COLORADO STATE UNIVERSITY

CIVIL ENGINEERING DEPARTMENT

FINAL REPORT

LAKE ADAIR PROJECT

MODEL STUDY FOR HOLLOW-CONE VALVE OUTLET BOX

SUBMITTED BY

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TO

TIPTON AND KALMBACH, INC.

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FOREWARD

Subsequent to the hydraulic model study reported herein, several changes have been made in the detailed design and concept of this project. The most pertinent is the reduction of the diameter of the hollow-cone valve from 36 inches to 30 inches. This change reduces the capacity of the outlet works from 400 cfs to 230 cfs. However, the final geometry tested will still be satisfactory as long as the location of the apex of the valve cone remains the same with respect to the baffle walls, so that the trajectories intercepted by the surrounding chamber walls remain unaltered. Another change involving the outlet works is the reduction of the capacity of the bypass from 170 cfs to 150 cfs. This change is minor, however, and need not affect the chamber dimensions.

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Introduction

This report describes an hydraulic model testing program for the hollow-cone valve outlet box of the proposed Lake Adair Project. The tests were conducted at the Engineering Research Center of Colorado State University under contract with Tipton and Kalmbach, Inc., Denver, Colorado, consulting engineers on the Lake Adair Project.

The Lake Adair Project is part of a development of the Port Holiday Authority involving the creation of a lake for recreational purposes northeast of Henderson and adjacent to the Lake Meade National Recreation Area in Clark County, Nevada. Several release structures are planned for the lake including three separate spillways designed to handle flood discharges, and a low-level outlet controlled by a 36-inch diameter hollow-cone valve for day-to-day flow releases. This study involves only the valve outlet which will be capable of discharging 400 cfs under a total head of 110 feet. The net head at the base of the valve (the total head less the head losses in the 4-foot diameter upstream conduit) is expected to vary with discharge as shown in Fig. 1.

Drainage into the basin forming the lake includes natural effluent from the residential and industrial areas of Las Vegas. It is planned to collect this effluent at the head end of the lake, bypass it under the lake through a 4-foot diameter conduit and release it from the same structure that contains the hollow-cone valve. The maximum discharge to be handled in this manner is 170 cfs. Overflows from greater drainage inflows would be sufficiently diluted to be introduced directly into the lake. The bypass flow, which would not be pressurized as it passes under the lake, would be released into the hollow-cone valve outlet box with a maximum velocity of 7 or 8 fps.

The outlet box is to be located at the toe of the Lake Adair Dam. A 9-foot diameter access tunnel with a horseshoe shape would extend under the dam from the outlet box to the dam centerline. The 4-foot diameter pressurized conduit for the low-level outlet would be located inside the 9-foot tunnel to facilitate inspection and maintenance. The bypass flow which would be discharged into the access-tunnel at the upstream end would flow along the floor of the tunnel to the outlet box. The slope of the tunnel would be .025 so that the bypass flow would be supercritical with a maximum depth of about 1.5 feet.

The combined bypass and low-level outlet flows released from the outlet box would follow a natural channel into Lake Meade. The first 1,000 feet of the channel would be improved by excavating to a .005 slope. The upstream end of the channel would be protected from the highly turbulent outlet box discharge by stone riprap. The normal depths for flow in this channel is given as a function of discharge in Fig. 2.

Hydraulic Model Arrangement

The general arrangement of the hydraulic model is shown in Photo 1. Flow is from left to right. The upstream plywood box represents a section of the 9-foot diameter outlet conduit which contains the outlet pipe. The bypass discharge is introduced separately by a line from the laboratory supply manifold and flows along the bottom of the plywood box. The lucite section represents the outlet box containing the valve and the downstream plywood box, lined with riprap, represents a portion of the discharge channel.

The scale of the model was set at 1 to 14.4 so that a 2½-inch model valve (obtained on loan from International Power and Engineering Consultants of Vancouver, Canada) could be used. The discharges were scaled at 1 to 788 according to the modeling laws governing gravity flow. At these model ratios good agreement could be expected between the model and prototype, extending even to the stability of the riprap.

Behavior of the Model Initially Tested

The geometry of the outlet box initially tested conformed with the design transmitted by Tipton and Kalmbach by letter dated 28 May 1968. This geometry is presented diagrammatically in Fig. 3. It consists of an outlet box 17 feet high and 12 feet wide extending 26 feet beyond the apex of the cone of the hollow-cone valve. Projections from the roof, the floor, and from part of the sides, which are located 10 feet downstream from the apex, serve as baffles to the flow from the valve. The floor of the box is located 3 feet below the level of the downstream channel which is lined with a 2-foot layer of riprap. Photo 2 shows initial operation of the model for 170 cfs through the bypass and no flow through the hollow-cone valve.

The hydraulic behavior of the initial design, while not completely acceptable, was not so seriously deficient as to have caused serious maintenance or operational difficulties. The main deficiencies that warranted correction consisted of:

1. Partial blockage of the bypass flow at high valve discharges causing the water level at the valve to rise approximately to its centerline. According to one manufacturer of this type of valve, this condition should be avoided if possible.

2. Part of the valve discharge deflected upstream by the baffles so that it filled the chamber around the valve with high velocity spray. This was caused by the conical discharge jet impinging directly on the baffle at the corners where the walls meet the roof, instead of first on the sides.

3. Part of the high velocity flow escaping through the gaps in the baffle causing high velocities in the flow passing over the riprap.

4. Plunging type of flow onto the riprap caused by a partial blockage of the flow by the 3-foot high end sill.

The first two conditions are shown in Photo 3 with the model discharging 400 cfs through the valve and 170 cfs through the bypass. In this photo the valve is almost completely obscured by back-spray, but the bypass water level can be seen to reach the centerline of the valve and conduit. The last two conditions listed above are shown in Photo 4 with the same discharges as in Photo 3. Very few rocks, if any, were dislodged from the riprap by this flow, but it was considered that the discharge condition could be improved upon. The Tipton and Kalmbach engineers mentioned that the model riprap was probably larger than the equivalent that would be available for the prototype and so smaller riprap was used for subsequent tests.

Intermediate Model Modifications Tested

The second geometry of the box tested, shown in Photo 5, differed from the initial geometry in the following respects;

1. The valve was moved upstream 2 feet to correct the impingement condition that was causing the back-spray.

2. A horizontal shelf was inserted to allow the bypass flow to pass underneath of, and unobstructed by, the valve discharge.

3. The baffle was made continuous on the roof, shelf and sides and the cross section of the baffle was given an upstream batter which sloped back 18 degrees.

4. The height of the end sill was reduced from 3 feet to 1 foot. This was intended to reduce the obstructive effect of the end sill. It also allowed a reduction of the slope of the prototype discharge channel from .005 to .003 which would result in lower velocities along the channel.

These changes greatly improved the performance of the outlet box in the area around the valve. The back-splashing was virtually eliminated and the blockage of the bypass flow was greatly reduced as shown in Photo 6.

The velocities of the discharges from the outlet box, however, were observed to be higher than before. These high velocity discharges were concentrated in the center of the channel as can be seen in Photo 7. Velocity measurements taken across the discharge channel using a small propeller meter are tabulated in Table I. These values were measured 12 feet (prototype scale) downstream from the end of the outlet box. This position was chosen because it was known at that time that Tipton and Kalmbach planned to lengthen the outlet box by about 12 feet to accommodate embankment changes.

Table I. Velocities for the Second Design Tested, Measured at Mid-Depth 12 Feet Downstream from the Outlet Box

	Right				Left
Distance from the centerline in feet	6	3	0	3	6
Velocity in fps	11.0	12.9	15.7	12.6	11.3

The stones in the riprap for these tests were smaller than for the initial tests and their average weight was 0.2 lbs., equivalent to 600 lbs. in the prototype. During the tests, some displacement of the riprap was noticed but was limited in extent to the dislodgment of one or two stones.

Several geometry changes were tested in an attempt to reduce the velocities in the flow coming from the outlet box. First, the baffles with a sloping face were replaced with baffles with a square cross-section. This change made no noticeable improvement in the flow. Second, blocks of various sizes and shapes were attached to the floor of the outlet box, but none of the block arrangements tested improved the downstream velocities to any extent. Last, a vertical column was placed in the center of the outlet box just downstream of the baffles. It successfully obstructed and dispersed the high velocities occurring in the center. This arrangement was fairly effective in reducing the velocities at the exit of the outlet box and after checking to see that the column would not interfere with the installation of the valve, it was decided in conjunction with Tipton and Kalmbach engineers to incorporate it into the final design.

A 12-foot extension to the outlet box was tested next. In the course of the testing it was found that the flow in the extension was more regular and the velocities were more evenly distributed if the extension walls diverged. Without diverging walls a strong standing wave occurred in the extended section indicating that the flow was fluctuating between tranquil and rapid flow. With diverging walls the flow remained tranquil or subcritical throughout.

Final Design Tested

The geometry of the final design tested is shown in Fig. 4 and in Photos 8 and 9. The changes to the initial design, incorporated into the final design as a result of the testing program, consisted of the following:

1. The valve was moved 2 feet upstream.

2. The valve centerline was raised 1 foot to accommodate design changes planned by Tipton and Kalmbach.

3. A horizontal ledge was provided to minimize interference with the bypass flow by discharge from the valve.

4. The baffle was made continuous on the roof, the sides and the ledge.

5. A vertical square column was added downstream of the baffles.

6. The outlet box was extended downstream by 12 feet with diverging side walls.

7. The end sill and the discharge channel level were lowered by 2 feet.

These changes combined to produce a completely effective outlet box for the entire range of discharges to be encountered. Photo 10 shows the final design tested operating with the valve closed and with 170 cfs discharging from the bypass. The entire flow is shown to pass under the ledge. Photos 11 and 12 show the maximum design flow with 400 cfs from the valve and 170 cfs from the bypass. Photo 11 shows that the valve is clear of the water even with the additional obstruction caused by the center pillar. Photo 12 shows the even distribution of the flow as it leaves the outlet box. The velocities measured at the exit of the outlet box for these conditions are given in Table II.

Table II. Velocities for the Final Design Tested, Measured at Mid-Depth at the Exit of the Extended Outlet Box

	Right				Left
Distance from the centerline in feet	8	4	0	4	8
Velocity in fps	12.4	11.2	10.1	11.4	12.6

Some water depth measurements were made with the final design tested with the results given in Table III.

Table III. Measured Water Depths for Final Design Tested

Bypass Discharge cfs	Valve Discharge cfs	Valve Base Pressure (Preset) feet	Depth at End of Bypass Conduit feet	Depth at Beginning of Riprap feet
170	0	110	1.5	2.7
170	100	107	1.8	3.4
170	200	98	2.1	3.7
170	400	62	3.8*	4.2
0	100	107	0	2.4
0	200	98	0.9*	3.2
0	400	62	2.9*	3.6

*These values would be reduced somewhat by raising the conduit floor as planned by Tipton and Kalmbach since they are influenced by downstream conditions.

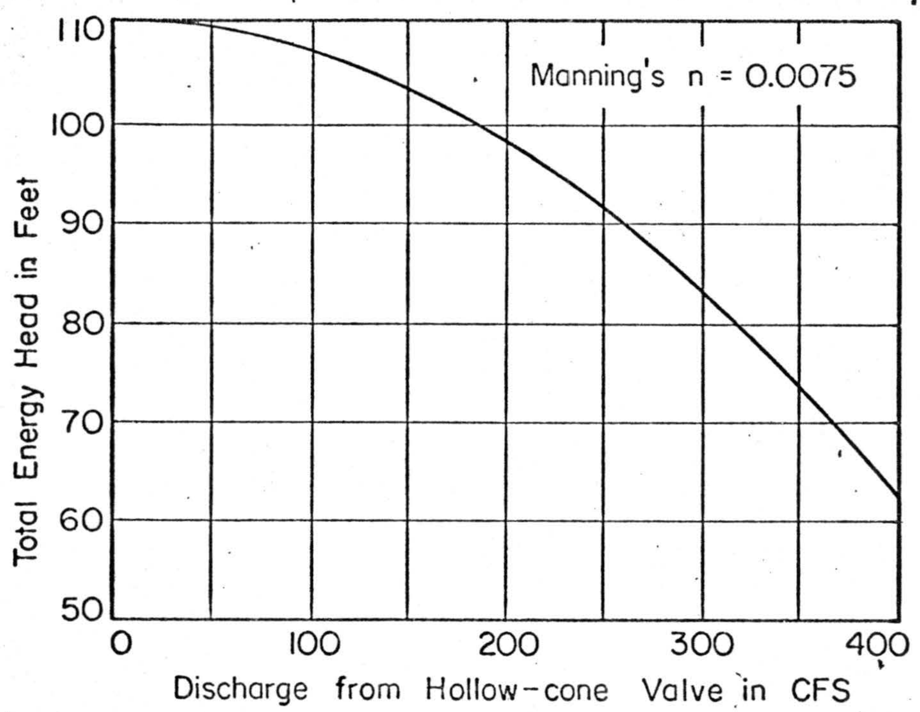

Fig. 1, Total Energy Head at the Base of the Hollow-cone Valve Determined Analytically

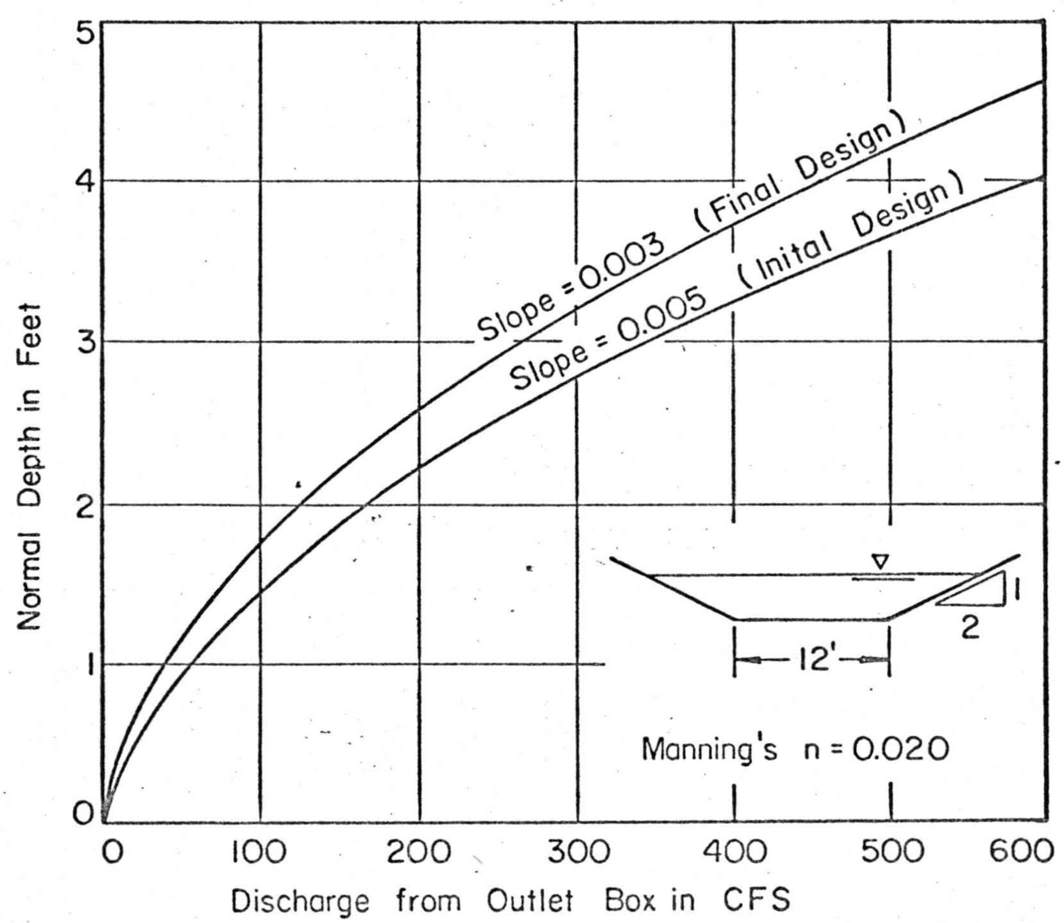

Fig. 2, Normal Depth of Flow in Discharge Channel Determined Analytically

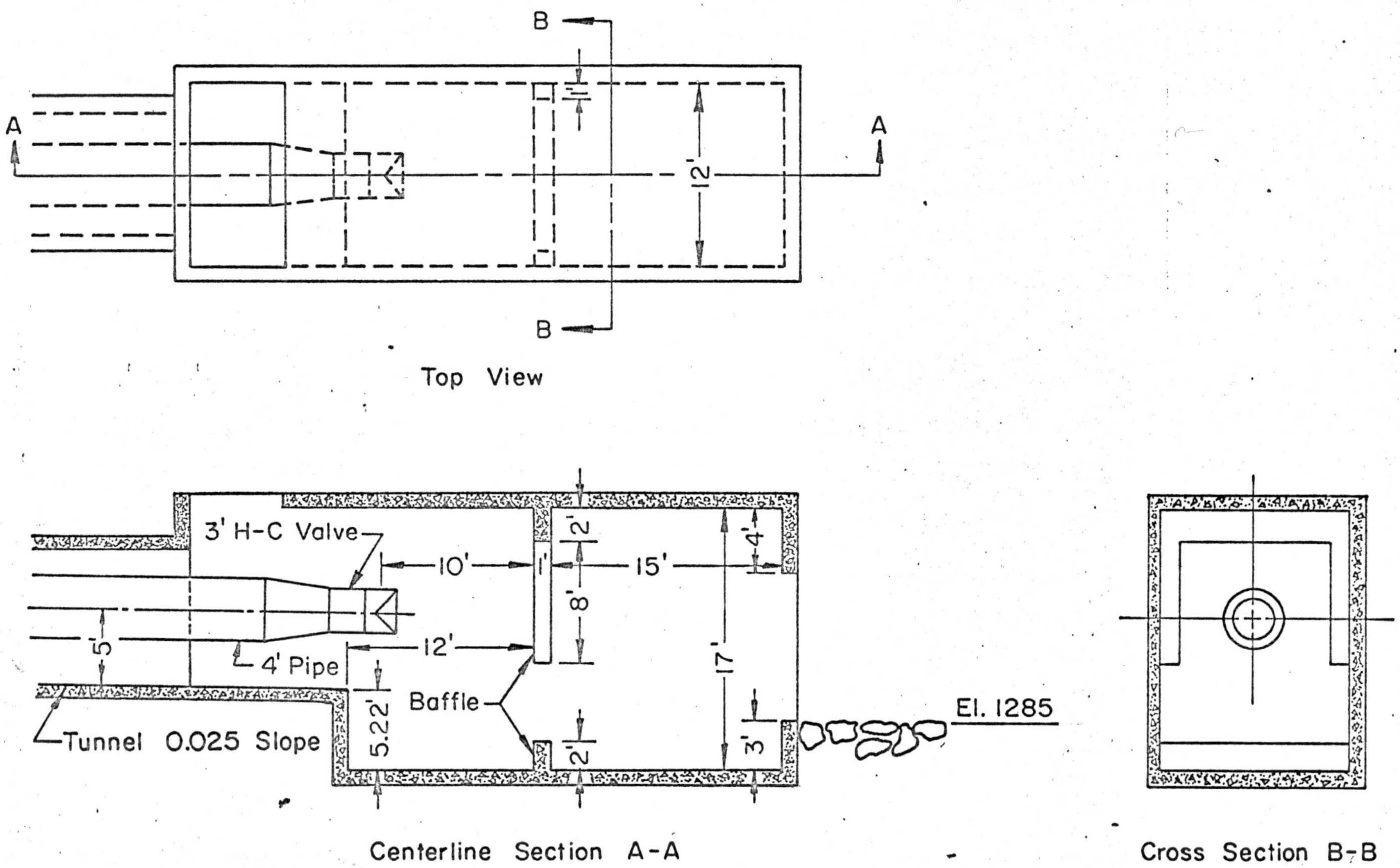

Fig. 3 — Initial Design Tested

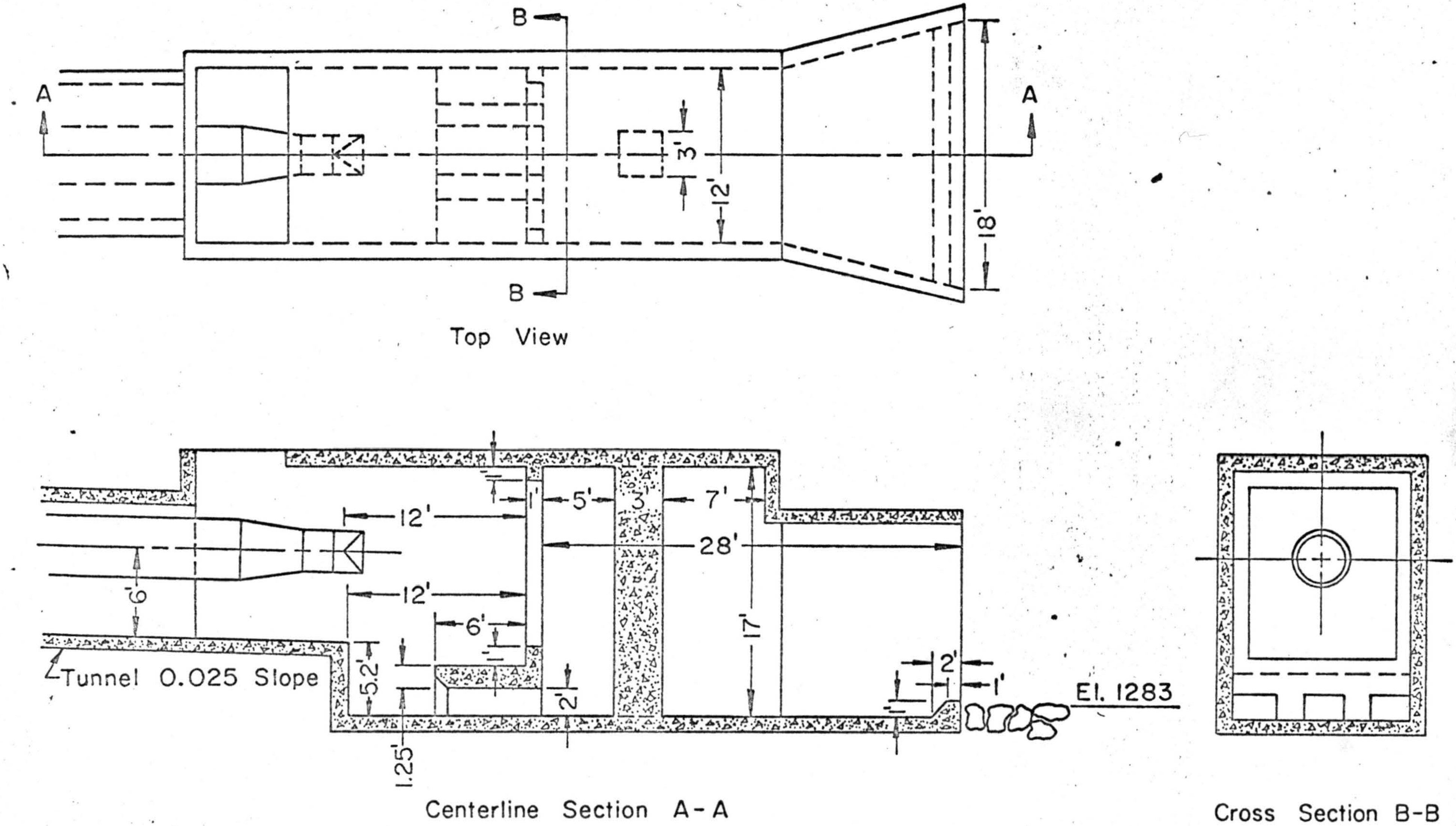

Fig. 4, Final Design Tested

Photo 1 (Serial No. 1425-1-10)

Arrangement of the Model

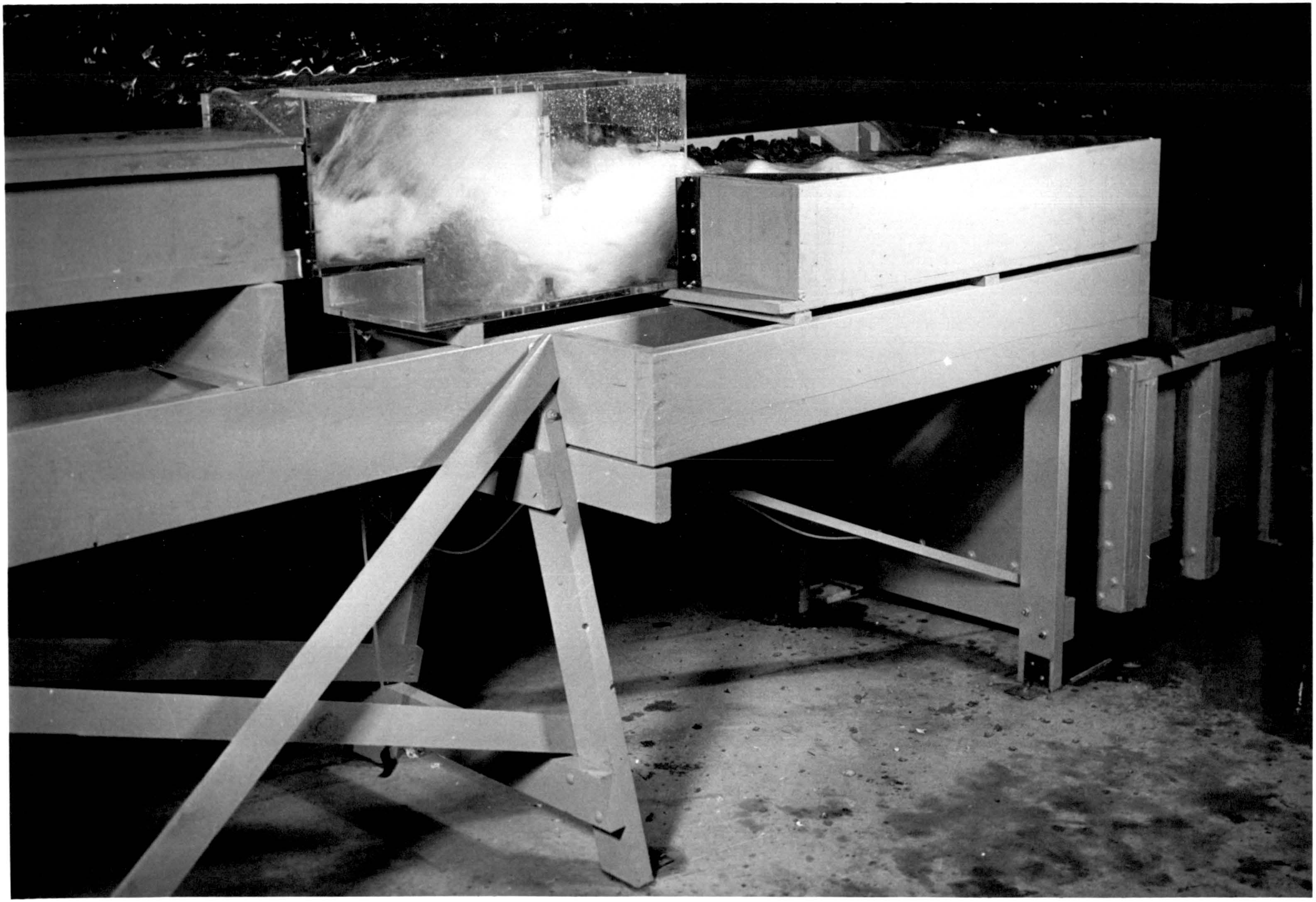

Photo 2 (Serial No. 1425-1-12)

Initial Geometry Tested with 170 cfs through

the Bypass and no Flow through the Hollow-cone Valve

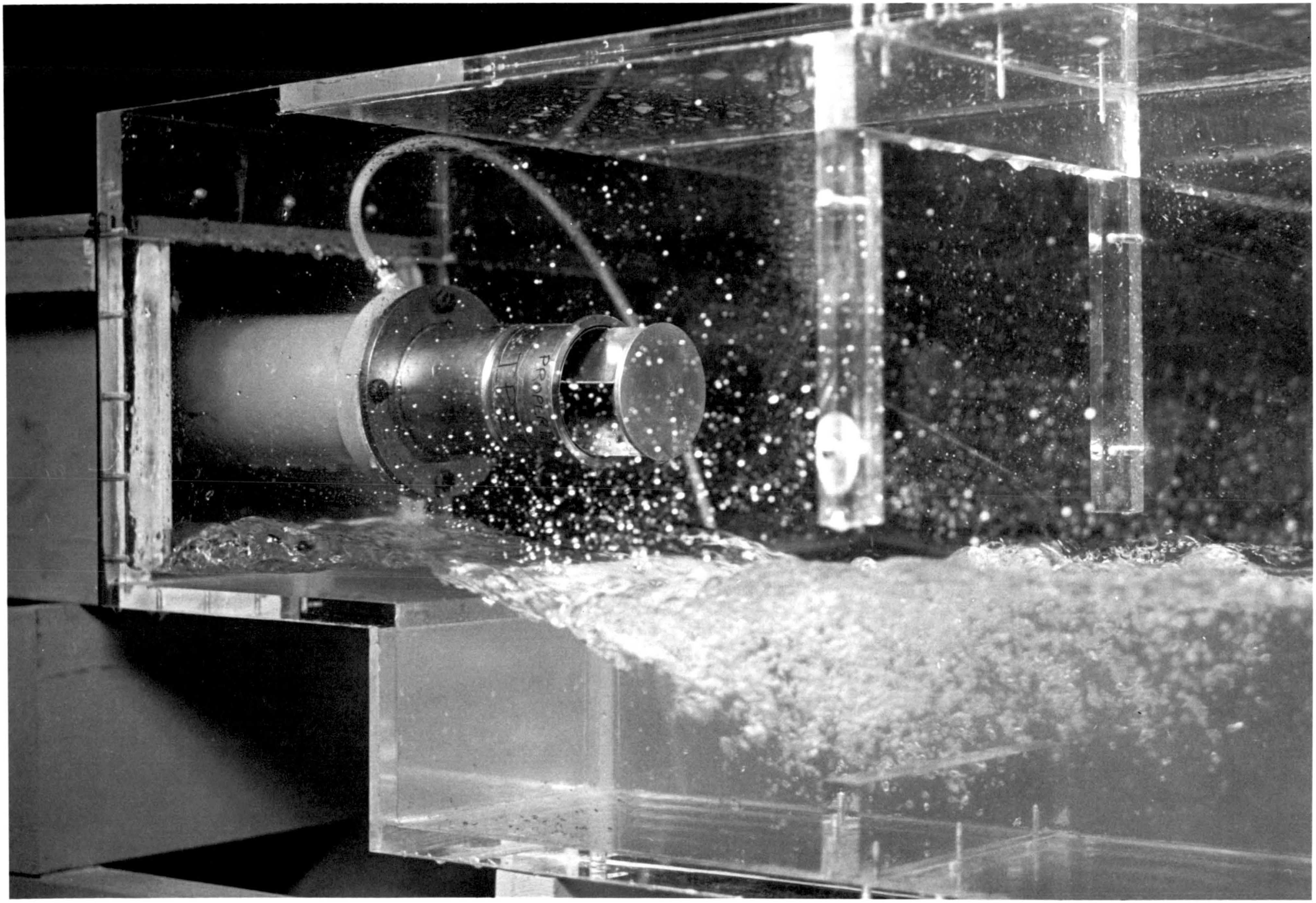

Photo 3 (Serial No. 1425-1-7)

Initial Geometry Tested with 400cfs

through the Valve and 170 cfs through the Bypass

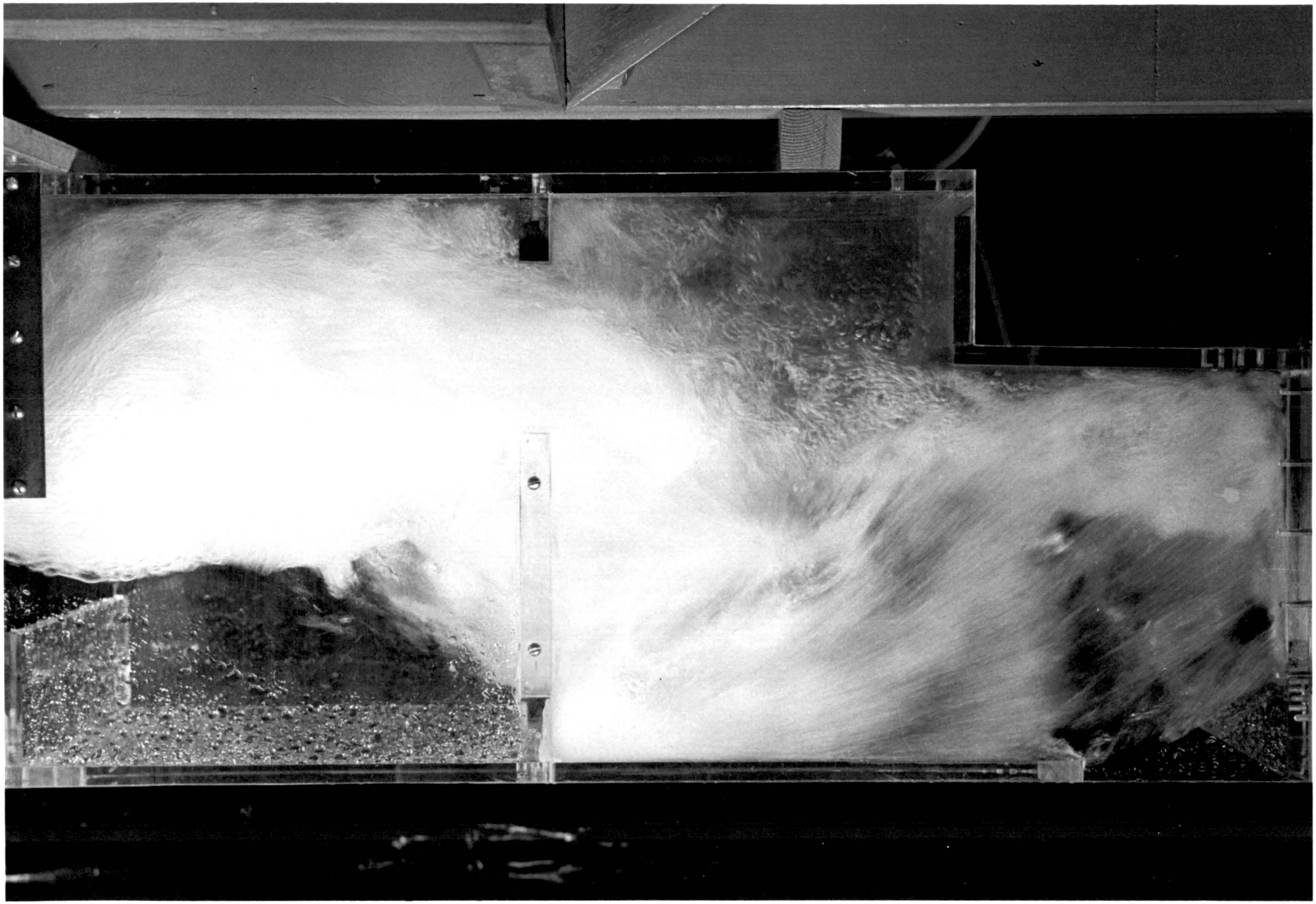

Photo 4 (Serial No. 1425-1-3)

Initial Geometry Tested with 400 cfs

through the Valve and 170 cfs through the Bypass

Photo 5 (Serial No. 1425-2-7)

Arrangement for the Second Geometry Tested

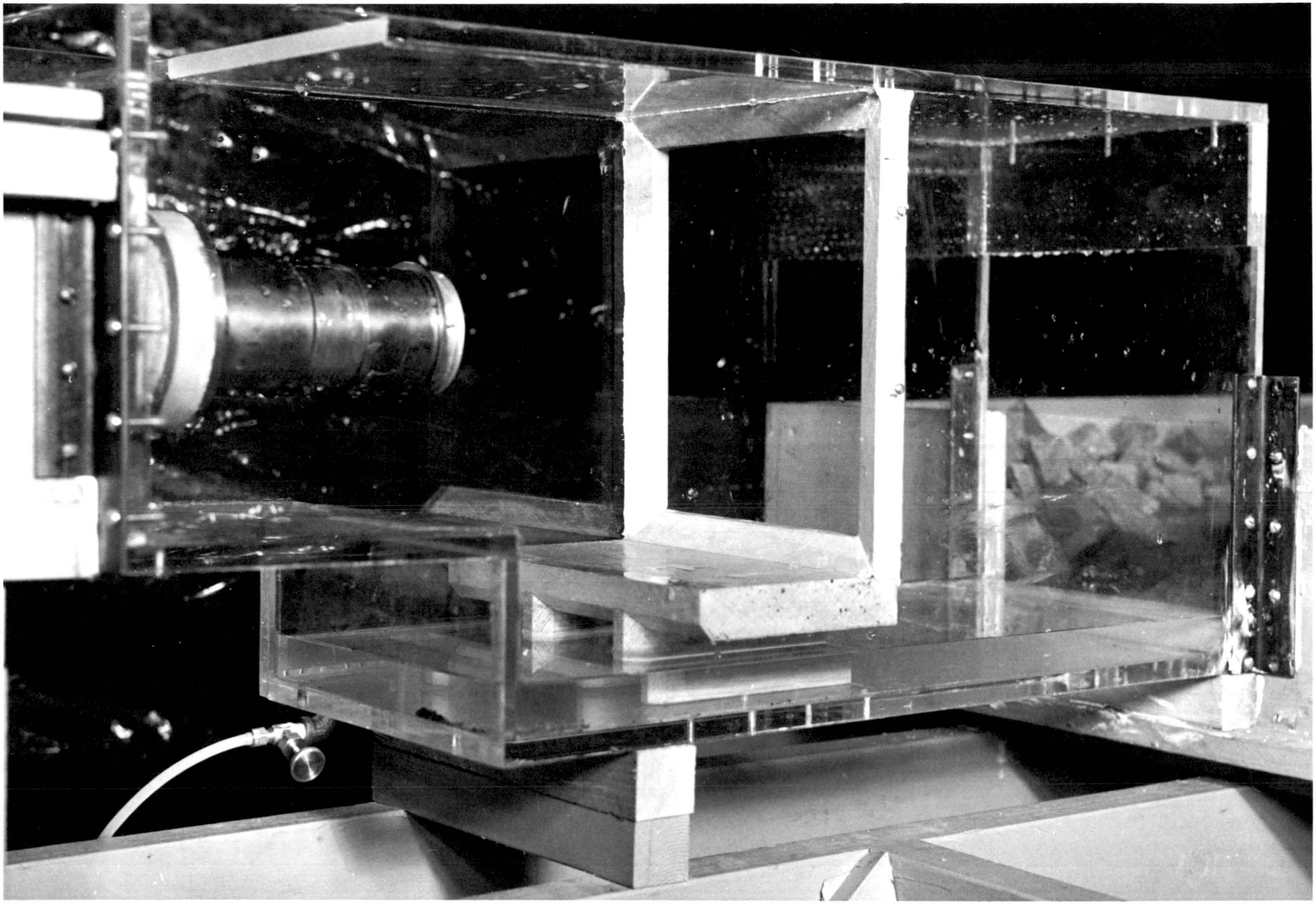

Photo 6 (Serial No. 1425-3-9)

Second Geometry Tested Showing the Improved Conditions at the Valve.

Valve Discharge is 400 cfs and the Bypass Discharge is 170 cfs.

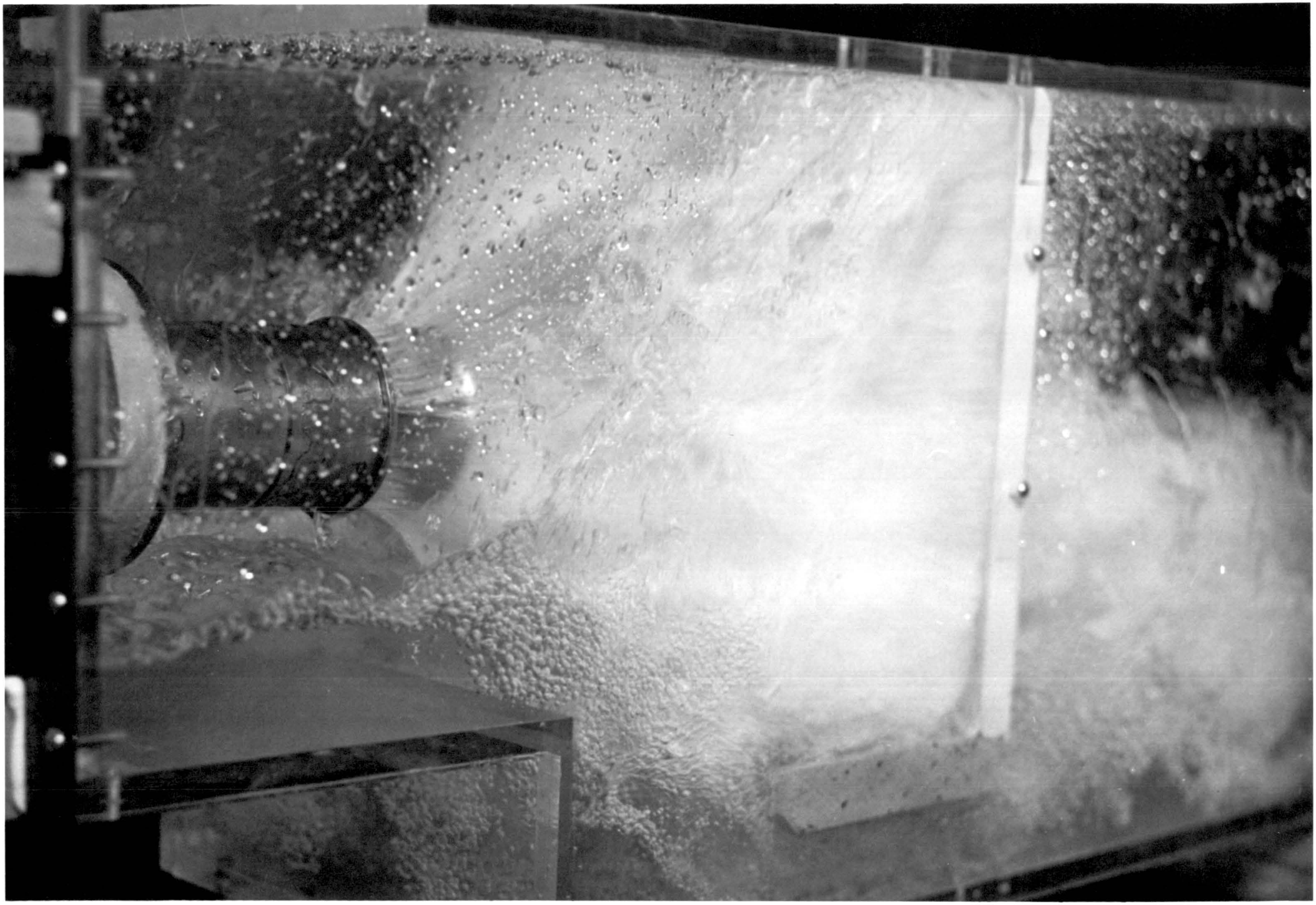

Photo 7 (Serial No. 1425-3-12)

Second Geometry Tested Showing High Mid-Channel Velocities with 400 cfs from the Valve and 170 cfs from the Bypass

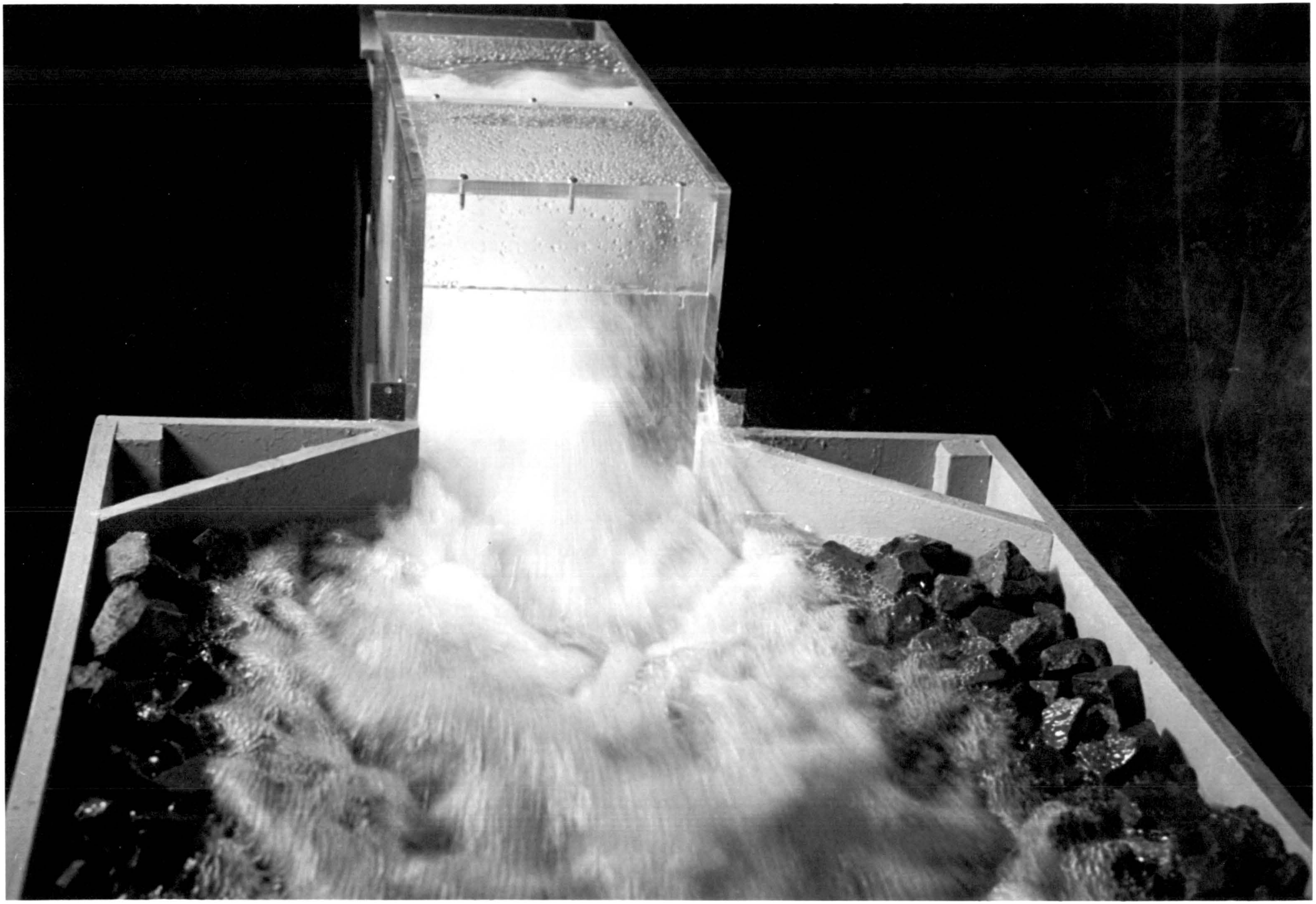

Photo 8 (Serial No. 1425-4-1)

Arrangement for the Final Geometry Tested

Photo 9 (Serial No. 1425-4-3)

Arrangement for the Final Geometry Tested

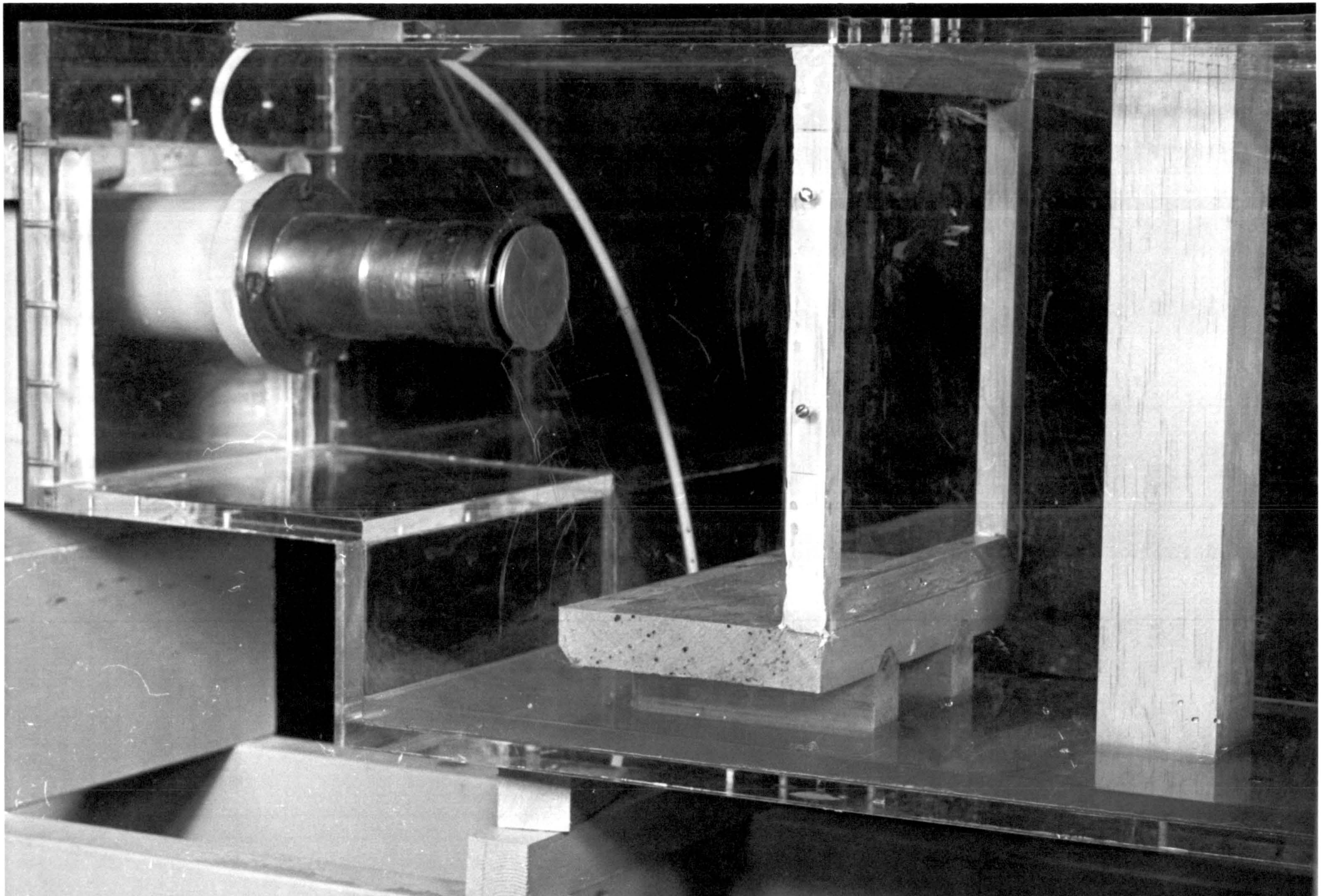

Photo 10 (Serial No. 1425-4-4)

Final Geometry Tested Operating with

170 cfs through the Bypass and no Flow through the Valve.

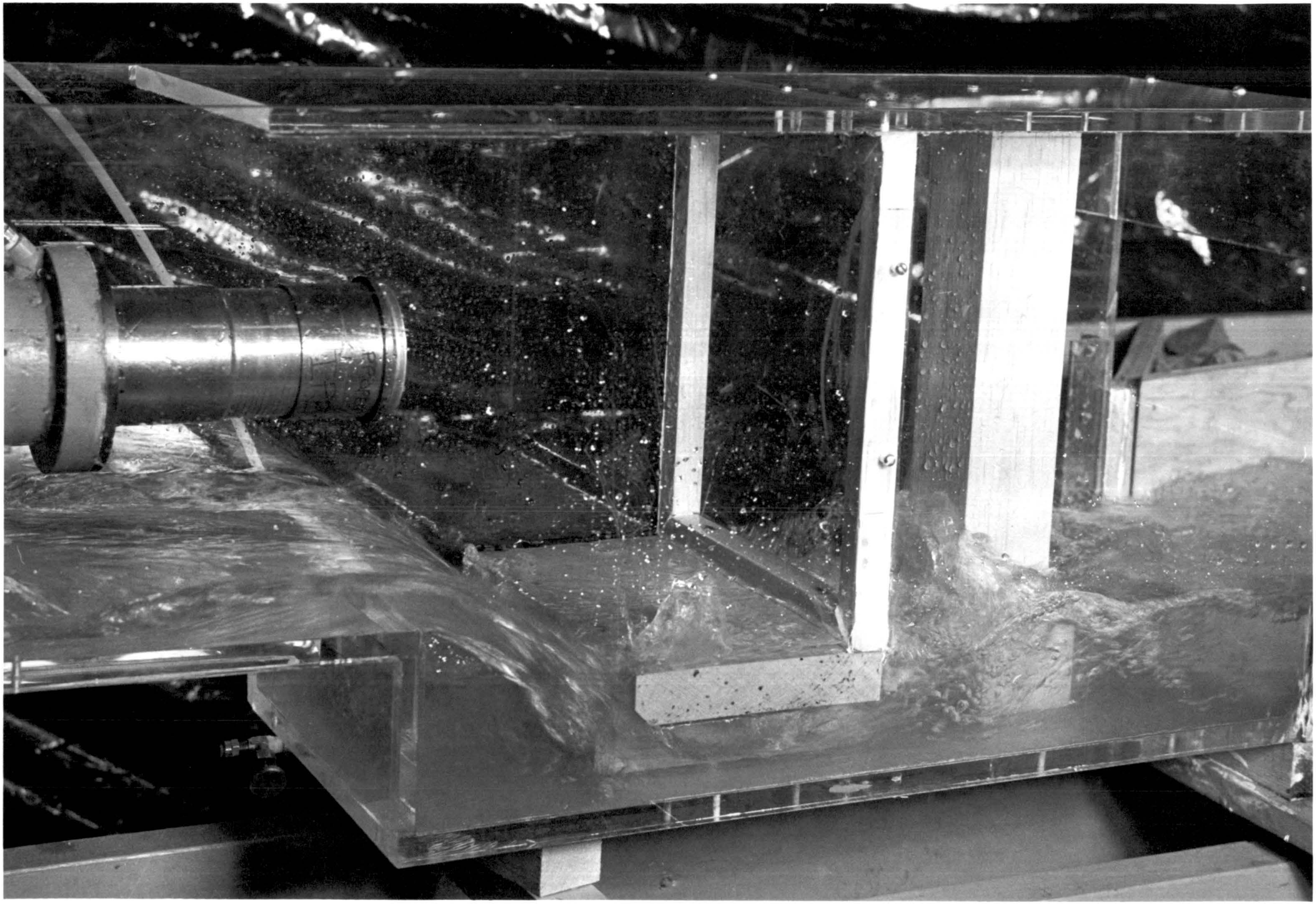

Photo 11 (Serial No. 1425-4-9)

Final Design Tested with 400 cfs from the Valve and 170 cfs from the Bypass

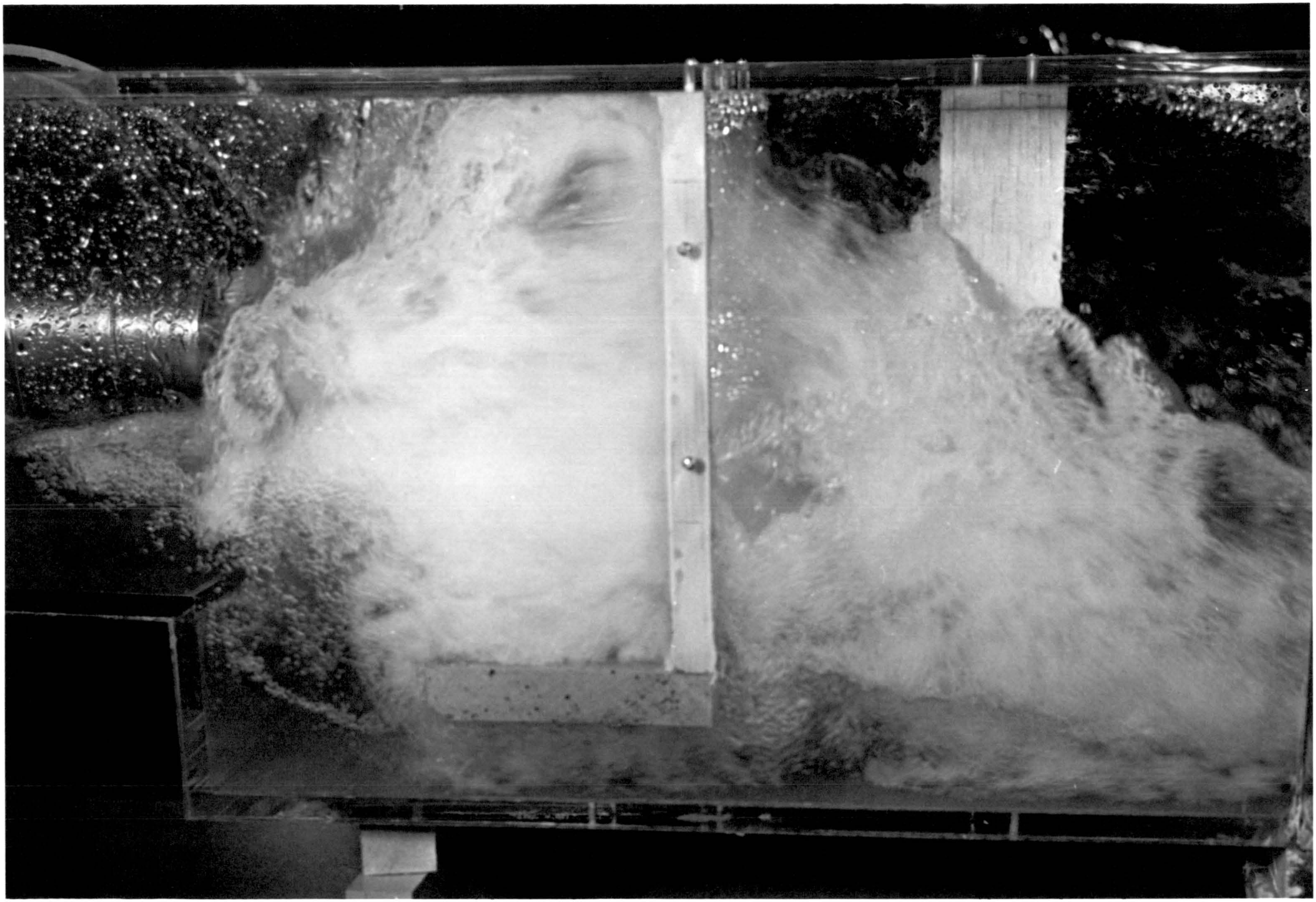

Photo 12 (Serial No. 1425-4-12)

Final Design Tested with 400 cfs from the Valve and 170 cfs from the Bypass