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**UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION**

LABORATORY STUDY--FISCHER-PORTER PUNCHED TAPE WATER FLOW RECORDER

Report No. Hyd-559

Hydraulics Branch
DIVISION OF RESEARCH

**OFFICE OF CHIEF ENGINEER
DENVER, COLORADO**

September 15, 1966

HYD 559

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ABSTRACT

A Fischer-Porter punched tape water flow meter and recorder for use in 12-in. pipe was studied in the hydraulic laboratory. This is a tapered-tube variable-area-type meter of 0.7 to 7.0 cfs capacity. The meter records by punching coded holes in paper tape. The meter was developed to provide automatic billing to the water user by computer processing of punched tape. When suitably calibrated, meter accuracy varies from about $\pm$ 3.6% at 0.7 cfs to about $\pm$ 0.6% at 7.0 cfs. Head losses were measured for the meter and varied from about 3.0 ft of water head at 0.7 cfs to about 6.0 ft at 7.0 cfs. The head losses for the meter tube alone varied from about 0.03 ft of water at 0.7 cfs to about 2.3 ft of water at 7.0 cfs. The float responded well to changes of discharge and was stable to within 1 punched coding unit for discharges set during tests. Laboratory experience with this 1 meter indicated no apparent operational difficulties except that an air-water mixture flowing through the meter produced shaking and vibration. No long or continuous operating tests were performed to determine dependability or ruggedness of construction.

DESCRIPTORS-- *hydraulics/ *discharge measurement/ water delivery/ water measurement/ errors/ *water meters/ water metering/ digital recording systems/ *head losses/ punched paper tapes/ flow meters/ calibrations
IDENTIFIERS-- variable area meter/ Fischer-Porter flow meter/ product evaluation

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Special Investigations Section
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LABORATORY STUDY OF A FISCHER-PORTER PUNCHED TAPE WATER FLOW METER AND RECORDER

SUMMARY

Fischer-Porter punched tape water flow meter and recorder, No. 6410A1950A1 for use with nominal 12-inch pipe, was tested in the Hydraulics Laboratory at the request of Region 2 and the Canals Branch, Office of Chief Engineer. This meter was developed to provide records of irrigation water delivery punched on paper tape for automatic accounting and billing of water users.

The meter is a tapered-tube variable-area-type flowmeter in which a "meter float" (actually a weight) rides in the flow passing through a tapered "flow tube," Figures 1 and 2. The meter weight has a "drive rack" extension that engages gears to position a "coding disc" for punching of the tape when the action is initiated by a battery-energized and clock-driven cam.

The meter was installed in the laboratory just downstream from a mitered elbow, similar to the Type "A" delivery for the Westlands Water District. After the meter installation and performance were checked, calibration and head loss tests were conducted.

The meter passed more water than given in the Fischer-Porter correlation table for discharges less than 4.5 cfs (cubic feet per second) i.e., overregistered and underregistered for discharges more than 4.5 cfs. The maximum deviation for both overregistration and underregistration was about 5 percent. However, the laboratory calibration tests showed that the accuracy of the meter varied from about plus or minus 3.6 percent at 0.7 cfs to about plus or minus 0.6 percent at 7.0 cfs.

Head losses determined for the flow meter varied from about 3.0 feet of water at 0.7 cfs to about 6.0 feet of water at 7.0 cfs. These losses are considered high as compared to losses for other meters of similar capacity.

Head losses were also determined for the meter tube alone, i.e., the flow tube and the meter float were removed, Figure 2. The head losses for the meter tube alone varied from about 0.03 feet of water at 0.7 cfs to about 2.3 feet of water at 7.0 cfs.

After the calibration and head loss tests were completed, the metering elements of the meter were inspected. Minor deposits of foreign material from the water were found on the drive rack, lower float extension, in the lower float extension bearing, and on the upper outside of the flow tube.

The significance of these deposits, considering the short testing period and the fact that relatively clean laboratory water was used, is not known.

Throughout all the operational tests, for discharges selected within the 0.7- to 7.0-cfs range of the meter, the float responded well to changes in discharge and was stable to within one punched coding unit for a set discharge. Also, there were no apparent operational difficulties except when an air-water mixture flowed through the meter; shaking and vibration resulted. There has not been enough experience with these meters, either in the laboratory or in the field, to evaluate their reliability over a period of time.

INTRODUCTION

The punched tape water flow recorder was developed to fill the need for simplified recording of water use and billing of the water user. The punched tape removed at regular intervals from the meter, can be fed through a translator and into a computer for processing. The punched tape unit of the meter can be locked to prevent meddling without restricting operating procedures. Also, using additional equipment, meter readings can be telemetered to a center for recording and processing to simplify the management of a distribution system.

Basic Principles of the Meter

This water flow meter is a member of a class called tapered-tube variable area flow meters which includes devices such as Bentzel tubes used to measure low velocities and Rotometers commonly used to measure discharge rates in industrial processes. Figure 1 shows a simple Rotometer. These devices have a shaped indicator weight (sometimes erroneously called a meter float) supported within a tapered meter tube by the flow of the fluid being metered. The indicator weight (shaped to provide stability in the flow) responds to any given rate of flow within the measuring range of the instrument. For each discharge the weight seeks and attains a unique elevation within the tapered meter tube. In this position the submerged weight just balances the force of the upward flow of the fluid being metered. Therefore, the weight itself can be used to indicate the discharge. The markings on the tube can be graduated in any desired measuring units. The annular-flow passage area between the shaped meter weight and the tapered-tube walls varies with discharge for both the Bentzel meters and the Rotometers; they are, therefore, also properly included in the variable area flow meter class. In some variable area flow meters the position of the meter float is indicated by a rod attached to the weight, which, through suitable linkage, actuates a recorder or telemetering device.

Description of the Meter

The Fischer-Porter punched tape recorder is a larger and more elaborate form of the usual variable area flow meter. As shown in the exploded view in Figure 2, the tapered flow section is labeled "flow tube." At the bottom of the flow tube there is a spider-held bearing (not shown) through which the "lower float extension" passes to keep the "meter float" centered. The "drive rack and upper float extension" mesh with the "punched tape recorder" gears. The gears convert the up and down movements of the meter float into a rotation of the "coding disc." The position of the disc determines what the punched tape reading will be when the electrically clock-driven cam initiates the punching sequence at 15-minute intervals. During the punching sequence the coding disc is temporarily locked in position. After punching, the coding disc is released and allowed to follow the motions of the meter float again. Each punching is a horizontal line (as oriented in Figure 3) of information consisting of either one or no perforation in each of the vertical column spaces in the line.

Interpretation of Punched Tape

The punched tape is interpreted as follows: The larger holes (shown in black) in the vertical center column (as oriented in Figure 3) are "sprocket drive or time holes" that been prepunched in the tape. The numbers printed in this column are hours. Thus, each printed horizontal line indicates the beginning or ending of 15-minute time intervals. The smaller holes (shown in white) punched in the black columns are "translator alinement holes" and are punched every 15 minutes. The punched tape recorder was designed for other uses requiring up to four-place numbers. The water flow recorder uses a two-place number from 00 to 99. Therefore, the portion of the tape to the left of the sprocket drive or to the left of the time holes is not used in this meter except for the left translator alinement holes.

Each of the used decimal channels marked "tens" and "units" in Figure 3 consists of four binary columns, all having values of 0 when not punched and values of 8, 4, 2, 1, respectively, when punched. These numbers are printed on the tape. The decimal reading in either the unit or tens channel is equal to the sum of the punched column values (see sample values in Figure 3). The discharge is then determined from a correlation table furnished with the meter that gives the number of cubic feet per second (or other units) in terms of the punched tape readings. For example, all zeros (no punches) in the 8, 4, 2, and 1 columns of the tens channel together with a sum of 6 (punched holes in the 4 and 2 columns) and no punches in the 8 and 1 columns of the units channel represents a reading of 06 or 0.70 cfs. A sum of 9 (an 8 and 1 punch in the tens channel) together with a sum of 8 (an 8 punched in the units channel) represents a reading of 98 or 7.00 cfs. These two discharges are the capacity limits of the meter. The sample tape also shows an intermediate punched reading of 47 which corresponds to a discharge of 3.10 cfs.

LABORATORY STUDIES

Test Facilities

Installation.--The Fischer-Porter punched tape recorder was installed in a pipeline connected to the water supply and discharge measurement system of the hydraulic laboratory (Figures 4 and 6). The test facility for the meter included 20 feet of 12-inch-diameter straight approach pipe, a mitered elbow similar to that used in a Type "A" delivery in the Westlands pipe distribution system, the flow meter and a pipe attached to the 10-3/8-inch-diameter side outlet of the meter to return the water to the laboratory supply.

Checkout.--The relationship of the punched tape output reading and the discharge scale on the coding disc was checked to assure proper adjustment of the meter and to be sure that no damage had occurred to the meter in shipment or during installation. Before the meter tests in the laboratory were begun, the drive rack (Figure 2) was disconnected from the punched tape input. The discharge scale on the right-hand coding disc (Figure 4C) was then positioned to a selected discharge reading between 0.7 and 7.0 cfs, and the punch was operated to provide a tape reading. These discharge scale and punched tape readings were then compared to the table supplied by the manufacturer. The table and the laboratory check of the punched tape and discharge dial scale relationship agreed or was within plus or minus one-half unit of the tape reading for each selected discharge position of the dial. Therefore, the meter was considered to be in working order after shipment and laboratory installation.

Preliminary operation.--Short tests conducted throughout the rated range of the flow meter showed that the float responded well to changes of discharge in the flow tube and was stable during test runs to within one punched coding unit. There were no apparent operational difficulties in the rated discharge range of the meter except when an air-water mixture flowed through the meter; shaking and vibration resulted. This latter condition occurred during the period of filling the test pipeline with water and might occur under similar conditions in an irrigation system. However, there was no apparent permanent detrimental effect on the meter or punched tape recorder for the few times the air-water flow occurred in the laboratory.

Calibration

Technique and data obtained.--Flow through the meter was measured by volumetrically calibrated sets of Venturi meters ranging in size from 6 to 12 inches. The discharges indicated by these Venturi meters are accurate to plus or minus 0.5 percent. Simultaneous recordings of the punched tape flow meter and Venturi discharges were made by actuating the punch out sequence of the tape recorder while reading the manometer differential of the Venturi meter. Thus, the discharges through the Venturi and flow meter were measured and indicated within the same time period. Fifty-three points were plotted for determining the calibration Curve A, (Figure 5), and each point was determined by averaging from 5 to 10 punched recordings.

Results of the calibration.--None of the 53 average punched readings versus Venturi discharge readings deviated from Curve A (Figure 5) by more than plus or minus 0.5 of a punch unit at any discharge in the range of the meter. Therefore, the accuracy of the punched tape water flow meter can be calculated at any discharge by applying this deviation to the laboratory calibration. The accuracy varied from about plus or minus 3.6 percent at 0.7 cfs to about plus or minus 0.6 percent at 7.0 cfs.

For comparison with the laboratory calibration plotted in Figure 5 as Curve A, the correlation table data supplied by Fischer-Porter was plotted in Figure 5 as Curve B. Differences between these two curves were used to compute the percentages of over and under registration plotted in Figure 5 as Curve C. Inspection of Curves A, B, and C shows that the table furnished by Fischer-Porter and the laboratory calibration were in good agreement at about 4.5 cfs and for discharges less than 1 cfs. The laboratory calibration showed that more water flowed through the meter for discharges above 4.5 cfs than indicated by the table, and less water for discharges smaller than 4.5 cfs.

Head Loss Tests

Head losses for entire meter. --The laboratory installation for head loss measurements was essentially the same as for the calibration tests except that piping and a valve were connected to the 10-inch-diameter outlet of the meter to provide a pressure head on the delivery flow equal to the head required for the Westlands Water District.

After the testing arrangement was modified in preparation for head loss measurements, additional calibration data were obtained for the discharges against the 5 feet of the delivery head or back pressure. These data confirmed the previous calibration data in Curve A, Figure 5, i.e., that the back pressure did not effect the calibration of the meter.

Piezometers located in the 12- and 10-3/8-inch pipes, as shown in the sketch in Figure 6, were used as a gage when the outlet delivery head was set at 5 feet, and to measure pressure head differences across the flow meter for various discharges in the range of 0.7 to 7.0 cfs.

The pressure head differences were plotted in Figure 6 as Curve A. The head losses were then computed and plotted in Figure 6 as Curve B. The difference between the pressure head and the head loss curve at a given discharge represents the difference in the velocity heads in the 12-inch inlet and the 10-3/8-inch outlet of the meter. The head loss varied from about 3.00 feet of water at 0.7 cfs to about 6.00 feet of water at 7.0 cfs. The head loss for the entire meter does not approach zero loss at no flow. This apparent anomaly is explained by the fact that the meter float must be forced from the seat at the bottom of the flow tube before any appreciable flow occurs. The meter float weighs 50 pounds and has a 7-inch-diameter projected area normal to the vertical flow axis of the meter. A pressure equivalent to 3 feet of water head on this projected area is required to lift the unsubmerged meter float off the bottom seat. Lift-off for the float when submerged requires 2.6 feet of water head. Further loss is caused by the contraction and expansion of the flow as it passes through the annular space at the meter float (Figure 2). The spider-held bearing (Figure 8) at the bottom of the flow tube contributes to the head loss by partially blocking the flow. The right-angle bend from the meter tube into the outlet and the fact that flow in the bend is further obstructed by the rack and upper front extension also add to the head loss. Some of the head loss represents energy required to overcome the friction between mechanical parts.

Head losses for the meter tube alone.--At the request of Region 2 and the Canals Branch of the Denver Office, head losses were determined for flow through the meter tube after the flow tube and meter float (the shaded parts shown in Figure 2) had been removed. The pressure head differences were measured with the same piezometers used in the previous head loss tests. The same approach and outlet flow conditions and discharge measuring equipment were also used.

The pressure head differences measured for the various discharges in the range 0.7 to 7.0 cfs were plotted in Figure 6 as Curve C. The head losses were then computed and plotted in Figure 6 as Curve D. The difference between the pressure head and head loss curve at a given discharge represents the difference in the velocity heads in the 12-inch inlet and the 10-3/8-inch outlet of the meter. The head losses varied from about 0.03 foot of water at 0.7 cfs to about 2.3 feet of water at 7.0 cfs. Curve D passes through zero and attains losses nearly equal to the values that can be computed for flow through the side outlet of a tee.

Inspection of parts removed for meter tube tests.--When the flow tube and the meter float were removed in preparation for the meter tube loss tests, the meter parts were inspected as a matter of course. Minor rust-like deposits were noted on the rack of the upper float extension, the lower float extension, and in the float extension bearing. The deposits shown in Figure 7 were easily removed with steel wool. There was also a thin black deposit 1-1/4 inches wide on the outside of the flow tube about 1/4 inch down from the top lip. This deposit was tenaciously attached but could be removed by steel wool. There was no indication of corrosion, pitting, or etching beneath any of the deposits.

CONCLUSIONS

Based on laboratory experience of one punched tape water flow recorder, the following was concluded:

1. During all the tests there were no apparent operational difficulties, except when an air-water mixture flowed through the meter; vibration and shaking resulted.

2. The float responded well to changes in discharge and was stable to within one punched coding unit for a set discharge.

3. Laboratory calibration data showed that the accuracy varied from about plus or minus 3.6 percent at 0.7 cfs to about plus or minus 0.6 percent at 7.0 cfs, assuming plus or minus 0.5 of a punch unit.

4. The laboratory calibration indicated overregistration with respect to the Fischer-Porter correlation table for discharges below 4.5 cfs and underregistration above 4.5 cfs. The maximum deviation for both overregistration and underregistration was about 5 percent.

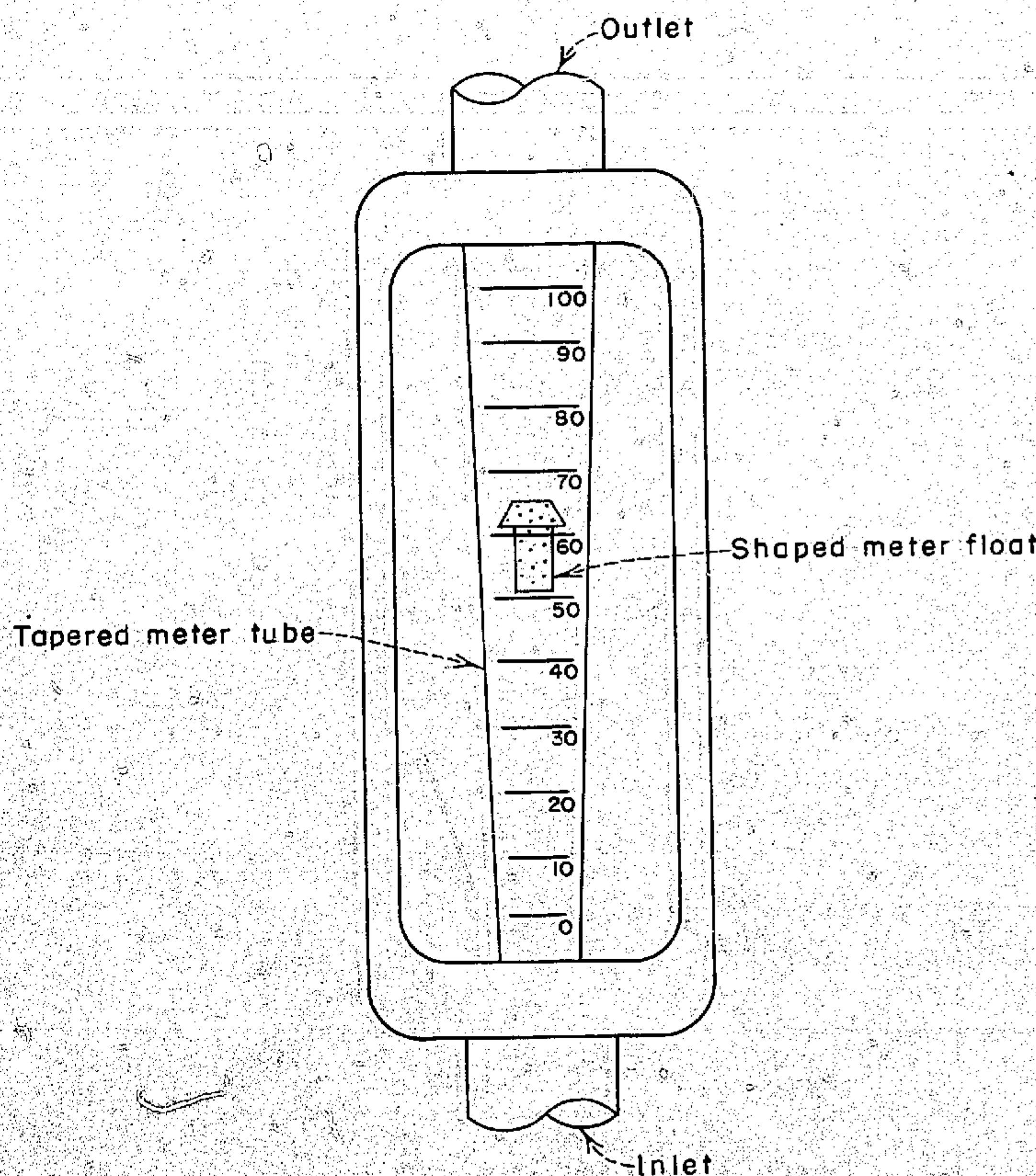
5. The head loss of the entire meter varied from about 3.0 feet of water at 0.7 cfs to about 6.0 feet of water at 7.0 cfs.

6. The head loss for the meter tube alone varied from about 0.03 foot of water at 0.7 cfs to about 2.3 feet of water at 7.0 cfs.

7. Minor deposits (from the water) were found on the float rack, lower float extension, in the lower float extension bearing, and on the upper outside of flow tube. These deposits could be removed with steel wool. There was no evidence of corrosion under any of the deposits.

8. The punched tape water flow recorder can provide a record of water deliveries. The advantages of this meter are: (a) Automatic billing of the water user can be accomplished by telemetering readings to a computer complex or by feeding the punched tape directly into computer equipment; (b) The meter can be used to provide feedback information for automatic control of a water system.

9. Possible disadvantages of the meter are: (a) Sediment, chemical or biological deposits in the space between the lower float extension and the guide bearing and/or deposits in the sealed gearbox could restrict the upward or downward movement of the float; (b) Weed and algae streamers entangled on the float and guide could prevent free movement of the float and cause erroneous discharge indications; (c) Wind-blown sand or water could enter an improperly seated cover assembly to cause malfunctioning of the punched tape recorder; (d) Battery failure could stop the flow recording; (e) Mechanical wear and maintenance could be a problem as with any other mechanically operated measuring device; and (f) Exceeding the manufacturer's specified temperature range of minus 35° to 122° F could result in operational difficulties.



FISCHER-PORTER PUNCHED TAPE FLOW METER STUDY
SIMPLE ROTOMETER

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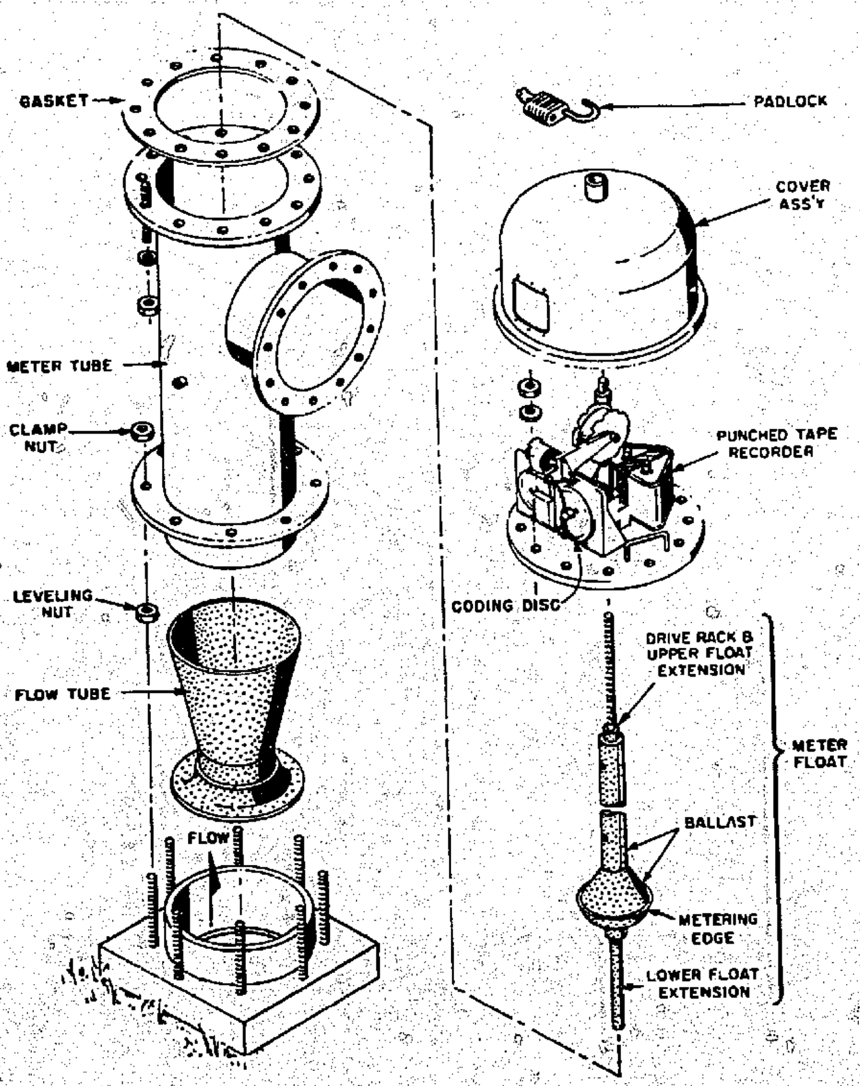
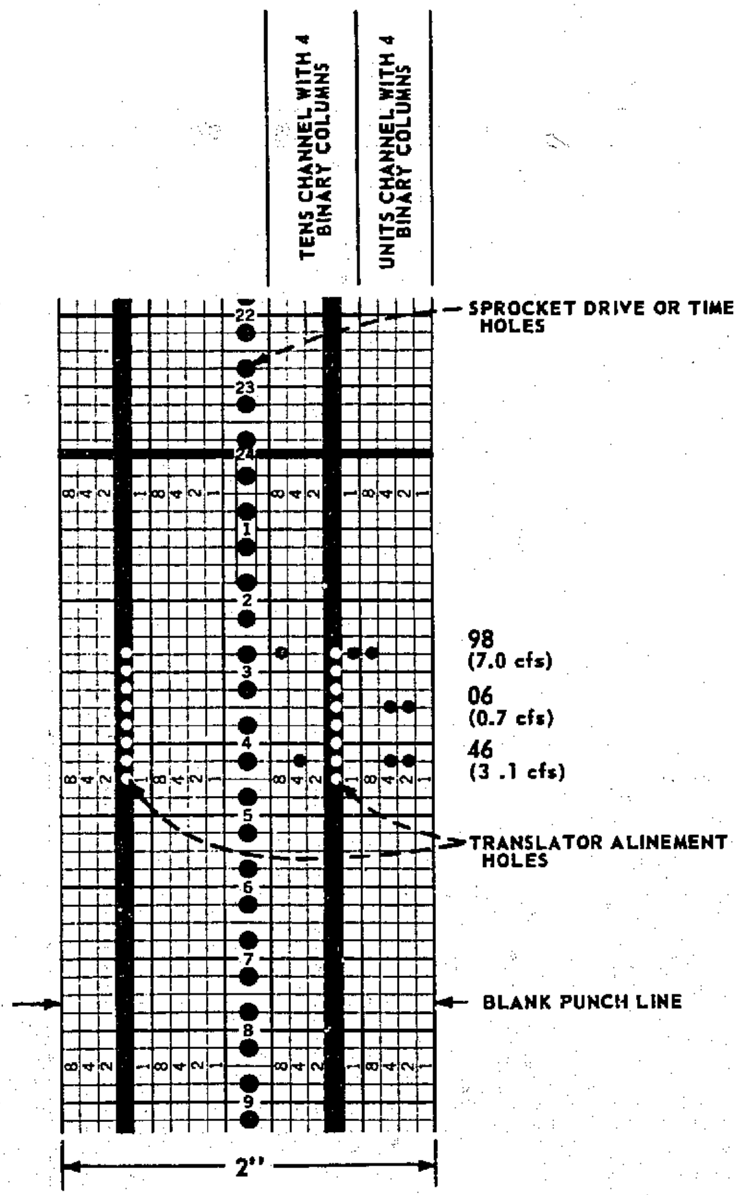


Fischer-Porter Punched Tape Flow Meter Study

EXPLODED VIEW OF PUNCHED TAPE WATER FLOW RECORDER



Fischer-Porter Punched Tape Flow Meter Study

PHOTOGRAPH OF PUNCHED TAPE

Figure 4
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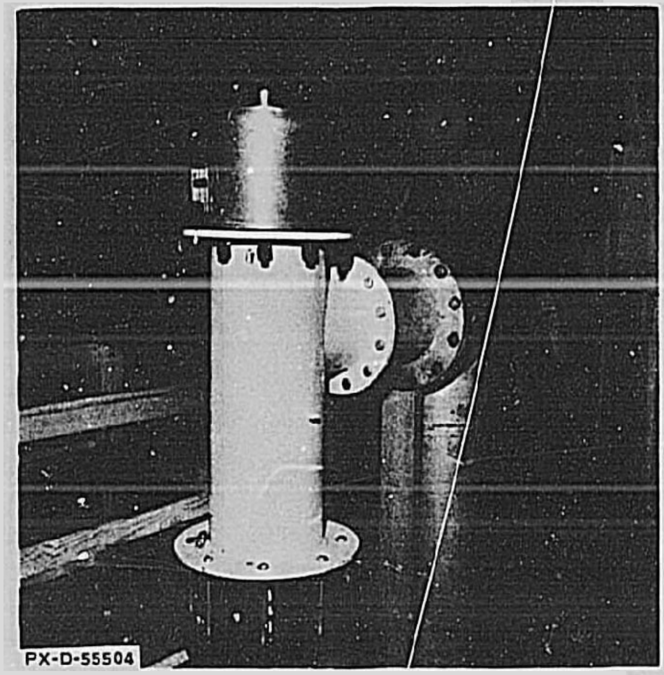
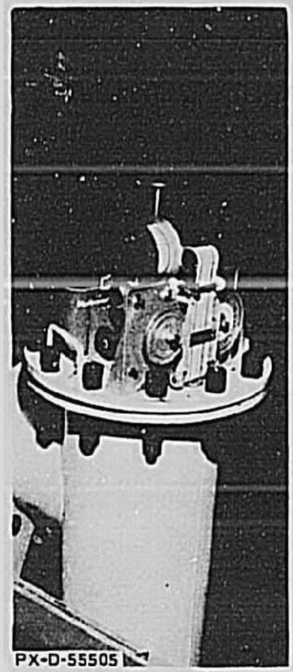
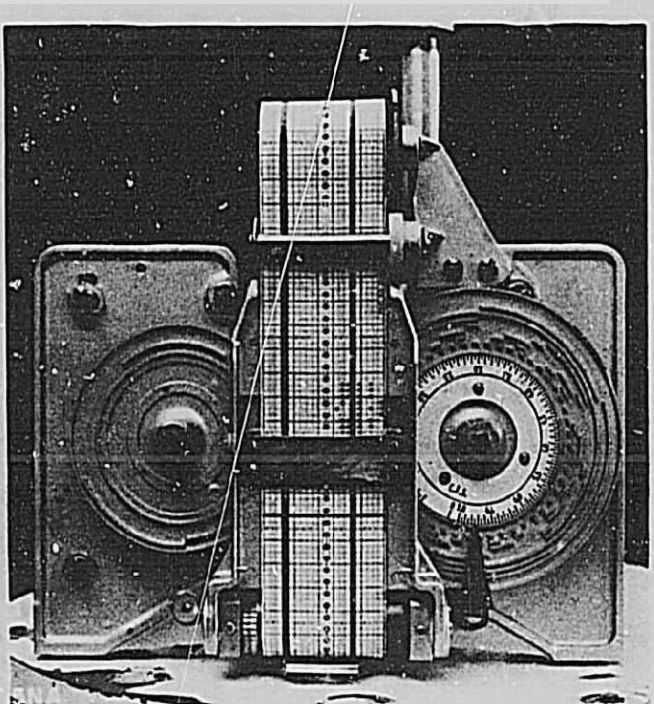


A. Meter and covered recording unit.



B. Recording unit uncovered



C. Punched tape and coding disc with discharge scale dial.

Fischer-Porter Punched Tape Flow Meter Study

METER INSTALLATION AND RECORDER

FIGURE 5
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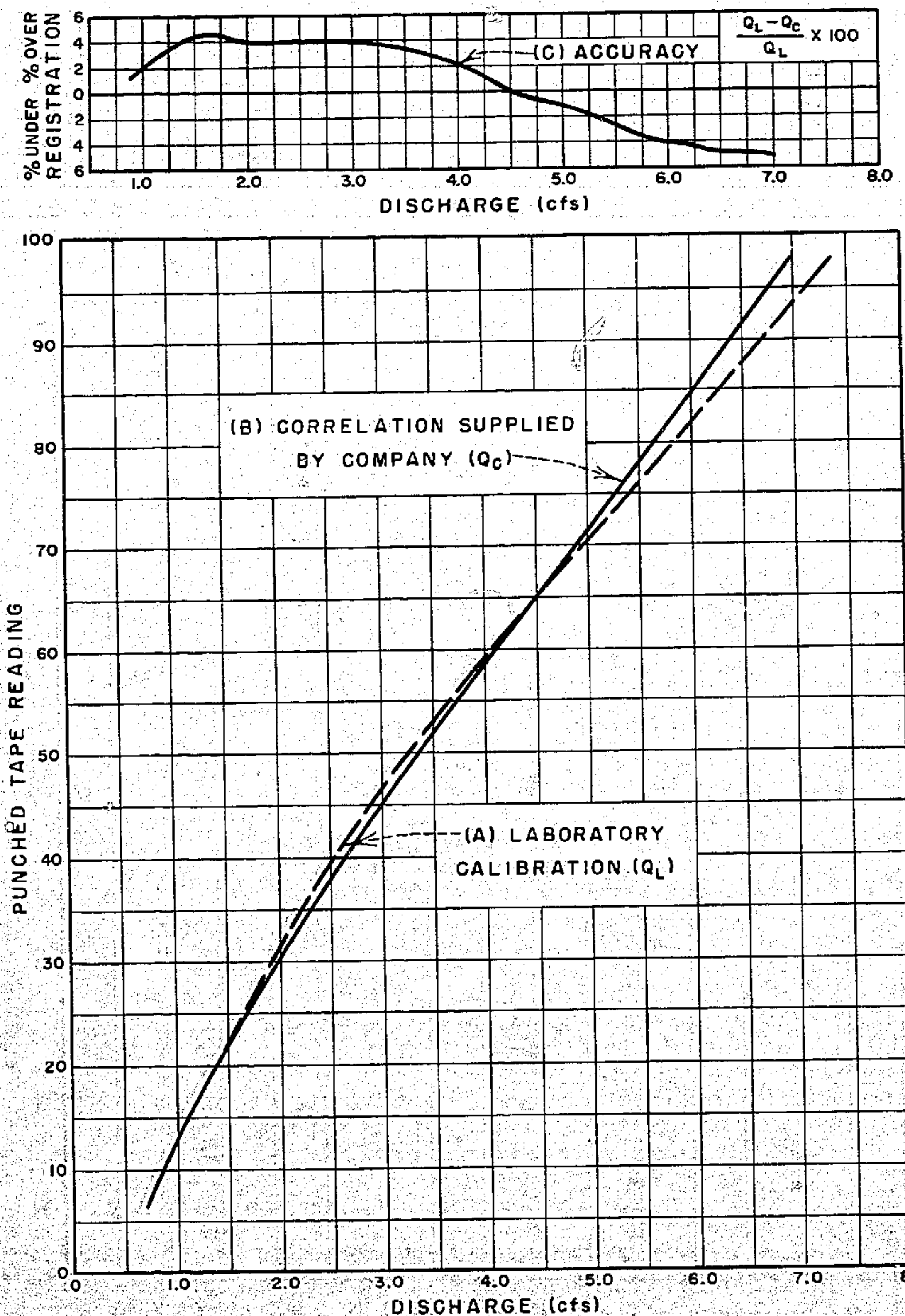

FISCHER-PORTER PUNCHED TAPE FLOW METER STUDY

CAPACITY AND ACCURACY CURVES

METER NO. 6410A1950A1

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FIGURE 6
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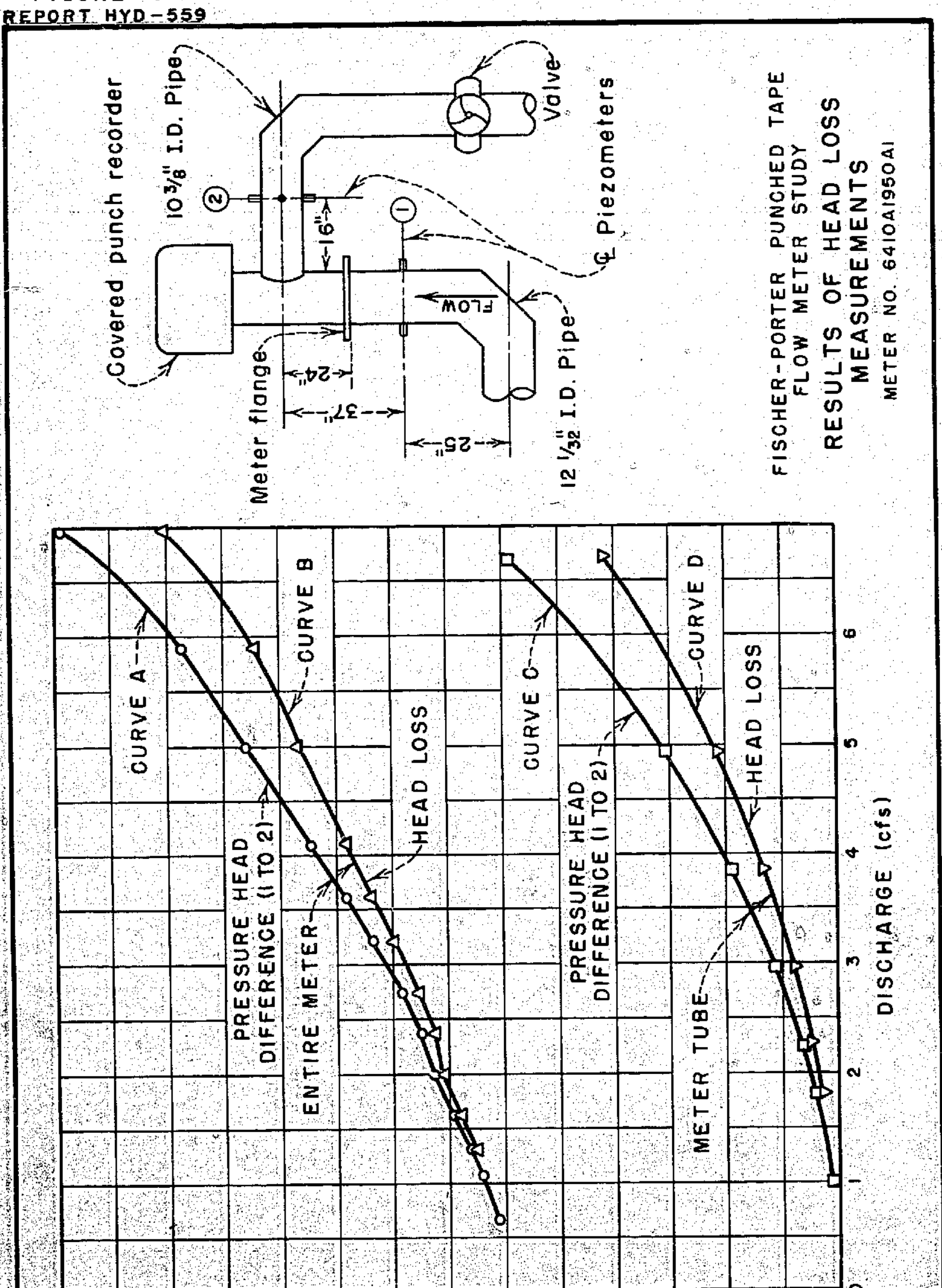
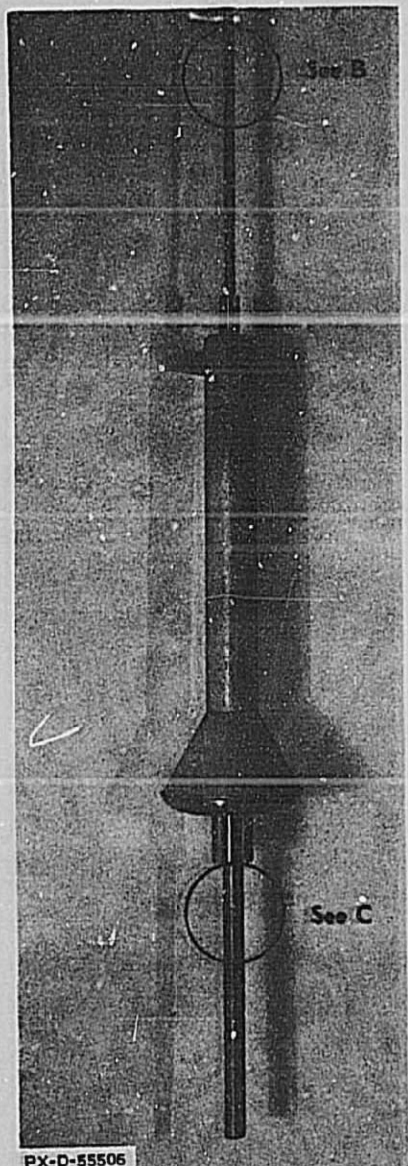
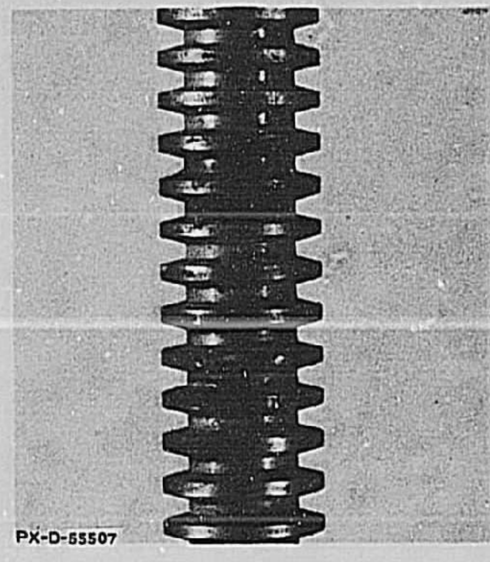
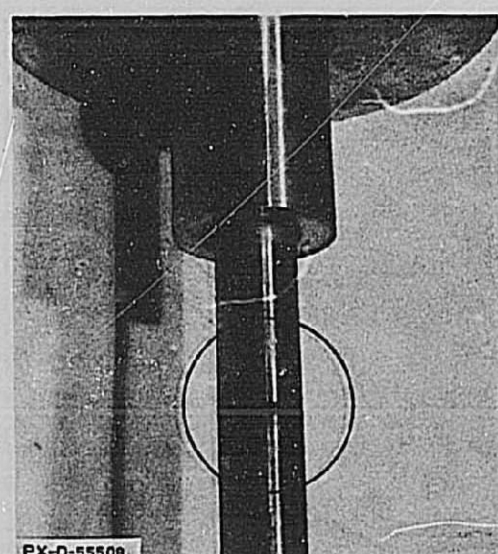




A. Deposits on meter float extensions.



B. Closeup of deposits on rack.



C. Closeup of deposits on lower float extension.

Fischer-Porter Punched Tape Flow Meter Study

DEPOSITS ON METER FLOAT EXTENSIONS

Figure 8
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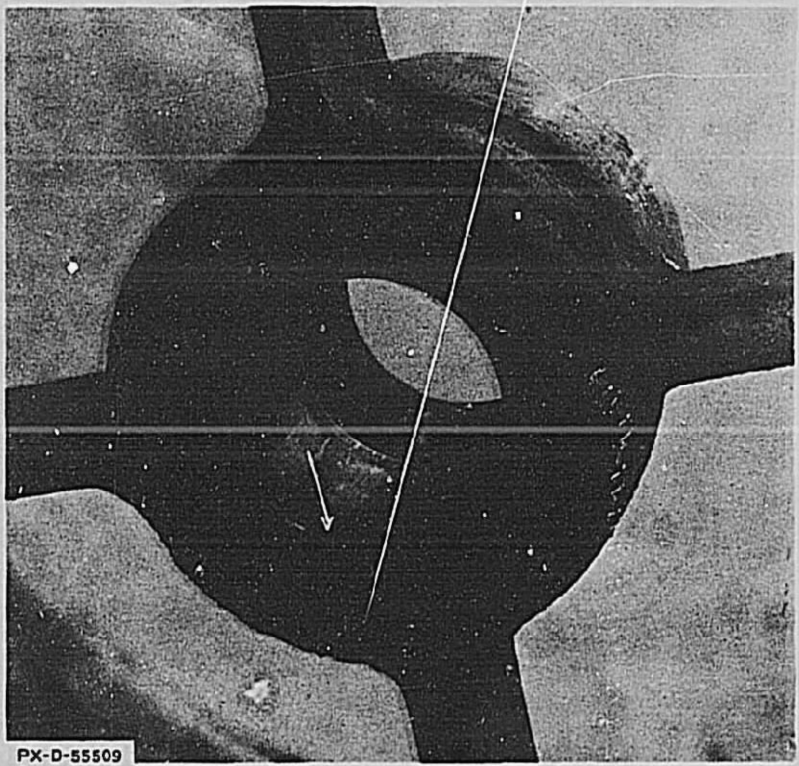

Deposits in bearing.

Fischer-Porter Punched Tape Flow Meter Study

DEPOSITS IN THE SPIDER-HELD BEARING IN THE FLOW TUBE

7-1750
(10-64)

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, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of 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.

Table 1

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03 (exactly)*	Square centimeters
	0.092903 (exactly)	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	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
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	9,463.58	Cubic centimeters
	0.946358	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	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
	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
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	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
	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
	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	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
	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
	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
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	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 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	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)	0.02903* (exactly)	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

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ABSTRACT

A Fischer-Porter punched tape water flow meter and recorder for use in 12-in. pipe was studied in the hydraulic laboratory. This is a tapered-tube variable-area-type meter of 0.7 to 7.0 cfs capacity. The meter records by punching coded holes in paper tape. The meter was developed to provide automatic billing to the water user by computer processing of punched tape. When suitably calibrated, meter accuracy varies from about ± 3.6% at 0.7 cfs to about ± 0.6% at 7.0 cfs. Head losses were measured for the meter and varied from about 3.0 ft of water head at 0.7 cfs to about 6.0 ft at 7.0 cfs. The head losses for the meter tube alone varied from about 0.03 ft of water at 0.7 cfs to about 2.3 ft of water at 7.0 cfs. The float responded well to changes of discharge and was stable to within 1 punched coding unit for discharges set during tests. Laboratory experience with this 1 meter indicated no apparent operational difficulties except that an air-water mixture flowing through the meter produced shaking and vibration. No long or continuous operating tests were performed to determine dependability or ruggedness of construction.

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Dodge, R A
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DESCRIPTORS-- *hydraulics/ *discharge measurement/ water delivery/ water measurement/ errors/ *water meters/ water metering/ digital recording systems/ *head losses/ punched paper tapes/ flow meters/ calibrations
IDENTIFIERS-- variable area meter/ Fischer-Porter flow meter/ product evaluation
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