UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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Memorandum to Chief Designing Engineer

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MODEL STUDIES PERTAINING TO THE AERATION OF DRUM GATES

BY

JAMES W. BALL, ASSOCIATE ENGINEER

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Denver, Colorado,
April 4, 1940.

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MEMORANDUM TO THE PIER DESIGNING ENGINEER
(J. W. Ball)

Subject: Model studies pertaining to the aeration of drum gates.

1. The problem of supplying air to the under side of a sheet of water passing over a drum gate in the raised position has been encountered in this laboratory on all hydraulic model studies pertaining to structures employing this type of gate for spillway regulation. The practice has been to admit air at the ends of the gates through openings bounded by the backs of the piers and the under nappe of the flowing sheet. Except for high gate elevations and very low heads, a maximum vent area is obtained in this manner. For the lower gate elevations these openings are of sufficient size to give adequate aeration. As the gates approach the upper limit of their travel, the thickness of the jets decreases, the trajectories become steeper, and the spaces between the piers and jets diminish rapidly. Also the area of the under nappe exposed to air becomes greater, thereby increasing the air demand. Model studies on spillways of the Boulder, Madden, and Grand Coulee Dams indicated that these spaces might be entirely eliminated for the higher gate elevations by "clinging" of the spillway jets to the backs of the piers. It was believed that the elimination of this action on the model, where surface tension is a contributing factor, would insure continuous aeration on the prototype. Various pier alterations, consisting mainly of abrupt offsets at the downstream edges, were investigated. Satisfactory results were obtained for the Boulder and Madden gates where the gate height and radius of the arc of rotation were small compared with those for Grand Coulee.

2. Because similar alterations to the Grand Coulee piers proved unsuccessful, it was necessary to resort to other methods. Three methods considered were: (1) the addition of vertical plates above the lip at the ends of the gates, to keep the water off the backs of the piers, (2) the installation of air ducts in the pier proper, and (3) the installation of splitter piers on the gate lip. The first plan was abandoned because of its impracticability. The third method seemed an obvious solution, in which the piers could be added to the prototype after actual flow conditions on the structure had proven them to be essential. Tests on the Grand Coulee gate were confined to the second plan in an attempt to determine its feasibility.

3. The model used for these studies was constructed of metal on a scale of 1:40. It was of the sectional type and included one pier and two half-gates, figure 1. The gates were of the hinge type, constructed to enable setting at any predetermined elevation. The model did not include the drum portion of the gate. The pier nose shape was that of the adopted design for Grand Coulee Dam.

4. Insofar as the model results were concerned, satisfactory conditions were obtained. However, in view of the limitation of models in predicting the air requirements of the prototype, the results on this model are presented with the belief that they have little practical value, other than to show the necessity of aerating drum gates and to point out the difficulties involved when the gates are near the upper limit of their travel. Probably the outstanding factor contributing to the question of the applicability of these data is the varying degree of air insufflation by the water at different velocities. Very little air is taken up by the model jet flowing at a low velocity, while large quantities, ranging up to 50 percent by volume, are picked up by the high velocity on the prototype.

5. While testing the final design pier for Grand Coulee Dam with the gate placed at elevation 1266, it was noted that the gates failed to aerate for reservoir elevations up to and including 1290.0. The adjacent spillway jets spread to form a water seal as they flowed past the gate lips and down the back of the pier, figure 2-A. The low pressure under the jets dropped their trajectories and caused them to strike the gate seats. The gates failed to aerate at low heads for all positions above elevation 1276.0. A definite vibration of the jets was observed with the gates at elevation 1284.0 when the head reached 4.15 feet. This phenomenon was attributed to rapid changes in pressure under the gate lips. Apparently the pressure fluctuation was due to the alternate sealing and breaking of the jets at the back edges of the pier. Action similar to that obtained on the model and attributed to incomplete aeration was observed at the Black Canyon Dam in 1939.[1] Placing 1-inch pipes through

[1] Pages 11 to 23, inclusive. Report on Vibration Studies Made at Black Canyon Dam, by Messers Glover, Thomas, and Hammett.

the nappes on the model eliminated all vibration and caused the jets to resume their normal position. However, the curtain of water at the back of the pier still formed a seal, figure 2-B. This occurrence (neglecting surface tension) indicated that some method of venting, other than depending on the water springing free of the piers, would have to be employed. Accordingly vent openings were placed in the pier and additional studies made.

6. Because an infinite number of vent arrangements were possible and time did not permit detailed study on various combinations, only one arrangement was used, figure 3. The vents were represented by holes drilled through the shell of the pier, the inside of which was open to atmospheric pressure. These openings, representing prototype sizes of 6, 10, and 12 inches, were tested singly and collectively for complete aeration. The intermediate and lower holes were plugged with plasticine and tests conducted to determine the adequacy of the 6-inch opening when the gates were in the fully raised position. The nappes assumed their normal position for all heads and the openings were considered adequate. However, the slowness with which the jets resumed their normal position when the vents were opened, after being closed for a short time, seemed to indicate a lack of reserve capacity. When the larger vents were tested in similar manner the jets resumed their normal position almost instantly, indicating that a 10- or 12-inch vent would be more desirable.

7. Although these tests proved that vibration of sheets of water passing over drum gates can be eliminated by adequate aeration and that more satisfactory operation of the gates will result when sufficient air is supplied, field observations at the Black Canyon Dam indicated that the vent sizes obtained by model studies would have been too small. In view of this fact it is suggested that field tests be made at every opportunity in an effort to correlate model and prototype relations for determining air vent sizes for drum gates. To obtain adequate aeration in some cases might necessitate the placing of splitter piers on the gate lip. Maximum vent area would be obtained in this manner and it would be possible to install them after actual operation had proven them to be essential.

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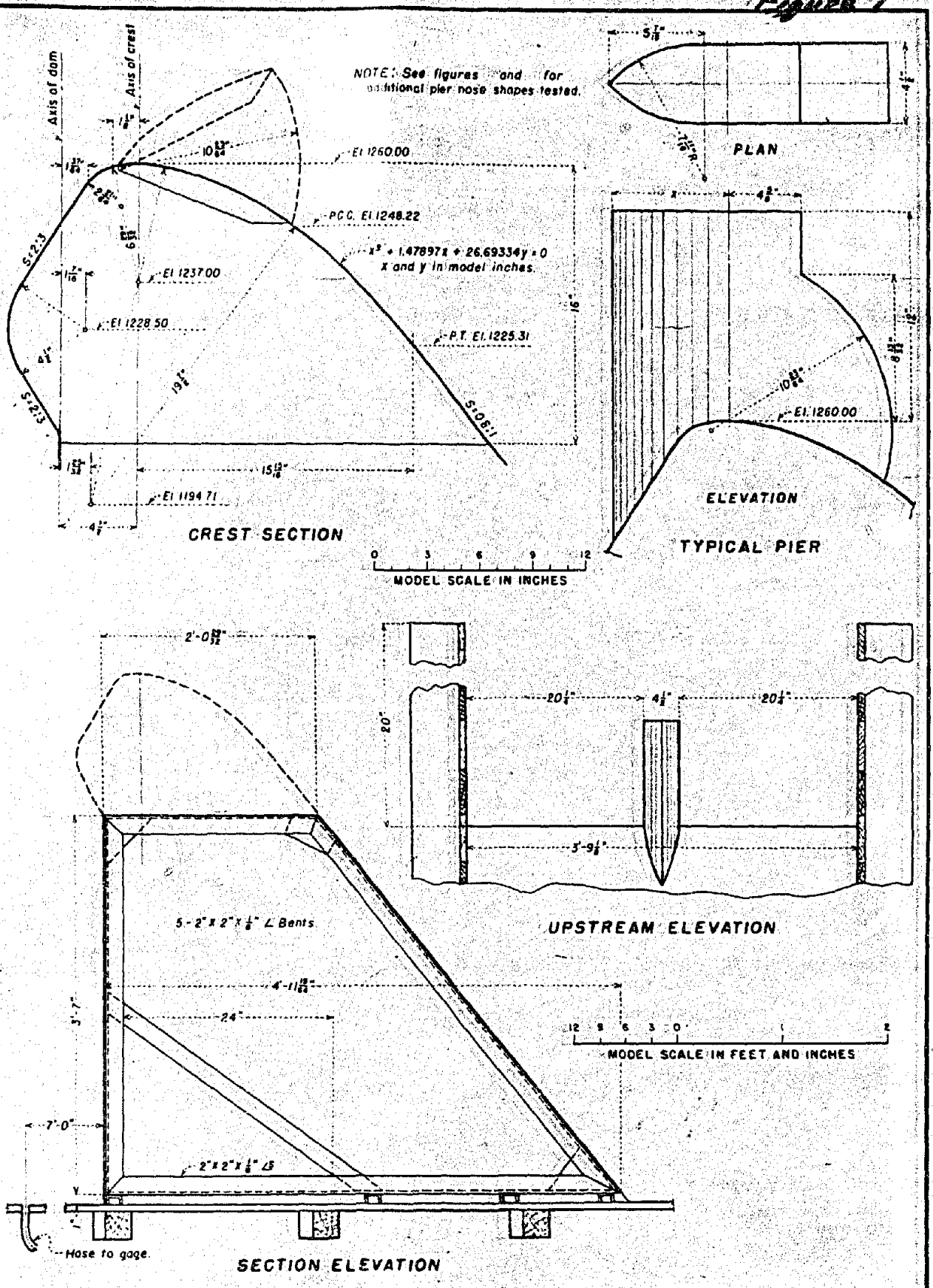
J. W. Bell.

Figure 1

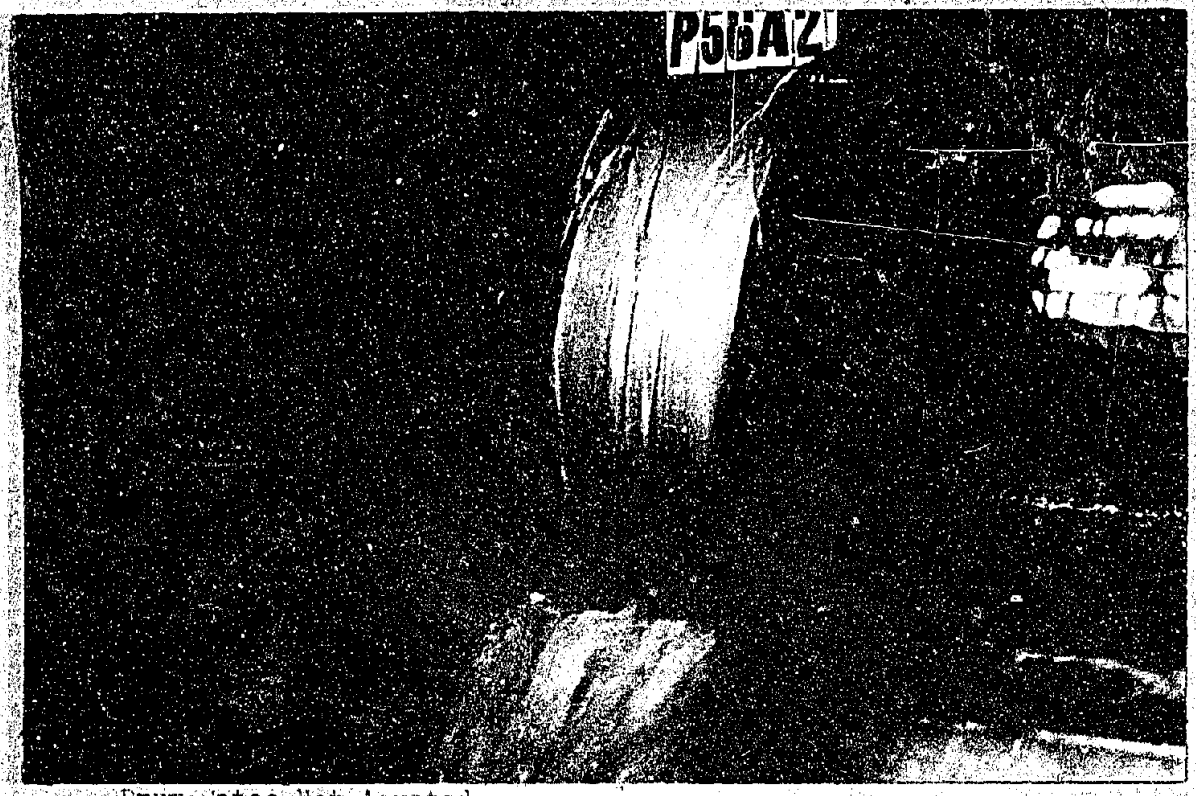


GRAND COULEE DAM

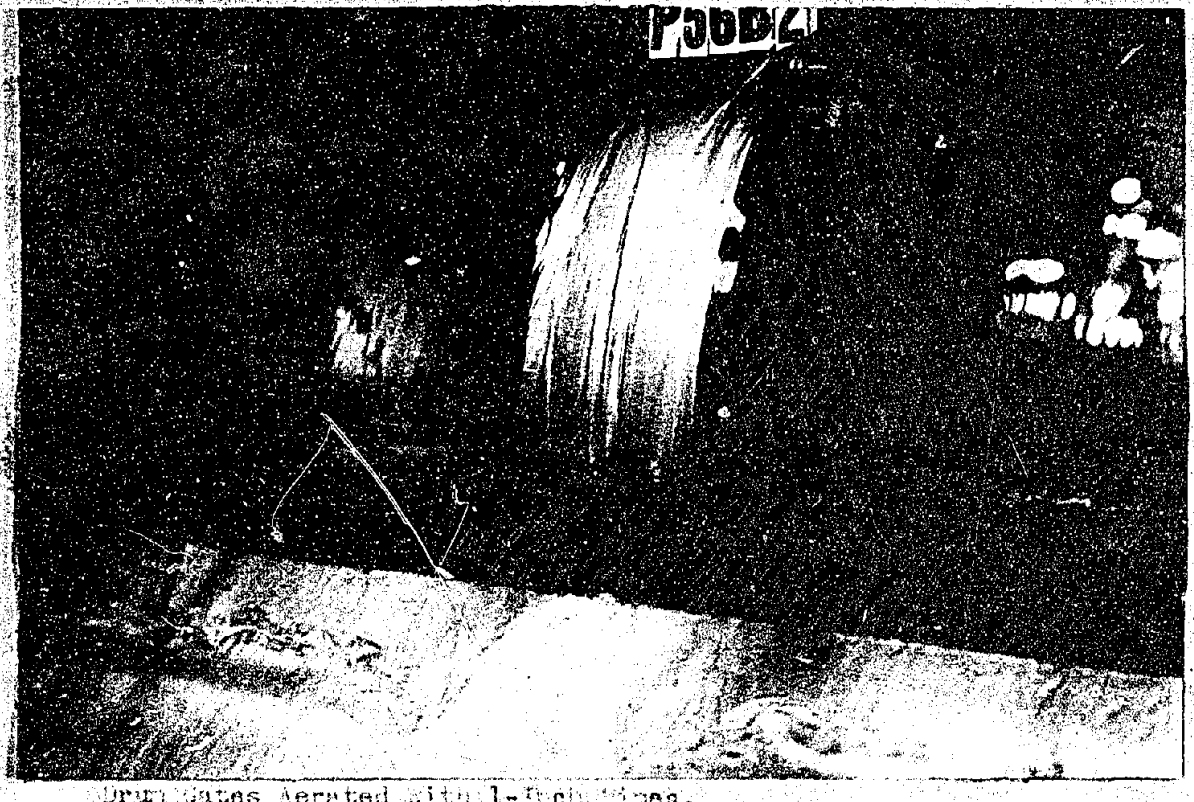
HYDRAULIC MODEL STUDIES - SCALE 1:40

MODEL DETAILS

DRAWN: R. A. G. - 1-24-39

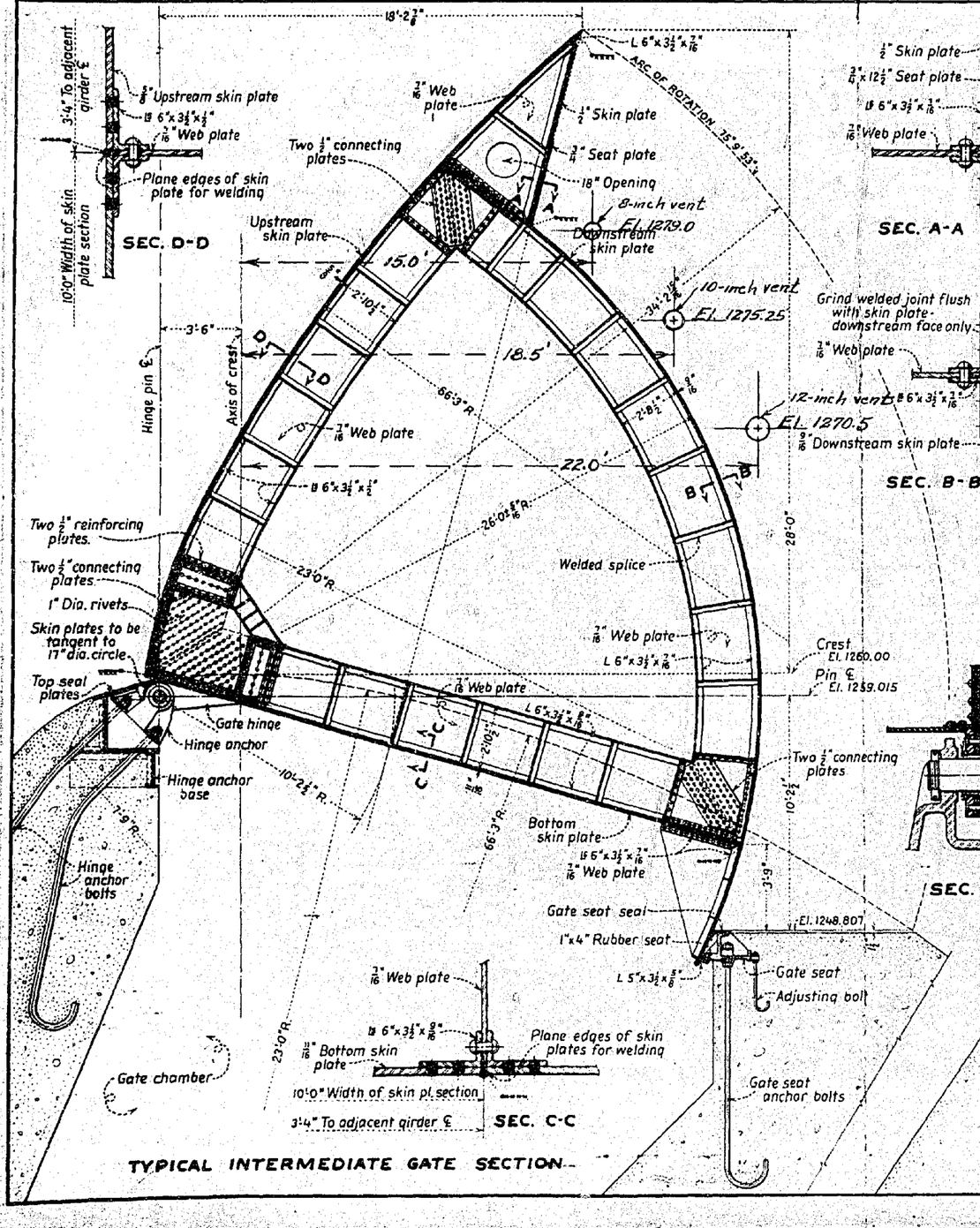


Drum Gates Not Aerated.



Drum Gates Aerated with 1-Inch Pipes.

Water Seal at Back of Pier.
Gate Elevation 1286.0 - Reservoir Elevation 1290.0.



NOTES

All rivets to be ⅞" dia. – 15/16" reamed holes, except as noted.
Rivets in the downstream face are to be countersunk outside and must be chipped and ground flush.
All plate joints at face intersections to be arc welded full length.
All continuous outside welds shall be watertight, the welding to be carefully performed to prevent distortion or loosening of rivets.
Crimp girder stiffeners and mill ends to close fits against outstanding legs of flange angles.
For painting see specifications.
Air vent locations for model tests are shown in red.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT—WASHINGTON
GRAND COULEE DAM
SPILLWAY
135'x28' DRUM GATE
TYPICAL INSTALLATION

DRAWN G.W. SUBMITTED L. N. McClellan
TRACED J.O.-R.M.S. RECOMMENDED
CHECKED M.G.K. APPROVED
29462 DENVER, COLORADO, SEPT. 26, 1941 222-D-156