UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

- - -

HYDRAULIC LABORATORY REPORT NO. 42

- - -

REPORT ON INSPECTION TRIP TO STUDY OPERATIONS OF OUTLET WORKS - ALCOVA DAM - KENDRICK PROJECT

By

C. W. Thomas

- - -

Denver, Colorado
November 16, 1938

HYD 42

Denver, Colorado, November 16, 1938.

From: Assistant Engineer C. W. Thomas

To: Chief Engineer

Subject: Report on inspection trip to study operation of outlet works, Alcova Dam, Kendrick project, Wyoming.

1. An inspection of the Alcova Dam outlet works was made during the period October 5, 1938, to October 12, 1938. This inspection consisted essentially of:

(a) Observations of the system supplying air to the needle-valve jets with a view of determining its adequacy, and if inadequate to determine some method of altering the system to provide sufficient air.

(b) An inspection of the valves to determine the amount of damage due to cavitation.

(c) Measurements of the pressure in the discharge tunnel.

(d) Observations of the behavior of the needle valves in operation.

(e) Observations of flow conditions in the tunnel.

(f) Observations of flow conditions in the stilling pool.

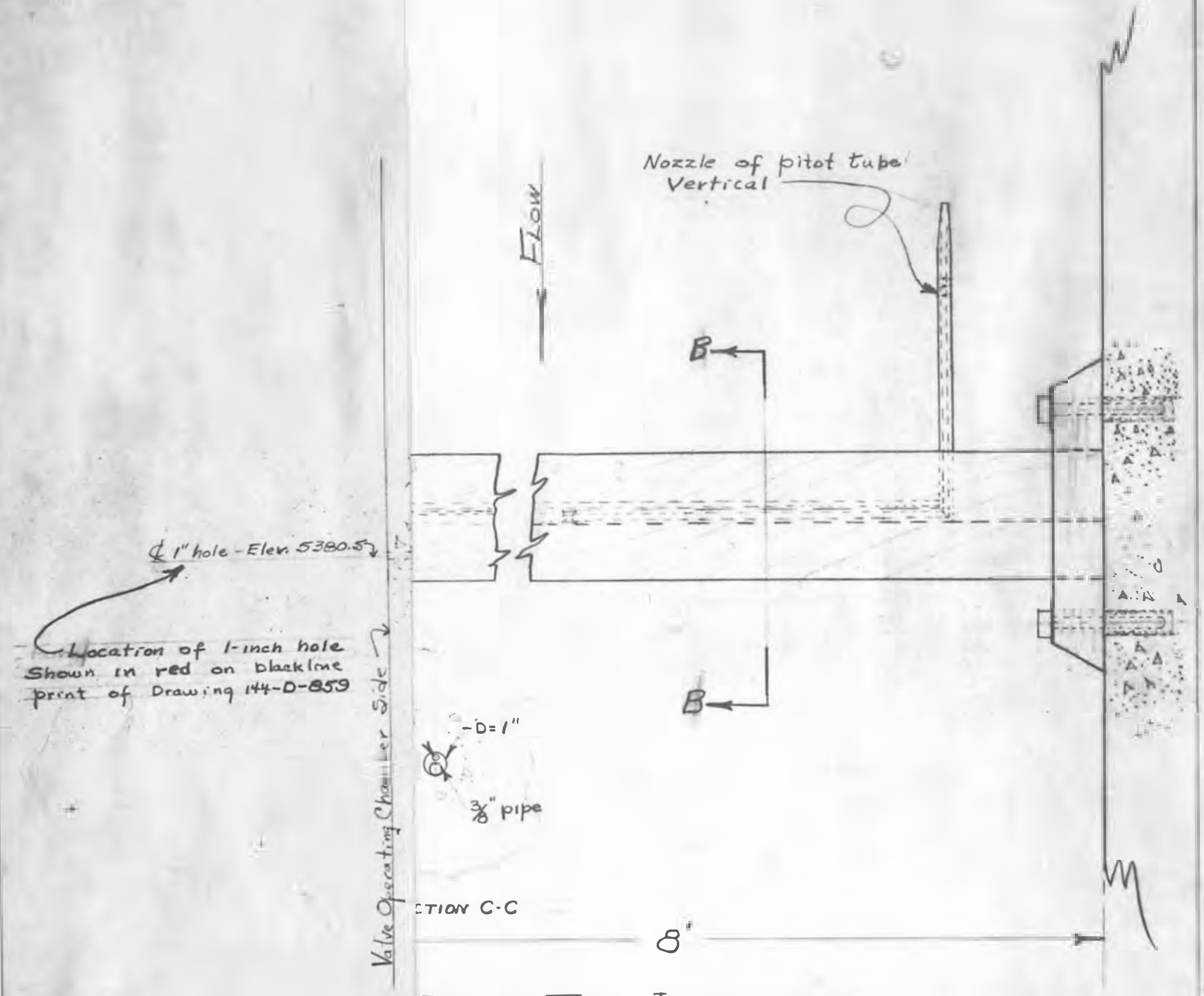
Air Supply to Jets from Needle Valves

2. As the needle valves were progressively opened during the preliminary testing, a drop in air pressure in the operating chamber became noticeable due to discomfort in the ear drums of the personnel. At approximately 50 percent valve opening, this discomfort became so severe that the valves were held stationary while an investigation was made to determine the cause. The 10-foot by 12-foot, 6-inch sheet-metal door (drawing no. 144-D-192) between the valve-operating chamber and the elevator shaft was open. A similar door between the elevator shaft and the pump room was closed to within six inches of the floor. A strong current of air was flowing under this door and the center was deflected a considerable distance toward the pump room. Attempts to raise the door to an open position failed completely, and before the needle valves could be closed, the door partially collapsed into the pump room. This allowed access to the pump room and it was determined that the air was being exhausted from this room into the shaft from the drainage gallery, and through the 3-foot by 3-foot drainage tunnel, into the needle-valve discharge tunnel (drawing no. 144-D-191).

3. The collapse of the door fouled the elevator car and it was necessary to use the emergency ladder to return to the ground level. When the operating house was reached, it was found that the sheet-metal door between the loading dock and the elevator shaft (drawing no. 144-D-188) had partially collapsed into the shaft, and had been prevented from falling down the shaft by the counterweights. No windows were broken because the large ventilator on the roof supplied sufficient air to relieve the pressure within the operating house. The upper elevator door was repaired and replaced. The lower door was completely removed and no attempt was made to repair it since it is planned to separate the pump room from the elevator shaft by a hollow tile partition. A 3-foot by 7-foot fire door will be installed in this partition for access to the pump room. A temporary 3-inch plank bulkhead was placed in the stop-log slot at the hot-water weir, in the 3-foot by 3-foot drainage tunnel, to prevent evacuation of air through this passage. A reading on the differential gage taken just prior to the investigation of the low-pressure condition showed the pressure in the discharge tunnel to be 1.25 feet of water below the pressure in the valve-operating chamber. The differential between atmospheric pressure and the pressure in the valve chamber was not measured, but was an appreciable amount. As soon as the repairs to the elevator were completed, the testing was continued. Several windows in the operating house and the sheet-metal door at the top of the elevator shaft were kept open.

4. Previous to the operation of the needle valves for test purposes, the construction engineer had installed, in accordance with drawing no. 144-JEW-101 (figure 1), a pitot tube and supporting strut in the 6-foot by 8-foot air shaft (drawing no. 144-D-1292). A differential gage from the Denver hydraulic laboratory was used to determine the velocity head at the pitot tube. With both needle valves being opened simultaneously, complete pitot tube traverses were made in the 6-foot by 8-foot air shaft at 25, 50, 75, and 100 percent valve openings. These observations showed an excellent velocity distribution. Pitot-tube readings were taken only on the center line of the shaft for the tenth-point valve openings. These readings were corrected to average cross-sectional velocity by a constant derived from the complete traverses. The mean cross-sectional velocity plotted against valve opening is shown in figure 2. The quantity of air flowing into the discharge tunnel plotted against valve opening is also given in figure 2. A study of these curves and pressures taken in the discharge tunnel resulted in a decision to remove the louvers and grill installed at the entrance to the air shaft (drawing no. 144-D-1064). Pitot-tube investigations were repeated for this condition and the results are given in figure 2. Since there was no simple means of further augmenting the air supply to the tunnel, no further air-demand tests were made.

5. The air-supply system as originally installed caused a very bad entrance condition to the shaft. Losses through the wire grill over the louvers were undoubtedly quite high. Air entering the system was deflected upward 45 degrees by the louvers and then turned through an angle



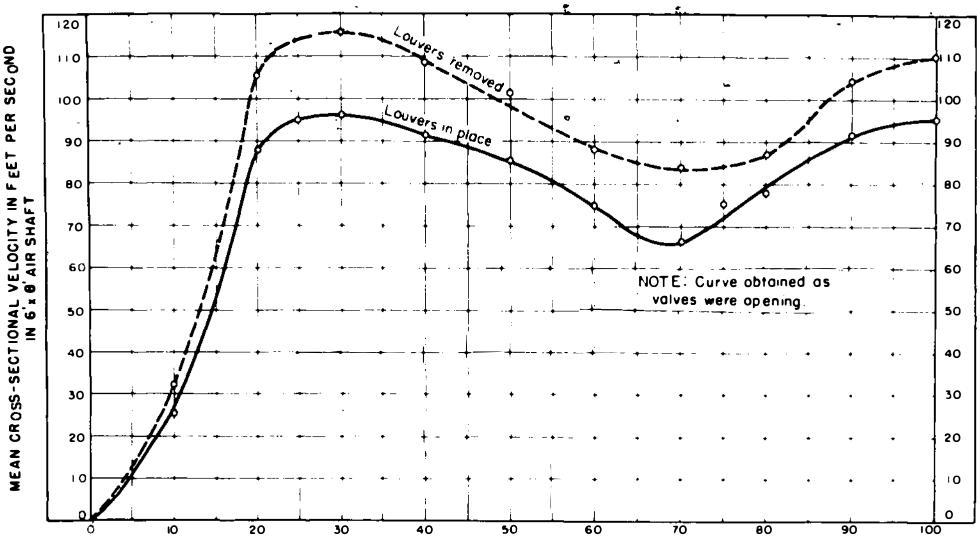
PITOT TUBE INSTALLATION

Note: The screw joint in the pitot tube should be greased well before the final assembly to avoid any leakage at this point. When completely installed the pitot tube should be free to move the entire length of the slot in the strut. Spreader blocks provided are to be installed in the ends of the slot in the strut in such a manner that they will prevent the slot from closing on the pitot tube and at the same time not restrict the movement of the tube.

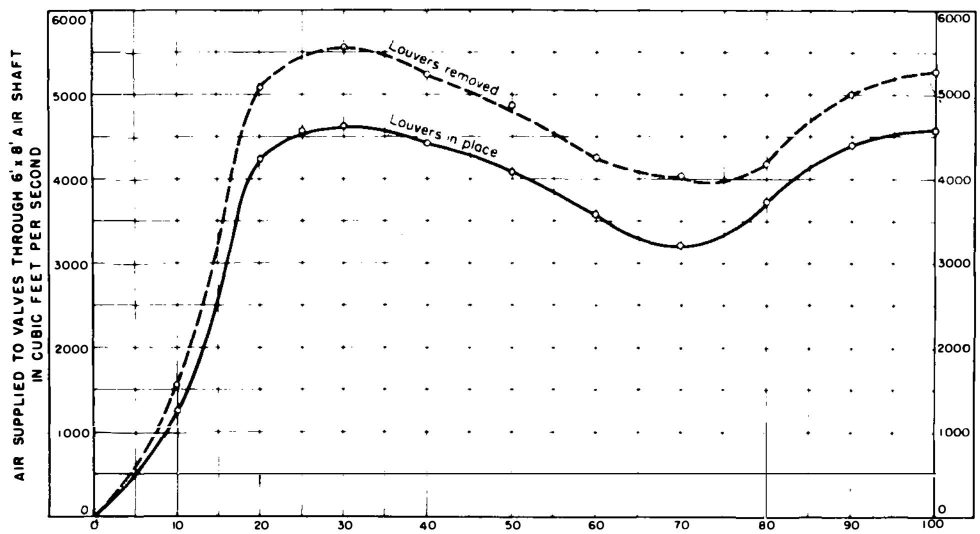
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
KENDRICK PROJECT - WYOMING
ALCOVA DAM
OUTLET WORKS
PITOT TUBE INSTALLATION
IN 6'X8' AIR SHAFT

DRAWN: CWT

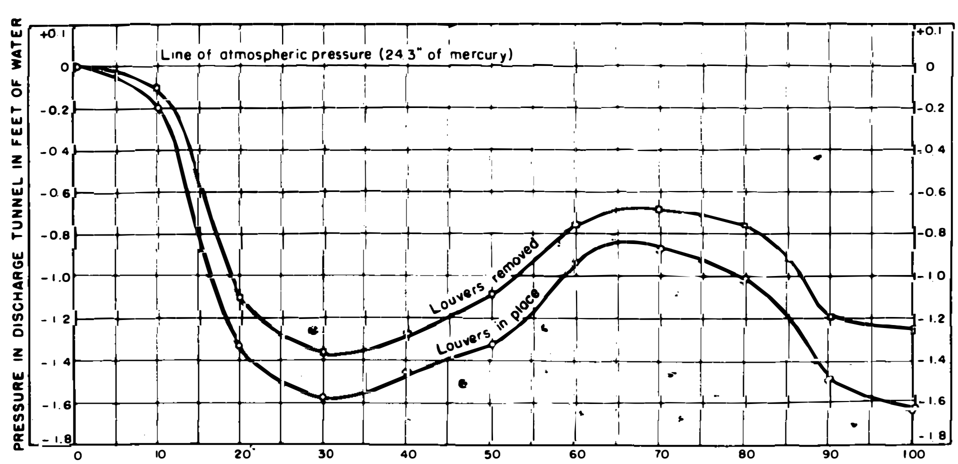
DENVER, COLO., SEPT 22, 1938 | 144-JEW-101



RELATION BETWEEN VALVE OPENING AND VELOCITY OF AIR IN 6' x 8' SHAFT



RELATION BETWEEN VALVE OPENING AND QUANTITY OF AIR FLOWING THROUGH 6' x 8' AIR SHAFT



RELATION BETWEEN VALVE OPENING AND PRESSURE IN DISCHARGE TUNNEL

ALCOVA OUTLET WORKS—NEEDLE VALVES

FIELD PERFORMANCE TESTS

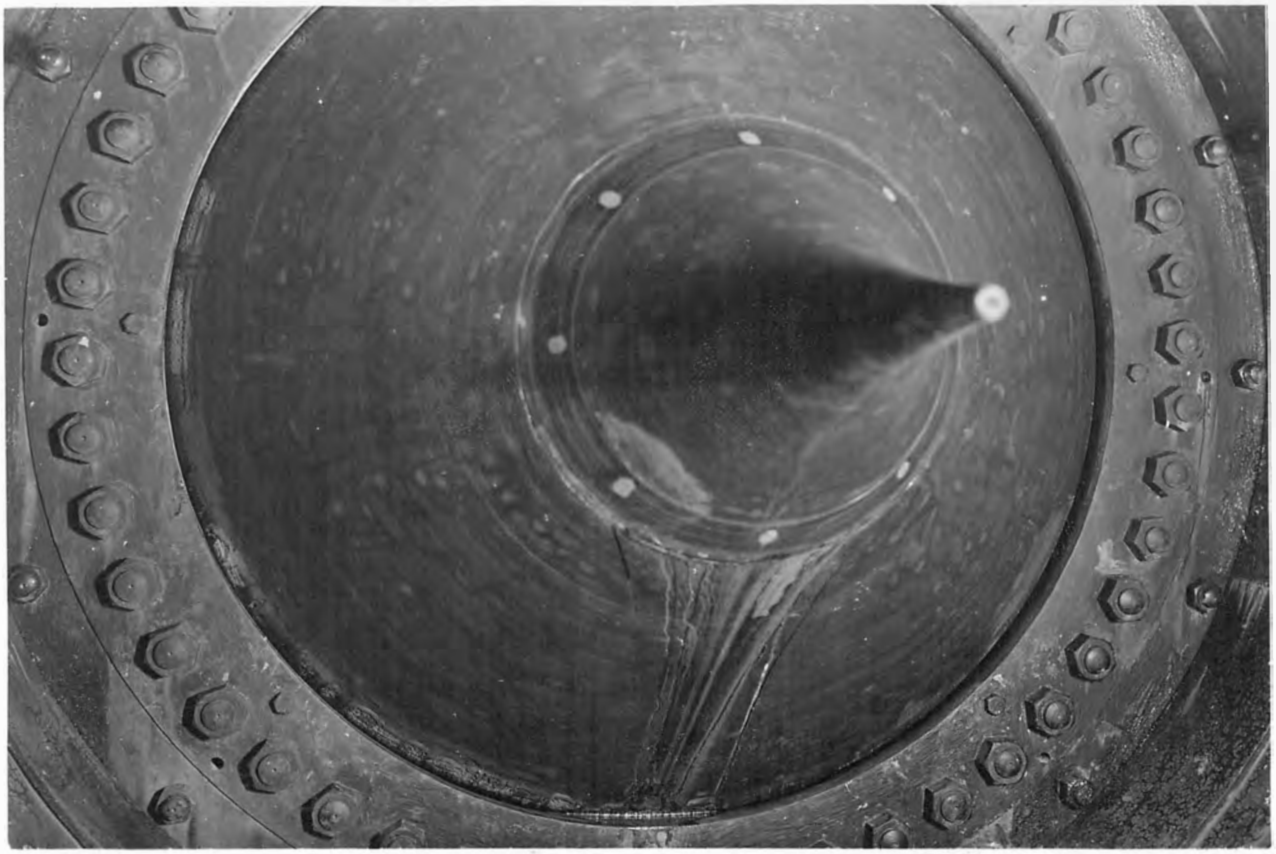
144-D-2902

of 135 degrees before starting downward in the shaft. This caused additional loss. The high velocity of the air passing through the louvers caused them to vibrate considerably. This vibration, combined with the noise caused by the air passing the grill, resulted in an intermittent high-pitched howl that could be heard a considerable distance from the operating house and was an annoyance to the residents in the neighborhood. Pitot-tube measurements showed the maximum velocity in the shaft was as much as 25 percent above the average velocity, and the minimum velocity an equal amount below. This rapid change in instantaneous velocity resulted in the air entering the louvers in gusts, with consequent change in pitch of the noise. The reason for the change in velocity in the shaft was the change in air demand of the jet, as will be explained later. The removal of the louvers almost completely eliminated the objectionable noise and allowed approximately 20 percent more air to be delivered to the jets. The velocities in the shaft were much higher and there was less variation in the velocity. However, the air supply to the valves is considered inadequate even with the removal of the louvers.

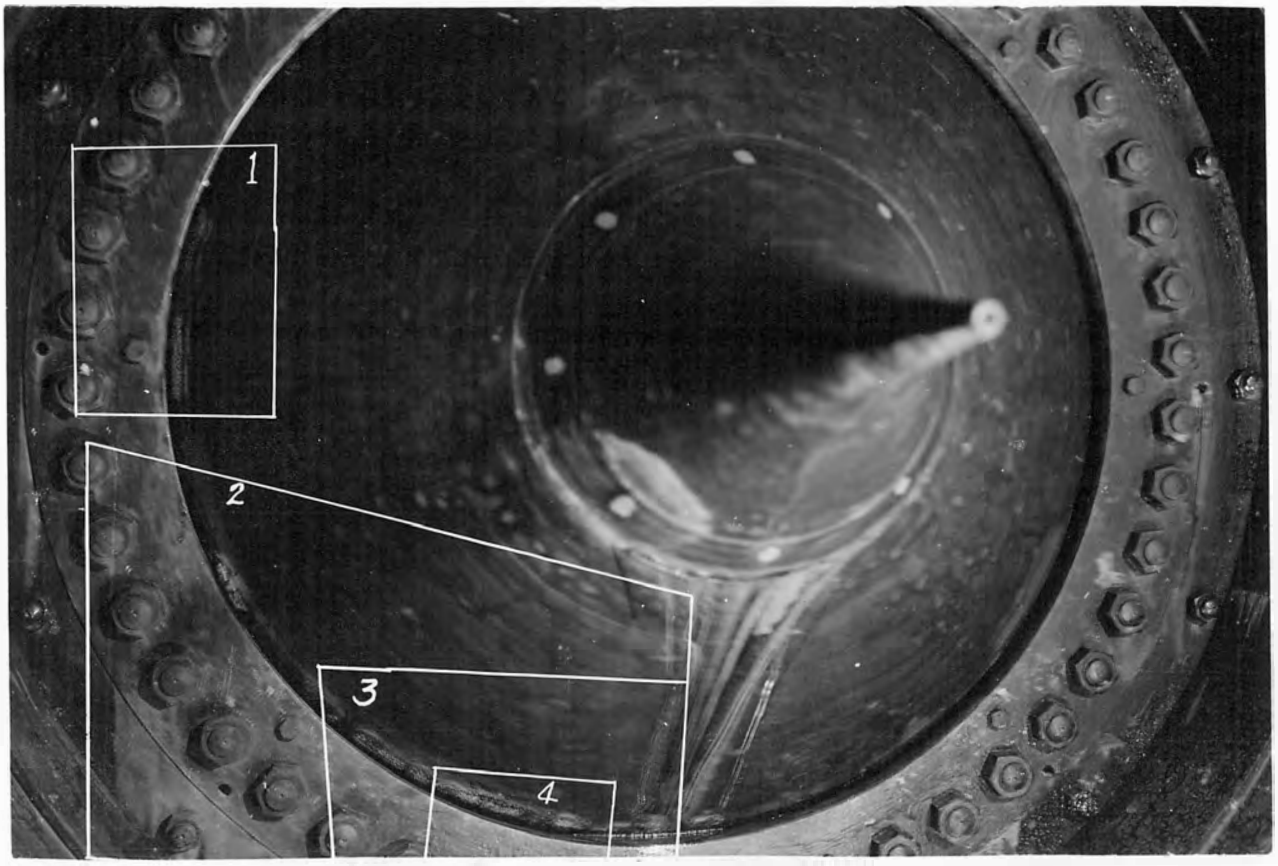
Damage to Valves Due to Cavitation

6. Both needle valves show evidence of cavitation. Damage to the needle and to the bronze nozzle seat is more pronounced in the right or no. 2 valve, where the semisteel portion of the needle immediately downstream from the bronze seat is pitted to a depth of approximately one-quarter inch in concentrated areas (figures 3, 4, and 5). These areas extend from 6 to 8 inches downstream from the bronze seat, and from 18 to 24 inches around the periphery of the needle, and are separated by areas of little or no damage. The pitted areas do not extend into the bronze seal ring. The nozzle seat is not damaged. In the left valve, the results of the cavitation are evidenced by channeling in both the bronze nozzle seat and the bronze needle seat. The channels are more or less evenly distributed over the entire periphery of the rings and on the needle, and extend into the semisteel portion. In both valves, the pitting is downstream from the seal, since no leakage occurs when the valves are closed.

7. From the closure of the dam on February 8, 1938, until the time of this inspection, approximately 1,000,000 acre-feet of water has passed Alcova Dam. Project records show that the reservoir was at elevation 5461.3 on May 20, 1938, and the total water passed prior to that time was 58,000 acre-feet. The passage of this water was through the needle valves. After that date, the operators estimate that between 90 percent and 95 percent of the flow was passed over the spillway, and the needle valves were used only for close regulation of the river. This means that the needle valves had, prior to this inspection, passed 58,000 acre-feet, plus an assumed 7-1/2 percent of the 942,000 acre-feet, or a total of approximately 128,500 acre-feet of water. Due to an inherent tendency for the right valve to vibrate during operation, it was used very little. Estimates differ as to the actual time that this valve has



VALVE NO. 2 - EXTENT OF DAMAGE DUE TO CAVITATION.



VALVE NO. 2 - MARKED AREAS ARE SHOWN IN THE FOLLOWING PHOTOGRAPHS.

AREA NO. 1.

AREA NO. 2.

ALCOVA OUTLET WORKS - NEEDLE VALVES

AREA NO. 3.

AREA NO. 4.

been in operation, but an average of the estimates indicates that it has passed less than 20 percent of the total quantity. Assuming this to be true, the left valve has passed 102,800 acre-feet, and the right valve, 25,700 acre-feet. This is an average flow of 214 cubic feet per second through the left valve and 54 cubic feet per second through the right valve for the 240-day period of operation. If an average reservoir elevation of 5480.0 is assumed, 102,800 acre-feet could have been passed through the left valve in a wide open position in 20 days, in a three-quarter open position in 23-1/2 days, in a one-half open position in 30-2/3 days, and in a one-quarter open position in 59 days. Under the same conditions, 25,700 acre-feet could have been passed through the right valve in a wide open position in 5 days, in a three-quarter open position in 6 days, in a one-half open position in 7-3/4 days, and in a one-quarter open position in 14-3/4 days. Very severe flow conditions must exist in the valves to produce this damage to the metal in such a relatively short period of operation. Apparently the contour of the needle and of the nozzle seat are conducive to the cavitation. The contours of these parts should be altered to conform to some curve that would cause the flow to remain on the surface of the metal. Some work is being done in the hydraulic laboratory, in connection with the Boulder valves, that should be applicable to the valves at Alcova Dam.

Pressure in Discharge Tunnel

8. A 1-1/2-inch pipe extending through the 3-foot concrete wall, separating the gate-operating chamber from the discharge tunnel, was installed during construction (drawing no. 144-D-190). A differential gage was connected to the valve-chamber end of this pipe for observing the differential pressure between the valve-operating chamber and the discharge tunnel. An aneroid barometer showed that the pressure in the valve-operating chamber remained atmospheric after the bulkhead was placed in the 3-foot by 3-foot drainage tunnel. Average pressures in the needle-valve discharge tunnel for the different gate openings, with and without the louvers at the entrance of the air shaft, are shown in figure 2. These curves show that the low pressure was relieved somewhat by the removal of the louvers. This average pressure was in no instance dangerously low but the fluctuation of pressure was of considerable magnitude and was rapid. For instance, with the valves 30 percent open and the louvers in place, the pressure varied from -1.0 to -2.1 feet of water, and the period was approximately one second. With the louvers removed and similar valve opening, the variation was from -1.1 to -1.6 feet of water and the period was slightly longer. The low pressure in the tunnel was a direct result of an insufficient supply of air to replace that carried away by the discharging jets. There was no outlet connection in the needle-valve discharge guides, so the actual pressure existing at the outlet of the valve was not measured. However, it was below that measured in the tunnel, as was indicated by the strong current of spray and water drops which flowed toward the exit of the guides during operation of the valves. It has been suggested to the operators that a suitable connection

be provided and pressure measurements made at a future date.

9. The internal pressure in the jet as it passes the control section in a needle valve is very low. If this jet passes into a region of higher pressure, the external pressure is sufficient to balance the internal pressure and stable flow results. If, however, the discharge is into a low-pressure region, the internal pressure is not balanced and the jet tends to disintegrate. The result is a very rough exterior on the jet and a tendency for the flow to separate from the guide surfaces near the exit of the valve. Cavitation and its harmful effect on the metal parts of the valve are a result. Although the existing low pressure in the discharge tunnel is not entirely responsible for the damage to the valves, it is conducive to the conditions causing the damage.

Behavior of Needle Valves in Operation

10. The mechanical operation of the left needle valve was very good. There was a very noticeable vibration in the right valve at all discharges. This vibration could be heard in the valve chamber and could be felt by placing a hand on the body of the valve or the discharge guide. Inspection of the body of the valve, both externally and internally, and of the needle, externally, yielded no explanation for the vibration. From all appearances, the two valves are identical. The vibration may be caused by the cavitation in the flow or by some maladjustment of the internal parts of the needle.

11. While the valves were being operated for the air-demand tests, observations were made of the head-discharge relation of the valves. This relation is given in the following table:

Valve opening (percent)	Head on center line of valves in feet	Discharge in cubic feet per second
25	124.7	1,645
50	125.4	3,175
	123.2	3,095
75	124.5	4,145
100	123.9	4,825
	122.8	4,800

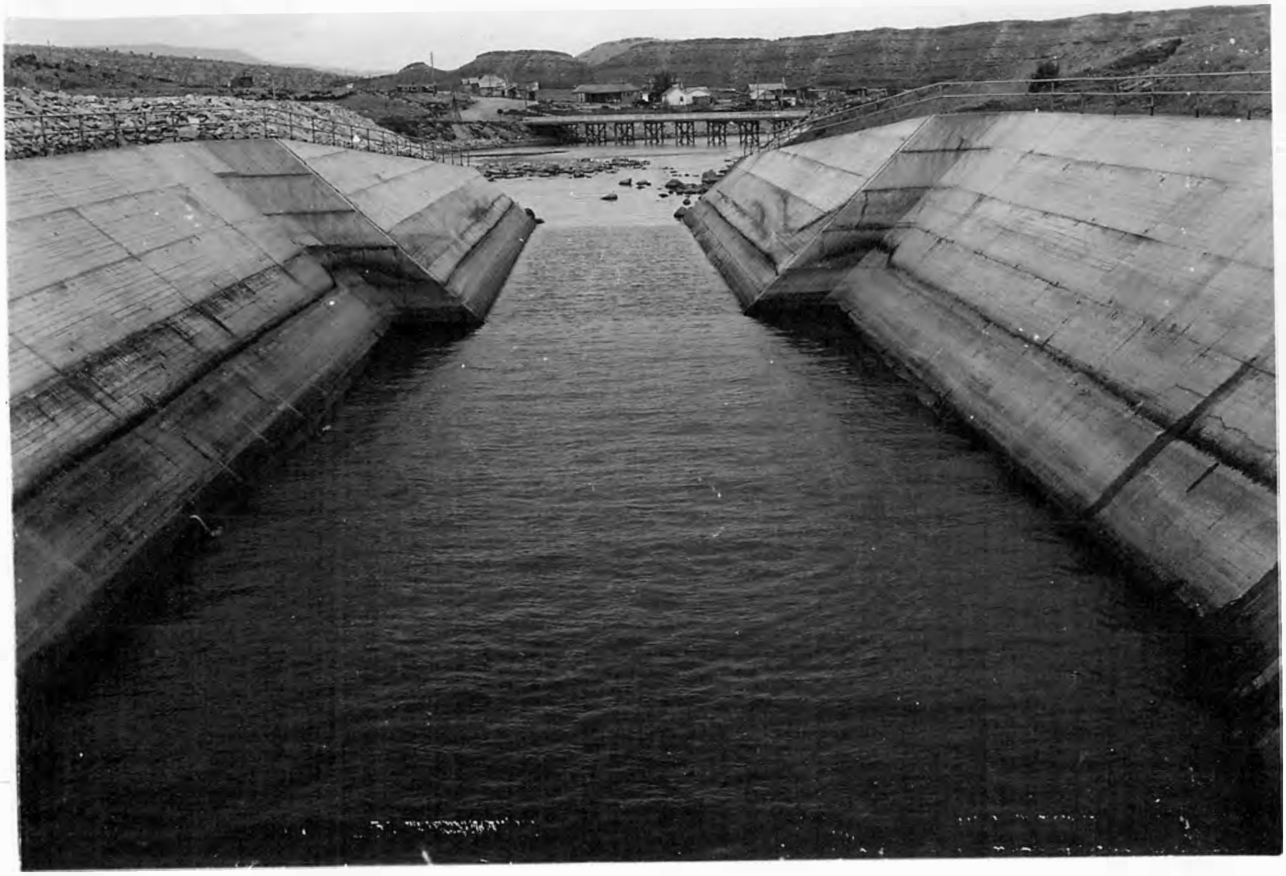
These values were obtained with both needle valves open the same amount. The discharge was taken at the gaging station just downstream from the dam. The accuracy of this section is probably within five percent.

Flow Conditions in the Tunnel

11. Some observation in the tunnel was made possible by the installation of a one-inch plate-glass window in the downstream wall of the valve chamber and a floodlight in the tunnel. The air shaft discharged into the tunnel above the window and the high-velocity jet of air agitated the spray to such an extent that visibility was very low. Occasional glimpses seemed to indicate that the smoother the surface of the jets, the less the demand for air in the tunnel. This relationship could not be definitely established because of the poor visibility. Since the portal of the tunnel did not seal, it seems probable that the fluctuations in the velocity in the air shaft, and the pressure in the tunnel, were directly related to the condition of the outside of the jets. The rough jet absorbed and carried away more air than the smooth jet. Spray was observed to travel toward the discharge cones and toward the left-hand side of the air-shaft exit. The velocity distribution of the air entering the tunnel was very bad because of the bends in the shaft and duct upstream from the exit. No observation of flow conditions was possible beyond a few feet from the valve chamber.

Conditions in Stilling Pool

12. Flow conditions in the stilling pool for four valve settings are shown in figures 6, 7, 8, 9, and 10. The hydraulic jump occurs within the tunnel for discharges below approximately 2,000 cubic feet per second, and conditions in the pool are fair. At higher discharges, the pool is very rough and turbulent. At discharges above 2,000 second-feet, there is a return flow along the left pool wall near the tunnel portal that enters the hydraulic jump from the side, thus impairing the stability of this phenomenon, and waves are produced in the pool. These waves overtop the walls of the stilling basin for discharges above approximately 4,000 second-feet. The tunnel did not flow full at any discharge (figures 8, 9, and 10). The flow leaves the lined section of the pool at high velocity (figure 10). The boulder-strewn stream bed downstream from the pool (figure 11) is sufficient protection against erosion in the bed. However, erosion of the right bank at the end of the lining is quite severe and has exposed most of the cut-off wall (figure 11). In fact, some of the large riprap was moved during the relatively short time that the tests were being made. The riprap on this bank was dumped from the top. The left bank shows little or no tendency to erode (figure 11). The difference in stability is due to the fact that the riprap on the left bank was placed and swings back on a long arc from the end of the concrete. If the right bank is allowed to erode until it is similar in plan to the left bank, and then covered with placed riprap, the tendency for erosion in this area should be completely eliminated. The sharp offset in the walls and floor of the stilling pool at station 15+00, causes the flow to leave the walls, and possibly the floor, immediately downstream from the square corner. An expansion joint traverses



NO FLOW.

VALVES 25% OPEN - DISCHARGE 1645 SECOND-FEET.

[illegible] OUTLET WORKS - STILLING POOL

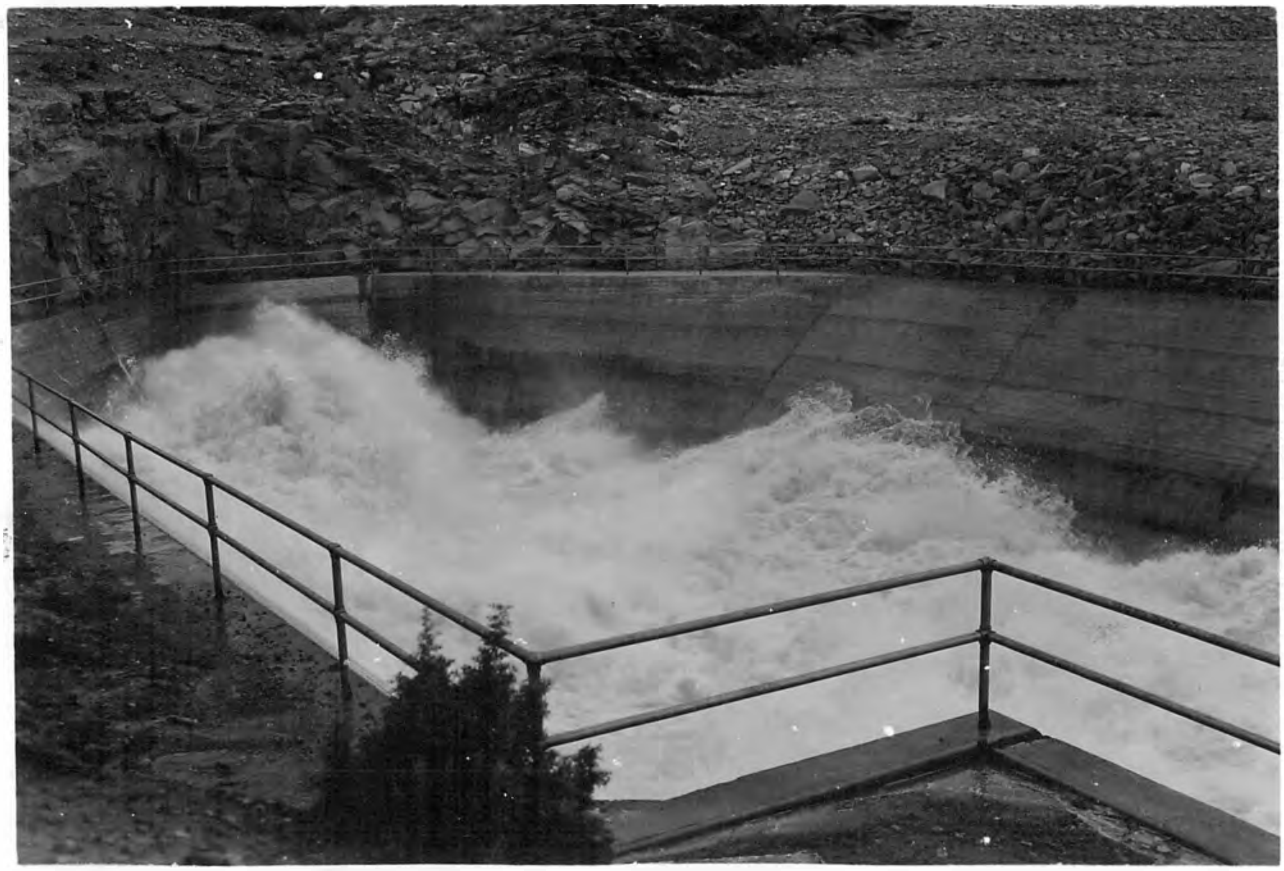
VALVES 50% OPEN - DISCHARGE 3175 SECOND-FEET.

VALVES 100% OPEN - DISCHARGE 4825 SECOND-FEET.

NO FLOW.

VALVES 25% OPEN - DISCHARGE 1645 SECOND-FEET.

VALVES 50% OPEN - DISCHARGE 3175 SECOND-FEET.



VALVES 75% OPEN - DISCHARGE 4145 SECOND-FEET.

ALCOVA OUTLET WORKS - STILLING POOL.

VALVES 75% OPEN - DISCHARGE 4145 SECOND-FEET.

VALVES 100% OPEN - DISCHARGE 4825 SECOND-FEET.

VALVES 100% OPEN - DISCHARGE 4825 SECOND-FEET.

ALCOVA OUTLET WORKS - STILLING POOL.

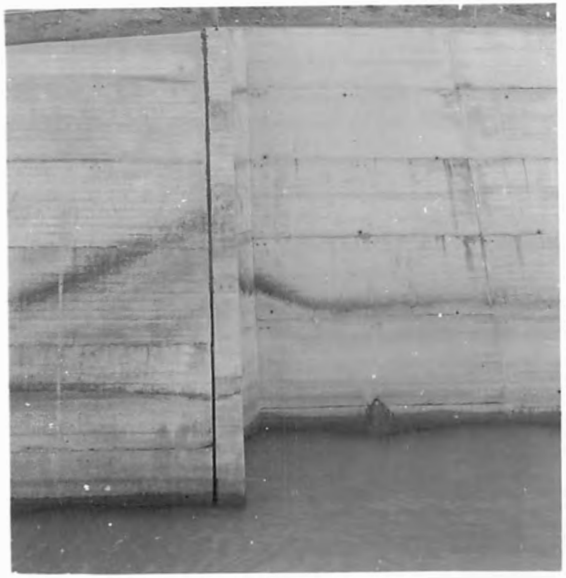
FIGURE 10

BEFORE TESTS.

AFTER TESTS.

RIGHT BANK - RIPRAP AT END OF POOL.

STREAM BED DOWNSTREAM FROM POOL.



EXPANSION JOINT AT STA. 15 + 00.

ALCOVA OUTLET WORKS - STILLING POOL.

FIGURE 11

the pool at this point (figure 11). The mastic in this joint had been removed to a depth of 2-1/2 feet due to the low pressure. The joint in the floor appeared to have suffered no damage. It is suggested that the remaining plastic be removed from this joint and the joint grouted to avoid possible damage to the walls.

Miscellaneous Observations

13. During the tests on the needle valves, the behavior of appurtenant equipment was also studied and several suggestions of improvement are offered. The service elevator between the operating house and the valve chamber is a constant source of trouble. While the general installation appears to be satisfactory, certain equipment is faulty. The safety switches on the elevator doors are corroding badly due to the excess moisture in the shaft, and the 440-volt fuses on the control board in the top of the operating house are due in part to too close spacing and in part to the moisture in the control room. During the preliminary testing, the elevator failed twice due to trouble in the safety switches. Since no one is allowed in the operating house but employees, the safety switches were taken out of the circuit. It was realized that this is not good practice but no other expediency existed at the time. With the elevator machinery on the top floor of the operating house, in case of failure, it is necessary to climb the emergency ladder and the stairway, make necessary repairs, and return to the elevator car by the emergency ladder. With the car at or near the bottom of the shaft, this means a round trip up 165 feet of ladder and 25 feet of stairway. It would seem advisable to include a manual control and indicator at the control board so that the car can be moved up and down by a person at the control board. If an electrician is available, he can attach leads to the control panel to raise the car, but this is dangerous due to the possibility of overrunning the car and damaging the machinery.

14. In making the tests on the needle valves, it was necessary to know the reservoir elevation to determine the operating head on the valves. Before the tests were started, attempts were made to determine the elevation of the reservoir water surface, using the mercury gage in the outlet-works operating house. Consistent results could not be obtained due to faulty installation of the conduits from the bottom of the reservoir to the gage and to probable leaks in these conduits. Benchmarks on the upstream face of the dam were used to determine the reservoir elevation for the tests. This was not satisfactory because waves and surface disturbances made it difficult to obtain accurate readings. When operation of the canal is started, it will be necessary to keep a very close check on the reservoir. This cannot be done with the present gage. A stilling well of standard galvanized pipe could be installed in the counterweight recess in the elevator shaft. A recording float gage, a neon-glow tape gage, or a gage of the type used at Pathfinder Dam could be placed at the top of the well and would be accessible from the

emergency door into the elevator shaft at the foot of the spiral stairway. Since the elevator shaft is warm, the gage would operate regardless of temperature outdoors. It is recommended that some change be made as soon as possible.

15. After the tests on the needle valves were completed, the inspection and drainage tunnel was unwatered by pumping. The pump recently installed operates satisfactorily. Approximately 2-1/2 hours' operation of the pump drained the shaft and tunnel. The blower in the ventilating system was allowed to run for approximately 1-1/2 hours before the shaft was entered. The shaft-cage hoist mechanism operates very satisfactorily. The shaft-cage safety mechanism was damaged during or shortly after installation and has been removed from the cage. This equipment should be repaired and replaced. The temperature in the shaft was approximately 130 degrees F. At the junction of the shaft and tunnel the temperature was approximately the same but dropped slowly until at the extreme end it was 97 degrees F. The temperature of the air entering the tunnel from the ventilating duct was slightly above 100 degrees F. It was very uncomfortable to work in such temperatures, even for short periods of time, particularly because of the high relative humidity. A blower of sufficient size to deliver twice the amount of air at the far end of the tunnel should improve conditions considerably. The ventilating duct passes through approximately 500 feet of heated rock; thus the air delivered to the tunnel is preheated and expanded. Some of the air is now lost through the drain from the air duct. It is recommended that a larger blower be installed. With the larger blower, the pressure in the air duct will be greater and the loss of air through the drain from the air duct to the sump in the shaft will be greater than at present. To prevent this loss, the drain line should be supplied with a valve that could be closed as soon as the air duct is free of water. The metalwork in the tunnel has been damaged very little from the action of the hot water. The valves on the drainage pipes opening into the tunnel are corroded. All metalwork in the shaft is corroded and pitted and is deteriorating rapidly, particularly near the top of the shaft.

16. Although the weather was too moderate to witness the condition at the time of the needle-valve tests, the operators related that during the winter months, the hot, humid air from the pump room rises through the elevator shaft and is cooled in the upper room of the outlet-works operating house. The operating machinery for the elevator, the blower and motor for the ventilating system, and the transformers are contained in this room. The moisture condenses from the air and completely covers the walls of the room and all contents. The previously mentioned tile partition between the elevator shaft and the pump room will partially relieve this condition but there will still be some condensate from the warm air rising from the valve-operating chamber and elevator shaft. The proposed partition will also prevent the escape of the vapor from the pump room. This vapor will condense on the pump and motor and all metalwork within the room, and damage will result.

A hood built over the shaft to the drainage gallery and vented to the outside of the room should greatly reduce the humidity. Likewise, a hood built over a portion of the grating in the floor of the upper room of the outlet-works operating house and connected by a pipe to the ventilator in the roof should lower the humidity in the room and lessen the damage to the elevator machinery. The portion of the grating not covered by the hood would necessarily have to be closed by some suitable means. The disposition of the air from the hood in the pump room will require further consideration.

Conclusions

17. Air supply to needle valves. The present air supply to the needle valves is not sufficient, although the louvers and grill at the entrance of the air shaft have been removed. These accessories may be safely left out of the opening but a fence should be constructed around the side of the outlet-works operating house in which the opening is located, to keep curious onlookers at a safe distance. Model studies of the type of needle valves installed at Alcova Dam show that the exterior of the jet is very rough at approximately the same valve settings that the air demand is the greatest, as shown in figure 2. This confirms the limited observations of the jets on the prototype. Model studies have also shown that the surface of the jet can be improved by changing the contour of the nozzle-seat ring. To correct the condition at Alcova Dam, it might only be necessary to replace the nozzle seats, thus improving the surface conditions of the jet sufficiently to diminish the air demand to the extent that the present system would supply adequate air. At least the air demand might be reduced enough that the present system could be altered by the introduction of vanes in the turns in the air shaft to make it adequate. The change would tend to reduce the damage to the valves due to cavitation. A manifold connection extending around the entire periphery of each discharge guide, as close to the nozzle of the valve as possible, could be installed at a nominal cost. The air could be supplied to these manifolds directly from the 6-foot by 8-foot vertical air shaft and should improve the jet, thereby further reducing the air demand. By taking the air from the vertical shaft above the lower turns, the ultimate capacity of the air system would be increased. A method of accomplishing a similar result, insofar as improving the jets is concerned, would be to dispense with the discharge guides and move the valves downstream until they would discharge directly into the tunnel. This would allow the jets to be discharged into a region of greater pressure than at the present and the air supply would be more evenly distributed around the jets. Other possible means of improving the conditions would be to enlarge the present shaft or drill an auxiliary shaft, or continue the 84-inch pipes to the end of the tunnel and allow the valves to discharge directly into the stilling pool.

18. Damage to needle valves due to cavitation. The damage to the needle valves due to cavitation is serious, considering the short

length of time that the valves have been operated. These valves will require repair at frequent intervals if they are operated to any great extent. Such maintenance will be costly because the valves are not readily accessible. The present nozzle seats could be replaced with seats of improved design at a very nominal cost. It is probable that this change would not entirely correct the cavitation conditions but would diminish them. Replacement of the needles, as well as the seats, would be necessary to eliminate the conditions. Although this would necessitate a greater initial expenditure, it would, no doubt, be more economical than the cost of maintenance over a period of years. If these changes are made on the valves, in addition to relieving the cavitation difficulties, the air demand would probably be materially reduced and the question of air supply would be solved, at least in part. The exact amount of reduction of air demand gained by this change cannot be definitely stated.

19. Pressure in the discharge tunnel. Although it is necessary for the pressure in the tunnel to be slightly below atmospheric before any flow of air down the shaft can be expected, the negative pressures existing at present are excessive. All observations indicate that the pressure in the discharge guide, although not measured, is considerably below the pressure measured in the tunnel. This low pressure is not the primary cause of the cavitation but is certainly a contributing factor. The discharge guides should be supplied with manifolds, or the guides removed and the valves moved downstream in order to supply more air to the discharged jet close to the valve. A greater air supply or an improved condition of the jets necessitating less air are the only means of eliminating the low pressures.

20. Operation of the needle valves. The vibration in the right valve may be due to cavitation or to some mechanical condition. Further inspection of the internal parts of the needle should be made to determine, if possible, the cause of this vibration. The manual control for this same valve is hard to start at times, and the reason for this should be investigated. The capacity of the valves is slightly above the contemplated discharge.

21. Flow conditions in the tunnel. Although very limited visual observation of flow in the tunnel was possible, no adverse conditions were noted. Insofar as it was possible to determine, the flow at no time sealed the tunnel. The tunnel was observed to flow free at the portal for all discharges.

22. Conditions in the stilling pool. Although the flow conditions in the stilling pool are not satisfactory, no damage aside from that outlined in paragraph 12 has resulted. The water that overtops the walls of the pool has eroded some material, but the right side of the pool, where most of the overflow occurs, is on rock and little damage can result. The sound character of the river bed below the pool is very resistant to retrogression. If the contraction joint is grouted and the

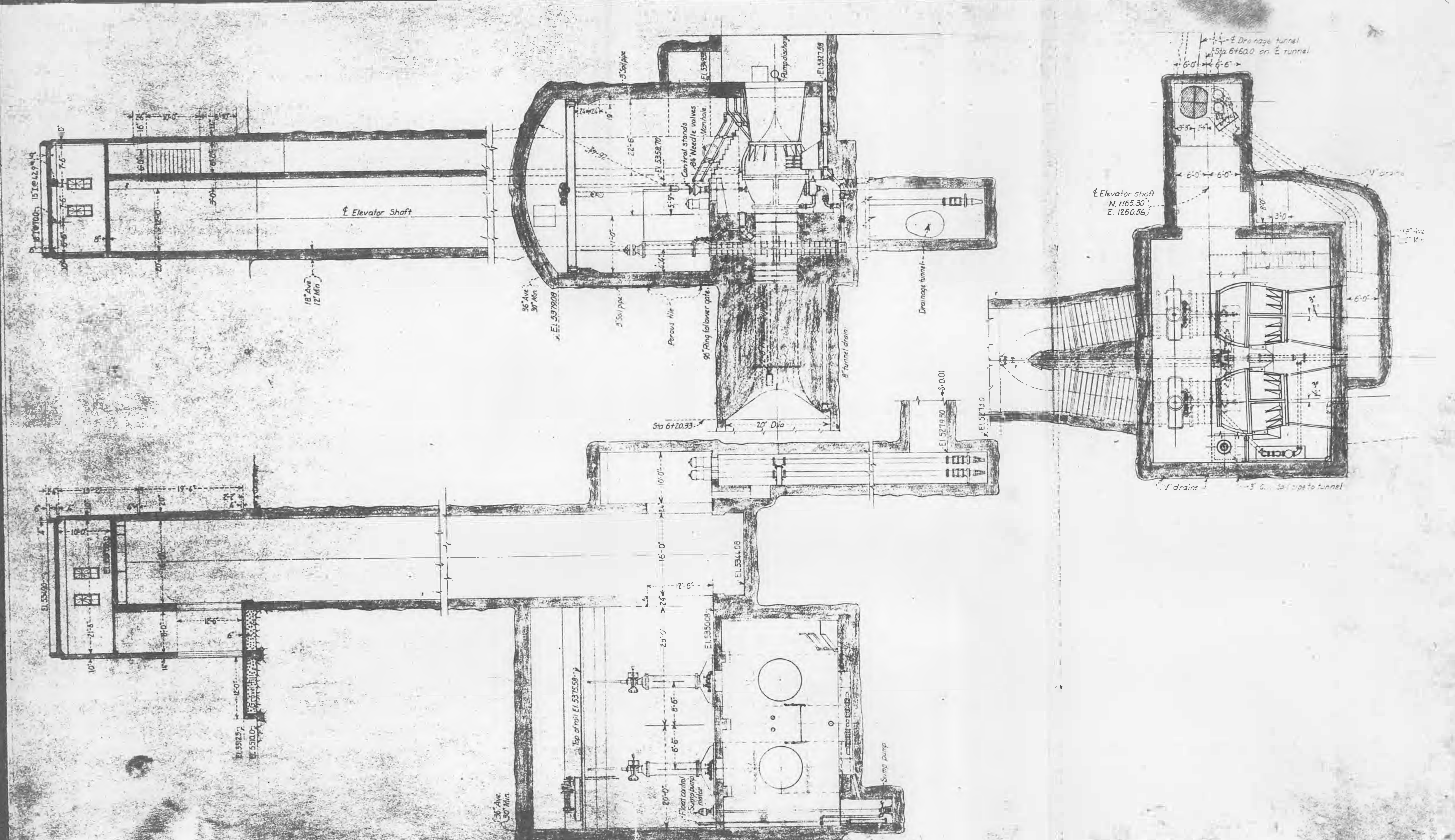
riprap on the right bank at the end of the pool is repaired, no further maintenance should be necessary for some time.

23. Operation of Alcova Dam. Regulation of Alcova reservoir should be accomplished by the use of the spillway as much as possible. The mechanical and hydraulic operation of this structure is very satisfactory. It is not possible to regulate the flow of the river below the dam to an exact discharge without considerable manipulation of the spillway gates. Therefore, it will be necessary to use the outlet works for close regulation. This should not necessitate opening the valves more than 15 percent. In the range from 0 to 15 percent open, the air demand is not excessive and the pressure in the tunnel is not dangerously low. However, it is probable that cavitation is more severe in this range. Otherwise no serious damage should result from this operation. If the valves are to be operated at greater opening, the operator should make sure that the wooden bulkhead in the 3-foot by 3-foot drainage tunnel is in good shape and that the damper on the end of the ventilating pipe in the pump room is closed. If either or both of these openings are left open while the valves are being operated, damage to the elevator-shaft doors and operating-house doors and windows might result and endanger the lives of the operating personnel. The bulkhead should be left in the 3-foot by 3-foot drainage tunnel. It should be inspected periodically and maintained in good condition. In fact, serious consideration should be given to the permanent plugging of the 3-foot by 3-foot drainage tunnel. The needle valves should be carefully inspected at least once every 15 days during operation to determine progress of cavitation and necessity for repairs.

24. Suggestions for future design. Where possible to do otherwise, the practice of discharging needle valves operating under high heads into a tunnel should be avoided. If this cannot be done, air passages should be provided to supply ample air to the tunnel to avoid low pressures. These air passages should be designed to eliminate insofar as possible losses due to entrance conditions and bends, or obstructions in the passages. Discharge guides should be used only as a necessity and then should be as short as possible. The shape of the valve and needle should be such that cavitation is reduced or eliminated.

\- - -

C. W. Thomas.



℄ Elevator Shaft
Control stands
84 Needle valves
Manhole
Pump discharge
3" Soil pipe
Porous tile
96" Ring follower gate
8" tunnel drain
Drainage tunnel
Sta 6+20.93
20' Dia
36" Ave 30" Min
18" Ave 12" Min
El. 5379.09
El. 5358.70
El. 5327.58
El. 5279.50
El. 5273.0
El. 5344.08
El. 5350.08
Top of rail El. 5375.58
Float control
Sump pump motor
Sump pump
℄ Drainage tunnel
Sta 6+60.0 on ℄ tunnel
℄ Elevator shaft
N. 1165.30
E. 1260.56
4" drains
3" Soil pipe to tunnel