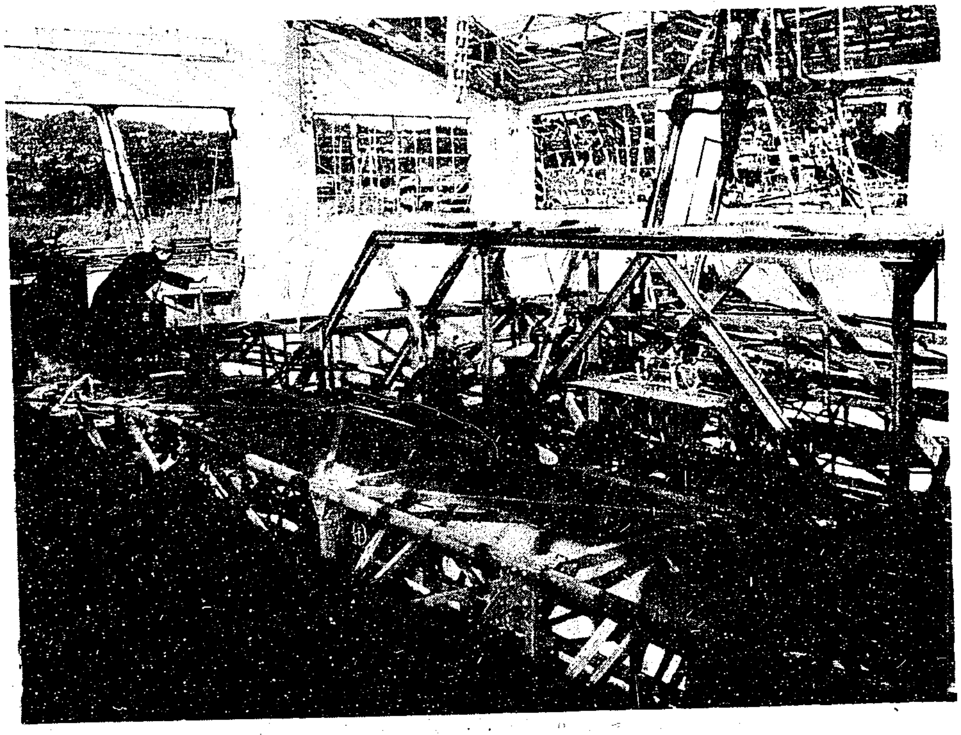


Figure 20
LARGE CARRIAGE AT NAGASAKI

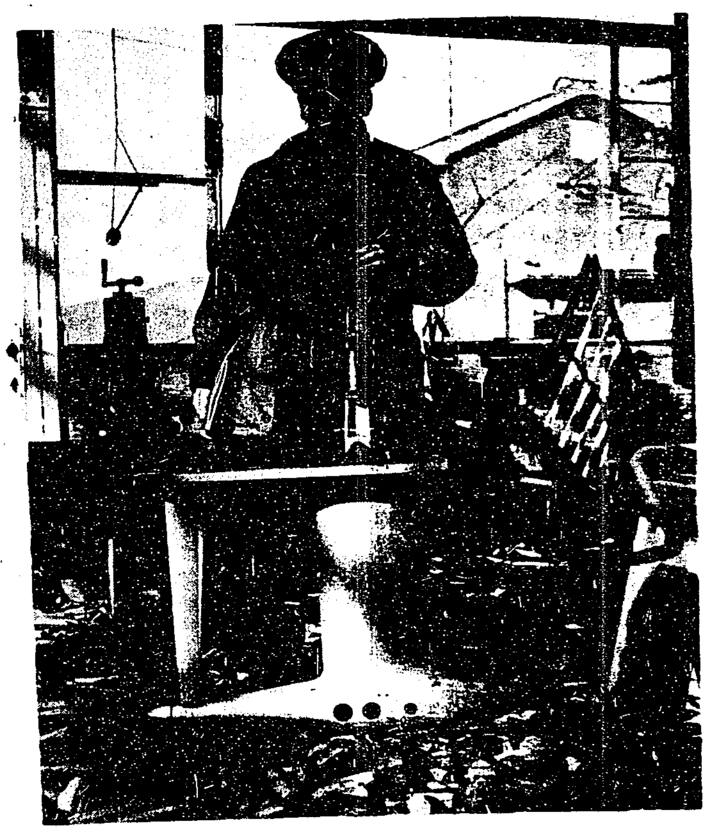


Figure 21
OPEN WATER PROPELLER DYNAMOMETER AT NAGASAKI

The large carriage (Figure 20) and dynamometer were of the same conventional type as found at the MEGURO and MEJIRO basins. It was powered by four 220-volt direct-current motors, each driving a wheel. A propeller dynamometer for open water propeller tests was in process of being constructed. A view of the underwater portion of this dynamometer is shown in Figure 21.

B. Research and Test Projects.

The following is a list of research projects carried out at this basin in the years indicated:

1940

Studies of the lines of the shallow draft cargo boat CHINKO MARU.
Approximate method of powering motorboats.
Design of lines and propellers of Icebreaker YS 389 and KS 644.
Design of lines and propeller of Shanghai liner "S-883".
Study of tow rope pull of tugs.

1941

Design of lines and propeller of Icebreaker YS 389 and KS 644 (cont'd).
Study of the air drawing of propellers.
Investigation of the speed fluctuations of towing carriages.

1942

Study of ship resistance to side motion.
Experiments on the resistance of spindle forms which rotate on an axis parallel to the direction of motion.
Study of bubbles which adhere to models in summer.
Study of damping ability of bilge keels on "K" type ore carrier.
On the variation of power due to small changes in speed.
Methodical series open water propeller tests.

1943

Study of propulsive efficiency of ferry with bow and stern propellers.
Approximate solution of Voight-Sneider propeller.
Study of lines of "AT" Type cargo boat.
Simplification of lines of a water barge.
On the lift variations of propeller blade elements due to wake variation.

1944

Study lines of improved "E" Type ship.
Standardization of trial analysis.
Studies of skin-friction correction of self-propelled tests.
Study on scale effect of model tests of high-speed motorboats.
High-speed boat with underwater wings.

1945

Study of lines of 4th "TL" Type tanker.
The test data on the above projects were reported to have been destroyed in the bombing of NAGASAKI.

Part IV - CAVITATION TUNNELS

There are two propeller cavitation tunnels in Japan, the larger at MEGURO and owned by the Navy, while a smaller one is located in the ship testing laboratory of the Communications Ministry at MEJIRO.

The large tunnel shown in Figure 22, which was built in 1938, was designed by Dr. Kempff in Germany. Admiral IZUBUCHI and an engineer from the Meguro Basins went to Germany for this work and brought back the finished plans. The test section (Figure 23) is practically square in cross-section, with slightly rounded corners. It measures 900mm across. A window is fitted in each side for light and observation, and a hatch for changing the propellers is fitted flush in the top of the test section. The discharge end of the test section (Figure 24) is divided at the downstream elbow to permit the use of shorter shafting and, in general, to shorten the dynamometer end. The inside of the tunnel was painted white. This painting was not satisfactory and frequent touching up was necessary. As evidence by Figures 23 and 25, considerable difficulty was encountered in maintaining the vacuum and all tunnel joints were heavily coated with a plastic paint to prevent leaks.

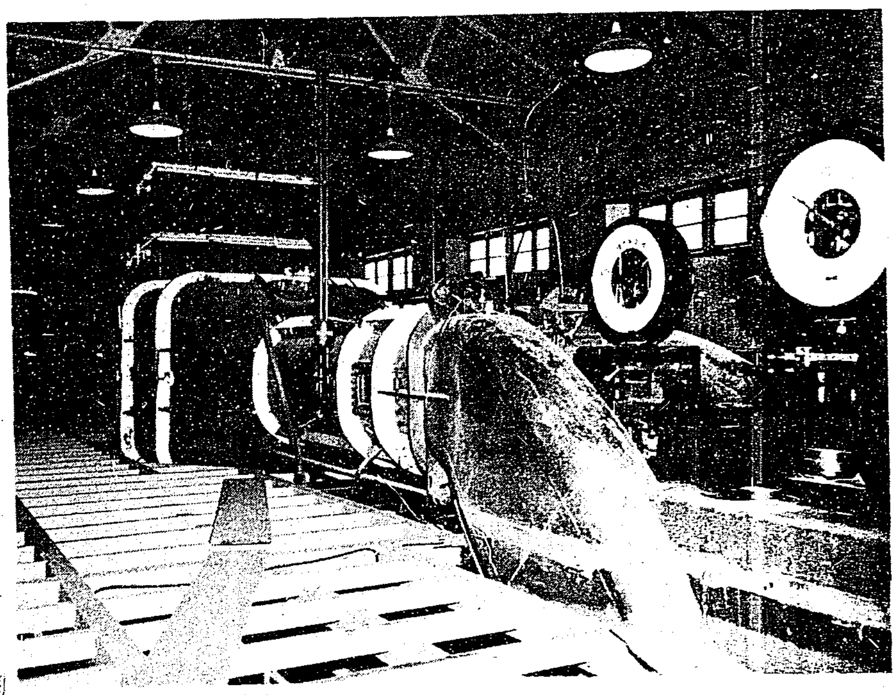


Figure 22

CAVITATION TUNNEL AT MEGURO, TOKYO

The water in the tunnel was circulated by a four-bladed impeller driven by a 150 kw electric motor through a reduction gear. The reduction gear had selective ratios of 1 to 1, 1 to 5 and 1 to 25, but only the last ratio was ever used. The maximum water speed attainable was six meters per second. It was stated that no provision was made for settling or clarifying the tunnel water other than a strainer in the upstream elbow. The air content of the water was measured occasionally by a chemical test on a sample, but this test required about two hours to perform. No attempt was made to establish a standard air content by the use of a "standardizing" propeller. A large stroboscope light was employed in cavitation observation, but no photographs were taken because no high-speed camera was available.

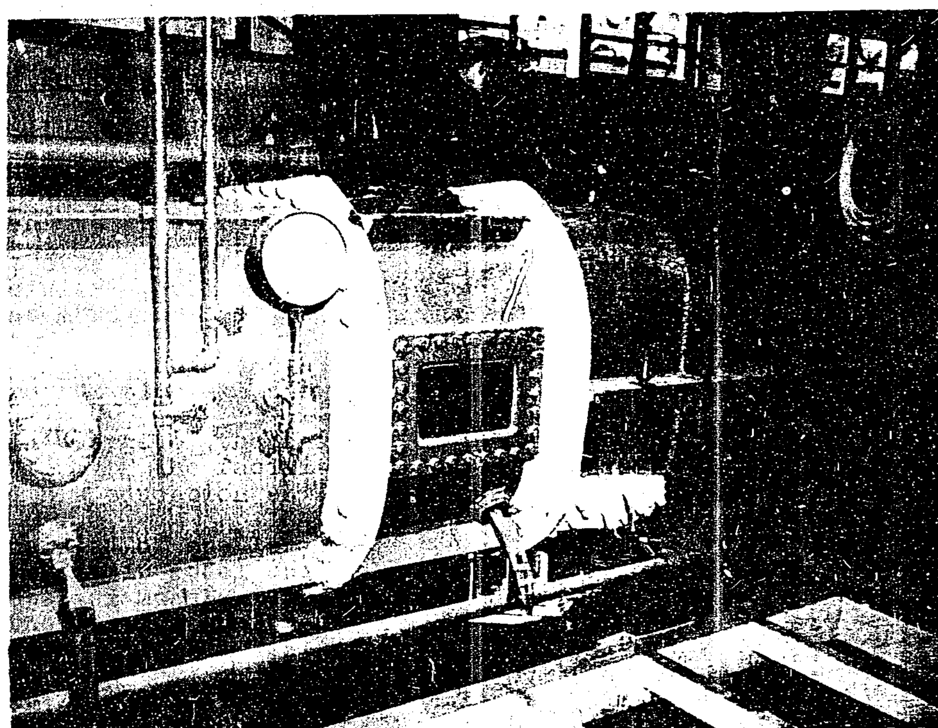


Figure 23
TEST SECTION OF CAVITATION TUNNEL

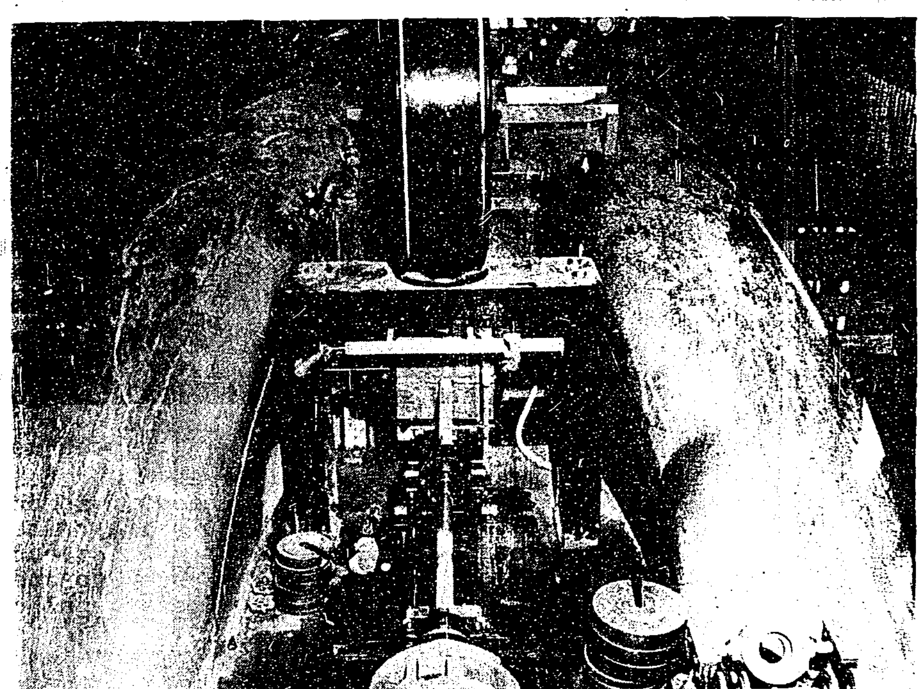


Figure 24
DOWNSTREAM ELBOW OF CAVITATION TUNNEL

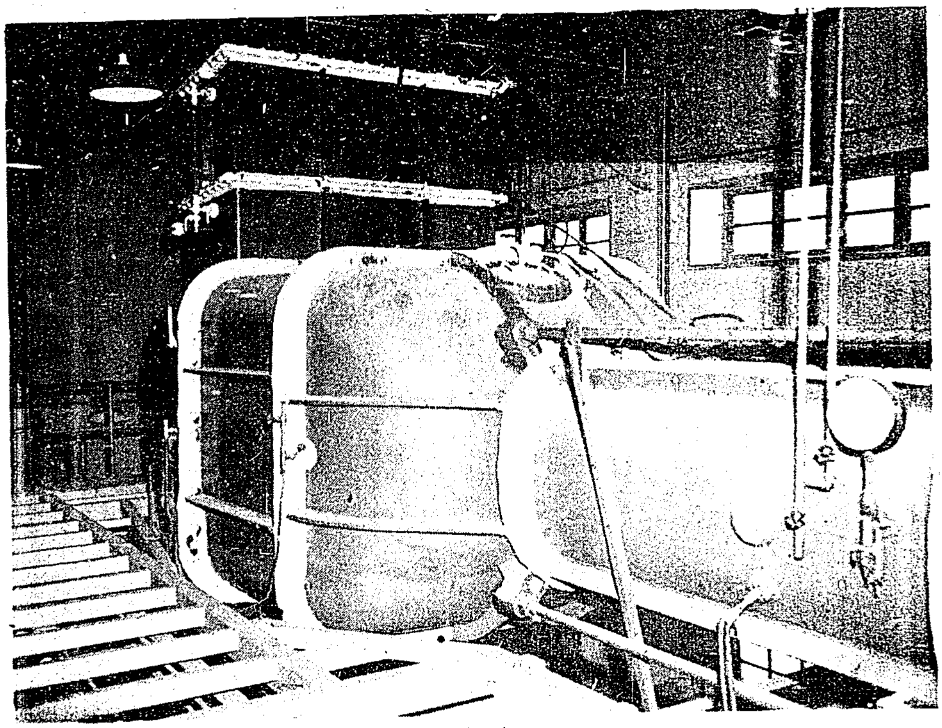


Figure 25
UPSTREAM ELBOW OF CAVITATION TUNNEL

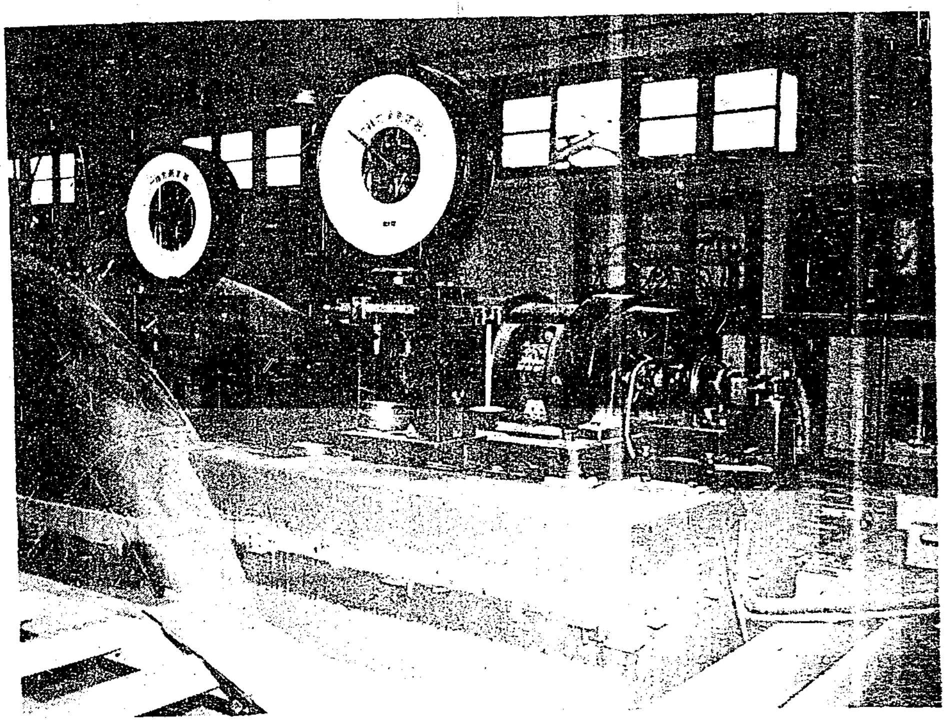


Figure 26
DYNAMOMETERS OF CAVITATION TUNNEL

Thrust and torque were transmitted by beam balance connected to the two large dial scales shown in Figures 22 and 26. No-load runs were made to correct for hub fairwater and friction losses. Propeller speed was rheostat-controlled and revolutions were measured by a geared counter. No instantaneous RPM indicator was available. The water speed was measured by a pilot tube located about three inches from the bottom of the test section. Under design and construction was an automatic recorder to be used for paper recording of thrust and torque during the run. Even the design was incomplete and it was impossible to obtain much information on either the need for such an instrument or just how it was to operate. In general design it appeared to be quite similar to the recording mechanism employed on the self-propulsion dynamometers.

The model propellers for cavitation testing were made of bronze and were finished by hand to very close tolerances. A standard diameter of 250mm was used for all models. Figures 27, 28, and 29 illustrate the pitch checking device and blade templates employed in checking the propellers. It was stated that bronze propellers were used to avoid blade edge damage in handling and testing. Templates used for checking the propellers were made of brass sheet approximately 1/16 inch thick and a face and back template were made for each 10mm of radius. With very few exceptions only three-bladed propellers were tested. There were no four or five-bladed propellers in use in the Navy, since they claimed higher efficiency could be obtained with the three-bladed design. Figure 30 illustrates some of the more extreme designs of propellers tested in open water. Their counterparts in bronze were not found.

The smaller of Japan's two cavitation tunnels was similar in test section to the one at MEGURO. It had a throat section 500mm across while the standard model size was 240mm. The actual tunnel design was the work of Mr. H. SHIBA, who held the position of test engineer for the ship testing laboratory of the Communications Ministry. The water was circulated by a 40 kw motor-driven pump, with a maximum speed of eight meters per second. A large strobo-light unit had been obtained for this tunnel, but had not been installed. No photographs of cavitating propellers had been taken here either.

The propeller drive shaft and devices for measuring thrust and torque were extremely crude, and Mr. SHIBA himself complained of the inaccuracy of the test results. The propeller shaft was driven by multiple belts through a torque spring and the measurement of torque was then read off two rotating drums by synchronized flashing light. One drum was rigidly attached to the driven end of the torque spring while the other was attached to the propeller shaft. The actual reading observed thus was the angular displacement of the torque spring. In an effort to avoid any friction effect in the torque reading the drive shaft was enclosed as it entered the tunnel wall in a sleeve which was independently rotated at the same speed as the shaft. As originally designed, this sleeve was driven by a separate motor, but due to the difficulty experienced in maintaining the same speed as the propeller shaft, this method was abandoned and a belt drive as shown in Figure 31 was installed from the shaft drive motor. The thrust was measured by a conventional thrust collar and bearing.

The only model propellers in evidence were made of dural, had four blades, and were of quite conventional merchant ship design. Mr. SHIBA stated that no testing was done here for the Navy, but is difficult to justify the existence of this cavitation tunnel on the basis of merchant ship testing alone. Figure 32 indicates the general arrangement of this tunnel and Figure 33 is a close-up of the propeller shaft drive and the thrust and torque measuring apparatus.

A book obtained from the laboratory which contains a complete description of the tunnel in addition to their model basins has been forwarded to the Taylor Model Basin under NavTechJap Document Number ND50-1295.

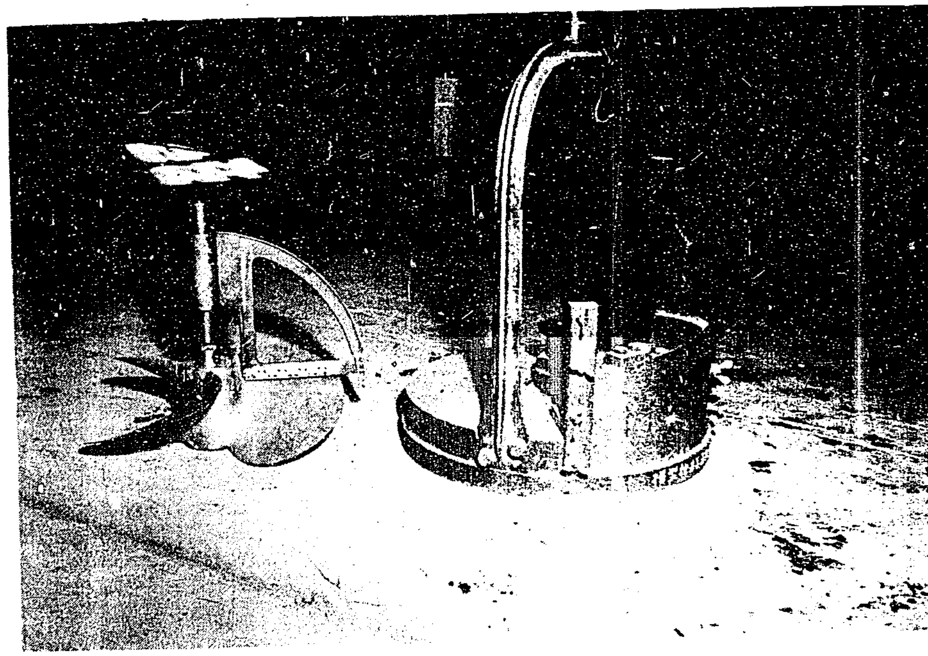


Figure 27
MODEL PROPELLER BLADE CHECKING DEVICE AT MEGURO, TOKYO

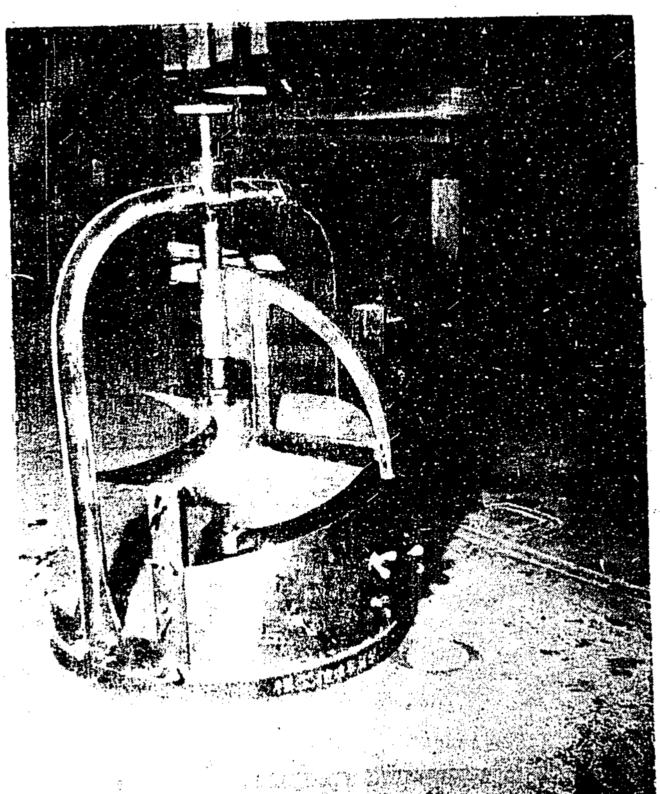
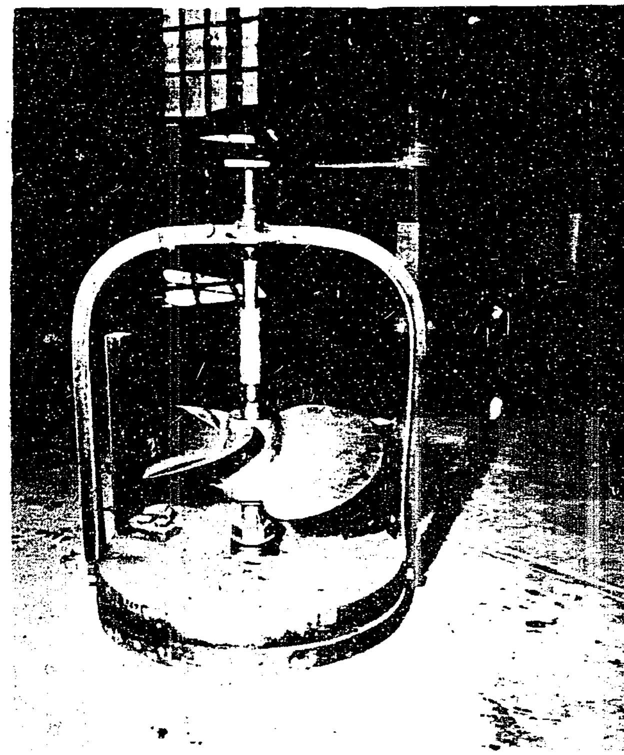


Figure 28
MODEL PROPELLER BLADE CHECKING DEVICE AT MEGURO, TOKYO

Figure 29
MODEL PROPELLER BLADE CHECKING DEVICE AT MEGURO, TOKYO



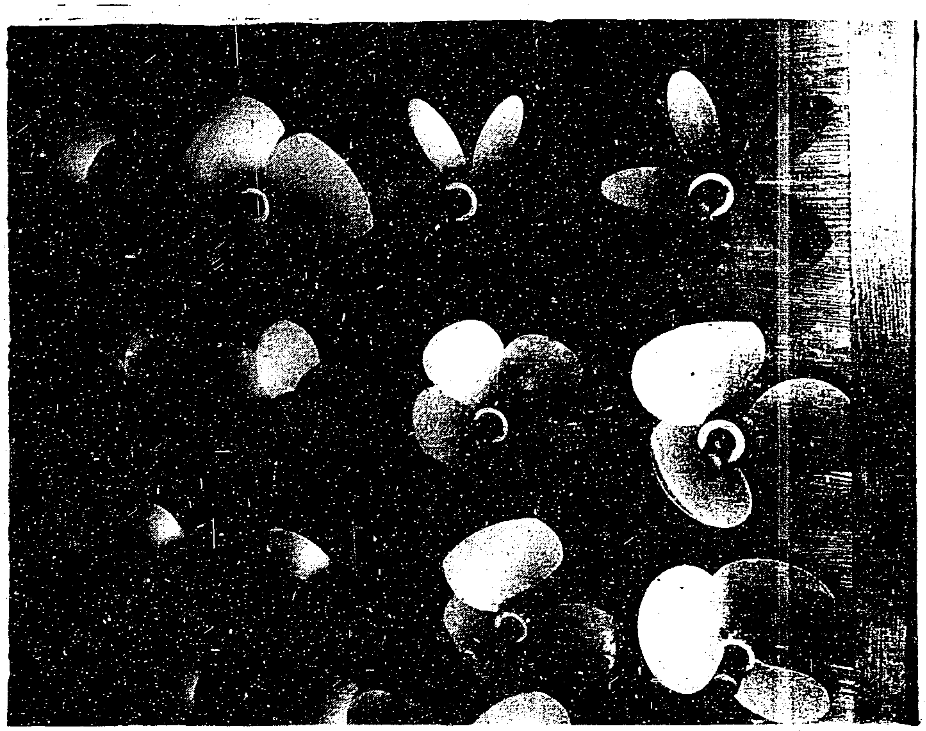


Figure 30
MODEL PROPELLERS AT MEGURO, TOKYO

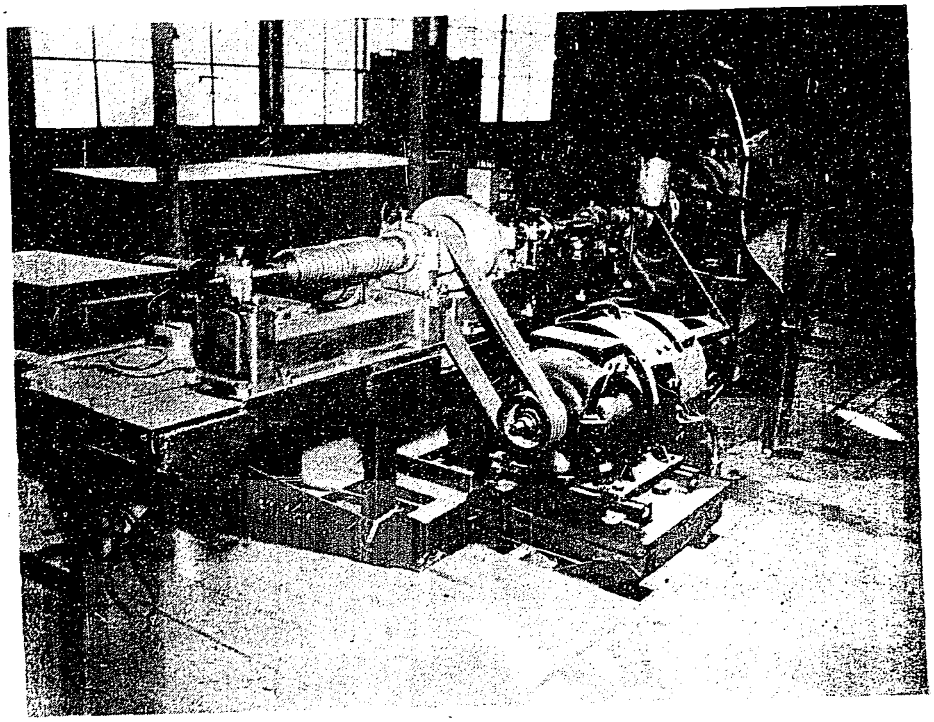


Figure 31
TORQUE DYNAMOMETER ON CAVITATION TUNNEL AT MEJIRO, TOKYO

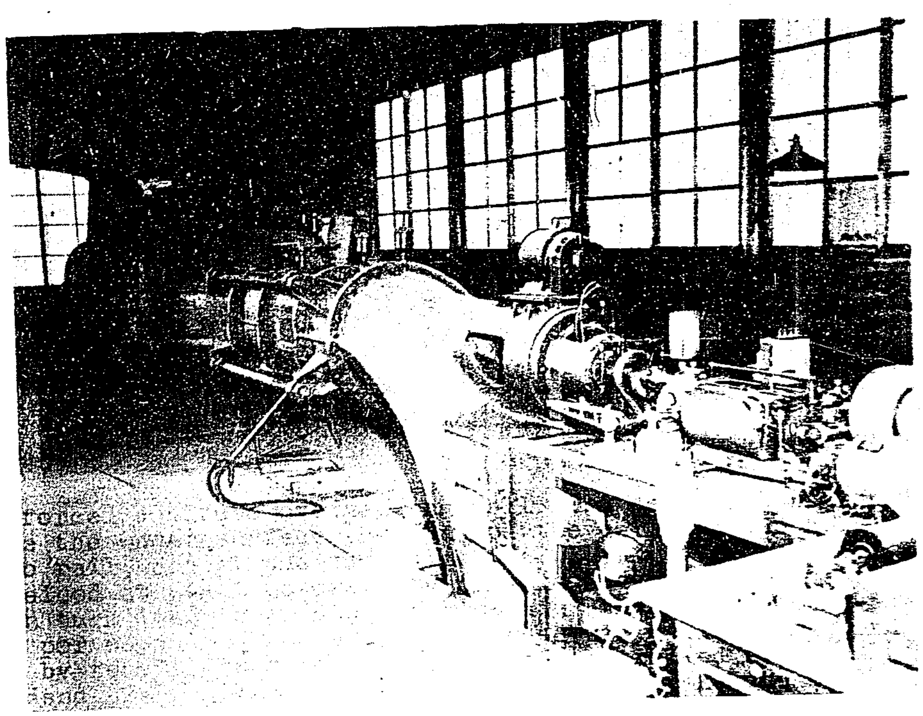


Figure 32
CAVITATION TUNNEL AT MEJIRO, TOKYO

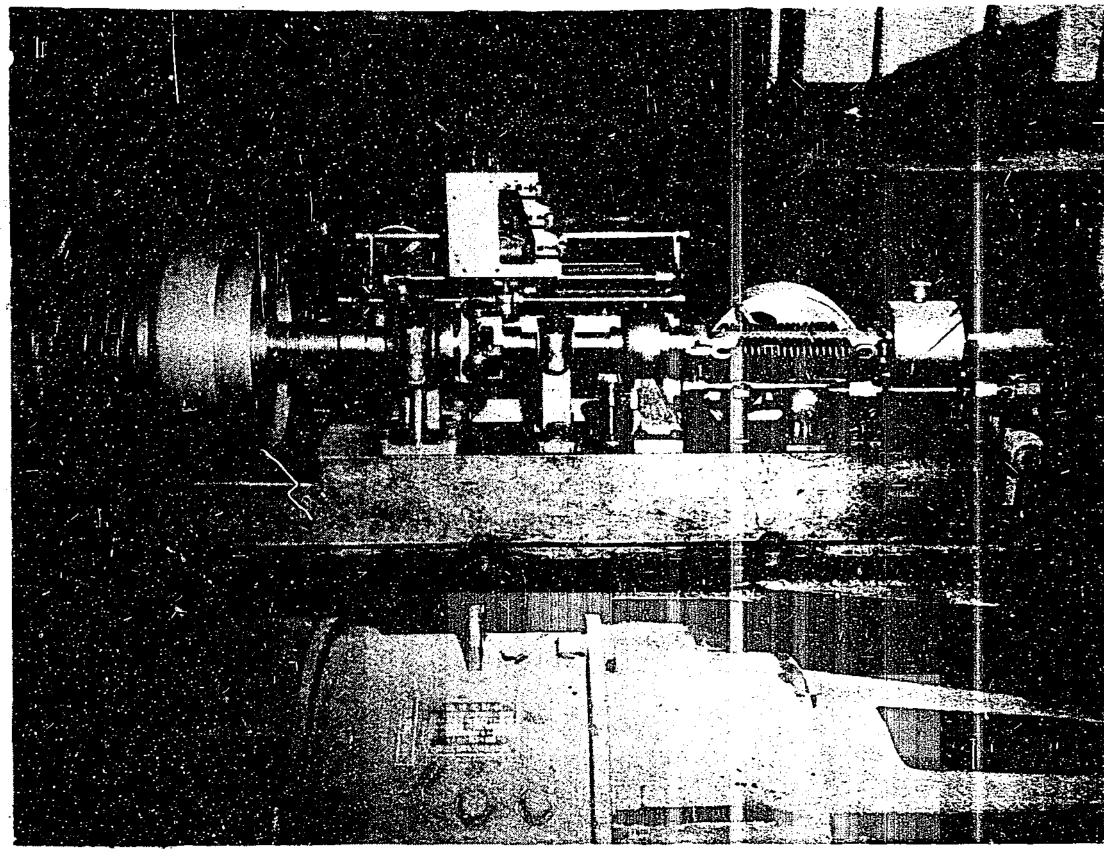


Figure 33
PROPELLER SHAFT DRIVE ON CAVITATION TUNNEL

Part V - TEST PROCEDURES

Resistance, self-propulsion, and open water propeller tests were conducted at all three basins discussed. The dynamometers used for resistance tests are as illustrated in Figures 34 and 35. The drum was driven by an electric motor with time and distance being electrically recorded along with the variation in resistance of the model. Fronde's frictional formula was used in in working up EHP curves, which were made for both bare hull, and with appendages attached. Fronde's method of determining the wake and thrust deduction factors by towing the model with the propellers operating behind it but independent of it was employed.

Self-propulsion tests were made with dynamometers of the type illustrated in Figures 36, 37, and 38. These were all inscribed: "GEBERS M28" over "OTTO A. GANSER, WIEN".

Automatic recordings of thrust and torque were made.

Revolutions were obtained from a counter attached to the main motor. Time and distance were recorded electrically. Temperature corrections were applied. Superstructure models were not made and towed upside down. The air resistance was calsulated by an empirical formula.

A streamlined strut arrangement as illustrated in Figure 21 was used for

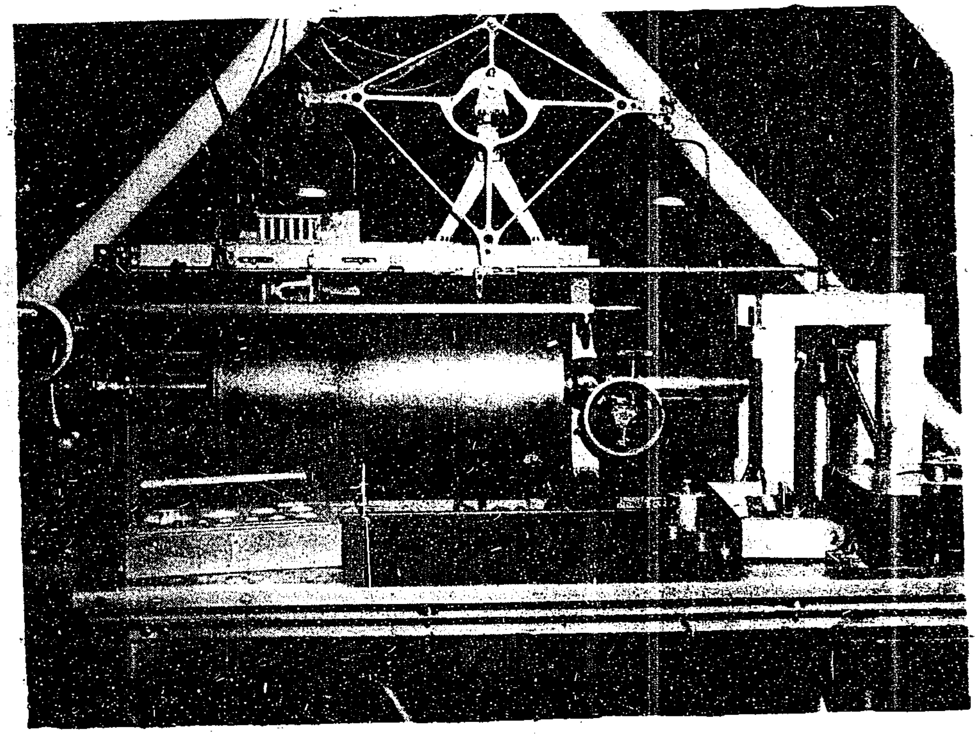


Figure 34
RESISTANCE DYNAMOMETER AT MEJIRO, TOKYO

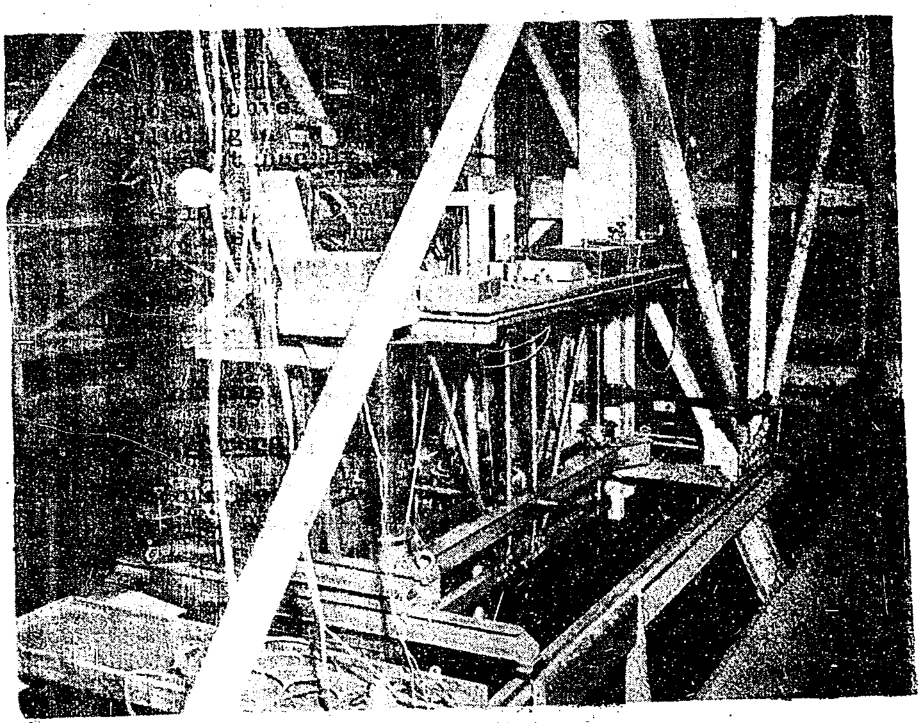


Figure 35
RESISTANCE DYNAMOMETER AT MEJIRO, TOKYO

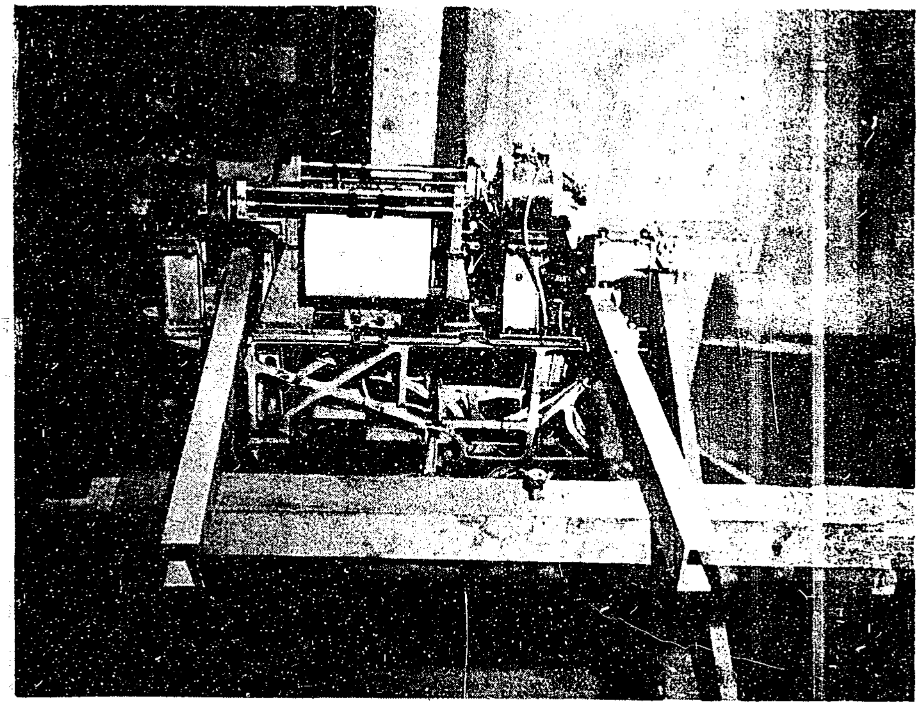


Figure 36

SELF PROPULSION DYNAMOMETER USED IN JAPAN

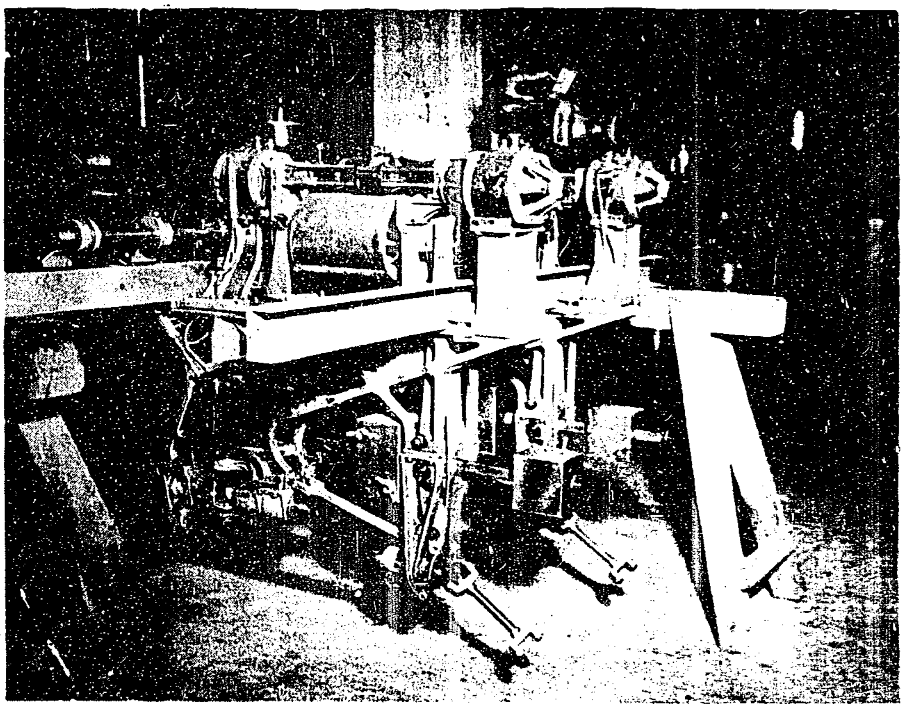


Figure 37

SELF PROPULSION DYNAMOMETER USED IN JAPAN conducting open water propeller tests. The propeller extends ahead of the centerline of the large strut approximately 4'4". "System Gebers 1930" over "Otto A. Ganser, Wien" was inscribed on the dynamometer. Revolutions were read from a counter attached to the propeller drive motor. Time and distance were electrically recorded. The dynamometer was secured to the carriage by an arrangement which makes possible a plus or minus five degree inclination of the propeller shaft to simulate actual working conditions.

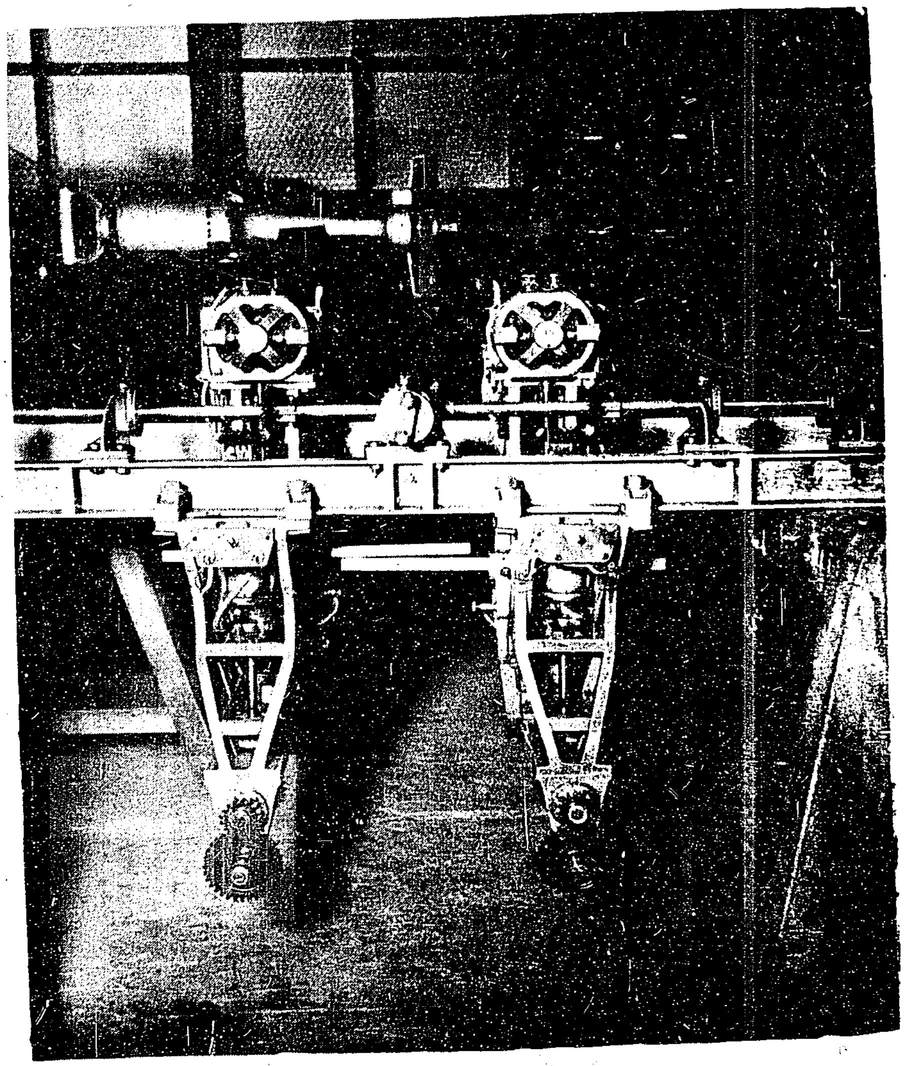


Figure 38

SELF PROPULSION DYNAMOMETER USED IN JAPAN

There has been forwarded to the Taylor Model Basin a complete design and test porfolio of a 120 meter merchant ship obtained from the Ship Testing Laboratory at MEJIRO. This report contains the ship's lines, body plan, propeller design and testing data, as well as the calculation sheets. The methods of conducting tests on model hulls and propellers were the same at all three model testing laboratories; hence this portfolio, which is identified as NavTechJap Document Number ND50-1296, gives a complete record of model testing as practiced in Japan.

ENCLOSURE (A)

LIST OF DOCUMENTS FORWARDED TO DAVID TAYLOR MODEL BASIN

NavTechJap No.	Title	ATIS No.
ND50-1290.1 to .12	Reports on rudder and turning model test performed at MEGURO Model Basin.	3558
ND50-1291	Personal work book to Technical Research Adminstrator IZUBUCHI, former Director of MEGURO Model Basin.	3586
ND50-1292	Research on resistance of high-speed boats.	3575
ND50-1293	Research on resistance of round-bilge type 3589 high-speed boats.	3589
ND50-1294.1 to .2	On the form of bottom of the "sea bus." Model experiment on the dynamic of forces acting on the ship's bottom in a rough sea.	3590
ND50-1295	Report of findings of ship-testing laboratory.	3588
ND50-1296.1 to .2	Calculation sheets for ship Model 300. Test results and plans.	3587
ND50-1298.1 to .8	Trial data, offsets, ship's data book: SHIGURE (DD).	3560
ND50-1299.1 to .9	Stress and vibrations in SUZUYA (CA).	3562
ND50-1300.1 to .9	Turning circle trial data: SUZUYA (CA), NOSHIRO (CL), MUTSU (BB), OYODO (CL), UNRYU (CV), TAKAO (CA), HA 201 (SS), RO 100 (SS), TAKE (DD).	3561
ND50-1301.1 to .4	Propeller drawings: SHINANO (CV), ZUIKAKU (CV), UNRYU (CV), MATSU (DD).	3559