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HYD 117

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

REPAIR OF 58-INCH BALANCED VALVES IN LOWER OUTLET TUNNEL SHOSHONE DAM

Hydraulic Laboratory Report No. Hyd-117

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

OCTOBER 30, 1942

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DEPARTMENT OF THE INTERIOR
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Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
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Laboratory Report No. 117
Hydraulic Laboratory
Compiled by: Jacob E. Warnock

Subject: Repair of 58-inch balanced valves in lower outlet tunnel - Shoshone Dam - Shoshone Project.

In accordance with office letter of September 30, 1942, to Superintendent, Powell, Wyoming, the two 58-inch balanced valves in the lower outlet tunnel in the south canyon wall downstream from Shoshone Dam were inspected during the afternoon of October 10, and the behavior of the west valve while discharging was witnessed during the morning of October 11, 1942.

The concrete for several feet downstream from the metal lining in each discharge conduit has been severely eroded and a majority of the twenty-four 2-inch pipes embedded in the conduit during the revision in 1931 have been torn out and washed away in the eroded areas. The leakage around the west valve in the closed position is abnormal indicating the seat packing is missing and a leakage through the needle face on the west valve has increased in size since it was noticed in December 1941. When repairs were made between the operating seasons of 1941 and 1942, the clearance on the west valve was apparently satisfactory inasmuch as the movement of the valve by use of jacks was easy, furthermore the valve has opened under all heads to date. The east valve has excess friction in it as evidenced by the breakage of timbers and jacking equipment during the last repairs and by the refusal to open under low heads when the reservoir was lowered to complete the Heart Mountain Intake.

Twenty-four 2-inch standard pipes are embedded in the conduit lining parallel to the center-line of each outlet, and equally spaced around the conduit. The inlet ends of these pipes (figure 1) are on the face of the cliff (figure 2A) at the discharge end of the conduits and the outlet ends are opposite the tip of the needle in the closed position of the valve. These pipes were installed to relieve the

sub-atmospheric pressures in the conduit downstream from the valve. In addition, an 8-inch pipe in each conduit was provided to conduct air from the space between the roof of the conduit and the roof of the original opening. The outlet end of the 8-inch pipe is downstream from the outlets of the 2-inch pipes.

In the east valve conduit, seven of the twenty-four 2-inch pipes are still intact, the remainder being torn out as shown in figure 2B and 3B. The concrete is stripped out from 6 to 10 feet downstream from the metal liner on the left side (figure 2C), 10 feet on the bottom, and 3 to 6 feet on the right side. In the bottom, the maximum depth of erosion was 11 inches below the original invert. The 8-inch pipe in the crown, which has been plugged since the trials on its effectiveness in 1931, is still intact but the concrete is torn from around it. The semi-steel conduit liner below the valve is severely pitted due to cavitation as shown in figure 2D. The severity of the pitting can be judged by study of figure 3A. The east valve closes satisfactorily but there is an extensive pitted area on the sealing ring at the invert. The face of the needle has pitted areas on which several kinds of metal have been tried such as Wilson 17, Airco Nickel, 25-12 stainless steel and Hobart cast iron. None have been satisfactory. Figures 3B and 4D show the extensive welding on the face of the needle. The areas of greatest pitting were directly below and above the respective valve guides. In those areas only 3/4-inch of the original two inches of parent metal remains. In repairing those areas studding has been used to hold the deposited metal. This is particularly the case on the west valve. The light color on the face of the needle in figures 3B and 4D shows the extent of the finish layer of nickel. It could not be used over the lower area when the metal had to be deposited practically overhead. The welding was done in place with an electric arc welder. The drummy sound produced by tapping this finish layer showed that the bond is none too good over a considerable area. It is significant that these valves have not been dismantled since their original installation was completed in May 1915.

The conduit downstream from the west valve is not as extensively eroded as the east valve but it is more severe in spots. Twelve of the twenty-four 2-inch pipes are still intact, the others being ripped from their embedment. Figure 3C shows the remains of these pipes and a hole in the concrete approximately 15 inches deep. In this conduit, the plug

in the outlet of the 8-inch air pipe had been torn out. It was plugged in 1931 the same as in the east valve. With this vent open, as the valve is opened past 25 percent, a crackling noise occurs resembling firecrackers. As the valve is opened further, a thundering or cannonading noise develops. This condition was described in detail in letters of September 25 and December 11, 1931, and was the reason for plugging the 8-inch vents.

The reason for the increased damage to the conduit lining and embedded pipes this season as compared to previous seasons, is that for the first time in the history of the installation the valves were operated for an extended period at 0.9 opening for flood control purposes. Previous to 1942, the valves had not been operated beyond 0.80 or below 0.30 opening for any length of time. The following table shows the operation from 1931 to 1941, inclusive, data on operation from 1915 to 1930 not being readily available in this office.

	East Valve		West Valve	
Year	Average Opening	Days	Average Opening	Days
1931	0.33	92	0	0
1932	0.67	44	0.73	26
1933	0.89	60	0.52	56
1934	0.42	113	0.42	19
1935	0.40	86-2/3	0	0
1936	0	0	0.30	79-22/24
1937	0.47	114-23/24	0.45	14-23/24
1938	0.40	22-19/24	0.43	131-1/24
1939	0.44	150-5/24	0.45	137-4/24
1940	0.53	172-18/24	0.53	174-23/24
1941	0.50	124-19/24	0.40	95-11/24

In 1942, the east valve was opened on April 14, and the west valve on April 15. Both valves were operated for the remainder of the month at 0.46 to 0.52 openings. During May they were operated at 0.52 openings until the 26th when they were opened to 0.9. They were operated at 0.9 opening until July 11, when the water surface in the reservoir had practically reached the crest of the spillway and sufficient water was flowing through the notch in the spillway to supply irrigation needs. On July 11, both valves were closed. The west valve was opened to 0.22 on August 5. On August 7, it was closed and the east valve opened and it has been operated at 0.22 to 0.48 for the remainder of the season. This operation of both valves at 0.9 opening from May 26 to July 11, or 47 days was for releasing stored water from Shoshone Reservoir for flood-control purposes,

an experiment made at the request of the Lovell (Wyoming) Commercial Club to benefit farmers along the Shoshone River in the vicinity of Kane whose lands are subject to flooding when there is a large quantity of water in the river. In his letter of March 6, 1942, on the subject, "Release of stored water from Shoshone Reservoir for flood control," the project superintendent offered the increased cost of valve maintenance as one of his reasons for not operating the reservoir for flood control.

In previous years, the damage due to pitting by cavitation has been concentrated on the face of the needle between the seat and the contact line between the piston and body of the needle as described in paragraph 4. The repairs have been by welding on the face with the valve in its open position. The valve in a partial open position creates a hydraulic passage whereby the high-velocity water around the sharp corner at the seat cannot follow the extreme curvature of the needle. A zone of cavitation is created adjacent to the seat and the collapse of those cavities causes the severe pitting which has required such intensive welding repairs. This season, however, with the valve at 0.9 opening that condition has been materially relieved and very little damage was evident on the face of the needle. Instead, with the much larger jet due to the larger valve opening the zone of cavitation has been intensified on the metal conduit liner and the collapse has occurred on the concrete immediately below, hence the extensive erosion in the concrete this year. The twenty-four 2-inch air pipes have relieved the zone of cavitation when the valve was operated at smaller openings but as the valve is opened the jet expands to fill the conduit a shorter distance downstream and the air space around the vena contracta becomes smaller both in width and length. If the valve had been operated at full opening, the damage would have been worse.

Another operating problem in these valves is the uncertainty of starting the closure of the valves from the full open position. This was mentioned in a report from the project manager in July 1918, and is the reason the valves are never operated beyond 0.9 opening. It was the intention in the design of the valves that the pressure to close them be supplied through the clearance gap between the valve plunger and the inner edge of the base. That pressure is then transmitted through the clearance between the bull ring and bull-ring cylinder into the chamber behind the valve piston where it acts to close the valve. Because of the slight reverse curve on the inner edge of the base at full valve opening, the

pressure at the clearance gap instead of being positive and capable of transmission into the chamber behind the valve plunger is probably sub-atmospheric, perhaps severely so. Naturally, with the pressure in the wrong direction the valve cannot be closed and when the pressure from the centrifugal pump in the operating chamber is applied, it is neutralized by escape around the bull ring into the low-pressure zone created by the high-velocity water past the clearance gap.

On the assumption that sufficient material can be obtained to make alterations, it is recommended that changes be made in the design of these valves based on model studies, preparations for which are under way on the instructions of the Chief Electrical and Mechanical Engineer. These changes would be:

(a) Modification of the needle so as to supply a less abrupt curve on which pressures would be positive for all valve openings.

(b) Complete removal of the present metal liners in the entrances to the conduits and replacing them with new liners in which would be incorporated air supply chambers connected by supply pipes of ample size to the passages above the roofs of the present conduits.

(c) Complete elimination of the present valve seat which produces bad hydraulic conditions and in which it is difficult to maintain packing because of the extremely low pressures above it during operation and replacing it with a metal-to-metal line contact seat similar to that now used in needle valves. This change will assist in establishing the stream lines now so grossly absent.

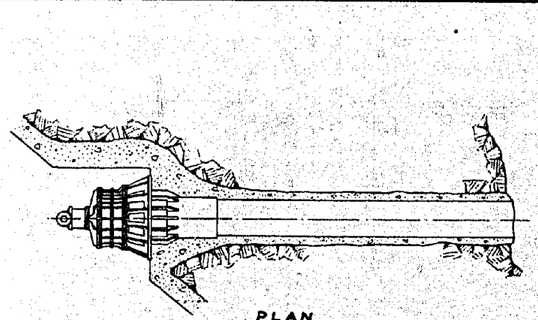
Should the procurement of material or the limited time available prevent the consummation of these plans before the beginning of the operating season about April 15, 1943, as an alternate it is proposed that the valve conduits be restored to their condition as of the beginning of the operating season of 1942, and the operating range be limited during 1943, or until such time as major revisions can be made to those openings indicated as most desirable by the model studies. It is further proposed that the 36-inch balanced needle valve in the bypass house below the powerhouse be removed from its present position and installed on the Heart Mountain siphon where it can discharge directly into the Shoshone River. This valve has been used extensively in its present location to release

irrigation water in past years, but it can no longer be so used because of the reduction of head on the power plant when operating at full capacity. As a third possibility, it may be possible at least for a year or two to allow a portion of the needed water to flow through the Heart Mountain siphon and canal to the first spillway at North Cottonwood Creek where it can be released into North Cottonwood Creek and thence in to the Shoshone River. This proposal is dependent upon the completion of intermediate structures and the capacity of North Cottonwood Creek. A fourth possibility is to alter the operating schedule of the power plant so that more water can be released by power generation.

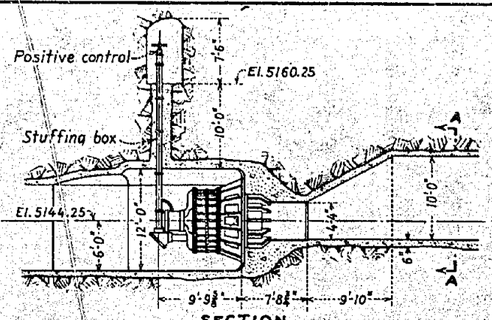
There has been considerable correspondence during the past two years between this office and the project on the question of closing the notch in the spillway permanently or with gates to avoid unnecessary waste of stored water by allowing the water to discharge through the notch regardless of the irrigation requirements. This notch was cut in 1922 to a width of 10 feet and a depth of 15 feet for making temporary diversions during the construction of the Shoshone Power Plant and has since been used at every opportunity to discharge water for irrigation thereby saving wear and tear on the two 58-inch balanced valves which are the subject of this report. While it is not intended to discuss the relative merits of closing this notch, it is considered advisable to clarify the point that permanent closure will increase the operating period of these valves by at least 10 percent.

In conclusion, it is believed that too much emphasis cannot be placed on the present condition of these valves. Based on actual inspection, on discussion with the operating personnel, and on the fact that these valves have been operated 27 years without dismantling, they are considered to be in a state of potential, if not actual, breakdown and should be dismantled immediately for major repairs and revisions based on model studies now in progress.

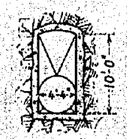
FIGURE 1



PLAN



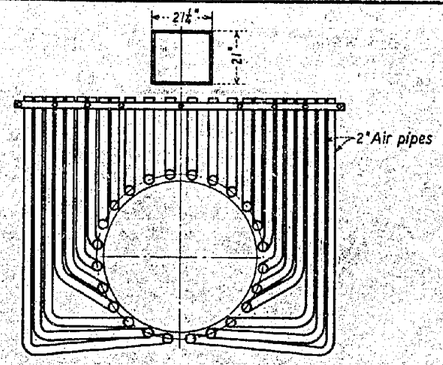
SECTION



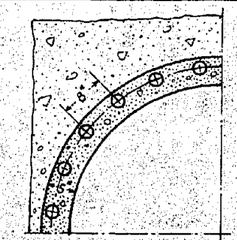
SEC. A-A

ORIGINAL DESIGN AS BUILT IN 1915

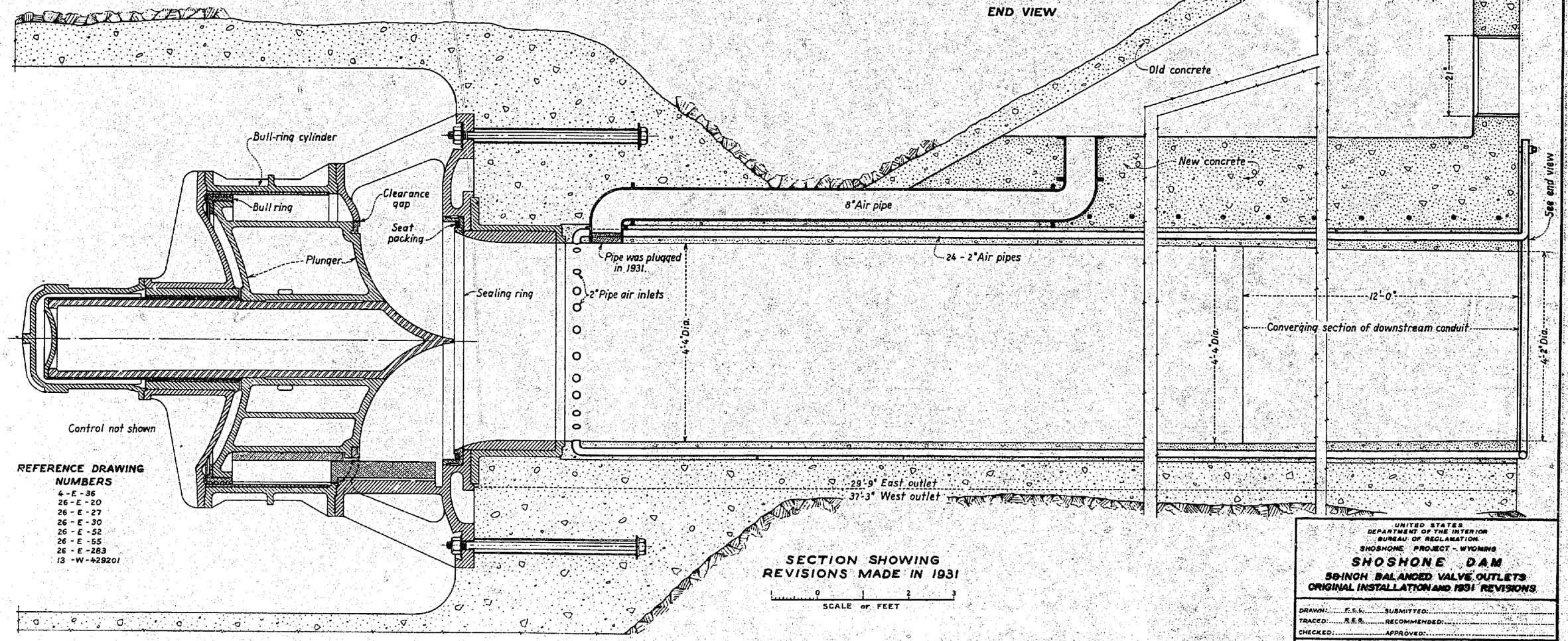
SCALE OF FEET



END VIEW



2-INCH PIPE AIR INLETS



REFERENCE DRAWING NUMBERS

4-E-36
26-E-20
26-E-27
26-E-30
26-E-52
26-E-55
26-E-283
13-W-42920

SECTION SHOWING REVISIONS MADE IN 1931

SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SHOSHONE PROJECT - WYOMING

SHOSHONE DAM

58-INCH BALANCED VALVE OUTLETS
ORIGINAL INSTALLATION AND 1931 REVISIONS

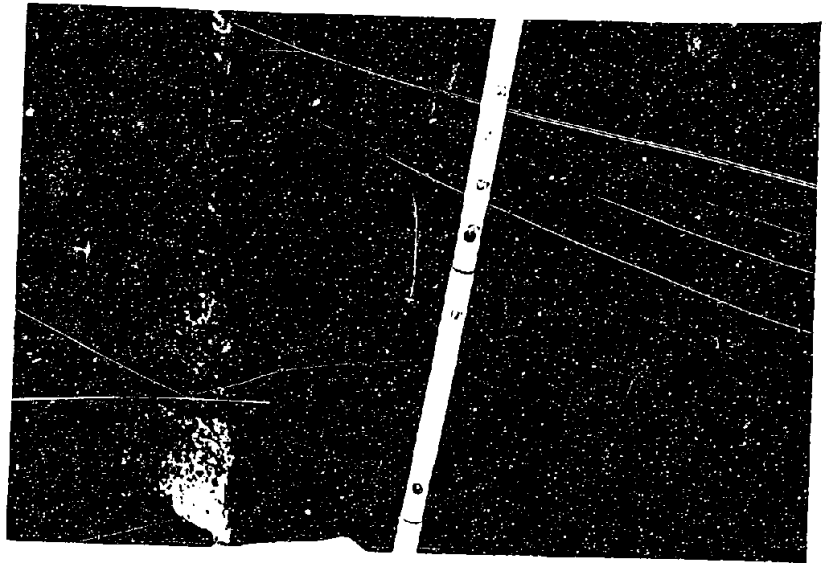
DRAWN: F.C.L. SUBMITTED:
TRACED: R.E.S. RECOMMENDED:
CHECKED: APPROVED:

DENVER, COLORADO, OCT. 30, 1942

A - Outlets of 58-inch balanced valves in south canyon wall.

B - Remains of 2-inch air pipes in vent of 52-inch conduit looking downstream from east valve.

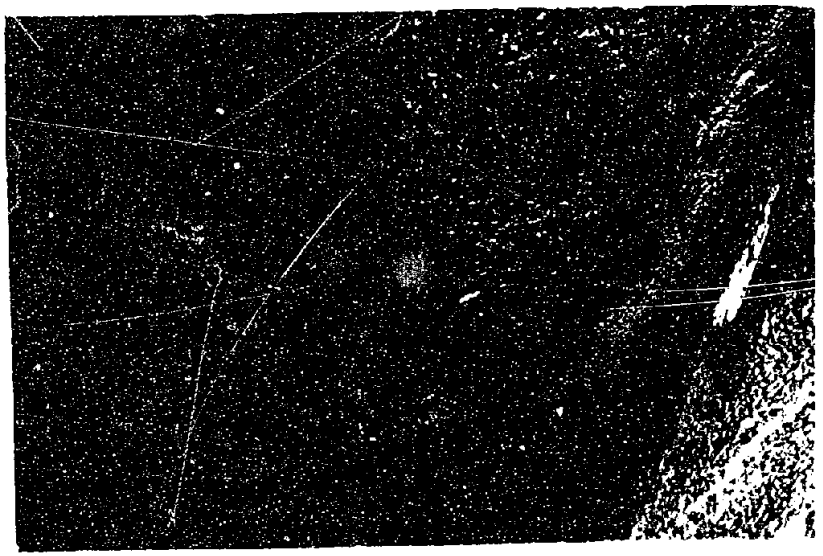
C - Two-inch air pipes laid bare by destruction of concrete downstream from east 58-inch balanced valve.



D - Severe pitting due to cavitation on conduit liner immediately below east 58-inch balanced valve.

BALANCED VALVES - LOWER OUTLET TUNNEL - SHOSHONE DAM

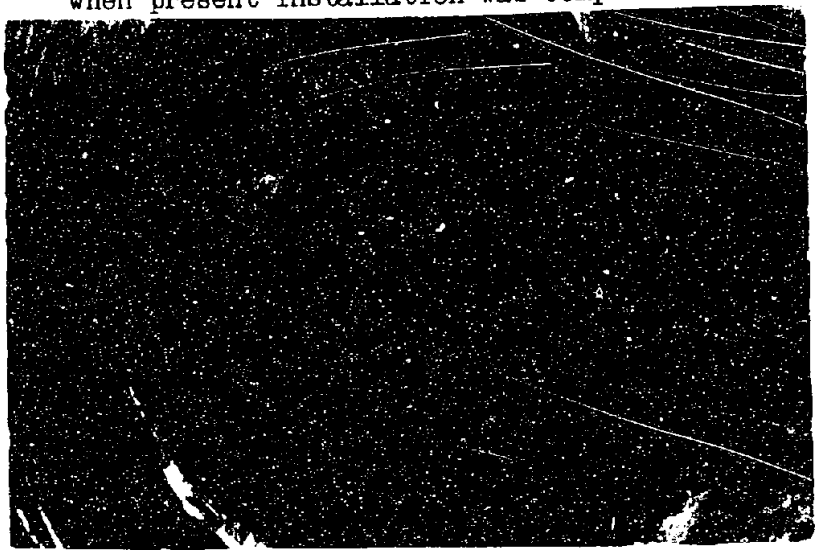
FIGURE 2



A - Pitting on metal liner near seat on east 58-inch balanced valve.

B - Remains of 2-inch air pipes in east valve conduit. Extensive welding on needle face is apparent. End of metal liner cut off in 1931 when present installation was completed.

C - Remains of 2-inch air pipes and 8-inch vent and deep hole cut in right side of 52-inch conduit downstream from west 58-inch balanced valve.



D - Face of needle in west 58-inch needle valve showing extensive welding and exposure of air vent pipes downstream from metal liner.

FIGURE 3

A - Severe pitting of metal liner and concrete in crown of conduit immediately downstream from west 58-inch balanced valve.

B - Extent of erosion in east valve on December 17, 1941, showing 2-inch pipes uncovered in crown and left side of conduit.

C - Two-inch pipe openings in conduit on December 17, 1941.

D - Extensive welding on face of needle and leakage through needle - December 17, 1941.

BALANCED VALVES - LOWER OUTLET TUNNEL - SHOSHONE DAM

FIGURE 4