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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. .008

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TEST OF BALANCED NEEDLE VALVES
SHOSHONE DAM

by
J. M. Gaylord

- - -

Denver, Colorado

October 20, 1922

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
October 20, 1922

Laboratory Report No. .008
Hydraulic Laboratory
Compiled by: J. M. Gaylord

Reviewed by: C. W. Thomas

Subject: Test of balanced needle valves, Shoshone Dam, October 28 to 30, 1922.

HYD-008

This technical memorandum, although written prior to the establishment of the Hydraulic Laboratory of the United States Bureau of Reclamation, contains the report of hydraulic model studies and has been used as a reference from time to time by members of the Hydraulic Laboratory staff in connection with similar studies on valves. Therefore, it is included in the reports of the Hydraulic Laboratory and is given a file number.

1. The 36-inch needle valve, shown in drawings 26-E-143, 154, and 222, is a part of the permanent equipment of the Shoshone Dam, and was installed in the summer of 1922. Its function is to regulate the flow below the dam during the winter when the main irrigation outlets can not conveniently be operated. This valve was tested October 29, to determine the effectiveness of the controlling devices, the coefficient of discharge, and the losses in the penstock which delivers the water to the power plant and the valve.

2. The 4-inch experimental valve, shown on drawings X-E-226 and 227, was designed to determine the effect of the shape of the needle and nozzle tip on the coefficients of the valve in an effort to obtain better discharge coefficients than previously obtained with the similar valves at Shoshone and Pathfinder Dams. This valve was tested at Shoshone Dam October 28 to 30, 1922.

36-inch Valve

3. The 36-inch valve is similar in operation to the Pathfinder needle valve and the original Ensign valves. It consists of a differential plunger moving in a close-fitting cylinder in which the pressure

is regulated to control the motion of the plunger. The cylinder is fixed centrally in the valve body casting, a space between the inner and outer shells forming the water passage. The control mechanism is of new design, located outside the valve, as will be seen in drawing 26-E-143. The motion of the plunger is communicated by means of two racks and pinions to a control valve which automatically maintains the plunger in any desired position when the control valve is once set by means of the handwheel. One of the splitters contains a small orifice and a valve to admit closing pressure to the cylinder when the plunger is in its wide-open position against the rear seat, which cuts off leakage into the cylinder. This pitot connection can also be used to pick up velocity head and increase the pressure in the cylinder to accelerate the closing motion of the plunger. Baffle plates (part 4 of drawing 26-E-143) were provided at the entrance to the annular chamber to pick up velocity head for continuing the opening motion after a considerable velocity had been established at this point. These plates were found to be not essential to the operation of the valve and were removed. It was also found unnecessary to use the pitot connection in the splitter, although the valve can be closed more quickly with this connection open. No means of applying pressure nor vacuum from an external source were provided and none are necessary. As shown on drawing 26-E-154, the valve discharges downward at an angle of 13-1/2 degrees through a rock tunnel into the river. This plan was adopted in order to turn the jet away from the power plant and to prevent spray by discharging under water. One of the attached photographs shows the disturbance caused by the jet at the outlet and tunnel, and while this disturbance is severe the spray is almost entirely eliminated.

4. In testing the operating functions of the valve, the plunger was moved throughout its full stroke several times to determine the facility of control, and then was allowed to come to rest at various points in the stroke, pressures in the water discharge and operating cylinder being noted for each definite position. From these pressures and the known dimensions of the valve, the forces acting on the plunger

were calculated and the results are shown in the curve on drawing 26-E-231. With the valve wide open, pressures were taken at various points along the valve, as indicated on drawing 26-E-231.

5. The plunger seats practically tight, leaking only three or four drops per minute. The control is perfect. The handwheel turns easily and the plunger responds instantly to the slightest motion. The movement is smooth in both directions, and there is no perceptible shock when the plunger reaches the seat at either end of its travel. The operation of the valve is practically fool-proof, but it is essential that air be drawn out of the cylinder and the water passages before attempting to operate the control mechanism, and that the stop valve in the control pipe be left open. Should this stop valve be closed when the plunger is off the forward seat, the entire force due to the pressure in the cylinder would be transmitted to the control valve, compressing the spring on the control valve stem and ultimately shearing the pin in the pinion on the outside rack. This shearing pin is provided to protect the control mechanism against damage, and shearing of the pin is the only difficulty which will result from improper manipulation of the mechanism. If the pin is sheared the valve may be closed by closing the stop valve tightly and opening the pitot valve, if necessary.

6. The leakage past the bull ring, upon which the operation of the valve depends, was measured at each end of the travel of the plunger. With the plunger near the forward end of its stroke, the leakage was 264 gallons per minute under a difference of pressure of 117 feet. At the other end of the stroke the leakage amounted to 92 gallons per minute with a difference of pressure of 51 feet. This leakage is large compared with the 58-inch valves at Pathfinder Dam, in which the corresponding leakage, after adding a 9/16-inch hole to increase it, amounted to 75 or 80 gallons per minute under a difference in pressure of 60 feet.

7. The discharge of the valve was determined by measuring the flow at the rating station, about two miles below the dam, before the valve was opened and again after the valve had been running wide open for a sufficient length of time for the flow to become constant. The results of these measurements were as follows:

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	Gauge	1921 Curve	1922 Curve	Current Meter
After valve was opened	1.79	848.6	805.0	772.7
Before " " "	1.00	400.0	370.0	375.4
Capacities		448.6	435.0	397.3

The weather was stormy and the measurements were subject to some error from this cause. Comparing the results with those obtained with similar valves at Pathfinder, it is believed that the current-meter readings are probably more reliable than those taken from the rating curve, and in this report the discharge is considered as 397.3 second-feet.

8. From the pressure readings at the valve and the measured discharge, the discharge coefficient can be determined. No measurements of the size of the jet were possible, and in order to determine the coefficient of contraction, velocity coefficient, and reaction of the jet, it is necessary to estimate the losses in the valve. The average velocity through the Pathfinder valves was 40 feet per second, and the loss 20 feet. The average velocity through the 36-inch valve was about 30 feet per second and the loss is estimated at 11 feet. This gives a velocity coefficient of 95 percent and a contraction coefficient of 68.8 percent based on the gross area of the nozzle. Using these estimated coefficients the actual velocity at the minimum section of the jet is 81.6 feet per second, and the reaction of the jet (calculated from the formula: Reaction = F3-F1 cos A) is 37,550 pounds. In the above formula, F3 is the reaction of the jet leaving the needle WE/G, F1 is the reaction of the stream at the point where it enters on the face of the needle, and A is the angle between the entering stream and the axis of the valve, 45 degrees in this case. On curve sheet 26-E-231 are given curves showing the forces acting on the plunger, computed from the pressure readings and the known areas of the plunger. The difference between curves C and E represents the reaction of the jet at various points of the stroke. From these curves the reaction at full discharge is slightly over 40,000 pounds. This is a fairly close check, considering that is was necessary to assume the losses through the valve in order to

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determine the maximum jet velocity which is directly proportional to the reaction of the jet. In these computations no allowance was made for the weight of the plunger. The angle which the angle of the valve makes with the horizontal is very nearly the angle of repose of the plunger and its guides so the effect of gravity practically offsets the friction in closing the valve.

9. The coefficients of the valve, based on the gross area of the nozzle and the total head at the upstream flange of the valve, are as follows:

Discharge coefficient	65.3%
Estimated velocity coefficient	95.0%
Estimated contraction coefficient	68.8%

10. While the valve was wide open, discharging 397 second-feet, pressure readings were taken at the various points along the penstock to determine the losses. Only one emergency valve was open at the time. The losses along the penstock were as follows:

	Lost Head
Above emergency valve	48.6 ft.
Below " "	53.6 "
At No. 2 turbine	53.0 "
At manhole below turbines	56.9 "
At 36-inch valve	80.7 "

Four-inch Experimental Valve

11. The test of the 4-inch experimental valve consisted in measuring the discharge, determining the head at the inlet flange, taking pressures at various points on the nozzle, and making accurate measurements of the jet. Tests were made only for the wide-open position of the valve, as the maximum discharge is the only point of much importance in a regulating outlet for irrigation reservoirs.

12. The valve was set up between the power plant and the bypass valve house, and connected with the manhole in No. 1 turbine in the plant. In this way the gate valve on the turbine was available for shutting off the water to change tips and examine the experimental valve. The jet was directed into the iron barrel backed up by the rocks and the discharge was collected into a testing flume, as shown

in the photograph. The flume was built of timber and lined with roofing paper to eliminate leakages far as possible. Spray from the discharge was collected and returned to the flume by canvas placed around the iron barrel. The water passed over a sharp-crested weir without end contractions at the lower end of the flume. An accurate hook gage was placed inside the flume 16 feet above the crest. The length of the weir was 6.02 feet, and the crest was 2 feet above the bottom of the flume. The hook gage was set to the average height of the crest, determined by readings taken to .001 ft. at each foot-length of crest. It was found that there was a large fraction of a second-foot leakage in the flume when it was filled with water, and in order to compensate for this leakage a stream of water was turned into the flume through a hose and adjusted until a slight flow over the weir was obtained with the test valve closed. In this way the effect of leakage was entirely eliminated up to the crest of the weir, and the increase of leakage due to raising of the water in the flume during the test was at least partially compensated. The readings are believed to be accurate to 1/10 second-foot.

13. The three different nozzles shown on drawings X-E-226 and 227 were tested. No. 2 nozzle was designed to approximate the velocity curve in the 58-inch valves at Pathfinder Dam, except that a sharp edge was left just below the valve seat. No. 1 nozzle was designed to give a more sudden acceleration of the water near the seat, and No. 3 nozzle was designed to give a slower acceleration and more gradual change of direction through the nozzle. The radial ribs projecting into the nozzle were chipped off after the first test but no perceptible difference in discharge or appearance of the jet was noted. The jet was measured by means of the caliper bars shown on drawing X-E-227, the use of which is well illustrated in the photograph. The valve was controlled by a 3/4-inch globe valve and a pitot valve was provided to start the piston from the full-open position.

14. <u>No. 1 nozzle</u>. With the pitot valve closed and 74 pounds pressure in the pipe, the piston started open with 24 pounds pressure in the cylinder. Water first made its appearance at the seat in the

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form of thousands of fine streams many of which did not follow the needle but shot out more nearly parallel with the axis of the valve. As the plunger opened slightly these streams became larger and the jet became very rough, some of the filaments crossing near the top of the valve. The jet became approximately solid at about 1-1/2 inches in diameter, but was still quite rough and even when wide open threw off considerable spray close to the nozzle. The plunger started closing with 42 pounds pressure in the pipe and 32 pounds pressure in the cylinder, and closed without shock. With the pitot valve open, the plunger opened and closed with the same pressures as before but closed more rapidly, coming to its seat with a considerable shock.

15. No. 2 nozzle. With 75 pounds pressure in the pipe line the piston started open with 27 pounds pressure in the cylinder. There were practically no fine streams such as were observed with No. 1 nozzle, and the jet was smooth and clear, even down to the smallest openings of the plunger. The tip of the needle could be distinctly seen through the jet.

16. No. 3 nozzle. The plunger started open with 75 pounds pressure in the pipe and 24 pounds in the piston, and starts closed with 39 pounds in the pipe and 26 pounds in the piston. The appearance of the jet was quite similar to that of No. 1 nozzle, the jet spraying badly when the valve was partially open, but the jet remained solid in closing down to approximately one-inch in diameter.

17. The shape of the jets from the three nozzles are shown on drawing X-E-230, and the coefficients and pressure heads at various points in the valve are given on drawing X-E-231. The discharge coefficients of the nozzles are as follows:

No. 1	72%
No. 2	62%
No. 3	74%

No. 2 nozzle gives the cleanest jet, but has the lowest discharge coefficient. The high discharge coefficient is of more importance in

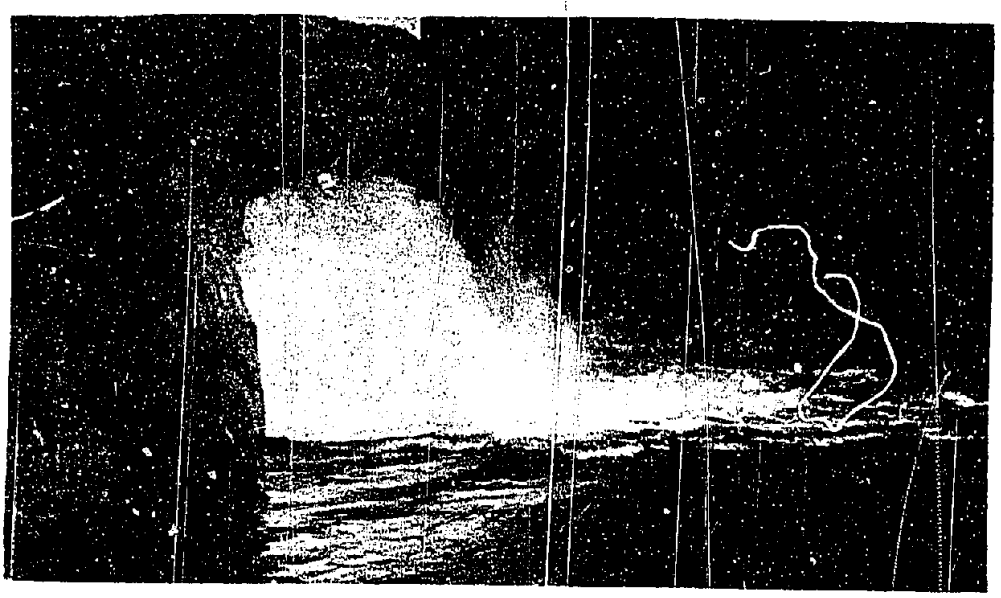
HYD-005

an irrigation outlet, and on this basis No. 3 nozzle is most satisfactory. This nozzle represents an improvement in discharge of 21 percent over the Pathfinder valve and 9 percent over the 36-inch valve at Shoshone Dam.

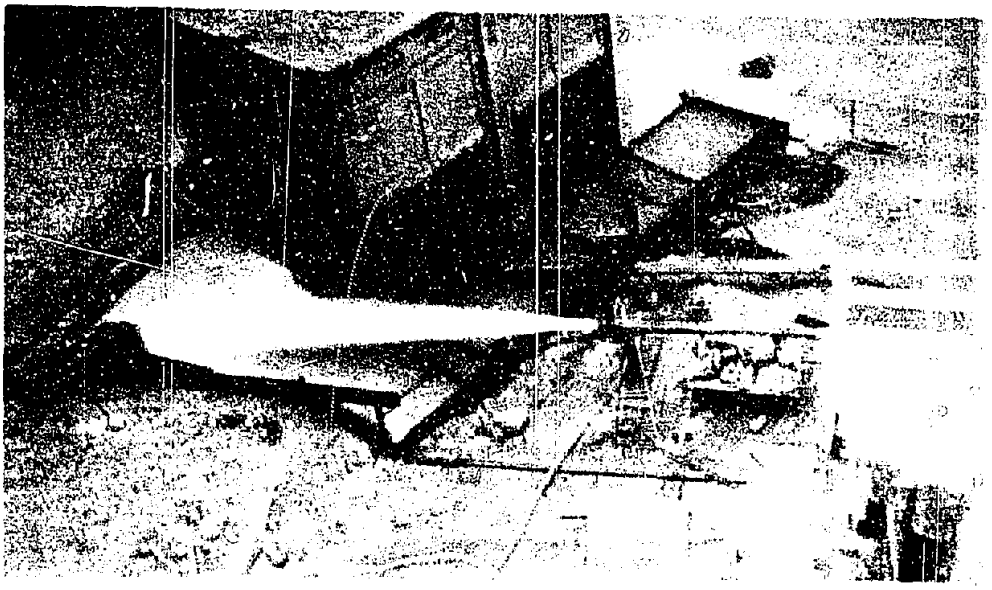
- - -

J. M. Gaylord.

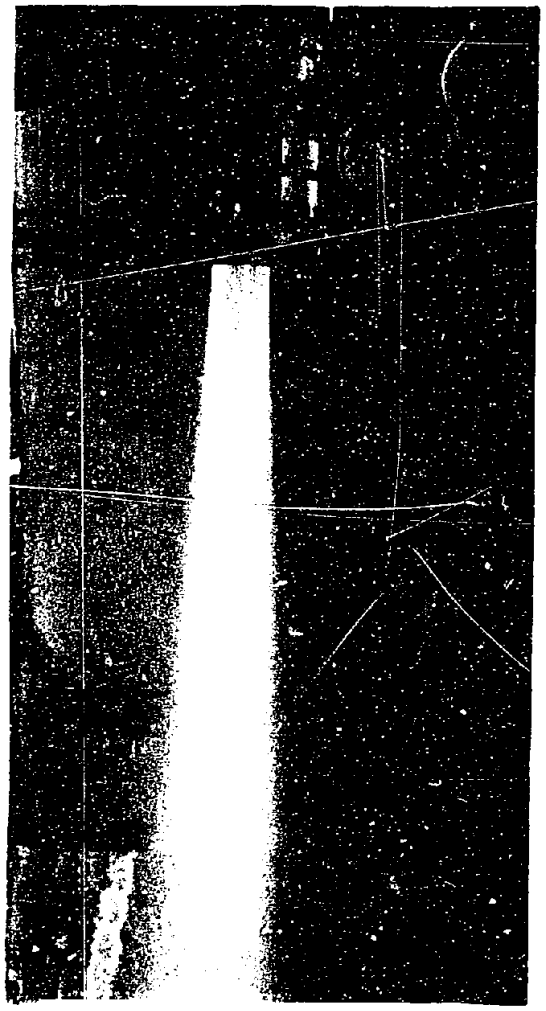
HYD-008



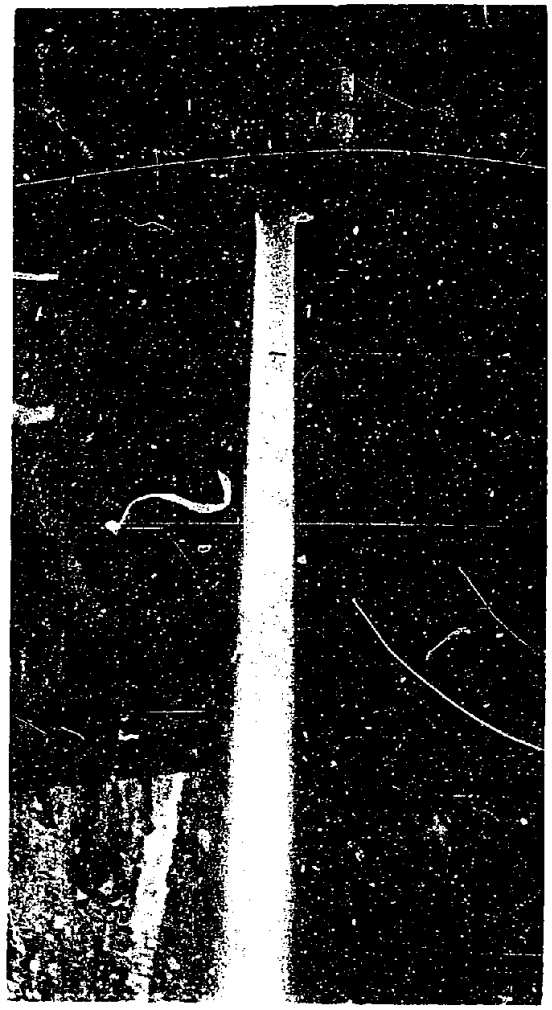
36-inch valve discharging 397 second-feet
Disturbance at lower end of tunnel.



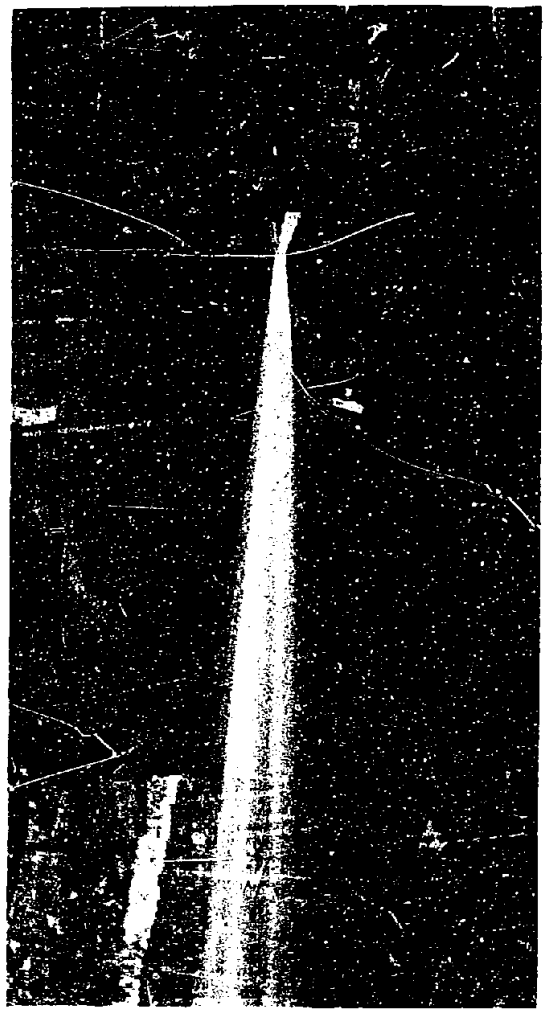
Testing plant for 4-inch valve.



Wide open.

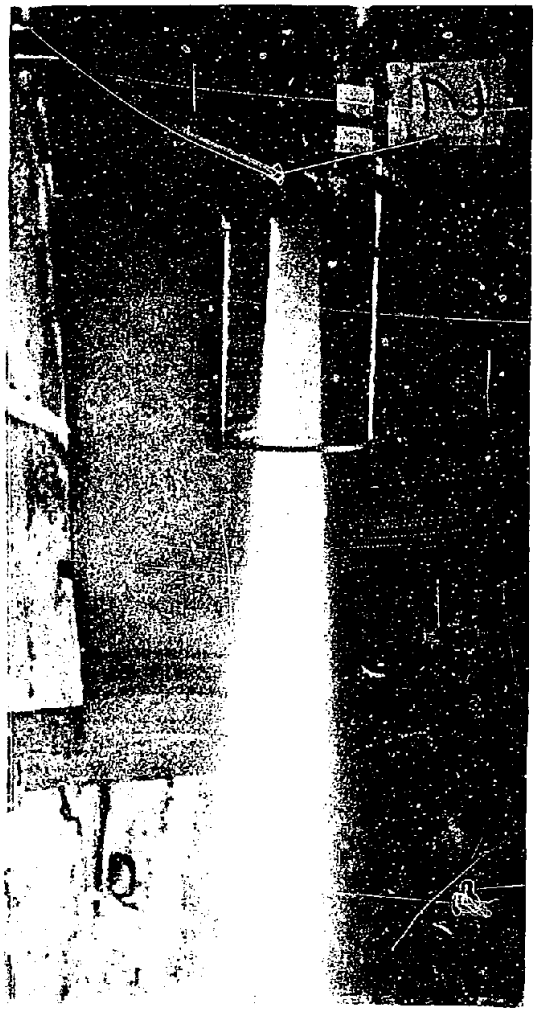


About half open.

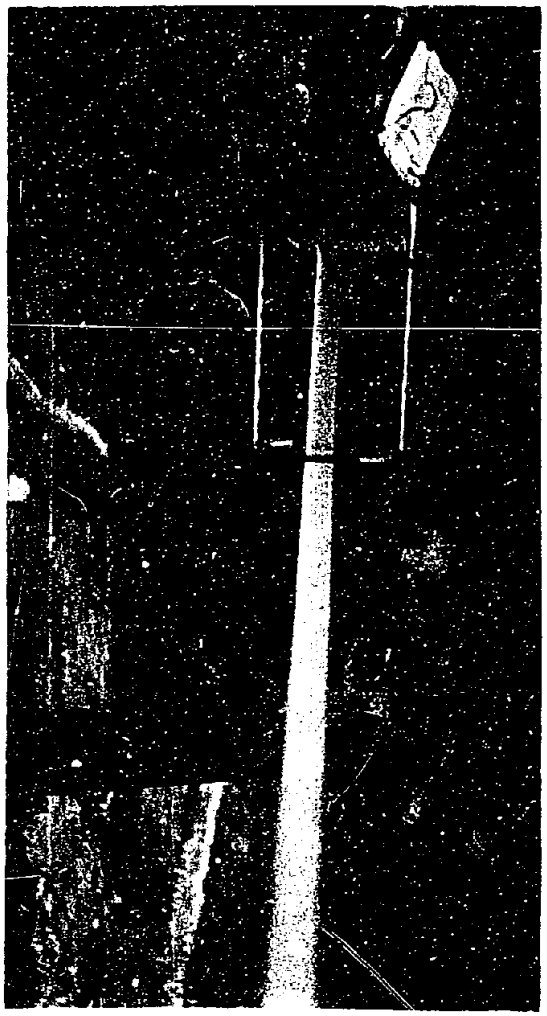


Starting open.

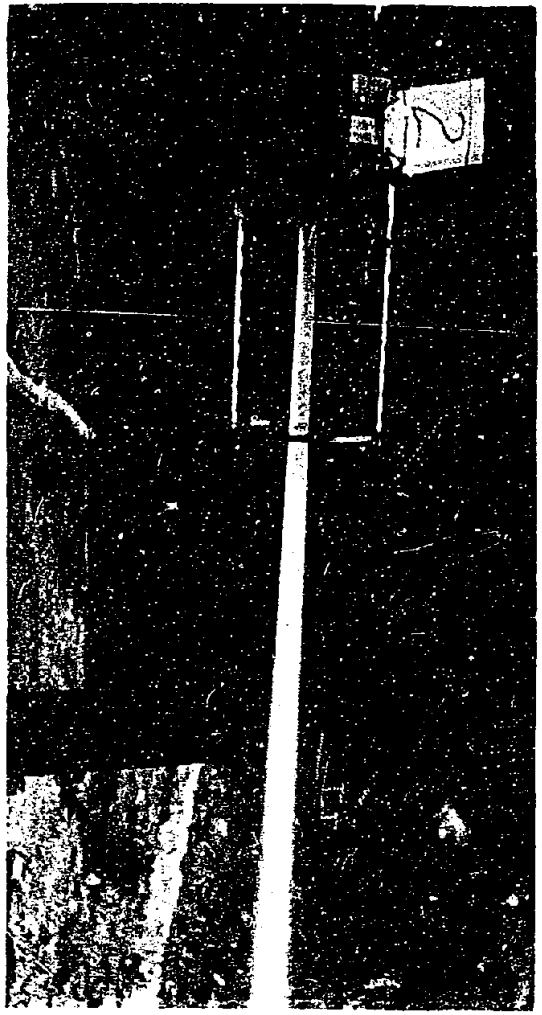
Jet from No. 1 Nozzle.



Wide open.

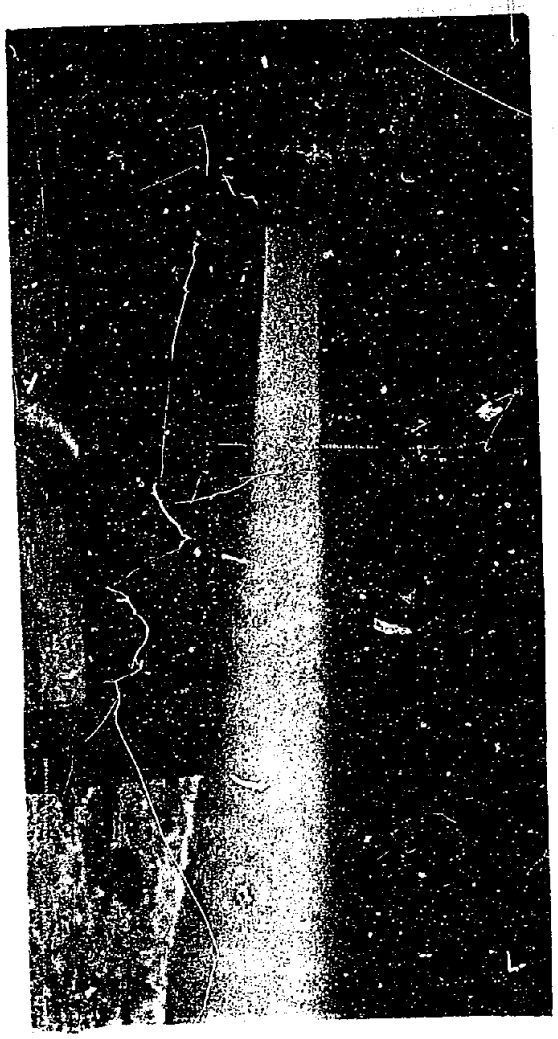


About 1/3 open.

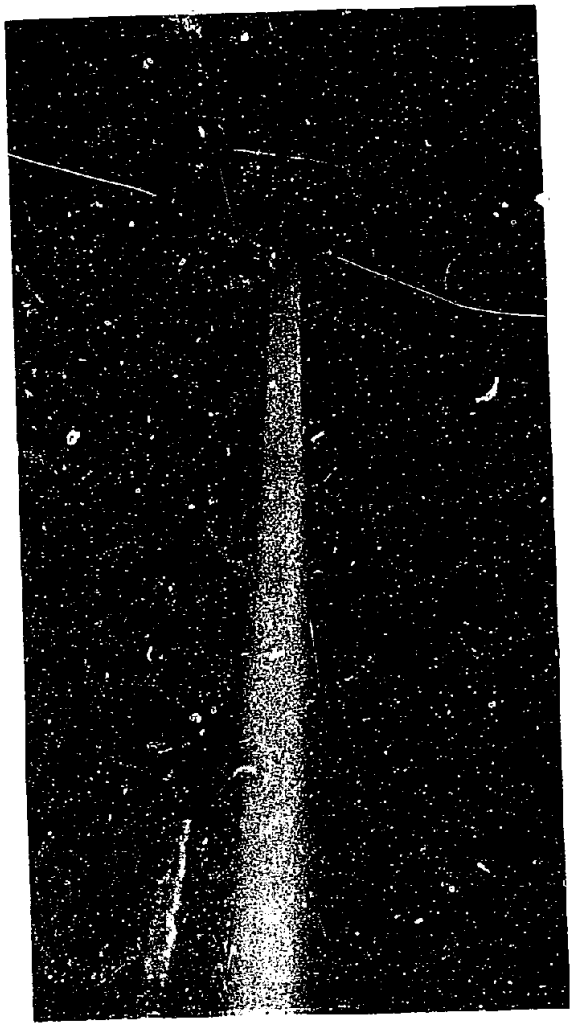


About 1/5 open.

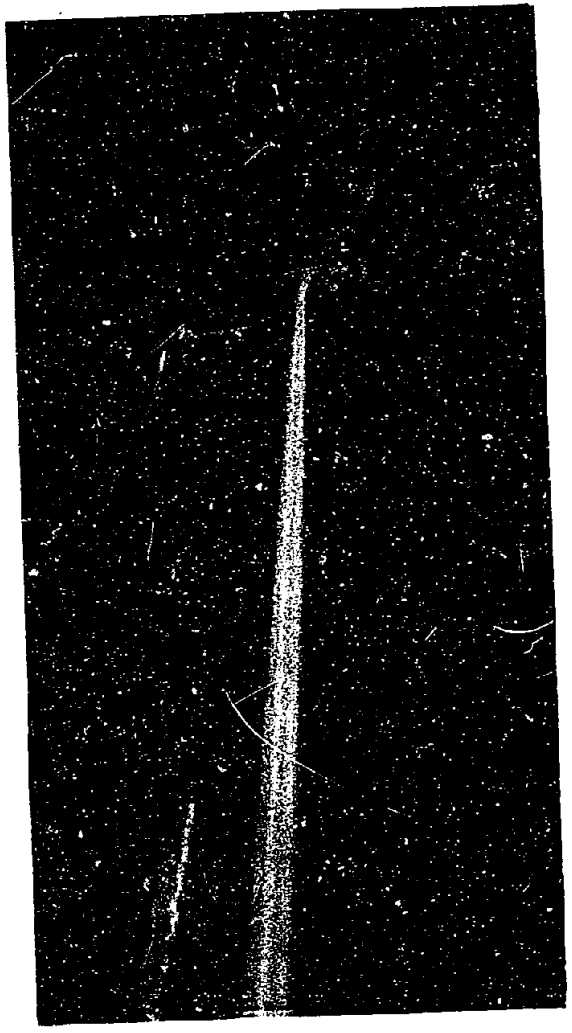
Jet from No. 2 Nozzle.



Wide open.

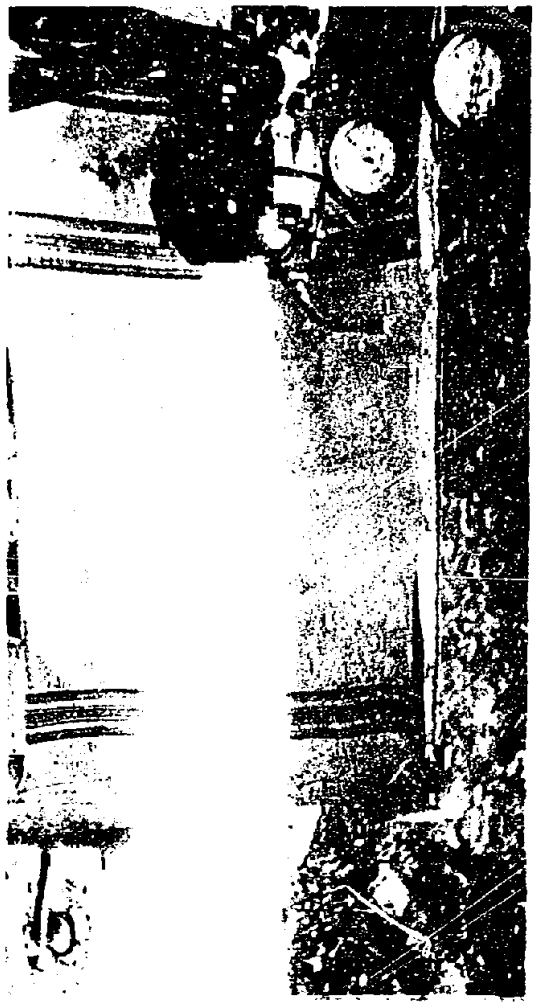


About 1/3 open.



Just opening

Jet from No. 3 Nozzle.

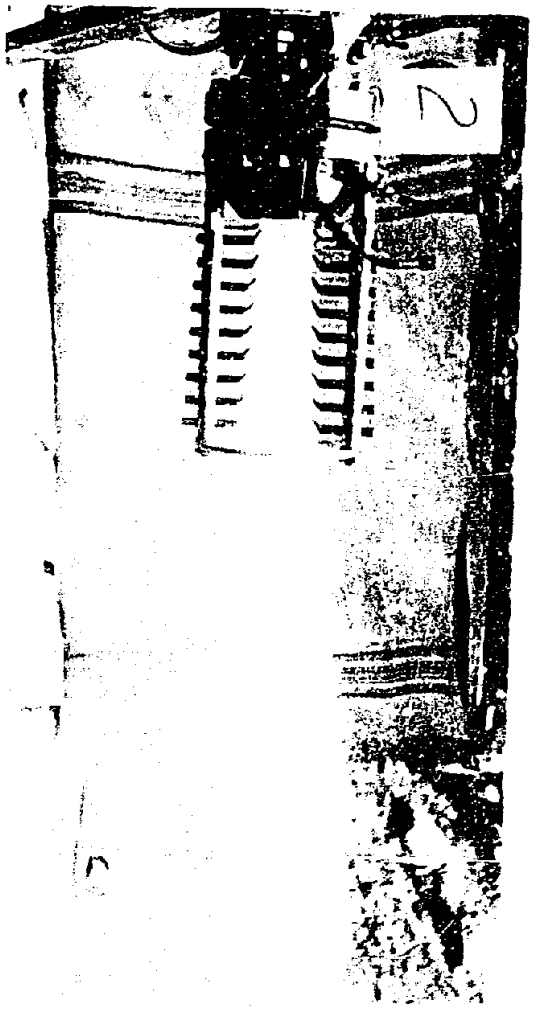


Wide open.

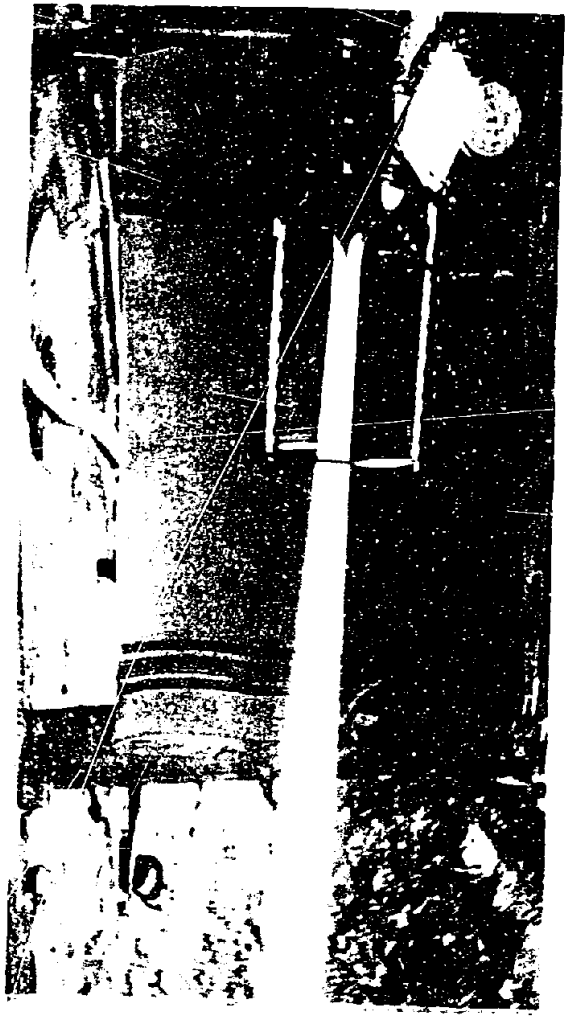
About half open.

Starting open.

Jet from No. 1 Nozzle.



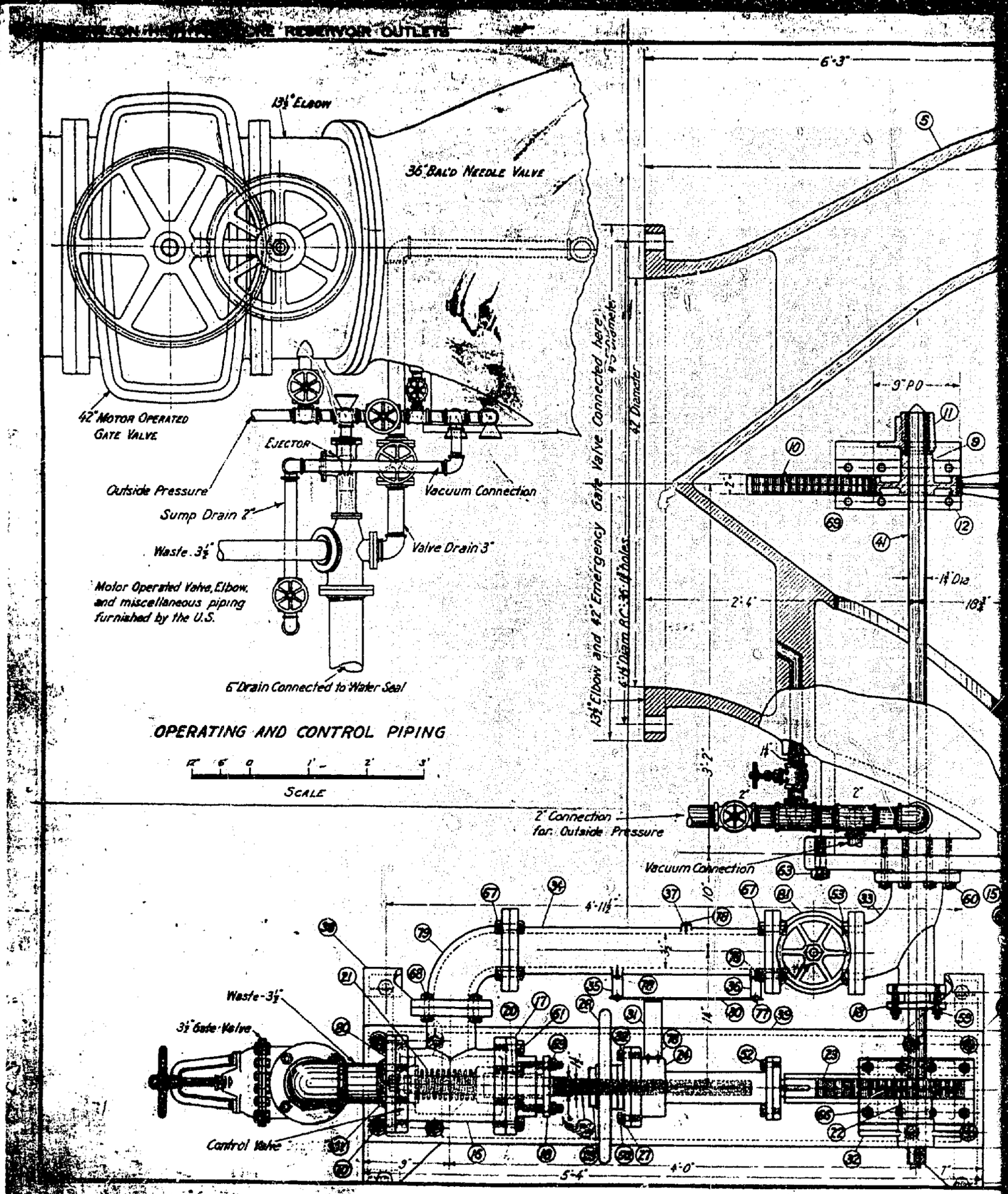
Wide open.



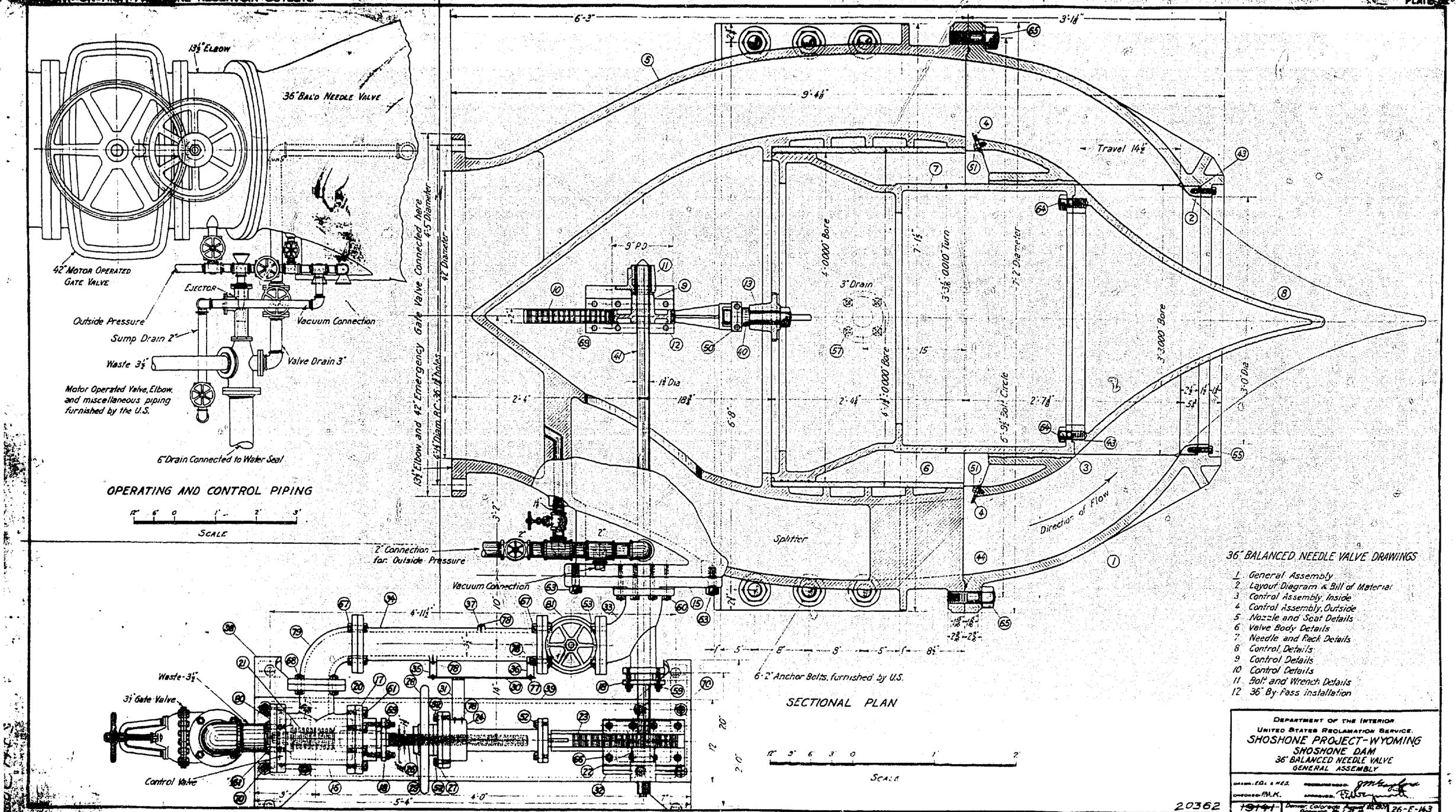
About 1/3 open.

Jet from No. 2 Nozzle.

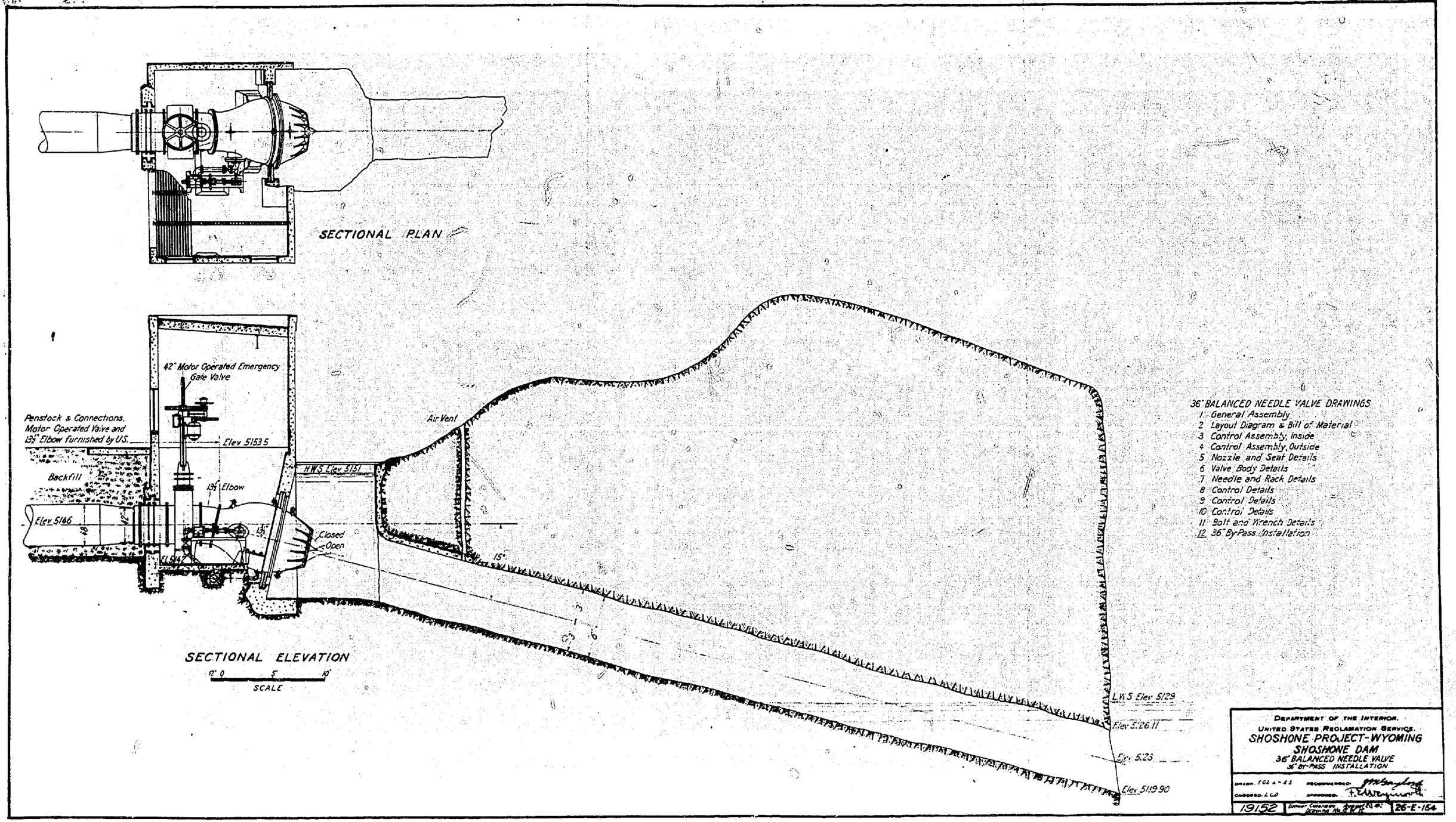
About 1/5 open.

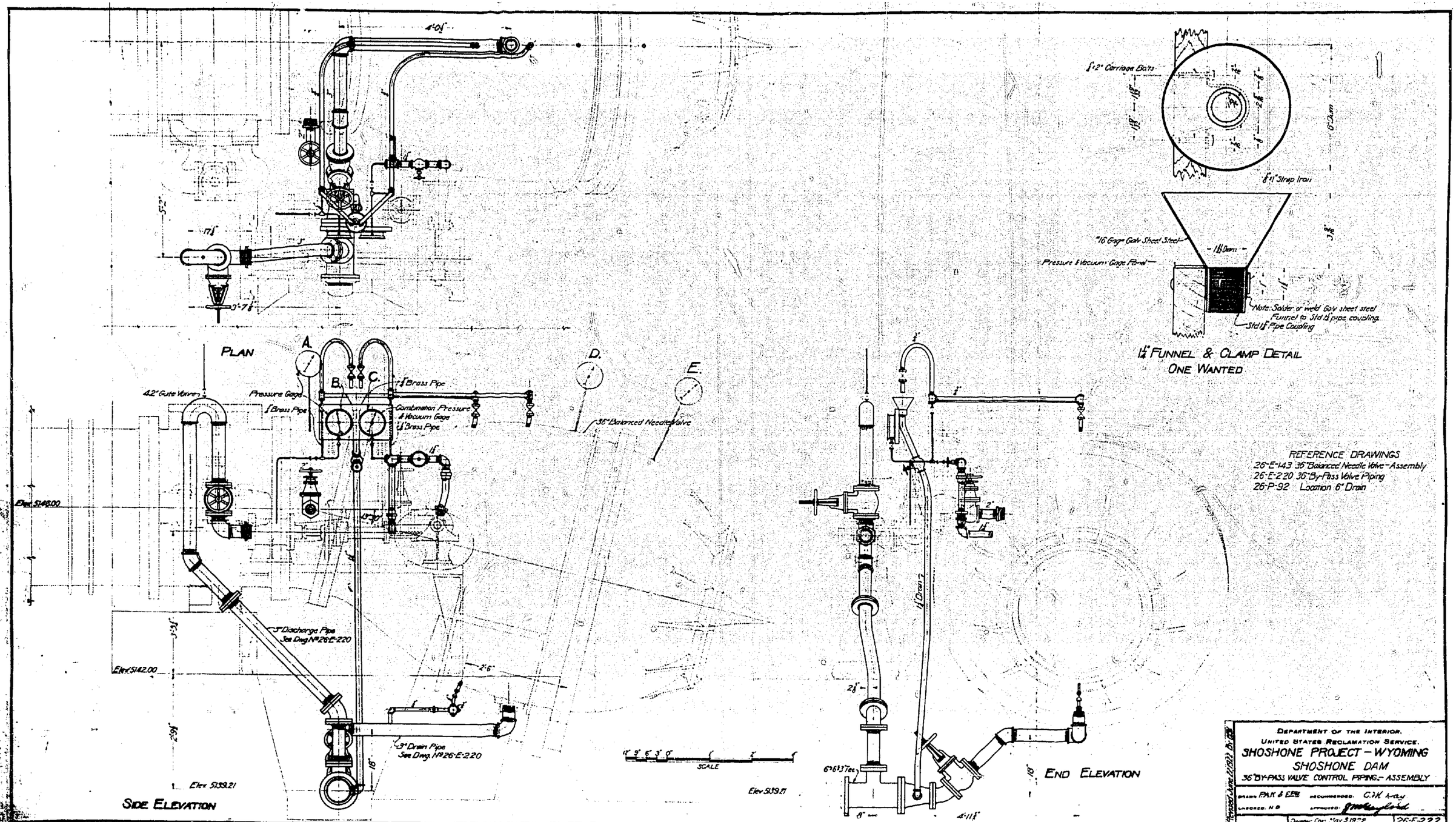

13½" Elbow
36" Bal'd Needle Valve
42" Motor Operated Gate Valve
Ejector
Outside Pressure
Vacuum Connection
Sump Drain 2"
Waste 3½"
Valve Drain 3"
Motor Operated Valve, Elbow, and miscellaneous piping furnished by the U.S.
6" Drain Connected to Water Seal
OPERATING AND CONTROL PIPING
Scale
6'-3"
42" Diameter
13½" Elbow and 42" Emergency Gate Valve Connected here
9" PO
1¼" Dia
2'-4"
2" Connection for Outside Pressure
Vacuum Connection
4'-11½"
Waste-3½"
3½" Gate Valve
Control Valve
5'-4"
4'-0"

CORRECTION

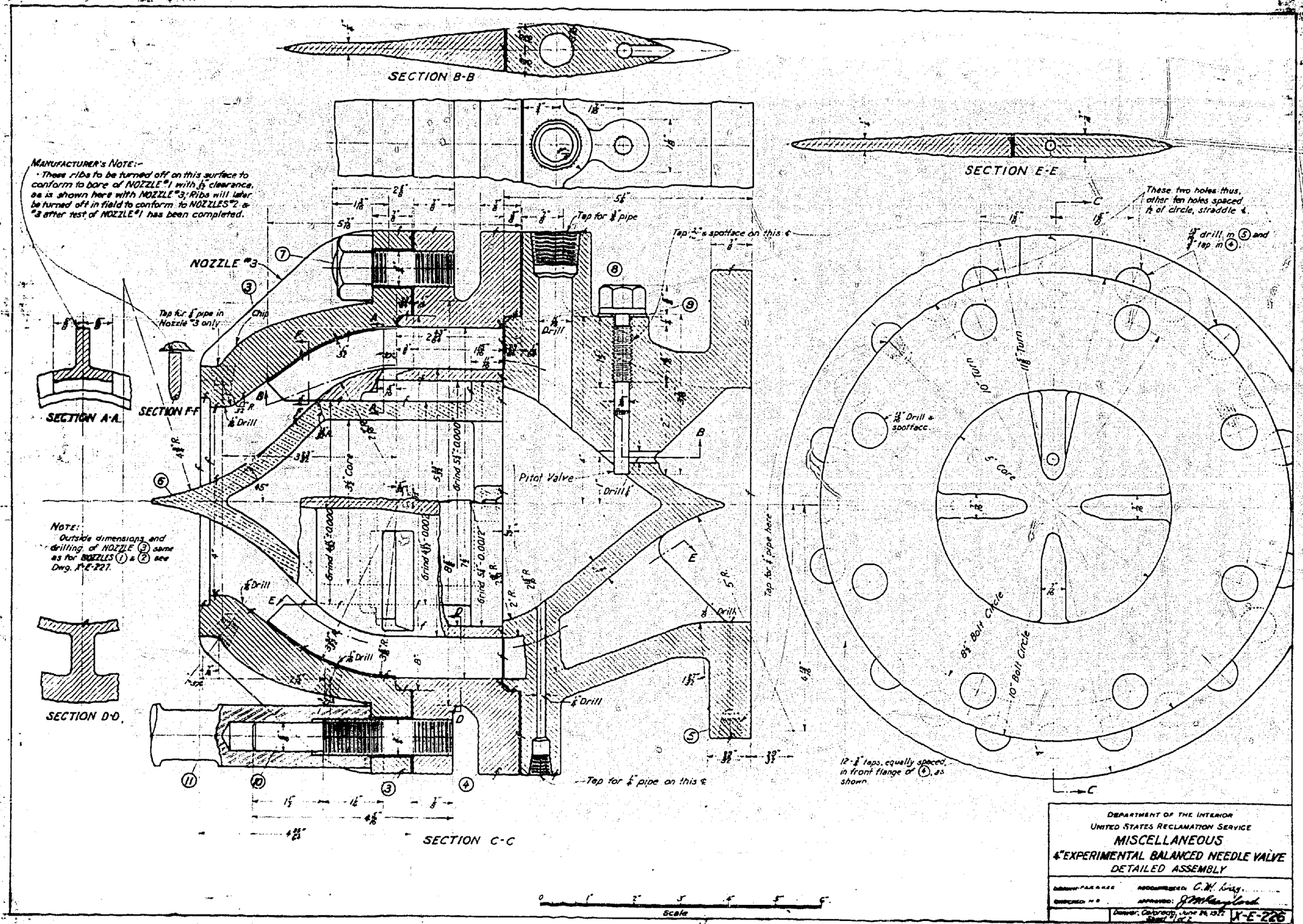


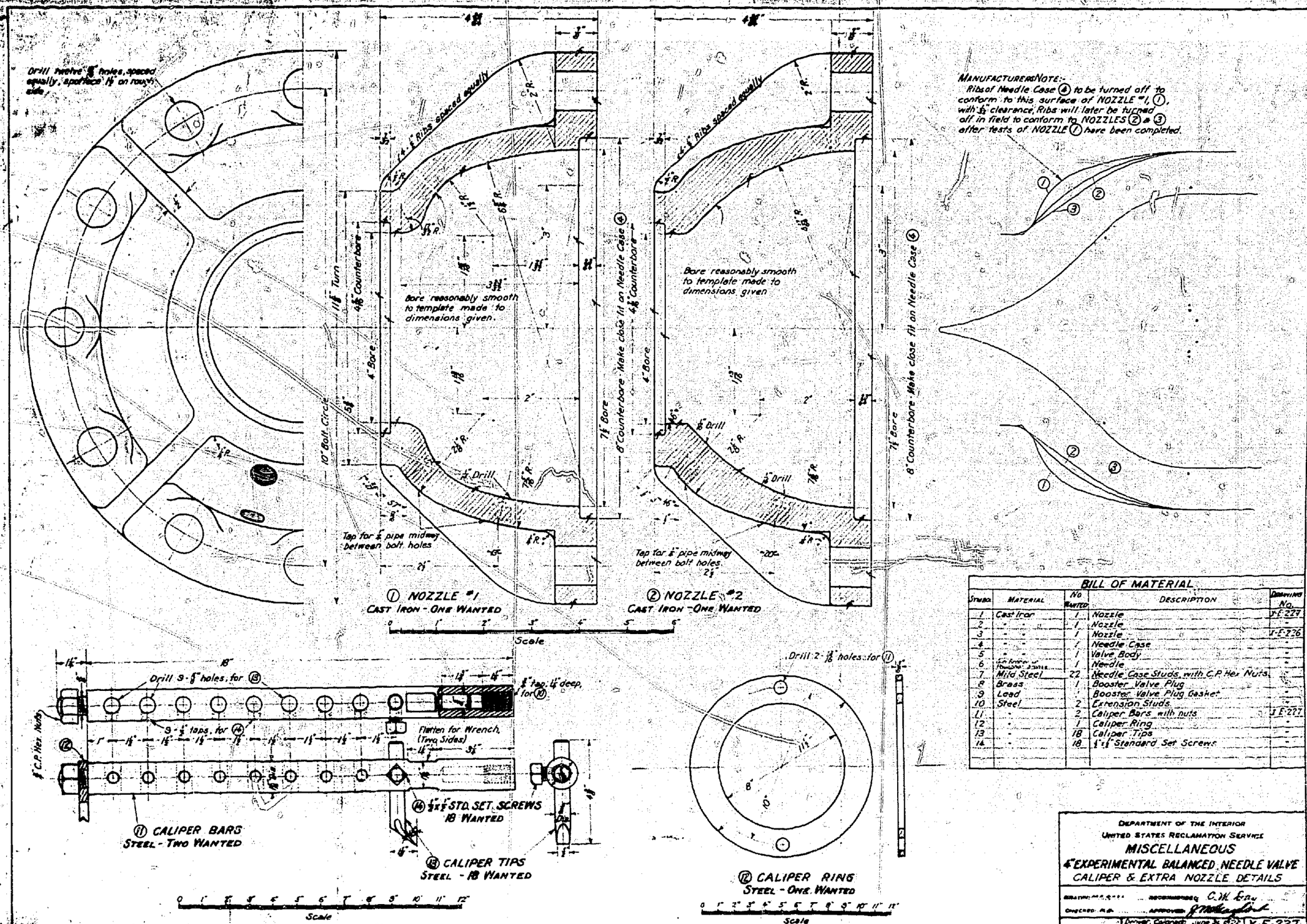
ON HIGH PRESSURE RESERVOIR OUTLETS
PLATE
13½" Elbow
36" Bal'd Needle Valve
42" Motor Operated Gate Valve
Ejector
Outside Pressure
Vacuum Connection
Sump Drain 2"
Waste 3½"
Valve Drain 3"
Motor Operated Valve, Elbow, and miscellaneous piping furnished by the U.S.
6" Drain Connected to Water Seal
OPERATING AND CONTROL PIPING
Scale
13½" Elbow and 42" Emergency Gate Valve Connected here
4'-5" Diameter
42" Diameter
6'-3"
3'-1⅛"
9'-4⅛"
Travel 14½"
9" P.D.
4'-0000" Bore
3" Drain
3'-3⅛"-0.010" Turn
7'-2" Diameter
3'-3000" Bore
3'-0" Dia
1¾" Dia
2'-4"
18¾"
6'-8"
2'-4¼"
4'-1¾"-0000" Bore
5'-9½" Bolt Circle
2'-7⅛"
Splitter
Direction of Flow
2" Connection for Outside Pressure
Vacuum Connection
6'-2" Anchor Bolts, furnished by U.S.
SECTIONAL PLAN
Waste-3½"
3½" Gate Valve
Control Valve
Scale
36" BALANCED NEEDLE VALVE DRAWINGS
1 General Assembly
2 Layout Diagram & Bill of Material
3 Control Assembly, Inside
4 Control Assembly, Outside
5 Nozzle and Seat Details
6 Valve Body Details
7 Needle and Rack Details
8 Control Details
9 Control Details
10 Control Details
11 Bolt and Wrench Details
12 36" By-Pass Installation
Department of the Interior
United States Reclamation Service
SHOSHONE PROJECT-WYOMING
SHOSHONE DAM
36" BALANCED NEEDLE VALVE
GENERAL ASSEMBLY
20362
26-E-143


SECTIONAL PLAN
42" Motor Operated Emergency Gate Valve
Penstock & Connections, Motor Operated Valve and 13½" Elbow furnished by U.S.
Elev 5153.5
Backfill
13½" Elbow
Elev 5146
48
42
13½
El 5142
Closed
Open
H.W.S. Elev 5151
Air Vent
15"
SECTIONAL ELEVATION
12" 0 5' 10'
SCALE
L.W.S. Elev 5129
Elev 5126.11
Elev 5123
Elev 5119.90
36" BALANCED NEEDLE VALVE DRAWINGS
1 General Assembly
2 Layout Diagram & Bill of Material
3 Control Assembly, Inside
4 Control Assembly, Outside
5 Nozzle and Seat Details
6 Valve Body Details
7 Needle and Rack Details
8 Control Details
9 Control Details
10 Control Details
11 Bolt and Wrench Details
12 36" By-Pass Installation
DEPARTMENT OF THE INTERIOR.
UNITED STATES RECLAMATION SERVICE.
SHOSHONE PROJECT-WYOMING
SHOSHONE DAM
36" BALANCED NEEDLE VALVE
36" BY-PASS INSTALLATION
19152
26-E-154



PLAN
SIDE ELEVATION
END ELEVATION
1¼" FUNNEL & CLAMP DETAIL
ONE WANTED
REFERENCE DRAWINGS
26-E-143 36" Balanced Needle Valve - Assembly
26-E-220 36" By-Pass Valve Piping
26-P-92 Location 6" Drain
A.
B.
C.
D.
E.
42" Gate Valve
Pressure Gage
Brass Pipe
Combination Pressure & Vacuum Gage
36" Balanced Needle Valve
3" Discharge Pipe See Dwg. No. 26-E-220
3" Drain Pipe See Dwg. No. 26-E-220
Elev. 5148.00
Elev. 5142.00
Elev. 5139.21
SCALE
Carriage Bolts
Strap Iron
16 Gage Galv. Sheet Steel
Pressure & Vacuum Gage Panel
Note: Solder or weld Galv. sheet steel Funnel to Std 1¼" pipe coupling
Std 1¼" Pipe Coupling
DEPARTMENT OF THE INTERIOR.
UNITED STATES RECLAMATION SERVICE.
SHOSHONE PROJECT - WYOMING
SHOSHONE DAM
36" BY-PASS VALVE CONTROL PIPING - ASSEMBLY
DRAWN P.A.K. & E.E.W.
RECOMMENDED C.H. Kray
CHECKED N.B.
APPROVED
Denver Colo. May 3, 1922
26-E-222


SECTION B-B
SECTION E-E
MANUFACTURER'S NOTE:-
These ribs to be turned off on this surface to conform to bore of NOZZLE #1 with 1/32" clearance, as is shown here with NOZZLE #3; Ribs will later be turned off in field to conform to NOZZLES #2 & #3 after test of NOZZLE #1 has been completed.
NOZZLE #3
Tap for 1/8" pipe in Nozzle #3 only
Chip
SECTION A-A
SECTION F-F
Pitot Valve
Drill
Tap for 1/4" pipe
Tap 3/8" & spotface on this ℄
These two holes thus, other ten holes spaced 1/2 of circle, straddle ℄.
13/16" drill in (5) and 3/4" tap in (4).
10" Turn
11 5/8" Turn
5" Core
13/16" Drill & spotface
8 1/2" Bolt Circle
10" Bolt Circle
Tap for 1/4" pipe here
12-3/4" taps, equally spaced, in front flange of (4), as shown.
NOTE:
Outside dimensions and drilling of NOZZLE (3) same as for NOZZLES (1) & (2) see Dwg. X-E-227.
SECTION D-D
Tap for 1/4" pipe on this ℄
SECTION C-C
Scale
DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
MISCELLANEOUS
4" EXPERIMENTAL BALANCED NEEDLE VALVE
DETAILED ASSEMBLY
DRAWN: F.A.R. & K.E.E.
RECOMMENDED: C.W. King
CHECKED: N.O.
APPROVED: J.M. Hazelwood
Denver, Colorado, June 24, 1922
Sheet 1 of 2
X-E-226



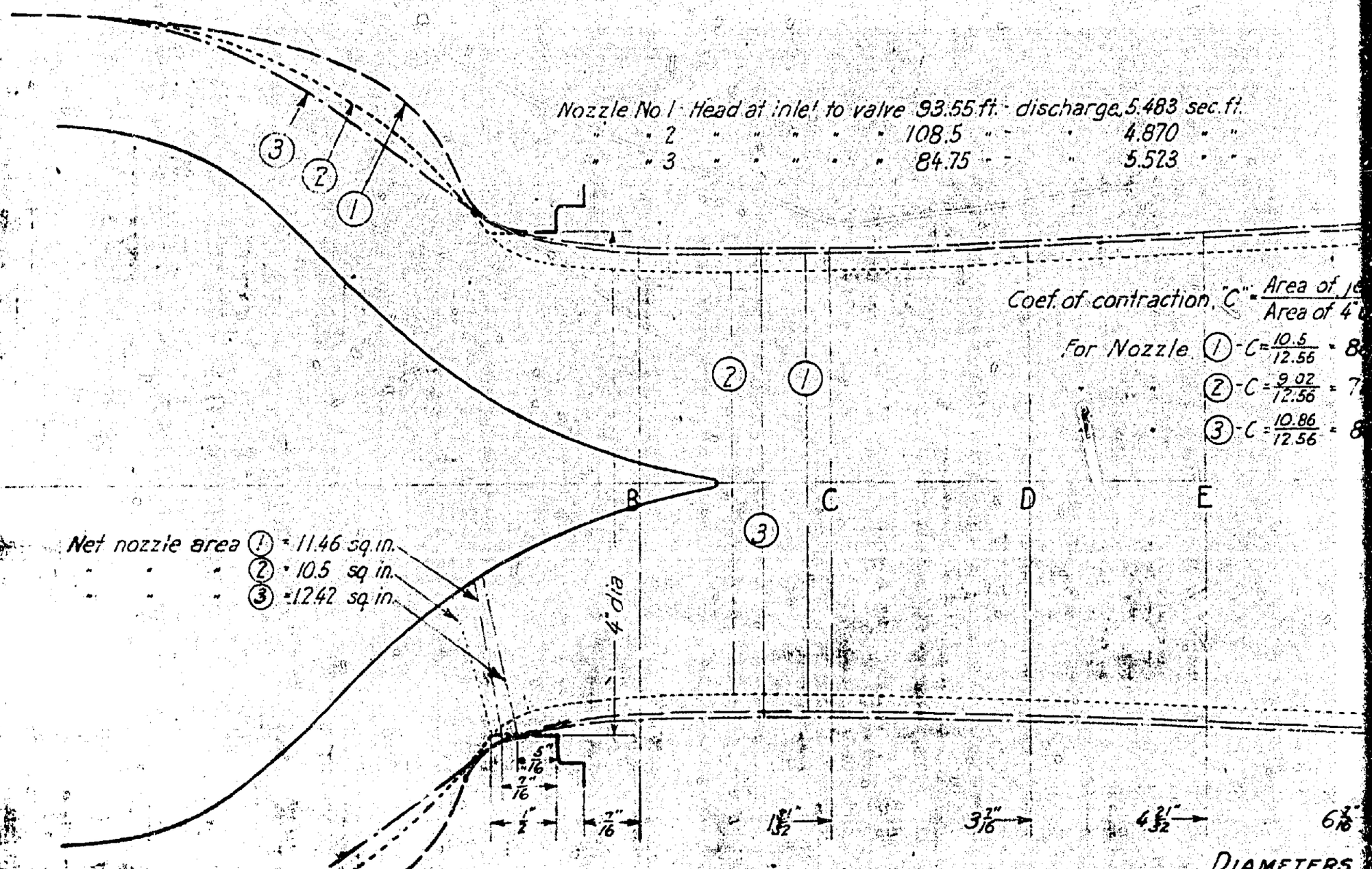
BILL OF MATERIAL

Symbol	Material	No. Wanted	Description	Drawing No.
1	Cast Iron	1	Nozzle	X-E-227
2	" "	1	Nozzle	"
3	" "	1	Nozzle	X-E-226
4	" "	1	Needle Case	"
5	" "	1	Valve Body	"
6	[illegible]	1	Needle	"
7	Mild Steel	22	Needle Case Studs, with C.P. Hex Nuts	"
8	Brass	1	Booster Valve Plug	"
9	Lead	1	Booster Valve Plug Gasket	"
10	Steel	2	Extension Studs	"
11	"	2	Caliper Bars with nuts	X-E-227
12	"	1	Caliper Ring	"
13	"	18	Caliper Tips	"
14	"	18	½"x½" Standard Set Screws	"

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE

MISCELLANEOUS
4" EXPERIMENTAL BALANCED NEEDLE VALVE
CALIPER & EXTRA NOZZLE DETAILS

DRAWN: [illegible] RECOMMENDED: C.W. [illegible]
CHECKED: [illegible] APPROVED: [illegible]
Denver, Colorado, June 30, 1922 Sheet [illegible] X-E-227



DIAMETERS

	B	C	D	E
Nozzle No. 1	3 43/64"	3 21/32"	3 49/64"	3 7/8"
" " 2	3 13/32"	3 [illegible]"	3 17/32"	3 45/64"
" " 3	3 [illegible]/32"	3 [illegible]/32"	3 [illegible]/32"	4 [illegible]/32"

HYD-008

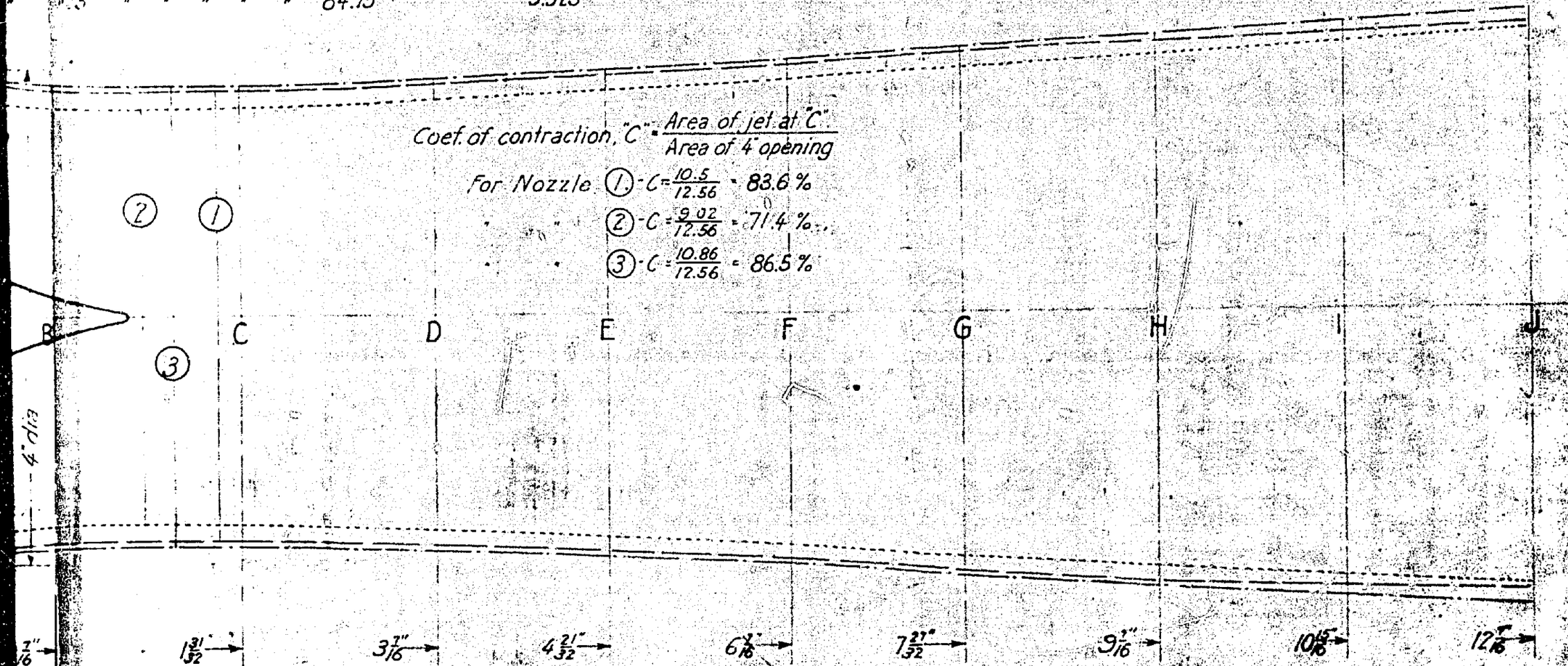
zle No. Head at inlet to valve 93.55 ft. - discharge 5.483 sec. ft.
" " " " " " 108.5 " - " 4.870 " "
" " " " " " 84.75 " - " 5.523 " "

Coef. of contraction, "C" = $\frac{\text{Area of jet at "C"}}{\text{Area of 4" opening}}$

For Nozzle (1) - $C = \frac{10.5}{12.56} = 83.6\%$

" " (2) - $C = \frac{9.02}{12.56} = 71.4\%$

" " (3) - $C = \frac{10.86}{12.56} = 86.5\%$

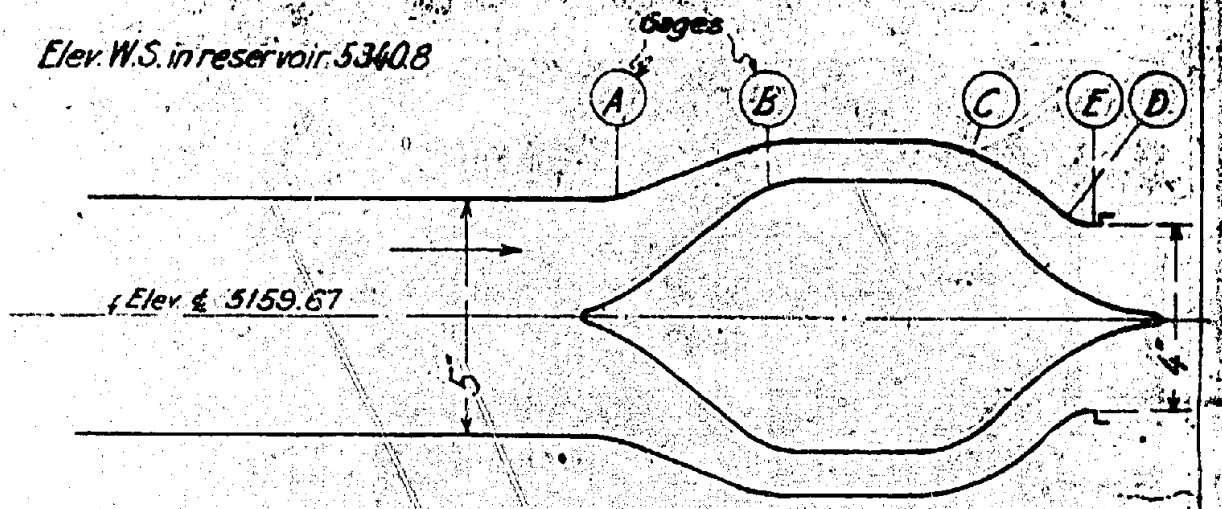


DIAMETERS OF JETS

B	C	D	E	F	G	H	I	J
3 [illegible]"	3 [illegible]"	3 49/64"	3 1/8"	4 1/16"	4 [illegible]"	4 39/64"	4 [illegible]"	[illegible]
3 [illegible]"	3 [illegible]"	3 17/32"	3 45/64"	3 [illegible]"	3 [illegible]"	4 [illegible]"	4 [illegible]	[illegible]
3 [illegible]	3 [illegible]	3 [illegible]"	4 7/32"	4 [illegible]"	4 [illegible]"	4 [illegible]"	4 [illegible]	[illegible]

TEST OF 4" EXPERMENTAL BALANCED NEEDLE VALVE
MADE AT SHOSHONE POWER PLANT - OCT. 29, 1922
MEASUREMENT OF JET WITH NEEDLE [illegible]

HYD-008



OUTLINE OF 4" EXPERIMENTAL VALVE

TABLE I - PRESSURE HEAD IN VALVE

Nozzle No.	Discharge Sec. Ft	Valve wide open					Valve closed	
		A	B	C	D	E	A	B
1	5.483	94	0	92	88	0	169	168
2	4.870	108	0	103	87	0	169	169
3	5.523	88	0	76	25	0	168	168

TABLE II COEFFICIENTS

	Size of Nozzle	Discharge Sec. Ft.	Total Head	Coefficient of Contraction	Coefficient of Velocity	Power Efficiency	Coefficient of Discharge
Nozzle No. 1	4"	5.483	119	84%	86 %	74 %	72 %
" " 2	4"	4.870	128	71%	85 %	73 %	62 %
" " 3	4"	5.523	113	86%	86 %	74 %	74 %
Pathfinder	58"	1058	138	66%	92 %	86 %	61 %
Shoshone	36"	397	114				68 %

Coefficients are based on the gross area of nozzle openings

RESULTS OF NEEDLE VALVE TESTS - 1922

gms

X-E 231