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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC STUDIES OF A SUDDEN ENLARGEMENT ENERGY DISSIPATOR USED DOWNSTREAM FROM A GATE VALVE

Report No. Hyd-535

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

August 18, 1964

Simmons, W P R 200 856

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IDENTIFIERS-- air admission/ back pressures/ cavitation control

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R 200 856 SUDDEN ENLARGEMENT ENERGY DISSIPATOR STUDIES

Limited studies were made under high heads to determine the effectiveness of a sudden-enlargement-type energy dissipator used downstream from an 8-in. gate valve and the effects of air admission and downstream pool depth. The enlarged section, which started at the downstream flange of the valve, was 16 in. in diameter (2.0 D sub 1) and 80 in. long (5.0 D sub 2). The valve throttled at heads up to 600 ft. Discharges of 1.0, 3.0, and 5.0 cfs were tested. A back pressure, or downstream depth of water, of only 1.0 ft above the centerline of the 16-in. pipe was sufficient to maintain the enlarged pipe full and obtain satisfactory energy dissipation at all conditions tested. Slightly more pool depth was needed to hold the pipe full as discharges increased. The water surface in the open tank just downstream from the enlargement was rough when the depth above the pipe centerline was small, but became much smoother at depths of 5 and 6 ft. Cavitation ranged from moderate to severe within the enlarged pipe. No erosion studies were made. Admission of air at the extreme upstream end of the enlargement greatly reduced cavitation noise and vibration. The air mixed thoroughly with the water and rose in the pool without causing disturbances in the pool. At 5.0 cfs, an air vent located at the top was found more effective than either side or bottom vents.

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ABSTRACT

Limited studies were made under high heads to determine the effectiveness of a sudden enlargement type energy dissipator used downstream from an 8-inch gate valve. The enlarged section, which started at the downstream flange of the valve, was 16 inches in diameter (2.0 D_1) and 80 inches long (5.0 D_2). The valve throttled at heads up to 600 feet. Discharges of 1.0, 3.0, and 5.0 cfs were tested. A back pressure, or downstream depth of water, of only 1.0 foot above the centerline of the 16-inch pipe was sufficient to maintain the enlarged pipe full and obtain satisfactory energy dissipation at all conditions tested. The water surface in the open tank just downstream from the enlargement was rough when the depth above the pipe centerline was small, but became much smoother at depths of 5 and 6 feet. Cavitation ranged from moderate to severe within the enlarged pipe. No erosion studies were made. Admission of air at the extreme upstream end of the enlargement greatly reduced cavitation noise and vibration. The air mixed thoroughly with the water and rose in the pool without causing disturbances in the pool. At 5.0 cfs an air vent located at the top was found more effective than either side or bottom vents.

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BUREAU OF RECLAMATION

Office of Chief Engineer
Division of Research
Hydraulics Branch
Denver, Colorado
August 18, 1964

Report No. Hyd-535
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HYDRAULIC STUDIES OF A SUDDEN ENLARGEMENT ENERGY DISSIPATOR USED DOWNSTREAM FROM A GATE VALVE

PURPOSE

Limited tests were made with a partly opened 8-inch gate valve at heads up to 600 feet to determine back pressure requirements for maintaining closed-conduit flow in a 2.0-D enlargement downstream, and to determine effects of air admission and downstream pool depth.

CONCLUSIONS

1. In the test arrangement used, a depth of 1.0 foot above the centerline of the 16-inch diameter downstream pipe was sufficient to maintain the pipeline full at discharges of at least 1.0 cubic foot per second (cfs) at a 600-foot head, 3.0 cfs at a 500-foot head, and 5.0 cfs at a 380-foot head, (Figures 4, 5, and 6). These operating points were the maximum available with the pumping facilities.

2. The depth of water required to hold the 16-inch pipeline full at a given discharge was essentially independent of the head producing the discharge.

3. Slightly more pool depth was needed to hold the pipe full as discharges increased.

4. Turbulent but reasonably good water surface conditions prevailed for discharges from 1.0 through 5.0 cfs when the pool depth was 3.0 feet above the pipe centerline.

5. Very good water surface conditions prevailed for flows up to and including 5.0 cfs when the pool depth was 5.0 feet or more.

6. Cavitation ranged from slight to severe at the valve and in the enlarged section.

7. Admission of air through one or more of the four vents in the 16-inch pipe, particularly during operation at large discharges, greatly reduced cavitation noise and vibration. At a discharge of 5.0 cfs, the top air vent was the most effective, the bottom one was least effective, and the side ones were of intermediate effectiveness. The air mixed thoroughly with the water and rose in the pool without causing disturbances.

8. Cavitation erosion tendencies, if any, were not studied in the enlarged pipe.

INTRODUCTION

The use of sudden enlargements downstream from regulating valves discharging under high differential heads provides an economical means of obtaining good energy dissipation and avoiding cavitation damage downstream from the valves. 1/ The general principles of avoiding cavitation damage by using sudden enlargements have been previously reported. 1/2/3/4/ Also, the energy dissipation achieved by using enlargements has received considerable attention. 5/6/7/ In both fields, the performance of enlarged sections downstream from throttling valves or orifices is dramatic and effective.

The availability of the sudden enlargement type energy dissipator designed for the 250 horsepower (hp) high head pump facility in the Bureau's Hydraulic Laboratory made possible a limited number of relatively large scale performance tests. An item of particular importance in the study was the determination of depth of water or back pressure needed to insure full-flow conditions in the enlargement section so as to effectively dissipate the high velocity jet issuing from the control valve.

TEST FACILITY

The energy dissipation system consisted of an 8-inch, 250-pound, round bottom gate valve followed by a 16-inch ID (2.0 D_1) lightweight pipeline 80 inches (5.0 D_2) long, and a back pressure tank 3 by 4 feet in cross section and 7 feet high (Figures 1 and 2). The 16-inch pipe entered the tank along the 4-foot side and was offset from the center due to space limitations in the laboratory. The pipe centerline was 21.88 inches (1.37 D_2) above the tank floor. An uncontrolled overflow weir with a minimum crest elevation of 62.13 inches (3.88 D_2) above the pipe centerline was provided. Stop logs could be placed above this crest for obtaining deeper pools, but were not used in these tests. A 10-inch-diameter gate valve was provided near the bottom of the tank to obtain water

1/Numbers refer to items in the Bibliography surfaces lower than the weir crest elevation. A staff gage graduated in feet and tenths of feet was installed inside the tank on the wall that the 16-inch pipe entered. The zero of the scale was set at the centerline elevation of the 16-inch pipe.

Water was supplied to the energy dissipation system by a 7-stage vertical turbine pump driven by a 250 hp direct-current, variable speed motor. Rate of flow was measured by a permently installed 8- by 4-inch venturi meter that had been calibrated in place. Flow was conducted from the meter to the 8-inch throttling valve by a 16-foot length of 8-inch standard pipe. Head on the valve was measured in the 8-inch line at the meter. Downstream head was measured at the staff gage in the back-pressure tank. Tests were made with upstream heads up to 600 feet of water, and back pressures of 0.6 to 5.8 feet of water.

Four 1/2-inch-diameter air vents were provided at the beginning of the 16-inch diameter enlarged section (Figure 2B). A vent was located at the top and bottom, and on each side of the pipe. Each vent was controlled by a separate valve so air could be selectively admitted or shut off.

TESTS

The back pressures required to maintain the enlarged section full of water, and hence effectively dissipate energy, were determined by setting the desired rate of flow and upstream pressure head by means of the variable speed pump and the control valve, and gradually lowering the water surface in the back pressure tank. These tests were made with no air admitted to the system. The back pressure requirements were surprisingly low (Figure 3A). At discharges below about 2.5 cfs the water surface could be level with or slightly below the crown of the enlargement with upstream heads as high as 500 to 600 feet. At discharges above 2.5 cfs, slightly higher water surfaces were needed. At 5.0 cfs, because of the limited outlet capacity of the 10-inch low-level outlet, the lowest water surface elevation that could be obtained in the tank was 1.3 feet above the conduit centerline. This depth definitely held the pipeline full, and it was estimated that a depth as low as 1.0 foot would also be adequate. The appearance of the flow in the tank for discharges of 1.0, 3.0, and 5.0 cfs is shown in Figures 4, 5, and 6. At small depths the flow was very turbulent with surges and boils. As the pool depth increased, smoother conditions prevailed. Slight turbulence was still present at the water surface for 5- and 6-foot pool depths, but no extremely rough conditions occurred at any depths tested. Air apparently separated from the water passing through low pressure regions in the system, and was visible in the tank (Figures 4, 5, and 6). Air was not admitted through the vents in these tests.

Upstream head had little effect on back pressure requirements. For example, at 1.0 cfs flow, observations made at heads of 100, 200, 300, 400, 500, and 600 feet showed that a depth of 0.6 foot above the conduit would hold the pipeline "full" and energy dissipation was satisfactory. Similarly, at 3.0 cfs, observations at heads from 100 to 500 feet showed that a depth of 0.7 foot was adequate. At 5.0 cfs, heads up to 380 feet showed that the minimum available tailwater depth of 1.3 feet was more than adequate.

Cavitation at the 8-inch throttling valve and in the enlarged section downstream was extremely light at a 100-foot head with the 1.0 cfs flow and increased to sharply defined but moderate cavitation at the 600-foot head. No air was admitted during any of the 1.0 cfs tests. As would be expected, cavitation decreased as the back pressure rose. The severity of the cavitation was evaluated by ear and by feeling vibrations in the pipe walls. At the 5.0 cfs discharge with no air admission, cavitation was moderate at a 100-foot head. Admission of air through the four vents almost completely quieted the noise and vibration. At a 380-foot head with no air admission the cavitation was severe. The main collapse zone, as judged by sound and pipe wall vibration, occurred between Stations 0.5 D_2 and 1.5 D_2 downstream from the valve. Some collapse appeared to occur as far as 3.0 D_2 downstream. The admission of air almost completely quieted the cavitation noise and vibration. At the 5.0 cfs discharge the top air vent was more effective than the others, and produced almost as much quieting as when all four were used. The bottom vent was least effective. Measurements of the rates of airflow were not made.

BIBLIOGRAPHY

1. Ball, J. W., and Simmons, W. P., "Progress Report on Hydraulic Characteristics of Pipeline Orifices and Sudden Enlargements used for Energy Dissipation," Report No. Hyd-519, USBR

2. Ball, J. W., "Sudden Enlargements in Pipelines," Journal of the Power Division, ASCE Volume 88 No. PO4, December 1962

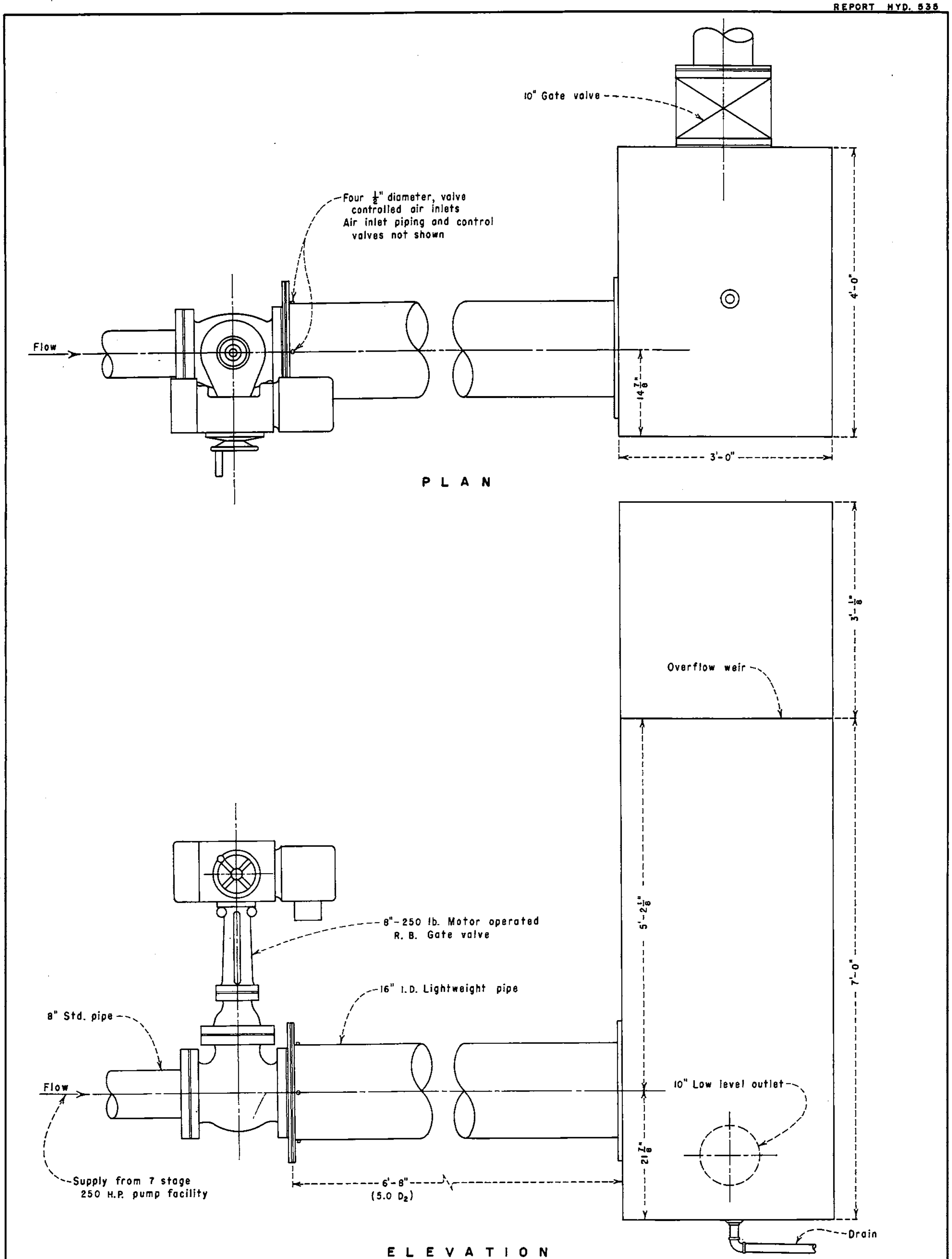
3. Tinney, E. Roy, Discussion of paper, "Sudden Enlargements in Pipelines," Journal of the Power Division, ASCE Volume 89, No. PO1, September 1963

4. Ball, J. W., "Cavitation Characteristics of Gate Valves and Globe Valves Used as Flow Regulators Under Heads up to About 125 Feet," Transactions of the ASME Volume 79, Number 6, August 1957

5. Kindsvater, C. E., "Energy Losses Associated with Abrupt Enlargements in Pipes," Geological Survey Water Supply Paper 1369-B, 1961

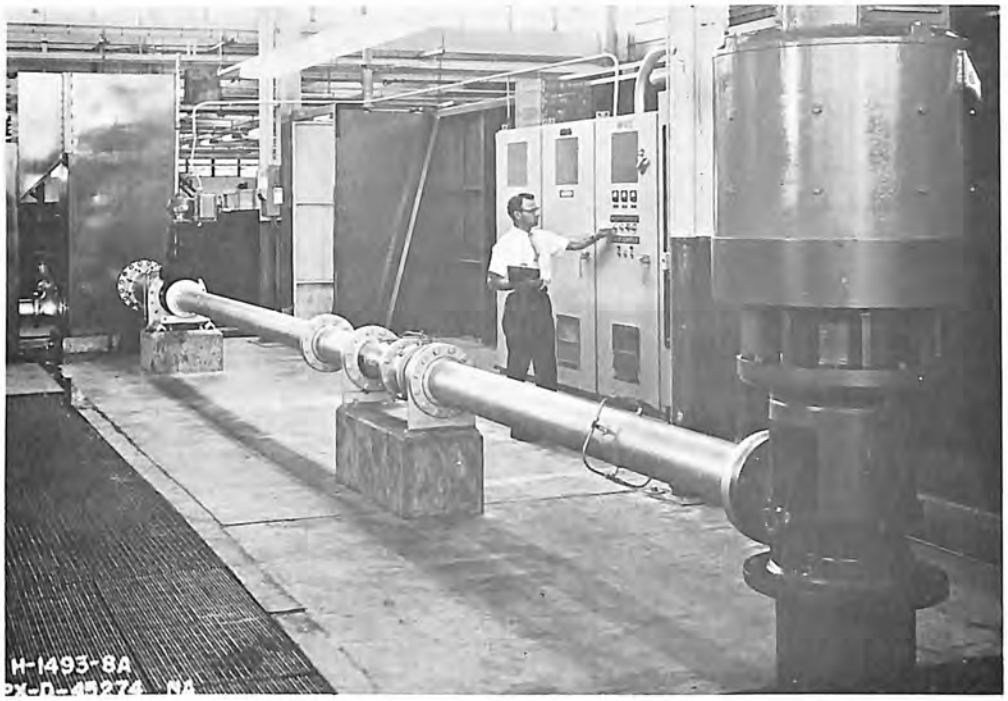
6. Archer, W. H., "Experimental Determination of Loss of Head Due to Sudden Enlargement in Circular Pipes," Transactions, ASCE, Volume 76, 1913

7. "Pressure Reducing Plant For a Water Power Station" Escher Wyss News, Volume 30, No. 1, 1957

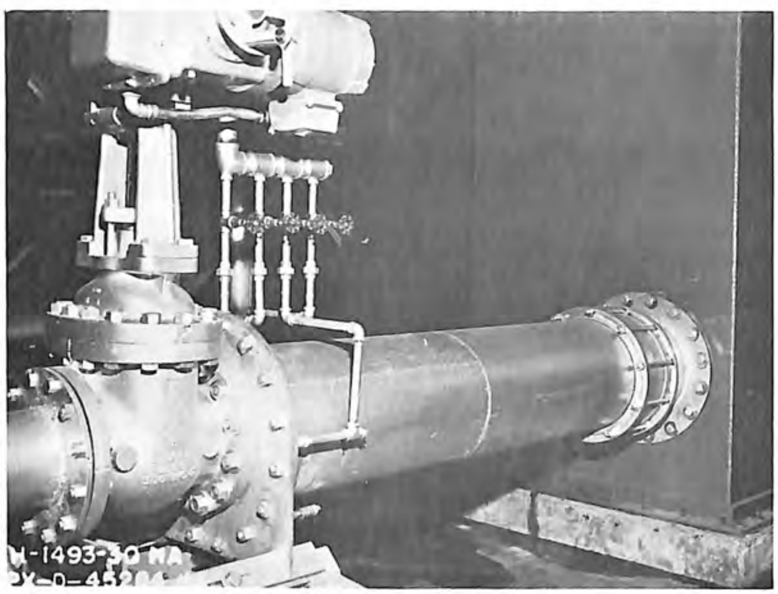


SUDDEN ENLARGEMENT ENERGY DISSIPATOR STUDIES

8-INCH GATE VALVE WITH 2.0-D_1 ENLARGEMENT AND BACK PRESSURE TANK



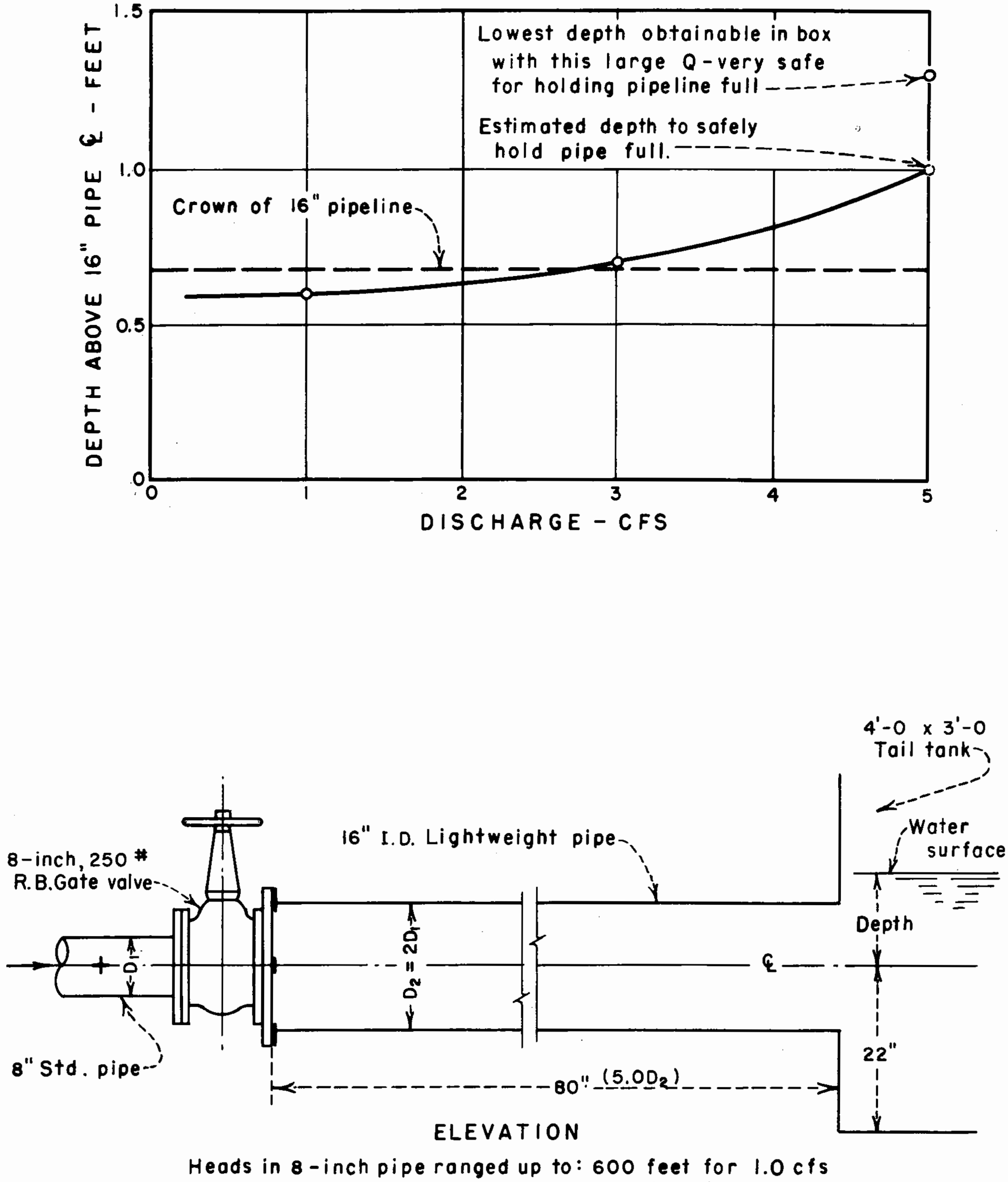
A. Overall view of high-head pump, 8-inch pipeline, Venturi meter, control valve, energy dissipator, and back pressure tank.



Energy dissipation system with 8-inch gate valve, 16-inch diameter enlargement, 1/2-inch air inlet pipes, and back pressure tank.

SUDDEN ENLARGEMENT ENERGY DISSIPATOR STUDIES

Photographs of High Head Pump Facility and Energy Absorber System



ELEVATION

Heads in 8-inch pipe ranged up to: 600 feet for 1.0 cfs
500 feet for 3.0 cfs
380 feet for 5.0 cfs

SUDDEN ENLARGEMENT ENERGY DISSIPATOR STUDIES

WATER DEPTH REQUIRED TO MAINTAIN 2.0-D_1 ENLARGEMENT FULL WITH VALVE THROTTLING FLOW

NO AIR ADMITTED

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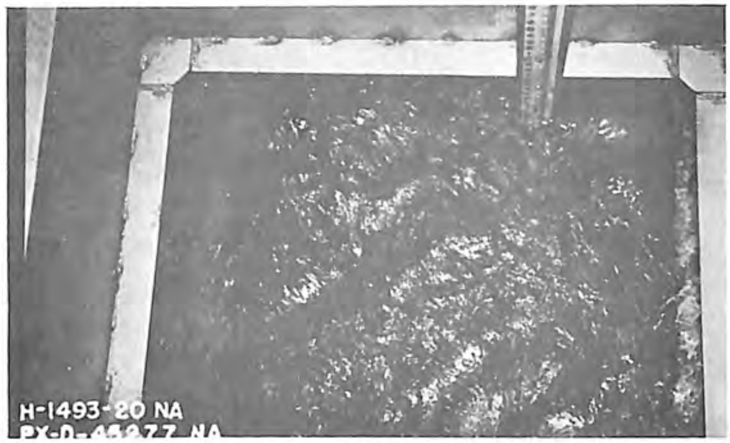
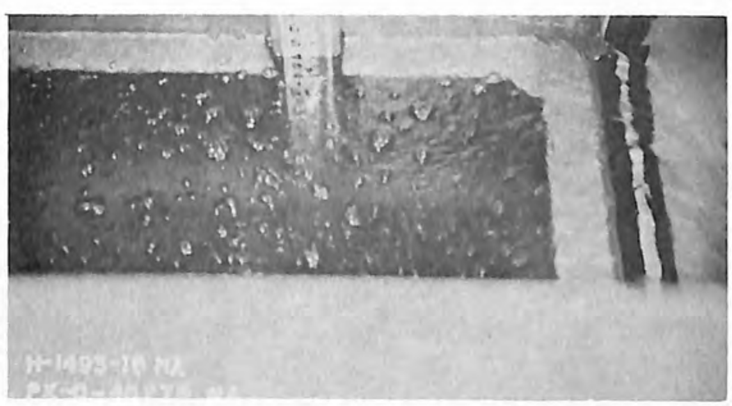


A. Pool 0.7 feet deep 1/12 sec.

B. Pool 3.0 feet deep 1/12 sec.



C. Pool 5.4 feet deep and passing over weir
1/12 sec.
Depths measured from ℄ of 16-inch pipe

SUDDEN ENLARGEMENT ENERGY DISSIPATOR STUDIES
Flow Conditions in Back Pressure Tank
Q = 1.0 cfs H_1 = 500 feet No Air Admission

Figure 5
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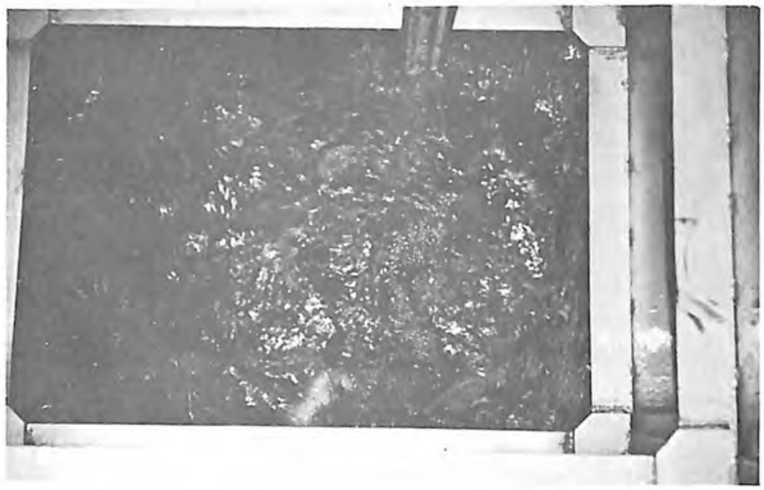
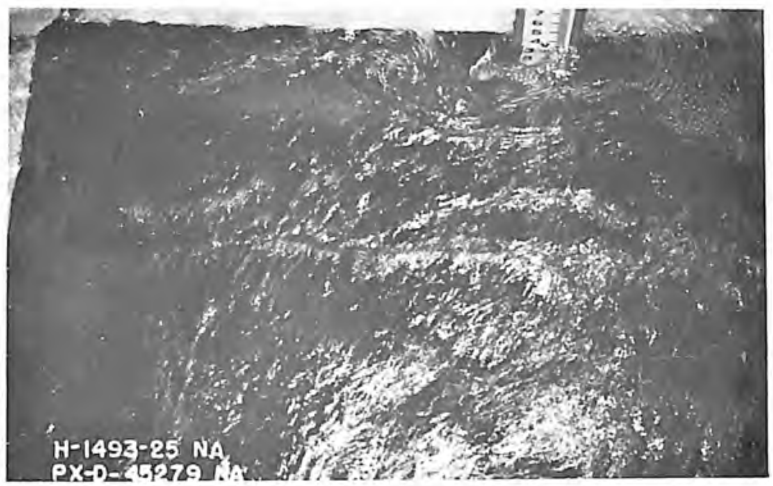


A. Pool depth 0.9 feet 1/12 sec.



B. Pool depth 3.3 feet 1/12 sec.

C. Pool depth 5.6 feet and passing over weir
1/25 sec.
Depths measured from ℄ of 16-inch pipe

SUDDEN ENLARGEMENT ENERGY DISSIPATOR STUDIES
Flow Conditions in Back Pressure Tank
Q = 3.0 cfs H_1 = 500 feet No Air Admission

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Figure 6
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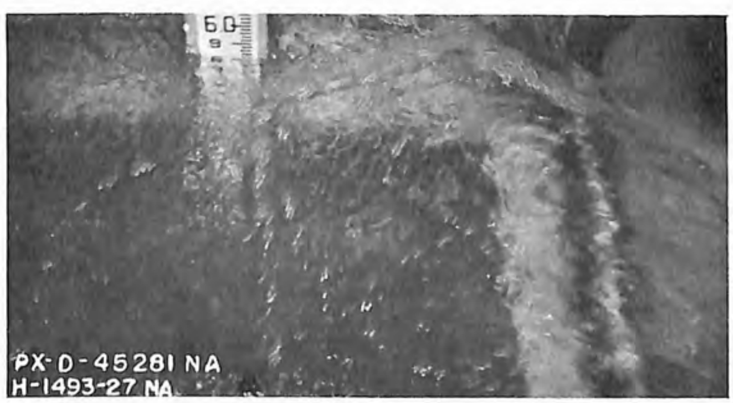
A. Pool depth 1.3 feet (lowest obtainable due to outlet restrictions) 1/12 sec.

B. Pool depth 3.0 feet 1/12 sec.



C. Pool depth 5.8 feet and passing over weir
1/25 sec.
Depths measured from ℄ of 16-inch pipe

SUDDEN ENLARGEMENT ENERGY DISSIPATOR STUDIES
Flow Conditions In Back Pressure Tank
Q = 5.0 cfs H_1 = 380 feet   No Air Admission

ABSTRACT

Limited studies were made under high heads to determine the effectiveness of a sudden enlargement type energy dissipator used downstream from an 8-inch gate valve. The enlarged section, which started at the downstream flange of the valve, was 16 inches in diameter (2.0 D_1) and 80 inches long (5.0 D_2). The valve throttled at heads up to 600 feet. Discharges of 1.0, 3.0, and 5.0 cfs were tested. A back pressure, or downstream depth of water, of only 1.0 foot above the centerline of the 16-inch pipe was sufficient to maintain the enlarged pipe full and obtain satisfactory energy dissipation at all conditions tested. The water surface in the open tank just downstream from the enlargement was rough when the depth above the pipe centerline was small, but became much smoother at depths of 5 and 6 feet. Cavitation ranged from moderate to severe within the enlarged pipe. No erosion studies were made. Admission of air at the extreme upstream end of the enlargement greatly reduced cavitation noise and vibration. The air mixed thoroughly with the water and rose in the pool without causing disturbances in the pool. At 5.0 cfs an air vent located at the top was found more effective than either side or bottom vents.

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