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HYDRAULIC MODEL STUDIES - AERATION OF THE SUBMERGED JET-FLOW GATES AT SEMINOE DAM

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16. ABSTRACT

A study was performed to evaluate placement of an aeration vent on a submerged jet-flow gate at Seminoe Dam. Size restrictions on the discharge tube downstream from the gate suggested aeration as a means to protect the downstream areas from cavitation damage. Four air vent locations were tested. The vent on the top centerline of the discharge tube just downstream of the gate frame performed the best. Ratios of Q_a/Q_w greater than 10 percent were measured throughout the entire range of gate openings. A minimum vent size of 16 inches in diameter is needed to keep air velocities through the vent below 200 ft/s; however, the use of existing 18-inch-diameter piping is recommended.

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by

K. Warren Frizell

Hydraulics Branch
Research and Laboratory Services Division
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Denver, Colorado

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CONTENTS

FIGURES

PURPOSE

Two 60-inch jet-flow gates are being installed as replacements to the needle valves in the outlet works at Seminoe Dam, Wyoming. Submerged operation of these gates using the existing discharge tubes will result in cavitation damage downstream from the gate. Aeration downstream from the gate is the only viable option without replacement of the discharge tubes with expanded conduit sections. A hydraulic scale model (1:21) was used to evaluate aeration downstream from the jet-flow gate. Discharge characteristics, pressures in the discharge tubes, and air demand were measured for four different vent configurations.

INTRODUCTION

Submerged operation of a jet-flow gate requires protective measures in the area downstream of the gate. An expanded conduit section downstream from the gate is normally used to ensure that the cavitation cloud occurring in the shear layer does not collapse on the discharge tube walls. The size of the recommended expansion is 3D, where D is the diameter of the jet-flow gate (Isbester, 1975). This expansion allows good circulation around the jet, protecting the downstream surfaces from cavitation damage (Isbester, 1974; and Burgi and Fujimoto, 1973). The diameter of the expansion can be reduced somewhat if the length of the discharge tube is kept very short (Mefford, 1987). Protection of the discharge tube from cavitation by using aeration is necessary when conduit expansions downstream from the gate are not possible.

Replacement of the needle valves at Seminoe Dam with two 60-inch jet-flow gates is underway. New tailwater studies project that these jet-flow gates may operate with up to 2.5 feet of water above the centerline of the gates. The existing discharge tubes provide only a 1.4D expansion. Without aeration of the jet, the discharge tubes will be subject to cavitation damage. Aeration of the discharge tubes by providing an air vent downstream from the gate was studied in a hydraulic model. Four different locations for the vent were tested. Recommendations for vent size and location are given.

THE MODEL

The studies were made using a 1:21 scale hydraulic model. The model included one jet-flow gate with existing piping upstream and downstream of the gate (fig. 1). The model was placed in the laboratory's low ambient pressure chamber for ease of operation and to observe the location of cavitation clouds in the model. The ambient pressure in this 600-ft^3 chamber can be reduced to 0.1 atmosphere and can deliver up to 10 ft^3/s through an installed model. Model scaling was based on equal Froude numbers in the model and prototype:

$$(V^2/gL)_m = (V^2/gL)_p \qquad (1)$$

where:

V	=	velocity
g	=	gravitational constant
L	=	characteristic length
m, p	=	model and prototype

Tests were conducted to compare four different air vent locations. Measurements taken included upstream head, discharge, gate opening, air velocity into the vent piping, and piezometric pressures at four locations on the invert of the discharge tube downstream from the gate. All tests were run with the maximum tailwater condition (elevation 6147.5 feet). Documentation also included still photographs and video.

THE TESTS

Four different air vent locations were studied (fig. 2). The test procedure was as follows:

1. Set gate opening.
2. Set tailwater elevation.
3. Adjust flow rate to achieve desired reservoir head upstream of the gate.
4. Record discharge and piezometric pressures.
5. Measure air velocity into air vent piping.

This procedure was repeated for the full range of gate openings from 5 to 100 percent.

TEST RESULTS

The test results are presented as follows: discharge characteristics (fig. 3), piezometric pressures downstream from the gate (figs. 4-5), and air demand curves (fig. 6).

Discharge characteristics of the jet-flow gate varied with aeration and the location of the air vent. The discharge coefficient C_d is defined as:

$$C_d = \frac{Q}{A_{up}[2g(H_{up} - H_{dn})]^{1/2}} \tag{2}$$

where:

Q	=	Discharge (ft^3/s)
A_{up}	=	Area of upstream pipe (ft^2)
g	=	Gravitational constant (ft/s^2)
H_{up}	=	Pressure head upstream from the gate (ft)
H_{dn}	=	Pressure head downstream from the gate (ft)

Without aeration, the discharge coefficient reaches a value of 0.88 when the gate is fully open. This value drops to 0.62 when the discharge tube is aerated with the top or 45° vent configurations and to only 0.41 for the bottom vent configuration (fig. 3).

The piezometric pressures on the discharge tube invert also vary with aeration. Without aeration, impact of the jet remains close to the gate for openings up to 30 percent (fig. 4). Above 40 percent open, negative pressures are produced just downstream of the gate. The jet impact point moves down the conduit to the second and third piezometer locations. When aerated from the top vent, the jet impact is near the first piezometer tap for the 5-percent opening and begins moving downstream as the gate is opened. At 100 percent open, the jet springs free over all four piezometer taps (fig. 5).

Aeration was best accomplished through a vent on the crown of the pipe just downstream from the gate (fig. 6). Air was pulled into the discharge tube for all gate openings tested. The quantities ranged from 13 to 22 percent (air to water ratio). The air was pulled down the gate slots and distributed evenly across the bottom of the gate orifice (fig. 7). The other tested vent locations pulled in much less air (2 to 6 percent) with gate opening above 20 percent.

CONCLUSIONS AND RECOMMENDATIONS

It is possible to aerate the discharge tubes downstream from the jet-flow gates at Seminoe Dam. When aerated from the top vent, amounts of air are admitted that are known to prevent cavitation damage (Peterka, 1953). The lower vent configurations tested only pull in air at larger gate openings. The recommended position of the vent is directly downstream from the jet-flow gate frame on the top centerline. Model data suggest that, to keep air velocities in the vent below 100 ft/s (due to noise), a vent size of 22 inches in diameter is necessary. The vent size could be reduced to 16 inches in diameter (190 ft/s) since operation will be remote and not continuous. Use of an existing 18-inch-diameter vent is recommended.

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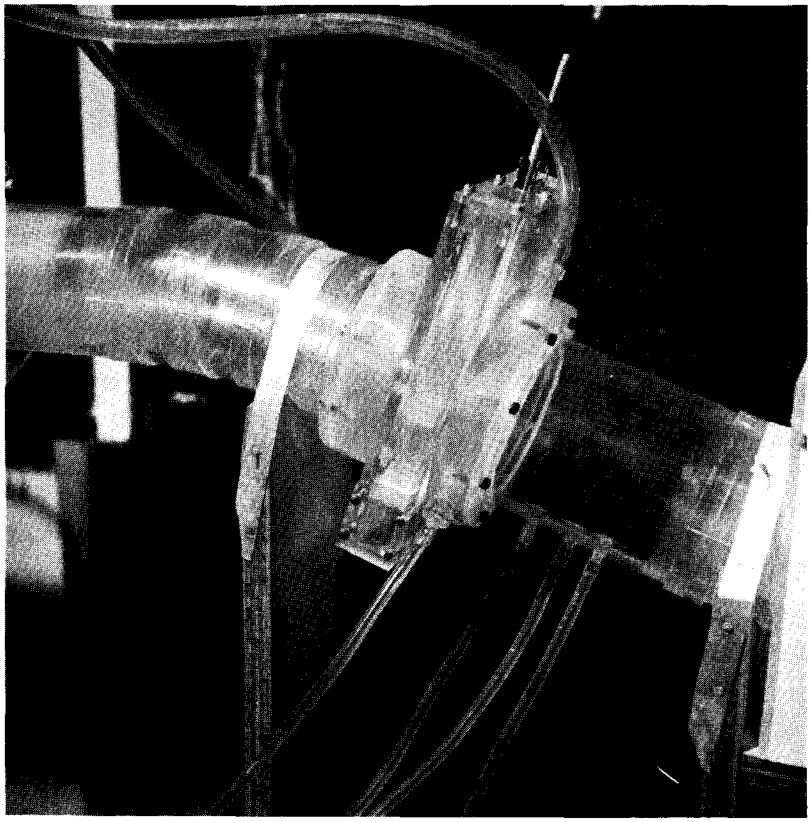

Figure 1. - 1:21 scale hydraulic model of one Seminoe jet-flow gate.

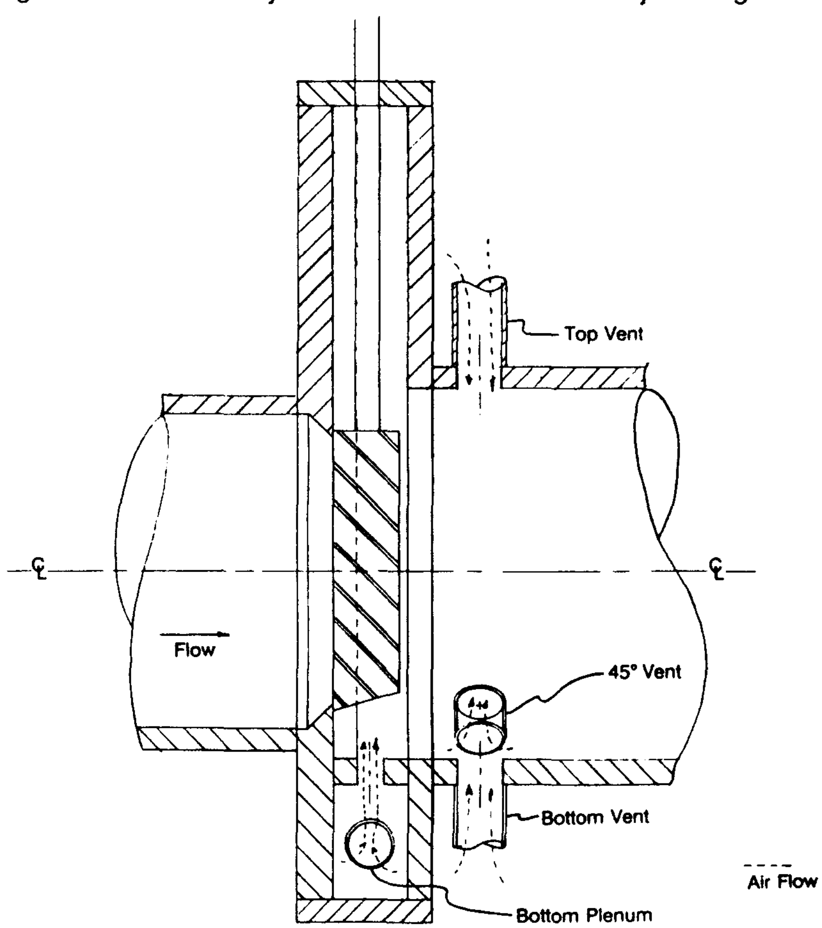

Figure 2. - Air vent locations tested.

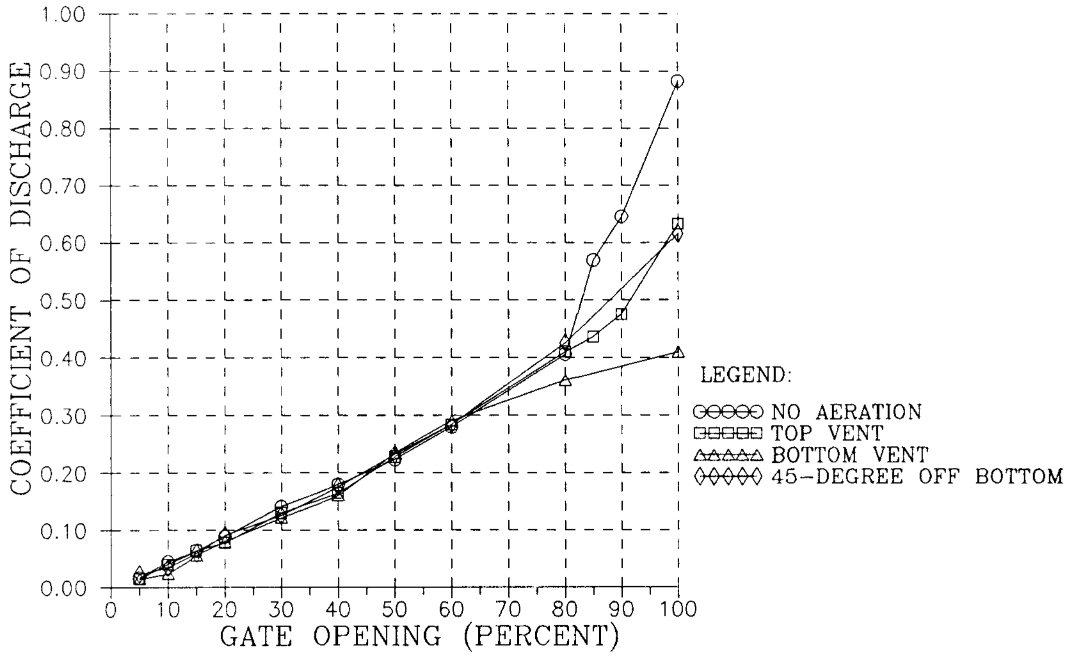

Figure 3. - Coefficient of discharge for 60-inch jet-flow gate, aerated versus nonaerated.

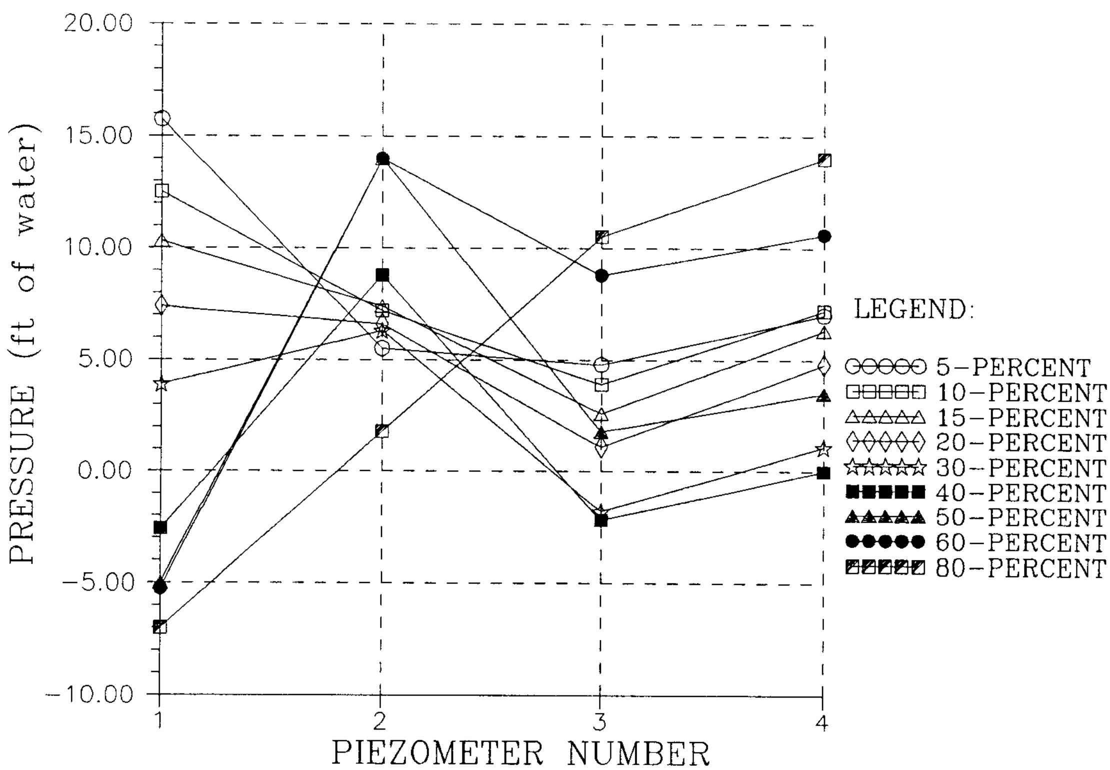

Figure 4. - Piezometric pressure on discharge tube invert, no aeration.

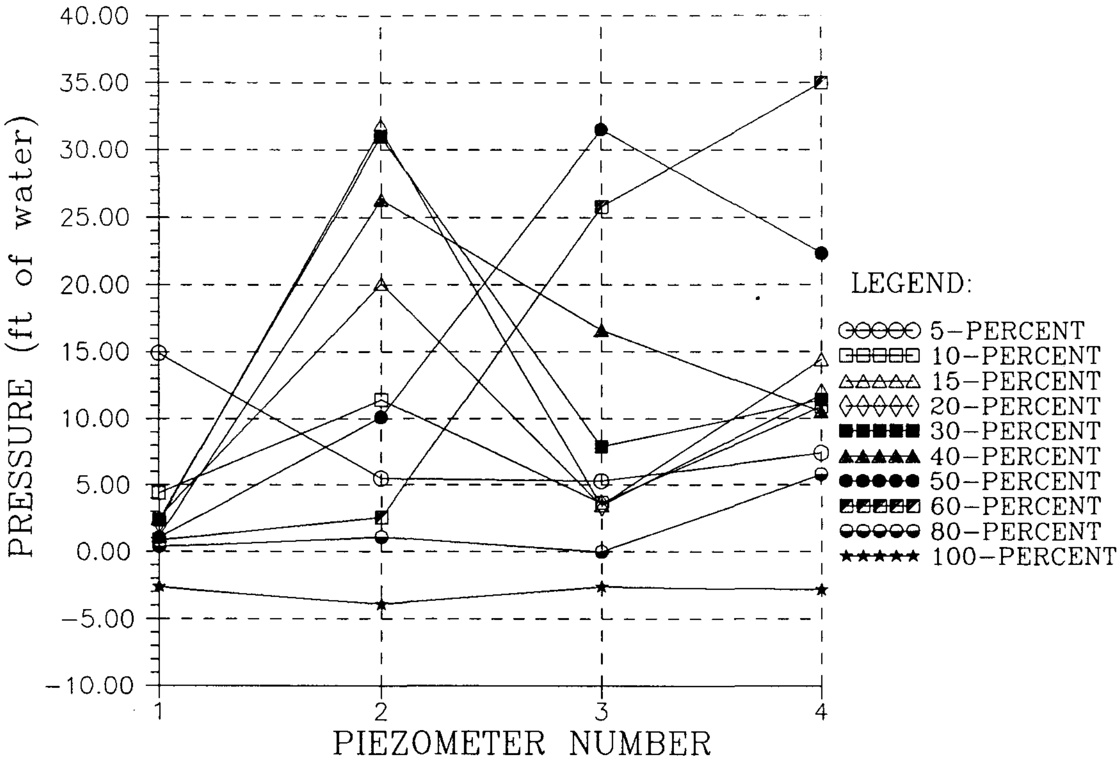

Figure 5. - Piezometric pressures in discharge tube invert, top vent open.

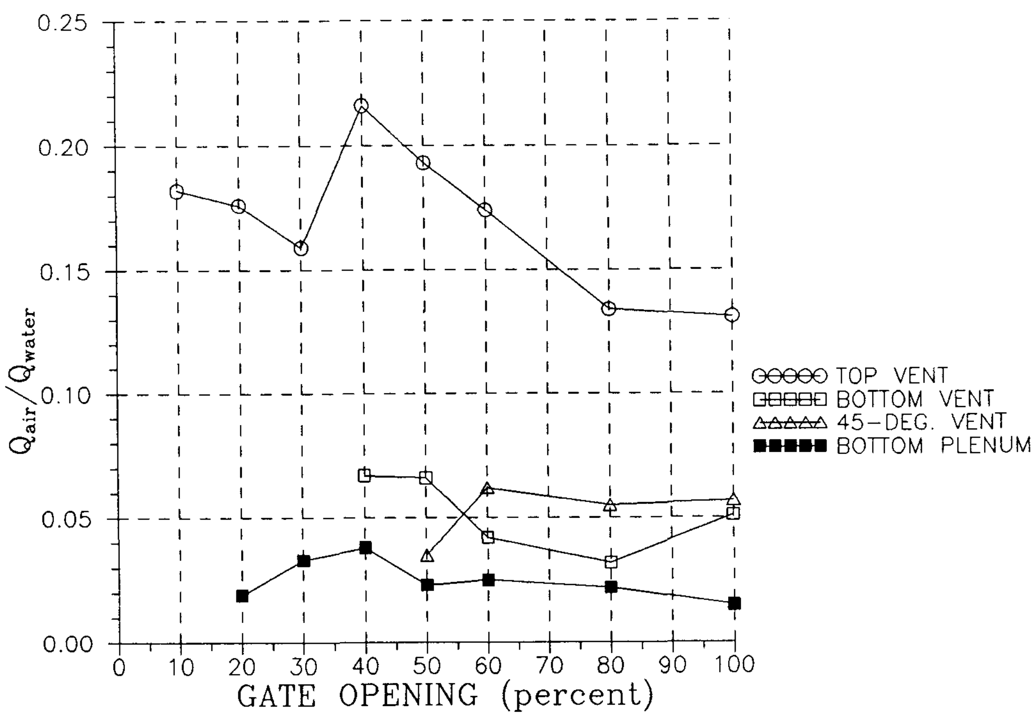

Figure 6. - Air demand curves, four vent configurations.

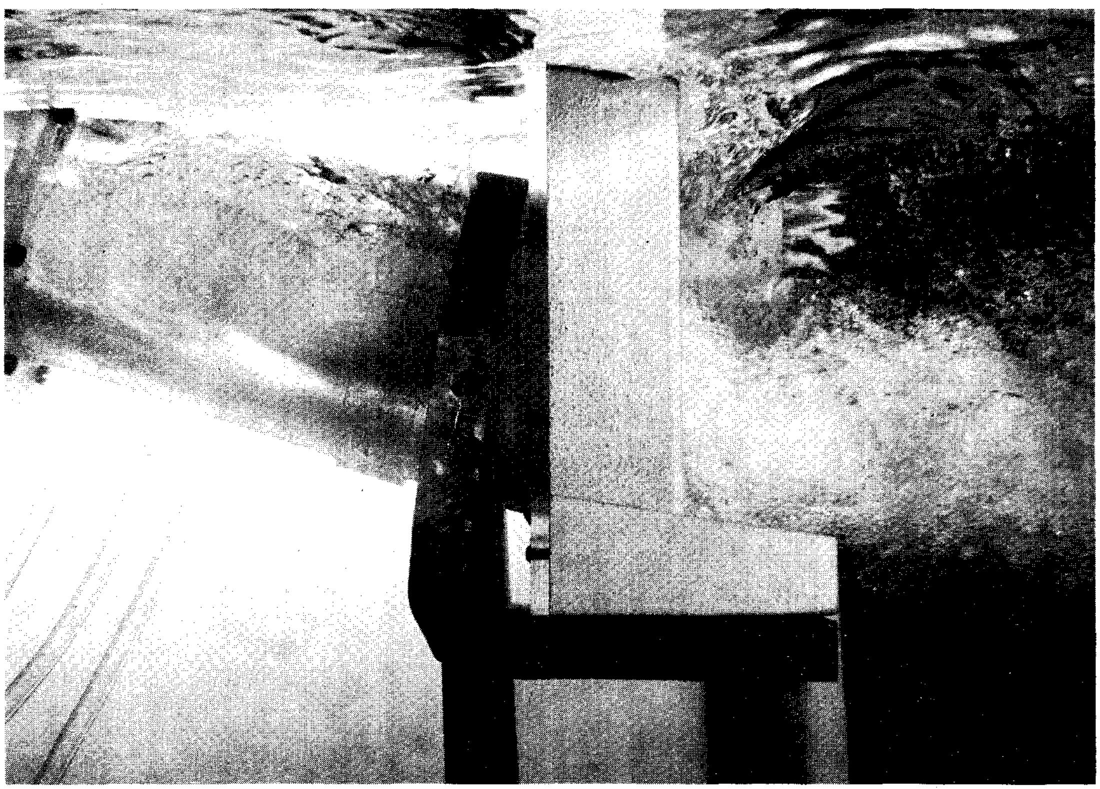

Figure 7. - Aeration from top vent; water mixture flowing along bottom of discharge tube.

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.