Seizo Motora

TANK TEST FACILITIES AND KINDS OF EXPERIMENTS CONCERNING MANOEUVRABILITY OF SHIPS NOW IN PRACTICF IN JAPAN

TRANSPORTATION TECHNICAL RESEARCH INSTITUTE

1. *Name and address of organization ;*
   Transportation Technical Research Institute.
   700 Shinkawa, Mitaka, Tokyo, Japan.
2. *Towing basin and other facilities ;*
   2.1. Towing Basin
   dimension : 29 m × 8 m × 3.3 m (ref. Fig. 1)
   (Length × Width × Water depth).
   carriage speed : 2.5 m/sec.
   2.2. Rotating Arm Basin
   dimension : 6 m × 1.2 m (ref. Fig. 1)
   (Radius × Water depth).
   2.3. Manoeuvring Basin
   dimension : 80 m × 80 m × 4.5 m (ref. Fig. 1)
   (Length × Width × Water depth).
3. *Models* :
   length of models for towing basin : 2.5 m;
   length of models for rotating arm basin : 1.5 m;
   length of models for manoeuvring basin : 5 m.
4. *Kinds of experiments* :
   4.1. Experiments on Manoeuvrability using Free Self-propelled Models.
   4.2. Experiments on Rudder Performance.
   4.3. Experiments on Derivatives of Ships.
   4.4. Experiments on Ship Motion in Waves.
5. *Instrumentation* :

measuring quantity	apparatus
heading angle	free gyro
angular velocity of turning	rate gyro
rudder angle	electric potentiometer
revolution of propeller	electric counter
running path	transit type tracer
rudder force	wire strain gauge type dynamometer

6. *Procedure of analyses and representation of test results.*
   6.1. Turning abilities and course keeping qualities of the models of different ships with different rudders and appendages are determined from the experimental results of free self-propelled models.
   6.2. Rudder characteristics are obtained from the experimental results of the rudders and the rudders working behind propellers. The results are sometimes represented as the design chart for practical use.
   6.3. Derivatives of ship motions are determined from the experiments at the rotating arm basin. From the results it is possible to analyse the steered motion of ships theoretically.
   6.4. Ship motion in regular and irregular waves are investigated from the stand point of not only oscillation but also course stability. Manoeuvrability of ships affected by strong wind are also investigated experimentally and analytically.

7. *Kinds of full-size manoeuver test and the procedure of analyses.*
   7.1. Experiments on Rudder Forces of Ships.
   The characteristics of the rudder performance are investigated from the record of the twisting moment of rudder at ship trial.
   7.2. Experiments on Manoeuvrability of Ships.
   Manoeuvrabilities of different ships are determined from the record of the turning path, the change of heading angle, the reduction of advance speed, the revolution of the propeller, etc. Comparing the results of actual ships with those of models, correlation of motion of steering between ships and models are investigated.

MEGURO MODEL BASIN

1. *Name and address of organization :*
First Research and Development Center.
Research and Development Institute.

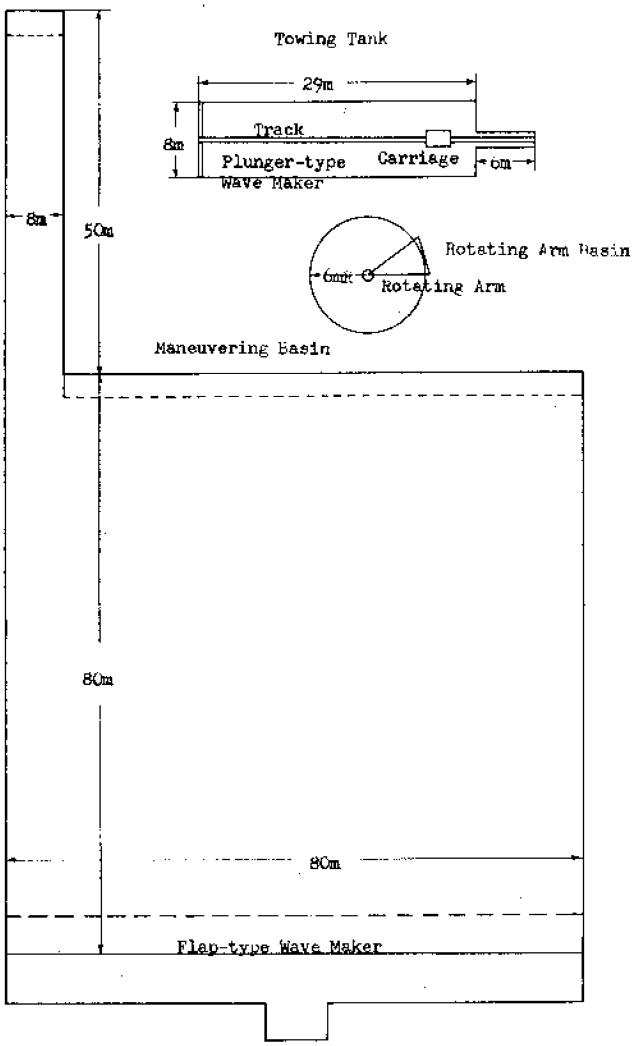


FIG. 1.
Transportation Technical Research Institute Towing Basin.

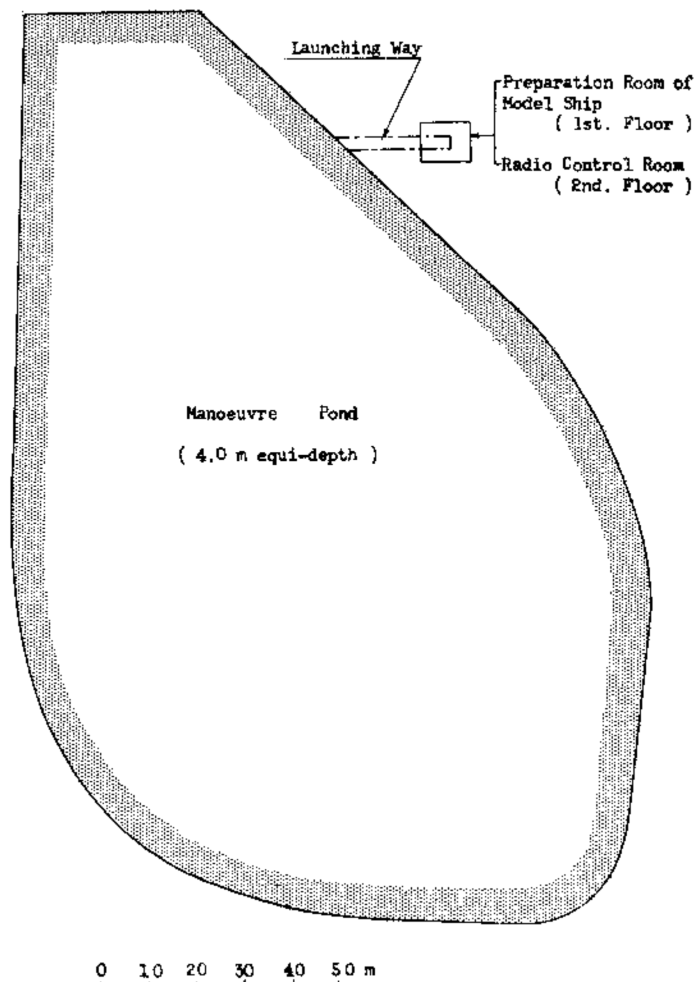


FIG. 2.
Meguro Model Basin Manoeuvre Pond.

THE LIST OF

NAME OF ORGANIZATION	TOWING BASIN & OTHER FACILITIES	MODELS (m)
Transportation Technical Research Institute	Towing Basin 29×8×3.3 m Rotating Arm Basin 6×1.2 m Manoeuvrability Basin 80×80×4.5 m	2.5 1.5 5.0
Meguro Model Basin First Research and Development Center Research and Development Institute Japan Defence Agency	Towing Basin Large Basin 255.0×12.5×7.0 m Small Basin 102.5×3.5×2.2 m High Speed Basin 364.5×6.0×3.0 m, Manoeuvre Pond 21,500 m^2	 5.0 — 8.0 1.0 — 2.0 2.0 — 4.0 6.0 & 8.0
Technical Research Laboratory Hitachi Shipbuilding and Engineering Co., Ltd.	Circulating Channel	1.5
Mitsubishi Nagasaki Experimental Laboratory, Mitsubishi Shipbuilding & Engineering Co., Ltd.	Towing Basin Large Basin 165×12.5×6.5 m Small Basin 120×6.1×3.65 m	5.0 — 7.0
University of Tokyo, Faculty of Engineering, Department of Naval Architecture	Towing Basin 86×3.5×2.6 m Turning Basin 15×15 m	2.0 — 3.0 1.7
University of Mercantile Marine of Tokyo	29 m Training-ship	—
Ship Research Laboratory, Mechanical Engineering Dept., Defense Academy	Circulating Tank 1.2×1.2×6 m	1.2
Osaka University, Faculty of Engineering, Department of Naval Architecture	Towing Basin 52×1.8×1.0 m Manoeuvre Pond	1.5 — 3.0 4.0 — 6.0
Kyushu University, Faculty of Engineering, Department of Naval Architecture	Towing Basin 80×2.5×5.3 m Turning Basin 30×5×5 m	1.0 — 2.0

TANK FACILITIES IN JAPAN.

KINDS OF EXPERIMENTS	REPRESENTATION OF TEST RESULTS	KINDS OF FULL SIZE MANOEUVRE TEST
Manoeuvrability Rudder performance Derivatives of ships Ship motion in waves	Turning abilities, Course keeping qualities Rudder Characteristics The steered motion of ships Ship motion in regular and irregular waves	Rudder forces of ships Manoeuvrability of ships
Circular turning test Sinusoidal steering test Kempf's standard manoeuvre test	First-order steering quality indices K_S & T_S Systematic formulation of steering quality indices First-order steering quality indices K & T	Kempf's standard manoeuvre tests Circular turning trials
Rudder performance Manoeuvre test	The practical formulae for the normal force and the centre of pressure of rudder in the single-screw vessel	The standard zig-zag manoeuvre tests The measurements of rudder torque
Rudder performance Manœuvre test		
Three components tests & yawing tests Kempf's standard tests Turning tests	Resistance derivatives and virtual moment of inertia around vertical axis The manoeuvrability indices K & T The manoeuvrability indices K & T	Turning tests
Standard manoeuvre test Turning tests Manoeuvring (propeller in an astern direction)		
Free yawing test Forced yawing test Frequency response test	The same forme as Tokyo University Tank's	
Manoeuvre test Rudder performance	Steering quality indices K, T_1. T_2 & T_3. First-order steering quality indices Resistance derivatives A systematic formulation of steering quality indices. Rudder normal force and rudder torque	Kempf's standard manoeuvre tests Sinusoidal and impulsive steering tests Conventional turning trials and hard-over to hard-hover steering tests and measurements of rudder torque
Oblique sailing test Turning test	The moment and force concerning with ship form The relation between turning and course stability properties	

Japan Defense Agency.
Address: No. 13 Mita, Meguro-ku, Tokyo, Japan.
Chief: Mitsuo Kanno.
Researcher: Seiji Takezawa.

2. *Towing basin and other facilities :*

2.1. Towing Basin

Large Basin
dimension: 255.0 × 12.5 × 7.0 m;
carriage speed: 0.5 — 10.0 m/sec;
Instrumentation: a set of usual instrumentation for towing and self-propulsion tests;
a set of wave-maker.

Small Basin
dimension: 102.5 × 3.5 ×o 2.2 m;
carriage speed: 0.3 — 7.0 m/sec;
instrumentation: a set of usual instrumentation for towing and self-propulsion tests;
a set of wave-maker.

High Speed Basin
dimension: 364.5 × 6.0 × 3.0 m;
carriage speed: 1.0 — 20.0 m/sec;
instrumentation: a set of resistance dynamometer for high speed tests;
a set of accelerator for carriage.

2.2. Manœuvre Pond (Fig. 2)

area	about	21,500 m²
max. length	about	215 m
max. width	about	130 m
depth	about	4.0 m

3. *Models :*

for towing basin
large basin: 5.0 — 8.0 m
small basin: 1.0 — 2.0 m
high speed basin: 2.0 — 4.0 m
for manoeuvre pond :
6.0 m (merchant ships);
8.0 m (destroyer, patrol-coaster, etc.).

4. *Kinds of experiments :*

Manœuvre test employing free-running, self-propelled models with radio-control.

1. Circular turning test.
2. Sinusoidal steering test.
3. Kempf's standard manœuvre test.

5. *Instrumentation :*

5.1. Measuring Item and Method.
See table on the following page.

5.2. Radio Control Equipment of Model Ships (Fig. 3).

This equipment is especially designed for manoeuvre tests of high speed ships as destroyers. Then that is usually used for the experiments of twin-screw and twin-rudder ships.

a) Radio Wave

transmission system		PWM-FM-FM
carrier wave frequency	about	320 MC
carrier wave output	about	10 W

b) Radio Instructions

Ist. channel (Ist. propeller)
2nd. channel (2nd. propeller)

± 150 - ± 3,000 r. p. m. and Stop

3rd. channel (1st. rudder)
4th. channel (2nd. rudder)

+ 60° - 0° - — 60°

Instructions of 1st. - 4th. channels are continuously variable. Both 1st., 2nd. channels and 3rd., 4th. channels are possible to operate on linkage and separateness.

5th. channel (Motor-driving camera)
on-off control

c) Propulsion System.

See scheme page 629.

* Engine — Generator
gasoline-engine: 4 cylinders, 21H.P. at 4,000 r. p. m.
D. C. generators
for the use of driving motors (X 2): 4.5 KW, 200 V, 4,000 r. p. m.
for the use of exciter (X 1): 1.0 KW, 100 V, 4,000 r. p. m. for the use of battery charger (X 1): 0.1 KW, 12 V, 4,000 r. p. m.

* Propeller driving motors (X 2)
4 H.P., D. C. 200 V, 300 - 6,000 r. p. m. (Ward Leonard control system).

Meguro Model Basin — Instrumentation.
Measuring Item and Method.

	ITEM	METHOD	RECORD
(1)	Propeller Revolution (X 2)	D. C. Generator	Motor Drived 35 mm Camera (inboard)
(2)	Helm Angle (X 2)	400 ~ Synchro	
(3)	Model Speed	Propeller and Pulse Generator	
(4)	Running Path	Tracking Transits	Pen-oscillograph

(1) — (4) are completed in 1960.

(1)*	Propeller Revolution (X 2)	D. C. Generator or Electric Contact	Pen-oscillograph in Radio Control Room by Wireless Tele-metering
(2)*	Helm Angle (X 3)	400 ~ Synchro	
(3)*	Model Speed	Propeller and Pulse Generator	
(4)*	Course Angle	Gyroscope and Synchro	
(5)*	Heel Angle	Gyroscope and Synchro	
(6)*	Propeller Torque and Thrust (X 2)	Strain Gauge or Differential-Trans	
(7)*	Rudder Forces	Strain Gauge or Differential-Trans	
(8)*	Running Path	Tracking Transit	X-Y Recorder

(1)* — (8)* will be completed in 1961.

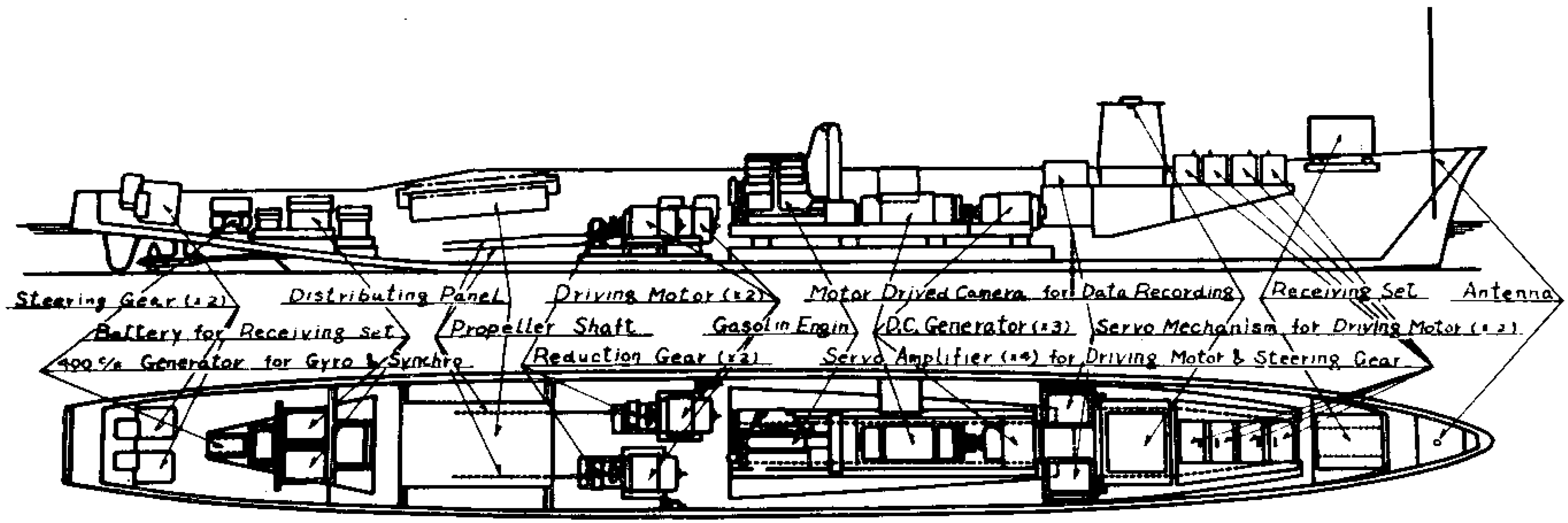
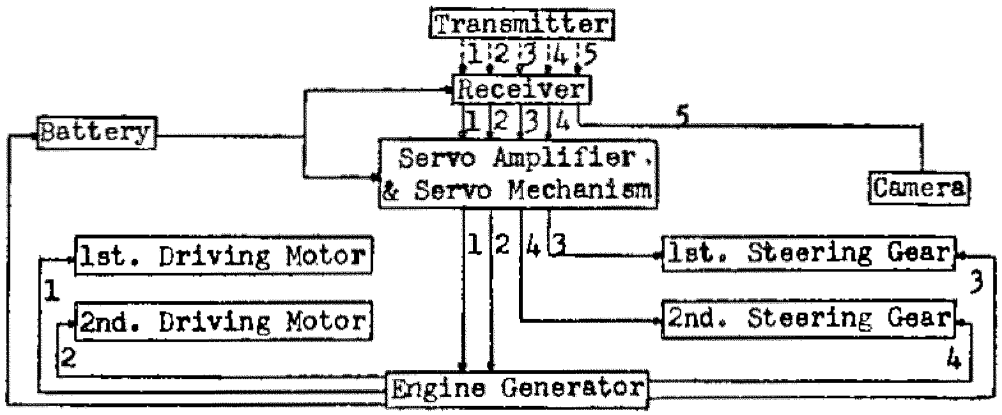


Fig. 3.
General Arrangement of the Radio-controlled Model Ship.

c) Propulsion System.



6. *Procedure of analyses and representation of test results :*
   6.1. To determine first-order steering quality indices K and T using Kempf's standard manœuvre tests [4].
   6.2. To determine first-order steering quality indices K_s and T_s using circular turning tests [5].
   6.3. To construct systematic formulation of steering quality indices as function of relative rudder sizes, slenderness factors, and some other factors.

7. *Kinds of full-size manoeuvre tests and the procedure of analyses :*
   7.1. Kempf's standard manoeuvre tests carried out using helm angle of 10, 15 and 20 degrees.
   The procedure of analysis is similar to one for a free-model test [4].
   7.2. Circular turning trials carried out using rudder angle of 10-40 degrees.
   The procedure of analysis is similar to one for a free-model test [5].
   Note: Full-size tests are executed in cooperation of Maritime Self Defense Force.

TECHNICAL RESEARCH LABORATORY

1. *Name and address of organization :*
   Technical Research Laboratory,
   Hitachi Shipb. and Eng. Co., Ltd., Osaka, Japan.
   Director: Masao Kinoshita.
   Researcher in charge: Shojiro Okada.

2. *Towing basin and other facilities :*
   2.1. Towing Basin.
   non
   2.2. Circulating Channel.
   Dimension and arrangement are given (Fig. 4)

3. *Model :*
About 1.5 m model for the circulating channel.

4. *Kinds of experiments :*
   4.1. Model experiments with reference to the rudder performance (at the circulating channel).
   Open test for a rudder.
   Behind test for a rudder with a propeller.
   Behind test for a rudder with ship and ship's propeller.
   4.2. Manoeuvre test employing the free-running, self-propelled models.
   This test will be carried, in future.

5. *Instrumentation :*
   Quantities to be measured are :
   Revolution of propeller,
   Rudder forces and moment
   Helm angle.

Synopses of detection of each quantity are as follows:

Revolution of propeller is detected by an usual electric contact with a reduction gear.

Rudder forces and moment : A rudder is supported by a rudder stock isolated mechanically from a gudgeon and shoe piece. A thin circular pipe of

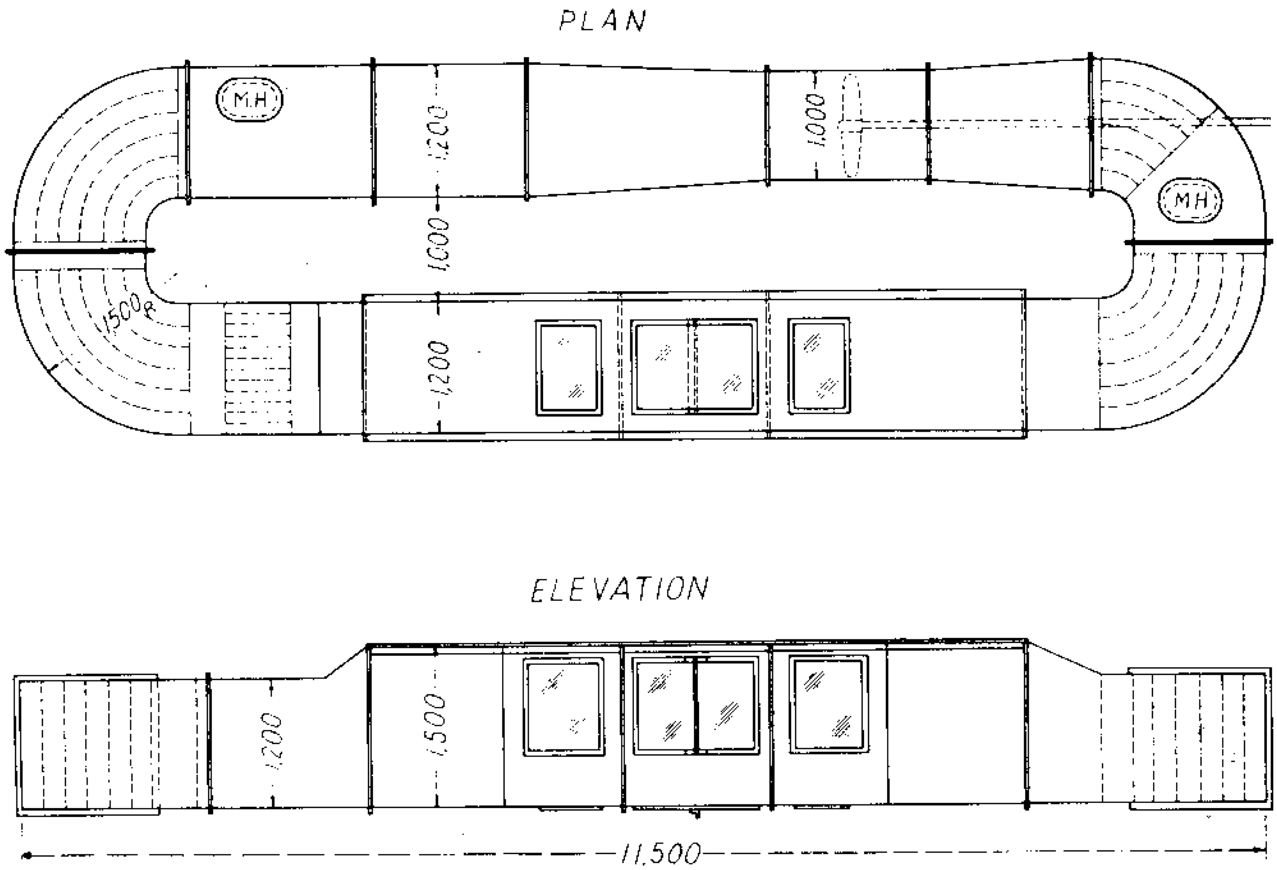


FIG. 4.
Circulating Channel at Meguro Basin.

steel constitutes an intermediate part of the rudder stock and a number of wire strain gauge are pasted on it so as to detect the normal force, the tangential force and moment acting upon the rudder and rudder stock.

Helm angle is detected by a variable electric resistance.

6. *Procedure of analyses and representation of test results :*

As the results of model experiments of the rudder placed behind the ship and ship's propeller, the practical formulae for the normal force and the centre of pressure of rudder in the single-screw vessel are given, as follows: [6], [10].

FORMULAE

$$N = \tfrac{1}{2}\rho V_S{}^{A} \left\{ 2.41 \left(1{,}3 - \frac{1}{2\lambda}\right)(1 - w_a)^2 (1 + k.s^{1.5}) \right\} \sin \alpha'.$$

where:

$$k = \begin{cases} 5.8\,(0.6 + \text{D.A.R.}) & \text{for the starboard rudder angle.} \\ 6.7\,(0.6 + \text{D.A.R.}) & \text{for the port rudder angle.} \end{cases}$$

$$\alpha' = \begin{cases} \alpha_R + (0.6 + 2s) - F(\varphi_R)\ (\text{deg.}) & \text{for the starboard.} \\ \alpha_R - (0.6 + 2s) - F(\varphi_R)\ (\text{deg.}) & \text{for the port.} \end{cases}$$

N: Normal force of rudder (kg).

ρ : Specific gravity of sea water ($kg.s^2/m^4$).

V_S: Ship's speed (m/s).

A: Area of rudder (m^2).

λ: Aspect ratio of rudder.

w_a: Mean effective wake fraction of propeller.

s: Actual slip ratio of the propeller placed behind the vessel.

D.A.R.: Developed area ratio of the propeller.

α_R: Rudder angle.

$F(\varphi_R)$: Modification term due to drift angle for the rudder angle.

The range of $\left\{\begin{array}{l} 1.00 \leqq \lambda \leqq 2.50 \\ 0.2 \leqq S \leqq 0.6 \\ 15^\circ \leqq \alpha \leqq 35^\circ \end{array}\right\}$ is the object.

$$\frac{l}{c} = 0.195 + 0.35 \sin\alpha - 0.07s \pm 0.058\, w_s + \tfrac{1}{2}\frac{\Omega}{\sin\alpha}.$$

where:

$\alpha = \alpha_R = F(\varphi_R)$.

$\Omega = C_j/V_s$.

c: Chord length of the rudder (m).

l: Distance from the leading edge to the centre of pressure of the rudder (m).

j: Angular velocity of steering (rad/s).

$\pm$: corresponding to the $\left\{\begin{array}{l}\text{starboard}\\ \text{port}\end{array}\right\}$ rudder angle.

In this formulae, the modification term for rudder angle due to the drift angle is not clarified at present.

So that, the studies along this item must be carried out, in future.

7. *Kinds of full-size tests and the procedure of analyses:*
   7.1. The standard zig-zag manoeuvre tests are carried out using the helm angle of usually ten degrees.
   7.2. The measurements of rudder torque as a function of time are carried out by using the torquemeter and strain gauges.

Mitsubishi Nagasaki Experimental Tank Laboratory

1. *Name and address of organization:*

Mitsubishi Nagasaki Experimental Tank.
Laboratory, Mitsubishi Shipbuilding & Engineering Co., Ltd.
Address: 712 Showa-Machi, Nagasaki, Japan.
Chief: Kaname Taniguchi.

2. *Towing basin and other facilities:*
   2.1. Towing Basin
   Dimension
   large tank: 165^m $(285)^m \times 12.5^m \times 6.5^m$
   small tank: $120^m \times 6.1^m \times 3.65^m$
   Maximum carriage speed
   large tank: 9.0 m/s
   small tank: 4.5 m/s
   (The towing carriage for the large tank can run 285^m through both tanks.)

3. *Models;*

Length of ship models 5m to 7m.

4. *Kinds of experiments:*
   4.1. Towing experiment with reference to rudder performance (at towing basin).
   Open test for rudders.
   Behind test with a straigth running ship model.
   4.2. Manoeuvre test with free-running, self-propelled ship models (at towing basin, in near future).
   Serpentine-test.

5. *Instrumentation:*

Quantities to be measured:
ship's heading angle;
helm angle;
number of revolution of propeller;
rudder forces.

University of Tokyo

1. *Name and address of organization:*

University of Tokyo.
Faculty of Engineering.
Department of Naval Architecture.
Motofuji-cho, Bunkyo-ku, Tokyo, Japan.
(Researcher in charge: Seizo Motora.)

2. *Towing basin and other facilities:*
   2.1. Towing Basin (Fig. 5).
   dimension: 86 × 3.5 × 2.6 m;
   carriage speed: 0.3 - 4.0 m/s.
   2.2. Turning Basin (Fig. 6).

3. *Models;*
   3.1. For the Towing Basin 2.0 - 3.0 m.
   3.2. For the Turning Basin 1.7 m.

4. *Kinds of experiments:*
   4.1. Three components tests and yawing tests:
   To get resistance derivatives.
   4.2. Kempf's standard tests: (in small rudder angles). To get manoeuvrability indices.
   4.3. Turning tests:
   To get manoeuvrability indices.

5. *Instrumentation:*
   5.1. Three components tests and yawing tests:
   Resistance, side force, yawing moment are measured by : magnetostriction dynamometers while running with steady yaw angles and in yawing models being towed.
   5.2. Kempf's standard tests:
   Ship's heading angle is measured by a free gyro.
   5.3. Turning tests:
   Ship's heading angle, advance, transfer, tactical

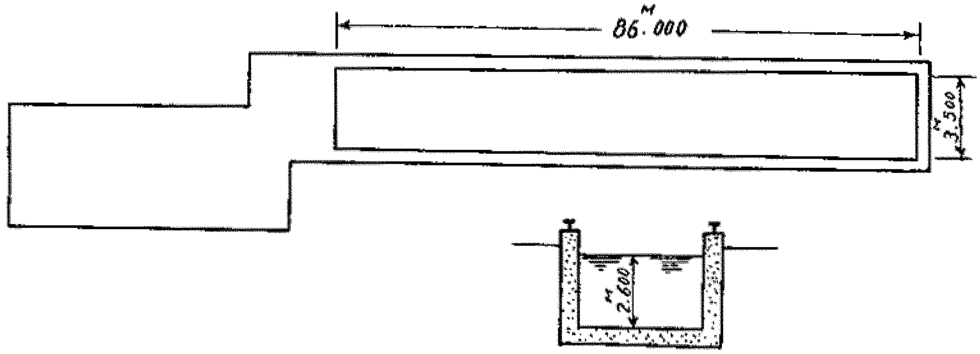


Fig. 5.
Towing Basin.

diameter, and radius of turning are measured by photographic method.

Models are controlled by a radio controller.

6. *Procedure of analyses and representation of test results;*

6.1. Three components tests and yawing tests: Resistance derivatives and virtual moment of inertia around vertical axis are obtained from measured values of resistance, side force, yawing moment, period of yawing, and the phase difference between yawing moment and yawing motion.

6.2. Kempf's standard tests:
The manoeuvrability indices K and T are obtained by Nomoto's method [14].

6.3. Turning tests:
The manoeuvrability indices K and T are obtained from the recorded locus of ships C.G.
The method of analysis is outlined in Ref. [11].

7. *Kinds of full size manoeuvre tests:*
Turning tests as usually done.
Items measured and the way of analysis are the same as model tests.

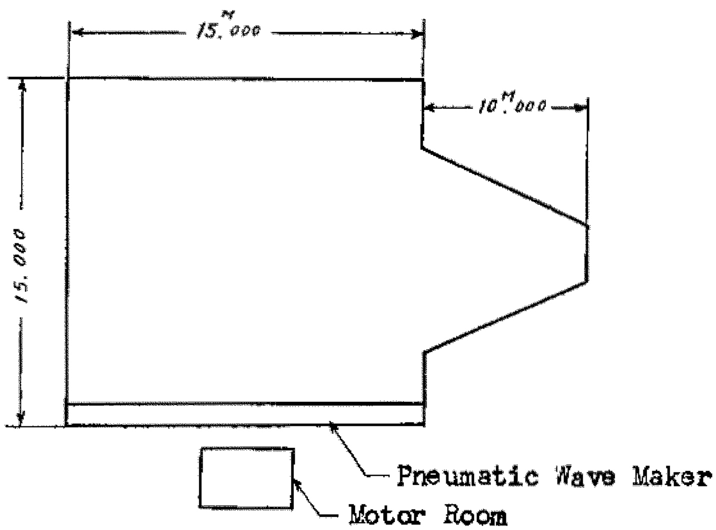


Fig. 6.
Turning Basin.

UNIVERSITY OF MERCANTILE MARINE OF TOKYO

1. *Name and address of organization:*
University of Mercantile Marine of Tokyo.
Fukagawa-Ecchujima, Koto-ku.
Tokyo, Japan.
2. *Facilities:*
29 m. Training-ship,

Length	29.000 m.
Breadth	6.200 m.
Depth	3.450 m.
C_b	0.530
C_w	0.754
Draft	2.459 m.
Displacement	251.7 t.

Rudder
Balanced and stream-lined.

Area	2.277 m^2.
$A/L \times d$	0.0357
Aspect-ratio	1.2

3. *Kinds of experiments:*
Standard manoeuver test.
Turning test.
Manoeuvering when operating propeller in an astern direction.
These tests are performed both in smooth sea and in wind sea. The comparison of these tests results with a similar model is now in preparation.
4. *Instrumentation:*
An electrically-driven gyroscope is used, by which the rate of change of heading is measured.

SHIP RESEARCH LABORATORY
OF DEFENSE ACADEMY YOKOSUKA

1. *Name and address of organization;*
Ship Research Laboratory, Mech. Eng. Dept.
Defense Academy, Yokosuka, Japan.
Researcher in charge: Masatoshi Bessho.
2. *Towing basin and other facilities:*
Circulating Tank (see Fig. 7).
dimension: 1.2 × 1.2 × 6.0 m in open channel;
velocity: 0 - 1.8 m/s;
dynamometer for rudder and model ship:
Three components with strain gauge.
3. *Models:*
Length 1.2. m or smaller.
4. *Kinds of experiments;*
Free yawing test for course stability measurement, (see Ref. 12).

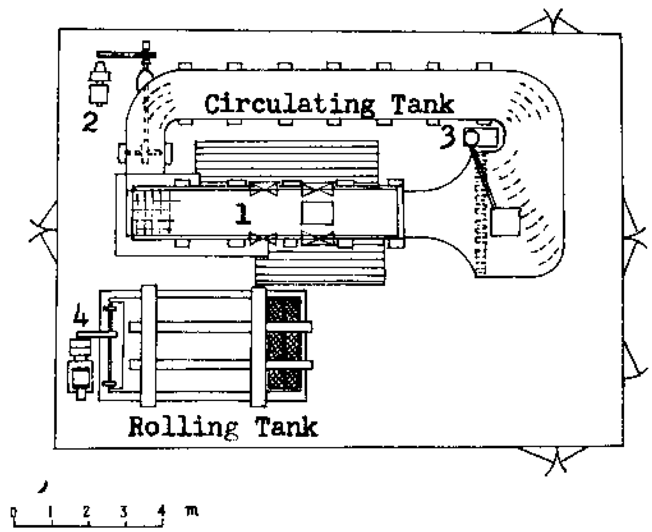


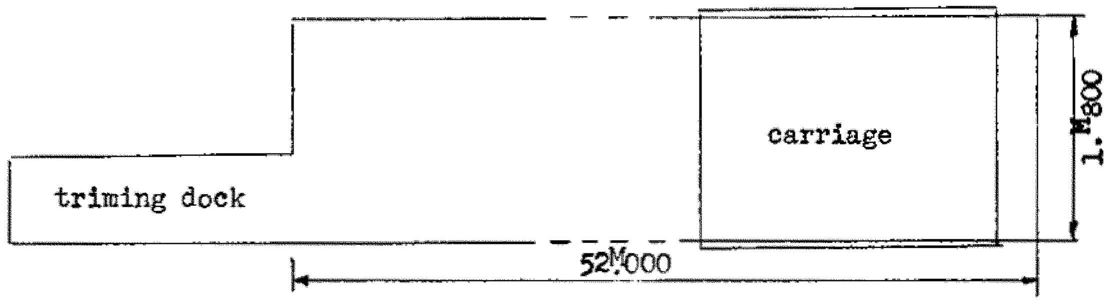
FIG. 7.
1. Open Channel for observation.
2. Motor (40 H.P.).
3. Vacuum pump (2 H.P.).
4. Wave maker (plunger type).

Test plan in near future.
a) Forced yawing test;
b) Frequency response test.

5. *Instrumentation:*
Ab.
6. *Procedure of analyses and representation of test results:*
The same form as Tokyo University Tank's.
7. *Kinds of full-size manoeuvre tests and the procedure of analyses:*
No experience.

OSAKA UNIVERSITY

1. *Name and address of organization:*
Osaka University. Faculty of Engineering.
Department of Naval Architecture.
Osaka, Japan.
(Researcher in charge: Kensaku Nomoto.)
2. *Towing basin and other facilities:*
2.1. Towing Basin.
dimension: 52 × 1.8 × 1.0 m;
carriage speed: 0.1 to 5.0 m/sec;
instrumentation : a set of usual instrumentation for towing and self-propulsion tests.
2.2. Manœuvre Pond.



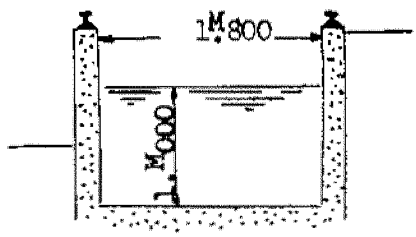


FIG. 8.
Osaka University.
Towing Basin.

3. *Models:*
for towing basin: 1.5 to 3.0 m;
for manoeuvre pond: 4.0 m usually;
6.0 m as required.

4. *Kinds of experiments:*

4.1. Manoeuvre test employing free-running, self-propelled models with radio-control (at manoeuvre pond).
Sinusoidal steering test.
Impulsive steering (transient response) test.
Circular turning test including one with small helm angles Kempf's standard manoeuvre test.
Hard-over to hard-over test with particular reference to rudder forces.
These tests are now underway largely for usual merchant ship types.

4.2. Towing experiments with reference to rudder performance (at towing basin).
Open test for a rudder and one accompanied by a propeller.
Behind test with a straight-running model ship.

5. *Instrumentation:*
Quantities to be measured are:
ship's heading angle as a function of time;
helm angle as a function of time;
revolution of propeller;
running path of a free-model } when necessary.
rudder forces }

These quantities except running path are detected electrically and recorded continuously by a mirror-galvanometer type oscillograph put in a free-model or on the towing carriage.
Synopses of detection of each quantity are as follows:

Heading angle (course angle): An electrically-driven free-gyroscope is used. Angle of rotation of the gyro gimbal which indicates immediately a change of heading angle is detected by a photo-electronic means (employing a saw-teeth disk and a photo-transistor) [13].
The accuracy rises to 0.03 to 0.05 degrees for measurements during a short period (less than 20 sec., for example, sinusoidal steering) and for relatively long duration (1 to 5 minutes) it is reduced to 0.2 to 0.5 degrees by reason of a stray drift of the free-gyro.

Helm angle is detected and recorded by a similar means as ones for heading angle. A saw-teeth disk attached to a tiller of a steering gear and a photo transistor are used.

Propeller revolution is detected by an usual electric contact with a reduction gear.

Rudder forces: A rudder is supported by a rudder-stock (rudder shaft) isolated mechanically from a gudgeon and shoe piece. A thin circular pipe of steel constitutes an intermediate part of the rudder-stock and a number of wire-strain-gauges are pasted

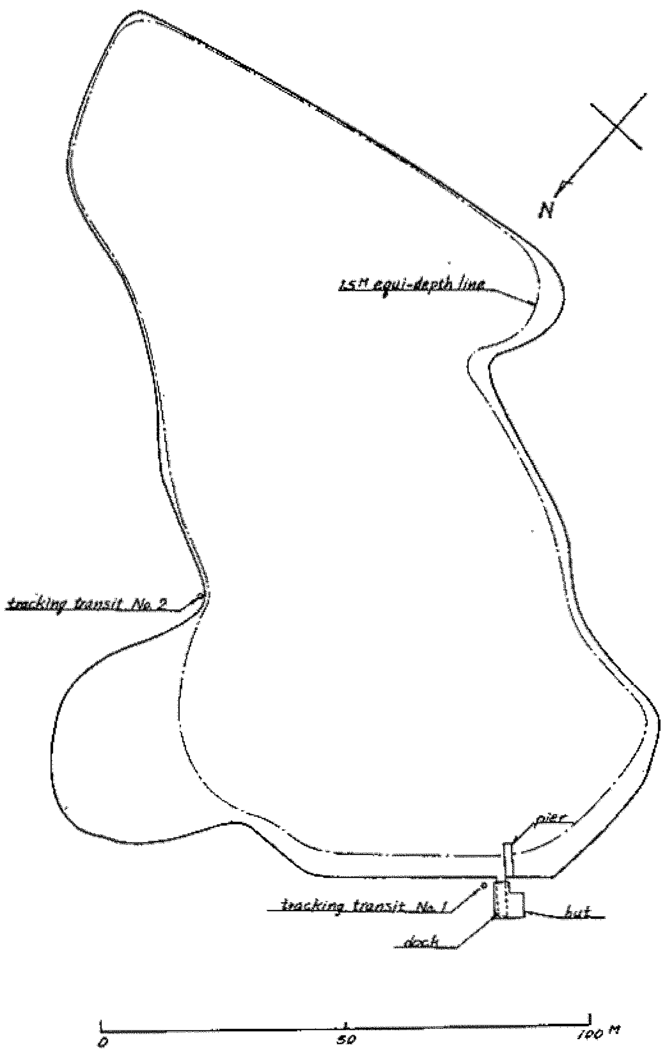


FIG. 9.
Osaka University. Manoeuvre Pond.

on it so as to detect normal force acting on a rudder and its moment about a rudder-stock. An all-transistorized strain-meter composed of a carrier oscillator and two amplifiers is used.

Running path of a model ship is determined by a pair of tracking transits, each of which yields continuous recording of traverse angle.

6. *Procedure of analyses and representation of test results*

6.1. to determine steering quality indices K, T_1, T_2 and T_3 through frequency response procedure using sinusoidal steering, impulsive steering and in some cases circular turning test results [4] [14].

6.2. to determine first-order steering quality indices K and T using Kempf's standard manœuvre results [13].

6.3. sometimes to determine resistance derivatives from the steering quality indices accompanied with results of measuring drift angle in circular turning tests.

6.4. to construct a systematic formulation of steering quality indices as functions of relative rudder sizes, slenderness factors, helm angles and some other factors when necessary.

6.5. to represent rudder normal force and rudder torque in an usual nondimensional form as functions of helm angle, propeller slip and ship travel in cases of behind tests.

7. *Kinds of full-size manoeuvre tests and the procedure of analyses:*

7.1. Kempf's standard manoeuvre tests are carried out using helm angle of usually 15 degrees and sometimes 10 and 20 degrees. The procedure of analysis is quite similar to one for a free-model test [13].

7.2. Sinusoidal and impulsive steering tests are sometimes carried out and the procedure of analysis is similar to one for a model test. These tests for actual ships are, however, usually difficult to practise by reason of their lengthy procedure.

7.3. Conventional turning trials and hard-over to hard-over steering tests are carried out and measurements of rudder torque employing wire-straingauge pasted upon a rudder stock are often accompanied.

Note: Full-size tests are executed in cooperation of shipbuilding companies and shipping ones.

KYUSHU UNIVERSITY

1. *Name and address of organization;*

Kyushu University.
Faculty of Engineering.
Department of Naval Architecture.
Fukuoka Japan.
(Researcher in charge: S. Inoue).

2. *Towing basin and other facilities:*

2.1. Towing Basin
dimension: 80 × 2.5 × 5.3. m.
carriage speed: 0.2 - 3 m/s.

2.2. Turning Basin
dimension: 30 × 5 × 5 m.

3. *Models:*
1 - 2 m.

4. *Kinds of experiments:*
   4.1. Measurements of force and moment of ships in the case of oblique sailing and turning.
   4.2. Measurements of heel and path in the case of turning.

5. *Instrumentation:*
Quantities to be measured are a ships heading angle, heel and running path of a free-model steered by wireless, and force and moment of a obliquely sailing and turning model.
These quantities are mainly determined by spring-type apparatus and cinecamera.

6. *Procedure of analyses and representation:*
   6.1. The moment and force are shown experimentally and theoretically by the ship form for example aspect ratio, beam by length, waterplane coef. etc. [16].
   The relation between turning and course stability properties is determined. [15].
   6.2. The maximum heel is determined comparing with steady turning heel.

7. *Kinds of full size manoeuvre tests:*
None.

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