

UNITED STATES GOVERNMENT

Memorandum

TO : Memorandum
Chief, Hydraulics Branch

Denver, Colorado
DATE: September 12, 1967

FROM : Wen Hsiung Huang

SUBJECT: Forces required to operate a gate valve.

PURPOSE

Tests were conducted to measure the forces required to open and close a conventional 4-inch gate valve. The effect of small holes drilled in the bottom of the leaf was also studied.

INTRODUCTION

The operation of gate valves at high upstream heads sometimes creates very low pressures at the downstream side when the valves are nearly closed. Cavitation at the downstream side of the disc may occur under such conditions and cause the disc or the valve itself to vibrate. Mr. Raoul M. Thibault (Civil Engineer, Canal Branch, Design Division) suggested that vibrations during gate valve operation result from cavitation, and he proposed that holes drilled in the downstream side of the disc bottom will reduce cavitation as well as the force (or torque) required to operate the valve.

This report presents the experimental results of studies on a 4-inch gate valve. The experiments determined the forces required to open and close the valve for a range of operating times. Tests were conducted without holes in the disc and with five 1/4-inch holes in the disc.

MODEL AND EQUIPMENT

A 4-inch wedge disc gate valve was used for the study (Figure 1a). The valve was hydraulically operated using an 8-inch cylinder equipped with a four-way valve. Initially two 100 psi pressure cells were used to simultaneously measure the pressure on either side of the piston in the cylinder and the results were recorded on a six-channel recorder. Later, a 25-psi differential cell replaced these two 100 psi pressure cells so that the pressure difference in the cylinder was read directly.

Pressures in the pipe system were measured with pressure cells located 1- and 20-pipe diameters upstream and 1- and 7-pipe diameters downstream from the valve. These pressures also were recorded on a six-channel recorder.

Figure 1 shows the overall model installation and a general view of the differential pressure cell installation. Figure 2 sketches the general arrangement of the model.



THE INVESTIGATION

Differential pressures in the cylinder and piezometric heads in the pipe system were recorded for the following test arrangements:

1. Conventional gate valve without holes drilled in the valve disc for operating time intervals of approximately 40, 60, 80, 140, and 350 seconds from valve closed to 100 percent open
2. Same as Item 1, except five 1/4-inch holes on 1/2-inch centers were drilled through the downstream corner of the valve disc bottom, Figures 3b and 4
3. Same as Item 2, except the valve disc was turned 180° so that the drilled holes were facing upstream

A 12-inch pump and an 8-inch pump at the south end of the hydraulic laboratory were used for the test. The 8-inch pump provided a shutoff head of 34.15 psi (approximately 79 feet of water) and the 12-inch pump supplied shutoff heads of 41.38 psi, 22.53 psi, and 9.11 psi. The 8-inch Venturi meter located at the southeast corner of the laboratory was used to measure the discharge in the model.

The test started with the 12-inch pump and a shutoff head of 9.11 psi. Since the valves between the pump and the test site were fully opened, the flow in the system at this particular shutoff head was at full capacity. The valve, which connected between city supply line and the four-way valve which controls the hydraulic cylinder, was adjusted so that the disc of the gate valve completely closed in 40 seconds. Then, the four-way valve was operated to close the gate valve. The variations in pressure at the piezometric locations as well as at the cylinder were recorded on the six-channel recorder. After the closing operation was completed, the opening operation was carried out and the necessary data as mentioned above were again recorded on the recorder.

The time of closing and/or opening was then adjusted to approximately 60, 80, 140, and 350 seconds, and the test procedure was repeated as described above.

After a complete set of data was collected at a given shutoff head, other shutoff heads were used and new sets of data were collected. The test procedure followed the same steps as mentioned above. The shutoff heads used in the test were 9.11 psi, 22.53 psi, 34.15 psi, and 41.38 psi.

The typical data output from the six-channel recorder is shown in Figure 5. It should be noted that the curves in Figure 5 do not include the record of the forces to unseat the disc from the gate valve. The force required to unseat the disc is several times

larger than the maximum forces as indicated in Figure 5, which shows the required operating force from the moment immediately after the disc is unseated until the valve is fully open.

The curves in Figure 5 show the differential pressure variation between each side of the piston for the opening cycle. Typical curves for the disc without holes are at the left, while the center curves indicate the force for the disc with five 1/4-inch holes facing downstream. The right curves are for the flow with the five 1/4-inch holes in the disc facing upstream.

The maximum force to overcome the hydraulic effect (and not the force required to unseat the disc) during the process of opening occurred between about 25 to 35 percent valve opening, depending on the shutoff head. When the disc has the holes in it, the forces required at the initial stage (1 to 25 percent) of opening are small in comparison with the case of no holes. When the holes face upstream (or high pressure side) the reduction in maximum force is significant (see Figures 5 and 6).

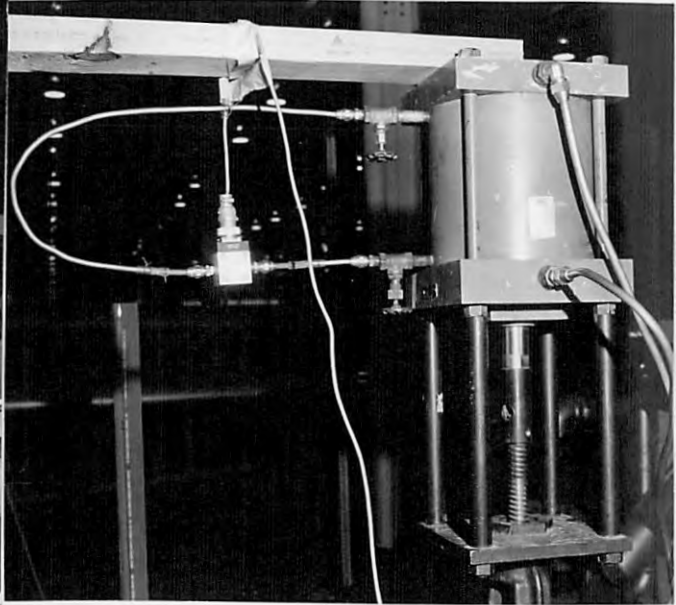
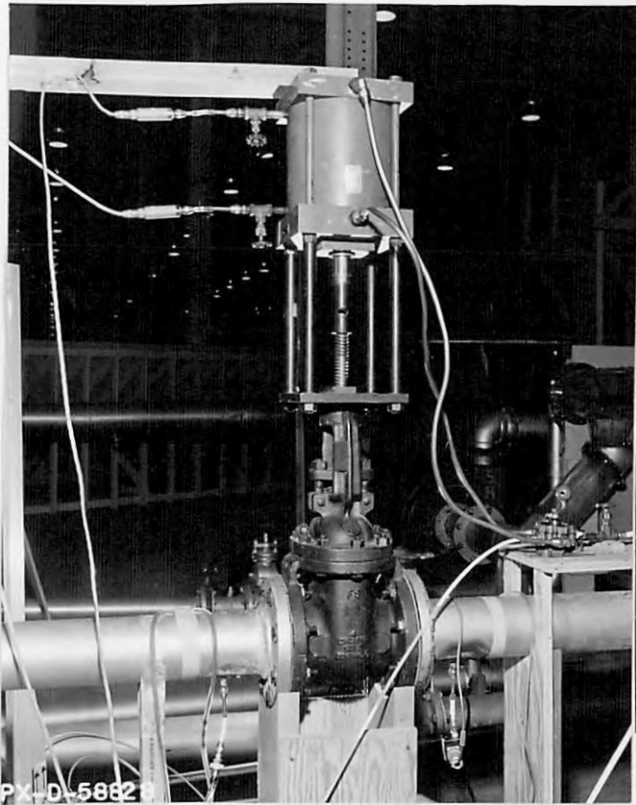
The maximum total force (i.e. maximum pressure typically shown in Figure 5 multiplied by the average area of the piston, 48.881 square inches) versus time of operation is plotted in Figure 6. This figure presents the curves for the maximum and minimum shutoff heads of 41.38 psi and 9.11 psi, respectively. When the operation time is short, the required force is large.

CONCLUSIONS

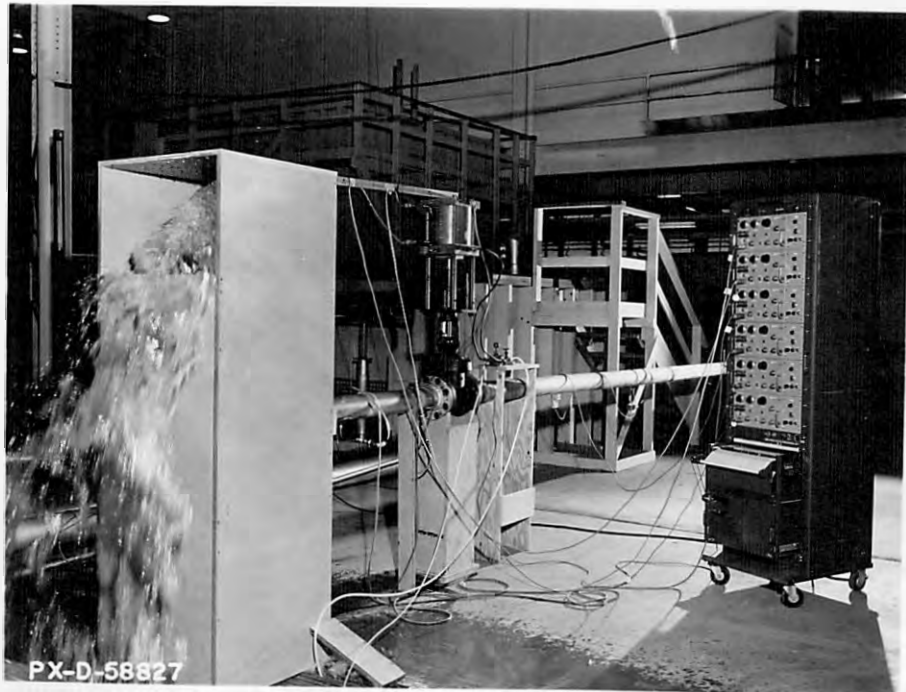
1. A relatively large force is required to seat or unseat the disc; this force reduces and then increases to a second peak at 25 to 35 percent gate opening. As the valve continues to open, the operating force decreases. The force-versus-time curve for closing the valve is identical to its opening curve except in the reverse order.
2. Holes drilled in the downstream corner of the disc bottom do not reduce significantly the force required to move the disc. Holes drilled in the upstream corner of the disc corner reduce the peak operating force at 25 to 35 percent gate opening an average of about 12 percent.
3. The force required to open or close the gate valve is directly proportional to the upstream head. The required force decreases as the operating time increases.

New Orleans, La.

FIGURE 1

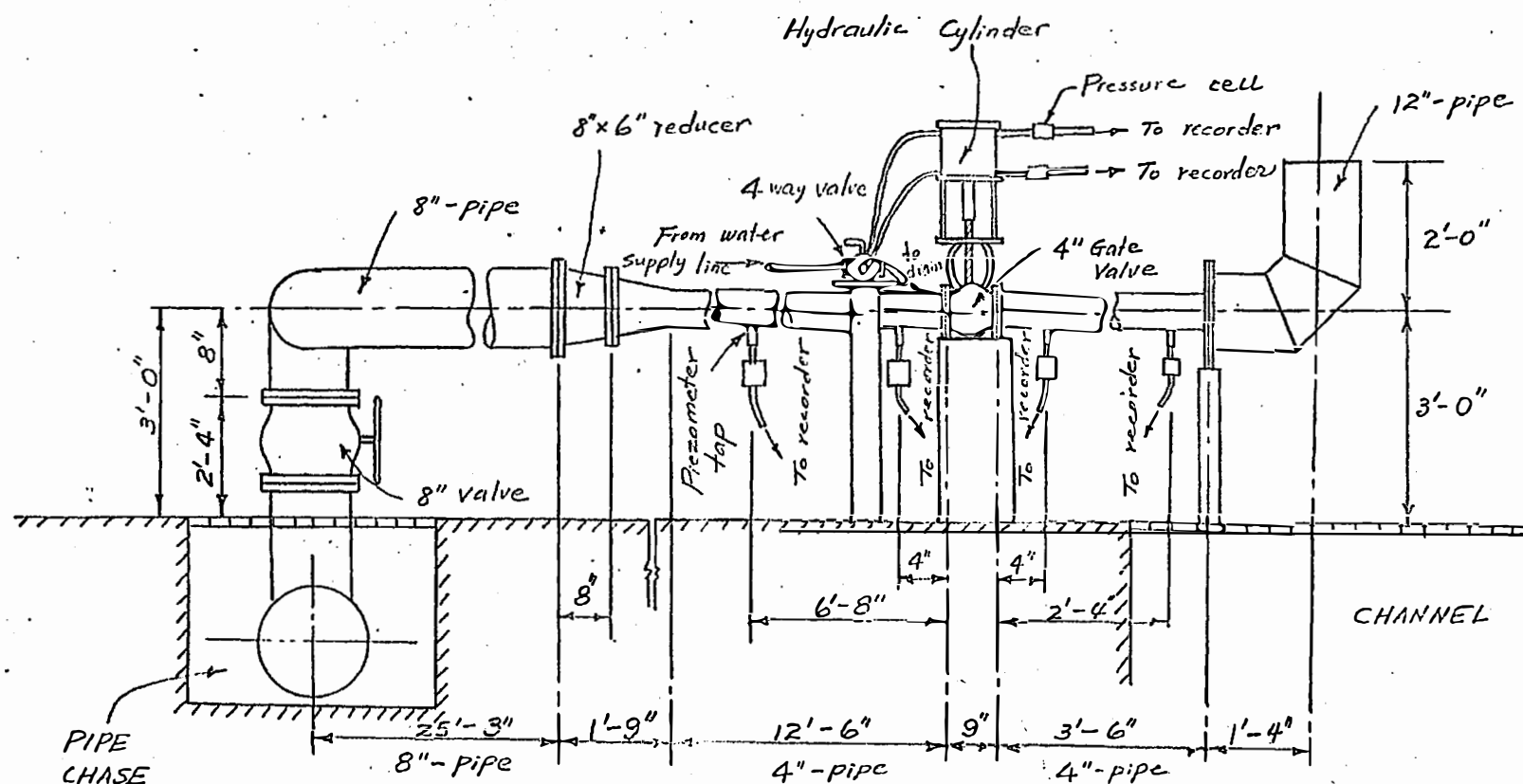


a. General View of Valve Installation and Differential Pressure Cell



b. General View of Model

FIGURE 2 MODEL FOR GATE VALVE STUDY



Not Drawn to Scale

W.H.H.

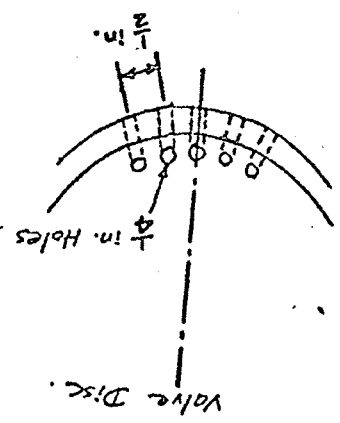
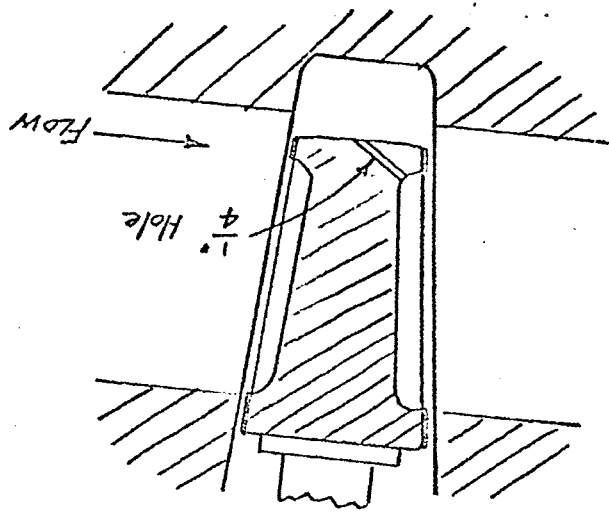


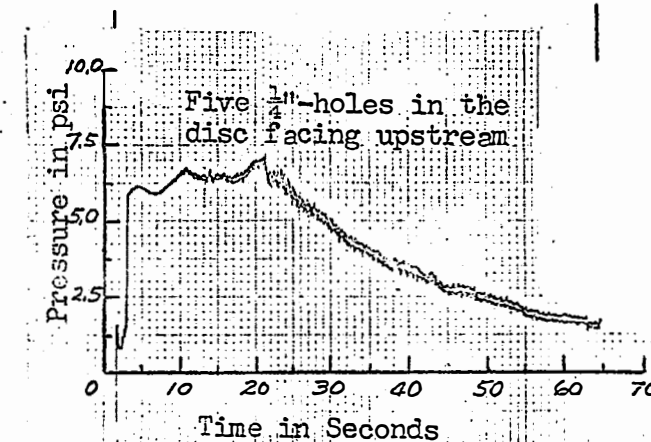
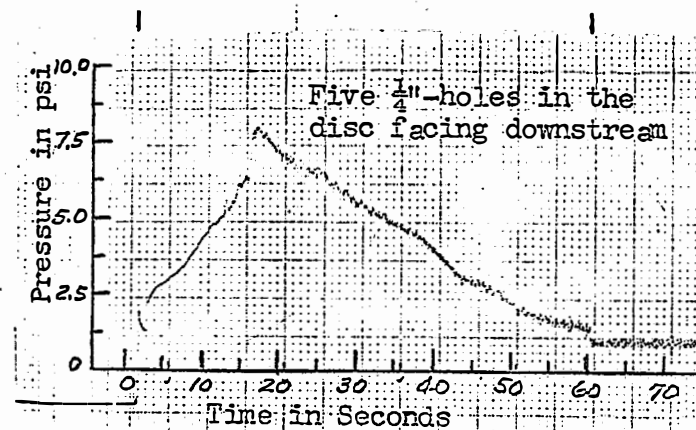
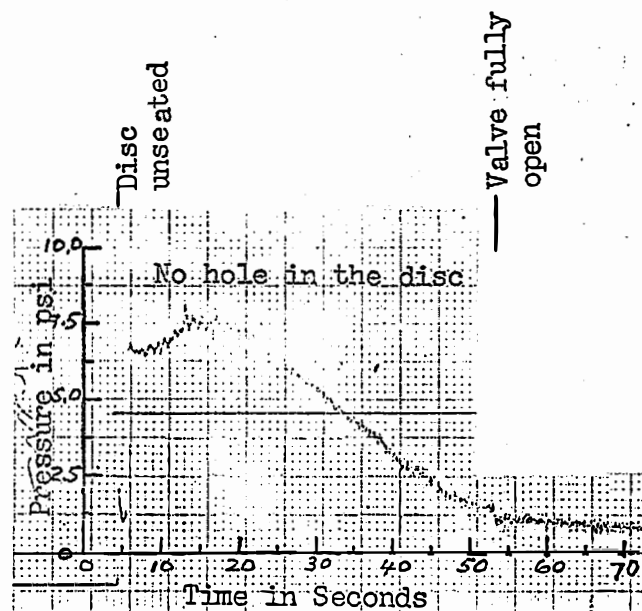
a. General View of The Parts of Hydraulic Cylinder



b. View of The Drilled Valve Disc

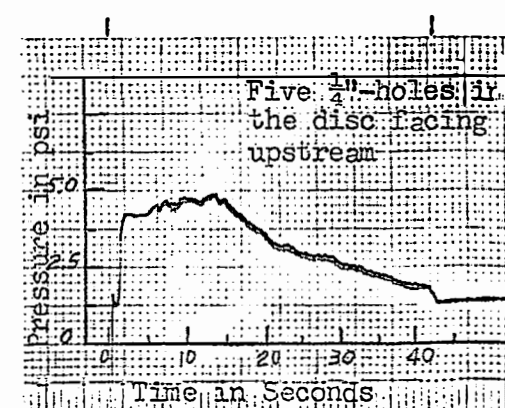
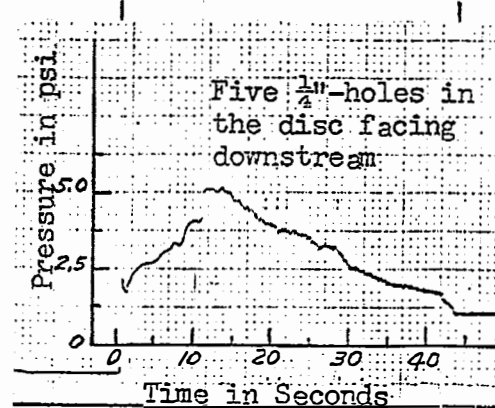
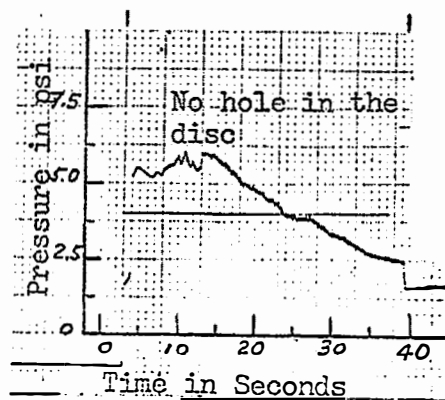
FIGURE 1. DETAILS OF HOLE DRILLING





Note: The average piston area is 48.881 in²

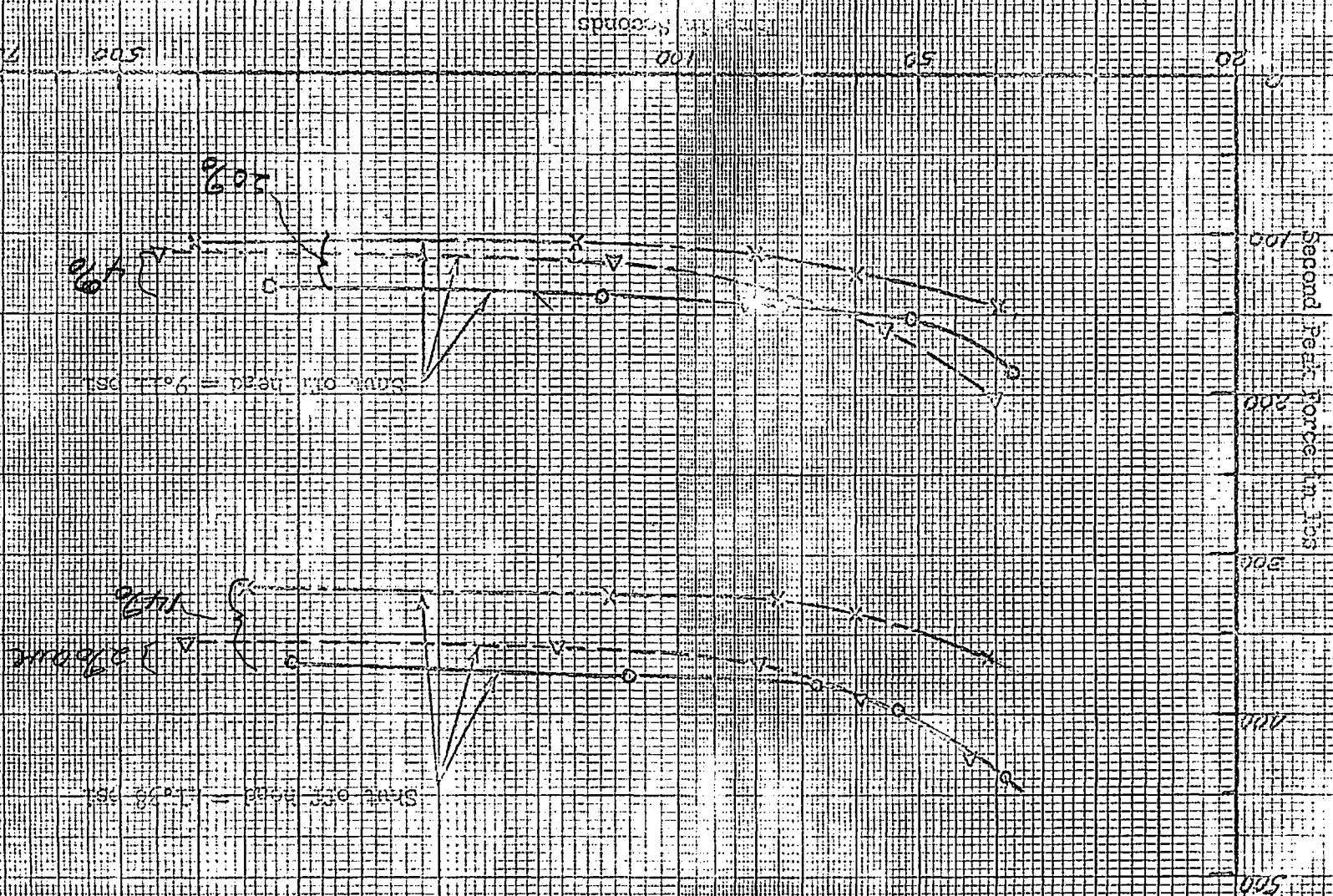
a. Shut of head of 41.38 psi Opening time = 60 ÷ seconds



b. Shut off head of 22.53 psi Opening time = 40 ÷ seconds

FIGURE 5 COMPARISON OF FORCE VARIATIONS BETWEEN WITH AND WITHOUT HOLES IN THE VALVE DISC

FIGURE 6 - THE RELATION BETWEEN SECOND PEAK FORCE AND TIME OF OPENING



Time of opening in seconds
Second peak force in lbs

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The maximum force to overcome the hydraulic effect (and not the force required to unseat the disc) during the process of opening occurred between about 25 to 35 percent valve opening, depending on the shutoff head. When the disc has the holes in it, the forces required at the initial stage (1 to 25 percent) of opening are small in comparison with the case of no holes. When the holes face upstream (or high pressure side) the reduction in maximum force is significant (see Figures 5 and 6).

The maximum total force (i.e. maximum pressure typically shown in Figure 5 multiplied by the average area of the piston, 48.851 square inches) versus time of operation is plotted in Figure 6. This figure presents the curves for the maximum and minimum shutoff heads of 41.38 psi and 9.11 psi, respectively. When the operation time is short, the required force is large.

CONCLUSIONS

1. A relatively large force is required to seat or unseat the disc; this force reduces and then increases to a second peak at 25 to 35 percent gate opening. As the valve continues to open, the operating force decreases. The force-versus-time curve for closing the valve is identical to its opening curve except in the reverse order.
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Ken Henry Huang

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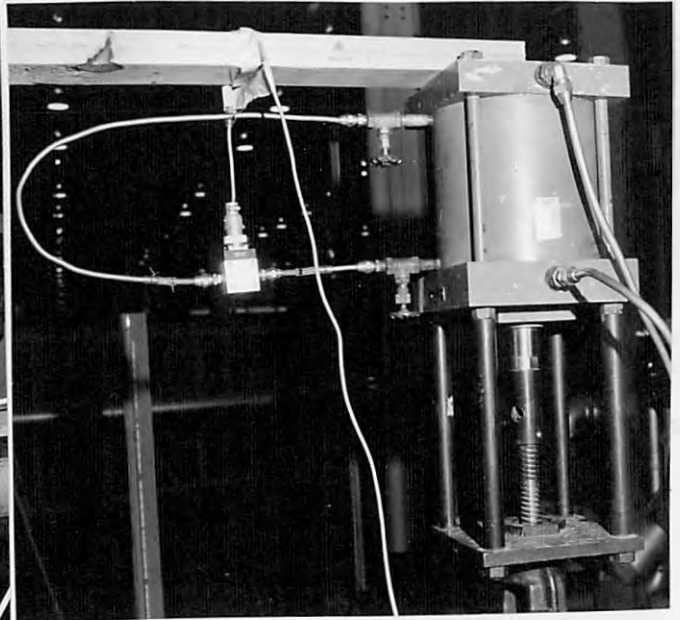
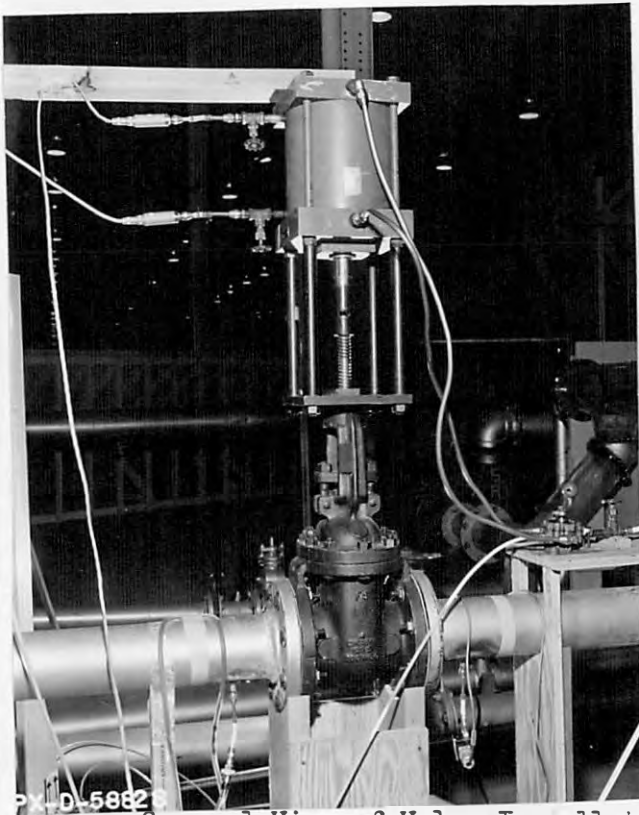
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Ken Hwang Huang

FIGURE 1



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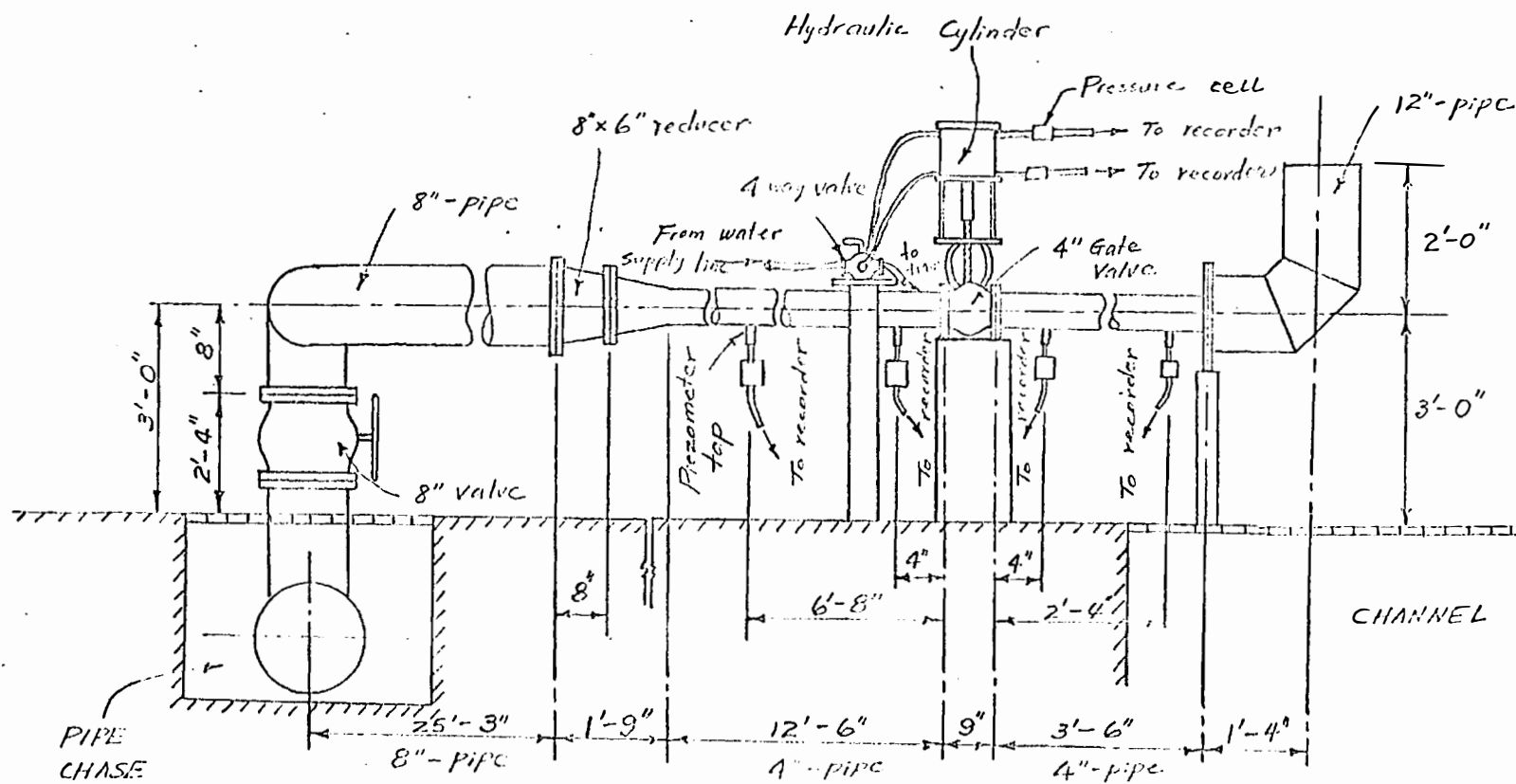
a. General View of Valve Installation and Differential Pressure Cell



PX-D-58827

b. General View of Model

FIGURE 2 MODEL FOR GATE VALVE STUDY

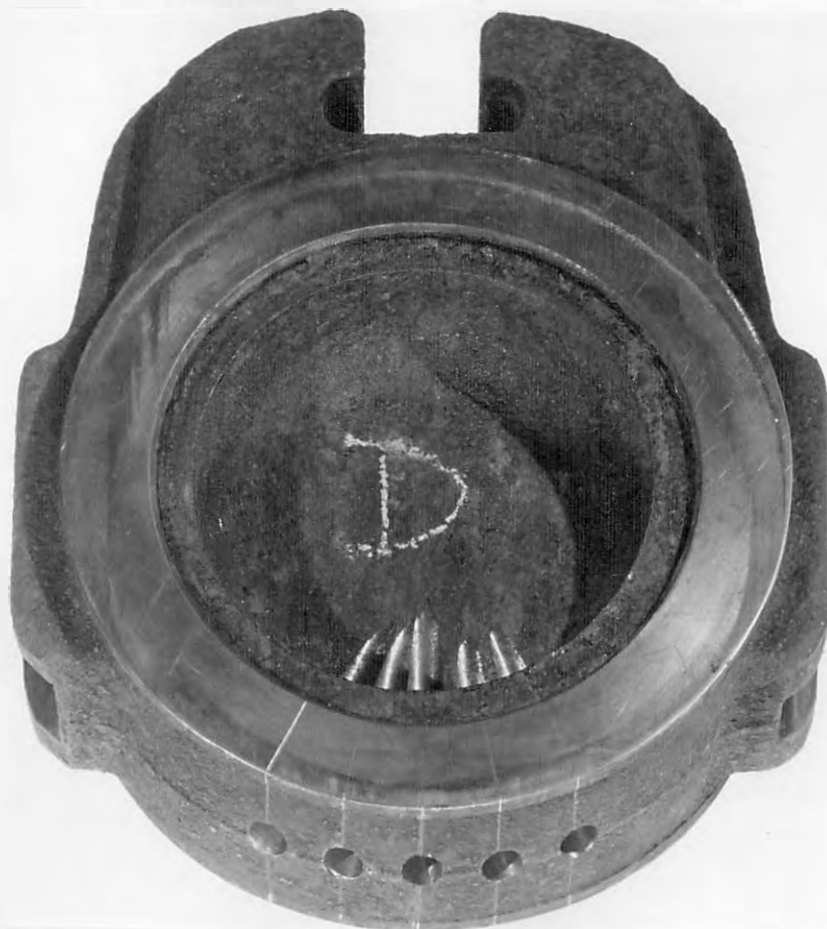


Not drawn to scale

WTH



a. General View of The Parts of Hydraulic Cylinder



b. View of The Drilled Valve Disc

FIGURE 4 DETAILS OF HOLE DRILLING

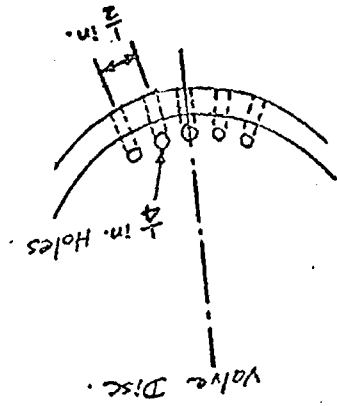
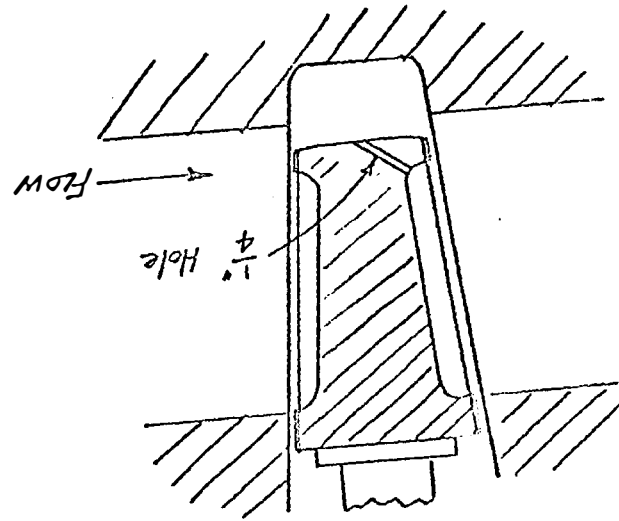
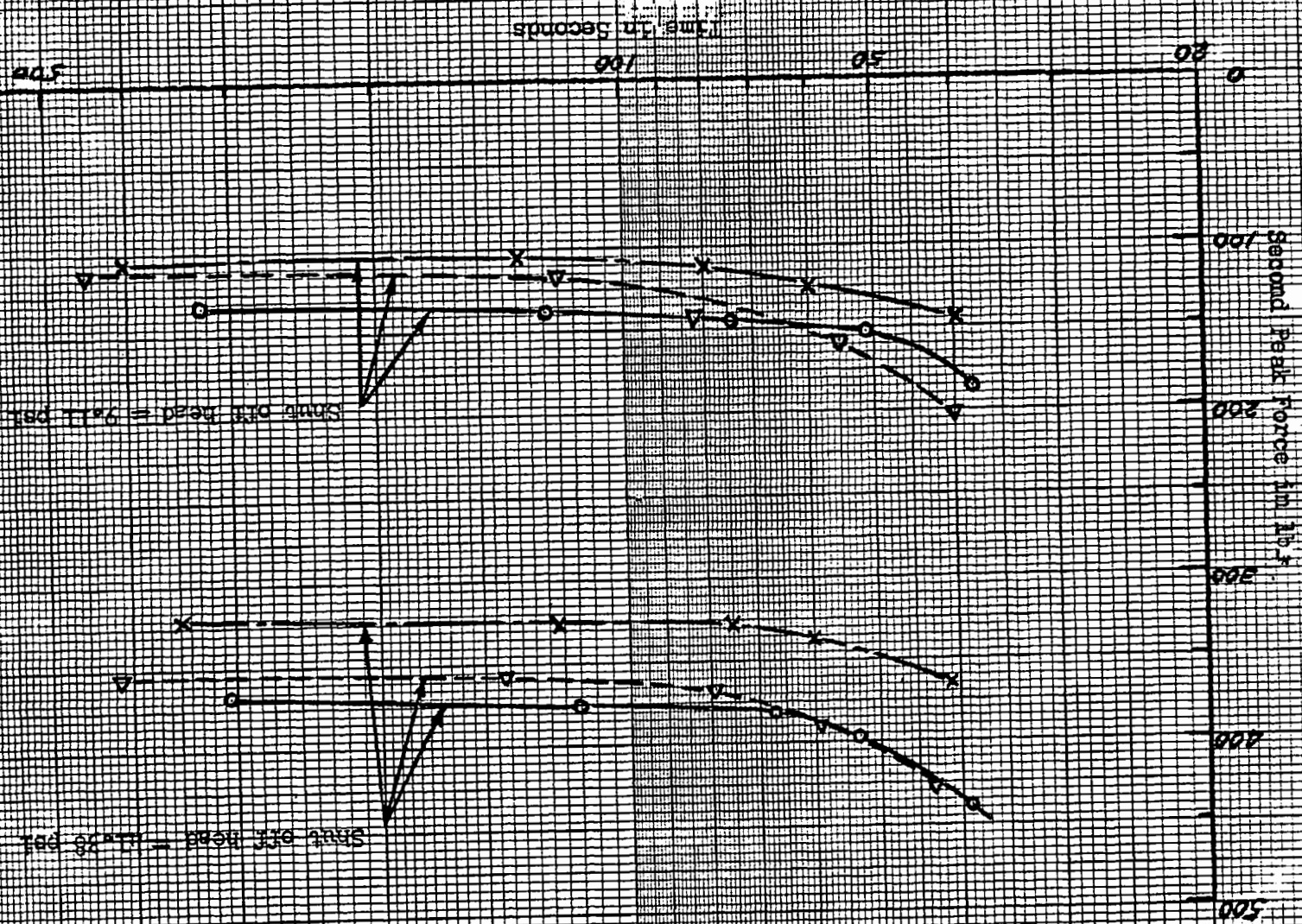
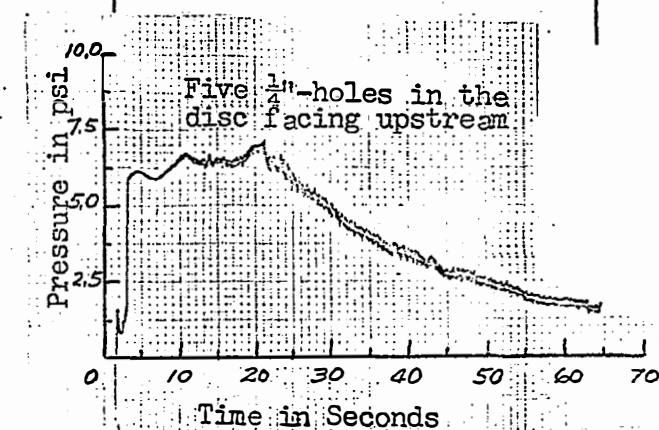
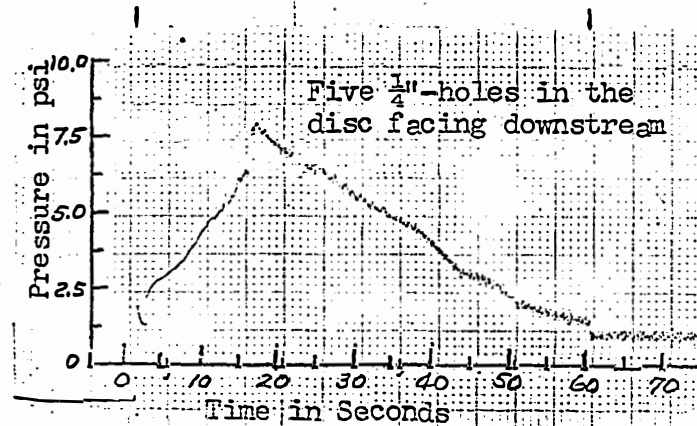
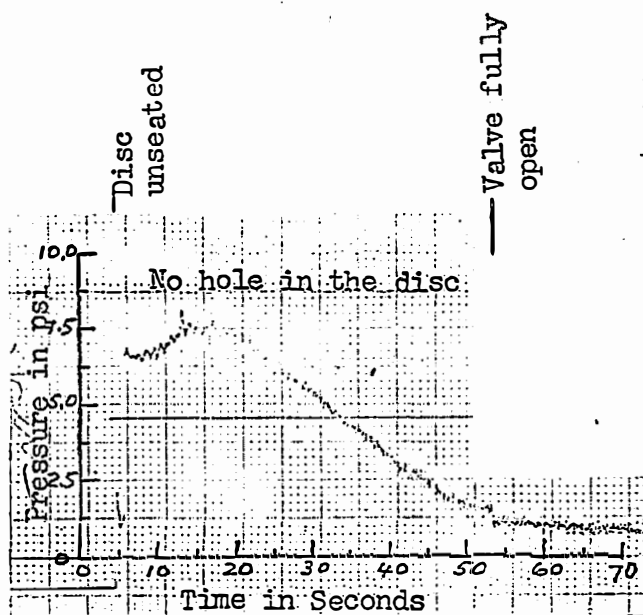


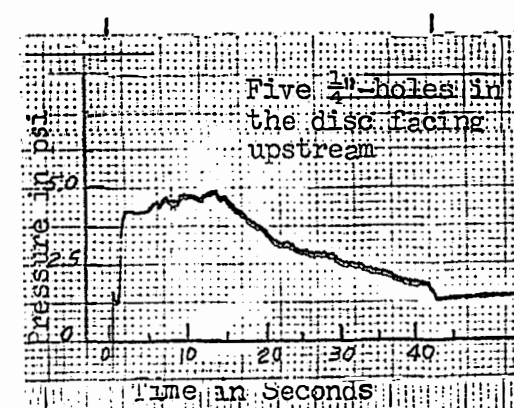
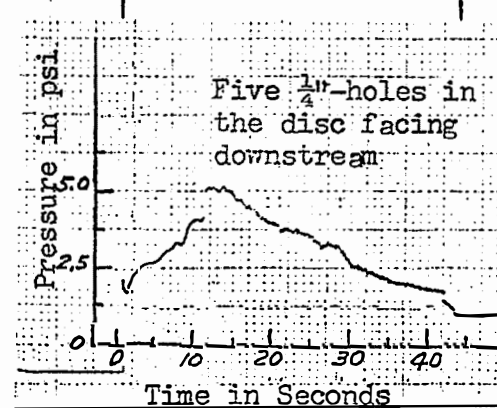
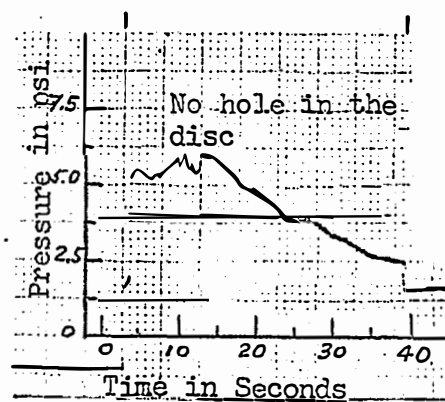
FIGURE 6 THE RELATION BETWEEN PEAK FORCE AND TIME OF OPENING



O — No holes in the disc
 A — Five 1/4" holes facing downstream
 X — Five 1/4" holes in the disc facing upstream



Note: The average piston area is 48.881 in²
 a. Shut of head of 41.38 psi Opening time = 60 \pm seconds



b. Shut off head of 22.53 psi Opening time = 40 \pm seconds

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