UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 179

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PRELIMINARY STUDIES ON THE AUTOMATIC FLOATING RADIAL GATES GRAND COULEE PUMPING PLANT COLUMBIA BASIN PROJECT

by

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Denver, Colorado

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Branch of Design and Construction
Engineering and Geological Control
and Research Division
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Laboratory Report No. 179
Hydraulic Laboratory

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Subject: Preliminary studies on the automatic floating gates - Grand Coulee Pumping Plant - Columbia Basin Project.

1. General. The proposed pumping installation at Grand Coulee Dam calls for the installation of twelve units connected in pairs to six generating units in the power plant. The pumps are to be operated on dump power and will lift the water approximately 300 feet to a canal where it will flow into a storage reservoir for later use in irrigation.

Two of the twelve units will be stand-by units and it is not anticipated that more than ten or less than four pumps will be operated at one time. As the outlets of the conduits discharge into an open canal leading to the reservoir and are below the tailbay water surface, some means will have to be provided for preventing backflow through the pumps which are not in operation. To prevent an excessive loss of water due to backflow through the discharge conduits when any or all of the units are shut down, the gate or other device employed will have to act quickly. Two types of structures have to date been considered for this purpose, the first was a siphon (Hydraulic Laboratory Report No. 163) discharging into the canal with an air valve at the highest point on

the line which would break the siphon action when backflow began in the pipe. The second was a floating radial gate which would automatically open and close due to the buoyance of the gate and the presence or absence of water on the upstream side of it.

This report deals with the latter scheme. The tests thus far conducted were qualitative only and served only to illustrate the manner in which the gate operated.

2. Qualitative tests on the radial gate. At the time that the floating radial gate was proposed for the Grand Coulee pumping plant, tests were being conducted with a model of the Gila pumping plant flap gates. As the Gila model was a rough approximation of the Grand Coulee arrangement, a floating radial gate was designed to fit the existing model. The model gate had a radius of 24 inches, was 12 inches wide, weighed 22 pounds, was approximately 20 inches high, and was hinged 19-1/2 inches above the gate sill.

The tests with this gate were not conducted with the purpose of obtaining any specific design data but were for the purpose of demonstrating whether the gate would close under the force of gravity when the supply of water from the pump was stopped and water started flowing back through the pump. These tests showed:

> (1) That with a water depth of approximately 18 inches model downstream the gate floated high on the water and the losses through the section were not excessive, that when the flow of water from the pump was stopped the gate closed in from three to four seconds with the water in the tailbay maintained at the pumping level.
>
> (2) That the gate seated with an appreciable shock and after starting the pump there was a surge in the area immediately upstream of the gate which occurred when the flow from the conduit reached the gate.

Additional tests showed that a lip extending downstream from the gate to create a drawdown force would cause the gate to close still more rapidly and also increase the shock at closure. The shock, however, was eliminated by placing a flat section on the bottom of the gate and seating it in a depression to form a constant water cushion as shown on figure 1.

3. Preliminary tests of Grand Coulee designs. Since the early tests on the Gila model indicated that a workable design embodying the radial gates might be developed for the Grand Coulee pumping plant, the flap-gate model was altered as shown on figure 1 with gate 1 of figure 1A installed as indicated by test 1 in the figure. The action of this gate was similar to the previous gate; however, with the new transition in place there was a sharp "slap" of the water in the transition when the pump was started with the afterbay filled with water. This was caused by the first flow from the pump reaching the gate thereby causing it to raise. The resulting backflow under the gate in combination with the opposing flow from the pump suddenly filled the transition with an accompanying sharp slap and surging of the water surface. No attempt was made to eliminate this at that time, instead, a series of tests were conducted to determine the overall head losses from the beginning of the transition through the gate to the afterbay water surface beyond the gate section. The prototype losses for gate 1, test 1, are shown on figure 2.

To reduce the losses for low depths of water in the afterbay, the hinge pin was moved as shown on figure 1A, test 2. This placed

more of the buoyant area of the gate in contact with the water when the depth in the afterbay corresponded to a lesser number of pumps operating and reduced the losses as shown on figure 2.

To reduce the head losses still farther the gate was altered as shown on figure 1B, test 3. The losses are shown on figure 2 from which it is evident that there was a reduction in head loss for afterbay depths of more than 13 feet. Below this depth there was a marked increase in head loss due to the increased weight of the gate which counteracted the additional buoyancy.

After it became apparent that the weight of the gate was the critical factor determining the head loss at shallow afterbay depths, the gate of figure 1C was built and tested. The head losses are shown on figure 2 along with the head losses for the installation without the gate in place. There was an appreciable reduction in head loss; however, the gate closed more slowly than the heavier gates and considerably more water was lost from back-flow down the discharge conduit. The closure speed was increased by adding a lip to increase the drawdown on the gate; however, this was not sufficient to cause it to close as rapidly as the two previous gates. It appears that additional weight will be necessary to give a convincingly positive closure. The added weight will increase the head losses. At this time it appears that some compromise will have to be made between head losses and the weight of the gate to obtain satisfactory closure.

The slapping of the water in the transition during the starting cycle was present with all three types of gates. It did not vary

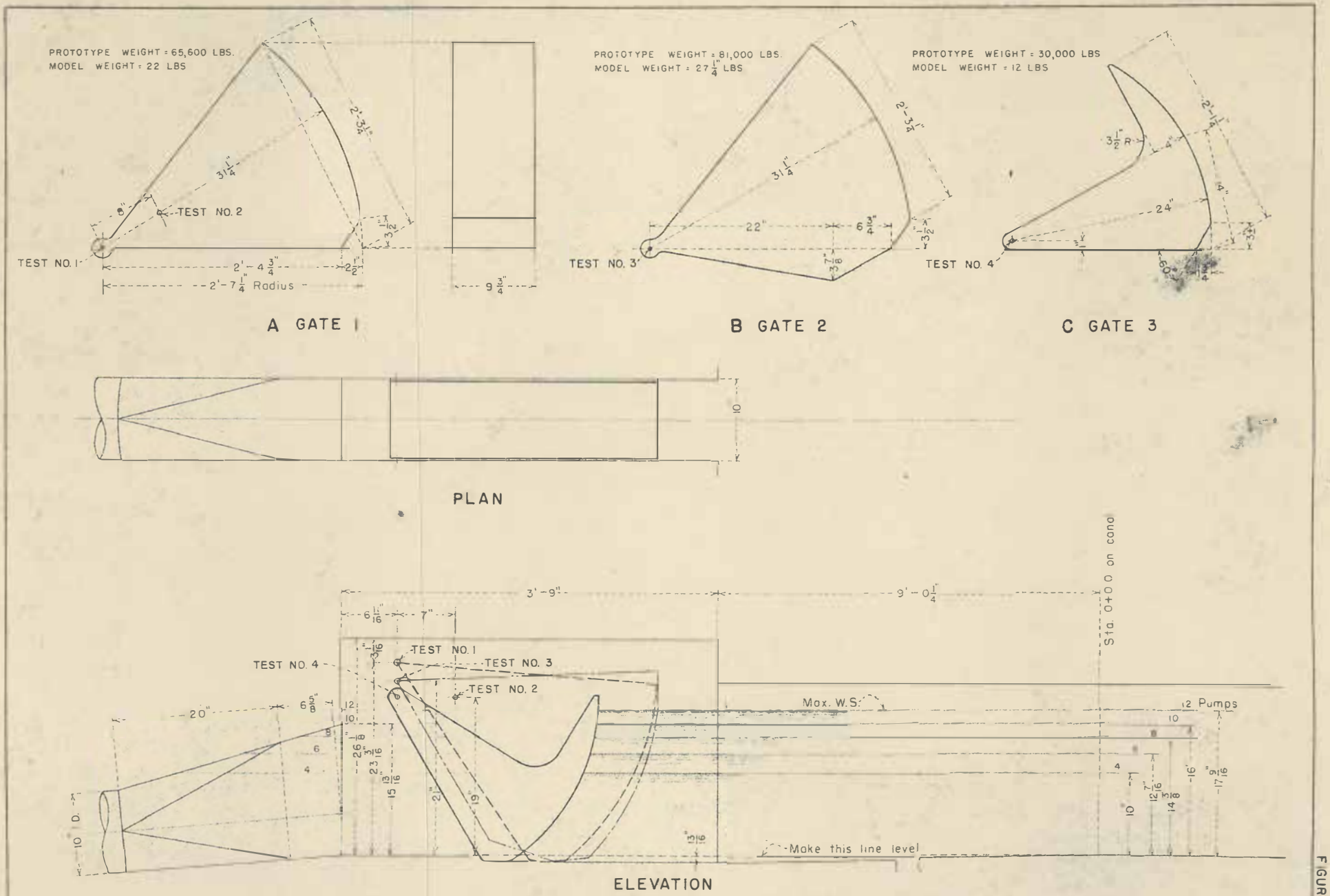
appreciably with the type or weight of gate. A low flow in the discharge line during a starting cycle reduced the intensity, but did not eliminate the action. It appeared that this condition could be improved by the use of a different transition placed at a lower elevation.

A new transition was developed and installed as shown on figure 3. Gate 3 of figure 1C was used in the new arrangement. The head losses were determined from the beginning of the transition through the gate section to the water surface in the afterbay downstream from the gate both with and without the gate in place. These losses are shown on figure 4. The new transition was not quite as efficient as the first one, as may be seen by comparing figures 2 and 4.

The gate closed without slamming. It closed at a uniform rate except for the last inch of travel. The slowing up of the gate at that point was due to the water cushion provided by the sill in the floor just upstream from the gate seat.

The original cause of the slapping of the water in the transition was eliminated by the new transition. However, slapping was present for another reason, but was of a smaller magnitude. When starting the system the first flow up the pipe would strike the sudden increase in grade at the exit of the transition and, lacking sufficient momentum to carry it upstream, would fall back on itself. This action closed the exit of the transition and trapped a considerable amount of air. At this instant the transition filled with flow from the pump, causing a sharp slap and considerable splashing

as the air escaped. The action was not considered to be serious enough to be detrimental. This test concluded preliminary testing of the automatic radial gates for the Grand Coulee Pumping Plant.



MODEL DETAILS OF 1:14.4 SCALE MODEL OF AUTOMATIC RADIAL GATES
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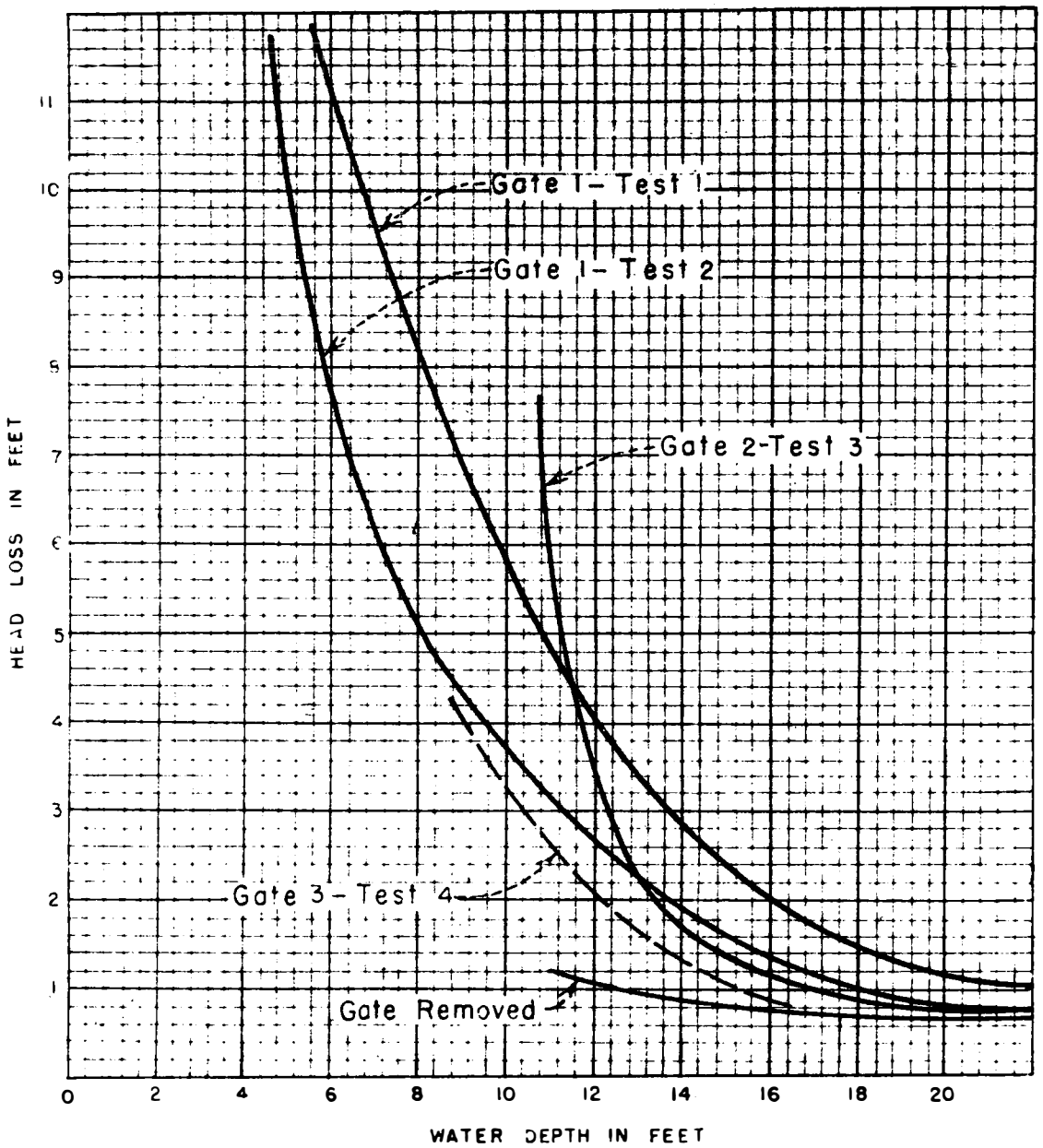
FIGURE 1

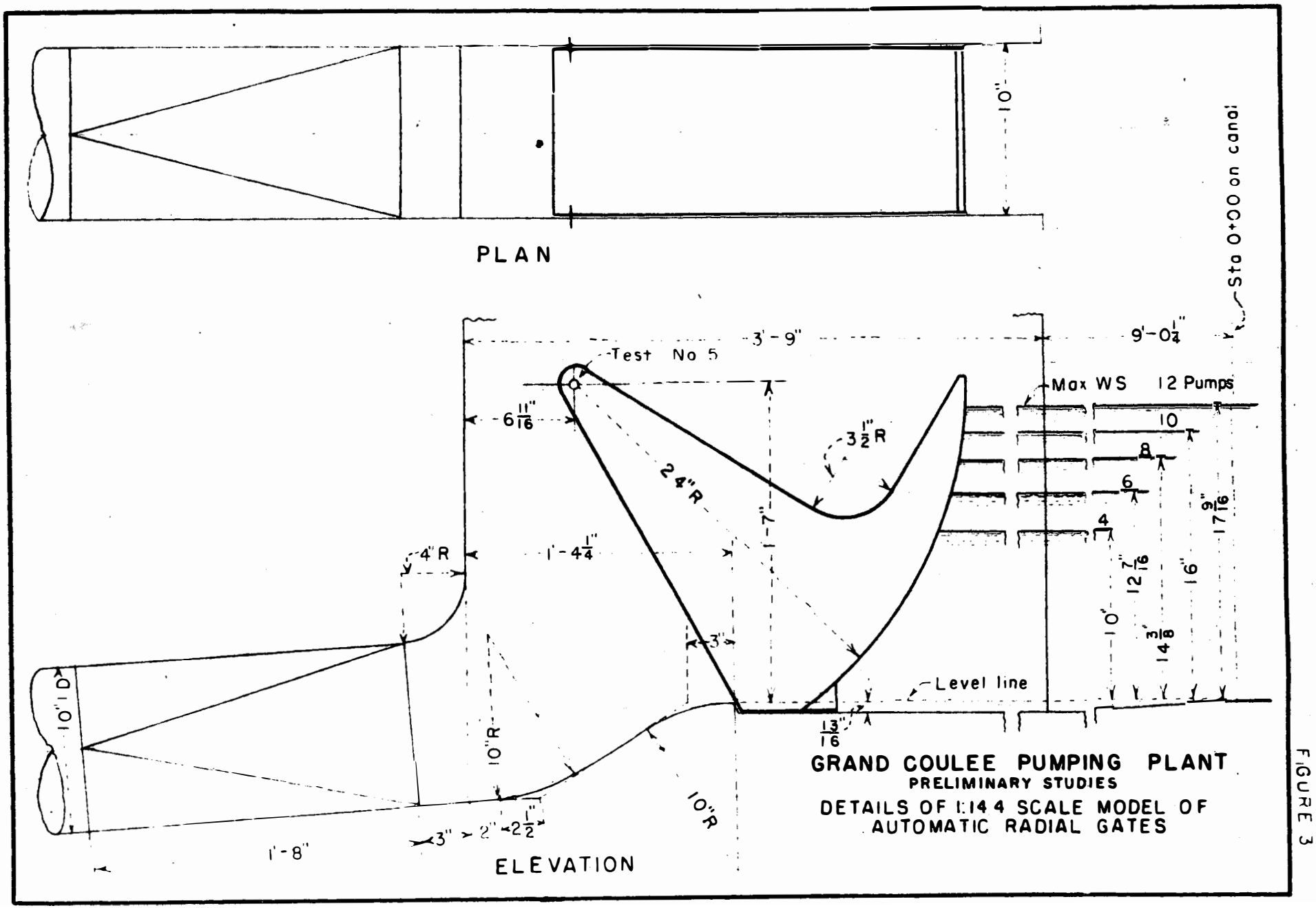
FIGURE 2



GRAND COULEE PUMPING PLANT

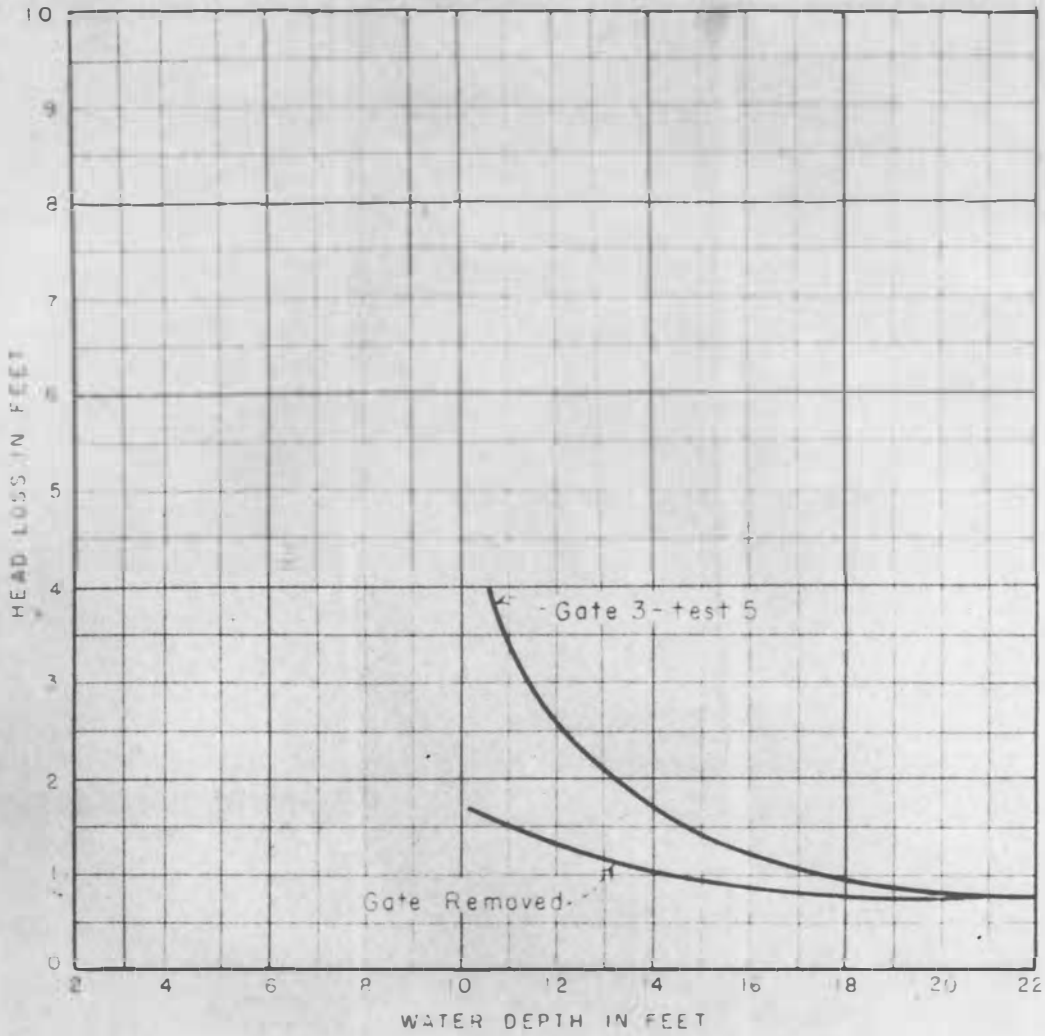
AUTOMATIC RADIAL GATES

PROTOTYPE HEAD LOSSES AT GATE SECTION



GRAND COULEE PUMPING PLANT
PRELIMINARY STUDIES
DETAILS OF 1:14.4 SCALE MODEL OF AUTOMATIC RADIAL GATES

FIGURE 3



GRAND COULEE PUMPING PLANT

AUTOMATIC RADIAL GATES

PROTOTYPE HEAD LOSSES AT GATE SECTION