UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LABORATORY TEST OF ONE 2-INCH SHUNTFLO METER MANUFACTURED BY THE BIF DIVISION NEW YORK AIR BRAKE COMPANY

Report No. Hyd-590

HYDRAULICS BRANCH
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

JUNE 1969

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by
R. A. Dodge

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CONTENTS

SUMMARY

A 2-inch Shuntflo meter designed to measure steam was tested with water in the laboratory. The tests were limited to 2 weeks of operation with the meter set to measure over its mid discharge range of 0.037 to about 0.26 cfs (cubic feet per second) water (about 1 to 7 liters/sec).

Analysis of data verifies company claims that there is a linear relationship between discharge and registration. Using data from Table 1, the discharge (Q) in cfs through the meter was related by the equation:

$$Q = 0.0144R \qquad (1)$$

where (R) is dial counts per hour. The average deviation of computed discharge from laboratory measured discharge for Equation (1) was 1.2 percent. All deviations were less than 2 percent.

The head loss across the meter is about 0.5 feet of water at 0.028 cfs and about 41 feet of water at 0.265 cfs (0.14 meter at 0.79 liter/sec and 12.5 meters at 7.5 liter/sec). Using data from Table 1, the discharge (Q) in cfs is related by the equation:

$$Q = 0.0414H^{1/2} \qquad (2)$$

where (H) is the head loss in feet of water across the meter. The average deviation of computed discharge from laboratory measured discharge for Equation (2) was 0.7 percent. All deviations were less than 2 percent.

No apparent mechanical difficulties were observed during about 80 hours of laboratory tests with the meter measuring clean water over the discharge range from 0.037 to 0.265 cfs (about 1 to 7 liters/sec). During the laboratory test it was noted that the sweep hand of the register turned in a counter-clockwise direction. The meter reader should be informed and reminded of this because of the possibility of readings taken during no flow.

APPLICATIONS

The Shuntflo meter is generally used to measure steam flow. The meter's main design concept seems to be based upon minimizing damage caused by slugs of condensate passing through the main flow passage. The limited tests conducted in the hydraulic laboratory did not suggest any reasons why the meter could not be applied to water measurements. However, the tests did not indicate any significant advantages of convenience or economics over other standard water measuring devices. The laboratory tests do not show how well the meter can resist damage due to sediment and debris often found in project water. Nor do the tests indicate how well the meter would operate under near freezing environments. Also, further research and development by the company would be required to apply the Shuntflo meter to water flow measurement and to provide discharge measuring capacity and calibrations for the magnitude and range of Bureau needs.

INTRODUCTION

Purpose

Studies were made to aid in determining possible Bureau of Reclamation applications of Shuntflo-type meters. The one used for this study was manufactured by the BIF Division of the New York Air Brake Company, Providence, Rhode Island.

Background

The Shuntflo meter, Figure 1, was designed primarily for measuring steam flow but has been applied to other natural or manufactured noncorroding and nonfouling gases. The Canals Branch requested that the meter be tested with water in hydraulics laboratory to see whether the meter could be applied to Bureau of Reclamation water measurement and control. Control Sales, Incorporated, Denver, arranged for the loan of one uncalibrated 2-inch (5.1-cm) Shuntflo meter (Model 0402-02 Serial No. 044636-1) to the laboratories for testing. Shuntflo meters are also manufactured in 1-, 3-, and 4-inch sizes.

Description of Meter

The Shuntflo meter, Figure 1B, operates as follows: the segment-shaped "orifice plate" in top of the main flow passage causes differential pressure across a shunt or bypass loop in the "top cover" of the meter. The company provides different sizes of orifice segments to attain different discharge measuring ranges. The shunted flow drives the propeller of the "top rotor assembly". Connected to the same shaft is a "damping fan". The damping fan idles in dead fluid space to reduce the speed of rotation and wear of moving parts. By means of gear trains and magnetic coupling, shaft turns are accumulated on a register that can be proportioned to read desired flow units.

LABORATORY INVESTIGATION

Test Program

Because of the press of other laboratory work, only limited tests were made with a middle-sized segment-shaped orifice Plate 2B as listed in the company catalog installed in the Shuntflo meter. This orifice plate projects about 3/4 inch (1.9 cm) into the top of the main 2-inch (5.1-cm) flow passage. The meter was tested in an inline configuration shown in Figure 2A rather than across a differential producing device in a bypass arrangement as shown in Figures 3 and 4. The inline configuration was necessary to correlate the register reading and head loss across the meter with discharge through the meter.

Laboratory Installation

The Shuntflo meter was installed in the domestic water supply system of the laboratory, Figure 2A. The meter was placed 20 pipe diameters downstream from the shutoff gate valve to assure good velocity distribution approaching the meter. Meter head losses were measured by means of four manifolded piezometers at 90° around the pipe (Figures 1A and 2A), one diameter upstream from the meter inlet and another set one diameter downstream of the meter outlet. A 2-inch (5.1-cm) Venturi meter was installed 20 diameters downstream from the Shuntflo meter as an alternative means of measuring the discharge. Downstream from the Venturi a 2-inch gate valve was used to maintain positive pressure in the meter and to bleed air bubbles from the piezometers and manometers. Just downstream from the gate valve, a 90° elbow was loosely threaded to a vertical pipe. The pipe could be used for directing flow to a weighing tank or for bypassing the flow between discharge determinations.

Measuring Techniques and Data Obtained

Discharge test range. - Because the meter is designed for gas flow and the company did not provide calibration data for measuring water, the rated capacity range of the meter for water was unknown. The capacity range for the meter with the middle-sized segment-shaped orifice plate installed was determined by the following procedure. The minimum discharge required to drive register was found to be bounded by 0.029 and 0.043 cfs (0.79 to 1.22 liter/sec). Then using a 7:1 range of rated capacity and a minimum discharge of 0.037 cfs (1.05 liter/sec), the rated capacity of the Shuntflo meter when measuring water was determined to be about 0.26 cfs (7.4 liter/sec).

Discharge measurements. - The weighing tank (Figure 2A) and a stopwatch were used to determine the lower discharges. When the flows were high and/or the time-of-filling measurement would be of low significance, the calibrated 2-inch (5.1-cm) Venturi was used to measure discharge.

Head loss measurements. - Values of head losses across the Shuntflo meter less than 10 feet (about 3 meters) of water were measured by a U-tube (Figure 2A) with a red indicating fluid of 2.94 specific gravity. For head losses greater than 10 feet of water, a mercury pot manometer (Figure 2A) was used.

Calibration. - For calibrating the Shuntflo meter, the register was read at the beginning and end of time intervals measured by a stopwatch. A closeup of the register is shown in Figure 2B. Calling once around the sweep hand dial a unit, readings can be estimated to about plus or minus 0.02 unit. The difference in dial readings (between the start and end of a measurement) divided by the time in hours was called (R) and used for calibration of the meter. The values of (R) are listed in Table 1 along with corresponding values of discharge (Q) and head loss (H) across the meter.

TEST RESULTS

Analysis of Laboratory Data

Calibration equation. - As indicated by the graph of laboratory data in Figure 5, and as claimed by the manufacturer, the relation of (Q) in cfs and (R) in units per hour is linear. The plot also indicated that the best straight line very nearly passed through (R) and (Q) equal zero. Therefore, in the equation

$$Q = A_1 + mR \quad \text{. (1)}$$

A_1 was considered zero. The slope (m) that resulted in the minimum average percent deviation of equation discharge from the laboratory measured discharge was found to be 0.0144. The average deviation of (Q) for this equation was 1.2 percent. All individual deviations were less than 2 percent.

Head loss equation. - The plot of data in Figure 5 indicates that the discharge (Q) in cfs is proportional to the square root of the head loss across the meter (H) in feet of water. Therefore, it was assumed that

$$Q = A_2 H^{1/2} \quad \text{. (2)}$$

The coefficient A_2 that resulted in a minimum average absolute percent deviation of equation discharge from laboratory measured discharges was found to be 0.0414. The average absolute deviation for this equation is 0.7 percent. All individual deviations were less than 2 percent.

Least square fit equations. - To further establish that A_1 equals zero for Equation (1) and that the exponent for Equation (2) is 1/2, the laboratory data were fitted by the method of least squares. A_1 for Equation (1) computed to be 4.33×10^{-5} and the exponent for Equation (2) computed to be 0.4990. No substantial reduction in deviations were obtained by allowing A_1 to vary from zero and the exponent to vary from 1/2.

Discussion of Test Results

Company accuracy and range specifications. - The company did not provide any statements of accuracy nor calibrations for the Shuntflo meter when measuring waterflow. But for steam flow the company stated an in-the-line accuracy of plus or minus 2 percent of actual flow for a 10:1 range of rated capacity. The company claims plus or minus 2 percent for steam flows with a 7:1 range of rated capacity when the meter is installed in a bypass arrangement like that shown in Figure 3. Meters can be installed as shown in Figure 4 to extend measuring capacity up to a range of 55:1 range.

Accuracy during laboratory tests. - Laboratory tests with the meter measuring water discharge over a range of 7:1 indicate the meter can be calibrated to measure waterflow to plus or minus 2 percent. No laboratory tests were conducted with the meter installed in a bypass nor in an extended range configuration to measure waterflow. However, the laboratory tests did not suggest any reasons why the bypass and extended range installations could not be applied to waterflow provided calibrations are available.

Mechanical performance. - No mechanical problems were observed during about 80 hours of laboratory operation with the meter measuring clean domestic water. The laboratory tests do not show how well the meter can resist damage due to sediment and debris often found in project water. Nor do the tests indicate how well the meter would operate under near freezing environments. During the tests, it was noted that the sweep hand turned counter-clockwise. Some error could result if this was unknown to a meter reader and if the meter was read during no flow.

Further research and development required. - These meters could be of use to the Bureau of Reclamation only if subsequent research and development are conducted to furnish calibrations for water capacity and accuracies in the range of usual Bureau of Reclamation requirements. Even if these requirements were satisfied, a Shuntflo meter does not seem to have any distinct advantages over other water measuring devices.

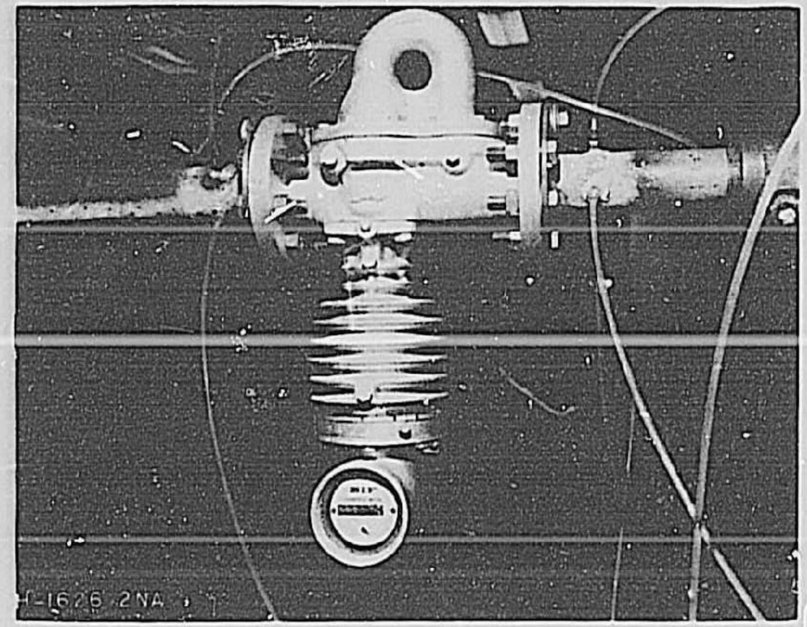
Table 1

LABORATORY DATA
LABORATORY INVESTIGATION OF ONE 2-INCH SHUNTFLO METER

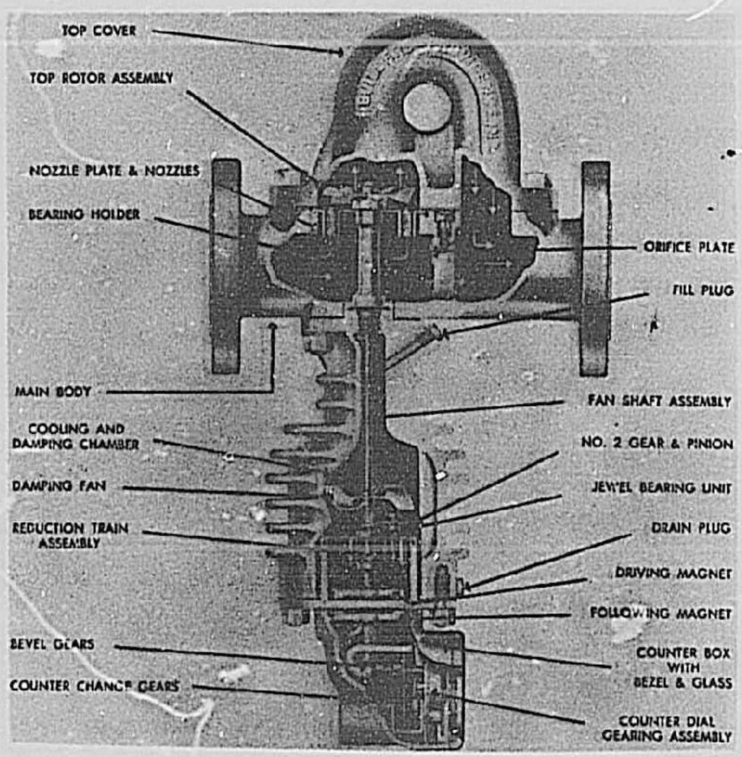
Q	H	R
Laboratory discharge cfs	Head loss feet of water	Counts per hour
0.028	0.47	#
0.043	1.05	2.94
0.077	3.47	5.28
0.105	6.49	7.31
0.156	14.55	11.00
0.218	27.70	15.30
0.265	41.08	18.19

#Register did not turn.

Figure 1
Report Hyd-590



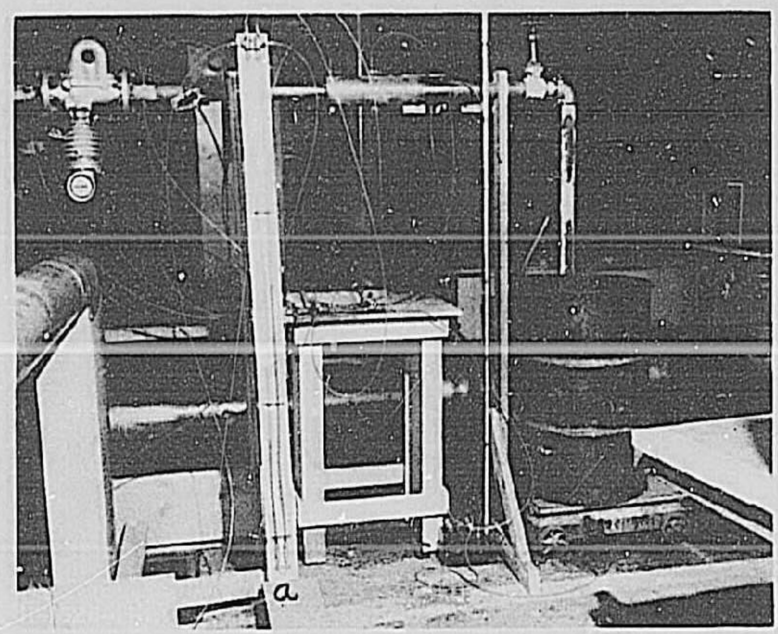
A. Two-inch Shuntflo meter installed for laboratory tests. Photo PX-D-64305



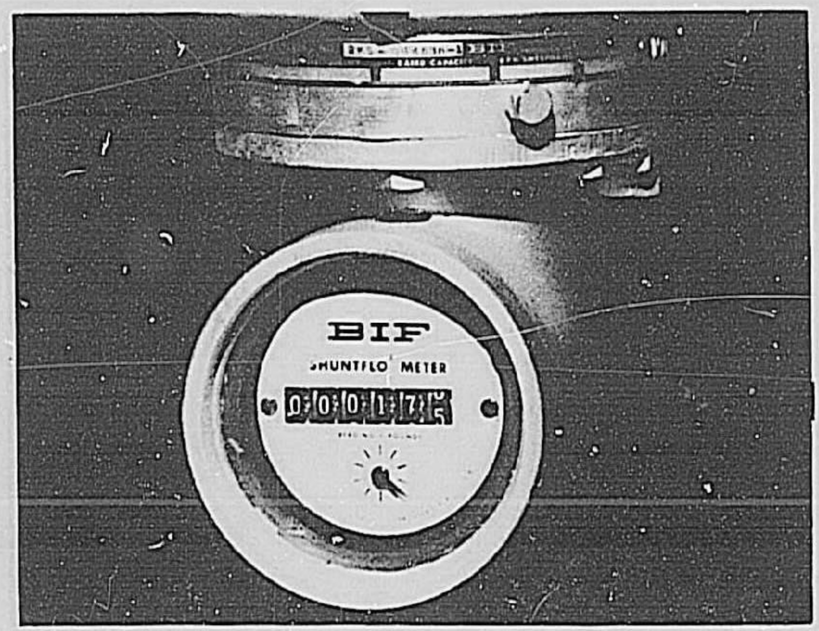
B. Cutaway view of meter from company brochure.

LABORATORY STUDY OF ONE 2-INCH SHUNTFLO METER

Figure 2
Report Hyd-590

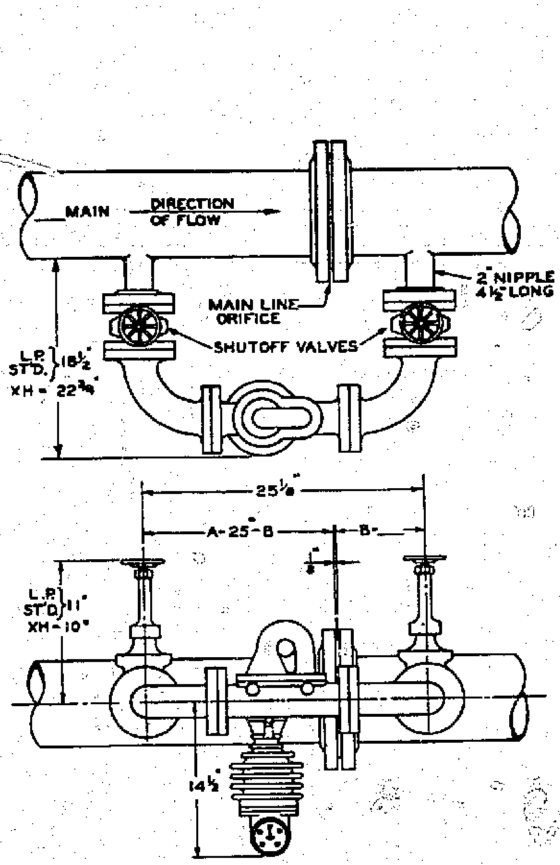


A. Laboratory test arrangement.
(a) U-tube
(b) 2-inch Venturi
(c) Mercury pot manometer
Photo PX-D-64303



B. Closeup of meter register.
Photo PX-D-64304

LABORATORY STUDY OF ONE 2-INCH SHUNTFLO METER



Meter installed in a bypass configuration, figure from company brochure.

Figure 4
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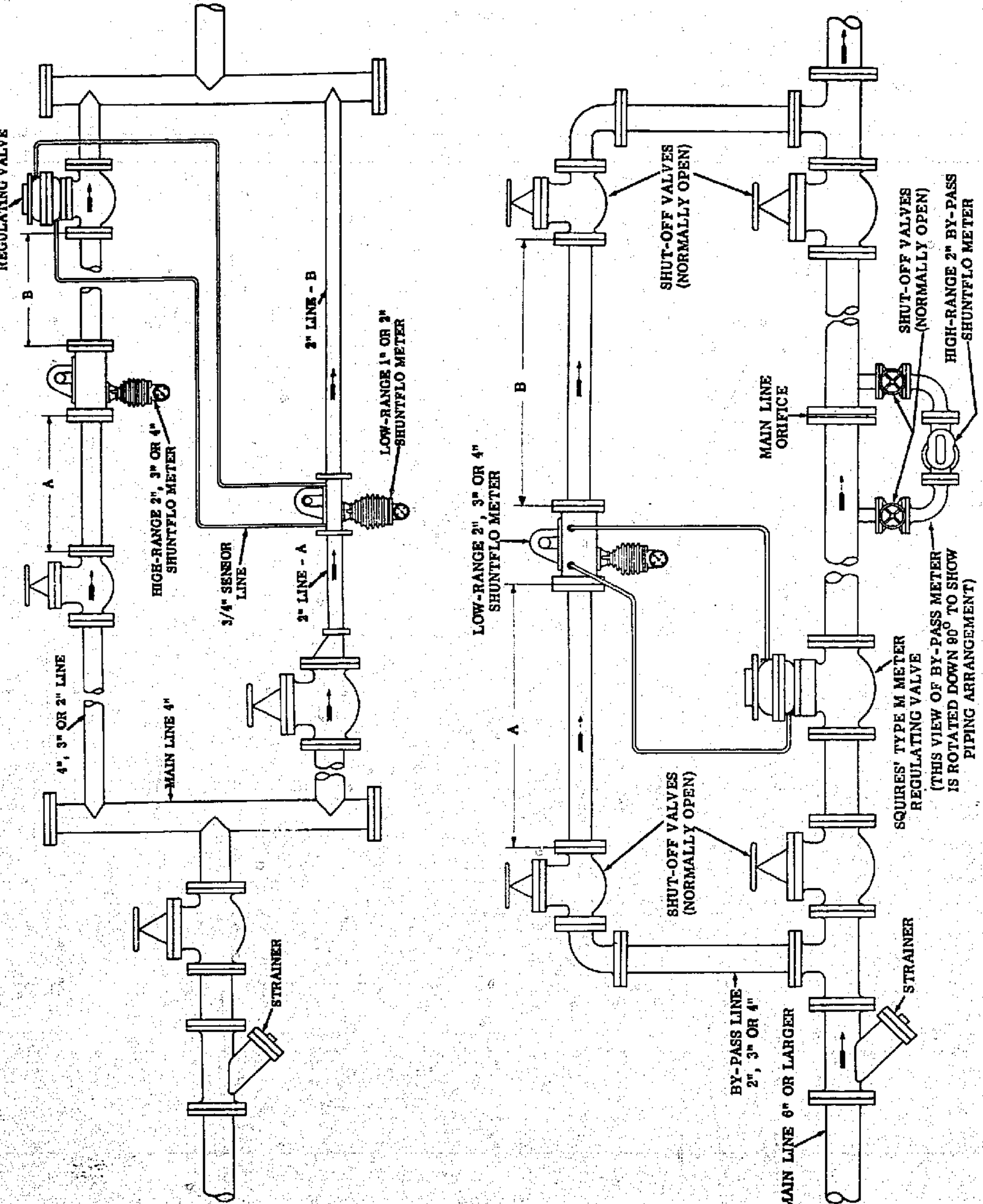
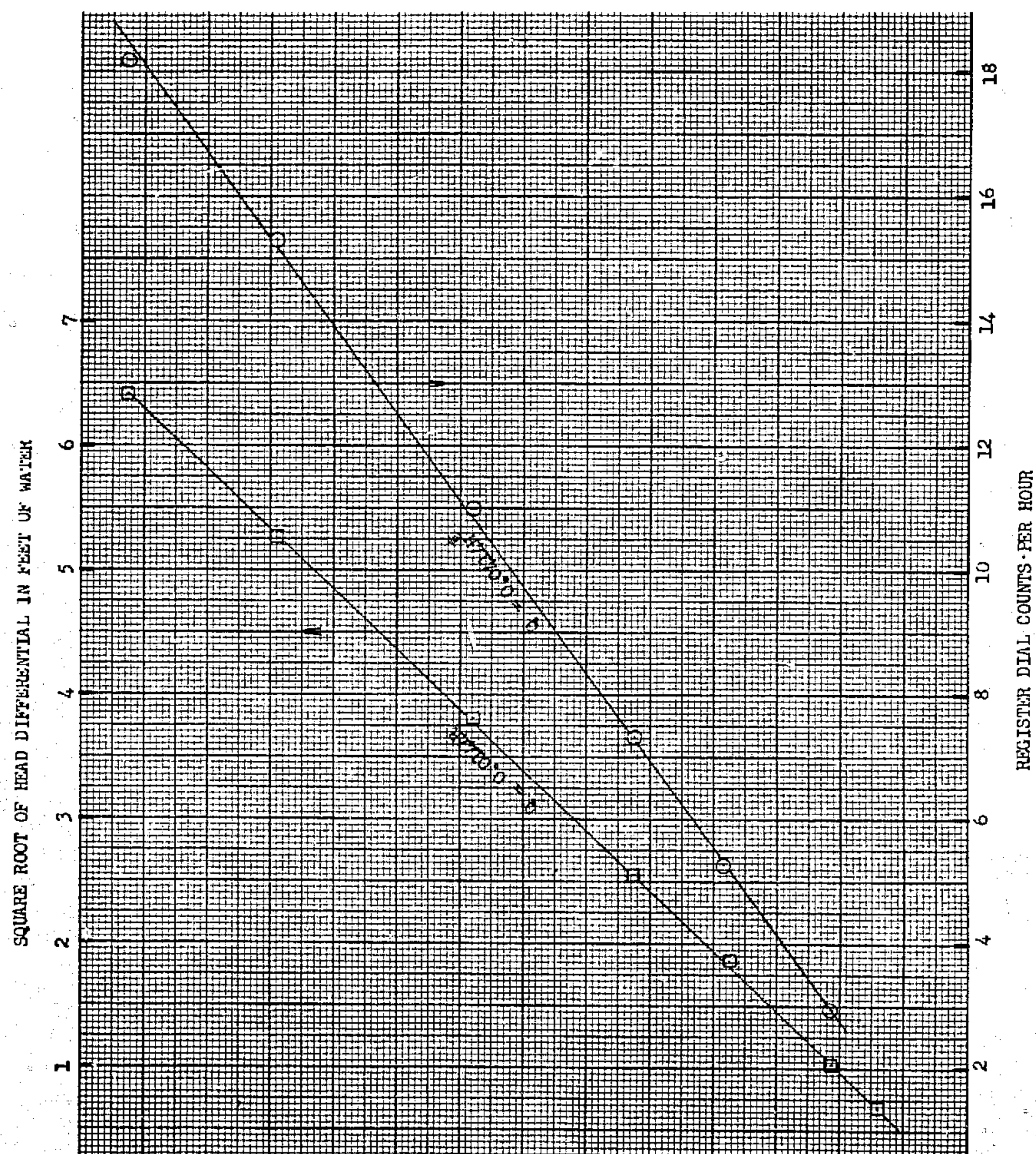


Extended range installations
from company brochure.



Plot of Laboratory Data and Best Fit Equations.

LABORATORY STUDY OF ONE 2-INCH SHUNTFLO METER

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Bureau of Reclamation

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 I

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*	Square centimeters
	0.092903	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.)	946.358*	Cubic centimeters
	0.946331*	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 x 10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582 x 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 x 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 x 10^{-5}*	Dynes

Multiply	By	To obtain
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)	0.092903*	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

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. A table of conversion factors - BRITISH TO METRIC UNITS OF MEASUREMENT - is provided at the end of this report.