UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

FLOW CHARACTERISTICS OF A CHALLENGER 4-INCH FLUID METER

Hydraulic Laboratory Report No. Hyd. 259

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

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Laboratory Report No. 259
Hydraulic Laboratory
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C. W. Thomas

Subject: Flow characteristics of a Challenger 4-inch fluid meter.

PURPOSE

1. To determine the flow characteristics of a 4-inch Challenger fluid meter.

2. To appraise the mechanical construction of this meter.

CONCLUSIONS

1. The Challenger meter can be adjusted to 100 ± 1 percent accuracy for flows of from 5 to 1,300 gallons per minute, except in the 150- to 400-gallon-per-minute range where a dip occurs in the registration accuracy curve. The minimum accuracy in this dip section of the curve is 96.3 percent at 265 gallons per minute (Figure 12). Additional development work will be required to remove the dip from the registration accuracy curve.

2. The meter-pressure drop was approximately twice that given by the manufacturer's curve (Figures 12 and 17). The meter-pressure drop can be reduced by streamlining the flow path (Figure 18).

3. The meter registration accuracy is independent of meter inlet pressure at constant flow (Figures 14, 15, and 16).

4. The Welsh-type plug of the control valve center passage is insecurely installed.

5. The clearance between the tally meter velocity adjustment No. 3 ramp and the roller attaching screwhead corners is too small (Figure 8b).

6. The capscrew for attaching the adjustment No. 2 linkage to the ratio adjustment sleeve (Figure 3) is too long and contacts the meter casting that forms the tally meter discharge passage (Figure 2). This interference prevents proper adjustment of the meter.

THE INVESTIGATION

Description of the Challenger Fluid Meter

The Challenger fluid meter is made by the Challenger Manufacturing Company, 41 Wilson Avenue, San Jose, California. This meter will also be made by the Hersey Meter Company, Boston, Massachusetts, sometime after December 1948. Copies of the manufacturer's drawings showing a general view and sectional view of the Challenger 4-inch fluid meter are shown in Figures 1 and 2, respectively. An exploded view of the meter tested is shown on Figure 3. This meter operates on the principle of a sliding metering valve, actuated by a common volume control valve. As the volume control valve is forced open, due to the pressure and momentum forces of the fluid, it simultaneously opens the metering port proportionally. As these valves are integral parts, they must open and close together. The control valve starts to slide open when the forces created by the fluid balance the force created by the return spring and friction. This occurs at approximately 1 to 1-1/2 pounds per square inch, which is high enough to assure starting and positive operation of the tally meter.

The amount of fluid that is actually measured by the tally meter may be varied, according to the accuracy desired, by means of three meter adjustments (Figure 3). The standard 4-inch meter records through a 1-1/4-inch tally meter unit, using 1/20 or 5 percent of the total flow. Total registration is recorded in gallons. The greatest percentage of the fluid passes through the main meter without a screen obstruction. All the fluid that passes into the positive displacement-type tally meter goes through an inlet screen. A view looking from above the tally meter mounting pad shows the inlet passage to the tally meter (Figure 4). The tally meter is manufactured by the Hersey Meter Company, Boston, Massachusetts.

Back registration is prevented through the sliding action of the control valve which closes when the fluid pressure is reduced below the 1-1/2 pounds per square inch mentioned above. Because it is impossible to have reverse flow, the meter also serves as a check valve. The control valve is the only moving part in the main meter, and moves only during a change of flow.

The manufacturer states that the 4-inch meter is designed for 150 pounds per square inch maximum working pressure. A modified venturi section is incorporated into the downstream side of the meter to improve velocity distribution.

The Challenger meter is an outgrowth of a hydraulic device developed for the United States Navy during World War II, and has been in use for over 3 years. The basic design shown is used throughout the complete line of meters from 3 inches through 12 inches. Larger sizes are available on special order.

Adjustment of the Challenger Fluid Meter

The meter contains three accuracy adjustments which are made in the following sequence and manner:

Adjustment No. 1 is to time the opening of the control valve ports to coincide with the opening of the metering port (Figure 5). This adjustment is made by means of an oval wedge-shaped ring which can be made to slide crosswise to the meter's longitudinal axis, as shown in Figure 6. The thin side of the wedge is on the right-hand side. Crosswise movement of this wedged ring gives the correct axial adjustment of the ratio adjustment sleeve such that the start of the flow through the main meter is coincident with the start of flow through the tally meter. This wedge ring is labeled "low flow adjustment" in Figure 2. Turning the adjustment clockwise moves the ratio adjustment sleeve upstream (wedge ring to the right, Figure 6) to increase the flow through the tally meter. Turning the adjustment counterclockwise moves the ratio adjustment sleeve downstream (wedge ring to the left, Figure 6) to decrease the flow through the tally meter. One method of making this adjustment with the meter partially disassembled is as follows:

1. Remove the tally meter assembly.

2. Remove the inlet flanged adapter and tally meter screen.

3. Remove the plug in center circular passage of the control valve.

4. Attach a metal stirrup diametrically across the inlet flange to the flange studs, and by means of the stirrup adjusting screw, set the control valve so that the ports are just starting to open. The return spring will then hold the control valve in this position regardless of the wedge ring adjustment.

5. Insert a light down the tally meter flow discharge passage in the main meter body.

6. By watching down the center circular passage of the control valve (plug removed), adjust the wedge ring until light just appears to come through the metering port. At this point, the start of flow through the main meter will be coincident with the start of flow through the tally meter.

7. Lock the adjustment locknut and install the cover plug.

8. Reinstall the control valve plug and reassemble the meter.

Normally, Adjustment No. 1 is made by the manufacturer during final assembly and it is unlikely to change during use of the meter. This adjustment is to prevent the possibility of flow passing through the main meter with no flow going through the tally meter, or vice versa. Either situation would result in an erroneous registration. There was no reason indicated to alter this adjustment on the meter tested.

Adjustment No. 2 regulates the circumferential width of the tally meter metering port at very low flow control valve positions, such that the correct proportion of flow passes through the tally meter based on the gear ratio of the tally meter (Figure 7). The gear ratio of the tally meter in the test meter is 20:1, i.e., when the meter is adjusted correctly, one-twentieth of the total flow passes through the tally meter. This adjustment is made at flows between 50 and 100 gallons per minute due to the characteristics of the meter. The circumferential width of the tally meter metering port is varied by rotating the ratio adjustment sleeve by an attached arm as shown in Figure 3 and the top of Figure 6. The detail parts of the linkage arm are shown in the lower part of Figure 8a. These parts have been replaced on later model meters by a large adjusting nut, shown in the upper part of Figure 8a. The T-handled wrench shown in the figure loosens the locknut. Turning the Allen wrench, which passes through the center of the T-handled wrench, in a clockwise direction closes the circumferential width of the metering port and decreased the flow through the tally meter. Conversely, turning the Allen wrench in a counterclockwise direction increases the circumferential width of the metering port and increases the flow through the tally meter. On the later meters with the large adjusting nut, a clockwise rotation of the nut increases the tally meter flow, while a counterclockwise rotation decreases it.

Adjustment No. 3 is a second adjustment to the circumferential width of the tally meter metering port at higher flow control valve positions so that the correct proportion of flow passes through the tally meter based on the gear ratio of the tally meter (Figure 9). This adjustment is made at flows of 500 gallons per minute or greater. As the flow increases, the velocity in the main meter increases, but the tally meter velocity does not increase proportionally to maintain the 1:20 ratio of flow of tally to main meter. Therefore, to compensate for the lower proportional tally flow velocity, the tally meter metering port area is increased to maintain the 1:20 flow ratio. This adjustment is incorporated into the meter by having the control valve rotate to increase the circumferential width of tally meter metering port as the control valve travels downstream with increasing meter flow. The mechanical means of providing this adjustment is shown in Figures 3, 6, and 8b. A ball-shaped wheel fixed to the control valve, Figure 3, rolls on an adjustable track or ramp (flat bar on left side of Figure 6) which is fixed to the inside of the meter body. The ramp, with rotary movement,

is adjusted to give the desired degree of control valve rotation (and correct tally meter metering port width). A closeup view of the ball-shaped wheel on the ramp at low flow position is shown on Figure 8b. Note the close clearance between the corners of the squarehead screw with the ramp shoulder. Possible interference existed at this location. The ramp shoulder was machined down before testing the meter to give clearance between the corners of the squarehead bolt and the ramp shoulder (Figure 8b). While making Adjustment No. 3 at higher flows, the ramp angle was changed in increments to maintain firm contact between the ramp and the roller wheel on the control valve. If the ramp angle was decreased while making the adjustment, the water and frictional forces resisting the rotation of the control valve were equal to or greater than the spring torque which normally holds the roller wheel on the ramp. Consequently, to keep the roller wheel in contact with the ramp and, thus, realize the effects of the ramp adjustment, it was necessary to relieve these forces by stopping the flow. Adjustment No. 3 is turned clockwise to increase the tally meter port width which increases tally meter flow, and turned counterclockwise to decrease the tally meter port width which decreases the flow.

Test Procedure

A general view of the test installation showing the upstream and downstream control valves is shown in Figure 10. A mercury "U" tube was used to record pressure drop across the meter, and a mercury pot gage was used to record meter inlet pressure. The true flow was determined by use of volumetrically calibrated tanks. The starting and ending of the flow measurement times were coordinated between the operator at the volumetric tank and the man reading the meter by telephone. The following tests were made in the order given:

1. Registration accuracy curve, meter as received; first calibration, Figure 12.

2. Registration accuracy and pressure drop curves, meter adjusted and before No. 2 adjustment interference was discovered; second calibration, Figure 12.

3. Registration accuracy curves with variable meter inlet pressure versus constant flow at 187, 354, and 510 gallons per minute, Figures 14, 15, and 16.

4. Registration accuracy curve with no control valve spring installed; all three adjustments as in Test 2, Figure 13.

5. Registration accuracy curve, meter adjusted with No. 2 adjustment interference removed; third calibration, Figure 12.

For Test 4, the control valve was secured in the full open position in a manner such that the control valve roller wheel was in firm contact with the ramp of Adjustment No. 3.

Meter Accuracy

After the first and before the second calibration, while Mr. Charles Hirst, the Challenger representative was present, difficulties were encountered in making the adjustments of the meter. Disassembly of the meter showed that the Welsh-type automotive plug that plugs the control valve center passage was not in place. The plug in the meter was not the screw-type shown in Figure 2. Figure 11 shows the Welsh-type plug. Another flat plug was soldered in to expedite testing while the Challenger representative was present. After Test 3 (Test Procedure) a screw-type was installed similar to that shown in Figure 2. A secure plug installation is required since back-pressures, when the meter acts as a check valve, provide a considerable plug knockout force.

The results of Tests 1, 2, and 5 are plotted in Figure 12. A complete explanation for the dip in the meter accuracy curves at about 265 gallons per minute is not known. The manufacturer's tabulated accuracy data indicated no dip with 98.2 to 100.2 percent accuracy between flows of 7.48 to 748 gallons per minute. It may be that the ranges of Adjustments No. 2 and 3 do not overlap sufficiently to maintain 100-percent registration in this flow range. On the other hand, there may be sufficient overlapping of Adjustments No. 2 and 3, but at a different setting combination of Adjustments No. 2 and 3 to give better accuracy in this flow range. This is suggested from the meter registration where the first calibration curve crosses the 100-percent line. Consequently, this dip can probably be partially removed but likely at the sacrifice of accuracy at some other section of the curve. A 100-percent accuracy curve from 5 to 1,300 gallons per minute undoubtedly can be obtained after additional development work by the manufacturer. A diagramic plot of the effect of the various adjustments on the registration accuracy of the meter is shown in Figure 13. The fact that the meter appeared to operate with the control valve wide open (fixed porting) above 450 gallons per minute is substantiated by the fact that the ramp wear from the roller wheel is uniform for 3 inches, the travel of the control valve. If below 450 gallons per minute is in the variable porting range, then perhaps a crowned ramp profile would remove the dip in the meter accuracy curve. The trial and error procedure used in adjusting this meter was to work for 100-percent accuracy at 100 and 875 gallons per minute.

After the completion of the second calibration, the meter was disassembled to investigate the reason for the dip as well as the inability to raise the lower end of the curve to the 100-percent line with Adjustment No. 2. Inspection showed that the capscrew for attaching the Adjustment No. 2 linkage to the ratio adjustment sleeve (Figure 3) was too long on the thread end, and contacted the meter casting that forms the tally meter discharge passage (Figure 2). This interference prevented proper adjustment, as shown by the third calibration. This capscrew was shortened about 1/8 inch.

On the third calibration, the accuracy curve started to rise at about 1,300 gallons per minute. This suggests that the main meter offers enough restriction to appreciably increase the meter inlet pressure and the pressure drop across the tally meter. This condition puts the main meter and tally meter flows out of the 20:1 proportion. This fact was not conclusive since this flow was the maximum pumping capacity available in the laboratory. Disassembly of the meter after running these high flows showed all parts, including the tally meter gears, to be in good condition.

The meter inlet pressure required to pass 1,300 gallons per minute was about 55 pounds per square inch (Figure 12). However, the discharge pressure was approximately 30 feet of water to reach the elevated volumetric tanks. This inlet pressure was well below the manufacturer's maximum allowable of 150 pounds per square inch.

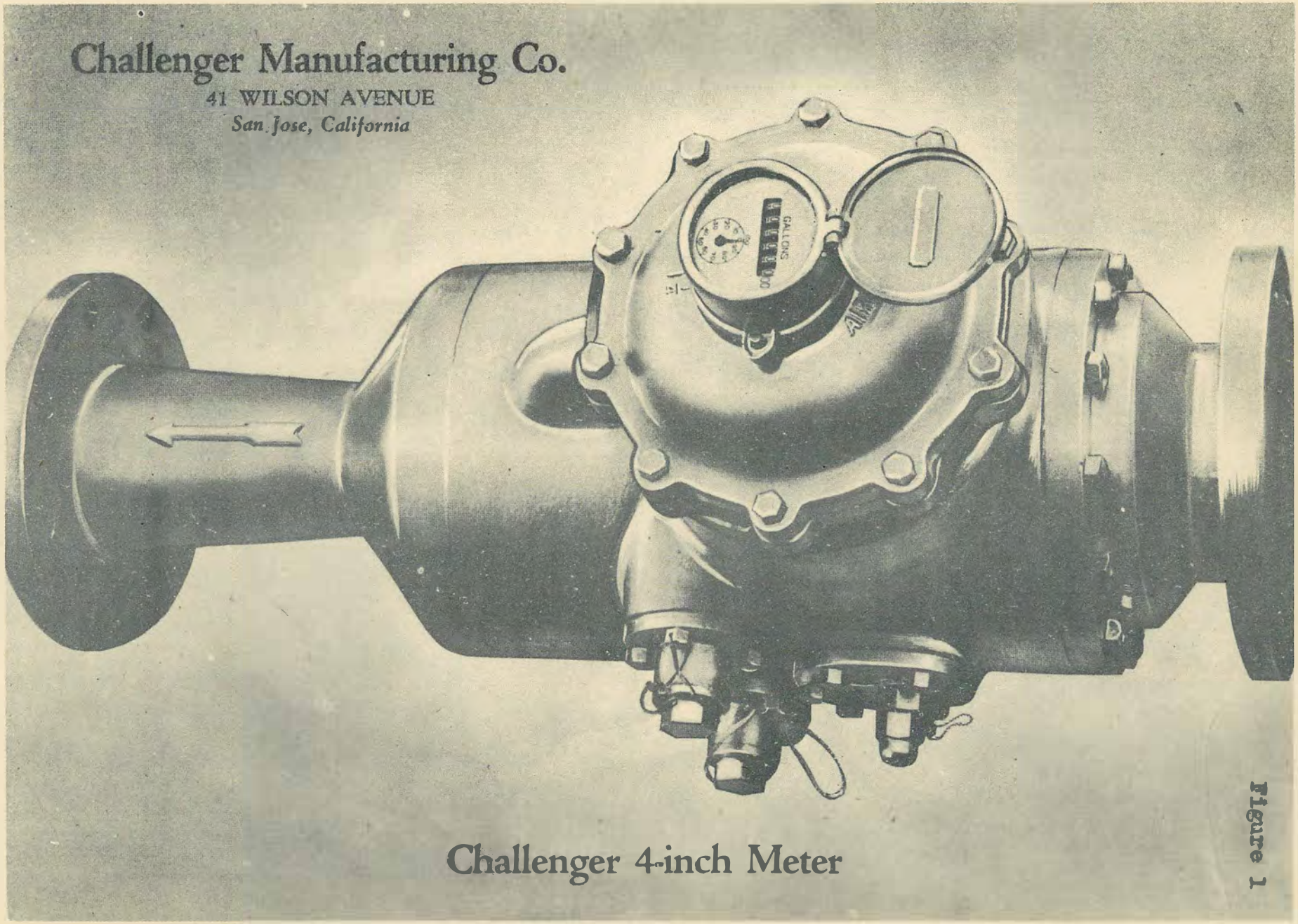
Tests run on a 6-inch Sparling meter, Hydraulic Laboratory Report No. Hyd-227, indicated that the accuracy of that meter varied with inlet pressure. This characteristic was checked on the Challenger 4-inch meter by obtaining variable meter inlet pressure versus constant flow curves at 187, 354, and 510 gallons per minute. The results showed no appreciable accuracy variation (Figures 14, 15, and 16). The curves on the upper half of the figures are plotted from the test data shown on the lower half of the figures. Since it was impractical to set constant discharge at various meter inlet pressures, the lower curves were obtained as follows: The flow in the range desired was set and the meter accuracy data recorded, using the volumetric tanks. This discharge was used for the constant flow datum. The control valve in the line downstream from the meter was then closed which increased the line pressure, but decreased the flow observed on a venturi meter gage. The control valve upstream from the meter was then opened until the flow observed on the venturi gage was slightly less than the datum constant flow. Meter accuracy was then recorded (lower point on short-dash lines) as well as true flow (lower point on long-dash lines). The meter upstream control valve was then opened more to increase the flow, observed on the venturi gage, to slightly greater than the datum constant flow. Meter accuracy was then recorded (upper point on the short-dash lines) as well as true flow (upper point on long-dash lines).

The meter reading at the datum constant flow was found by dividing the meter Q^2 versus p straight line (short dashes) (at constant discharge area, or opening) in the same proportion that the constant flow point divided the true flow (volumetric tank) Q^2 versus p straight line (long dashes). The fact that the meter accuracy does not vary appreciably on the short-dash lines plotted makes this method valid. The process was then repeated at higher line pressures.

Meter Pressure Drop

The pressure drop across the meter was measured by connecting a mercury U-tube between two 4-tap piezometer rings as shown in Figure 10. The measured pressure drop (Figure 12) is about twice that given by the manufacturer's pressure drop curve.(Figure 17). For instance, the measured pressure drop at 800 gallons per minute was 12.4 pounds per square inch, whereas the manufacturer's curve shows 5.8 pounds per square inch.

It is believed that the meter pressure drop can be reduced appreciably by revising the control valve design to a needle valve form shown schematically in Figure 18. Inspection indicates a close clearance and flow restriction between the control valve outside diameter and the casting (Figure 2). Also the flow must change direction 90° twice in flowing through the four radial ports. If a needle-shaped control valve is used, the flow path would be straightened and the flow would be continuous around its circumference allowing the use of a valve with a smaller outside diameter. The flow area at the above-mentioned restriction would be increased. The present control valve could be reworked to attach the cone section with capscrews. The present valve center plug would be eliminated. A spring with a smaller spring constant may be required.



Challenger 4-inch Meter

Figure 1

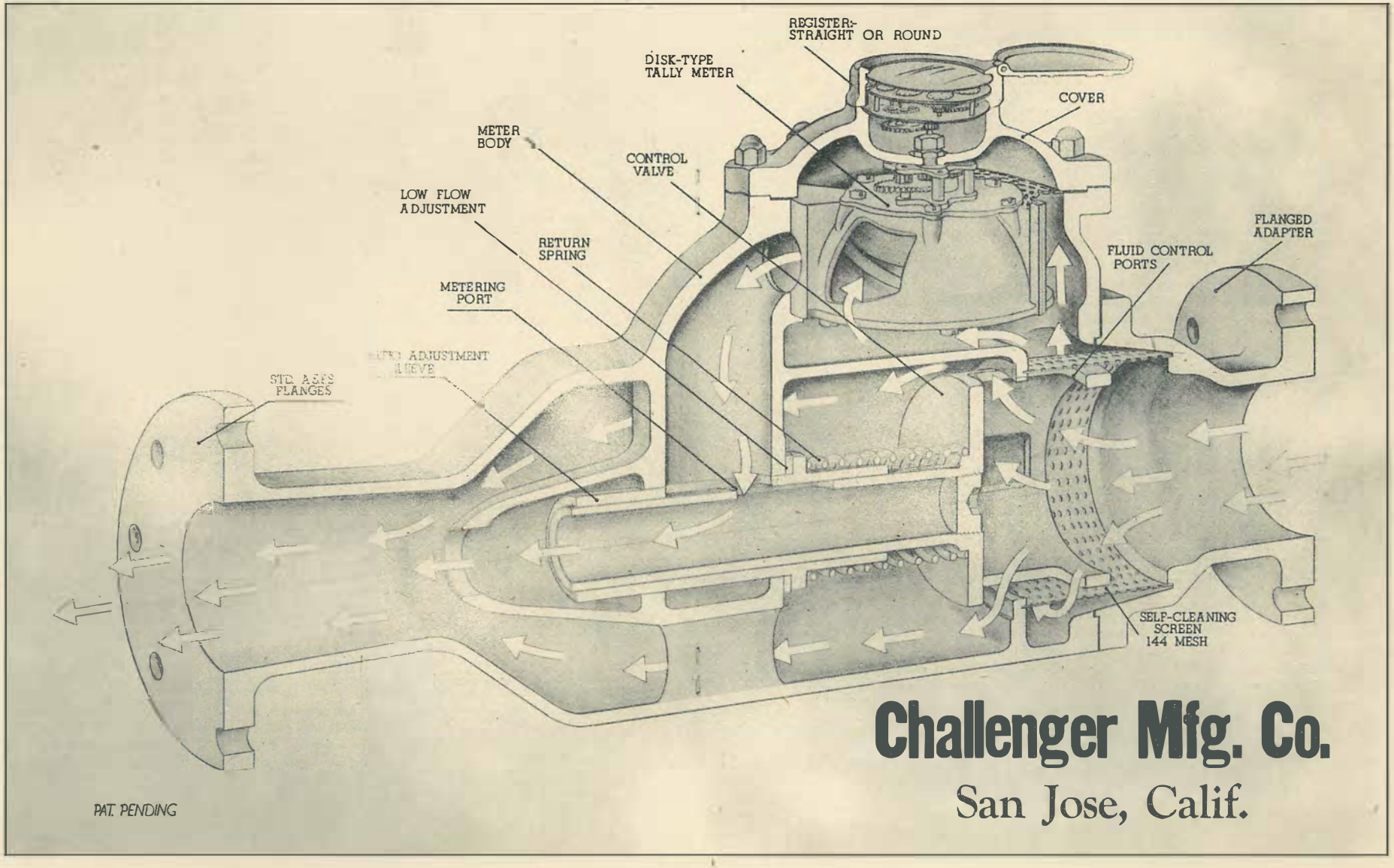
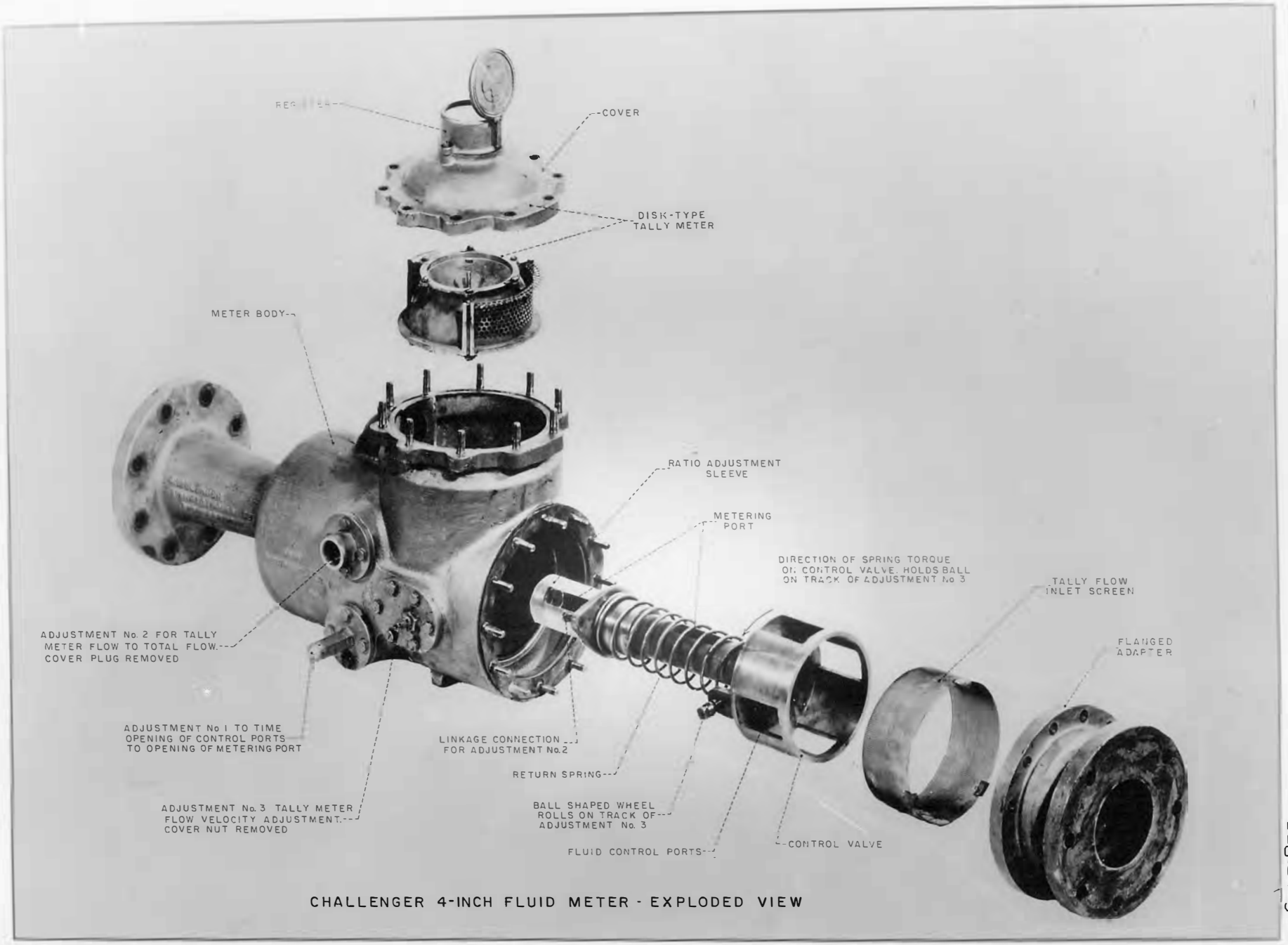

REGISTER:-
STRAIGHT OR ROUND
DISK-TYPE
TALLY METER
COVER
METER
BODY
CONTROL
VALVE
LOW FLOW
ADJUSTMENT
RETURN
SPRING
METERING
PORT
FLANGED
ADAPTER
FLUID CONTROL
PORTS
STD. ASPS
FLANGES
SELF-CLEANING
SCREEN
144 MESH
PAT. PENDING
Challenger Mfg. Co.
San Jose, Calif.

Figure 2



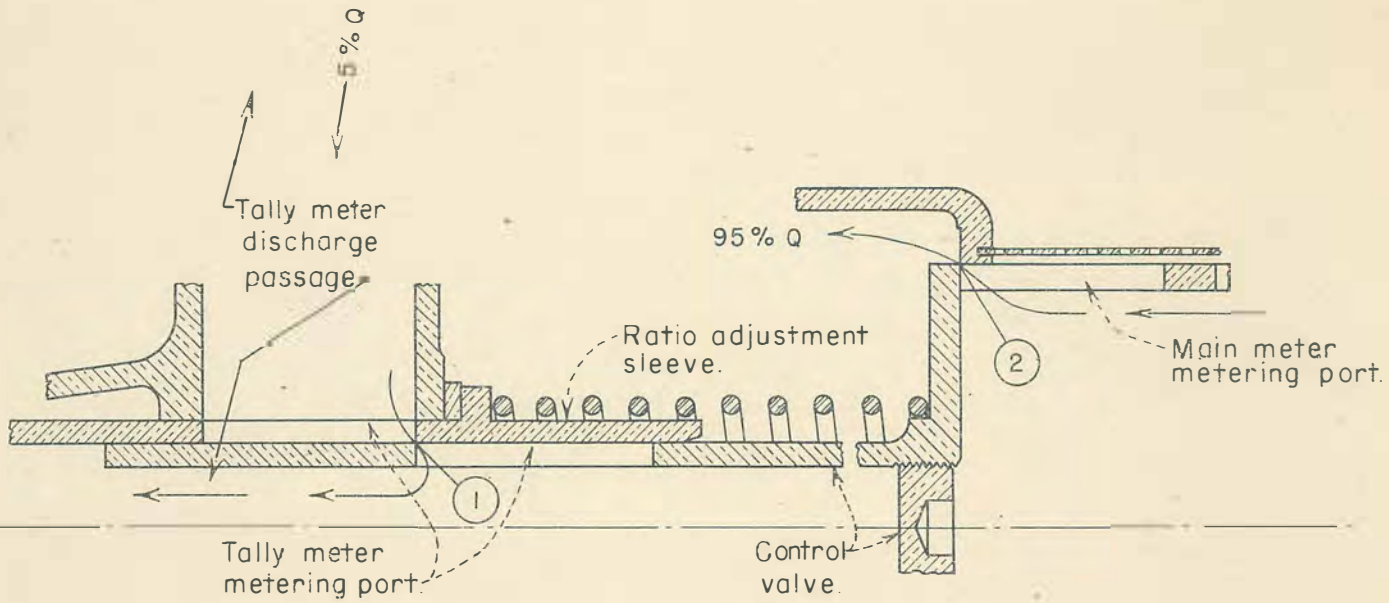
CHALLENGER 4-INCH FLUID METER - EXPLODED VIEW

Figure 3

Tally Meter Inlet Passage

Figure 4

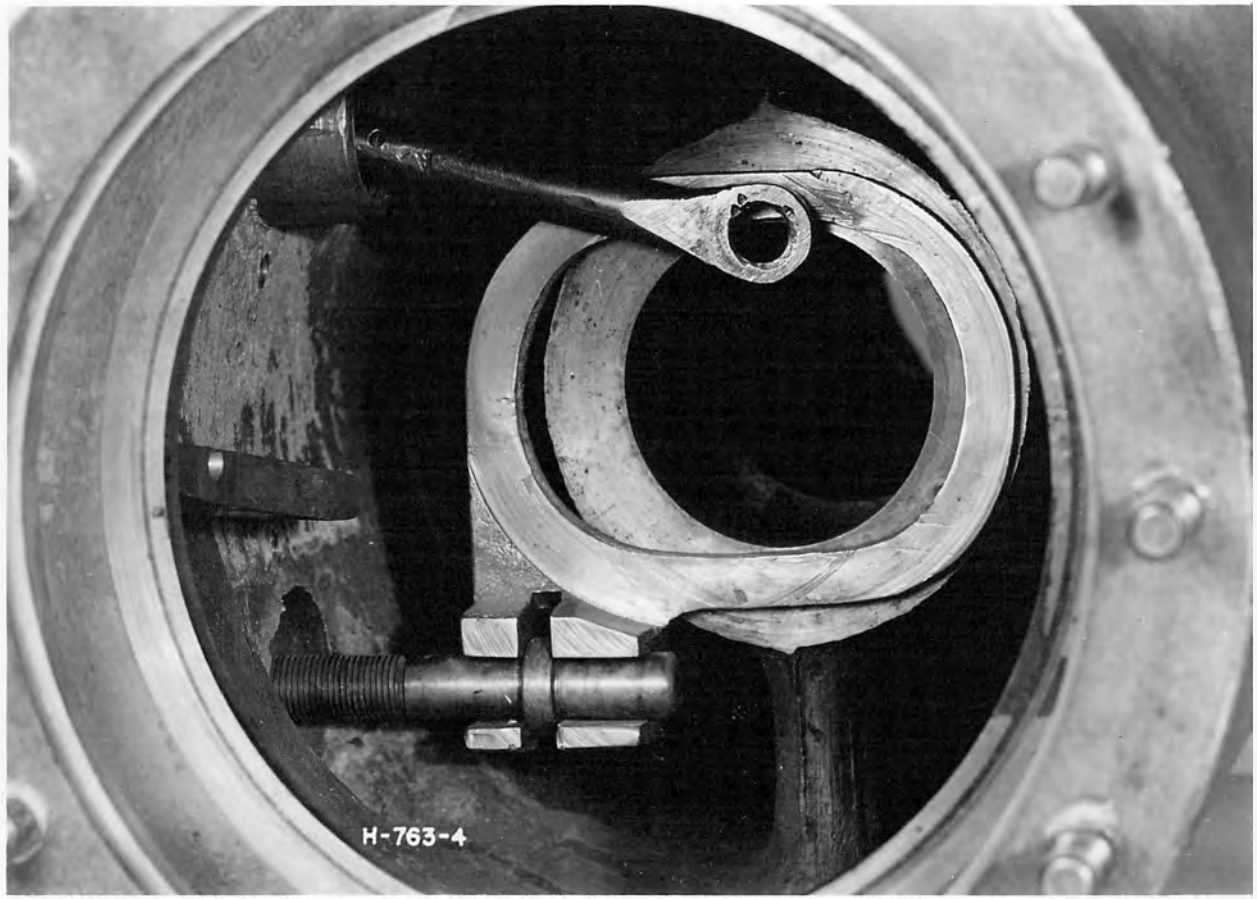
CHALLENGER FLUID METER



ADJUSTMENT No.1

Provides adjustment so that both ports open simultaneously at points ① and ②.

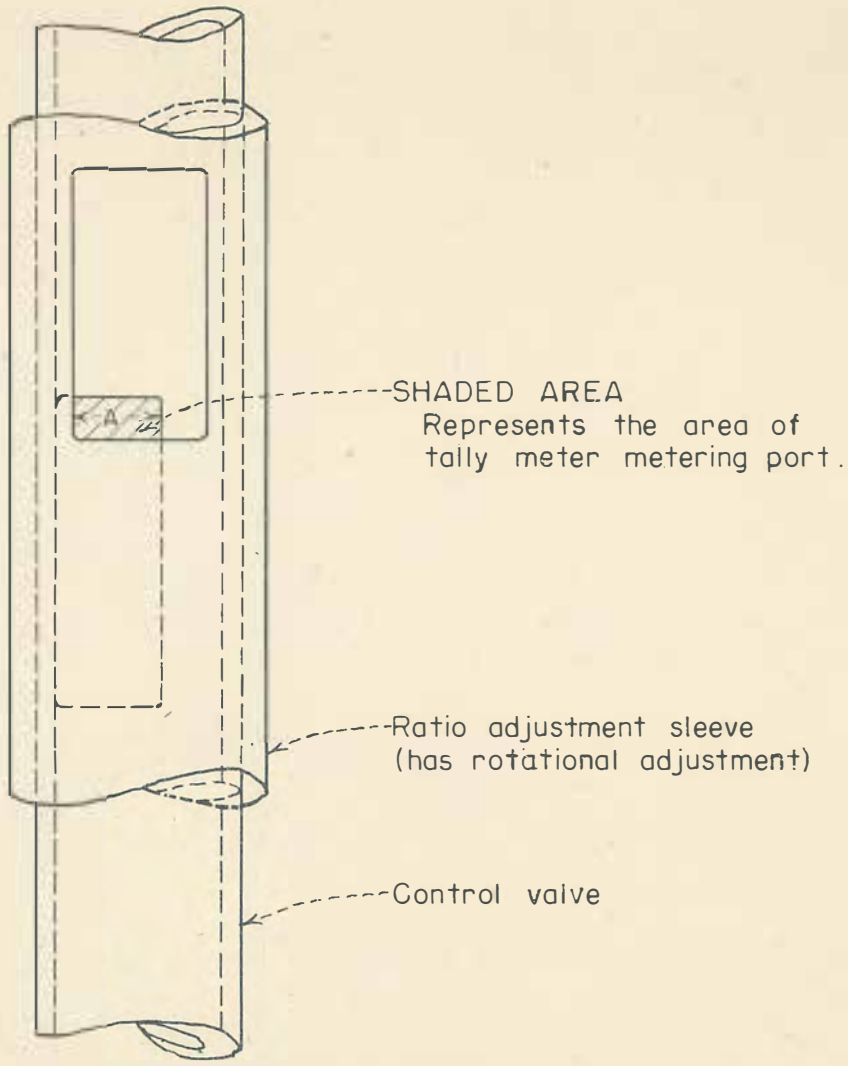
FIGURE 5



Meter Inside-View Showing Adjustments

Figure 6

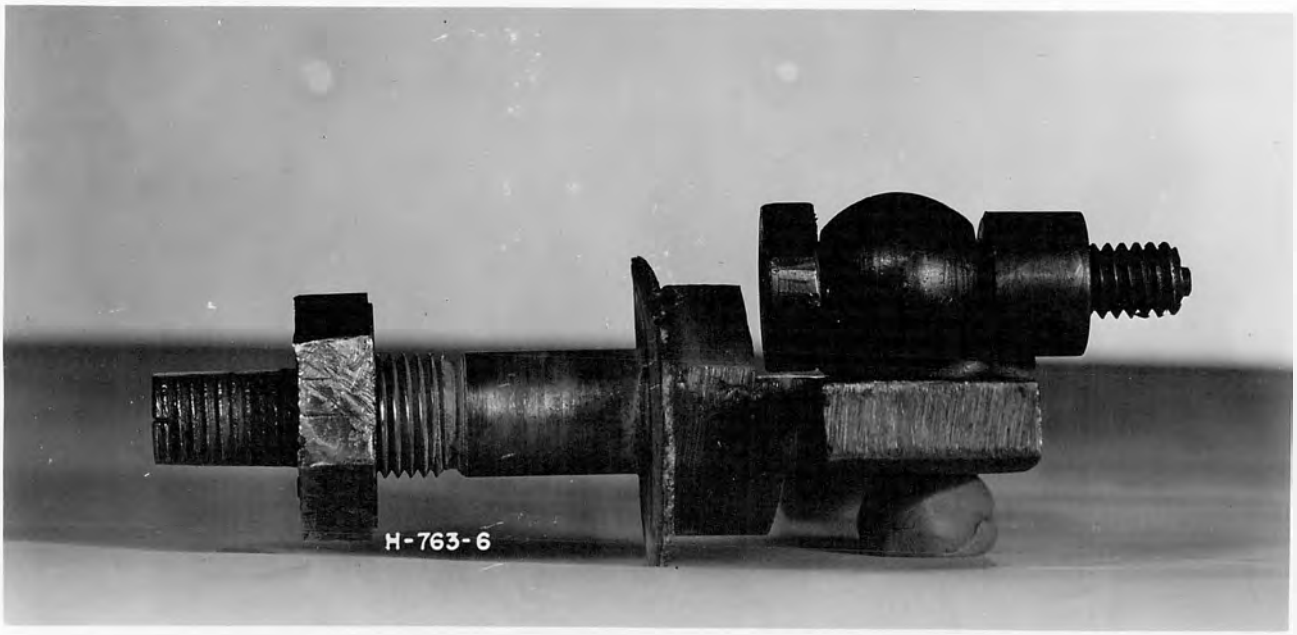
CHALLENGER FLUID METER



ADJUSTMENT No. 2

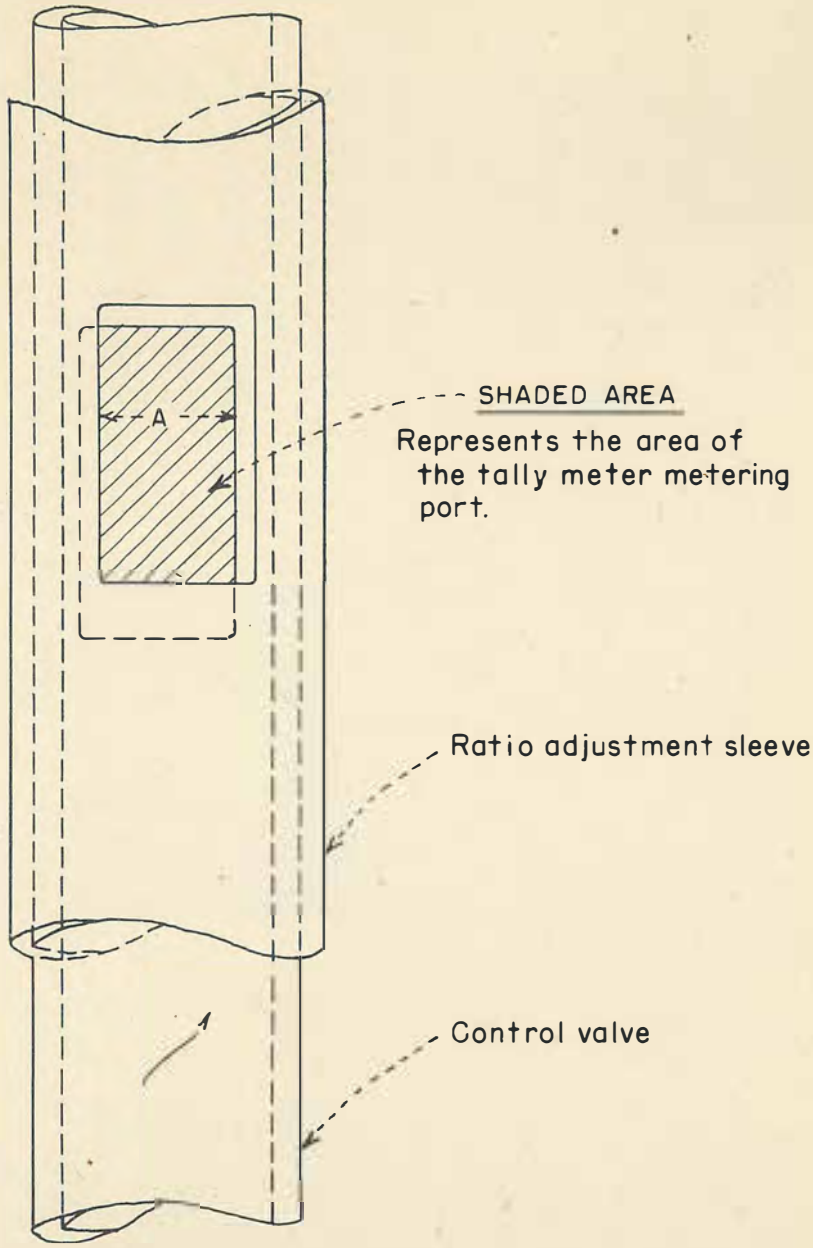
Provides adjustment of dimension A, the circumferential width of the tally meter metering port, by rotating the ratio adjustment sleeve (rotates outside port) to maintain a 1:20 ratio of tally meter flow to main meter flow.

(a) Adjustment No. 2 Detail Parts (lower) and Large Adjusting Nut (upper) Which Supersedes Lower Parts.



(b) Adjustment No. 3 Detail Parts

CHALLENGER FLUID METER

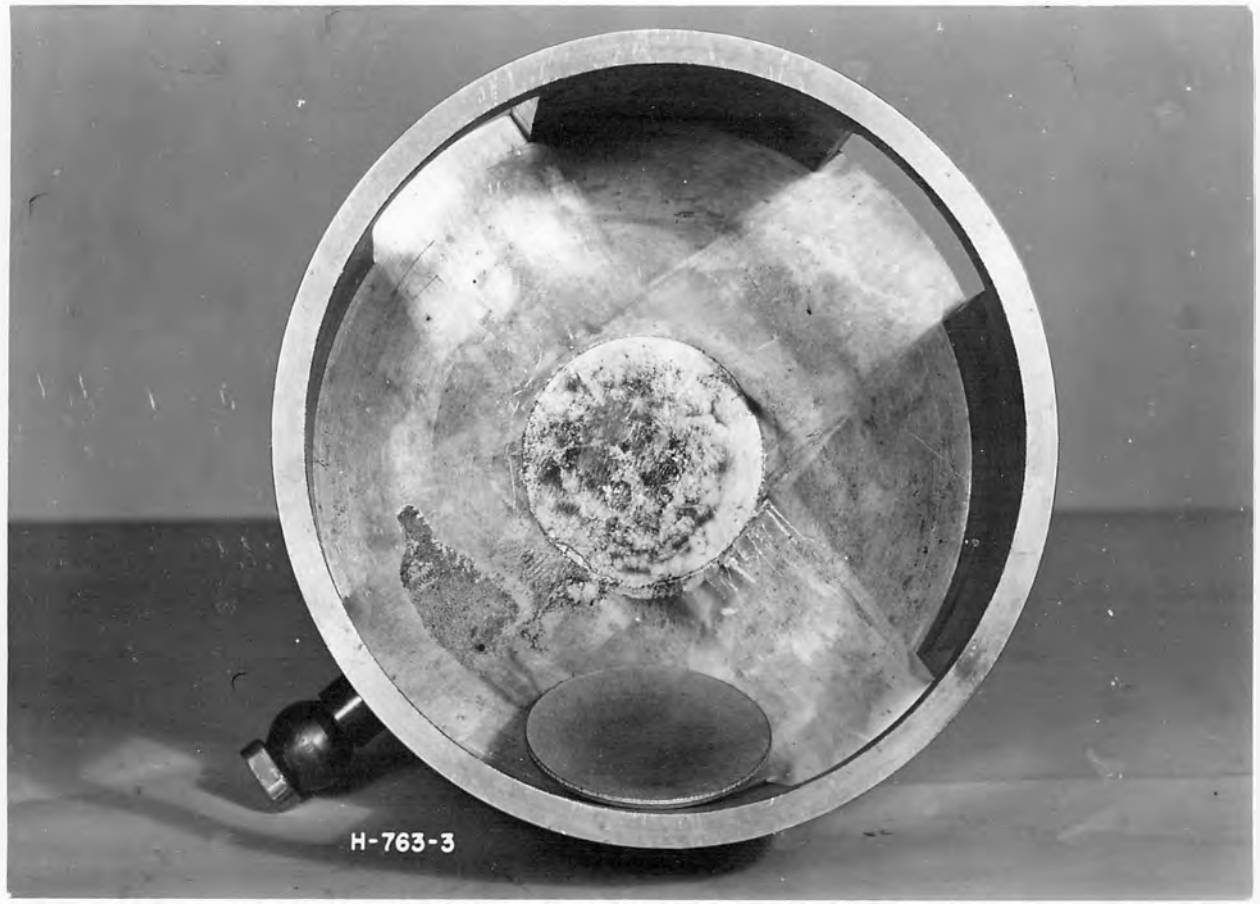


ADJUSTMENT No. 3

Provides additional adjustment of dimension A, the circumferential width of the tally meter metering port, by rotating the control valve (rotates inside port) as it travels downstream – thus maintaining a 1:20 ratio of tally meter flow to main meter flow.

Challenger Meter Test Installation--General View

Figure 10

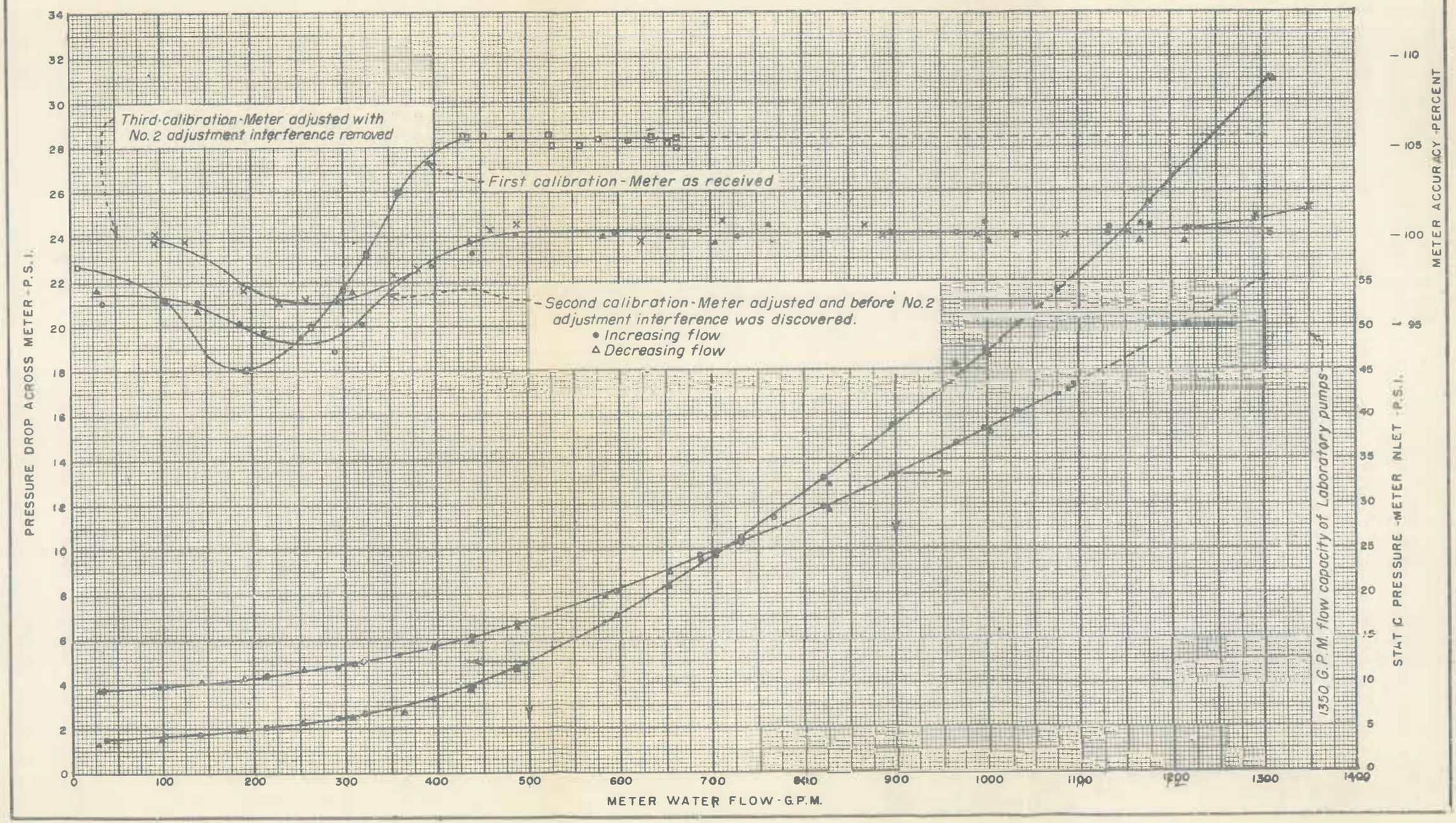


Control Valve Center Passage With Temporary Plug Soldered In Place. Meter Standard Welsh-type Plug Lying Below.

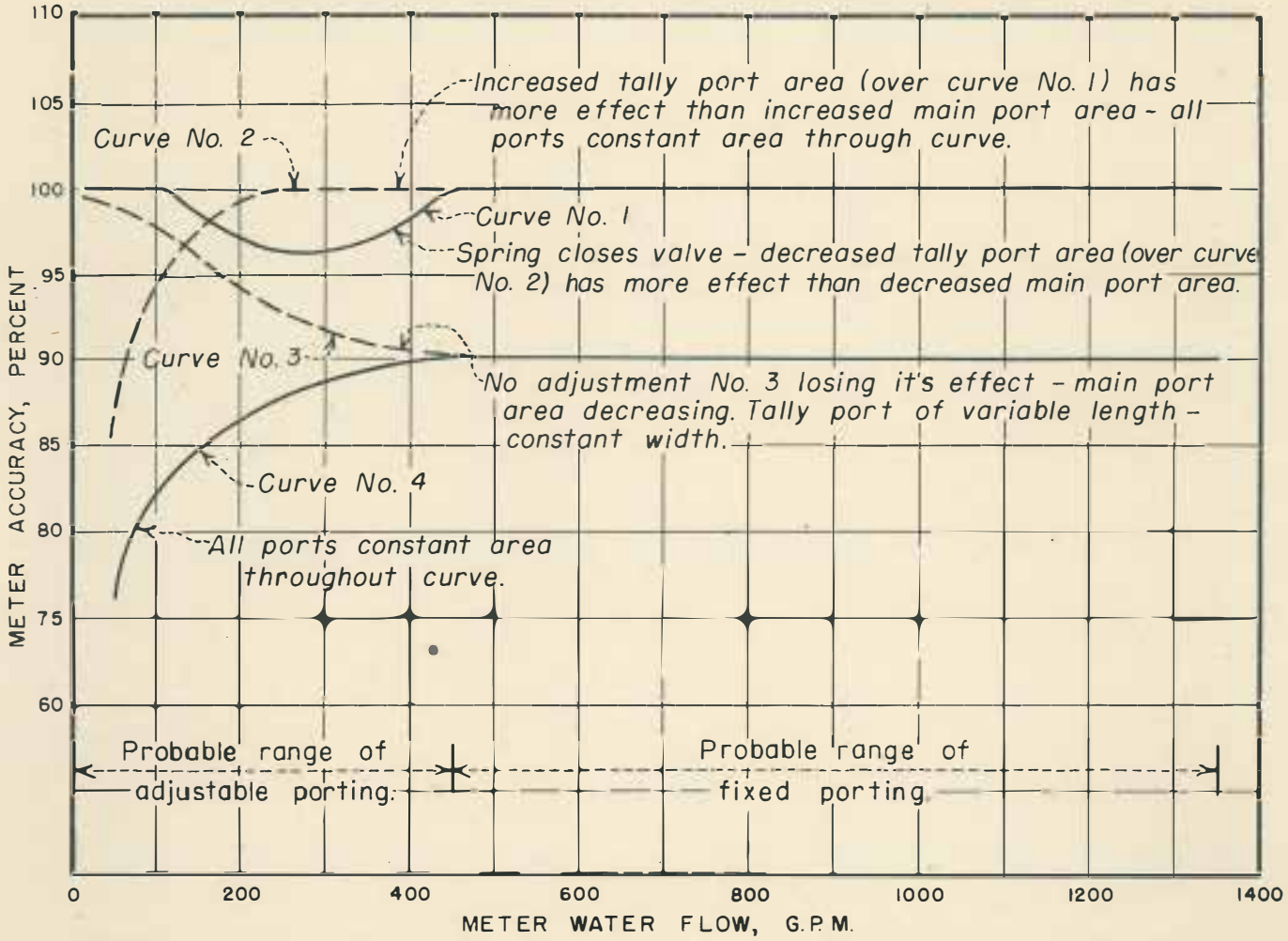
Figure 11

FIGURE 12

CHALLENGER 4" FLUID METER CALIBRATION



FOUR INCH CHALLENGER METER
DIAGRAMIC PLOT OF ADJUSTMENT EFFECTS

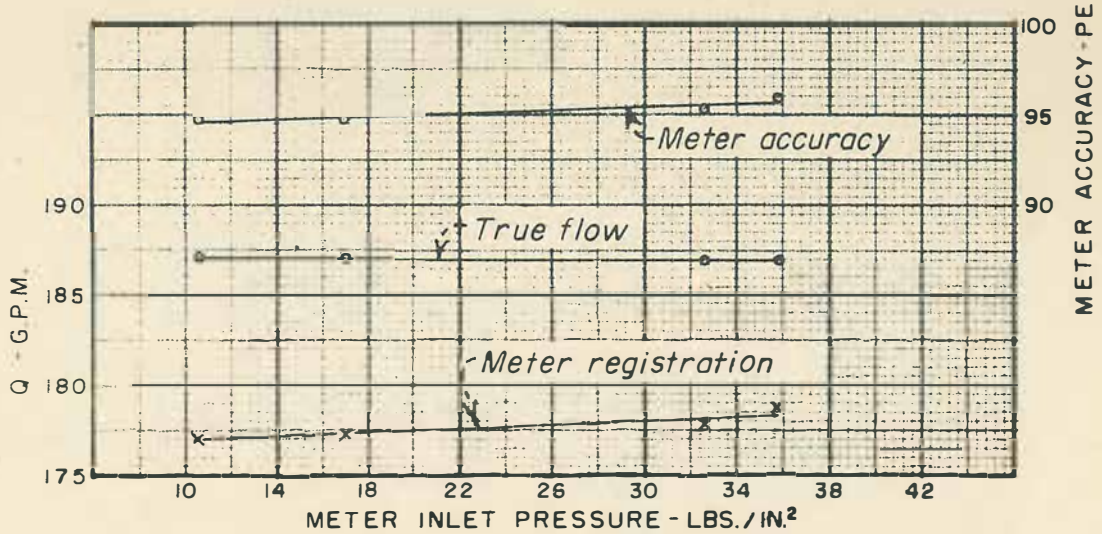


Curve No. 1 - All adjustments in, test 5
Curve No. 3 - No adj. No. 3 - Ramp horizontal, curve estimated.

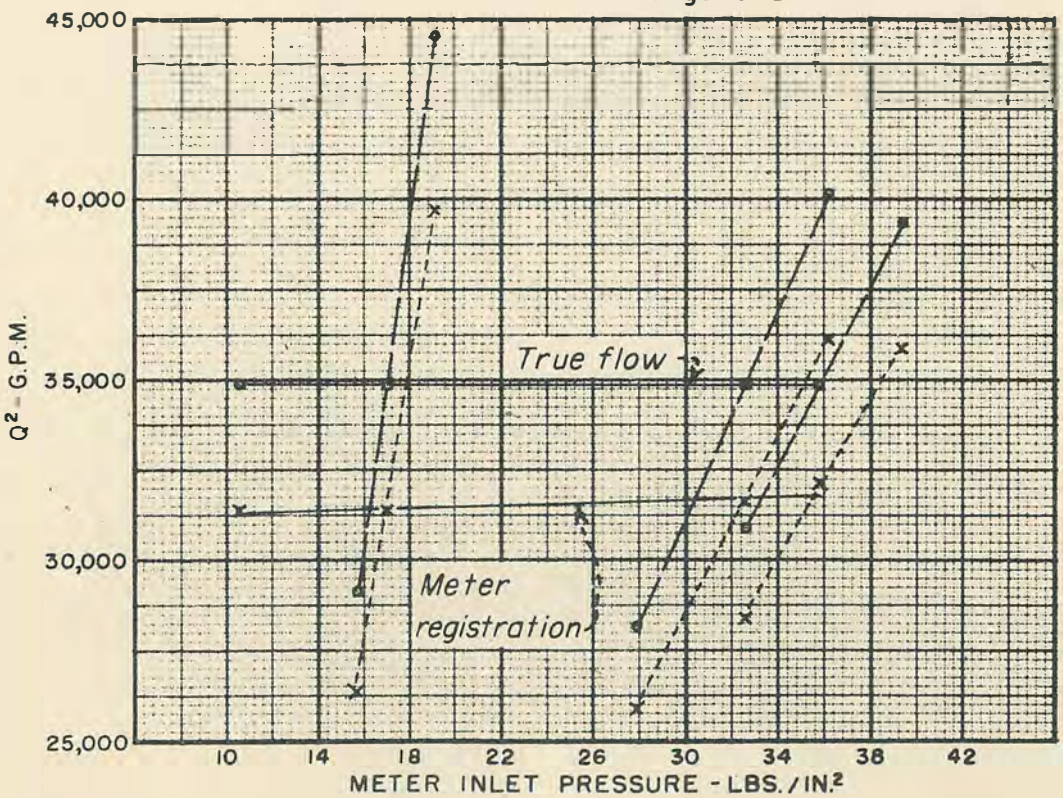
Curve No. 2 - No spring, test 4.
Curve No. 4 - No spring - no adj No. 3 - ramp horizontal, curve estimated.

FIGURE 13

METER ACCURACY
187 G.P.M. CONSTANT FLOW Vs. VARIABLE LINE PRESSURE
CHALLENGER 4" METER CALIBRATION

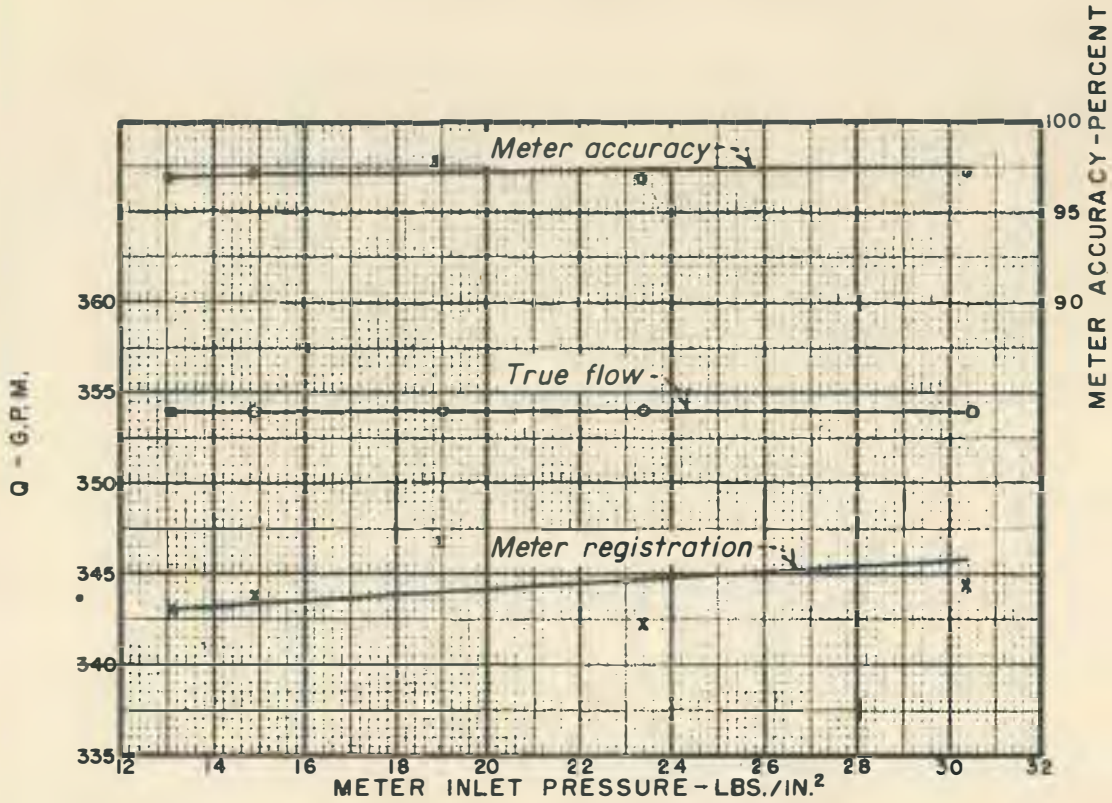


NOTE: Test run after calibration No. 2 meter adjustment, Figure 12



METER ACCURACY
354 G.P.M. CONSTANT FLOW Vs. VARIABLE LINE PRESSURE

CHALLENGER 4" METER CALIBRATION



NOTE: Test run after calibration No. 2 meter adjustment, Figure 12

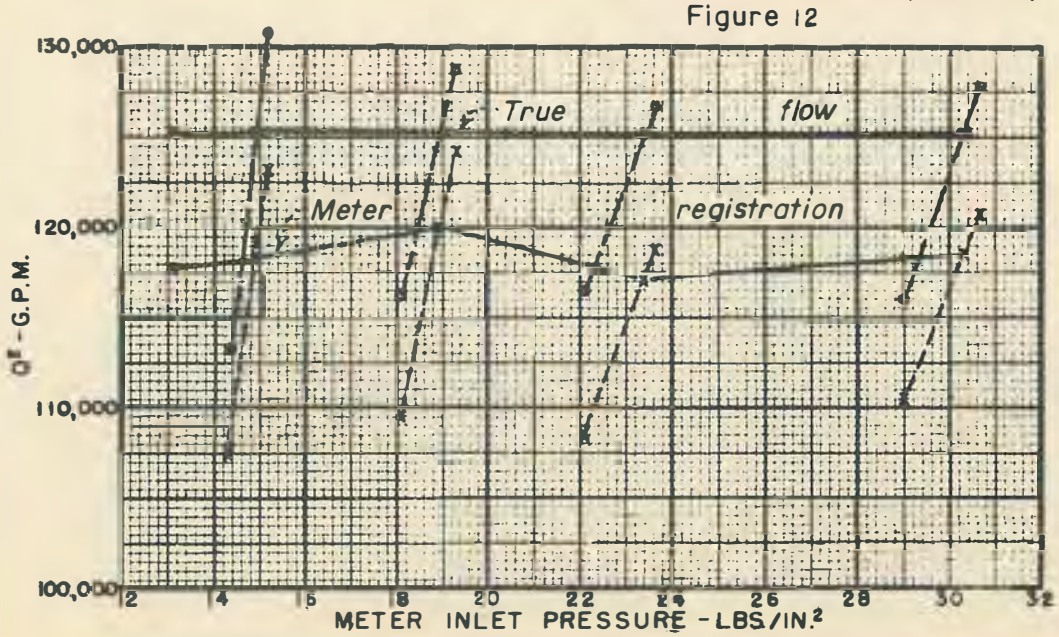
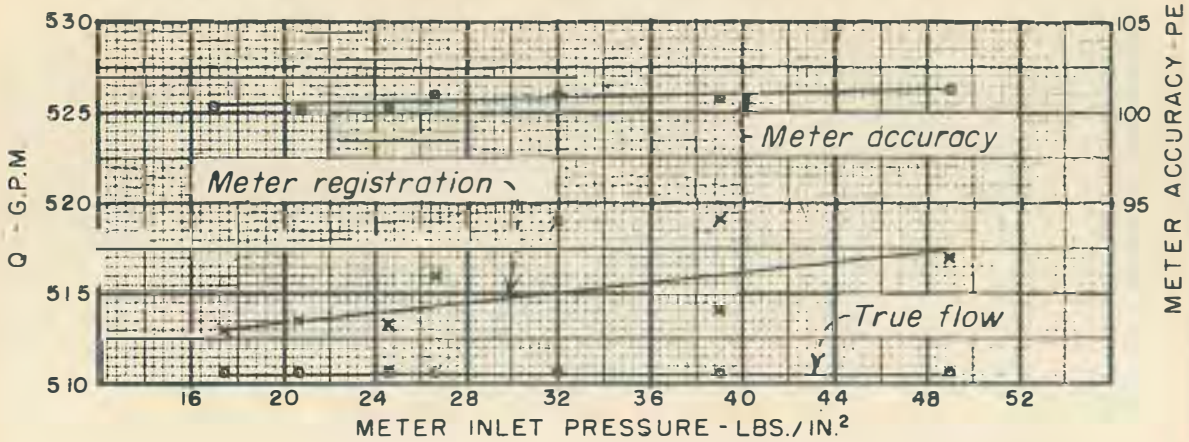
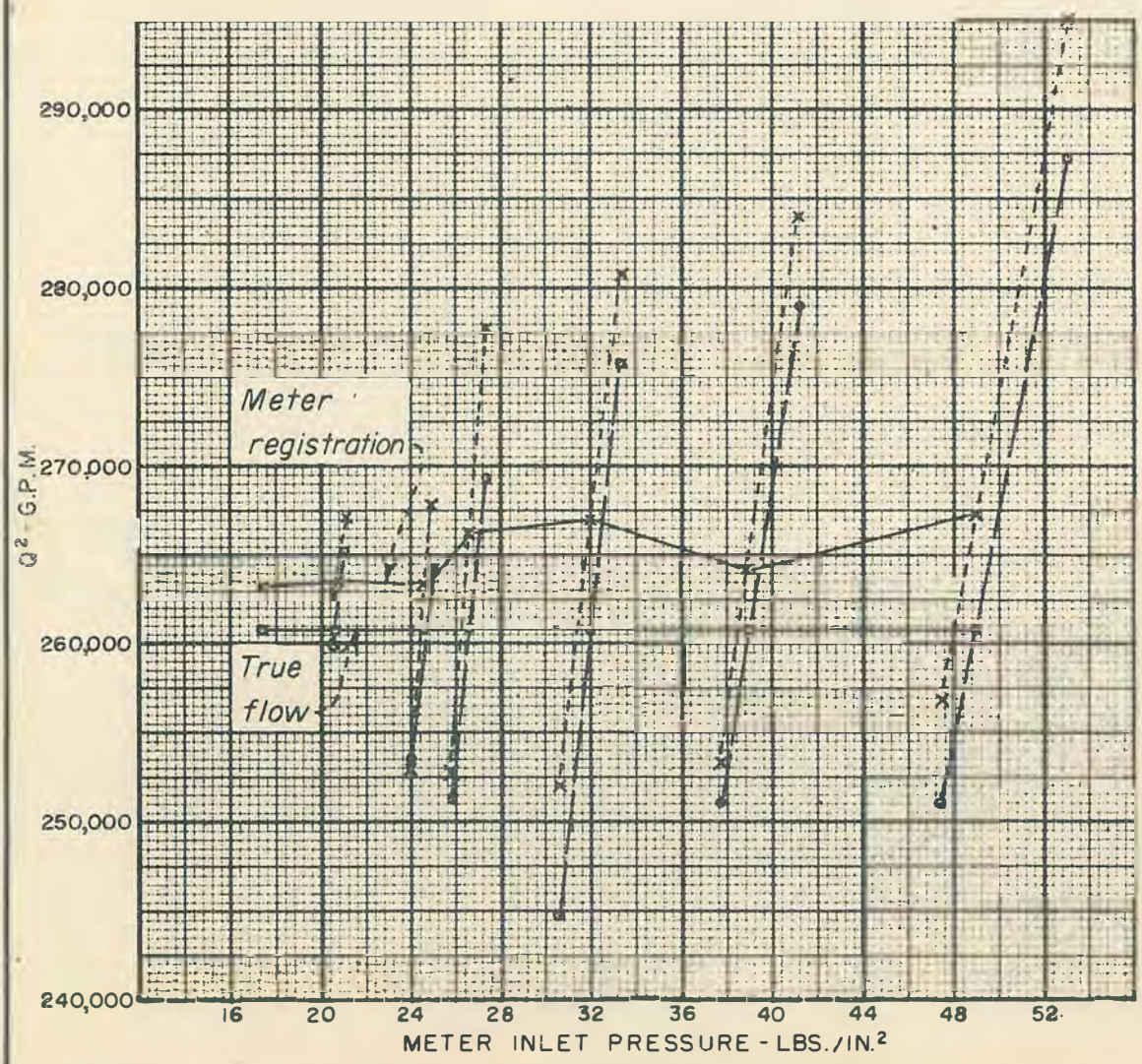


FIGURE 16

METER ACCURACY
510 G.P.M. CONSTANT FLOW Vs. VARIABLE LINE PRESSURE
CHALLENGER 4" METER CALIBRATION



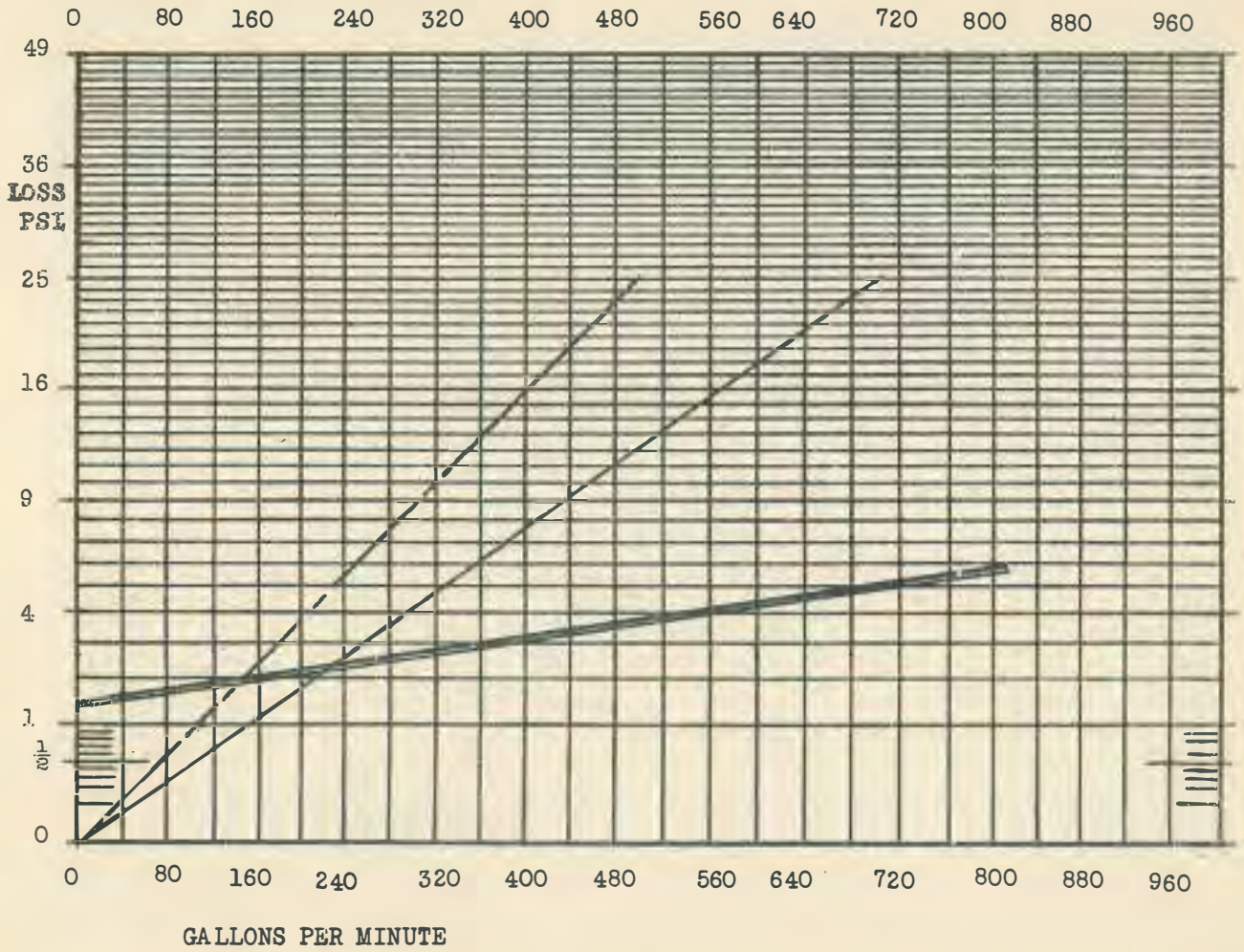
NOTE: Test run after calibration No. 2 meter adjustment, Figure 12



CHALLENGER MANUFACTURING CO.
SAN JOSE, CALIF.

Figure 17

4" CHALLENGER METER MODEL 400 CAPACITY CHART

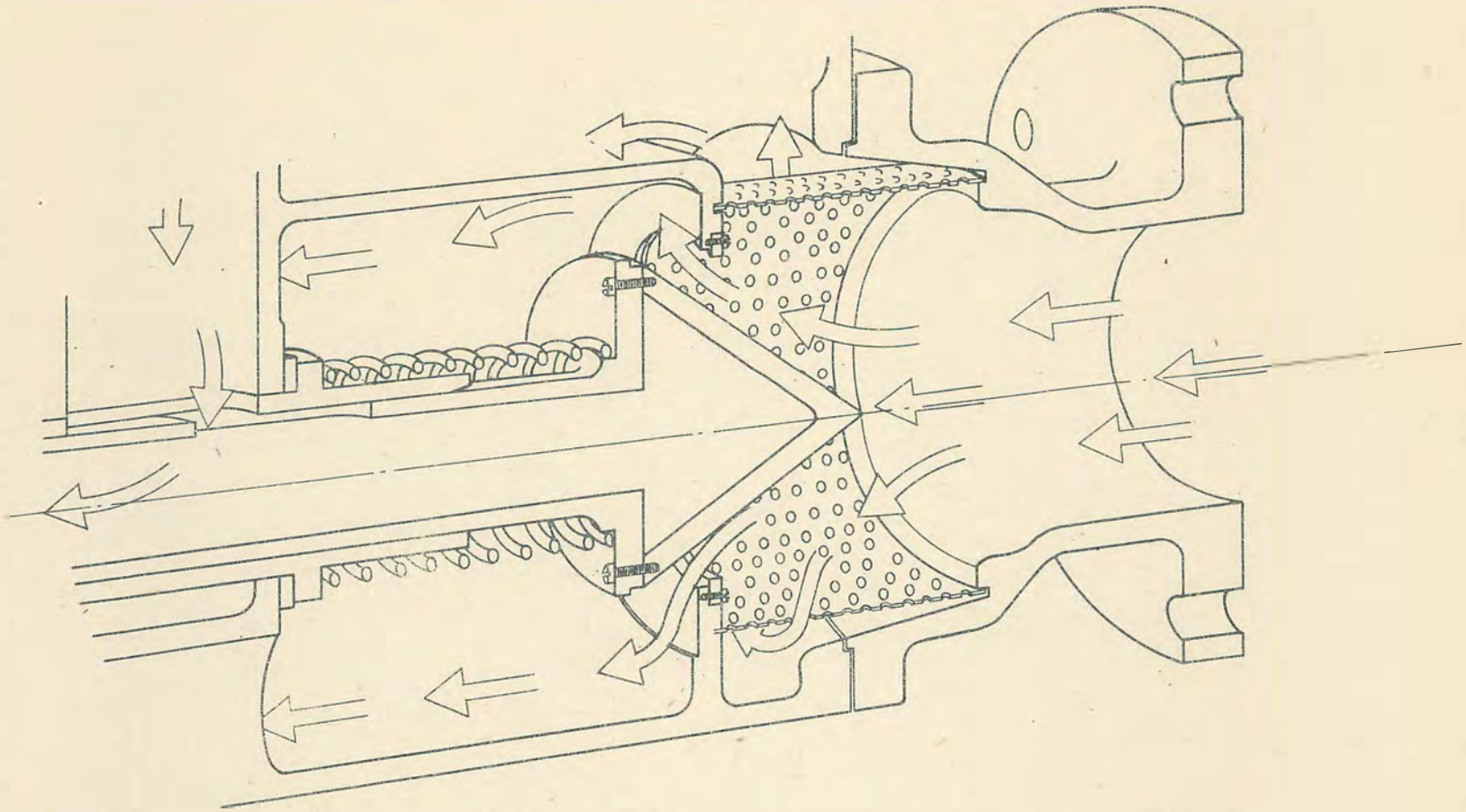


A.W.W.A. & N.E.W.W.A. STANDARD FOR DISK & COMPOUND TYPES.

A.W.W.A. & N.E.W.W.A. STANDARD FOR CURRENT TYPES.

CHALLENGER 4" MODEL 400

ALL CHALLENGER METERS HAVE SAME COMPARABLE LOSS OF HEAD.



SUGGESTED NEEDLE TYPE CONTROL VALVE TO REDUCE METER PRESSURE DROP.

FIGURE 18