UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Denver, Colorado

February 3, 1955

Memorandum

To: Chief, Hydraulic Laboratory Branch

From: Head, Hydraulic Equipment Section

Subject: Hydraulic Laboratory tests pertaining to vibration in the Y-branch of the Mexican Outlet Works--Falcon Dam

A letter from the Commissioner for the United States, International Boundary and Water Commission, transmitted a letter from the Commissioner for Mexico containing portions of a report of Mexican engineers on the operation of the 102-inch butterfly valves.

The report discussed the tendency of the No. 2 butterfly valve in the left branch to vibrate and move toward the closed position and outlined the corrective measures applied. The report also described noise in the system and the movement of the piston-operating mechanism of the butterfly leaf. The movements and sounds were described as having a frequency of from 2 to 3 seconds. The sounds, referred to as cavitation sounds, were described as being rather loud and heavy thumping or slapping noises. The conditions were believed to result from turbulence originating at the Y junction.

A letter from the Assistant Commissioner and Chief Engineer to the Commissioner, International Boundary and Water Commission, dated September 20, 1954, stated that studies pertaining to the vibration and possible cavitation conditions would be made as a part of the model calibration tests. Since pressure variations and intensities are important factors when such conditions are present, 32 piezometers were installed in critical pressure zones of the Y-branch. Some of these piezometers are shown in Figure 1. The critical zones were: (1) the left inner wall of the left branch immediately downstream of its intersection with the upstream pipe, (2) the joint formed by the intersection of the two legs of the Y-branch, and (3) the butterfly valve stations.

An attempt was first made to measure transient pressures at each piezometer using an inductance-type pressure cell. The results obtained were erratic and inconsistent, and it was found necessary to change to a strain gage type of pressure cell. Oscillograph records were taken for nearly all piezometers with equal flows through both branches and with all flow through the left branch. A study of the oscillograph records showed pressure variations and instantaneous low pressures to be more severe when the flow was equally divided between the two legs of the branch than when it was confined to the left leg. With equally divided flow, substantial pressure variations occurred at the left butterfly valve. Much smaller variations occurred at the right butterfly valve. This is in agreement with prototype observations.

The surges at the left valve were most pronounced on the invert and left side and appeared to be the result of a zone of turbulence along the upstream left side of the left branch. The frayed condition of the jet from an orifice placed at the No. 2 butterfly valve position during the calibration tests showed that turbulence from the Y-branch extends downstream to the butterfly valve. The maximum pressure variation recorded in the initial tests, 48 feet of water prototype and the minimum instantaneous pressure, -16.5 feet of water prototype, were measured in this zone (Piez. No. 5). Such pressure variations undoubtedly exist in the prototype and are responsible for the vibration in the structure and for the forces which tended to close the left butterfly leaf. It is possible that more severe subatmospheric pressures than measured exist momentarily and that these low pressures may reach vapor pressure causing a cavitation-like action. There was indication that this was the case when tests were made later with the addition of piezometers A, B, C, D, E, and F (Figures 1 and 2).

Operation of the valves simultaneously at small openings, or confining the flow to one valve until it reaches full opening before opening the second valve might be used to minimize the pressure fluctuations and vibration. Limitations of this type are not conducive to efficient operation so further study of the problem seemed desirable. It is believed that converging instead of expanding water passage areas would have given better conditions in the branch. The sum of the areas of the two branch legs of the Mexican outlet works is greater than the area of the passage at the branch entrance. While this condition may not be a major influence on the pressure surges and vibration, it is decidedly a contributing factor.

A review of test results obtained from models of the penstock branches for Hoover Dam (Part VI, Bulletin 2, Boulder Canyon Project Final Reports) disclosed that much was accomplished toward eliminating zones of turbulent flow in the branches when filler blocks were placed to occupy the turbulent zones. Because of the effectiveness of these filler blocks a decision was made to install one at the left wall of the left branch and study its influence on the pressure surges. It was hoped that the Hoover tests would indicate the shape of block required and data from the Bulletin was plotted. It was found, however, that because of the difference in shapes of the Y-branches the data could serve only as a general guide, and a modified shape was arbitrarily sketched. The shape is shown on Figure 1 as the 8.9-inch filler block. The block was placed with the upstream end at the intersection of the branch leg with the main pipe, and extended into the pipe to occupy the turbulent zone indicated by the initial pressure records. The inner surface of the block (flow surface) was made using straight, vertical elements because of simplicity of construction for the prototype structure. Piezometers A, B, C, D, E, and F were placed in the filler block and pipe walls at the locations shown in Figure 1 and pressure records (using a strain gage type pressure cell) were taken with an oscillograph. Records were taken both with and without the filler block in place.

An examination of the oscillograph records disclosed that an extensive reduction in pressure fluctuations had been accomplished by installing the filler block (Figure 2). There seemed also to be a decided reduction in the noise and vibration of the model. The fluctuation in pressure at the No. 2 butterfly valve location was reduced considerably (Piez. 32, Figure 2). Because of the pronounced effectiveness of the filler block in reducing the pressure fluctuations and vibration it seemed desirable to determine if a smaller filler block would accomplish as much. A similar, but smaller, filler block was installed (Figure 1). A comparison of the oscillograph records for this filler block showed it to be much less effective.

After a study of the records for conditions with and without the blocks, it was believed that improvement could be obtained in the region of piezometers B, C, D, and E by using a block that was longer and thicker than the 8.9 inch one. The 10.9 inch long block was therefore installed. Pressure fluctuations along the block were still somewhat larger than those at the branch entrance, or those at the butterfly valve, and further improvement might be accomplished by a still longer block. The added length was not considered justified in this case since the maximum fluctuation was 19.5 feet compared with 4.0 feet at the branch entrance. The following table of pressure fluctuations shows the relative effectiveness of the filler blocks.

Table 1

	Without Filler Block	Short (6") Filler Block	Intermediate (8.9") Filler Block	Long (10.9") Filler Block
Location of Max. Surge	Piez's D & E	Piez C	Piez C	Peiz B
Magnitude of Max. Surge	62.0	63.0	19.5	19.5
Location Lowest Pressure	Piez 5	Piez C	Piez A	Piez A
Magnitude Lowest Pressure	-16.5	-27.3	7.2	2.8

Pressures given in feet of water, prototype

The following table gives the average pressure at the various piezometers for the maximum head and both valves fully open.

Table 2

Piezometer Number	Without Block	With 6" Block	With 8.9" Block	With 10.9" Block
6	57.5	55.3	56.3	53.4
7	62.3	61.4	60.0	60.0
1	22.5	10.7	13.5	16.7
A	7.8	28.8	11.0	6.6
B	7.2	37.5	38.3	36.5
C	15.6	58.2	49.8	49.5
D	32.4	61.5	61.5	57.2
E	52.8	57.0	65.3	-
F	53.7	57.0	62.4	61.8
29	53.3	54.2	56.0	55.7
30	56.9	58.5	58.8	58.8
31	57.0	58.2	59.9	60.6
32	56.9	57.9	59.7	59.0
12	83.6	86.0	89.0	86.3
13	88.5	96.8	94.5	94.5
16	-	95.7	97.5	100.7
17	-	117.0	111.0	117.0

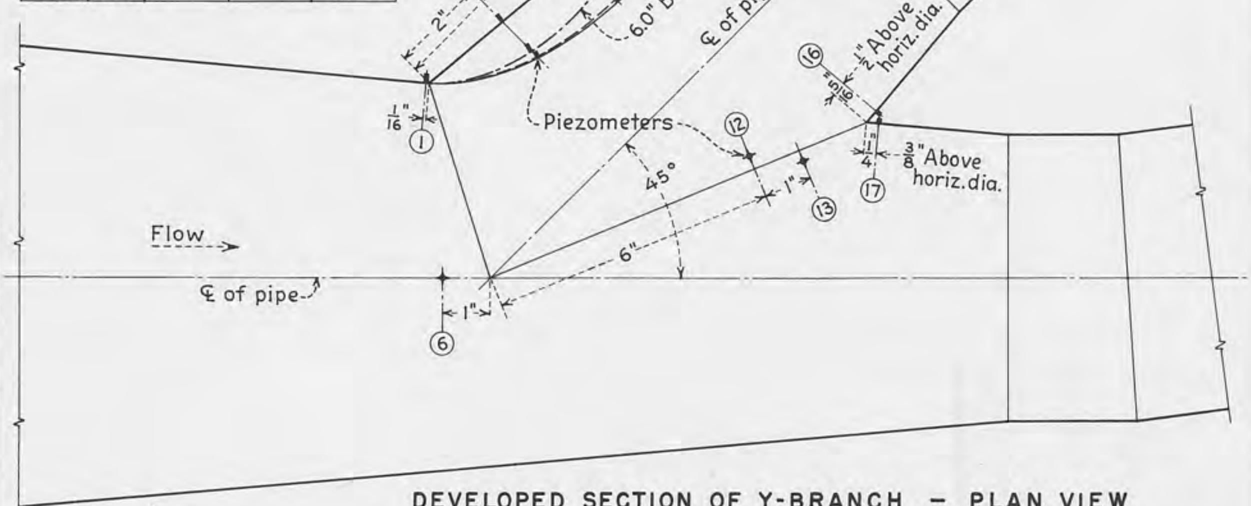
Because of the effectiveness of the two long filler blocks in reducing the vibration and pressure fluctuations in the model, it is recommended that consideration be given to installing a similar shape in the Y-branch of the Mexican outlet works. The shape could be formed of flat plate stock bent to shape and welded to the pipe walls. The length should be at least that of the 8.9 inch block (13.4 feet proto) and preferably should be longer. The space between the plate and pipe walls might be filled with concrete. We feel certain that the vibration described in the report of the Mexican engineers will be reduced to an acceptable amount by the installation of the filler block.

James W. Ball

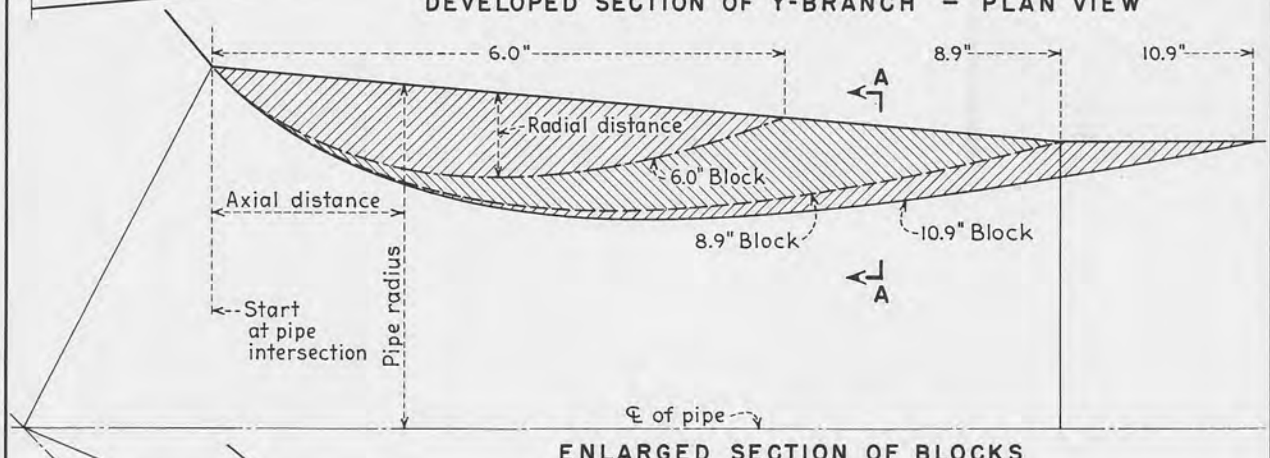
Copy to: International Boundary and
Water Commission #4

TABLE OF COORDINATES

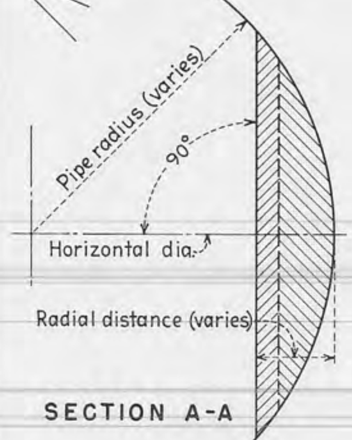
AXIAL DISTANCE ON ℄	PIPE RADIUS (INCHES)	RADIAL DISTANCE (INCHES) 6.0" BLOCK	8.9" BLOCK	10.9" BLOCK
0	3.78	0.0	0.0	0.0
1"	3.70	0.64	0.69	0.69
2"	3.61	0.89	1.03	1.05
3"	3.53	0.89	1.17	1.21
4"	3.44	0.73	1.15	1.23
5"	3.35	0.43	1.04	1.16
6"	3.26	0.0	0.84	1.00
7"	3.17		0.59	0.81
8"	3.08		0.30	0.59
8.9"	3.00		0.0	–
9"	3.00			0.35
10"	3.00			0.17
10.9"	3.00			0.0



DEVELOPED SECTION OF Y-BRANCH – PLAN VIEW



ENLARGED SECTION OF BLOCKS



SECTION A-A

FALCON DAM
OUTLET WORKS – MEXICAN SIDE
PRESSURE VARIATIONS IN Y-BRANCH

PIEZOMETER LOCATIONS AND FILLER BLOCKS
1:15 SCALE MODEL

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