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LABORATORY INVESTIGATIONS OF COMBINED VERTICAL FLOWMETER AND FLOW CONTROLLERS USED FOR IRRIGATION WATER DELIVERY

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16. ABSTRACT

Combined rotameter-type flowmeter and flow controllers were studied in the laboratory. These devices totalize flow, indicate flow rate, control flow to preset rates over a large range of line pressure, and provide shutoff in single units. Head loss, accuracy, and operational tests were performed on used devices that had been modified in the field to correct totalization inaccuracy noted in previous studies. Tests were also performed on unused new version devices to check compliance with specifications. Further field operation and experience are necessary to fully evaluate mechanical design of the new devices. During laboratory tests operational difficulties such as leakage, failure to internally recognize closure initiation and slowness of or even refusing to control flow were experienced with both versions of the device. These difficulties were mostly related to low line pressure or prior periods of no line pressure. Laboratory tests also indicate that pump operations can cause temporary overdelivery. Low head conditions and overdelivery in response to pressure increase should be considered in terms of specific project requirements during design.

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LABORATORY INVESTIGATIONS OF COMBINED VERTICAL FLOWMETER AND FLOW CONTROLLERS USED FOR IRRIGATION WATER DELIVERY

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December 1971

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CONTENTS

LIST OF TABLES

CONTENTS—Continued

LIST OF FIGURES

INTRODUCTION

Purpose

Laboratory tests were conducted on three sizes of two versions of a combined flowmeter and flow-controller device. The two versions of the device were a used field modified and an unused newer version. The used field-modified version was tested primarily to check the effectiveness of modification by the company to attain specified totalization accuracy. Tests were performed on both versions to help assess mechanical reliability, accuracy of indicated and totalized flow, head losses, closure characteristics, and discharge response to and recovery from supply line pressure changes caused by pump manipulation.

Background

Since June of 1967, Westland Water District has been using a combined rotameter-type flowmeter and flow-control device. The primary purpose of this device is to measure delivery of irrigation water. The device combines rate of flow indication, control to maintain preset flow rate at any pressure from low head to maximum design head, integration of the water delivered, and shut off by means of a small hand valve. These functions are incorporated in a single unit designed to operate without an external source of electrical power. This combination permits less supervision of the turnout by operating personnel, and allows the user to turn flow on and off but limits him to a locked, preset maximum delivery rate. The district is also aware of possible adaptations for remote and/or automated operations by means of coding devices for telemetry to a centralized computer station, and by motorizing the shutoff valve and ratesetter for control. This device offers possible economic advantages provided it measures flow accurately and is relatively free from maintenance problems.

Denver Office personnel made examinations of combined flowmeter and flow-control devices that were in service at the Westlands Water District in October 1967. They recommended that the Denver office laboratories perform further tests to aid in writing equipment purchase specifications.

The recommended investigations were performed and are summarized in REC-OCE-70-54. The tests with one 10-inch (25.4-cm) device showed that it did not meet specified accuracy and that shutoff and leakage problems were encountered at low heads. The poor accuracy results were verified by a disinterested third party. Also, Westlands Water District reported operation difficulties with the devices. However, laboratory analyses of data indicated that sufficient accuracy could be attained, provided the devices were properly calibrated and rugged enough to maintain calibration adjustment.

The manufacturer agreed to field modify the integrators of all devices of the original contact. The manufacturer also requested that if any future tests were conducted, they preferred that Bureau of Reclamation laboratories do them. Designers requested tests that included accuracy of rate of flow indication, totalization accuracy, head loss, closing time, and discharge response and recovery of the flow-controllers to changes of pressure that might occur during pumping plant operation.

Tests were made with 10-, 12-, and 14-inch (25.4-, 30.5-, 35.6-cm) sizes of the used field-modified devices and on one each of 10-, 12-, and 14-inch sizes of the unused newer-version device. The tests were conducted from May to February 1969. This report describes these tests for the head and flow ranges shown in Table 1.

SUMMARY OF LABORATORY STUDIES

The first two used field-modified devices that arrived at the laboratory were improperly prepared for shipping. The 12-inch (30.5-cm) meter was operable and was tested. The 14-inch (35.6-cm) meter was inoperable. Both of these devices were disassembled and inspected in the presence of manufacturer's representatives and were found to be damaged.

The clock and timing circuits of all of the devices shipped to laboratory were not operating properly. They produced spurious pulses that triggered excess accumulation on the digital dial totalizer. Two reconditioned clocks provided by the manufacturer lasted only long enough to finish the testing of one meter. The manufacturer developed and provided one transistorized version of a clock and timing circuit that was transferred from meter to meter to complete the testing program. It cannot be predicted by these laboratory tests how well the new clock and timing circuits will perform in a field environment.

None of the used field-modified devices fully complied with the specified totalization accuracy. Possible contributing reasons are inadequate modification, field use, shipping damage, and inadequate mechanical design. However, all the unused new version devices complied with the specified totalization accuracy within laboratory discharge measuring capability. Some features of the newer device indicate that the

Table 1

FLOW CHARACTERISTICS

Nominal meter size inches (cm)	Minimum cfs (lps)*	Flow range Normal cfs (lps)*	Maximum cfs (lps)*	Maximum design head ft (m)	Head loss at normal flow inch water (cm water)
10 (25)	0.6 (1.7)	3 (85)	6 (17)	175 (53.3) all sizes	30 (76) all sizes
12 (31)	0.8 (2)	4 (11)	8 (23)		
14 (36)	1.1 (31)	7 (20)	10 (28)		

*lps (liters per second)

manufacturer has made efforts to provide a more rugged version that is likely to maintain calibration accuracy better than the used field-modified version.

Reading of discharge from the rate of flow indicator near normal flow produced indicated discharges ranging from 92 to 107 percent of true flow for the field modified devices, and 93 to 99 percent for the new version.

Every device tested, except the field modified 14-inch (35.6-cm) device, complied with the maximum head loss of 30 inches (762 cm) of water at normal flow. This device, produced about two times the specified maximum head loss. After thoroughly checking the laboratory measurements, it was concluded that the high loss was caused by internal damage similar to that noted for the devices that were disassembled and inspected.

The only field-modified device tested that entirely satisfied the specified closing time requirements was the 14-inch (35.6-cm) device. The new version devices complied with the closing time requirements, provided initiation of closure was internally recognized. Occasionally, after shutting off the external hand valve, a device failed to start to close for undetermined reasons. However, closure could be actuated either by manipulation of a set point control, or increasing the supply line pressure. The field-modified 12-inch (30.5-cm) device that was improperly prepared for shipment and/or otherwise damaged, leaked in excess of specified limits.

Occasionally the devices failed to control after periods of no line pressure. However, control could be actuated either by manipulating the set point control, increasing supply line pressure, or temporarily closing the shutoff valve. The larger size devices were often slow (10 to 15 minutes) to control after a period of no supply line pressure.

After setting a discharge near normal flow all the devices tested returned the flow back to within plus or minus 3 percent of the set discharge for pressure changes within a head range of 100 to 20 percent of maximum design head. Pressure increases such as might be caused by pump speed changes, resulted in large temporary overdelivery.

Some vibration problems were encountered during high head tests with field modified devices. During one test the handwheel that is used to set maximum allowed discharge delivery, turned due to flow induced vibration. The device delivered twice the set maximum discharge. Another time an integrator cam vibrated loose from its mounting. It cannot be clearly distinguished by the laboratory tests alone whether field use, improper shipping, preparation, inadequate mechanical design, or a combination of these were responsible.

Results of field experience and these laboratory tests can be used to help determine if the flowmeter and flow-control devices are feasible for use in particular projects and to aid in writing equipment purchase specifications that more fully consider the peculiar characteristics of those projects.

DESCRIPTION AND CAPABILITIES

The vertical flowmeter, flow-controller, and integrator combine in one unit the capability of (1) flow measurement of instantaneous rate of flow and integration for totalized flow in acre-feet, (2) limiting of flow to a preset maximum rate or to maintain a nearly constant flow rate over a range of head by adjusting the set point, and (3) a valve to shut off or turn on delivery to the user. External electrical power is not required. However, internal batteries are required to totalize flow.

Measuring Principles

Basically, the measuring part of the device is a rota-meter-type variable area flowmeter, Figure 1. The water enters the meter vertically from the bottom, flows upward around the metering float situated within the tapered throat, and discharges horizontally through the side outlet. The metering float moves up and down in direct response to the volumetric flow rate. The position of the metering float within the tapered throat is determined by the balance of upward force exerted by the flowing water and the downward force of the weight of the metering float. The shape of the metering float and the tapered throat causes the float to seek specific elevations for given discharges. Therefore, the meter can be calibrated in any desired units of flow.

Readout Conversion

A round, hollow float shaft extends through the center of the float and is guided by bearings for vertical movement, Figure 1. The float shaft extends up through the top cover plate into the integrator unit. Permanent magnets are attached to the top end of the float rod. As the flow is increased from off towards maximum flow, the magnets rise the same distance as the float. The field-modified device has a vertical helical shaft not shown in Figure 1 that converts changes of float elevations into rotation. The helical shaft is external to, but magnetically coupled to the float shaft magnets. The rate of flow is indicated on a horizontal scale by a pointer (Figure 2) attached to the top of the helical shaft. The scale is calibrated in cubic feet per second (cfs) for direct reading.

The newer version is not dependent upon conversion of change of float elevation into rotation for readout. A pointer (Figure 3) on a magnetic follower assembly moves in direct vertical relation to the movement of the magnets on the float extension rod.

Totalization

To totalize delivery flow, the field-modified devices have a horizontal cam attached to the top of the vertical rotating helical shaft. Magnets on a rotor, timed and driven by an electric clock and motor, force a contact lever to touch the cam once every 60 seconds. When there is no flow, a reed switch responds to the magnet on the float extension rod and breaks the circuit to the motor of the contact level drive. During flow the stroke of the contact lever from a zero or rest position to cam contact is accumulated (Figure 2) by a 6-digit dial counter. The cam is cut to proportion the length of stroke to the rate of flow. The dials read totalized flow in acre-feet.

The amount of flow through the new version device is also accumulated (Figure 3) on a 6-digit dial register. Attached to the magnet follower pointer assembly is a cam which represents flow rate. This cam differs from the modified old device in that the cam has a sloped face and is vertical. The contact lever drive is essentially the same as for the field modified version.

Set Point Control

Varying the maximum discharge limit of the field-modified device is accomplished by raising or lowering the pilot valve seat by means of the set point handwheel, Figures 1 and 2. The top end of the float shaft is beveled to mate with or act as a needle for the pilot valve. When the needle is seated the float cannot rise. As the inlet pressure continues to increase, the discharge would tend to increase, but seating of the pilot valve needle prevents bypass pressure relief on the control piston, which is sealed with respect to the meter body by a flexible diaphragm, Figure 1. The pressure continues to build up above the control piston and the piston is forced downward. A sleeve valve containing shaped orifices (Figure 4) is attached to the control piston. The orifices on the sleeve valve restrict the flow as the sleeve is forced downward. In this way, inlet pressure in excess of that required to just seat the pilot valve is consumed as orifice loss rather than delivering more water. When the inlet pressure decreases below that required to seat the pilot valve, the float drops as the discharge reduces.

Internally, the flow rate limit for the new version is maintained in the same way as for the field-modified

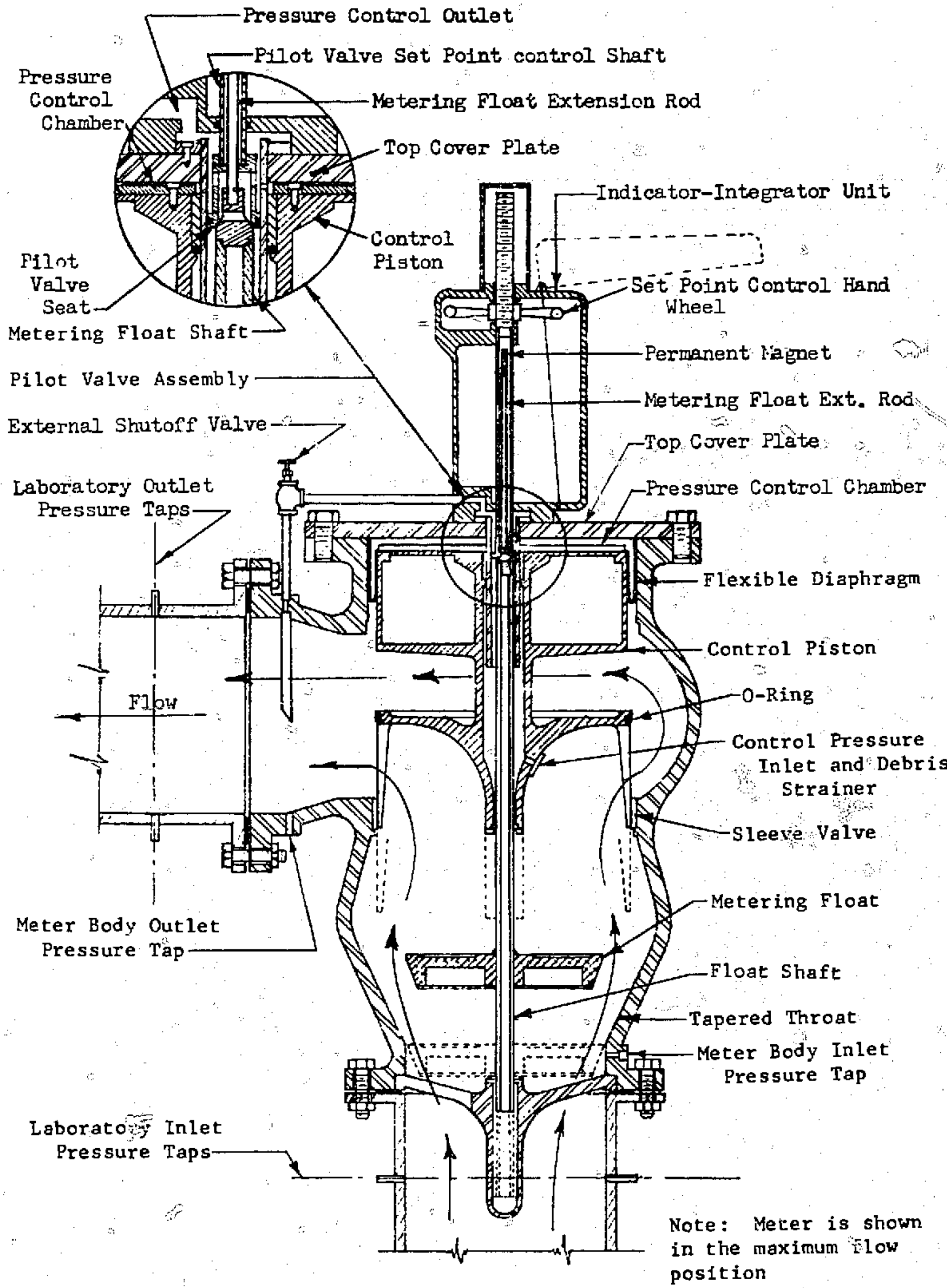


Figure 1. Assembly drawing.

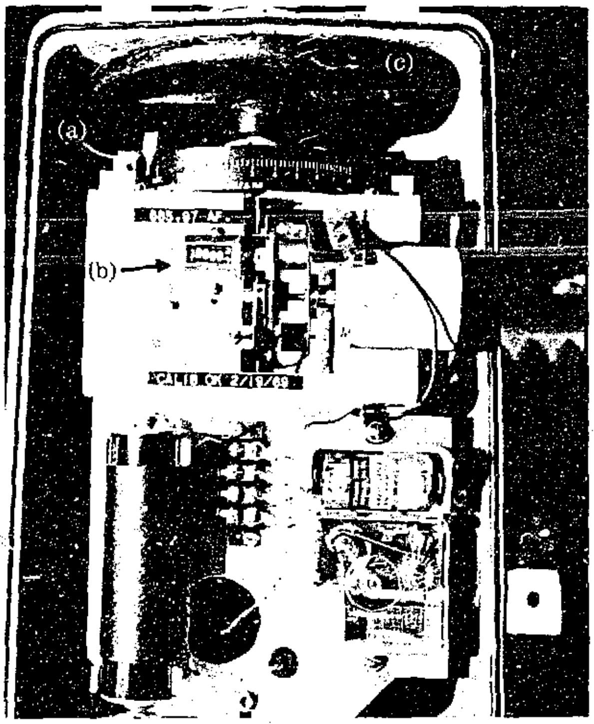


Figure 2. Horizontal scale and pointer of used field-modified device. Discharge pointer (a). Totalizer dials (b). Set point handwheel (c). Photo PX-D-70502

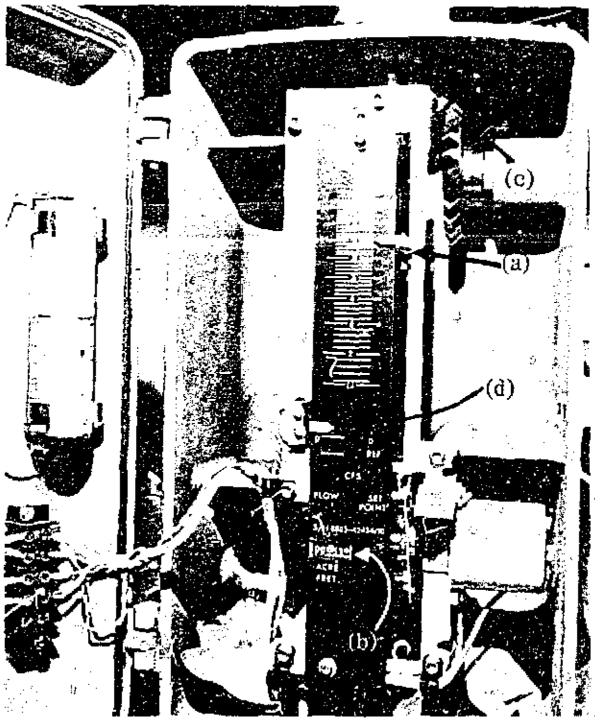


Figure 3. Vertical following pointer of newer-version device. Set point indicator (a). Totalizer dials (b). Set point hand crank and gear drive (c). Discharge indicator (d). Photo PX-D-70501

version. However, the rate of flow is set to the desired value by means of a quick engaging handcrank and gear drive (Figure 3) rather than a handwheel.

Opening and Closing

To shut off flow through the field-modified version, a small external hand shutoff valve (Figure 1) located adjacent to the meter outlet is closed. The external shutoff valve provides flow shutoff without changing control set point or opening the integrator cover. The external valve shuts off bypass relief in the control chamber and the pressure on top of the control piston builds up to inlet pressure. Thus, the sleeve valve is forced downward until the O-ring at the top of the sleeve seats and shuts off the delivery flow. All that is necessary to resume flow is to open the small external valve.

The hand shutoff valve of the new version operates in the same manner as above, but the hand valve of the new version differs from the field-modified device in that it may be padlocked so that the flowmeter cannot be turned on.

LABORATORY INVESTIGATIONS

Installation

Each flowmeter and flow-controller was unpacked, inspected for damage, and installed on the test stand, as shown in Figure 5. Water was pumped through a 12-inch (30.5-cm) supply line controlled by a gate valve, through an upright 12-inch tee, blind-flanged on one end, reduced to the diameter of the device being tested, through a 5-diameter length of vertical approach pipe, and on through the device. The 5-diameter length of approach pipe was the minimum allowed by design. On the outlet side of the meter a short horizontal section of pipe was installed that matched the size of the device being tested. The pipe was connected to a reduction or expansion, as needed, to match a 12-inch upturned elbow that maintained a

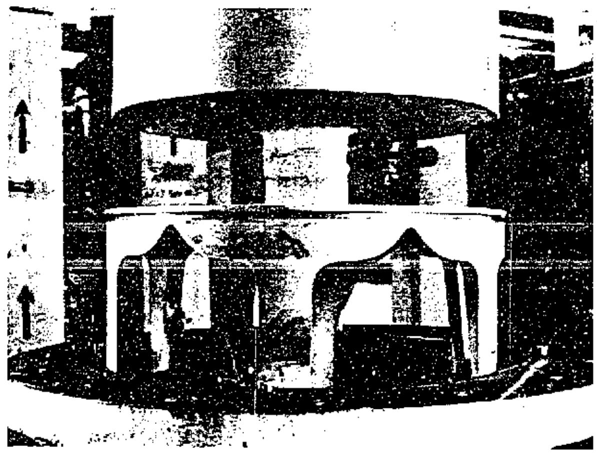


Figure 4. Sleeve valve with shaped flow control orifices. Photo PX-D-70499

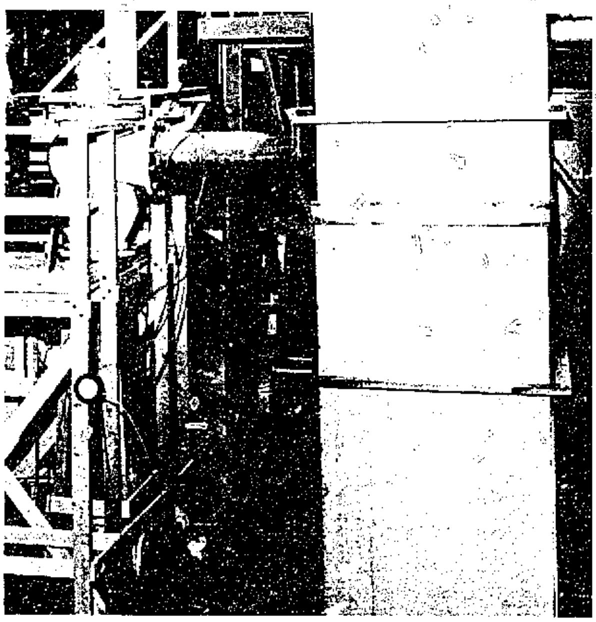


Figure 5. Laboratory installation of flowmeter and flow-controller—Used field-modified device. Photo PX-D-70494

positive outlet head. Overflow dropped through a box, back into the laboratory pump supply.

Discharge Measurements

Calibrated venturi meters that are permanent fixtures of the hydraulic laboratories were used to measure the actual rate of flow through all devices tested. A mercury manometer was used to measure the head differential across the venturi meters. Using the average of this differential over the test period, the flow was determined from laboratory calibration tables. The manometers and venturis were calibrated using the laboratory volumetric tank. The laboratory-measured flow rates through the devices are accurate to within plus or minus 1 percent.

Pressure Measurements

Piezometer taps were installed about one-half diameter upstream from the inlet and about one diameter downstream from the outlet. To obtain a more accurate average of the flow pressure at each of these sections, four piezometer taps were placed at 90° intervals around the circumference of the piping, and were manifolded. The manifolds were connected to the manometer or piezometers. In the case of high head conditions and/or flow controlled by the device, a mercury manometer was used to obtain pressure differential readings. For the low head range and/or flow controlled by laboratory gate valves, separate water columns were used to obtain more accurate pressure measurements.

Pressure measurements were also obtained between the inlet and outlet using plugholes drilled and tapped in the meter body of the device by the manufacturer. These holes are not ideally suited for pressure measurements and do not indicate true head loss. However, these holes provide a convenient means for head differential comparisons if data should be obtained with the same devices in the field.

Totalization Measurements

The totalizer accuracy was determined by pumping water through the device for periods ranging from 1-1/2 to 20 hours. A calibrated laboratory venturi meter was used to measure the true flow. Sufficient numbers of manometer readings were taken to obtain a meaningful average discharge value. During the totalization tests, continuous charts of head differential across the laboratory venturi meter were recorded. The charts were used to assure that the discharge remained essentially constant during the totalization measurements. The acre-foot dials of the register were read at the beginning and ending of time intervals. These intervals were made long enough to provide plus or minus 1 percent accuracy based on reading limitations of the register dials.

Rate of Flow

During many of the laboratory tests the rate of flow, as read from the dial indicator, was recorded. These dial readings could be estimated to plus or minus 0.02 cfs (0.57 lps) between scale divisions.

Closure Time Measurements

Closing times were measured by stopwatch and full closure of the sleeve valve was determined by observing the rate of flow indicator needle and also the flow from the exit pipe.

Leakage Observations

The sleeve valve of the devices did not always fully seat. Leakage was usually estimated visually rather than measured since when leakage occurred it was obviously in excess of the small amount specified, 1-1/2 to 1-3/4 oz/minute (44 to 52 ml/min).

Response to Supply Line Pressure Changes

Discharge recovery tests were made by setting a discharge at an inlet head near maximum design and then successively reducing laboratory supply pump speed in steps toward the minimum head required to deliver the set discharge. The laboratory venturi discharge was measured after the devices had fully recovered from each pressure change.

Tests were made to check the discharge control response of the devices to supply line pressure changes similar to those that occur in pump-operated distribution supply systems. Surge tests were accomplished by rapidly changing laboratory pump speeds and simultaneously measuring the inlet pressure and the pressure of the laboratory venturi differential on recording charts. To prevent damage to the devices, line pressure was reduced by slowing the laboratory pumps whenever inlet pressure or discharge exceeded specifications.

RESULTS

Inspection of the First Devices Received

The first two devices that were shipped to the laboratory were 12- and 14-inch (30.5- and 35.6-cm) used field-modified devices. Upon uncrating, it was immediately observed that they were not properly prepared for shipment. Rubber blocks had not been placed between the bottom of the floats and float shaft guide bearing spiders. The set points were left well above reference allowing the bearing spiders, floats, and pilot valve seating surfaces to be subjected to blows during shipment. The bottom end of the helix shafts in the integrator units were not lifted off their jewel bearings by means of wooden wedges as is recommended by the manufacturer. This permitted the jewel bearings to be subjected to blows during shipping. Both meters were disassembled in the presence of manufacturer's representatives. Their interpretation of the inspection is included in the appendix.

Our inspection of the 12-inch (30.5-cm) meter disclosed two wear spots on the magnetic end of the float rod. One wear spot was near the top of the magnet, and the other was near the bottom, but on the opposite side of the shaft. The float rod was bent one-fourth inch as determined on a machine shop lathe. The needle on the float shaft had acquired an extra wear groove on the lowest portion of the seating bevel. This was probably due to the bent float rod. The debris strainer had broken off from the meter and was missing. Wear was noted on the lower part of the flexible diaphragm and also on the diaphragm's flange. Only half of the sleeve valve O-ring was in the groove. The other half was missing. The pilot valve seat showed no excessive wear. The float rod had an indentation of about 3/8 inch in diameter by 1/16 inch deep.

Our inspection of the 14-inch (35.6-cm) meter disclosed dirt particles in and around the inside of the integrator housing. The magnet head of the float shaft showed wear similar to the 12-inch (30.5-cm) meter. The set point shaft was frozen to the integrator housing by corrosion. The float rod was bent by 3/16 of an inch.

All the devices that were subsequently delivered were properly prepared for shipment and no damage was noted upon uncrating.

Mechanical Problems

None of the clock and timing circuits shipped with the devices was functioning properly. They produced random pulses that triggered extra accumulations on the digit dial counters of the integration units. When this difficulty was demonstrated to manufacturer's representatives, they furnished two reconditioned clocks and tests were continued starting with another device. After about 2 weeks of daily operation, the first reconditioned clock started to produce spurious pulses and rapidly became unusable. The second reconditioned clock was installed and operated long enough to complete totalization tests with the device. The clock was then transferred to the next device to be tested, but did not produce sufficient pulse voltage to trigger integration. The manufacturer furnished a new clock with a transistorized timing and pulsing circuit. This new clock and timing circuit was used without any further difficulties. The testing program was completed by transferring the new clock from one device to another.

Both the field-modified and the 14-inch (35.6-cm) newer-version devices were slow to control the flow after a period of no pressure in the supply line. Usually 10 to 15 minutes was required. The devices were not consistent in response to various efforts to stimulate control, such as moving the set point up and down, increasing line pressure, temporarily closing the shutoff valve, and bleeding water from above the control piston to remove trapped air. Once, the field-modified 14-inch device failed to control for 2 hours. After closing the shutoff valve and opening it again, the controller became operable.

Blame for mechanical problems experienced in the laboratory with the field-modified 12-inch (30.5-cm) device that was improperly packed for shipping cannot be clearly distinguished between possible contributing causes of field use, shipping damage, or inadequate mechanical design. The magnetic reed switch of the timing rotor came apart. The rubber sleeve on the totalizer stroking arm was cut or worn through so that there was metal-to-metal contact between it and the integration cam. The totalizer was out of adjustment and the manufacturer's representatives adjusted the cam to zero. However, it was noted that final adjustment was made by bending the cam by hand to vary the integrator arm stroke length. This procedure suggests that the integrators of the field-modified devices were of inadequate design. Once the cam came loose due to flow-induced vibrations. High head vibrations caused the last place totalizer dial to travel backwards at about 0.005 acre-foot in 4 minutes (about 6 cubic meters). Another time, at high inlet head, the set point handwheel vibrated in such a manner so as to change the set discharge from 50 to over 100 percent of maximum design. No vibration problems were encountered during laboratory tests of other field-modified devices. During one test the magnetic rotor that drives the integrator stroking arm stuck, but by forcing it to make one revolution, it continued to operate properly. On another occasion, the device failed to control when the controller was set to maintain about 33 percent maximum design flow, and the supply line pressure was increased by 80 feet (24.5 m) in 8 seconds. The discharge rose to 130 percent of maximum design and made an unscheduled closure. This action suggested that the needle of the pilot valve had wedged into a seated position. This was verified when the set pointing control was raised up and down with the rate of flow needle following. The totalizer stroking arm of the other field-modified 12-inch (30.5-cm) device dragged on the cam, preventing the cam from returning to the zero reference position when there was no flow.

On one occasion the totalizing rotor of the newer-version 12-inch (30.5-cm) device ran continuously. Disconnecting the clock wiring temporarily and then reconnecting stopped this action, and this problem did not reoccur.

Free Flow Head Loss

Free flow head loss data were obtained for all devices tested to check for normal flow head loss required by specifications. All the new-version devices tested complied with the 30-inch (76.2-cm) water loss specification.

The field-modified 12-inch (30.5-cm) device that was improperly prepared for shipment did not produce a consistent head loss data, probably due to the bent float shaft. However, the data did average 30 inches plus or minus 6 inches (76.2 cm plus or minus 15.2 cm). The field-modified 14-inch (35.6-cm) version produced losses two times greater than specified. After thoroughly checking the laboratory measurements, it was concluded that the high loss was caused by internal damage similar to that noted for the two devices that were disassembled and inspected. However, this device was not disassembled because of the considerable time required.

Totalization Tests

The used field-modified devices operating near 50 percent discharge totalized flow in a 20 percent band ranging from 96 percent to 116 percent registration, Figure 6. The solid data points represent double data points. All the new devices complied with the totalization specifications. The specifications require plus or minus 5 percent from 10 to 25 percent maximum and plus or minus 2 percent from 25 percent to maximum discharge. These requirements are demarked by the areas bounded by the heavy lines in Figures 6 and 7. Laboratory measurement of discharge was measured to plus or minus 1 percent. The totalization time interval was also selected to produce a plus or minus 1 percent discharge accuracy due to the relative effects of the precision of dial reading. The remainder of the error was due to the devices themselves. Some of the data scatter shown for the field-modified devices was due to including data obtained from the 12-inch (30.5-cm) meter that was improperly prepared for shipping and was found to be damaged.

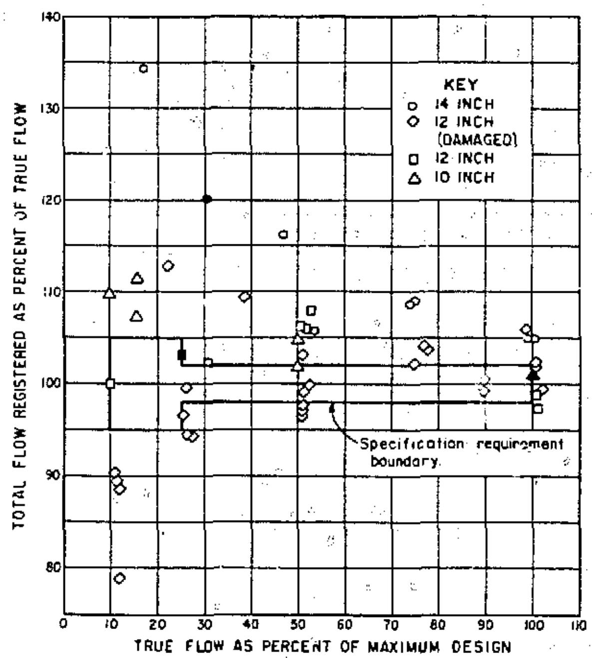


Figure 6. Totalization accuracy of used field-modified devices.

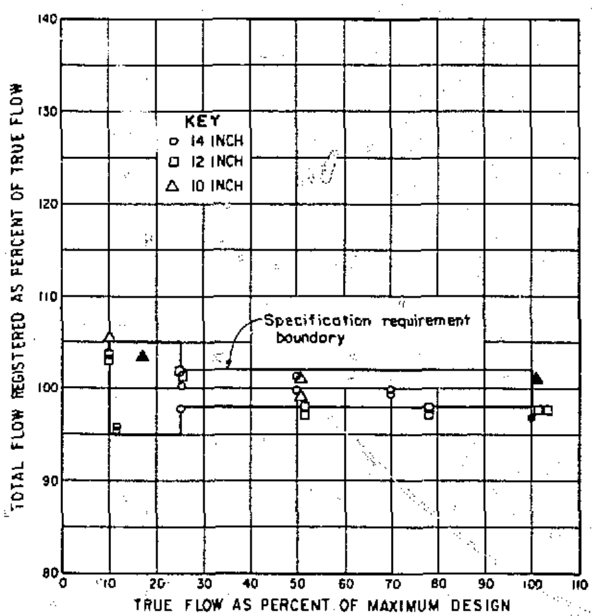


Figure 7. Totalization accuracy of newer-version devices.

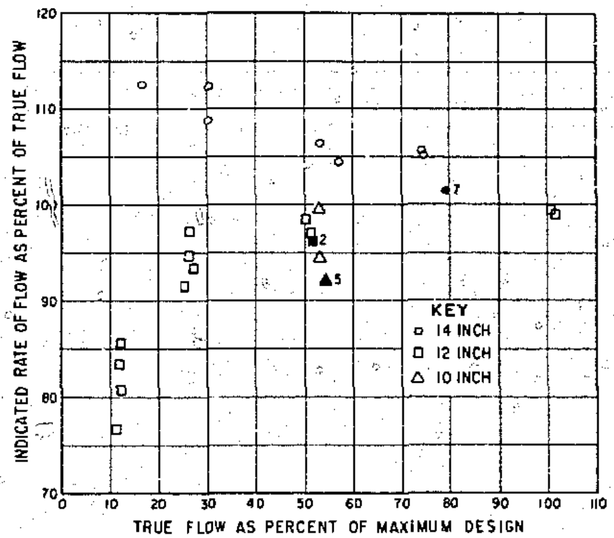


Figure 8. Rate of flow indication accuracy of the used field-modified devices.

Rate of Flow Indication

The field-modified devices operating near 50 percent maximum design discharge indicated flow in a 15 percent band, ranging from 92 to 107 percent of true flow, Figure 8. The new meters operating near 50 percent of maximum discharge fell in a 6 percent band ranging from 93 to 99 percent of true flow, Figure 9. The solid data points with numbers in Figures 8 and 9 represent multiple data points. It should be remembered that the laboratory discharge measurements are only accurate to within plus or minus 1 percent.

Closure Time Tests

Only the data for the field-modified 14-inch (35.6-cm) device fully complied with the specified closing time limits after the closure cycle was accepted internally, Figure 10. The vertical lines demark specified upper and lower specified closing time limits for the three sizes of devices. The solid data points represent double data points. One of the data points for the field-modified 10-inch (25.4-cm) device was out of specified range and two of the data points for the field-modified 12-inch (30.5-cm) devices that was properly shipped were out of specified range. However, all the data for the new version devices were within specified range after the closure cycle was accepted internally, Figure 11.

During closure tests, the field-modified 12-inch (30.5-cm) device that was improperly prepared for shipment, leaked. The amount of leakage varied from 3

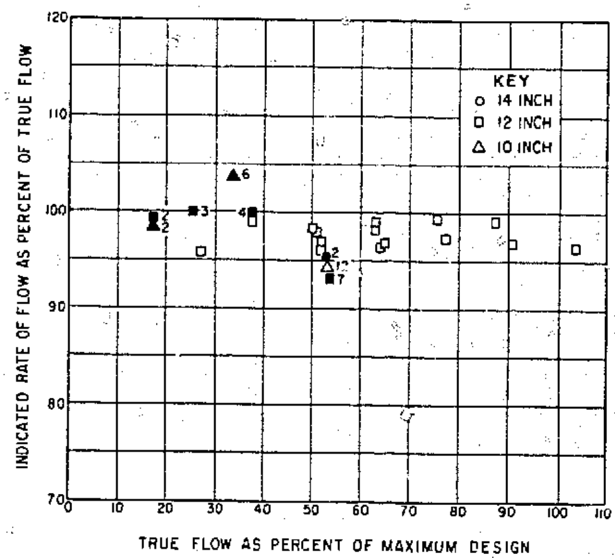


Figure 9. Rate of flow indication accuracy of the newer-version devices.

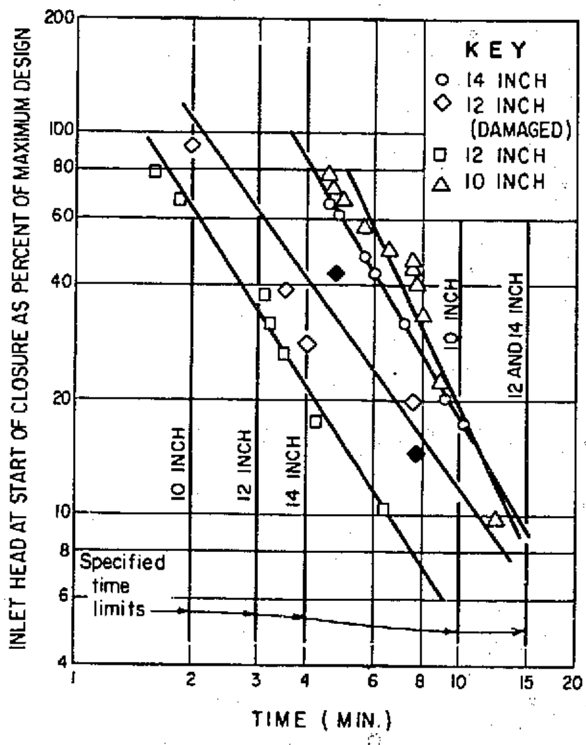


Figure 10. Closing characteristics of the used field-modified devices.

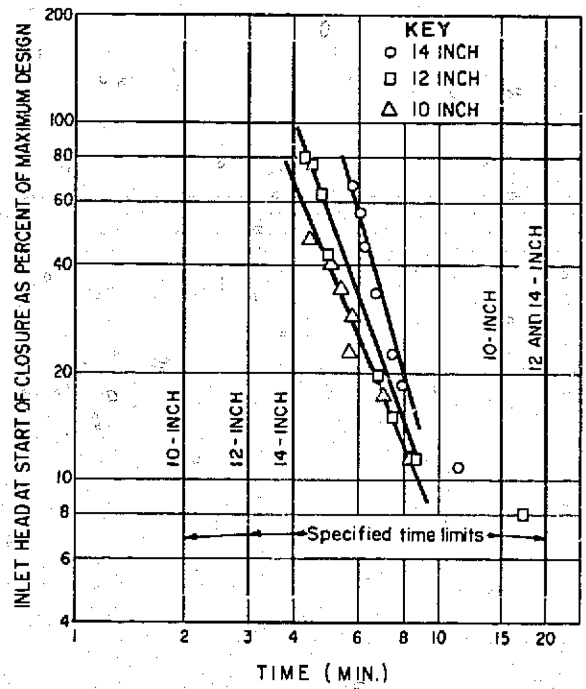


Figure 11. Closing characteristics of the newer-version devices.

gpm (0.19 lps) with the inlet head at the start of closure at 92 percent maximum design to 12 gpm (0.76 lps) with initial head at 17 percent maximum design. This device would not start to close below 7 percent maximum design head. The properly shipped field-modified 12-inch (30.5-cm) device failed to internally initiate closure twice. One failure was at a head of 66 percent of maximum design and another was at a head of 50 percent of maximum design. On one occasion, the new 10-inch (25.4-cm) device failed to internally initiate closure.

Discharge Response and Recovery After Pressure Decreases

The flow-controller will return the flow back to nearly its initially set discharge after a drop of pressure head provided pressure head does not go below the minimum required to deliver the set discharge. The pressure head reduces similar to a decay curve and the discharge reduces to a minimum value and returns to near its initial value. This response is shown qualitatively in the sketch of Figure 12. All sizes of the field-modified and new-version devices returned delivery to within plus or minus 3 percent of an initially set discharge, after each step change of pressure starting from 100 percent and successively

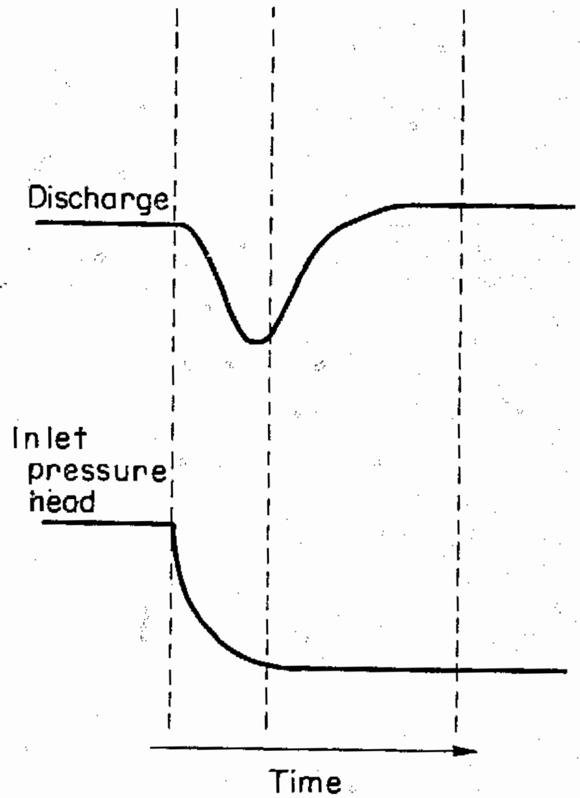


Figure 12. Qualitative diagram of flow-controller response to decrease of inlet pressure.

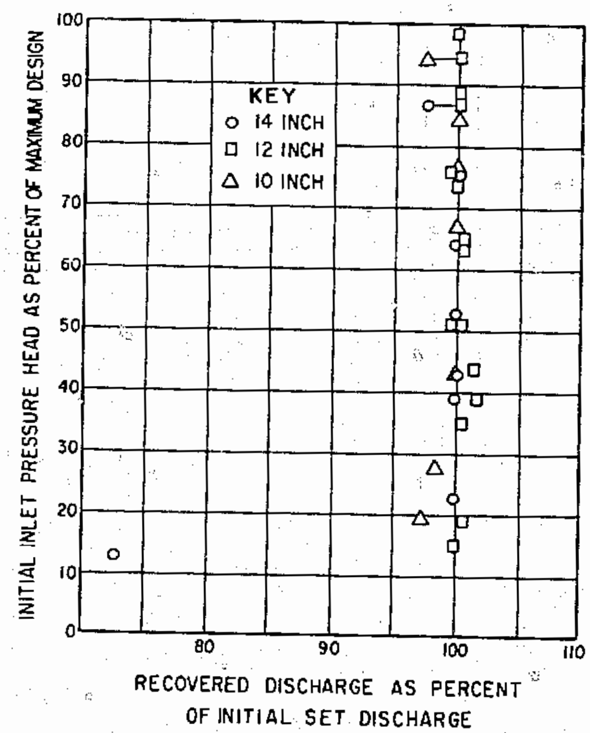


Figure 13. Discharge recovery after pressure decreases—Used field-modified devices.

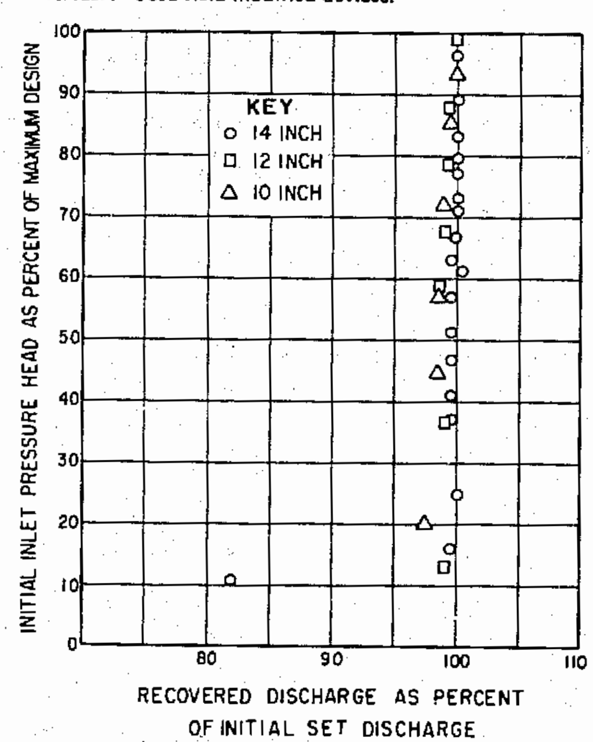


Figure 14. Discharge recovery after pressure decreases—Newer-diversion devices.

approaching 20 percent of maximum design head. These tests were performed with discharges set near 50 percent maximum and/or normal flow. These recovery data are plotted in Figures 13 and 14. It should be remembered that the laboratory discharge measurement was accurate to within plus or minus 1 percent.

Discharge Response and Recovery After Pressure Increases

Increase of inlet head, such as occur during normal operation of pumping plants, can overdrive the controller and the device will temporarily deliver more discharge than intended. This resonse is qualitatively shown in the sketch of Figure 15.

To further illustrate this response, data for the 12-inch (30.5-cm) used field-modified device will be described. Initial set discharges ranged from 44 to 78 percent maximum design. The maximum ratio of the maximum change of discharge to initially set discharge attained during laboratory tests was 0.74 at a corresponding pressure ratio of 4.3. The values used for this pressure ratio were the change of inlet pressure to the initially

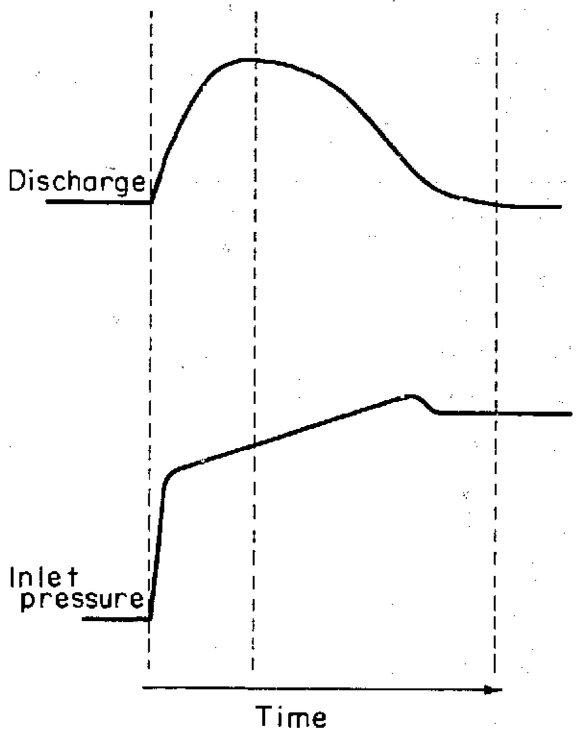


Figure 15. Qualitative diagram of flow-controller response to increase of inlet pressure.

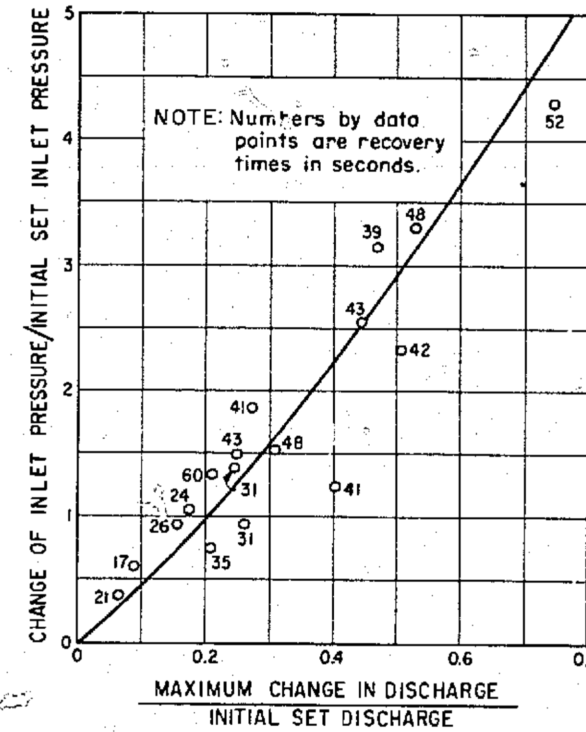


Figure 16. Discharge response and recovery after increase of inlet pressure—12-inch used field-modified device.

set inlet pressure. The recovery times varied from 17 to 60 seconds. The discharge ratios versus the pressure ratio are plotted in Figure 16. The numbers by the data points are recovery times in seconds. It should be remembered that the maximum possible overdelivery and time to recover could not be determined because tests were aborted whenever discharge or inlet pressure attained maximum design values.

FIELD PERFORMANCE REPORTS

From July 1970 to July 1971, Westlands Water District made monthly performance reports on the new version devices. Numerous failures, mostly associated with the integrator units were as follows:

(1) Clocks have stopped.

(2) The clock driven magnets and the reed switches that pulse the integrator motors have come loose.

(3) The motors have failed.

(4) The magnets on the rotor assembly have not held their adjustment.

(5) The clutches that drive the stroking arms of the totalizers have slipped.

(6) The motor micro limit switches that stop the integrator rotors after each totalization stroke have ceased to function.

(7) The lower micro limit switches that break the circuit to the integrator motors when there is no flow have not operated properly.

(8) The external 1/2-inch (1-1/4-cm) valves that actuate shutoff of the main flow have leaked, thus causing failures of closure.

CONCLUSIONS

1. None of the field-modified devices tested fully complied with specified totalization accuracy requirements. Possible contributing reasons are inadequate modification, field use, shipping damage, and inadequate mechanical design.

2. All the new version devices tested did comply with specified totalization accuracy requirements within

laboratory measuring capability. The effectiveness of the new-version mechanical design will be more fully determined from field operation and maintenance experience. However, visual inspection indicates that the manufacturer has made efforts to provide a more rugged version that is more likely to maintain calibration more effectively than the used modified devices.

3. All devices tested complied with the specified 30-inch (76.2-cm) water head loss maximum allowed at normal flow, except the used field-modified 14-inch (35.6-cm) device which had twice the maximum allowed head loss. It was concluded that this large loss was caused by internal damage.

4. All clock and timing circuits that were shipped with both the used field-modified and new-version devices produced errors of totalization. The new transistorized version developed by the manufacturer during the test period operated satisfactorily in the laboratory. However, field reliability will have to be determined from operation and maintenance experience.

5. Other mechanical problems, such as leakage, refusing to internally recognize closure initiation, and slowness or refusal to assume control, were mostly related to low line pressure or prior periods of no line pressure.

6. Vibration difficulties were experienced with the used field-modified 12-inch (30.5-cm) device that was not properly prepared for shipping. The totalizing cam came loose once and the set point crept to maximum delivery. Possible contributing reasons are field use, shipping damage, and inadequate mechanical design.

7. All the devices that were tested returned flow back to within plus or minus 3 percent of a set discharge for pressure changes within a head range from 100 to 20 percent of maximum design head.

8. Pressure increases such as might be caused by normal pump system operation can cause large temporary overdelivery. Maximum time to recover and maximum overdelivery could not be determined because the tests were aborted whenever maximum pressure and discharge specifications were exceeded.

9. Mechanical problems experienced in both the laboratory and the field indicate that further research and development by the manufacturer are needed to improve reliability of the devices.

APPLICATION

Further field experience, along with the material presented in this report, can be used to help determine if the flowmeter and flow-control devices are feasible for use in particular projects and to aid in writing equipment purchase specifications that more fully consider the peculiar characteristics of those projects. No further laboratory tests are recommended until further research and development has been performed by the manufacturer.

APPENDIX

EXCERPT FROM MANUFACTURER CORRESPONDENCE

Upon complete disassembly and visual inspection of the two meters, the following observations and conclusions were made:

A. 12" Meter, Serial No. 6612-69817/25
Total acre feet 685.97
Checked OK in California 2/19/69
Retrofit Integrator

1. Damaged lower helix bearing causing "dead band." This probably due to damage in shipment.

2. Sand and dirt particles found in instrument case and critical bearing surfaces. This would indicate that case was not kept closed.

3. Float rod damaged and bent. (Refer to Photographs 1, 2, 3, and 4, taken at Bureau.)

a. Float rod bent as indicated by wear spot on extension (Photographs 1 and 2.)

b. Pilot plug shows wear on one side of seating surface (Photograph 3). Approximately 0.040 inch flat on plug. This caused by misalinement of magnet extension.

c. Float rod shows indentation damage of approximately 3/8 inch diameter by 1/16 inch deep (Photograph 4) in critical area. This area passes through restriction ring in main valve. In this condition, error "over" amount of pilot flow will be created, causing a controlling error.

d. Total runout measured from float head to magnet extension 1/4 inch TIR.

4. Plug "O" Ring damaged. One-half section of this ring missing and vent holes plugged with epoxy, making tight shutoff impossible.

Conclusion: Misalinement probably caused by improper shipment. Damage to float rod happened when meter in severe service.

B. 14" Meter, Serial No. 6612-69818/35
Total acre feet 1,015.00
Checked OK in California 12/19/68

1. Set point adjustment "frozen"—cause unknown. This, of course, makes the unit inoperable.

2. Excessive dirt and corrosion inside cases (Photograph 5). Evidence of moisture inside case. This indicates that case was kept open in service.

3. When float rotated at "no flow" position, flow indicating pointer moved approximately 3/16 inch, indicating a bent float rod. Runout measured from float head to magnet extension 3/16 inch. This condition caused by improper shipping.

4. Main valve seat shows damage probably caused by foreign object on seat during closure.

5. Main valve "O" Ring damaged and small pieces missing, probably caused by foreign object on seat during closure.

Based on the above findings, these meters do not in any way represent the instruments as shipped.

The damages are definitely indicated as improper shipment and unnecessary abuse in field service.

The following steps must be taken to return the meters to original operation:

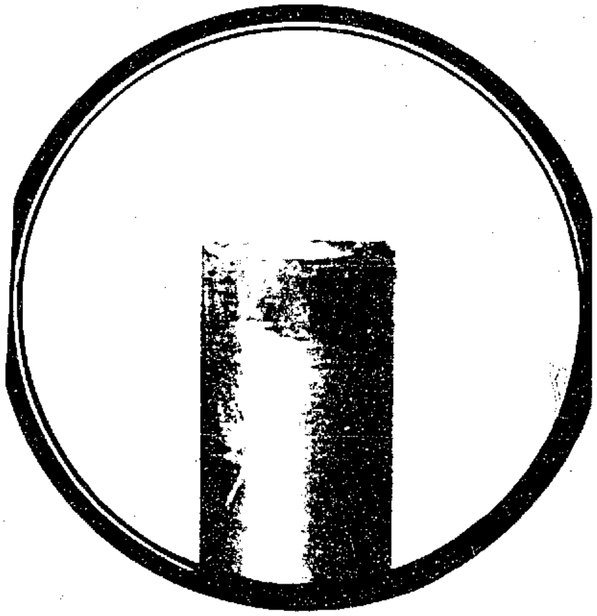
12" Meter

1. Replace float
2. Rebuild integrator
3. Rebuild plug and replace "O" Ring
4. Completely inspect working parts
5. Test and recalibrate

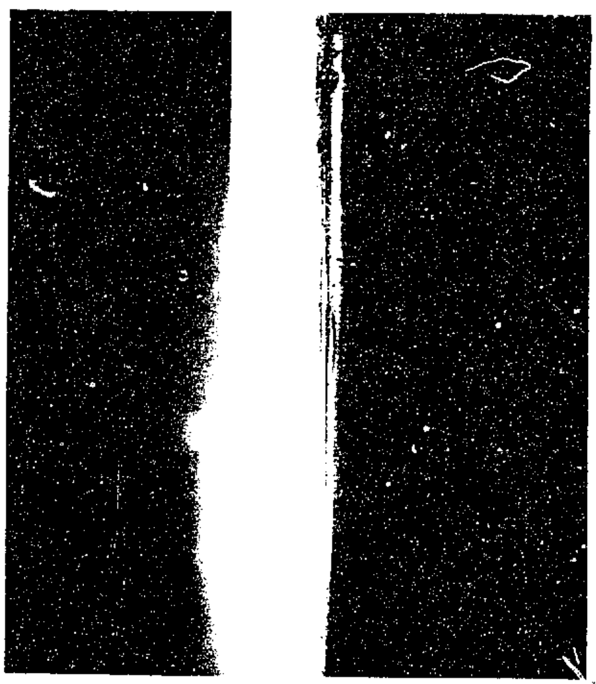
14" Meter

1. Straighten float rod if possible and refinish pilot plug
2. Replace integrator case and extension well
3. Completely inspect working parts
4. Test and recalibrate

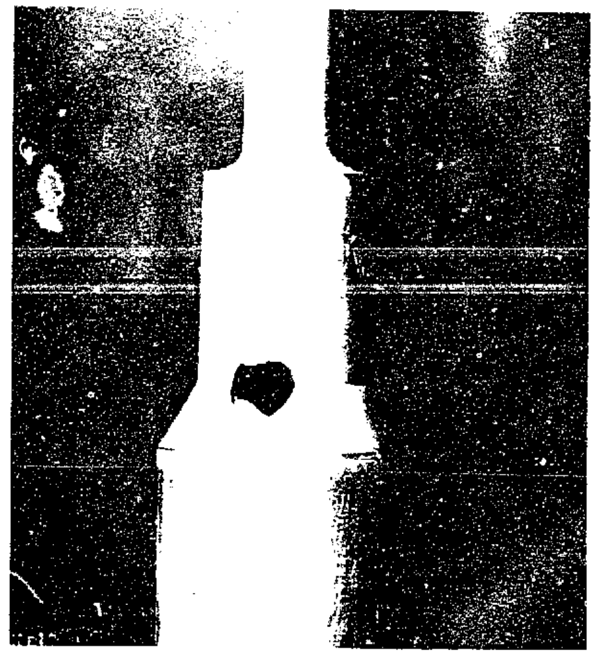
In addition to the above steps, meters should be repainted and repaired as required.



Inspection Photograph 1. PX-D-70495

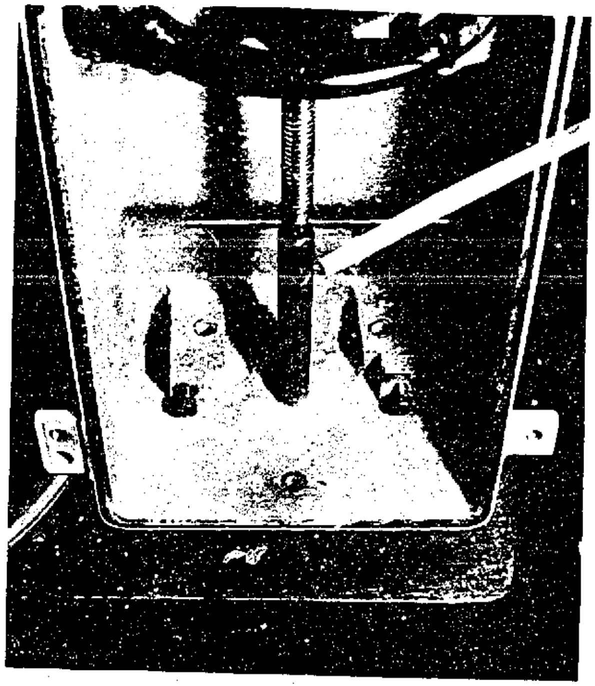


Inspection Photograph 2. PX-D-70496



Inspection Photograph 3. PX-D-70497

Inspection Photograph 4. PX-D-70498



Inspection Photograph 5. PX-D-70500

GPC 839-951

CONVERSION FACTORS–BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg, that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
LENGTH		
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
Inches	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
Feet	0.3048 (exactly)*	Meters
Feet	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
Miles	1.609344 (exactly)	Kilometers
AREA		
Square inches	6.4516 (exactly)	Square centimeters
Square feet	*929.03	Square centimeters
Square feet	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	*0.40469	Hectares
Acres	*4,046.9	Square meters
Acres	*0.0040469	Square kilometers
Square miles	2.58999	Square kilometers
VOLUME		
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
CAPACITY		
Fluid ounces (U.S.)	29.5737	Cubic centimeters
Fluid ounces (U.S.)	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
Liquid pints (U.S.)	0.473166	Liters
Quarts (U.S.)	*946.358	Cubic centimeters
Quarts (U.S.)	*0.946331	Liters
Gallons (U.S.)	*3,785.43	Cubic centimeters
Gallons (U.S.)	3.78543	Cubic decimeters
Gallons (U.S.)	3.78533	Liters
Gallons (U.S.)	*0.00378543	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
Gallons (U.K.)	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	*764.55	Liters
Acre-feet	*1,233.5	Cubic meters
Acre-feet	*1,233,500	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
Short tons (2,000 lb)	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
Pounds per square inch	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
Pounds per square foot	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
Pounds per cubic foot	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
Inch-pounds	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
Foot-pounds	1.35582×10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
Feet per second	0.3048 (exactly)*	Meters per second
Feet per year	*0.965873×10^{-6}	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
Miles per hour	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	*0.3048	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	*0.028317	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	*0.453592	Kilograms
Pounds	*4.4482	Newtons
Pounds	*4.4482×10^5	Dynes

Table II—Continued

Multiply	By	To obtain
WORK AND ENERGY*		
British thermal units (Btu)	*0.252	Kilogram calories
British thermal units (Btu)	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	*1.35582	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 degree F (k, thermal conductivity)	1.442	Milliwatts/cm degree C
Btu in./hr ft^2 degree F (k, thermal conductivity)	0.1240	Kg cal/hr m degree C
Btu ft/hr ft^2 degree F	*1.4880	Kg cal m/hr m^2 degree C
Btu/hr ft^2 degree F (C, thermal conductance)	0.568	Milliwatts/cm^2 degree C
Btu/hr ft^2 degree F (C, thermal conductance)	4.882	Kg cal/hr m^2 degree C
Degree F hr ft^2/Btu (R, thermal resistance)	1.761	Degree C cm^2/milliwatt
Btu/lb degree F (c, heat capacity)	4.1868	J/g degree C
Btu/lb degree F	*1.000	Cal/gram degree C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
Ft^2/hr (thermal diffusivity)	*0.09290	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor) transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	*304.8	Liters per square meter per day
Pound-seconds per square foot (viscosity)	*4.8824	Kilogram second per square meter
Square feet per second (viscosity)	*0.092903	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	*35.3147	Millicuries per cubic meter
Milliamps per square foot	*10.7639	Milliamps per square meter
Gallons per square yard	*4.527219	Liters per square meter
Pounds per inch	*0.17858	Kilograms per centimeter

ABSTRACT

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Bur Reclam Rep REC-ERC-71-48, Div Des, Div Gen Res, Dec 1971, Bureau of Reclamation, Denver, 19 p, 16 fig, 1 tab, 5 photo, append

DESCRIPTORS--/ hydraulics/ *discharge measurement/ water delivery/ water measurement/ flow control/ *head losses/ flowmeters/ calibrations/ tests/ product evaluation/ *flow measurement/ laboratory tests/ accuracy/ field tests/ performance/ vibration

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