NEW WIND-WAVE FLUMES AT DELFT

J. de JONG
Delft Hydraulics Laboratory, The Netherlands

Introduction

On March 24, 1969, the new wind-wave flumes at the Delft Hydraulics Laboratory (Figures 5 and 6) were officially opened by the Director-General of the Rijkswaterstaat. The design work started in 1964, and the building and installations were completed in November 1968. A general description of this equipment and some insight into its underlying principles are given below.

Wave generation

In the past basic research was undertaken in the Delft Hydraulics Laboratory on the generation of artificial wind-waves. Studies of the fetch necessary to obtain pure wind-waves of the desired dimensions in test facilities had, however, long showed that this required an unrealistic length of the flumes. So in the existing installations waves were generated by wind in combination with a monochromatic wave-maker.

By careful choice of the periods and amplitudes of the regular waves and, by using rather high wind speeds it was possible to get irregular waves of the required significant height, but it transpired that neither the wave-height distribution nor the energy spectrum as observed in nature could be reproduced in this way.

In 1966 a prototype of a new wave generator was installed in a flume at Delft, and the experience gained by this instrument led to the final choice of the wave-makers installed in both new flumes.

The installations comprise wave boards driven by a hydraulic servo system which generate waves according to an arbitrary programme. As an input signal, actual wave records from nature can be used by means of punch tape. On the other hand, arbitrary records can be simulated by means of a random noise generator (See paper 2: "Generation of irregular waves on model scales").

The signals are fed into two hydraulic drive actuators, one driving the upper edge of the wave-board, causing its rotation and the other attached to a carriage bearing the wave-board and thus causing its translatory motion.

By this equipment the parameters of the wave-energy spectrum can be varied over the total range required. But in addition to the wave-maker wind appeared to be still necessary to adjust the steepness of the wave fronts. Moreover, the wind itself can effect the attack on structures. Tests in the flumes at Delft and De Voorst showed that wind speeds exceeding 15 m/sec had an adverse effect on the wave pattern. Therefore this is the maximum wind speed in the new flumes. Normally, in combination with the wave-boards speeds not exçeeding 5 m/sec will do.

Dimensions

The length of the flumes is still determined in one way or the other by the necessary fetch in the flumes. It is clear that this length, using the wind mainly to adjust the geometrical shape of the waves, can be much shorter than by using the wind as the only wave-generating force. It was impossible, however, to give an exact prediction of the required length.

The most acceptable approximation was found by a rough extrapolation of the results attained in the old installation, using the required wave length as a parameter. As a result of this extrapolation, a length of 100 m was selected (Figure 1). The achievements of the installation since its completion indicate that this length is sufficient.

To find the necessary width of the new flumes, it was first tried to find a criterion in the desired length of the wave crest in the flumes. Studies were made comparing the crest length of wind-waves generated in a flume and similar waves found in nature, but this study did not provide the requirements for flume dimensions.

Moreover, because it was decided to install a wave-board as the main driving force it was clear that the length of the wave crests (being infinite under these conditions) was no longer a criterion at all. So the now chosen width of the flumes was mainly based on the practical requirement of testing breakwaters and dikes at arbitrary angles to the wave attack. The available width of 4 m in the flumes at Delft and De Voorst turned out to be too small for this purpose, whereas a basin at the end of a flume turned out to be profitable for studies on complex situations and for the reproduction of certain combinations of waves and currents. Based upon these considerations, one of the new flumes was given a width of 8 m with a widened "hammer-end" of 25 m, and the other one a width of only 2 m (Figure 2), which meant that in this flume only wave-attack perpendicular to the models can be simulated. It is expected that the series of 3 flumes now available, with widths of 2, 4 (De Voorst) and 8 m, will enable all problems arising in the near future to be dealt with.

The height of both flumes was fixed at 2.45 m, giving a reasonable possibility of passing through the flumes. The cross-sections of the flumes were minutely tested in a wind tunnel of the Delft University of Technology to ensure a reasonable velocity distribution in the wind profile and to prevent secondary wind currents, thus ensuring a uniform distribution of the shear stresses over the water surface, and also near the walls.

The study led to a cross-section of the 8 m flume in which the wind profile is about 1.50 m larger that the water surface (Figure 3).

As a systematic difference in water depth will give a difference in wave propagation, rigorous requirements to the accepted tolerances had to be laid down.

Control measurements afterwards showed that a random tolerance of less than 2 mm has been reached for the floors in both flumes.

Wind generation

Five axial ventilators, each capable of removing 60 m^3 air per second, are housed in the air-ducts below the flumes. Four of them serve the large flume, the fifth serves the small one. Adjustable D.C. motors make continuous adjustment of wind speeds possible within 2% of the desired value.

Model investigations in a wind tunnel led to the final shape of the diversion vanes, diffusors and stilling chambers in the air-ducts. Thus the air turbulences caused by the ventilators are smoothed and an acceptable velocity distribution above the water level is obtained, even when one ventilator of the large flume is not in operation.

Water circulation system

In both flumes a maximum steady current of 25 cm per second is required in a water depth of 0.5 m. This is done by 5 water-lubricated pumps of 0.2 m^3/sec each at a lift of 8 m, all housed in a pumping-room on the ground floor. Under normal conditions one pump serves the small flume, the other four the large one (Figure 4).

The water flows in and out through perforated pipes in specially-designed stilling channels in the bottom of the flumes. Investigations on small-scale models of these units were made by the laboratory to prevent distortion of the waves above the openings. The whole installation, including pipework, butterfly valves and pumps, is nylon-coated to prevent corrosion which would lead, for instance, to difficulties in making observations of the underwater parts of the models.

Auxiliary installations

Experience in the existing flumes at the Laboratory showed that the construction of models in the test section of the flumes interfered with the test programme on an unacceptable way. So in the new flumes these activities take place on an adjoining site. The completed models can be easily lowered into the test sections by crane.

After a model study on a rubble mound has been finished, the model can be hoisted out and all composing materials be dumped into a screen table on the ground floor from which they can be sorted out and stored again. The service crane for this purpose reaches the test sections of both flumes, the hammer-end and the construction site.

As an additional provision the flumes can be divided into sections by watertight gates, making it possible to empty the test sections, independently of the rest of the flumes, into the main water reservoir situated on the ground floor between the air-ducts.

Wave generators, ventilators, pumps and valves are all operated from control rooms near the respective flumes (Figure 7). These rooms contain, in addition to the main operation and control panels, also the different measuring instruments such as wave height meters, flow meters and strain gauge amplifiers.

Special instruments are available for "direct" evaluation of the statistical properties of measured quantities such as autocorrelation function, energy spectrum and exceedance probability. The control rooms are separated from the flumes by glass walls with doors, so that the models in the test sections can be easily observed and handled during test runs.

The electronic instruments in the control rooms need a low and constant air humidity not exceeding about 50%. To achieve this in rooms situated next to flumes in which an air humidity of some 100% can be reached during test runs, it was necessary to maintain a difference in temperature between the flumes and control rooms. Moreover, a simple air-conditioning unit installed in each control room dries the air entering.

The layout of the equipment was developed by the Laboratory in co-operation with the "Associatie van Ingenieurs en Architekten Buro op ten Noort-Blijdenstein" (consulting engineers), Utrecht, whose staff was responsible for the design and engineering of the plan and for the supervision and overall co-ordination of the construction.

Delft Hydraulics Laboratory: Wind-wave Flumes

completed	1938 (Delft)	1957 (De Voorst)	1968 (Delft)	1968 (Delft)
eff. length (m)	50	100	100	100
eff. width (m)	4	4	8	2
eff. height (m)	0.94/0.99	2.00	2.45	2.45
max. water depth (m)	0.45	0.80	0.80	0.80
max. wind velocity (m/s)	14	25	15	15
max. water circulation (m^3/s)	-	3	1.0	0.4

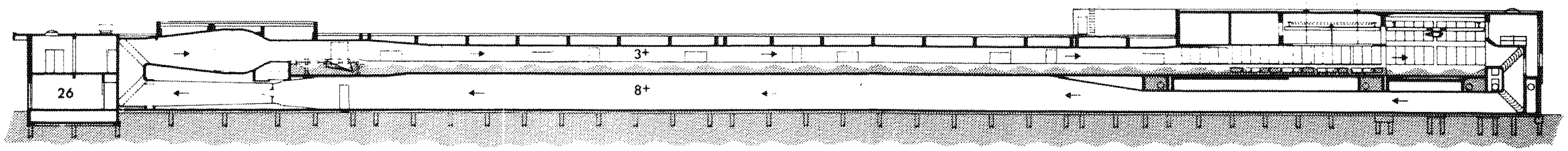

FIG. 1

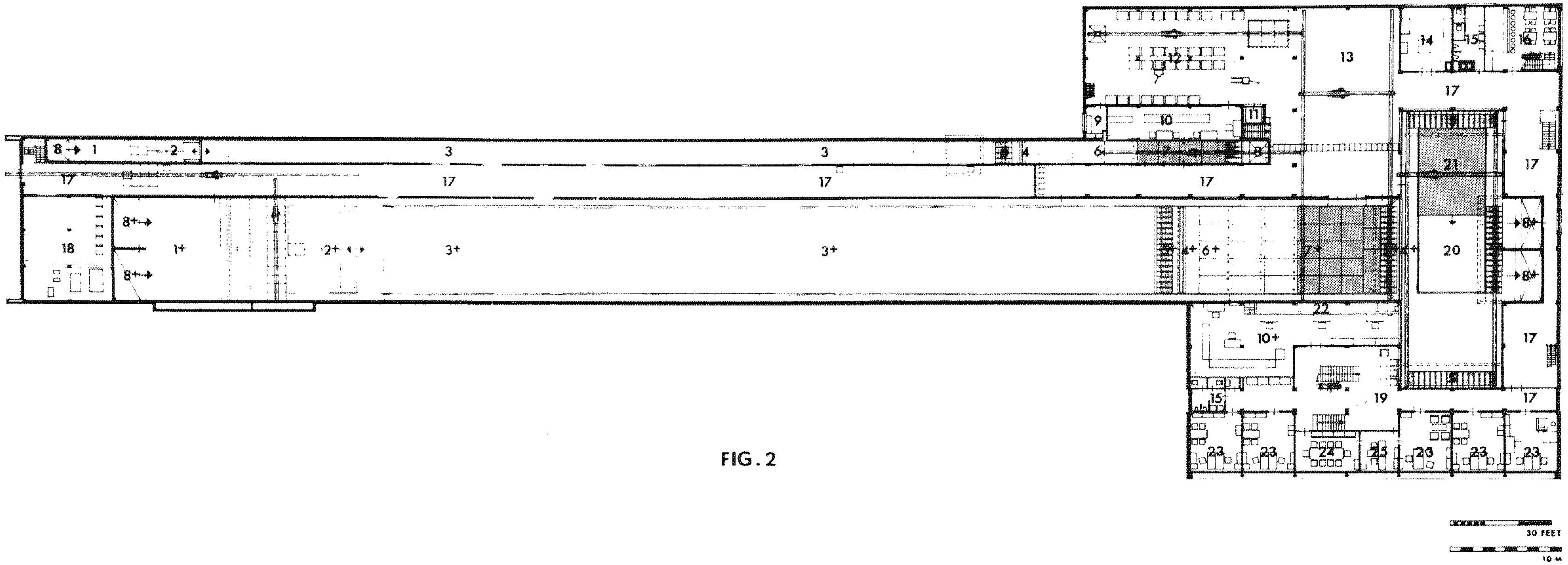

FIG. 2

Reference

1- 1+	Stilling chamber	14	Workshop
2- 2+	Wave-generator	15	Toilets
3- 3+	Wave-generation section	16	Canteen
4- 4+	Movable barrier	17	Corridor
5- 5+	Discharge channel	18	Engine room
6- 6+	'Adjustable sea-bed' section	19	Entrance hall
7- 7+	Model section	20	Wave-basin
8- 8+	Return channel	21	Movable floor
9	Room for control of material densities	22	Recessed walkway
10-10+	Control room	23	Offices
11	Elevator	24	Conference room
12	Storage	25	Reception room
13	Construction hall	26	Transformator room

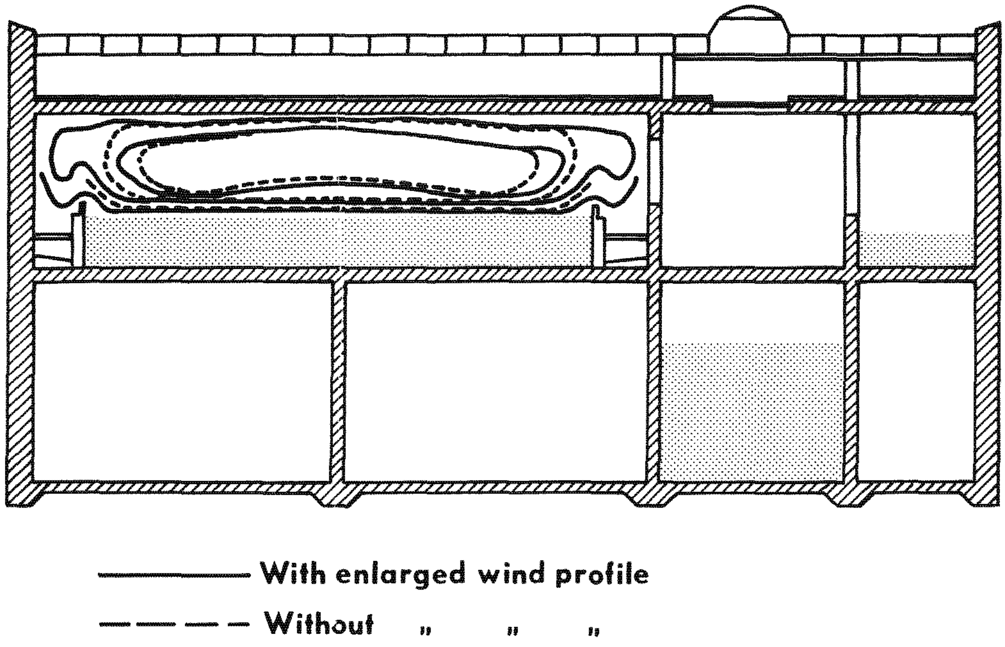

FIG. 3 CROSS SECTION WITH WIND-SPEED DISTRIBUTION

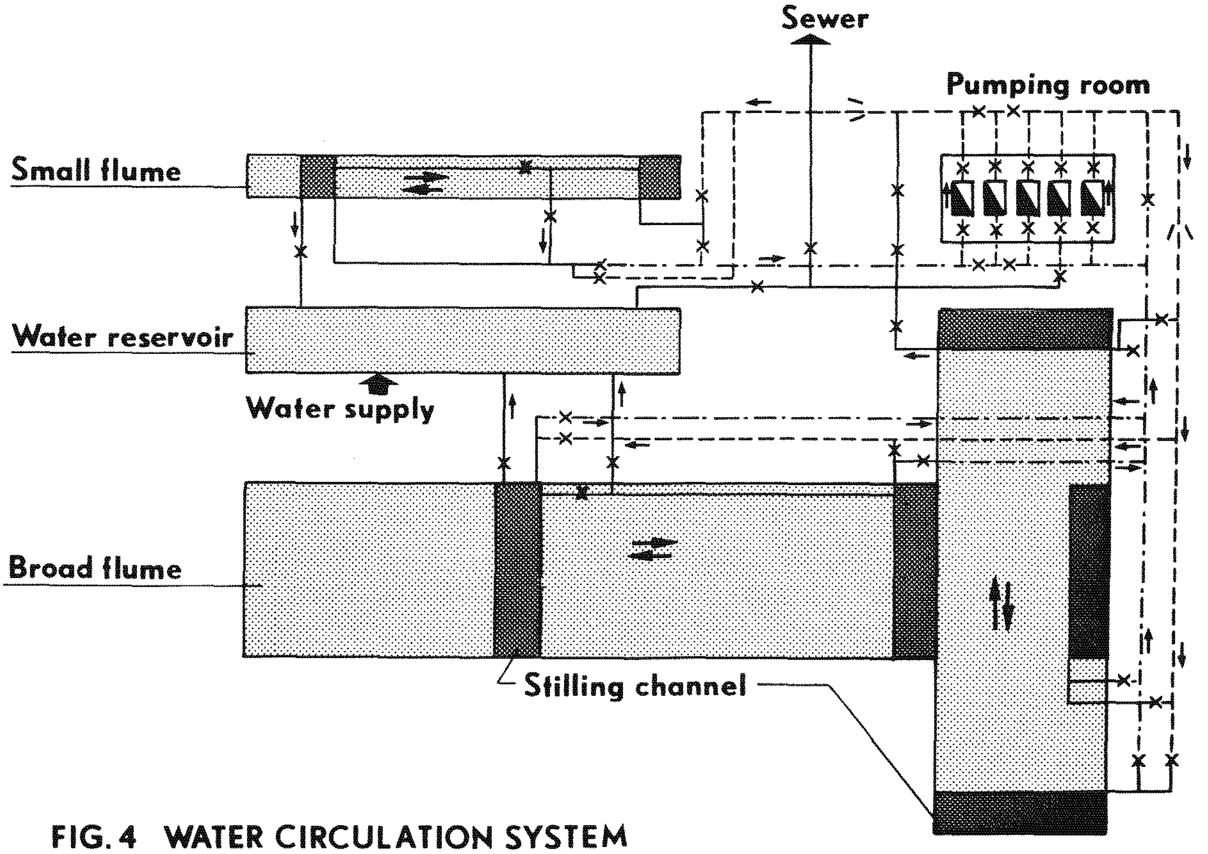

FIG. 4 WATER CIRCULATION SYSTEM

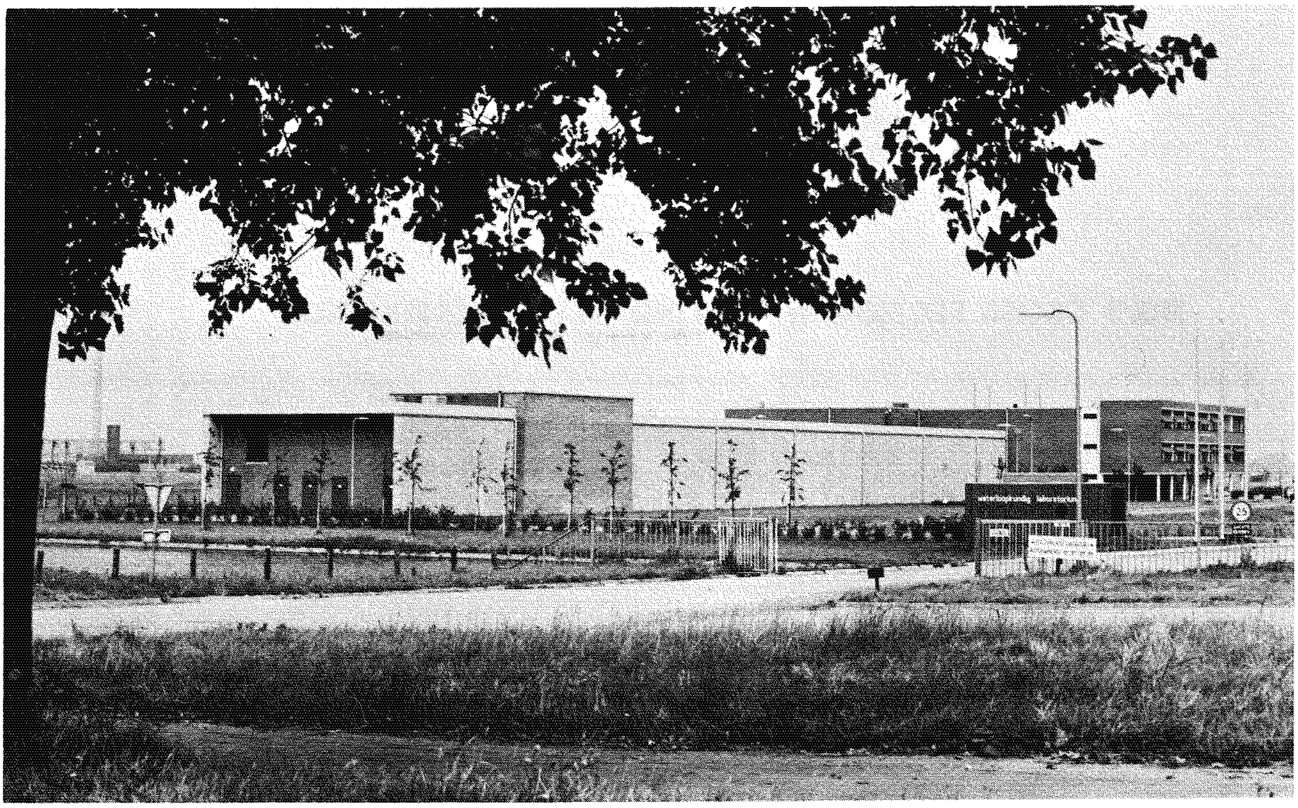

FIG.5 VIEW OF THE BUILDING

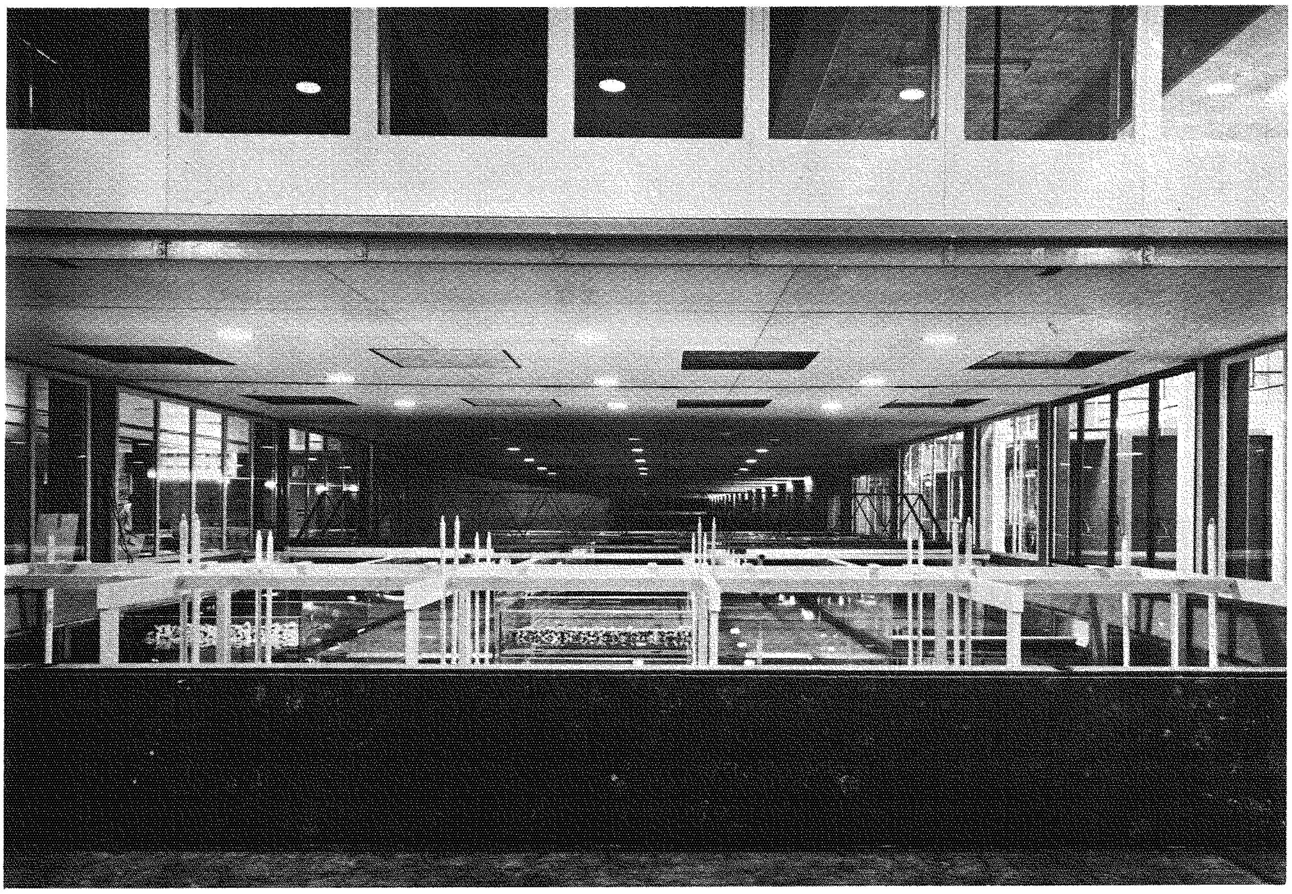

FIG. 6 LARGE FLUME AS SEEN FROM THE HAMMER-END

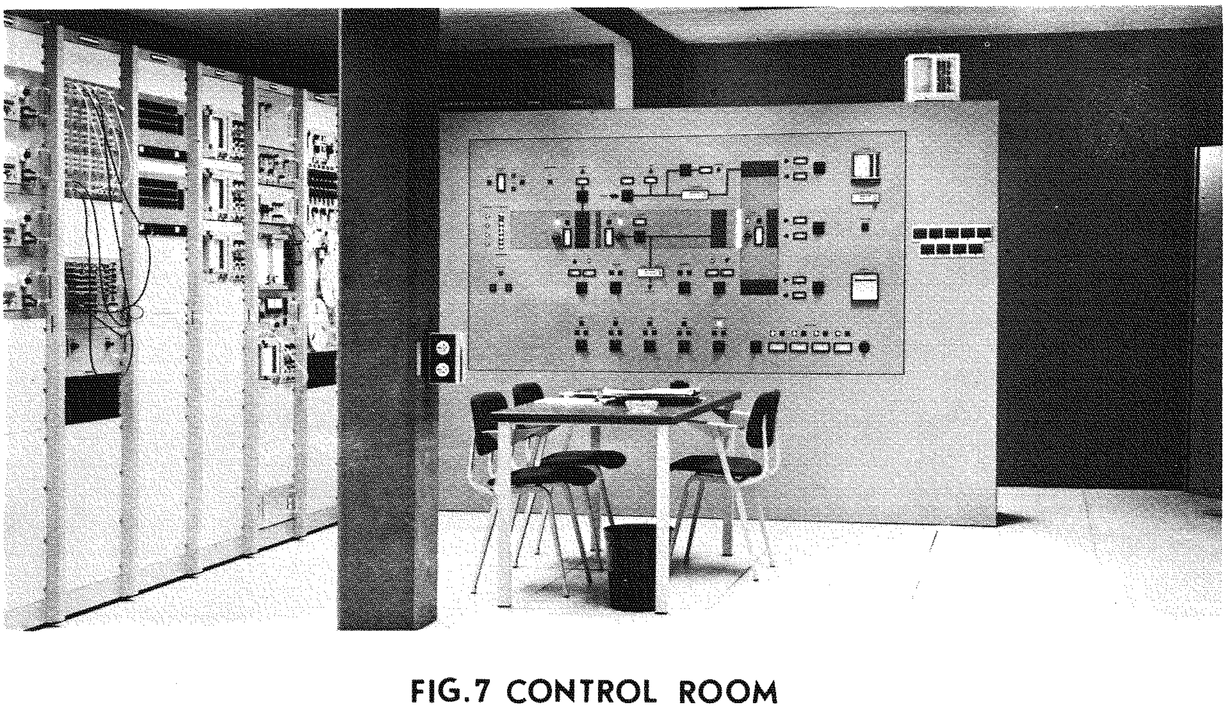

FIG. 7 CONTROL ROOM