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DESCRIPTION OF FACILITIES FOR SEAWORTHINESS TESTING OF MODEL HULLS AT COLORADO STATE UNIVERSITY

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INTRODUCTION

This report describes the facilities for conducting seaworthiness experiments with small model ships and seaplanes available at the Colorado State University Wave Basin. It brings up-to-date a previous report (1) published in the proceedings of the First Conference on Ships and Waves.

The Wave Basin is made up of the following basic elements (1) towing basin, (2) wave generator, (3) wave absorbers, (4) wave guides, (5) towing bridge, and (6) towing motor, each of which will be described in detail below.

WAVE BASIN

Towing Basin:-The towing basin has been constructed in a circular outdoor tank 85 feet in diameter and 6 feet in depth. Shallow water experiments have been conducted by lowering the water level until the desired depth is obtained. The actual testing area or seaway is 42 feet by 65 feet, although the present plans call for enlarging this area to 50 feet by 76 feet late in 1957. The testing area has been provided with a smooth concrete floor whose elevation at all points is within ± 1/8-inch of a true plane surface. This has been done so that shallow water experiments could be carried out. The static water level is controlled to a specified value, within ± 1/32-inch.

Wave Generator:-Wave trains are generated either by a steel bulkhead wave generator hinged at the floor of the tank or by a cylindrical plunger generator described in reference (2), depending on whether a shallow or deep sea is desired. The period of the waves may be varied by changing the sprocket ratio in the final drive of the motor driving the generator. The wave amplitude is varied by changing the radius of the crank-pin. The wave height-length ratio generally decreases as the wave length increases. The wave length capabilities and the maximum height-length ratios available are shown in the following table.

Wave Length (feet)	Maximum Height-Length Ratio
3.0	1/15
4.0	1/15
5.0	1/20
6.0	1/20
7.0	1/30
8.0	1/30
9.0	1/40

The wave generators are powered by a 10 HP, 3 phase, 440 volt induction motor, through a worm gear and a roller chain sprocket drive. The motor-worm gear combination has proven to be satisfactory for imparting sinusoidal motion to either of the wave generators. To date, tests have utilized only simple wave trains, although plans are under way to study model performance in the more complex stochastic seas.

Wave Absorbers:-The energy of the waves is absorbed on a sloping bed of expanded steel mesh located at one end of the basin. The absorber bed is approximately eight inches thick and has 80 percent openings. The slope of the bed is 10°.

Wave Guides:-Diffraction of the wave front is prevented by wave guides. The wave guides are constructed of cement blocks. Plywood panels are provided at proper intervals where the model must start its run from behind the wave guide walls. The wave guides are visible in Fig. 2 and 3. Fig. 1 shows an earlier plywood panel type of wave guide which has been replaced by the rigid cement block wall.

Towing Bridge:-A portable truss bridge spans the testing basin. This bridge can be easily rotated to any orientation relative to the direction of wave travel. Fig. 2 shows the towing bridge in relation to the wave basin. The towing bridge supports two carefully leveled and aligned rails. The rails consist of 5/16" x 2" x 2" steel angles supported at 6-foot intervals.

The rails provide the reference datum from which the model motions are measured. An aluminum towing carriage travels on these rails. The carriage tows the models, provides the reference for measurements, supports any movie cameras used during the tests and transmits the electric power needed by the model. The lower part of the carriage is shown in Fig. 3.

At the present time the models are restrained in surge, sway and yaw. Current plans include modification of the carriage to permit more degrees of freedom, and measurements of sway and surge. A sub-carriage similar to that described by Sibul (2) will be utilized.

Towing Motor:-The models and towing carriage are motivated by a 1/16-inch diameter steel cable. This cable is moved by a sheave turned by an electronically controlled D-C motor. The towing motor control was designed and built in the Colorado State University Electrical Engineering Department. Both the field and armature current are controlled by a Thyratron circuit. The speed-torque characteristics of the motor may be adjusted. The principal characteristics of the system are:

1. Approximately 50-fold [illegible]

2. High starting torque,

3. Dynamic braking,

4. No speed variation for a particular setting [illegible]

5. Excellent reliability.

The control panel for the towing motor also includes special switches and devices which stop the motor at pre-set limit switches at either end of the run, control the time of starting, and provide a safety interlock which stops the carriage in the event that any of the vital connections between the model and carriage are broken.

The time of starting a test run is controlled by the wave phase. This requirement is very important in obtaining information on the transients present during a part of the run. The start-of-towing control is initiated by the starting of the wave generator. This starting control permits the towing motor to start only after a predetermined number of waves have been emitted by the wave generator and then only at a predetermined phase of the wave.

INSTRUMENTATION

Current instrumentation includes (1) wave probes, (2) model motion instrumentation, (3) data recording equipment, (4) amplifier system, (5) motion pictures and still photograph equipment and, (6) machine computing facilities.

Wave Probes:-The wave profile is sampled by two probes at a point some distance away from the model so that a wave profile undisturbed by the model is recorded. One of these probes is a float-type probe while the other consists of a capacitance wire similar to the type developed by the David Taylor Model Basin (3).

In addition to these fixed probes, a number of moving probes are used to measure the wave profile in the immediate vicinity of the model. These moving probes or influence probes are attached to the carriage and record the wave of encounter relative to carriage or true datum.

The oscillographic records from the moving probes yield direct measurements of (1) the period of encounter, (2) the phase lags between model motion and the wave, and (3) information on how the ship influences the waves. These influence probes do not touch the water; they employ the principle of change of capacitance between the water surface and a small plate placed a short distance above the water. To date two influence probe units have been completed; however, present plans call for the construction of several additional units so that the model may be surrounded by a moving sampling grid.

Model Motion Instrumentation:-The motion histories of the model are obtained using micropotentiometers in a simple D-C Wheatstone bridge circuit. The potentiometers gives an electrical signal proportional to the motions of the model relative to a towing stem which is attached to the carriage. All connections between the model and carriage are made through carefully aligned precision ball bearing mounts. The model is isolated from the carriage by means of a sponge rubber filter which eliminates the high-frequency structural vibrations of the carriage and bridge, but passes the low-frequency model motions. Figs. 3 and 4 show the details of the mounting of the model to the steel stem.

Accelerometers may be mounted at the bow and stern to record information concerning slamming or impact loads when the forefoot emerges from a wave. It has been observed that forefoot emergence as noticed from movies taken during the test does not always indicate the occurrence of hydrodynamic impact (4); therefore, instances of slamming must be obtained from an accelerometer or pressure pickup.

Strain gages are used when forces or moments must be measured. These have proved to be very reliable, inexpensive and versatile.

Data Recording Equipment:-Originally all data were obtained from movies taken during the test runs. Most of the experimental data are now recorded on a 16-channel Heiland oscillograph. The records from the various transducers are recorded on photosensitive paper. The oscillograms are processed in a semi-automatic developer. A great variety of interchangeable galvanometers are available for the oscillograph.

Amplifier Systems:-Unfortunately in many applications of electronic or electrical instrumentation some form of amplification is necessary. A 11-channel Hathaway carrier type amplifier is used for most of these applications. The amplifier is most often used in connection with either the bonded or unbonded strain gage transducer. This amplifier system may also be used in connection with the inductive or capacitative transducers now available.

In some cases a cathode follower and a simple current amplifier is used. This is employed when the output impedance of the transducer is much greater than that required by the galvanometers used in the oscillograph.

Motion Pictures and Photographs:-Two specially modified remotely controlled, 16-mm movie cameras are available for photographing the test runs. These cameras may be mounted on camera booms on the towing carriage so that simultaneous front and side views of the model may be obtained. These movies yield information on the behavior of the model. A 4 x 5 Graphic camera is also available for "still" pictures. This camera may also be mounted on the camera boom and may be operated by remote control.

Developing service for all black and white and color movie film is available on a 24-hour basis in Denver. Other film is developed locally on short notice.

Projection facilities for 16-mm movie film are available. Any exposure may be stopped for an indefinite time so that measurements can be made.

Experience has shown that more accurate measurements of the model motion can be obtained from the oscillographic records of the micro-potentiometers outputs; however, movies are always very useful and often yield data which were not originally included in the testing program.

Machine Computing Facilities:-Some machine computing facilities are available. At the present time the University Business Office and the Registrar's Office handle all their records and business through an IBM facility which is leased for this purpose. These machines are available for other purposes on a rental basis. The machines available are tabulated in the following list:

Key Punch	Card Sorter
Card Verifier	Collator
Interpreter	Tabulator
Reproducer and Summary Punch	602A Calculating Punch

In addition IBM Model 650 and 704 computers are available in Denver on a rental basis.

A small D-C analog computer and a reflex-integraph are available for solving ordinary differential equations.

1. Schulz, B. F. Equipment for Testing Model Ship and Seaplane Hulls in Oblique Seas". Proc. First Conference in Ships and Waves. pp. 342-350, Richmond, Calif., 1954.

2. Sibul, O. J. The Effect of Method of Towing on Ship Model Motions. Proc. American Towing Tank Conference, Washington, September, 1956.

3. Campbell, W. S. An Electronic Wave-Height Measuring Apparatus. David Taylor Model Basin, Washington, D. C. IBM Rep. 859, Oct. 1953.

4. Szebehely, V. G. Progress in Theoretical and Experimental Studies of Ship Slamming. Proc. First Conference on Ships and Waves pp. 230-250, Richmond, Calif. 1954.

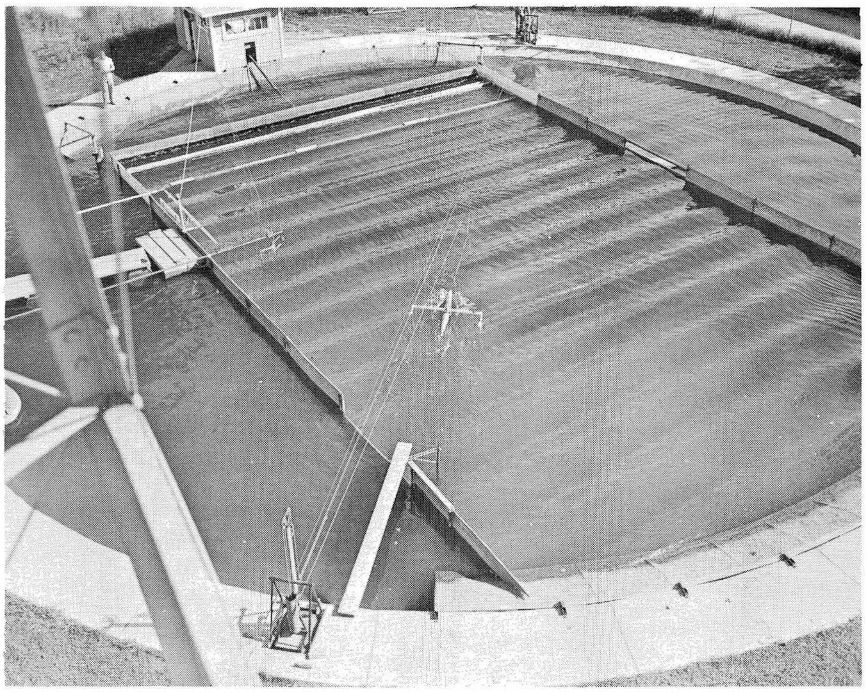

Fig. 1 Wave basin showing model seaplane being towed at 135° to direction of wave travel. Waves represent deep-water waves 5 feet high and 100 feet long.

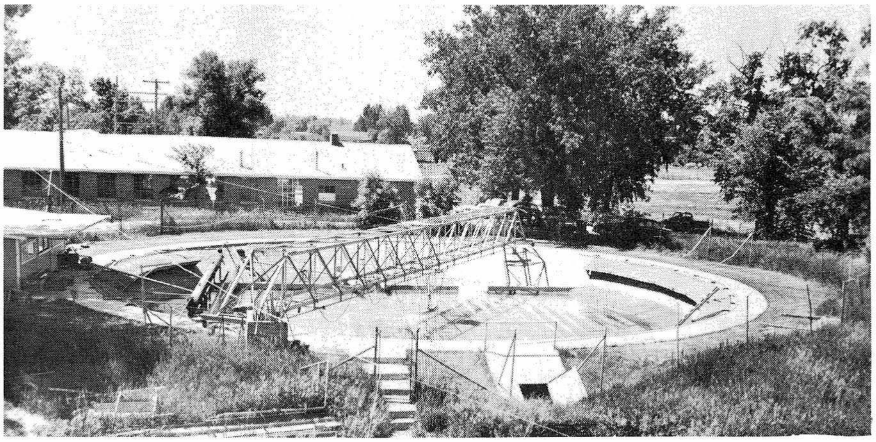

Fig. 2 Wave basin showing model ship being tested in shallow water waves. The steel truss towing bridge may be moved to any angle of travel relative to wave front.

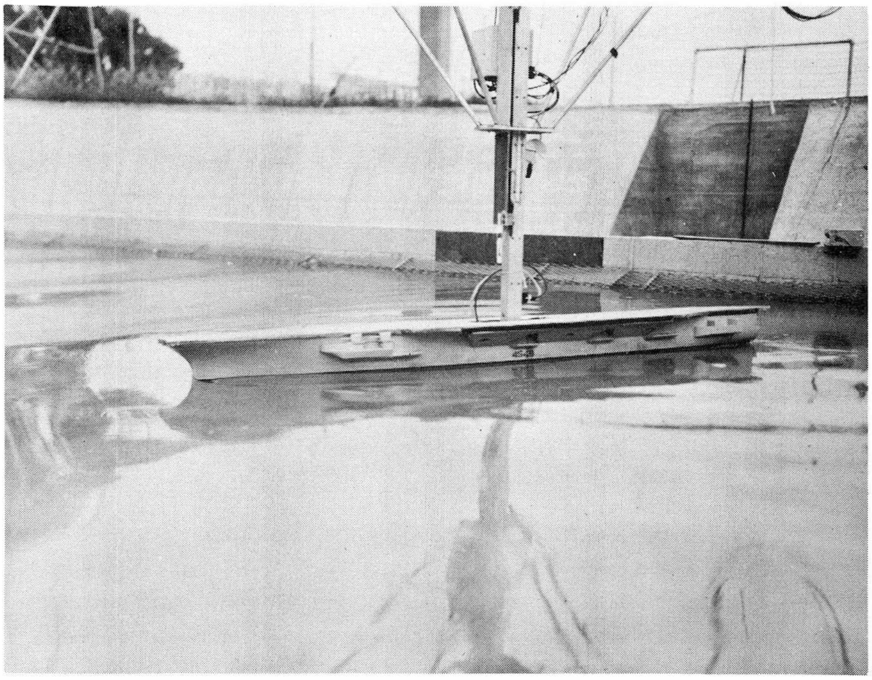

Fig. 3 Model aircraft carrier being tested in shallow water waves. Note square aluminum stem which attaches model to towing carriage. Electrical leads transmit signals from model to the recording oscillograph.

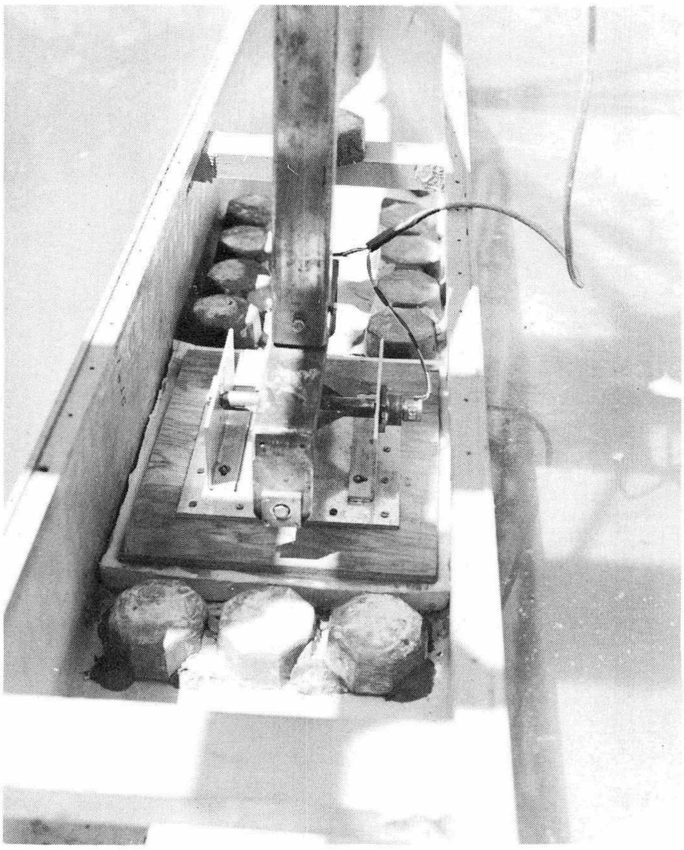

Fig. 4

View of inside of model cargo ship which has been constructed of fiber-glass-plastic laminate. Wires lead to pitch and roll transducers. Lead weights are used for ballast to achieve proper displacement and dynamic properties.