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WAVE-WIND CURRENT RESEARCH FACILITY

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Scripps Institution of Oceanography

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TECHNICAL REPORT

WAVE-WIND-CURRENT
RESEARCH FACILITY

Robert Oversmith

SCRIPPS INSTITUTION OF OCEANOGRAPHY
University of California, San Diego
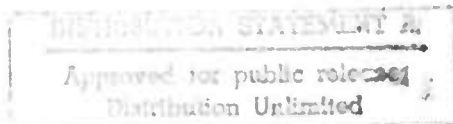Dr. William A. Nierenberg, Director

ADVANCED OCEAN ENGINEERING LABORATORY

sponsored by

October 1, 1970

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Acknowledgements

Recognition is given to the following six persons
who have been involved intensely in the development
and operation of the facility:

John D. Powell and Wesley A. Dillon	Design, construction, and operation of the channel, wave generator, and equipment
Donald R. Bellows	Wave pressure field measurements and Model Test Engineer
Loren N. Van Hoy	Operation of auto collimator and development of light flashing system and data monitoring system.
Dudley B. Mills	1130 computer programming

The design concept for the facility and guidance
during construction were provided by the SIO
Hydraulics Panel under the chairmanship of Dr.
Douglas L. Inman.

SUMMARY

This report gives a general description of the
new Wave-Wind-Current Research Facility placed into
operation by the Advanced Ocean Engineering Laboratory
of Scripps Institution of Oceanography in 1970.
The unique installation was developed to support
hydrodynamic research associated with large floating
ocean platforms and other structures in the sea and
studies of air-water and water-sediment interactions.

Three experimental programs have been undertaken
at this date using the facility: measurement of
motions of various configurations of floating platform
1/100 scale models; measurement of motions of tethered,
submerged, buoyant bodies; and measurement of moments
on bottle-shaped platform leg 1/100 scale models.

The channel has a length of 146 feet, a width of 7
feet - 10 inches and a maximum water depth of 6
feet - 6 inches. The floor of the channel was
placed 16 inches above grade to permit easy
installation of research instruments through the
floor and walls in studies of wave dynamics and
wind-wave interactions. The channel is located in
the Hydraulics Laboratory Building on the Scripps
Institution Campus.

The principal components of the facility include:
 Generator for regular and irregular waves
 Wave absorber at opposite end of channel
 Capacitance wave height staff
 Bi-axial auto collimator for tracking motions
 of bodies
 Light flashing system for tracking two targets
 simultaneously
 1130 computer to give on-line data processing
 and spectral analysis
 Wind generating system
 Current generating system

The experiments conducted thus far have been made using regular motions of the wave generator. The production of irregular waves and on-line data processing and spectral analysis are scheduled for calendar year 1971. The wind and current generating systems are still under construction.

The formation of the Advanced Ocean Engineering Laboratory in January 1969, the research on floating platform technology by the laboratory, and the development of the Wave-Wind-Current Research Facility were instigated by Dr. William A. Nierenberg. The principal investigator on the floating platform project is Dr. Fred N. Spiess. The Wave-Wind-Current Research Facility was designed by John D. Powell and Wesley A. Dillon under the direction of Dr. Charles S. Cox and Dr. Douglas L. Inman.

Channel

The general configuration of the channel is drawn in Figure 1 and photographs showing various details are given in Figures 2 through 4.

The channel has an inside length of 146 feet, an inside width of 7 feet - 10 inches, and a maximum water depth capability of 6 feet 6 inches. The distance from the wave paddle to the toe of the wave absorber is 98 feet.

The channel has a small width relative to length and was designed to support research for the case of a single direction sea. Six, one inch thick plexiglass windows permit the direct observation of models from the side. Most experiments to date have been conducted at the 8 by 8 foot window near the center of the channel.

The floor of the channel was constructed 16 inches above grade to facilitate the installation of research equipment through the floor and walls. Galvanized steel truss frames are spaced 2 feet on center over the entire length. The frames have high rigidity and allow only small deflections due to water loads (less than 0.05 inches at the water line with the maximum water depth of 6 feet - 6 inches). The walls are straight, within $\pm$ 0.1 inches. Three-foot wide working platforms three feet below the top of the channel along each side provide additional strength and rigidity.

The floor and walls are constructed of exterior plywood $1\frac{1}{2}$ and 1 inch thick respectively. An

interior liner of epoxy fiberglass is approximately
0.06 inches thick. Various methods of coating the
interior were investigated and tested, including
elastomeric linings and polyester resin fiberglass.
A lining composed of two layers of fiberglass cloth
laminated with an Aromatic-Amine cured epoxy resin
was finally selected because of its dimensional
stability, superior strength and elasticity, and
impermeability to water. The liner is finished
with a white pigmented resin gel coat.

The wood and fiberglass construction is easily
modified and repaired for removal of instruments and
probes through the floor and sides of the channel.

Wave Generator

The wave paddle is suspended from the building
overhead by four bar linkages as shown in Figures
1 and 5. The top right pivots in Figure 1 are at
fixed locations while the top left pivots are
moveable to permit adjusting the paddle motion.
With the distance between top pivots set equal to
distance between bottom pivots the paddle motion
is coplanar without rotation which may be desirable
in shallow water wave research. When the distances
are not equal, the paddle experiences both translation
and rotation as may be required in certain deep water
wave research.

The suspension provides convenient means for
retracting the paddle from the channel. It isolates
the reactions of the drive machinery from the channel
structure.

The wave paddle is driven by an electric-hydraulic
servo system shown schematically in Figure 6. The
system is designed to provide either regular or
irregular motions. At this date, only regular
operation has been attempted and a single electronic
function generator has been used to provide commands.
It is planned that irregular motions will be commanded
by spectra that are prerecorded on magnetic tape.

The wave generator may be operated from a control
panel near the wave paddle or from a remote wire
connected station.

Satisfactory forms of regular waves have been
obtained in experiments already conducted with a

still water depth of 70 inches for wave periods of
0.8 to 0.9 and 1.3 to 4.0 seconds. Transverse
resonant oscillations develop at periods of about
0.5, 0.7, and 1.0 seconds and there are significant
changes in wave height across the channel. Longi-
tudinal standing waves appear at periods of 1.0,
1.2, and 2.2 seconds which give appreciable
differences in wave height along the channel. Wave
height values in the model experiments have commonly
been 1.5, 2.5, 2.8, and 3.4 inches.

The maximum wave height obtained with the 70 inch
water depth is 15 inches at a period of 1.5 seconds.
The maximum wave height is smaller at periods below
1.5 seconds because of the tendency of the waves to
break. The heights are reduced at periods above
1.5 seconds due to the limited stoke of the wave
generator paddle. The maximum wave height with a
48 inch water depth is 24 inches at a wave period
of 2.0 seconds.

Wave Absorber

The wave absorber is shown in Figures 1 and 7. A beach of asbestos concrete material is supported by the floor of the channel. The beach is in two sections having lengths of 6 and 34 feet. The shorter section originates from the floor and has a slope of 15 degrees, while the longer section has a slope of 7.2 degrees.

An array of standard concrete blocks 8 by 8 by 16 inches is placed on the beach with open cores up. The blocks are spaced 6 inches apart in both the longitudinal and lateral directions relative to the channel to give, in effect, a fairly regular thin wall cell structure. A two inch thick blanket of rubberized animal hair is located on top of the blocks and is held in place by six $\frac{1}{2}$ inch diameter stainless steel tubes oriented longitudinally.

It is believed that the resulting wave absorber formed by the combination of treatments, i.e., the beach, the core, and the blanket, is quite efficient for wave periods in the present studies except at periods where longitudinal standing waves occur (1.0 to 1.2 and 2.2 seconds). This judgement has been reached from visual observations of waves, recorded measurements of wave heights, and recorded measurements of wave pressure fields.[1]

The beach with only one treatment, either the core or blanket alone, gives wave feedback which can be seen readily over a wide range of wave periods. With the beach bare, the feedback is unacceptable for the purposes of the present research.

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[1] Don Bellows, "Wave Pressure Calibration of Wave-Wind-Current Research Facility," Advanced Ocean Engineering Laboratory Report No. 12, Scripps Institution of Oceanography, October 1970

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Capacitance Wave Height Staff

The capacitance wave height staff was developed
initially in 1968 by Richard C. Stettler to read
crest-to-trough wave heights on a meter. An
adjustable automatic time delay held outputs in
the meter long enough for visual reading. The
range of wave height was 10 inches. The instrument
was modified in 1970 by Loren N. Van Hoy to give
continuous reading of wave height and send the
outputs into a chart recorder and the 1130
computer.

The wave height sensor consists of two brass rods
supported vertically through the interface. One
rod is shielded with dielectric tubing while the
other is bare. The probes form a variable capacitor
which is sensitive to the height of the water.

The sensor is connected to a transformer driven by
an RF oscillator. Considerable electronic circuitry
is employed in the processes of rectifying, filtering,
matching, referencing, and amplifying the signal from
the transformer secondary. Techniques are used to
obtain good linearity over the 10 inch range as
shown in Figure 8. Measurements from the instrument
have been checked dynamically by careful visual
measurements of wave height from a meterstick.

Auto Collimator

Requirements were established in the present research investigations to measure the motions of models moving in a seaway without having any instrumentation aboard the models and without any mechanisms attached to the models. It was desired to do the tracking from outside the channel while viewing through a side window.

Conventional methods for measuring model motions include using accelerometers placed inside the models with wires routed ashore and using sensing devices which are attached mechanically to the models. Neither of these techniques seemed desirable here due to the small sizes of the 1/100 scale models and the effects which wires or mechanisms could have on the motions of the models.

A Physitech Model 440 bi-axial auto collimator was selected to fulfill the assignment after investigating several different approaches. A 50 mm lens is used with the optical head (Figure 9). With the lens placed 13 feet from the window the field of view is approximately 2 feet square.

The models are finished in a dark dull color and are provided with white targets 2.4 inches square at appropriate locations as shown in Figure 10. The targets are illuminated from the side.

The collimator completely scans the field of view 30,000 times per second in both the vertical and horizontal directions. Position coordinates of the target are given by DC voltage outputs. The collimator has no mechanical parts which are required to move during tracking.

The calibrations of the vertical and horizontal
outputs of the collimator are quite linear and
are given in Figure 11. It has been necessary in
tracking a target that is submerged to keep the
water in the channel reasonably clean due to the
scattering of light by particles in suspension.

Light Flashing System

A light flashing system has been developed to provide the capability of tracking two targets simultaneously with a single auto collimator. The targets are illuminated alternately and the collimator reads the vertical and horizontal locations of whichever target is lighted.

The 1130 computer is used to process heave and surge data and to calculate pitch angle motions. A sample 1130 computer data plot of heave and surge trajectories for one target is given in Figure 12.

Each target is lighted approximately ten times per second. The collimator requires finite time to lock on the targets and readings are taken with a time delay when the collimator output voltages are stablized.

A 1/100 scale model of FLIP equipped with two targets is shown in Figure 10. An image splitter formed with two mirrors is employed to display both targets in the field as may be seen in Figure 13.

The light flashing system uses four modified 40 watt fluorescent tubes per target. The filaments are energized full time. The gas is ionized by high voltage transistorized triggering. A black hood has been constructed over the entire working area from the collimator to the far side of the channel to keep out ambient light.

1130 Computer

The capabilities derived from employing the 1130 computer in the present research activities include the following:

1) On-line processing of data with the elimination of delays, labor, and innaccuracies of longhand data reduction.
2) Spectral analyses of wave height, wave pressure field, model motions, and other data with regular motions of the wave generator to determine the real degrees of physical regularity.
3) Spectral analyses of wave height, model motions, and other data with irregular waves.
4) The sampling frequency is adequately fast to permit the processing of data with the two target light flashing system.
5) The computer can perform quickly a variety of theoretical calculations such as motion responses, wave pressure fields, and BG separation.

Wind Generator

The wind generator under construction (Figure 14) will permit the testing of models of ocean platforms in the environment of both waves and wind. The facility will be useful also in research of wind-wave interactions.

The top of the channel will be covered along its entire length. Air will be inducted from the wave generator end of the channel by a 78 inch diameter variable pitch axial flow fan at the beach end.

A 40 horsepower hydraulic motor driving the fan is expected to produce air flow velocities up to 60 feet per second with 4 feet of water in the channel.

Current Generator

A recirculating water flow system to provide current
in either upstream or downstream direction relative
to the waves is presently under construction. A
hydraulically-driven pump and the water main will
be located below the channel. The maximum water
flow rate will be approximately 5000 gallons per
minute. With a 70 inch water depth in the channel,
the maximum current velocity will be of the order
of 0.2 feet per second.

Advancements and Comments

It seems appropriate to discuss what may be advancements in the wave channel model testing technology. These include: (1) the use of an auto collimator for tracking, (2) the employment of a light flashing system for tracking two targets simultaneously with one collimator, and (3) the on-line processing of regular and irregular test data by digital computer. The complete data acquisition concept is shown diagramatically in Figure 15.

The setting up, development, synchronization, and calibration of the equipment has been complicated, time-consuming, and, at times, frustrating. Competent technical people are required to operate and maintain the systems. It is felt that the benefits derived certainly justify the effort expended.

The wave generator and wave absorber give good quality waves except at certain periods as discussed on pages 7 and 8. The wood-epoxy fiberglass floor and wall construction has given no problems and does permit the easy installation of research equipment. The placement of the floor of the channel 16 inches above grade gives good access and the climbing up and down has been good exercise.
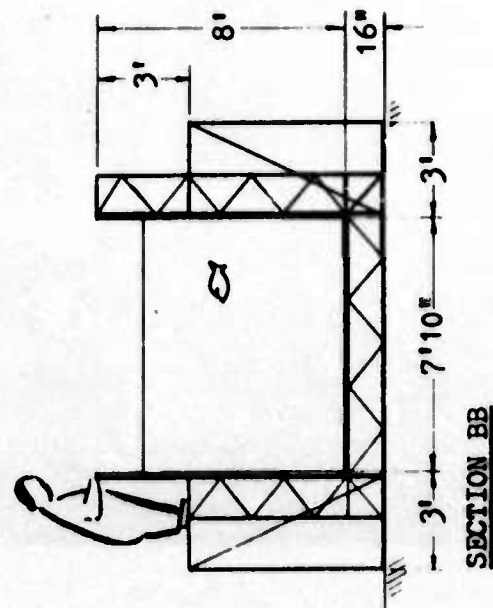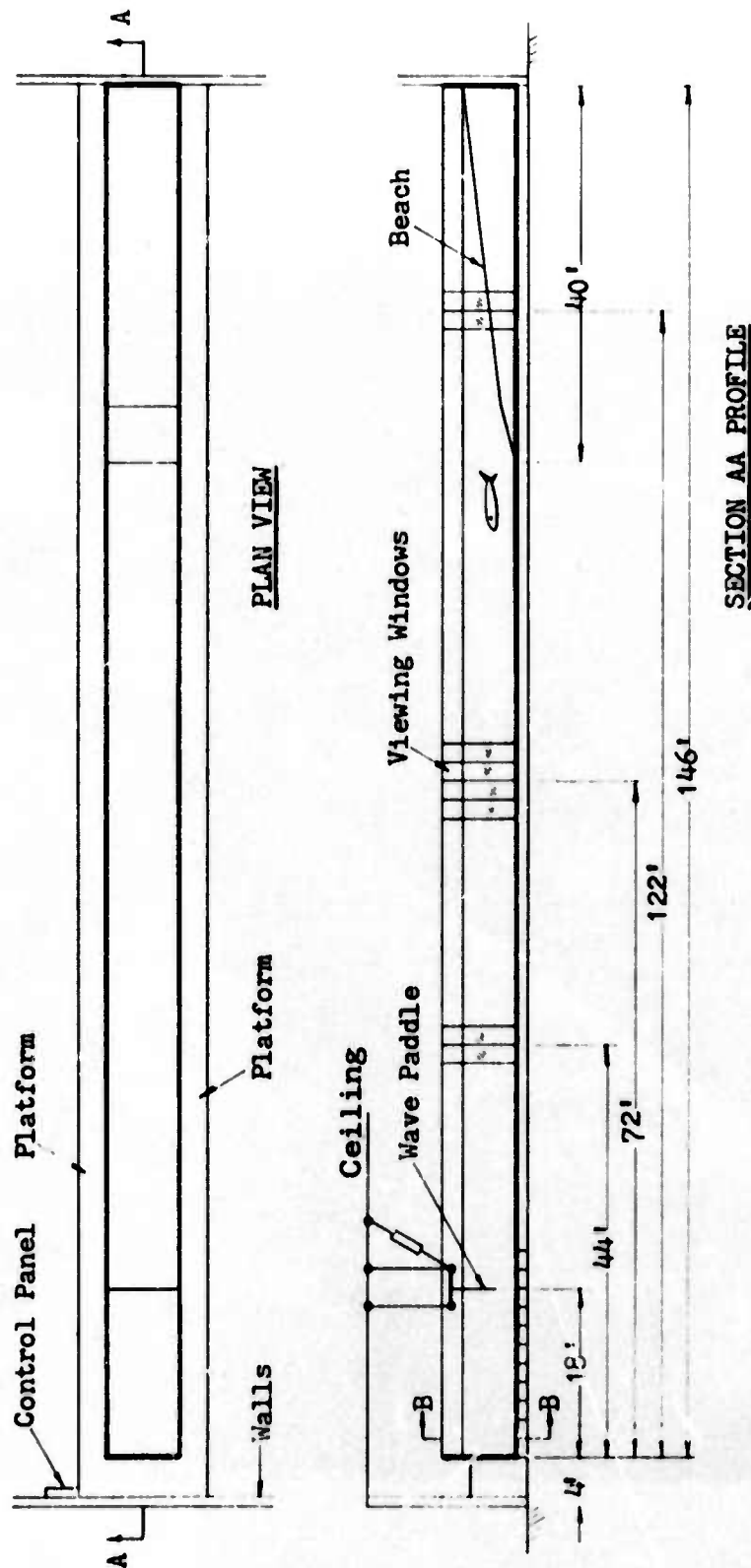
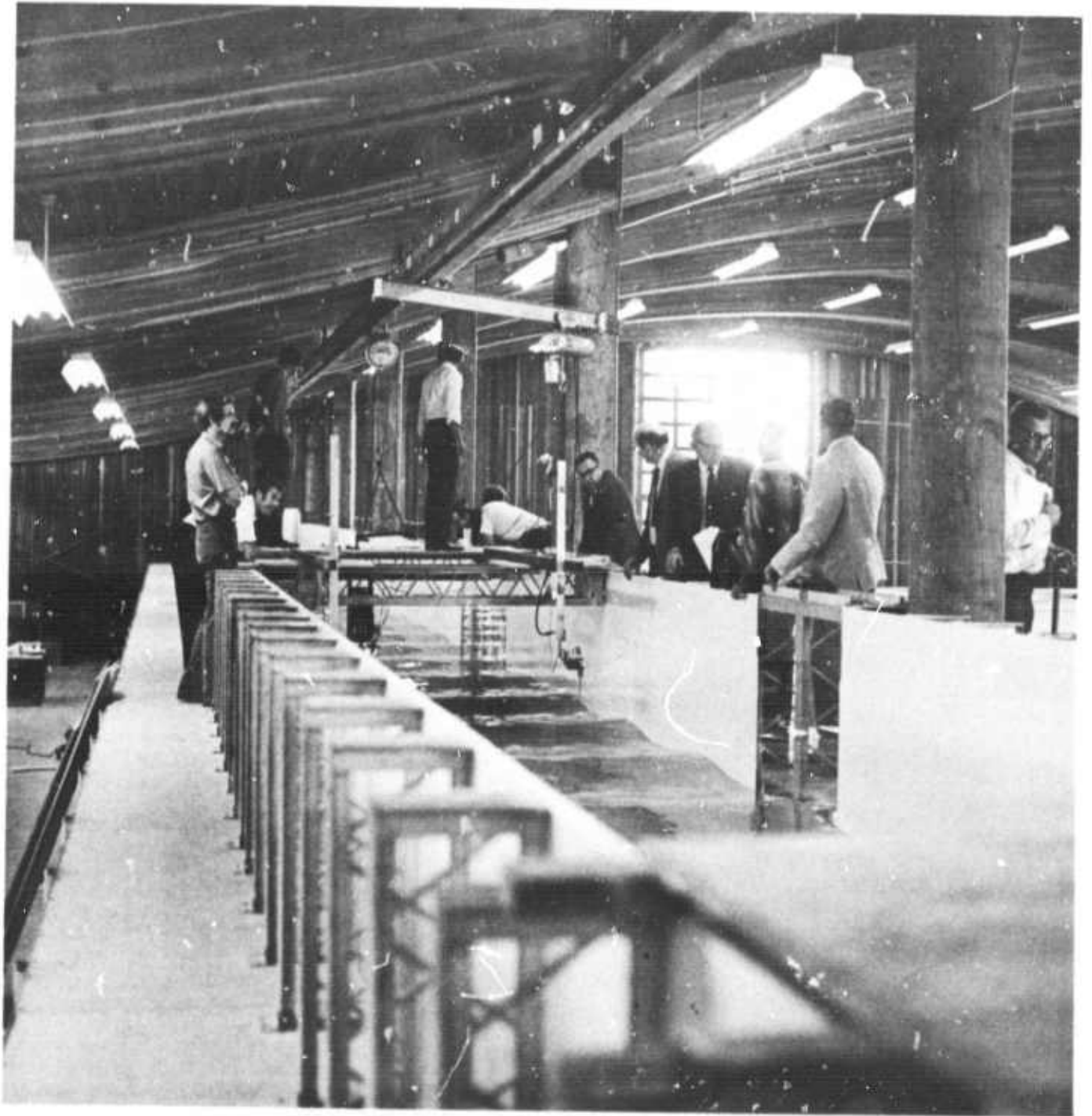Figure 1. General Configuration of the channel.

PLAN VIEW

Control Panel   Platform

Platform

Walls

A

A

SECTION AA PROFILE

Ceiling

Wave Paddle

Viewing Windows

Beach

B

B

18'

4'

44'

72'

122'

146'

40'

SECTION BB

3'

8'

3'

16"

7'10"

3'

-17-

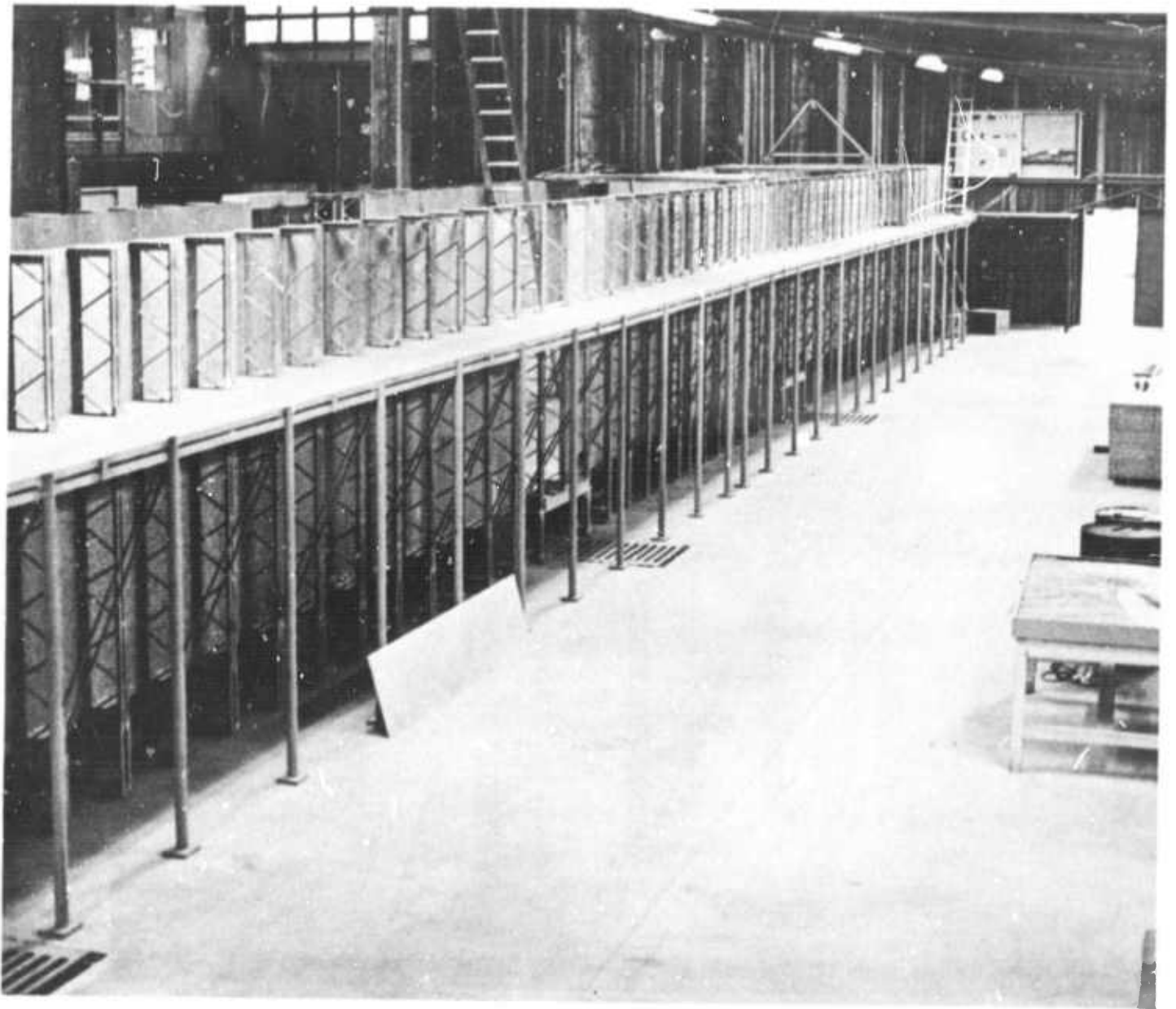Figure 2. Channel viewed from location of wave generator.

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Figure 3. Galvanized steel truss frames are spaced 2 feet on center over the length of the channel.
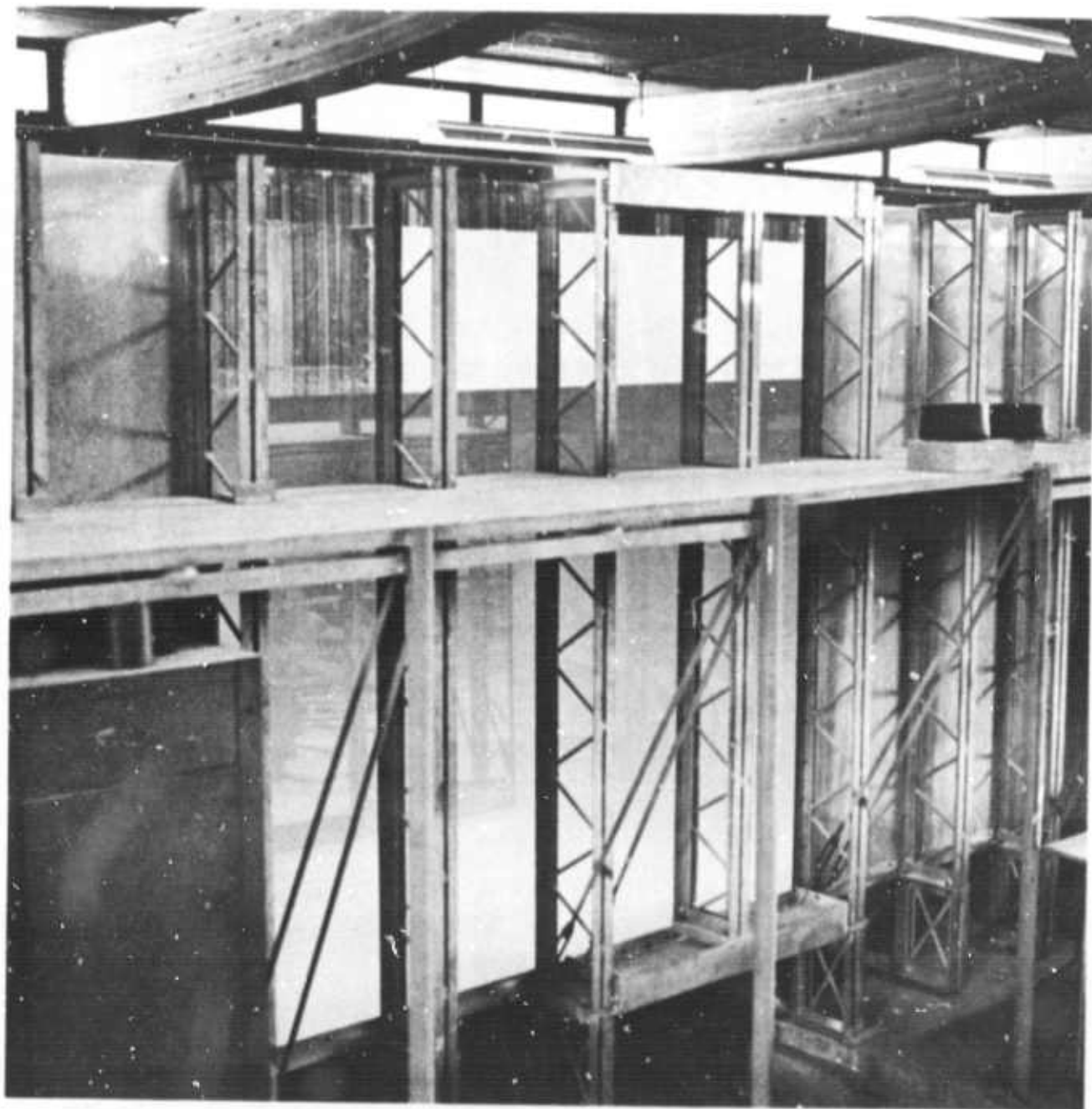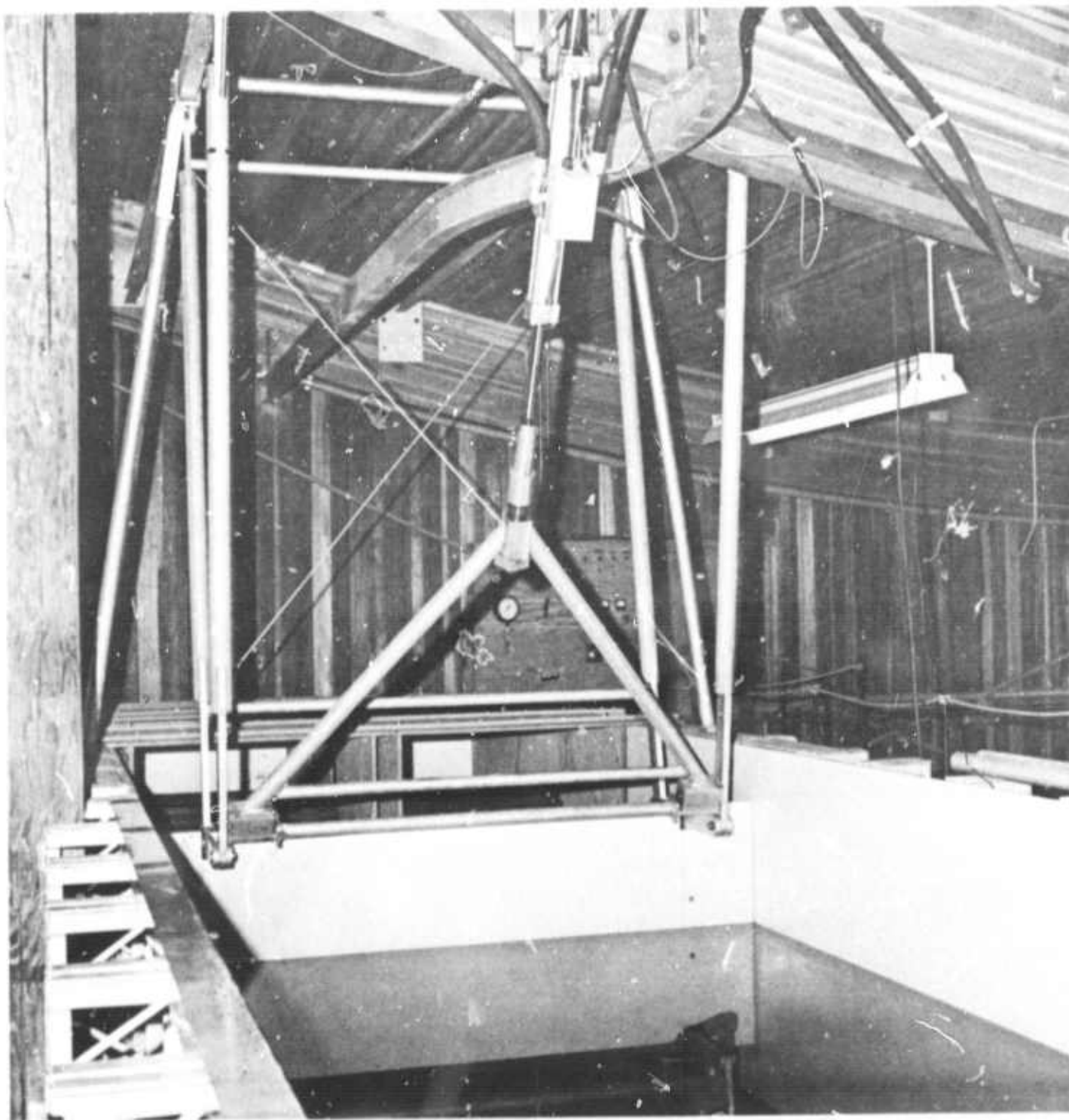
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Figure 4. The 8 by 8 foot viewing window.

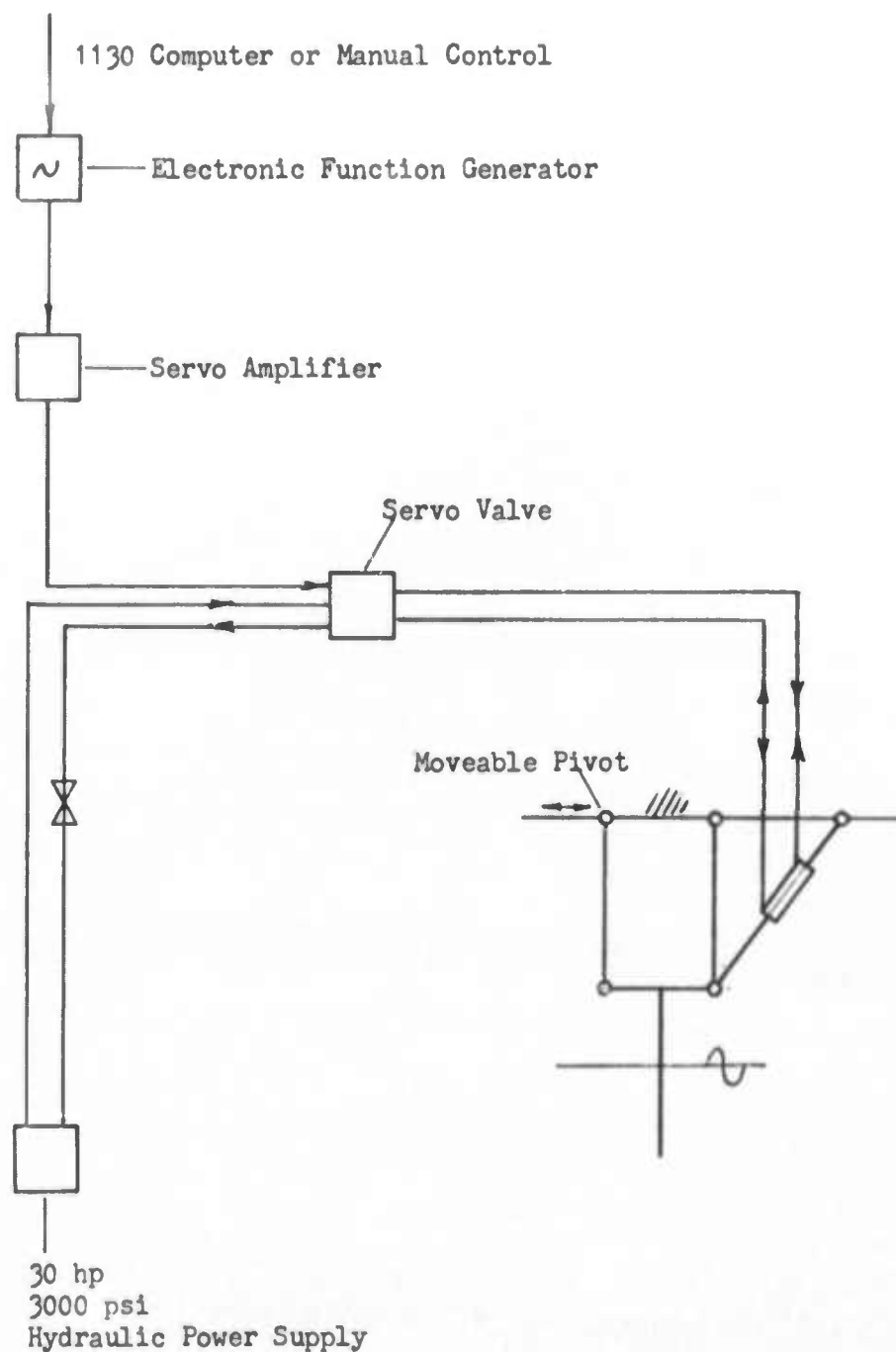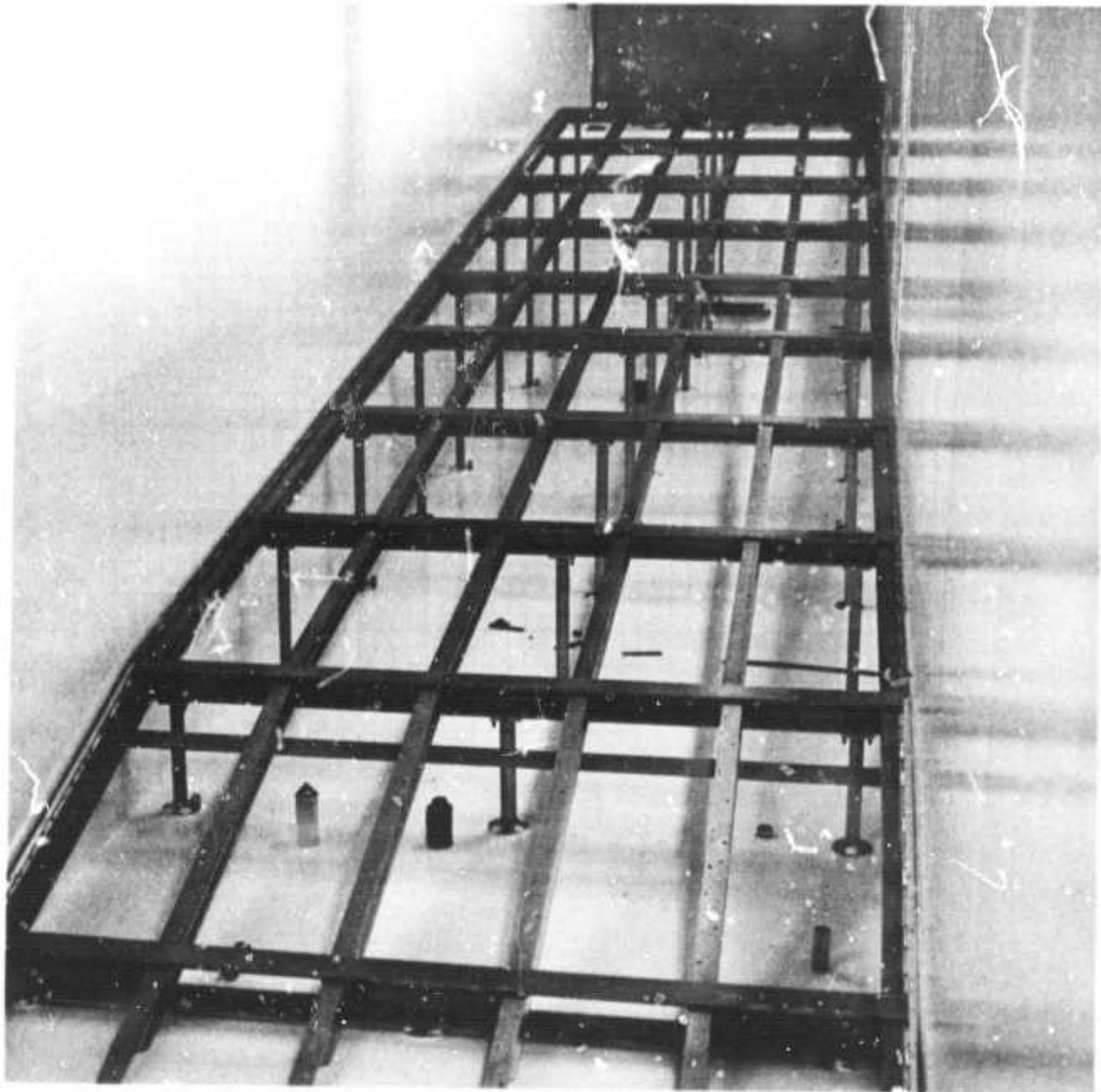Figure 5. The wave paddle, suspension mechanism, and hydraulic cylinder.

1130 Computer or Manual Control

□∿□ ——Electronic Function Generator

□ ——Servo Amplifier

Servo Valve

Moveable Pivot

30 hp
3000 psi
Hydraulic Power Supply

Figure 6. Wave Generator Schematic.

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Figure 7. Support structure for wave absorber beach.
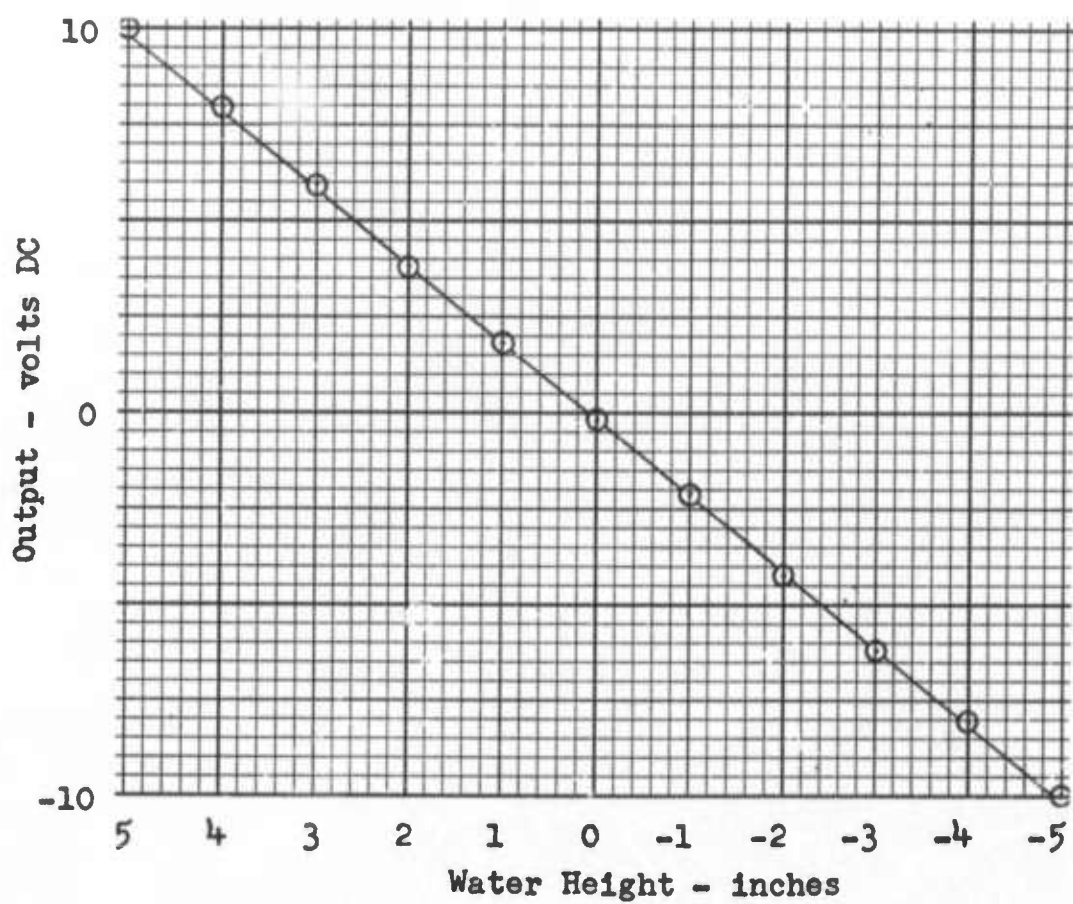
Figure 8. Calibration of Capacitance Wave Height Staff.
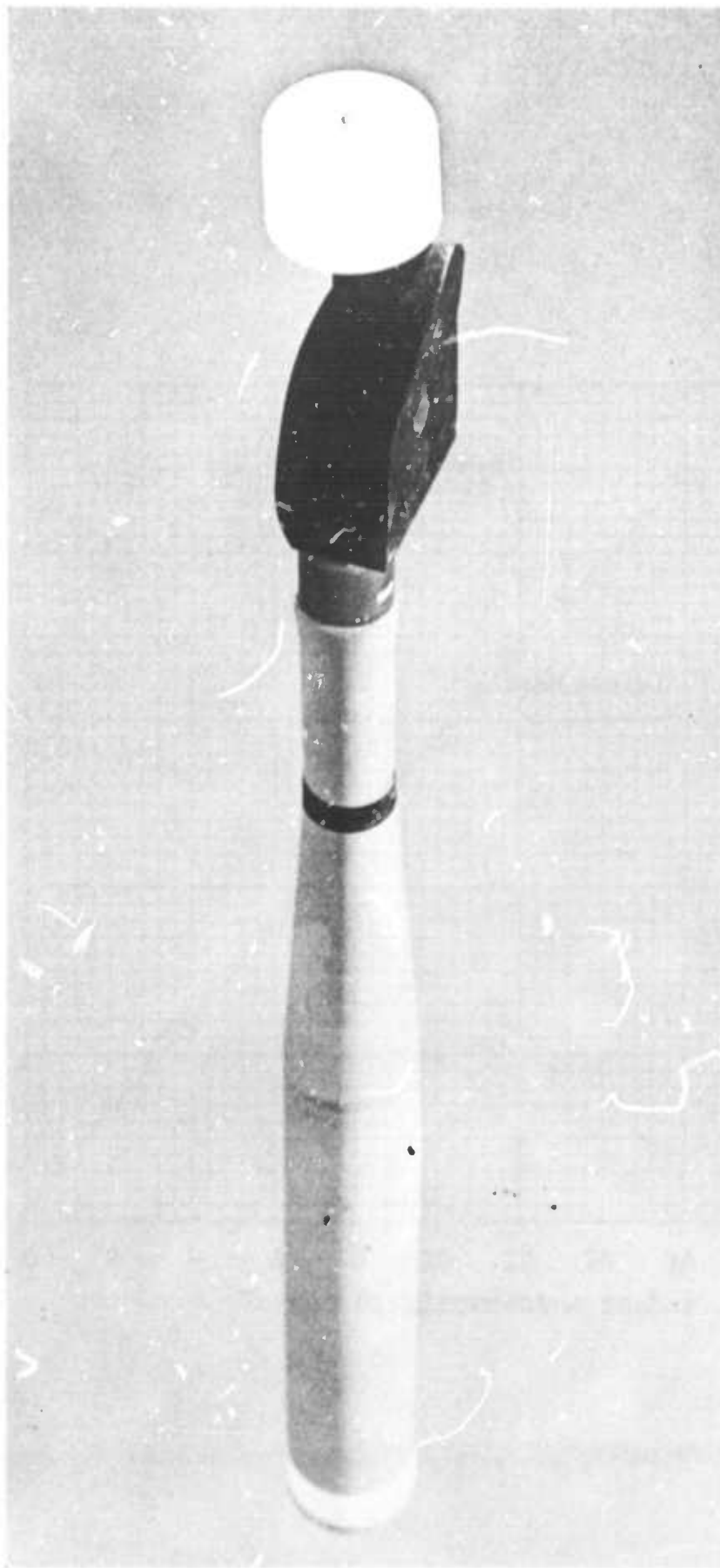
Figure 9. Auto collimator optical head.

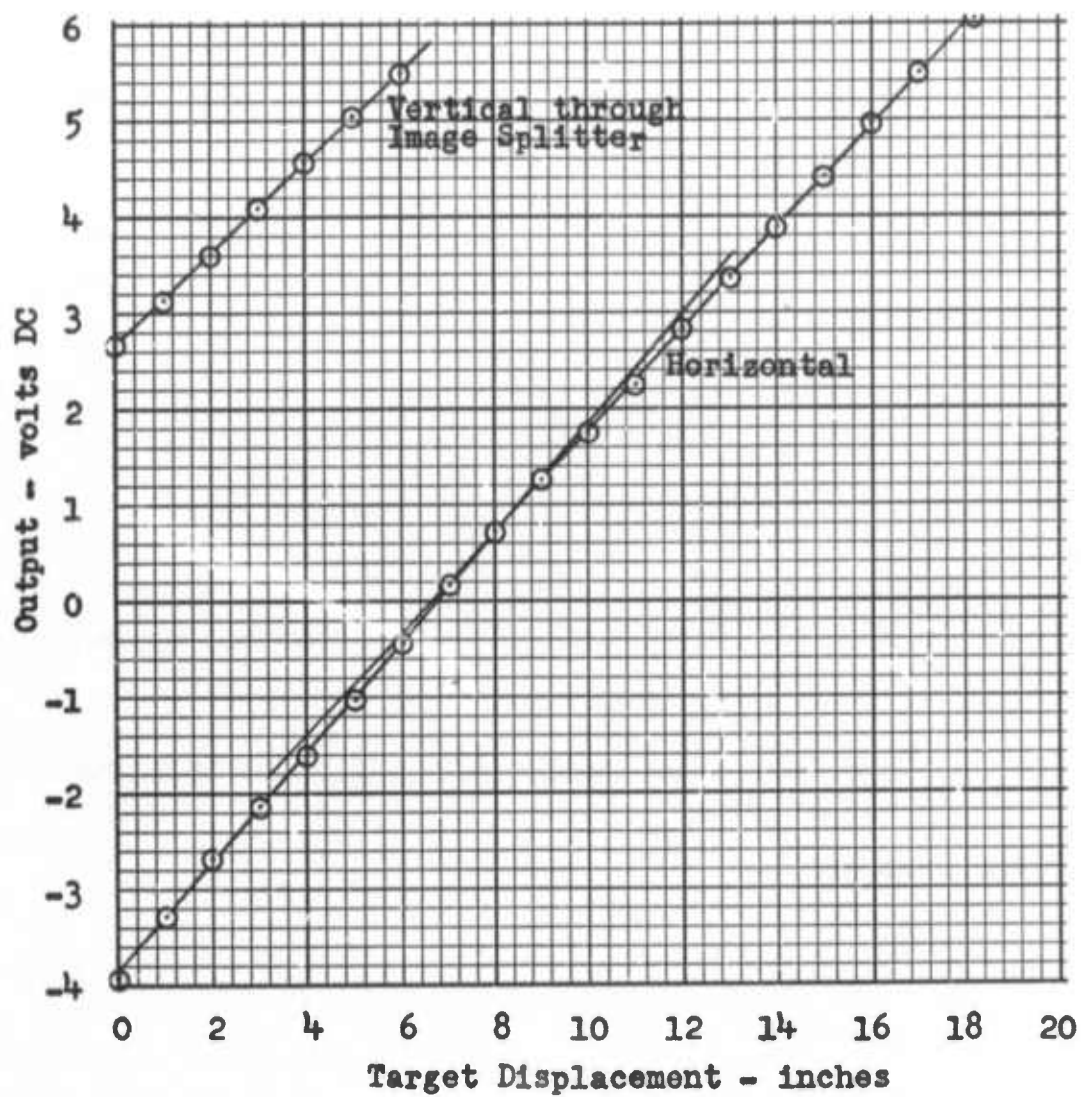Figure 10. 1/100 scale model of FLIP equipped with two targets.

Figure 11. Calibration of Auto Collimator.

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CHAN 1 MAX=   7608   MIN= -4232   AVG=   1897·05

                                                              Heave

CHAN 2 MAX=   3540   MIN= -7368   AVG=   -1458·72

                                                              Surge

CHAN 3 MAX=   3140   MIN= -8063   AVG=   -2327·20
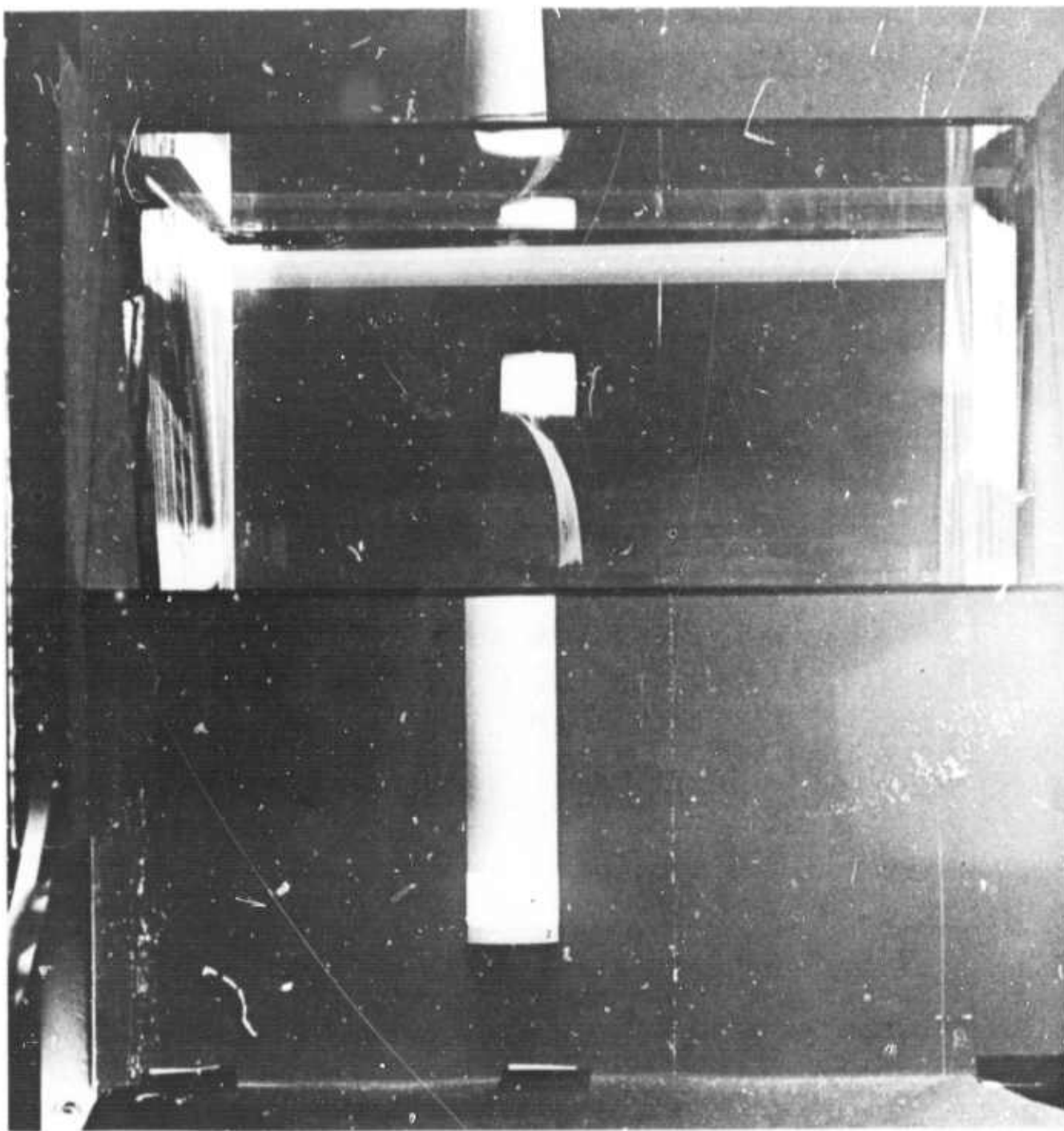
                                                              Wave Height

Figure 12.   Sample 1130 computer data plot for one target.

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Figure 13. View of 1/100 scale FLIP model through image splitting mirrors.

78 inch diameter Joy Fan
variable pitch

4 x 8 ft top covers

Straightener

Filter

40 hp Hydraulic Motor

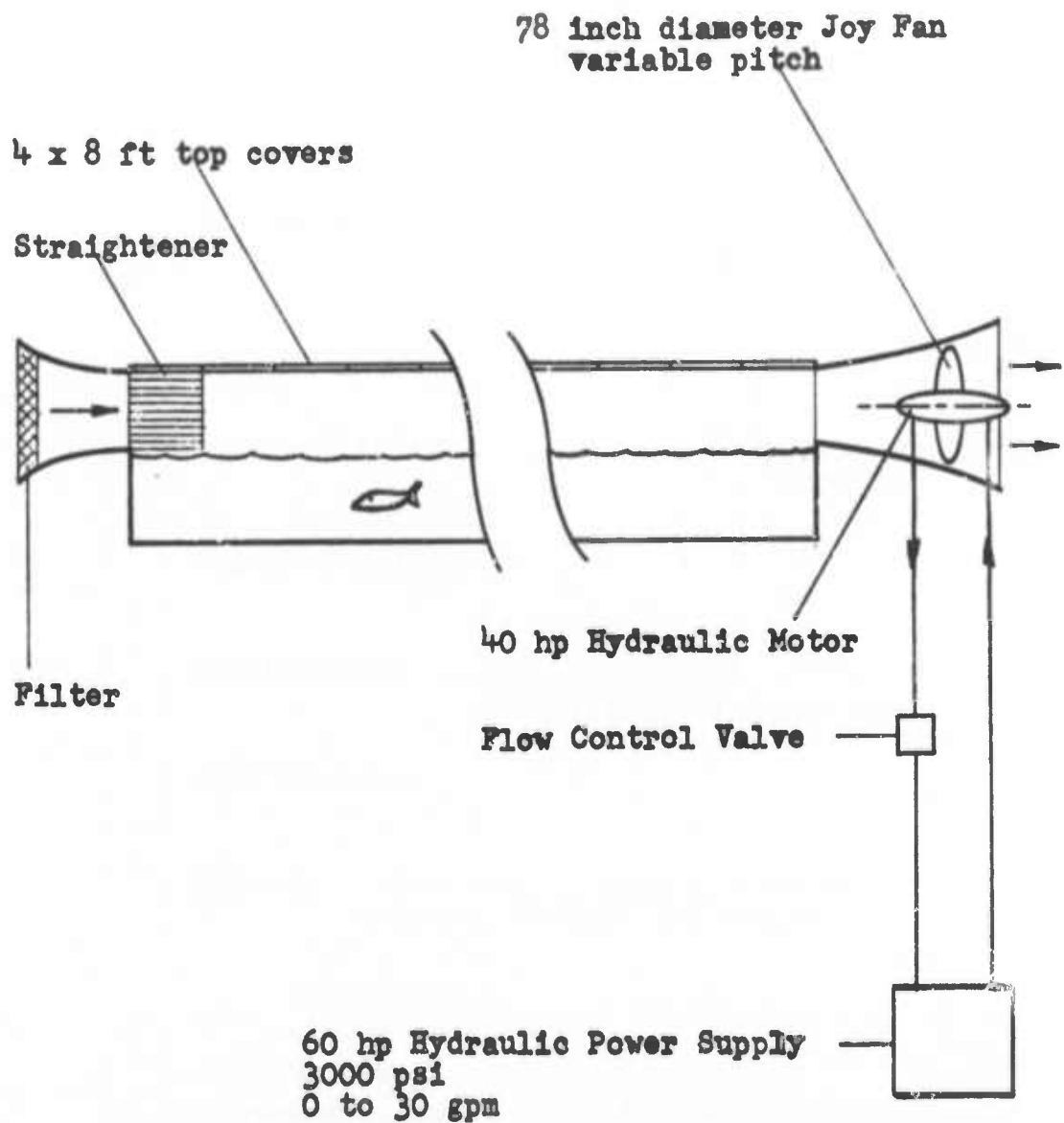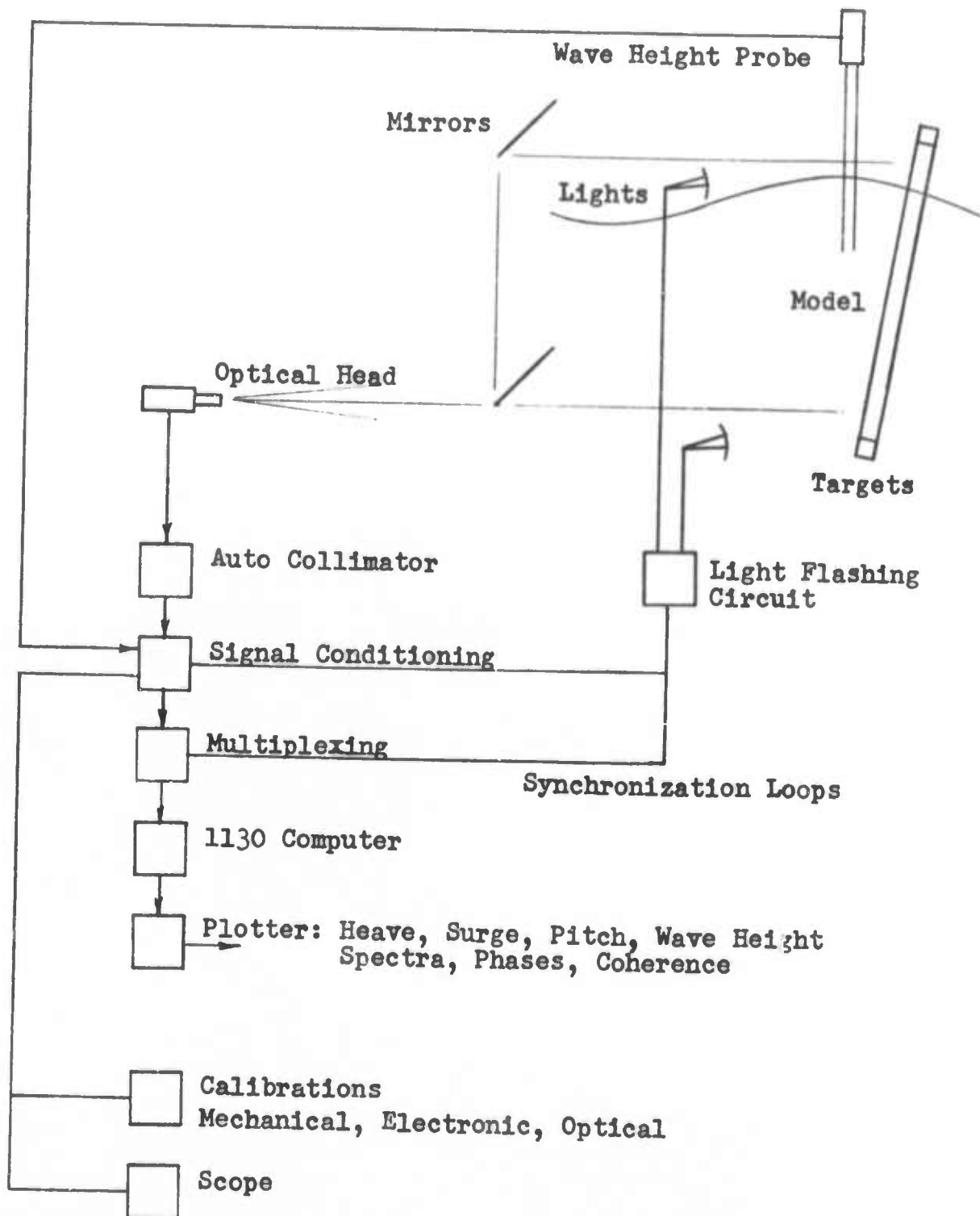Flow Control Valve

60 hp Hydraulic Power Supply
3000 psi
0 to 30 gpm

Figure 14. Wind Generator System.

Figure 15. Data acquisition concept.