NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN
WASHINGTON, D.C.

MODEL TESTS TO DETERMINE THE FORCES ON THE STERN-GATE OPERATING MECHANISM OF THE ARD12 CLASS OF FLOATING DRYDOCKS IN WAVES

by

M. Gertler

February 1947

Report R-310

PERSONNEL

The project described in this report was carried out by Morton Gertler of the Hydromechanics Division, assisted by C. Wagley of the Structural Mechanics Division in the assembly and calibration of test equipment and by A. Menzak of the Electronics Section in the operation of the electronic equipment. The report was written by Mr. Gertler and checked by C.E. Janes.

MODEL TESTS TO DETERMINE THE FORCES ON THE STERN-GATE OPERATING MECHANISM OF THE ARD12 CLASS OF FLOATING DRYDOCKS IN WAVES

ABSTRACT

Tests were conducted at the U.S.Experimental Model Basin, Washington, on a 1:20-scale model of the ARD12 Class of floating drydocks equipped with a stern gate, to determine the forces on the gate-operating mechanism when the dock is subjected to the action of waves. The data have been evaluated to determine the stresses in the component parts of the full-scale gate-operating mechanism. The results revealed stresses that were of low order of magnitude and well within the safe engineering limits for the materials used on the full-scale mechanism. The derived data are presented and discussed in this report.

INTRODUCTION

The Bureau of Yards and Docks of the Navy Department has designed and constructed several large floating drydocks designated as the ARD12 Class. The hulls of these docks are ship-shaped. Within each hull is a docking chamber which is sealed off from the sea by a single stern gate hinged horizontally at the bottom. The dock can be sunk or raised to any draft within its operating limits by flooding or draining the buoyancy tanks, which are located in the wing walls and in the double bottom of the hull. Figure 1 shows the general arrangement of the dock.

The stern gates on most of the docks of this class are opened and closed by a mechanism which consists of two roller chains connected by links to the upper port and starboard corners of the gate. Each chain passes over a sprocket wheel on the drive shaft of a reduction gear. The gate is lowered by gravity and raised by two 10-horsepower 60-cycle 3-phase alternating-current motors, one driving each gear.

Several failures occurred in mechanisms of this type while the docks were operating at sea. The forces produced by the combined action of the sea and the pitching of the vessel were of sufficient magnitude to break the roller chains, with consequent loss of the gate.

Motion pictures of a trial docking operation showed how the failure probably occurred. In this trial the gate was released and allowed to open outward and downward while the docking chamber was partly full of water and the dock was pitching moderately. As the bow rose, the gate was slammed almost shut so that the roller chains became slack. In the succeeding upward rise of the stern the gate was whipped open, and the sudden impact broke the chains, as might have been expected.

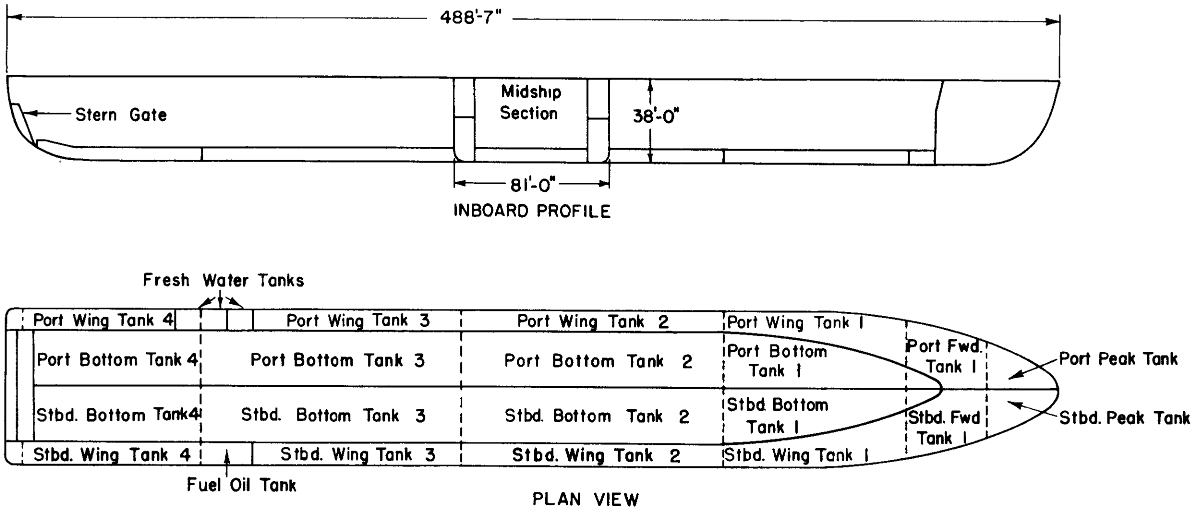

Figure 1 - General Arrangement of Floating Drydocks of the ARD12 Class

To overcome these difficulties, the Bureau of Yards and Docks designed a new gate-operating mechanism which has since been installed on several drydocks of the ARD12 Class and which is described in the section following.

The Taylor Model Basin was requested (1)* by the Bureau of Yards and Docks to install a scale model of this newly designed mechanism on the gate of a 24-foot model of the ARD12 Class of floating drydocks and to conduct tests on it while the model dock was being subjected to the action of waves. Conditions for the performance of the tests, such as ship draft, wave height, and wave length were specified by the Bureau. The purpose of these tests was to determine how the dynamic action of sea waves on the dock and on the gate affects the gate-operating mechanism. The data obtained in these tests can be used as a basis for the calculation of stresses in the mechanical parts of present and future installations. For the convenience of the users, the results of these tests are presented in this report in terms of full scale.

DESIGN OF NEW FULL-SCALE GATE-OPERATING MECHANISM

The new type of gate-operating mechanism employs hydraulic equipment to prevent uncontrolled motion of the gate. Figure 2 shows a device of this type. The gate is operated by two of these devices, one mounted on the port and one on the starboard side of the dock. With this mechanism the gate can be held in any predetermined position. It cannot swing freely to develop the impact loads which formerly broke the roller chains.

---

* Numbers in parentheses indicate references on page 27 of this report.

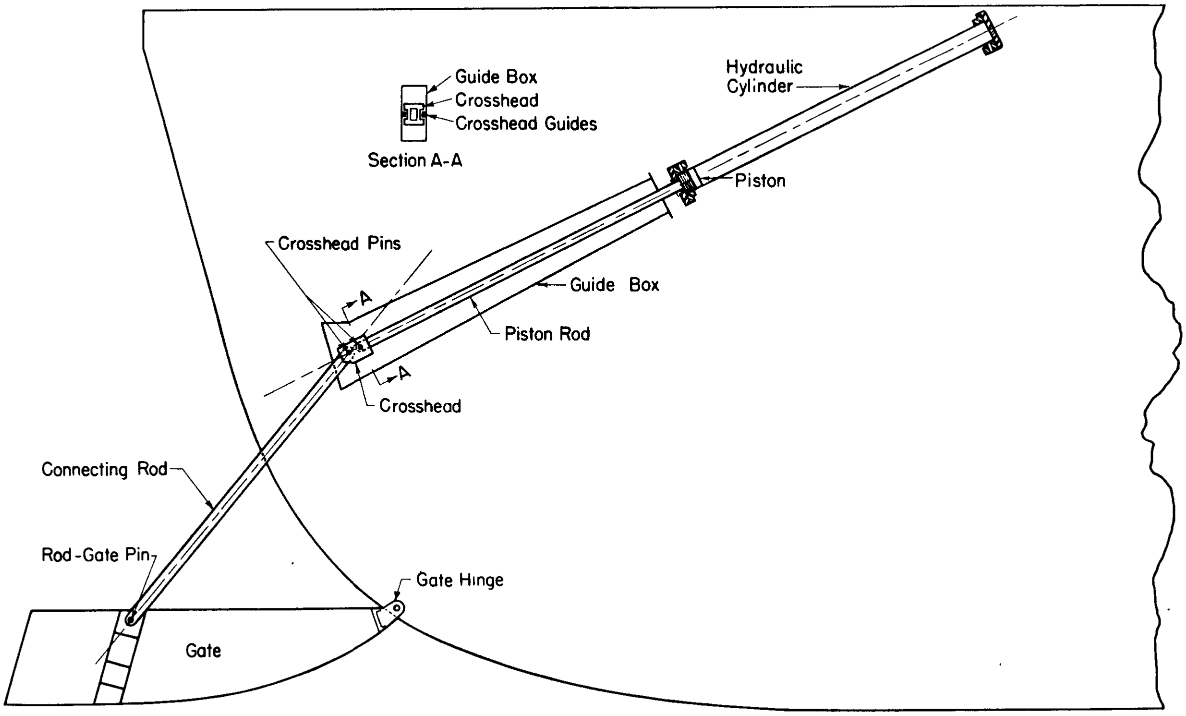

Figure 2 - Hydraulic Gate-Operating Mechanism on Full-Scale Dock

A connecting rod is attached to the gate by a pin, at a point 14 feet 4 inches from the center of the gate hinge. The connecting rod is secured to a piston rod at a crosshead which slides in fixed guides attached to the hull. The piston rod is secured to a piston which moves in an oil-filled double-acting hydraulic cylinder. When the gate is closed, the connecting rod and piston rod lie in the same straight line. The installation shown here is duplicated on the other side of the dock.

GENERAL CONSIDERATIONS

When planning these tests it appeared preferable to measure the forces required to hold the gate in position rather than the stresses in the gate-operating mechanism.

Since the forces on the model gate would be developed from wave action and hydrodynamic drag, they would have to be expanded by the cube of the linear ratio, in these tests by a factor of 8000. On the other hand, according to the rules for dynamic testing of elastic structures, the stresses for corresponding points in model and prototype would have to be equal. This latter requirement would mean that the model force would have to be 1/400 of the full-scale force. The size of the model waves necessary to produce such a large force would bear no relationship to the full-scale waves even if it were possible to produce waves of this magnitude in the basin, and consequently the tests would be valueless.

In the proposed tests, the frequency of the force acting on the gate-operating mechanism would be considerably lower than the natural frequency of any of the component parts of the structure. This condition would minimize dynamic actions in the system so that for practical purposes the problem could be treated as one in statics.

Although it is customary, even in model tests involving strength of structures where the forces exerted are static in nature, to produce equal stresses at corresponding points in model and prototype, it is nevertheless not necessary to do so. The only fixed requirement in the design of the model is that full-scale behavior can be deduced from observations of the model. Similarity of model and prototype is necessary only to the extent of meeting this requirement; in fact, the model often is by no means a scale replica of its prototype (2).

For the tests described here, the simplest approach was to use the connecting rods between the dock model and the gate as instruments to measure forces, then to expand these forces according to Froude's law of similitude, and finally to determine approximate stresses by calculation, using the form and dimensions of the mechanical parts of the prototype installation.

TEST SETUP

A wooden model of the hull of the drydock about 24 feet long was constructed by the Taylor Model Basin and fitted with a gate and gate-operating mechanism. The construction of the model and the special methods which were devised to measure the forces on the gate are described in the following sections.

MODEL OF DRYDOCK AND GATE

The model dock simulated the full-scale vessel with regard to the exterior shape of the hull and the shape of the docking chamber, which included a sill at the stern of the vessel. The sides of the model hull were made hollow to supply the necessary buoyancy by adding waterproofed inner walls which were constructed of plywood.

The Bureau of Yards and Docks provided a 1:20-scale model of the stern gate, constructed of sheet metal, similar to its prototype in size, shape, weight, and construction (3). As may be seen in Figure 3, the gate consists of a curved plate stiffened by girders on the back, two side plates, and a top plate. When the gate is closed, the inside edges of the gate seat tightly against rubber gaskets mounted on the wing walls of the dock to form a watertight seal. The girders within the gate contain holes to allow free circulation of water within the gate when the dock is submerged.

The gate was hinged to the stern of the model hull slightly below the top of the sill. Two rods which represented the full-scale connecting rods served as links to support the gate at its port and starboard outboard

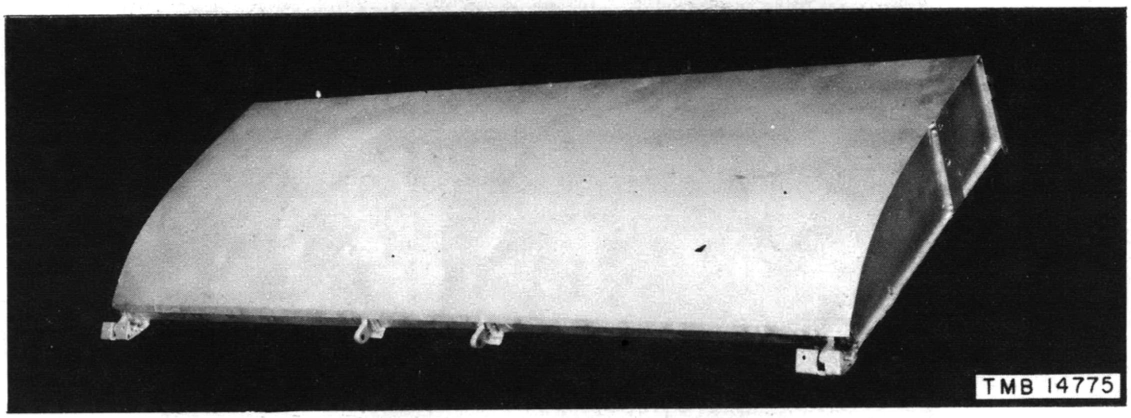

Figure 3a - View Showing Curved Frontal Surface and Reinforced Side of the Stern-Gate Model

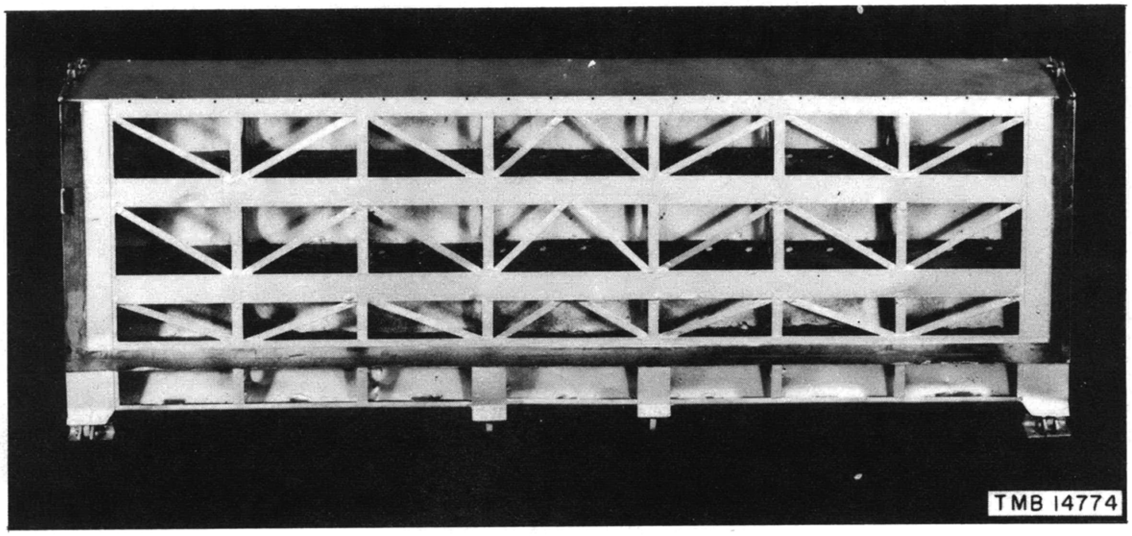

Figure 3b - View Showing Internal Construction

Figure 3 - Photographs of the Model Gate

corners. Figure 4a shows a stern view of the model of the drydock. The arrangement of the model gate-operating mechanism is shown in Figure 4b.

Each connecting rod was pin-connected at one end to the gate and at the other end to a bracket which was screwed to the inner wall of the hull of the model. Thus the gate could be held rigidly in place at any given gate angle. Prior to the test, separate positions for the upper bracket were laid out to hold the gate at angles of 0, 20, 40, and 67 degrees with the horizontal. For each position of the upper bracket, the center of the upper or wrist pin was located on the line of action of the piston rod. No attempt was made to simulate the full-scale piston, piston rod, or hydraulic cylinder. The two connecting rods, one on each side of the gate, were identical in construction.

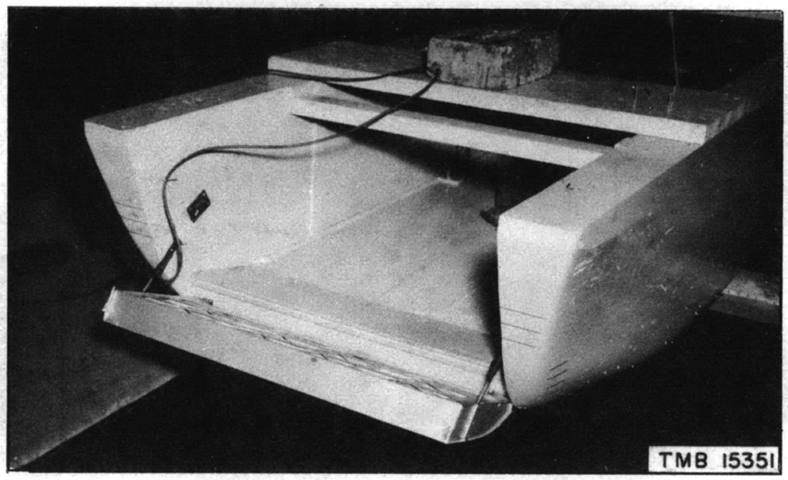

Figure 4a - Stern View of Drydock Model

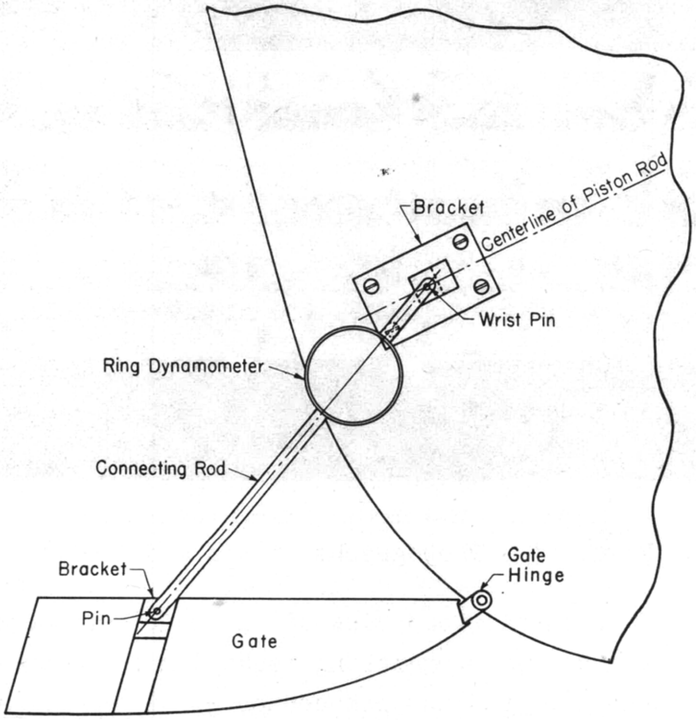

Figure 4b - Arrangement of Gate-Operating Mechanism in Stern of Model

Figure 4 - Drydock Model and Gate-Operating Mechanism

Each connecting rod is pin-connected at one end to the gate and at the other end to a bracket which is screwed to the inner wall of the hull of the model. The gate angle is adjusted by changing the position of the upper bracket along the indicated centerline of the piston rod.

The tension in the rods was equalized by adjusting the positions of the upper brackets. The pertinent dimensions for the component parts of the drydock model and its prototype are given in Table 1.

A ring dynamometer was inserted in each connecting rod, as described later.

TABLE 1

Dimensions of Component Parts of Floating Drydock

Particular	Dimension, feet	
	Model	Prototype
Overall length of hull	24.429	488.58
Beam	4.050	81.00
Height of wing-wall deck from base line	1.900	38.00
Width of gate	3.050	61.00
Height of top of gate above base line, when gate is closed	1.250	25.00
Distance of lower pins from center of gate hinges	0.712	14.33
Length of connecting rods from lower pins to center of upper pins	0.926	18.51

FORCE-MEASURING APPARATUS

The project presented problems which necessitated the use of specially designed instruments, considering the magnitude and nature of the forces involved in the model tests. These forces, although they were anticipated to reach values as high as 20 pounds, would have been difficult to detect without special means of amplification, because of their rapidly varying magnitude when the model was pitching in waves and the water was swashing back and forth inside the dock. Purely mechanical devices could not be used for this amplification because of limitations in space on the model itself. Furthermore, at a given fixed gate angle, the motion of the model gate had to be restricted within very small limits, corresponding to the very limited movement of the full-scale gate when it was held in a fixed position by its hydraulic operating mechanism. A mechanical instrument of the type which depends on an appreciable extension of a spring to yield the required sensitivity could not be used since the model gate would have been displaced through a considerable angle while the forces were being measured. Finally, the forces, although reasonably periodic, were not repeated within a reasonable testing time. It was, therefore, necessary to provide an instrument which recorded the forces on a continuous time base.

These limitations made the use of purely mechanical instruments impractical. It was decided, therefore, to use SR-4 wire-resistance gages on a relatively stiff elastic member. These gages, although generally used to make strain measurements, can be combined with calibrated mechanical linkage to record force in pounds.

Preliminary calculations revealed that, in order to get strains large enough to be measured with the required accuracy, the sections of the connecting rods on which the SR-4 gages were to be mounted had to be made extremely thin. The stiffness in these thin sections of the rods was not sufficient to prevent bending when the forces acted in compression. To overcome this difficulty, the gages were mounted on rings designed to give the required strains; these rings were then inserted into the rods.

Each force-measuring assembly, which consisted of a ring equipped with SR-4 gages, is referred to here as a "ring dynamometer," since it is calibrated to denote force in pounds. Each assembly was designed for a maximum load of 80 pounds, in either tension or compression.

The placement of the gages on the ring is shown in Figure 5. Four pairs of gages were mounted on the ring, but actually only one pair, one gage on the inside and one opposite it on the outside of the ring, was used in the test; the other pairs served as spares. The measuring gages were connected in an electric circuit, so as to form two arms of an a-c bridge. This ar-

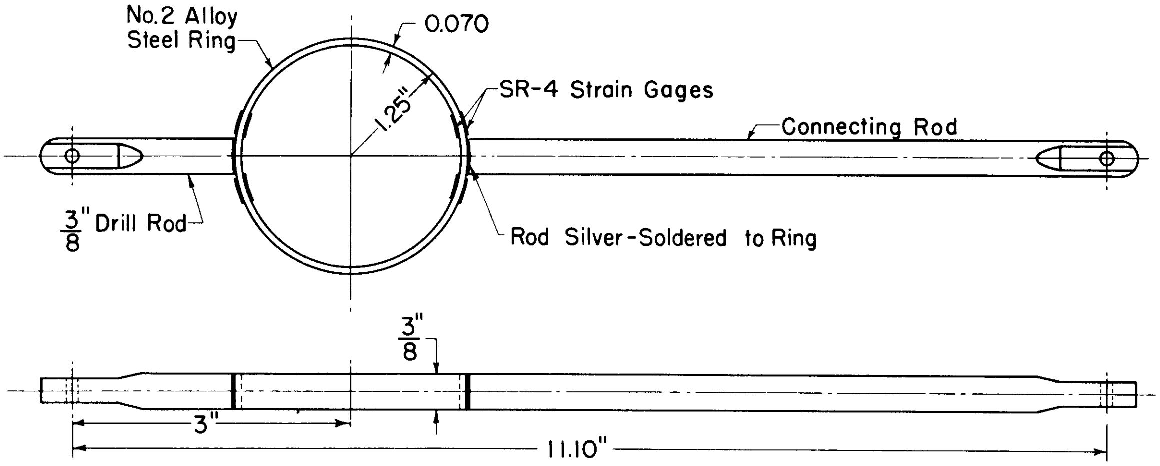

Figure 5 - Ring Dynamometer for Measuring Dynamic Forces on the Model

This is an elastic ring type of dynamometer, similar to the proving rings used to calibrate testing machines except in the use of metalectric gages to measure strains. Any outside gage, applied with its wire parallel to the metal of the ring, measures compression when the connecting rod is shortened; the gage opposite it, on the inside of the ring, measures tension.

rangement had the double advantage of compensating for temperature changes and of increasing the sensitivity of the instrument, since the strains produced by temperature changes are in the same direction, whereas the forces on the rods produce strains whose direction on the inside of the rings is opposite that on the outside.

Since the ring dynamometers were to be immersed in water for long periods of time during the tests, the SR-4 gages had to be waterproofed. After the gages were cemented to the ring, they were dried carefully by a hot-air drier and were then sprayed with a very thin coat of wax. Several grains of calcium chloride were cemented to the inside of the ring to absorb condensation moisture. Thin latex tubing was stretched over the entire ring and gage assembly. The ends of the tubing were bound to the connecting rod with rubber tape and were sealed with wax to form a watertight shield. This latex shield was found to be a very effective waterproofing device and, in addition, was so elastic that it caused no hysteresis in the calibration of the ring dynamometer, as was previously experienced when the ring and gage assembly was coated with wax which was thick enough to ensure complete waterproofing.

The ring dynamometers were calibrated with their complete waterproofing gear before the tests, by applying static loads in 1-pound increments. The sensitivity was found to be 0.02 pound, and the calibration curves were linear. After the tests, the dynamometers were recalibrated. This calibration checked the previous one within one-half of one per cent.

An electronic device, known as the TMB Dynamic-Strain Indicator, was used to detect and record the forces exerted on the ring dynamometers. This equipment is described in a separate TMB report (4); a block diagram of it is shown in Figure 6.

TEST PROCEDURE

The Bureau of Yards and Docks specified (1) that the model was to be tested under the following conditions:

a. drafts corresponding to 20, 22.5, and 25 feet on the full-scale dock,

b. separate fixed gate angles of 0, 20, 40, and 67 degrees with the horizontal for each draft, and

c. in three sets of waves with full-scale heights of 5, 10, and 15 feet and full-scale lengths of 100, 200, and 300 feet, respectively, for each gate setting at each dock draft.

This made a total of 36 conditions for which the model was to be tested.

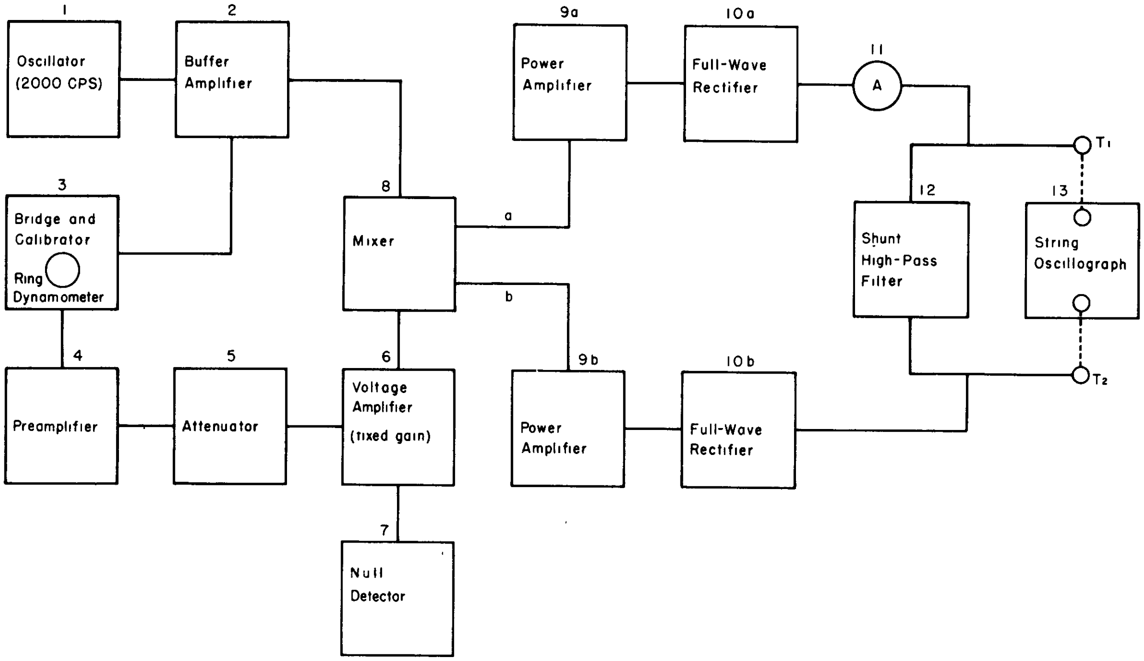

Figure 6 - Block Diagram of the TMB Dynamic-Strain Indicator

The model was immersed to the proper draft by lead ballast weights placed on the floor of the docking chamber. In order to simulate full-scale docking operation, water was permitted to enter the docking chamber until the height of water on the inside and the outside of the gate was the same. At each draft, the longitudinal metacentric height of the model was adjusted to correspond to the pertinent metacentric height of the full-scale dock. The metacentric heights for the full-scale dock were obtained from stability data provided by the Bureau of Yards and Docks (1).

The procedure for adjusting the longitudinal metacentric height of the model was as follows: A 50-pound weight was moved a known distance forward or aft on the model, and the trim which resulted was observed. The metacentric heights GM_e were then calculated by the formula

$$GM_e = \frac{12\,wdL}{WX}$$

where GM_e is the longitudinal metacentric height in feet,

w is the movable weight in pounds,

d is the distance through which the weight is moved in feet,

L is the length of the model in feet,

W is the displacement of the model in pounds, and

X is the total trim in inches.

If the calculated GM_e did not agree with the specified value, the ballast weights were raised or lowered until agreement was obtained.

No attempt was made to simulate the longitudinal moment of inertia about the transverse axis of the model dock beyond uniformly distributing the ballast weights in a fore and aft direction.

The tests were conducted in the Experimental Model Basin at the Naval Gun Factory, Washington, where a wave-making device* is available.

For each test the model was placed in the center of the model basin about 50 feet from the wavemaker and head-on to the crests of the waves. It was held in this position by mooring lines from the bow to each side of the basin. The mooring lines were sufficiently slack to permit free pitching of the model. The electronic equipment was placed on the towing carriage, which was situated about 20 feet behind the model. Rubber-covered cables connected the strain gages to the electronic equipment. The general arrangement for the test is shown in Figure 7.

After all preliminary preparations had been made, the gate on the model hull was fixed at one of the predetermined angles. A reading was taken on the TMB Dynamic-Strain Indicator and recorded on the string oscillograph. A force which resulted from supporting the gate in still water was exerted on each connecting rod. The readings of this force on the indicator and oscillograph were arbitrarily adjusted to read as zero. This adjustment was made so that the zero reading could be checked after each run without disturbing the apparatus on the model.

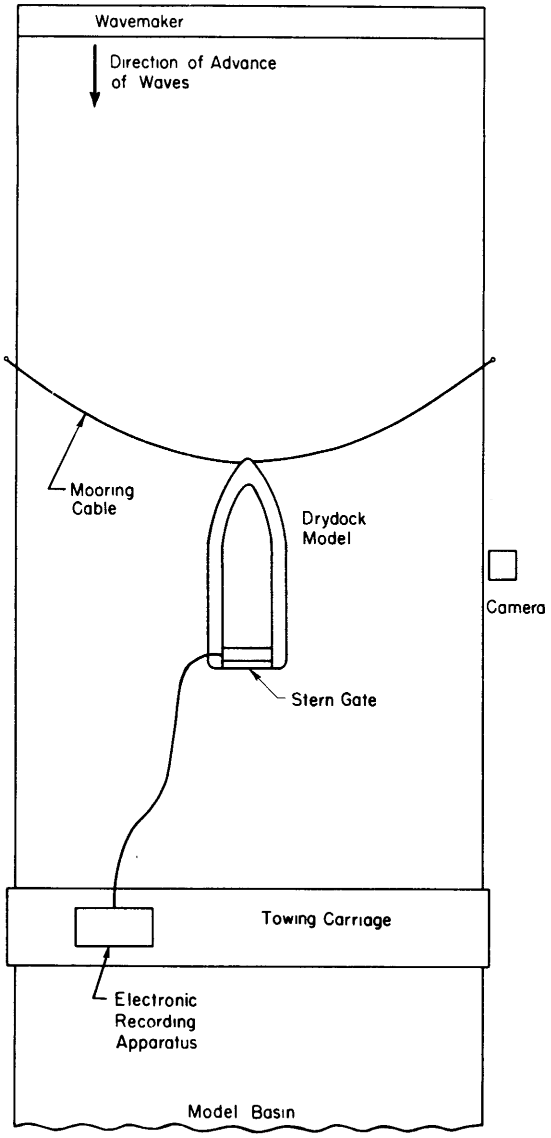

Figure 7 - General Arrangement of Drydock Model and Test Apparatus in the Model Basin

---

* A separate TMB report describing this wavemaker is in preparation.

The wavemaker, which had been previously set to generate waves of a given size, was than started and allowed to run until the waves attained approximately constant dimensions. The forces on each connecting rod which resulted from the action of the waves were observed on the galvanometer of the indicator until a maximum force occurred. The string oscillograph was turned on before the maximum force was repeated and was allowed to run for several seconds. A special attenuator on the indicator was adjusted for each run so that maximum amplification of the recorded forces could be obtained without having the reading exceed the scale of the instrument.

The same procedure was repeated for each of the 36 conditions. After the dynamic tests were performed, the force which acted on each of the connecting rods while the model was in still water was measured for each of the four gate positions at each draft, first by taking a zero reading with the gate disconnected from the rod containing the dynamometer, and then by taking a reading with the gate attached to the rod.

In all the test conditions, the gate was supported by connecting rods on both sides, but readings of force were taken on only one side since insufficient electronic equipment was available at the time for obtaining readings on both sides simultaneously.

Figure 8 is a sample of the record obtained on the oscillograph. Figures 9, 10, and 11 are photographs of the model taken during the test, for the purpose of checking wave dimensions.

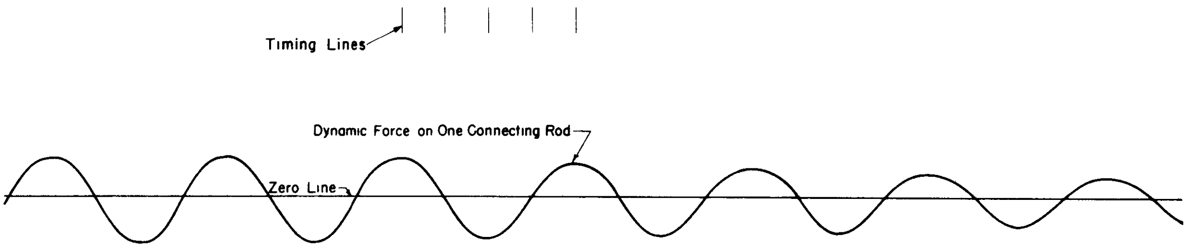

Figure 8 - Sample String-Oscillograph Record

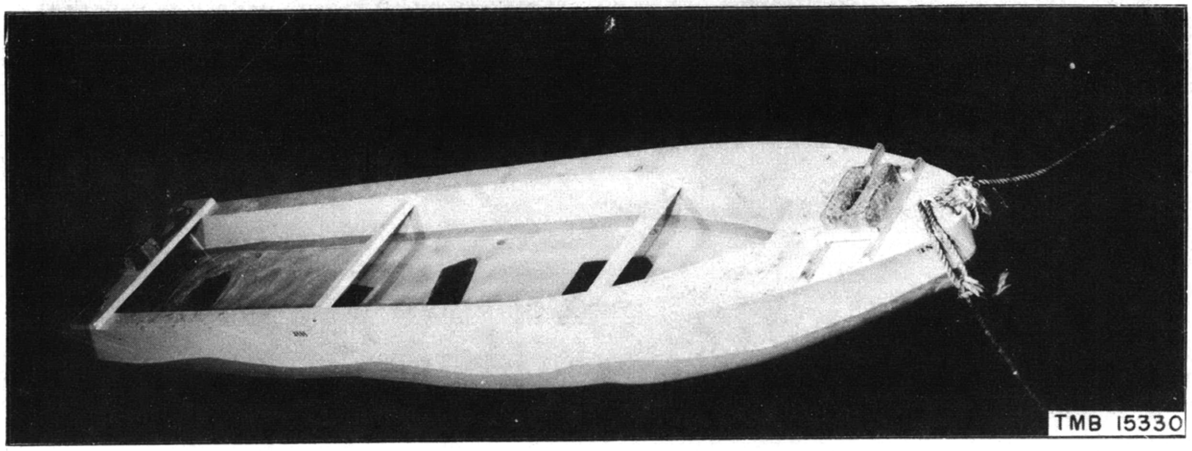

Figure 9a - Wave Height 5 Feet and Wave Length 100 Feet, Full Scale

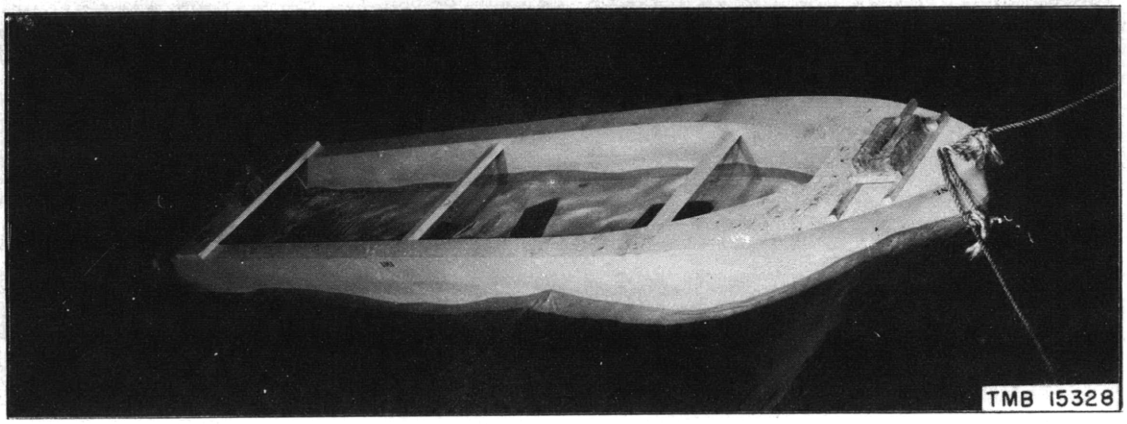

Figure 9b - Wave Height 10 Feet and Wave Length 200 Feet, Full Scale

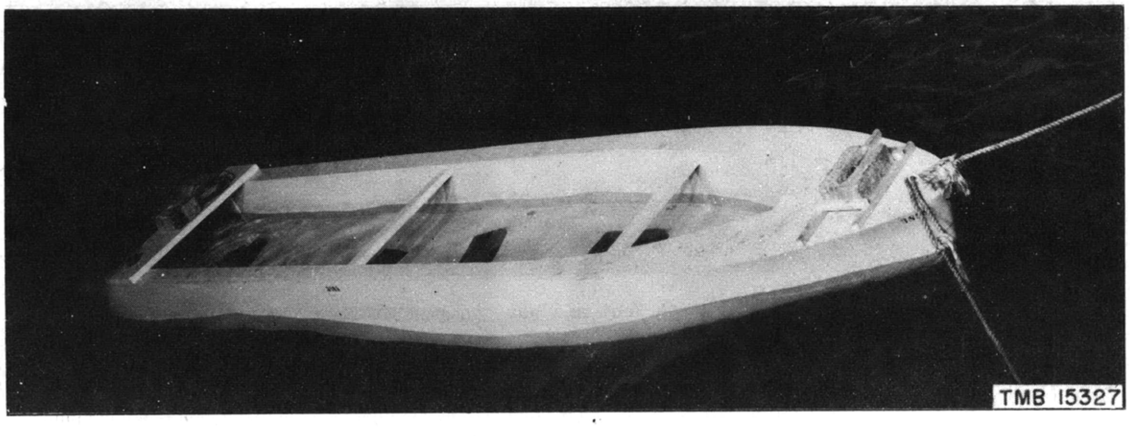

Figure 9c - Wave Height 15 Feet and Wave Length 300 Feet, Full Scale

Figure 9 - Model Floating Drydock in Waves at a Draft
Corresponding to 20 Feet, Full Scale

The photographs in Figures 9, 10, and 11 do not show the gate; they were made to obtain actual wave dimensions inside and outside the dock.

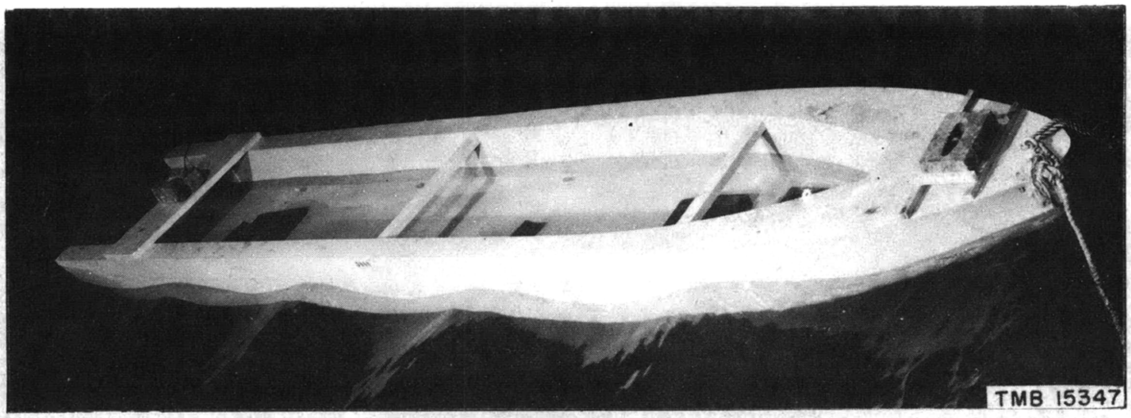
TMB 15347

Figure 10a - Wave Height 5 Feet and Wave Length 100 Feet, Full Scale

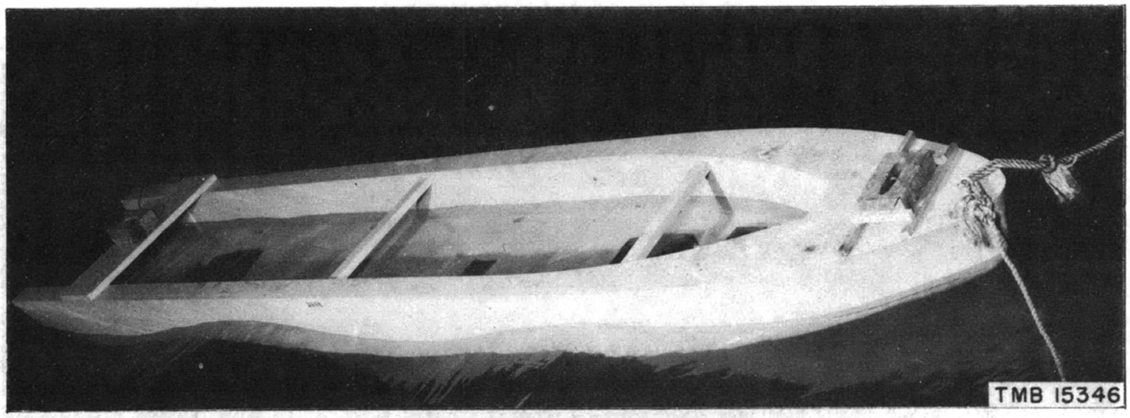
TMB 15346

Figure 10b - Wave Height 10 Feet and Wave Length 200 Feet, Full Scale

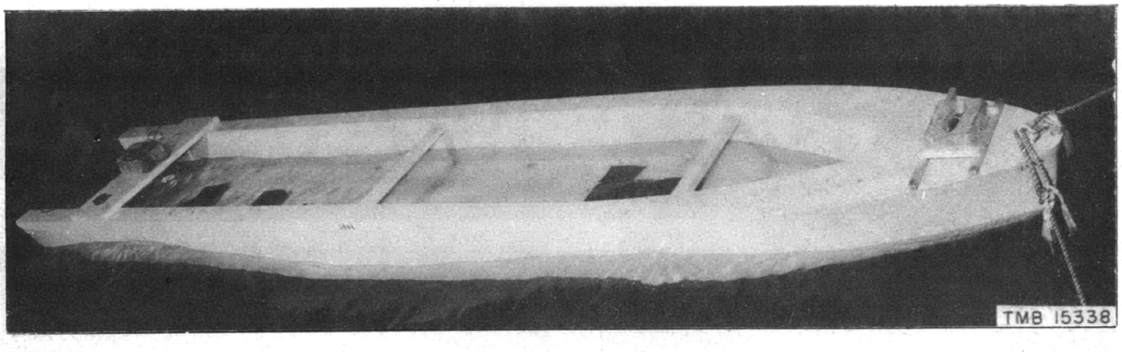
TMB 15338

Figure 10c - Wave Height 15 Feet and Wave Length 300 Feet, Full Scale

Figure 10 - Model Floating Drydock in Waves at a Draft Corresponding to 22.5 Feet, Full Scale

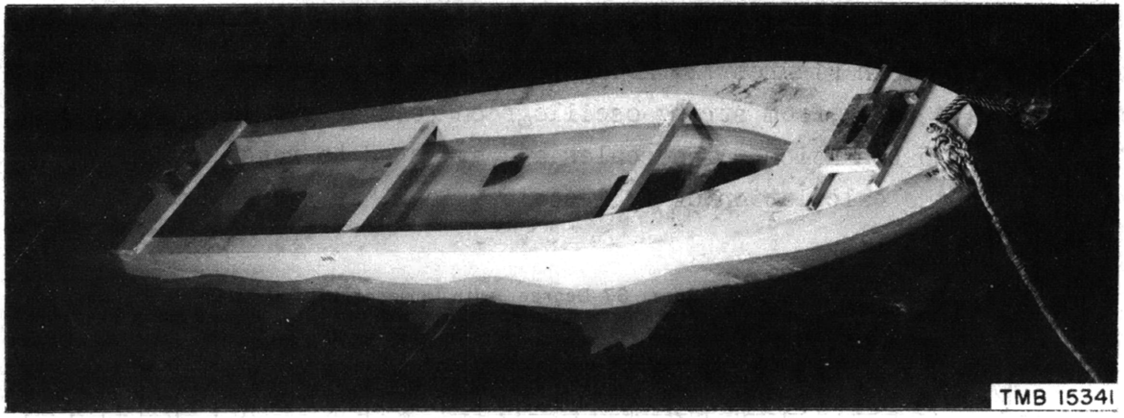

Figure 11a - Wave Height 5 Feet and Wave Length 100 Feet, Full Scale

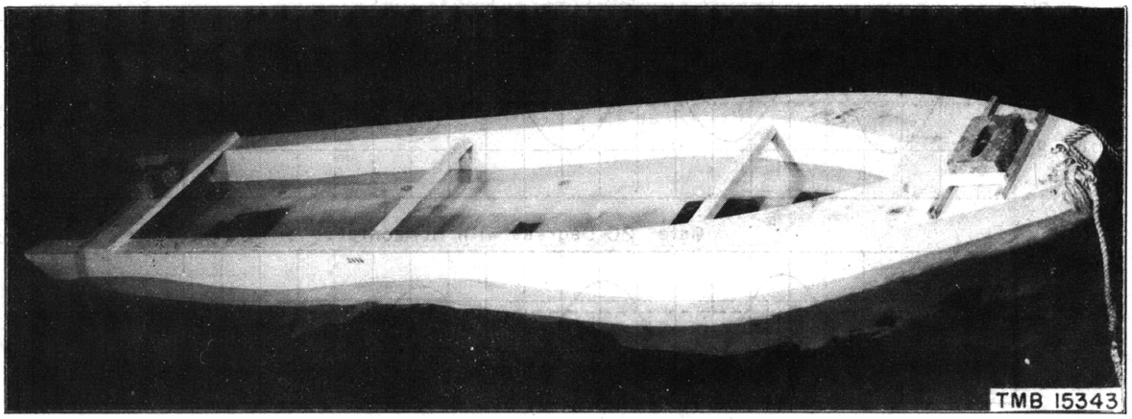

Figure 11b - Wave Height 10 Feet and Wave Length 200 Feet, Full Scale

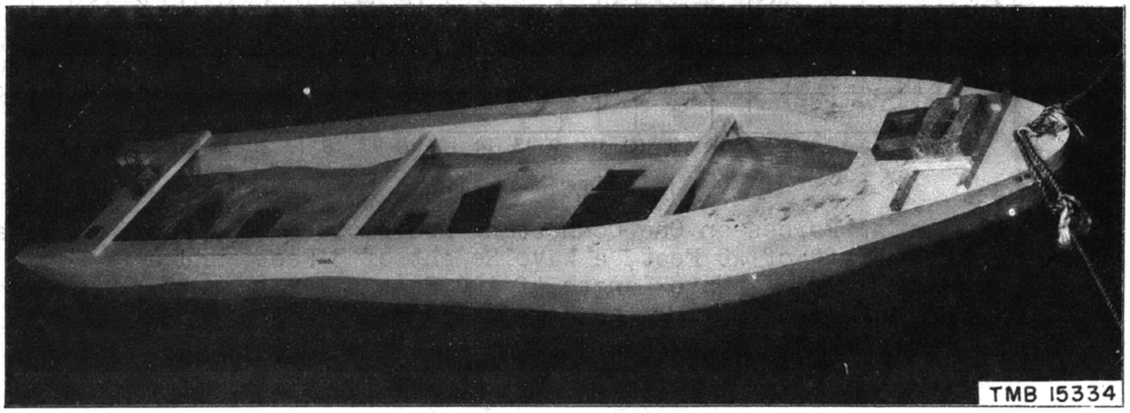

Figure 11c - Wave Height 15 Feet and Wave Length 300 Feet, Full Scale

Figure 11 - Model Floating Drydock in Waves at a Draft Corresponding to 25 Feet, Full Scale

TEST RESULTS

Curves of axial force on the connecting rod, plotted on a basis of time, are shown in Figures 12 through 20. These curves were drawn from the original data taken from string-oscillograph records showing the maximum force for each condition. The scales are adjusted to read in full-scale values. In the calculation of full-scale values, it was assumed that Froude's

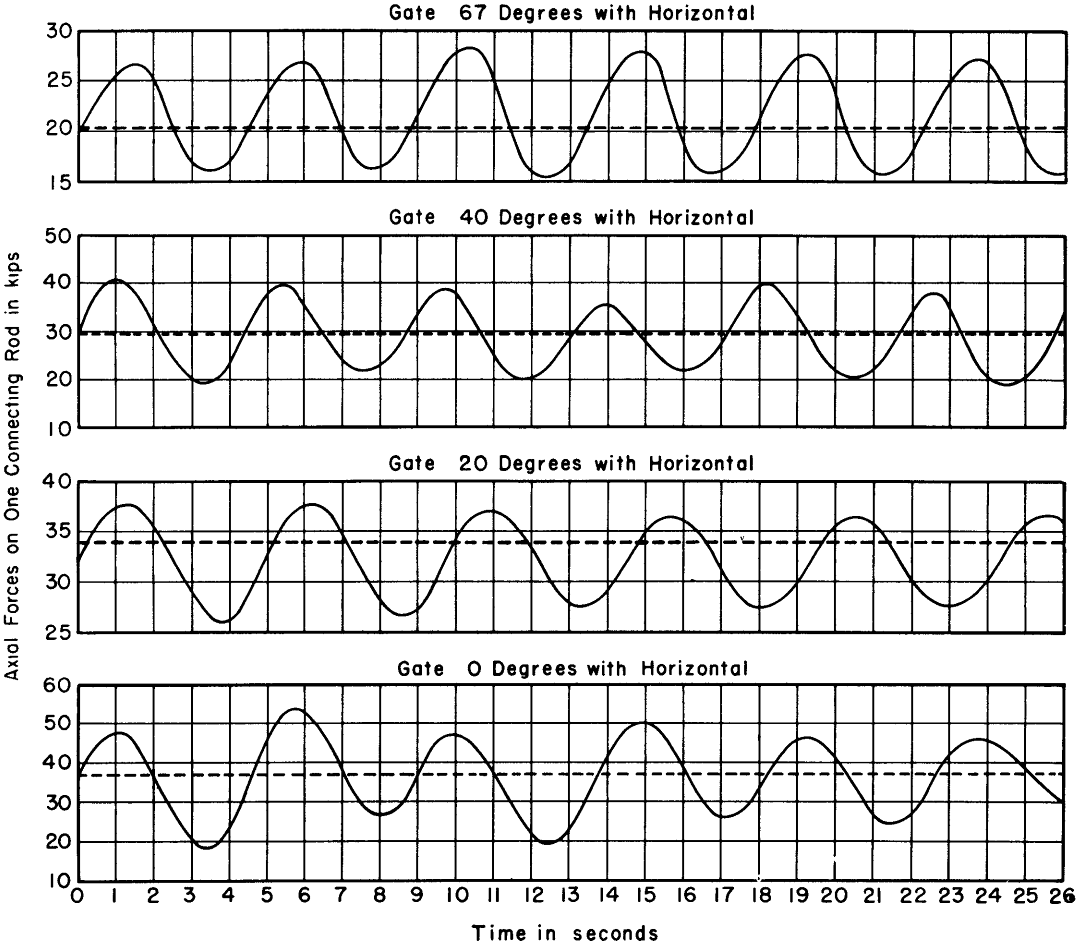

Figure 12 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 20 Feet, a Wave Height of 5 Feet, and a Wave Length of 100 Feet

The solid curves denote the forces due to the action of waves, and the broken lines denote static forces on one connecting rod while the dock is in still water.

law applied, according to which the forces vary as the cube of the linear ratio and the time varies as the square root of the linear ratio. It will be noted that the force scale varies on most of the curves. This variation is due to the attenuator settings of the indicator which were used on the test. The time scale, however, remains constant throughout. The maximum forces acting on one connecting rod for each condition are shown in Table 2.

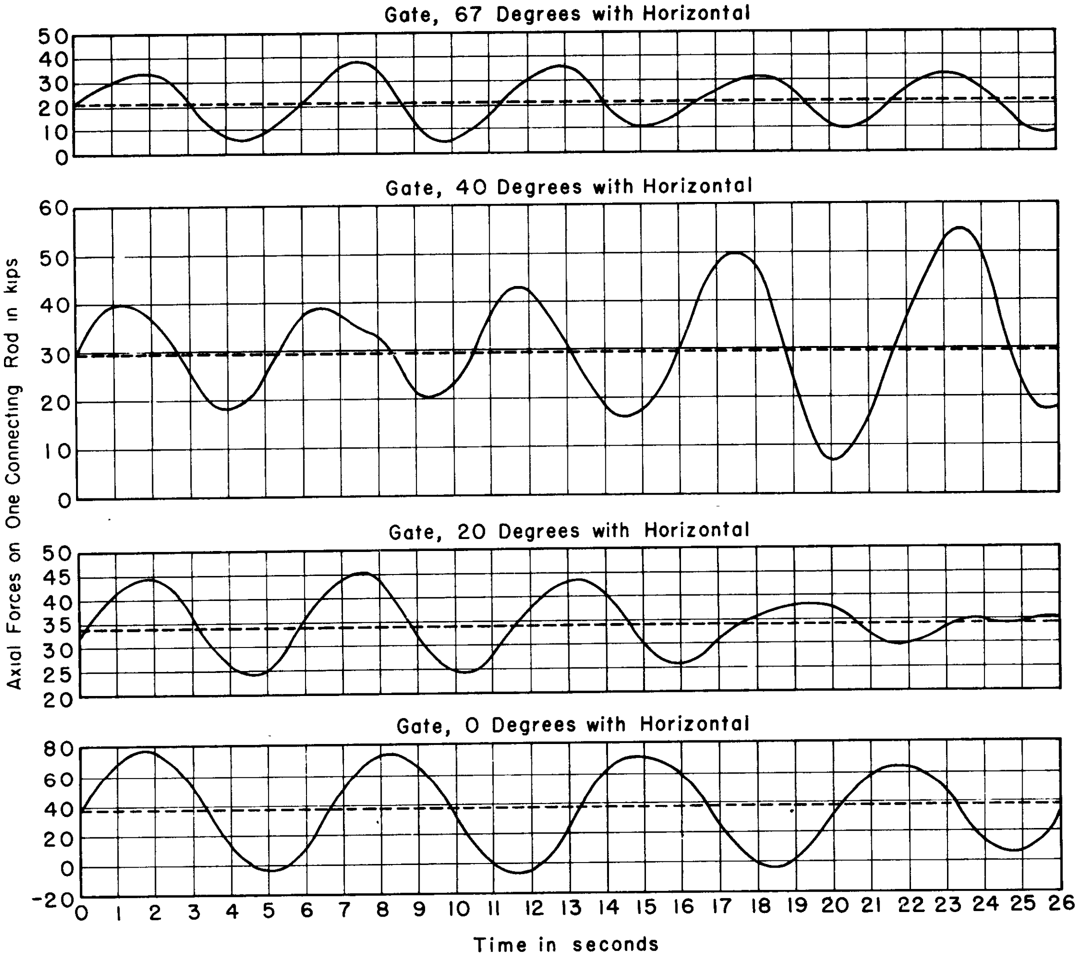

Figure 13 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 20 Feet, a Wave Height of 10 Feet, and a Wave Length of 200 Feet

The solid curves denote the forces due to the action of waves, and the broken lines denote static forces on one connecting rod while the dock is in still water.

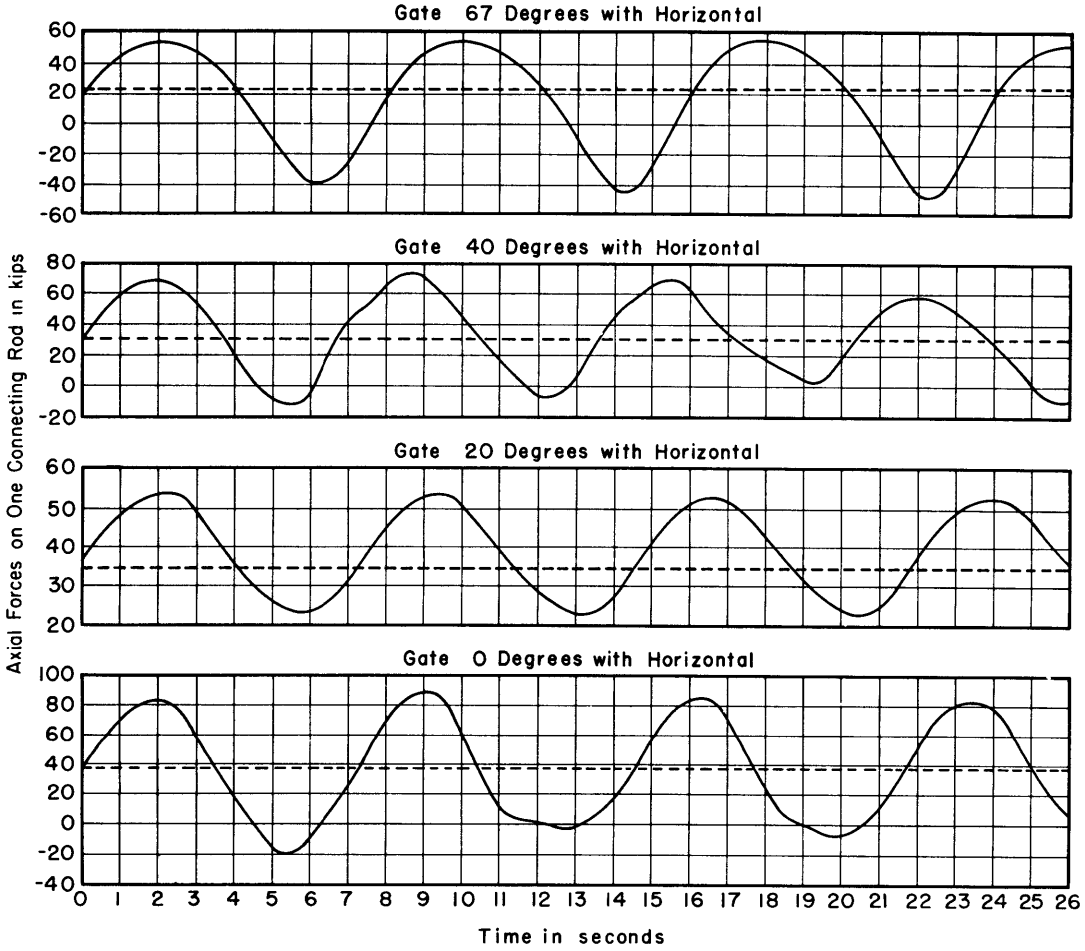

Figure 14 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 20 Feet, a Wave Height of 15 Feet, and a Wave Length of 300 Feet

The solid curves denote the forces due to the action of waves, and the broken lines denote static forces on one connecting rod while the dock is in still water.

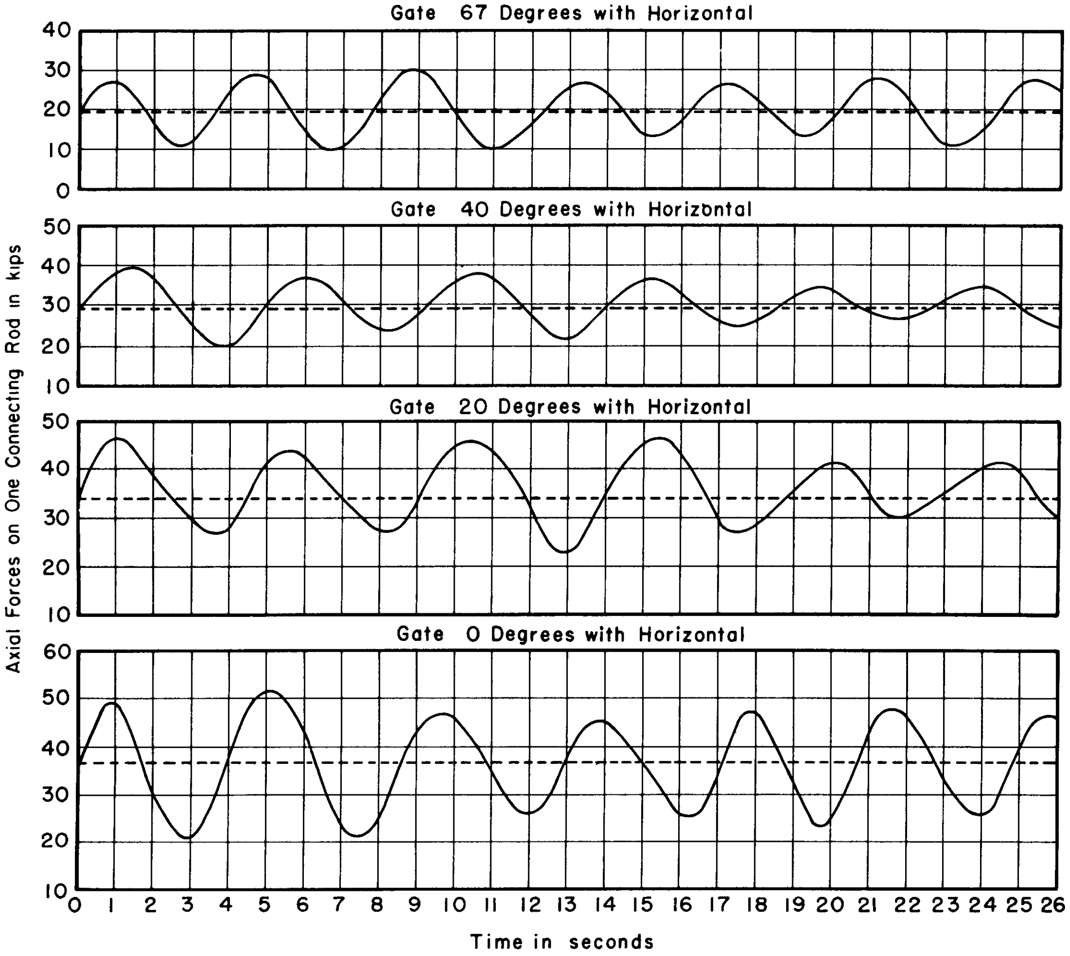

Figure 15 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 22.5 Feet, a Wave Height of 5 Feet, and a Wave Length of 100 Feet

The solid curves denote the forces due to the action of waves, and the broken lines denote static forces on one connecting rod while the dock is in still water.

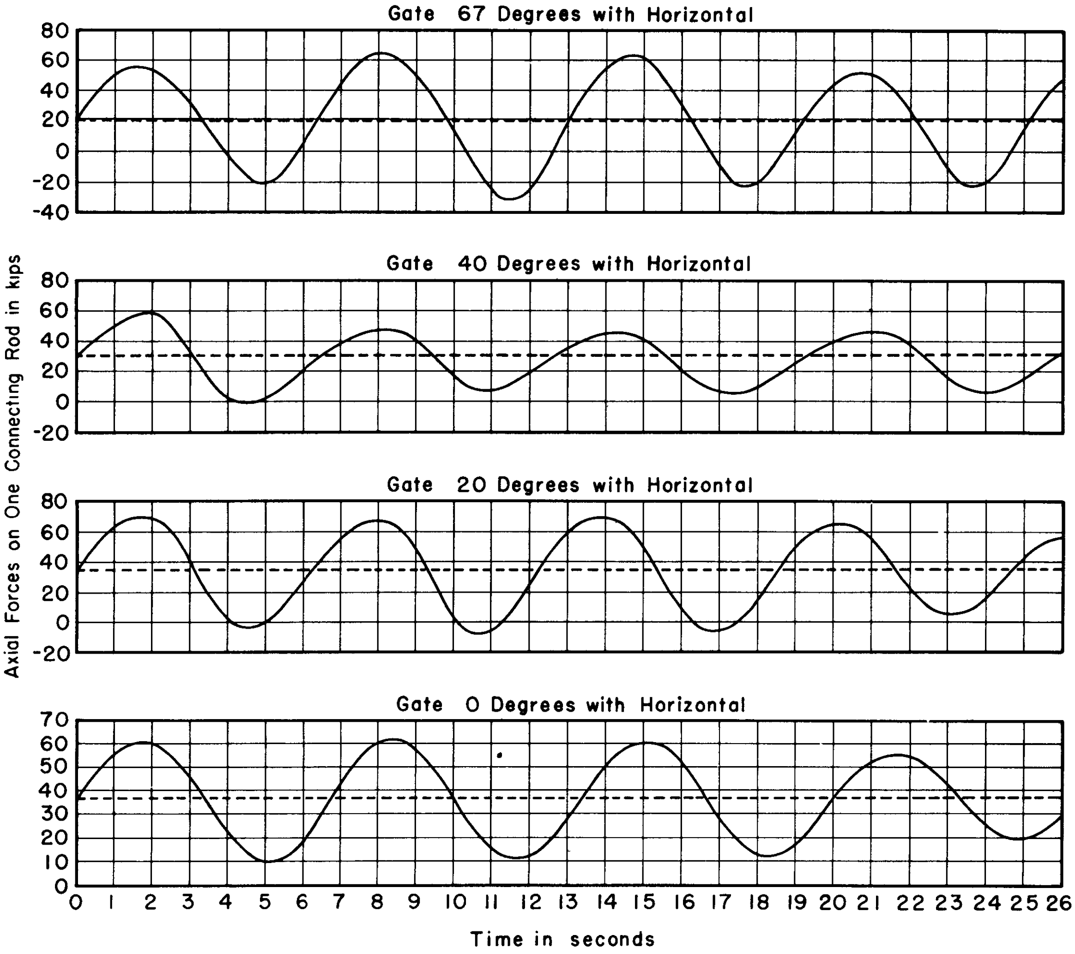

Figure 16 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 22.5 Feet, a Wave Height of 10 Feet, and a Wave Length of 200 Feet

The solid curves denote the forces due to the action of waves, and the broken lines denote static forces on one connecting rod while the dock is in still water.

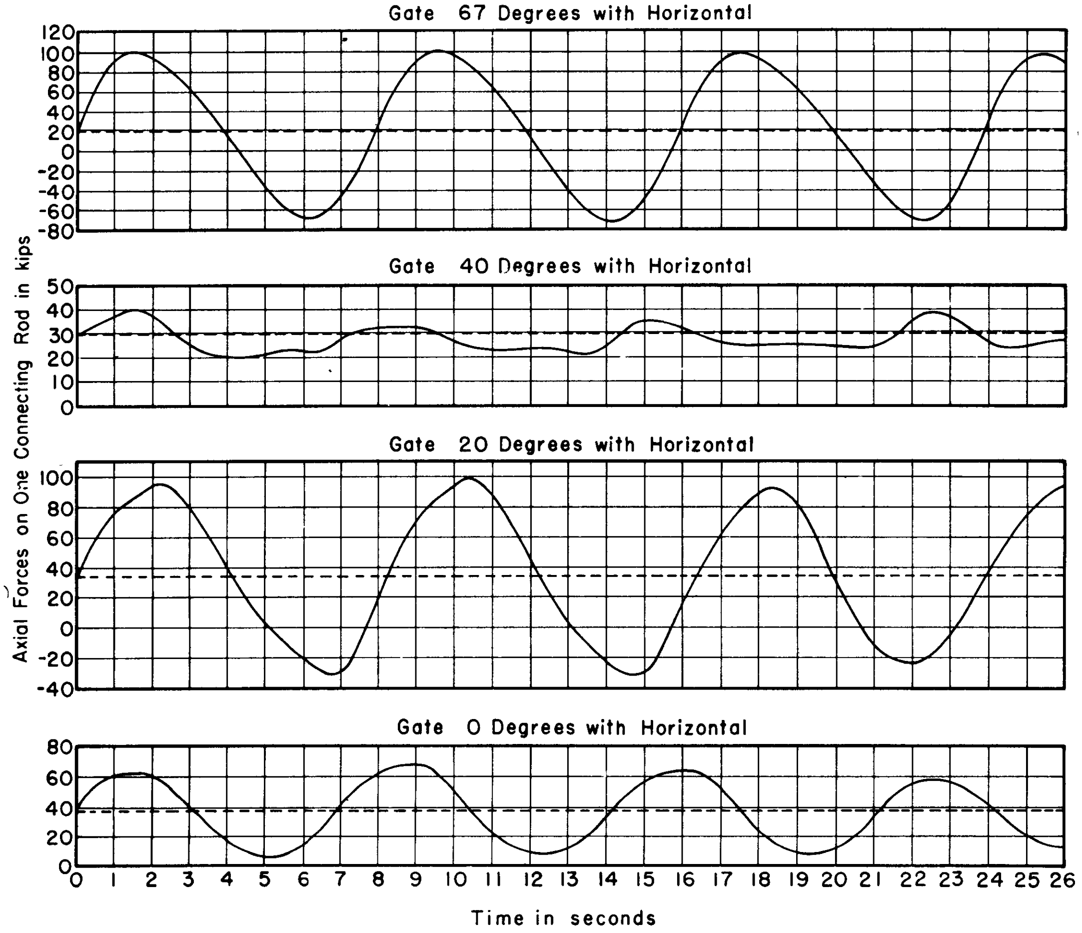

Figure 17 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 22.5 Feet, a Wave Height of 15 Feet, and a Wave Length of 300 Feet

The solid curves denote the forces due to the action of waves, and the broken lines denote static forces on one connecting rod while the dock is in still water.

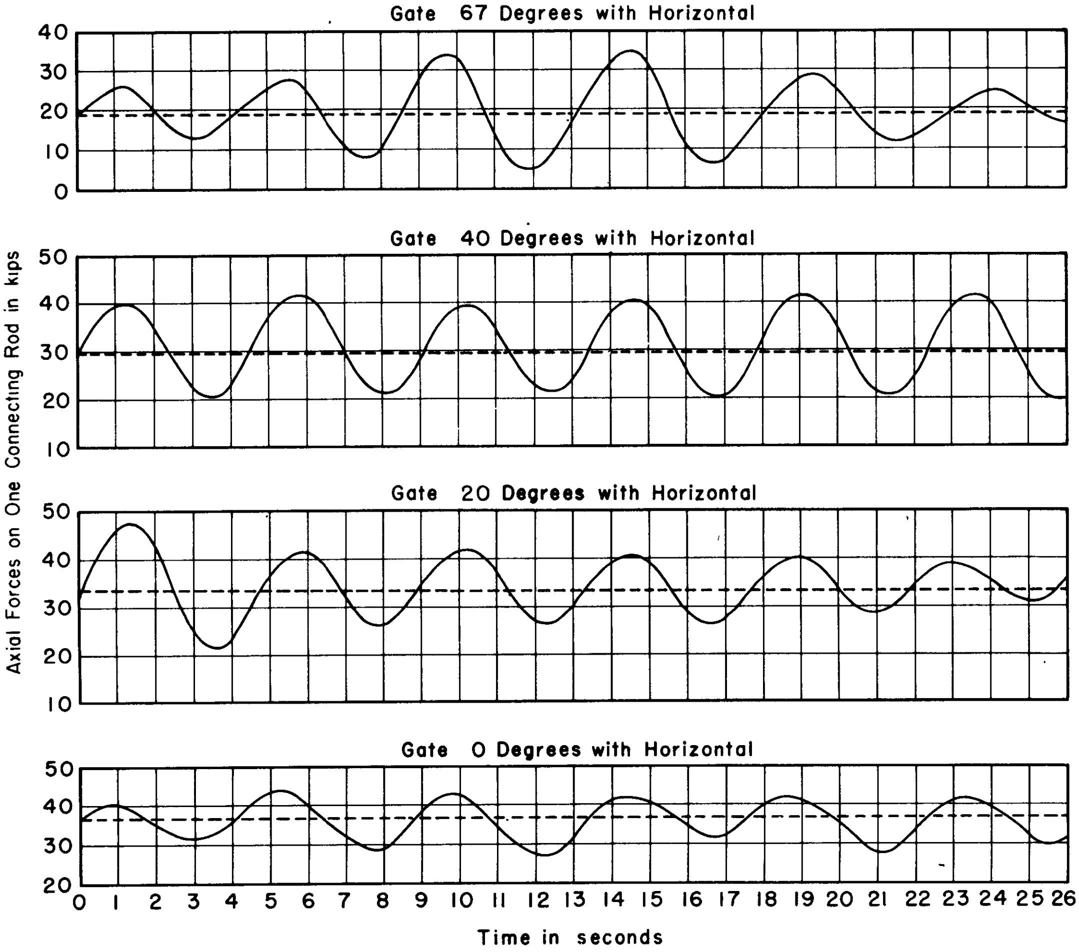

Figure 18 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 25 Feet, a Wave Height of 5 Feet, and a Wave Length of 100 Feet

The solid curves denote the forces due to the action of waves, and the broken lines denote static forces on one connecting rod while the dock is in still water.

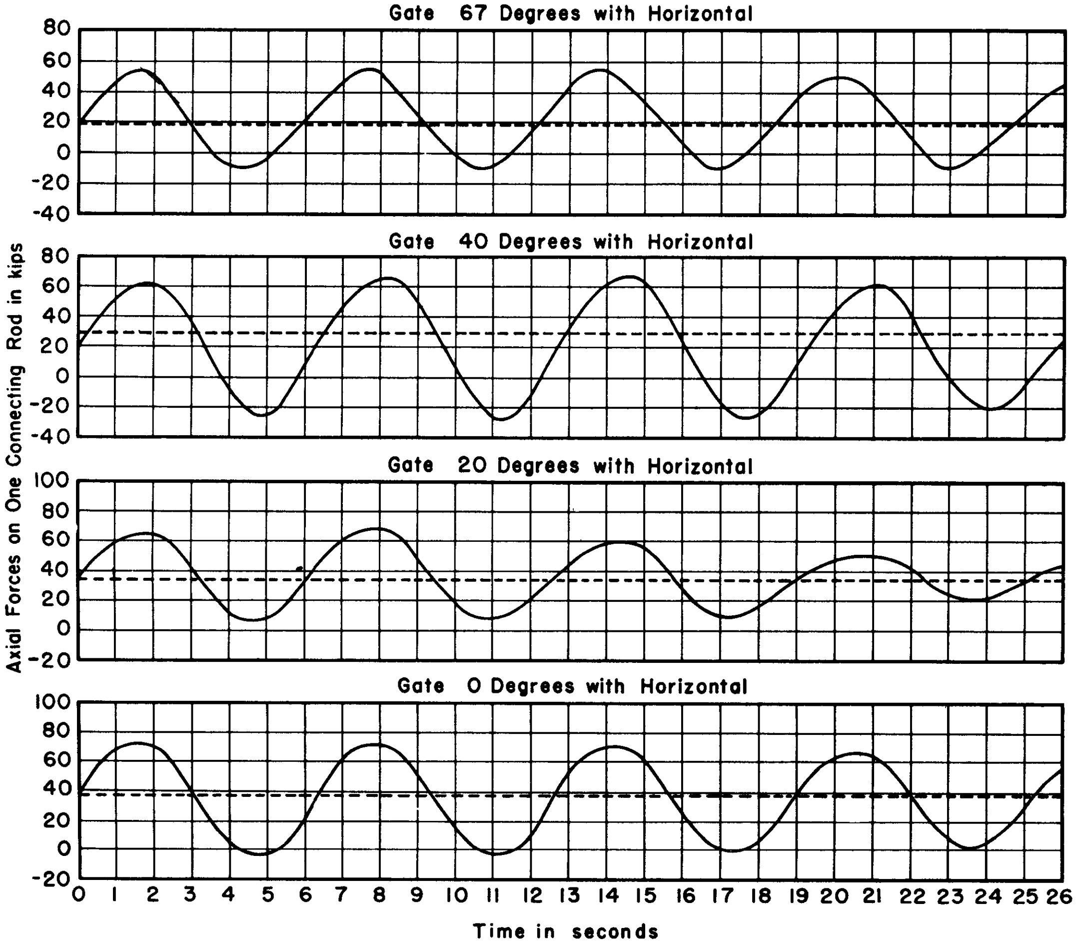

Figure 19 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 25 Feet, a Wave Height of 10 Feet, and a Wave Length of 200 Feet

The solid curves denote the forces due to the action of waves, and the broken line's denote static forces on one connecting rod while the dock is in still waters.

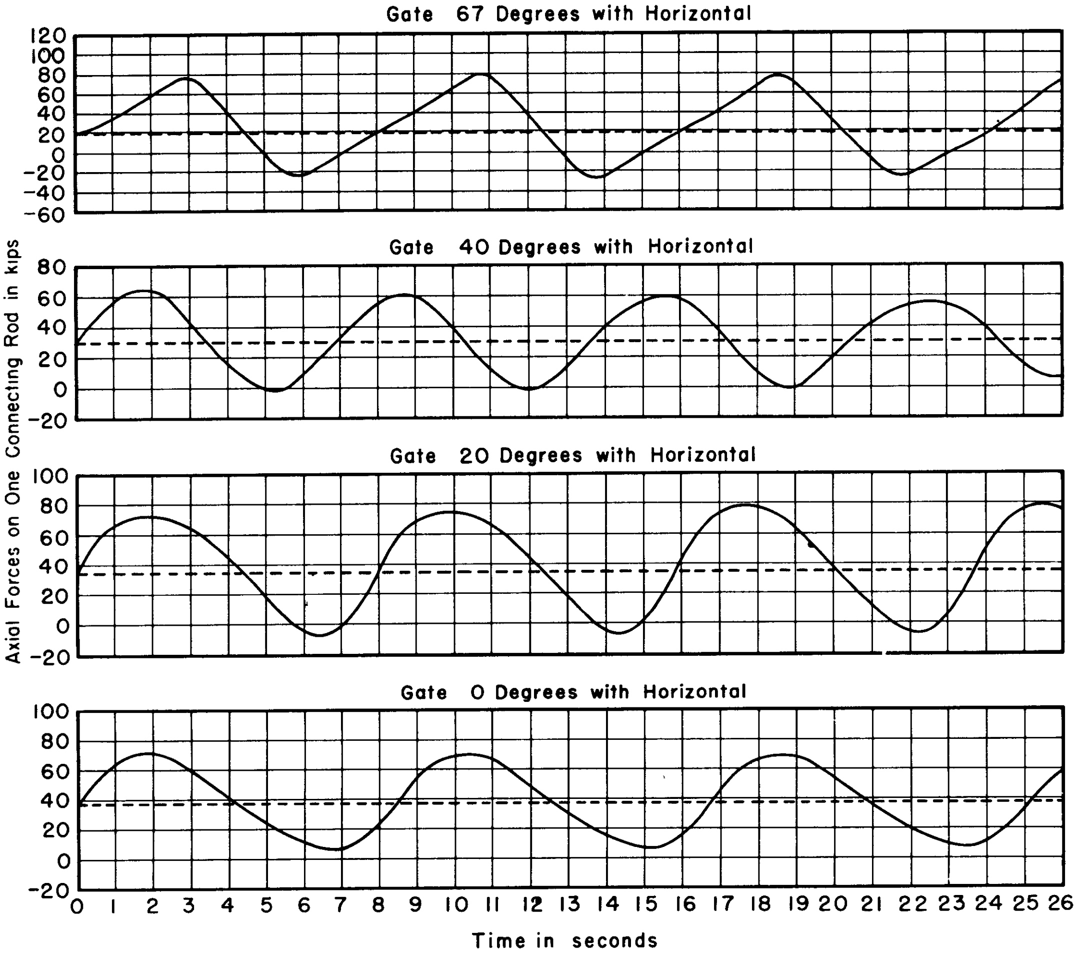

Figure 20 - Axial Forces on One Connecting Rod Plotted on a Basis of Time for a Draft of 25 Feet, a Wave Height of 15 Feet, and a Wave Length of 300 Feet

The solid curves denote the forces due to the action of waves, and the broken lines denote static forces on one connecting rod while the dock is in still water.

TABLE 2

Maximum Forces in One Connecting Rod

Angle of Gate with Horizontal degrees	Wave Length feet	Wave Height feet	Forces Acting to Produce Tension in One Connecting Rod, kips			Forces Acting to Produce Compression in One Connecting Rod, kips		
			Dock in Waves	Dock in Still Water	Total	Dock in Waves	Dock in Still Water	Total
20-Foot Draft								
67	100	5	7.0	21.0	28.0	- 5.0*	21.0	16.0
67	200	10	17.0	21.0	38.0	-16.6	21.0	4.4
67	300	15	35.8	21.0	56.8	-70.0	21.0	-49.0
40	100	5	11.0	29.3	40.3	-10.3	29.3	19.0
40	200	10	24.7	29.3	54.0	-22.9	29.3	6.4
40	300	15	45.2	29.3	74.5	-41.3	29.3	-12.0
20	100	5	4.1	33.9	38.0	- 7.4	33.9	26.5
20	200	10	11.6	33.9	45.5	- 9.9	33.9	24.0
20	300	15	19.6	33.9	53.5	-11.9	33.9	22.0
0	100	5	17.2	36.7	53.9	-18.7	36.7	18.0
0	200	10	41.3	36.7	78.0	-44.3	36.7	- 7.6
0	300	15	51.7	36.7	88.4	-56.2	36.7	-19.5
22.5-Foot Draft								
67	100	5	11.3	19.4	30.7	- 9.9	19.4	9.5
67	200	10	44.6	19.4	64.0	-54.0	19.4	-34.6
67	300	15	83.6	19.4	103.0	-95.0	19.4	-75.6
40	100	5	10.3	29.3	39.6	- 8.8	29.3	20.5
40	200	10	28.6	29.3	57.9	-31.3	29.3	- 2.0
40	300	15	10.5	29.3	39.8	- 8.8	29.3	20.5
20	100	5	12.6	33.9	46.5	-10.4	33.9	23.5
20	200	10	36.5	33.9	70.4	-41.9	33.9	- 8.0
20	300	15	64.7	33.9	98.6	-65.9	33.9	-32.0
0	100	5	15.3	36.7	52.0	-15.2	36.7	21.5
0	200	10	25.6	36.7	62.3	-27.4	36.7	9.3
0	300	15	31.4	36.7	68.1	-30.7	36.7	6.0
25-Foot Draft								
67	100	5	15.5	19.0	34.5	-14.0	19.0	5.0
67	200	10	36.0	19.0	55.0	-29.0	19.0	-10.0
67	300	15	61.0	19.0	80.0	-44.0	19.0	-25.0
40	100	5	12.7	29.3	42.0	- 9.8	29.3	19.5
40	200	10	38.9	29.3	68.2	-57.3	29.3	28.0
40	300	15	35.7	29.3	65.0	-32.3	29.3	- 3.0
20	100	5	13.1	33.9	47.0	-11.9	33.9	22.0
20	200	10	33.4	33.9	67.3	-25.9	33.9	8.0
20	300	15	44.2	33.9	78.1	-41.2	33.9	- 7.3
0	100	5	7.4	36.7	44.1	-10.4	36.7	26.3
0	200	10	35.0	36.7	71.7	-40.7	36.7	- 4.0
0	300	15	34.8	36.7	71.5	-30.4	36.7	6.3

* Forces in compression are denoted by a negative sign.

DISCUSSION OF RESULTS

The maximum force recorded in this series of tests occurred at a gate position of 67 degrees with the horizontal, a wave height of 15 feet, a wave length of 300 feet, and a draft of 22.5 feet. This force amounted to 103 kips on one connecting rod on the prototype. Resolving this force by the laws of mechanics on the component parts of the gate-operating mechanism,* stresses in the various members have been calculated; these stresses are shown in Table 3.

TABLE 3

Calculated Stresses in the Structural Members of the Gate-Operating Mechanism

Member	Force kips	Area square inches	Stress pounds per square inch
Connecting rod	103	38.5	2680 (tension)
Rod-gate pin	103	9.6	5360 (shear)
Crosshead pins	103	9.1	5660 (shear)
Piston rod	103	31.9	3230 (tension)

The pressure within each hydraulic cylinder while the valves are closed is 807 pounds per square inch when a force of 103 kips is exerted.

During the tests it was observed that the maximum force occurred when water from within the docking chamber poured over the inside upper edge of the gate, causing a considerable amount of drag accompanied by a surge of water within the gate itself.**

It is apparent, from the values listed in Table 2, that there is no correlation of maximum forces for the various gate positions and dock drafts. A definite trend, however, is exhibited between the forces developed when the dock is in waves of different dimensions; higher waves produce larger forces.

CONCLUSIONS

As far as the strength of the gate-operating mechanism is concerned, lowering and raising of the gate when the dock is pitching in 15-foot waves 300 feet long should present no difficulties.

---

* The arrangement and details of this mechanism are shown on a plan prepared by the Pacific Bridge Company, dated 18 October 1944, carrying Bureau of Yards and Docks drawing number 266416.

** The gate is reinforced on the inside by girders as described in Reference (3).

REFERENCES

(1) BuDocks letter ARD-12, D-5-1-6 of 11 November 1944 to TMB; TMB file N16-5.

(2) "Structural Models, Part I: Theory," by Lt. R.D. Conrad (CC), USN, C. and R. Bulletin 13, 18 June 1938, p. 11.

(3) "Free-Fall Test of a Model of the Gate of an ARD12-Class Floating Drydock," by M. Gertler, TMB RESTRICTED Report R-303, August 1946.

(4) "A Carrier-Type Strain Indicator," by George W. Cook, TMB Report 565, October 1946.