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Final Report

CALIBRATION OF ORIFICE-ASSEMBLY— CONDENSER-PUMP DISCHARGE HEADER AS SHOWN BY DETROIT EDISON COMPANY DRAWING 5P515-254 FOR RIVER ROUGE POWER PLANT UNIT No. 1

by

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Project 2339

THE DETROIT EDISON COMPANY
DETROIT, MICHIGAN

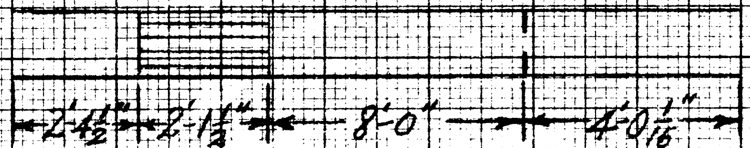
July 1955

ABSTRACT

This report includes graphic and tabular results from the calibration of the subject orifice assembly, relating the A.S.M.E. flow coefficient K to Reynolds' number at the orifice diameter. These results are reported separately for the two diametrically opposite sets of pressure taps provided in the assembly. Also included are orifice and pipe line diameters and pressure tap locations as measured, and a description of the apparatus and procedures.

OBJECTIVE

The objective of this project was to determine the A.S.M.E. flow coefficient K in relation to Reynolds' number for the condenser-pump discharge orifice for Unit No. 1 of the River Rouge power plant of the Detroit Edison Company.



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DETROIT EDISON COMPANY
RIVER ROUGE POWER PLANT
UNIT No. 1.

CONDENSER-PUMP DISCHARGE ORIFICE
FLOW COEFFICIENT, K.

FLOW RATE EQUATION

$W' = 358.9\ K\ D_2^2 \sqrt{\rho h_w}$

See Equation (99), Page 49,
A.S.M.E. Flow Meters Bulletin
Fourth Edition, 1937.

Hagan Orifice No. 8929. Enlarged by D. E. Co.
Vena Contracta Taps, K = 12", K = 8 1/8"
Tap Inst. No. 1-355 and 1-356.
Test water temperature, 69F.
Orifice Diameter (Corrected for area of vent hole) = 6.0758"
Ave. I.D. of Pipe = 12.008"
β Ratio = 0.5060
D. E. Co. Ref. Draw No. 5P515-254.

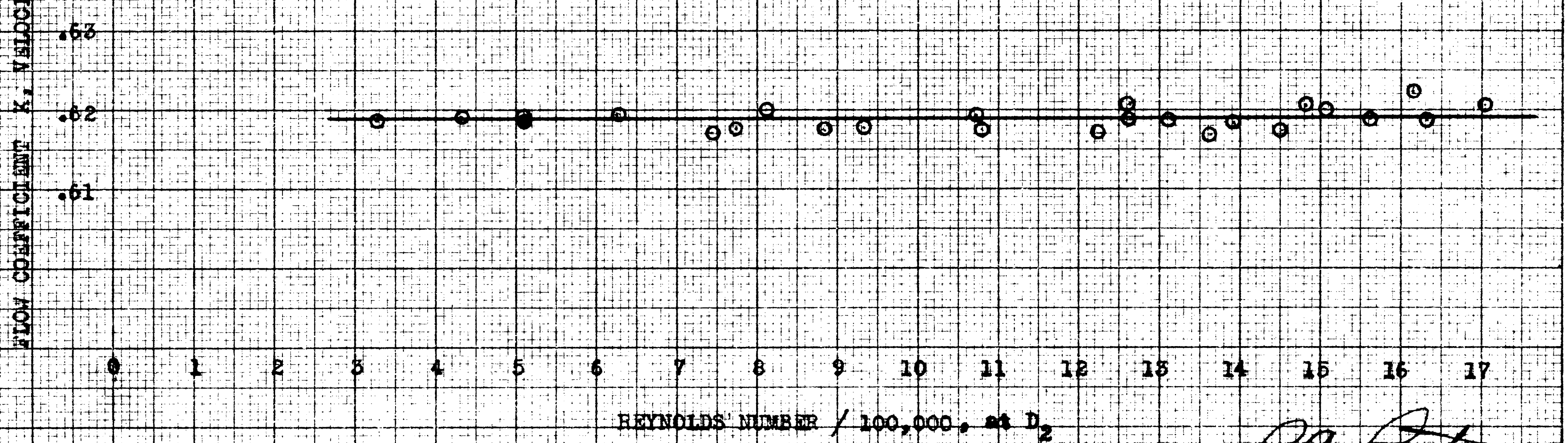

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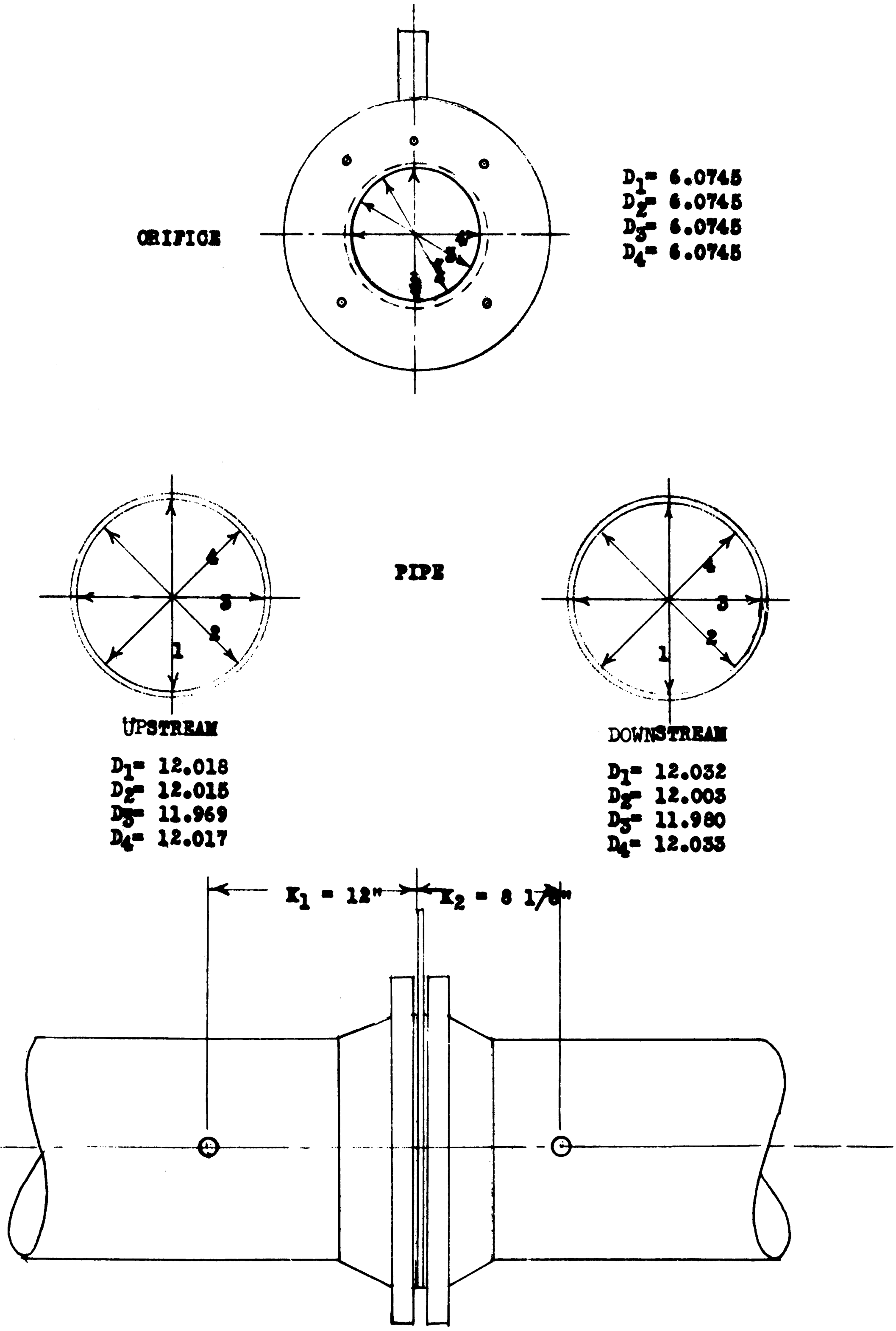
TABLE OF CALIBRATION RESULTS

Reynolds' Number at Orifice Diam ÷ 100,000	A.S.M.E. Flow Meters Coefficient K For Taps 1B55 and 1B56	For Taps 1B57 and 1B58
3.30	0.6187	0.6184
4.31	0.6190	0.6193
5.08	0.6184	0.6185
5.10	0.6188	0.6188
6.25	0.6194	0.6201
7.45	0.6169	0.6167
7.76	0.6176	0.6179
8.13	0.6200	0.6202
8.84	0.6172	0.6162
9.34	0.6177	0.6201
10.72	0.6192	0.6176
10.79	0.6174	0.6163
12.26	0.6170	0.6173
12.65	0.6189	0.6182
12.68	0.6207	0.6212
13.14	0.6188	0.6185
13.63	0.6169	0.6176
13.94	0.6185	0.6185
14.53	0.6173	0.6169
14.80	0.6206	0.6198
15.06	0.6200	0.6191
15.63	0.6189	0.6178
16.13	0.6223	0.6235
16.37	0.6187	0.6192
17.03	0.6208	0.6190



ORIFICE AND PIPE DIMENSIONS

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PROJECT No. 2339. June, 1955.

EQUIPMENT

The equipment is diagrammatically illustrated on page 6. A variable-speed motor-driven centrifugal pump rated at 5000 gpm against 50 feet head of water served as the water circulator. A laboratory pit was used as a sump for the pump intake and weigh-tank discharge. Flow rate was controlled by means of the variable-speed pump and the 12-inch gate valve located immediately downstream from the orifice assembly line.

The 39,000-lb-capacity weigh tank was mounted on Fairbanks-Morse scales with a beam rating of 50,000 lb. The dump valve at the bottom of the weigh tank was compressed air operated through long, flexible hose connections. Effective dump-valve leakage was reduced to zero by means of a drip return gutter and return pump mounted on the scales integrally with the weigh tank.

Pot-type mercury manometers of 60-inch range, as manufactured by King Engineering Corporation, were located entirely below the level of the orifice assembly line for measuring the pressure differentials across the orifice. The gage lines were liberally provided with risers and vent valves for assurance against air collection in the lines. Conventional stop watches were used for timing the water collection in the weigh tanks.

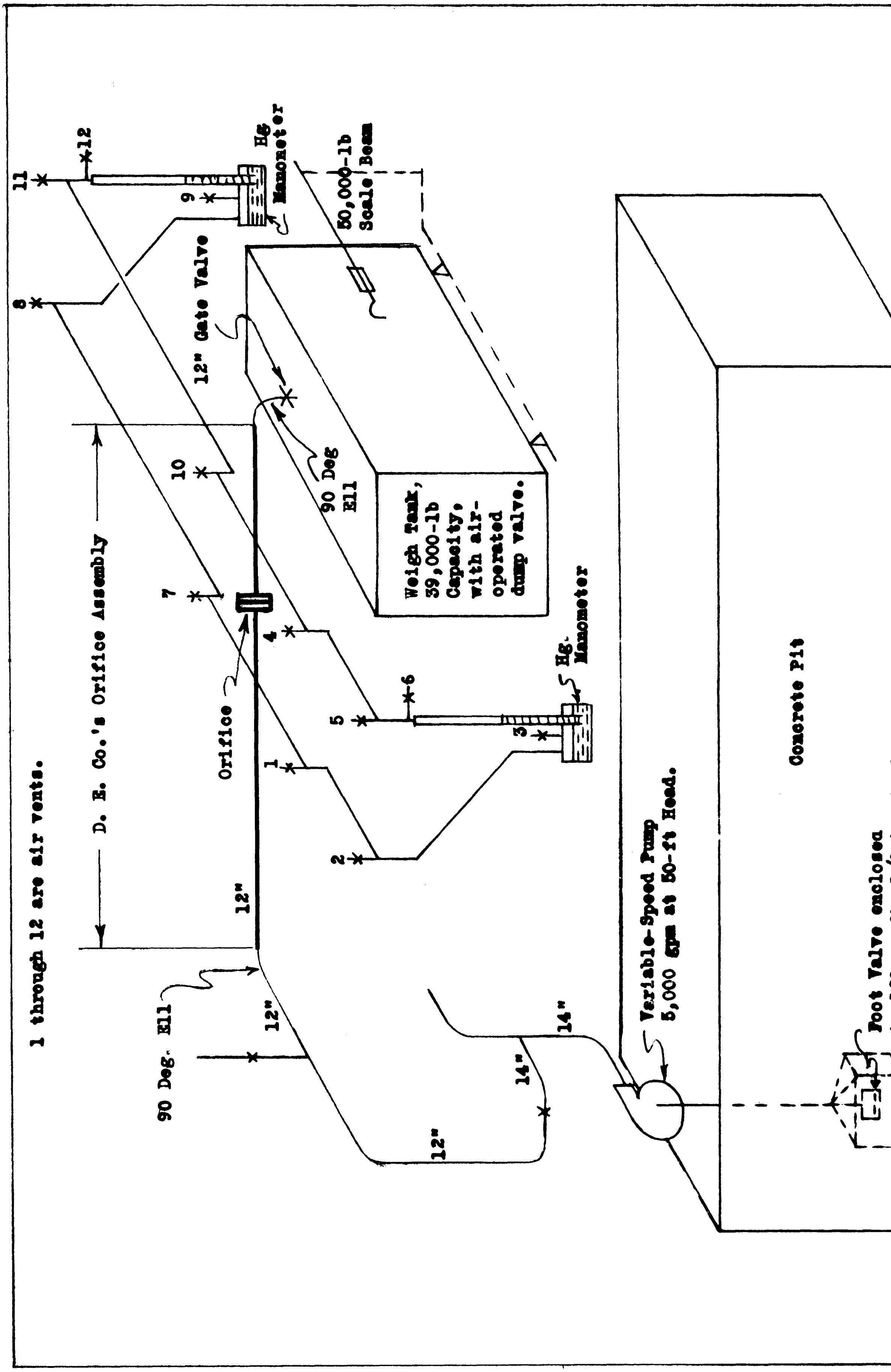
PROCEDURE

PRELIMINARY WORK

During the first calibration attempt, an accumulation of rust scale inside the laboratory's permanent piping flaked off and damaged the original orifice to the extent that it became necessary to recondition the orifice before calibrating it. The Detroit Edison Company did the necessary reconditioning, slightly increasing the orifice diameter to provide a new sharp edge. All pipe lines and the associated hydraulic system were thoroughly cleaned before the orifice was remeasured and replaced for calibration. A large screen was placed around the intake of the pump to guard against further damage from external sources of foreign matter.

CALIBRATION OF EQUIPMENT

The weigh-tank scales were calibrated by the State of Michigan's Division of Weights and Measures and sealed accordingly on May 24, 1955. With



SCHEMATIC DIAGRAM
-of-
EQUIPMENT

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39,000 lb of water in the tank, the scale balance was sensitive to the addition of a 10-lb weight.

The mercury manometers were calibrated by connecting them in parallel with a mercury U-tube and subjecting the group simultaneously to air pressure held essentially constant by means of a Moor pressure regulator. The range of the instruments was traversed and no perceptible error was observed in either of the manometers.

The three stop watches used in the work were calibrated by comparison with United States Government radio time signals. No error was observed.

MEASUREMENTS

The inside diameter of the orifice was measured with a Lufkin inside micrometer at four different positions, as illustrated on page 4. The inside diameter of the pipe line was likewise measured at four different positions opposite the upstream and downstream pressure taps as illustrated on page 4. Pressure-tap location or K values were measured with a conventional steel scale.

ORIFICE CALIBRATION

After placing the orifice in the assembly line with the vent hole at the top position (orifice handle pointing up), water was circulated through the system to displace air from the pipe lines. With the supply pump operating, the 12-inch gate valve was closed, thus pressurizing the orifice assembly line. All air-vent valves were opened and reclosed one at a time until there was no sign of air bubbles in the manometers or in the connecting lines. The manometer scales were adjusted to read zero.

The 12-inch valve was then gradually opened and set to obtain an arbitrary and essentially constant rate of flow. Water was collected in the weigh tank for a timed period limited by tank capacity, and the manometers were alternately read as rapidly as possible to obtain a large number of readings during this same timed period. The weight of water collected, the length of the collection period, the manometer readings, and the temperature of the circulated water and of the room constituted the test data. The 12-inch valve was then adjusted to other arbitrary settings and the previously described run repeated until a total of 25 runs up to and including the maximum possible output of the pump was obtained. The maximum rate of flow was 1,634,285 lb per hour and the maximum average manometer reading was 50.73 inches of mercury under water at 69°F.

The water weighing and timing procedure actually involved three distinctly independent weights and their corresponding independent time intervals for each run, thus affording an average of three rate measurements for greater accuracy. The procedure consisted of selecting three tare weights separated by small weight increments and starting one of the three stop watches as each of these tare weights balanced the scale beam after the tank's dump valve was closed. Each watch was stopped after the selected net collection weight for the run had been added to the particular watch's starting tare weight. Thus the three weighing and time operations were for the most part simultaneous, yet they were distinctly independent of each other. The selected net collection weight was made as large as possible, with due consideration for time needed for operations, 20,000-lb and 25,000-lb being used. The shortest time interval used was 0.77 minute, during which seven readings of each manometer were obtained.

CALCULATIONS

ORIFICE DIAMETER

The effective orifice diameter was calculated as that diameter of a single orifice having an area equal to the combined area of the major orifice and the 1/8-inch-diameter vent hole.

EFFECTIVE DIFFERENTIAL PRESSURE

The effective differential pressure for any one run was determined by converting the arithmetic average of the manometer readings for that run to inches of water of 68°F, with due consideration for room temperature, in accordance with the A.S.M.E. Fluid Meters bulletin.

ACTUAL FLOW RATE

The actual flow rate for any one run was determined by correcting the net collection weight for that run for the effect of air buoyancy (thus increasing the observed weight by 1/10 of one percent), and then dividing by the average of the three stop-watch readings for that run.

FLOW COEFFICIENT "K"

The flow coefficient K was calculated by substituting the data obtained in the various runs into equation (99) on page 49 of the A.S.M.E. Flow Meters bulletin, Fourth Edition, 1937. All viscosities and densities used in the calculations were taken from this same A.S.M.E. publication.

REYNOLDS' NUMBER

All Reynolds' numbers were calculated in accordance with equation (132), page 57 of the above-mentioned A.S.M.E. publication.

EXAMPLE OF DATA AND CALCULATIONS
(Run No. 8)

DATA

Orifice differential, Delta P (in. of Hg under water)	Time in minutes for water collection simultaneous with Delta P measurement	Pounds of water collected simultaneous with time measurement	Temperature, °F
34.4	Watch No. 1,	20,000	Flowing
34.1	0.898		water, 69.0
34.0	Watch No. 2,	20,000	
34.1	0.900		
34.0	Watch No. 3,	20,000	Room, 76.0
33.8	0.900		
33.9			
33.5			
8)271.8(33.975	Avg. Time, 0.899	Avg. Wt. 20,000	

Orifice diameter, 6.0745"   Vent hole diameter, 0.125"

CALCULATIONS (according to A.S.M.E. Fluid Meters Bulletin, Fourth Edition,1937)

$$W = \text{pounds of water per hour} = \frac{20{,}000 \times 60}{0.899}$$

$$= 1{,}334{,}816 \text{ uncorrected for air buoyancy.}$$

$$\text{Pounds of water per hour corrected for air buoyancy} = \frac{W \times 0.075}{62.32} + W$$

$$= 1.001\ W$$

$$= 1{,}336{,}150.$$

Effective orifice D_2^2

including vent hole $= (6.0745)^2 + (0.125)^2$
$= 36.8995 + 0.015625$
$= 36.9151.$

Effective orifice $D_2 = 6.07578$ in.

Reynolds' number (see page 57 of A.S.M.E. Fluid Meters Bulletin)

$$Rd = \frac{48w}{\pi D_2 \mu} = \frac{48 \times 1,336,150 \times 1000}{3.1416 \times 6.076 \times 3600 \times .67} = 1,393,000.$$

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h_w = inches of 68°F water equivalent to orifice differential.
Thus, for the particular conditions of Run No. 8,

$$h_w = \left[\text{orifice differential in inches of Hg at 68°F}\right]\left[\frac{\text{density of Hg at 76°F} - \text{density of } H_2O \text{ at 76°F}}{\text{density of } H_2O \text{ at 68°F}}\right]$$

$$h_w = (33.975)\left[\frac{844.964 - 62.253}{62.317}\right]$$

$= 426.731.$

$\sqrt{h_w} = 20.657.$

ρ_1 = density of test flowing water, or 69°F water in case of Run No. 8

= 62.310 from A.S.M.E. Fluid Meters Bulletin Chart.

$\sqrt{\rho_1} = 7.8937.$

Referring to equation (99), page 49, A.S.M.E. Fluid Meters Bulletin,

w' = pounds per hour $= 358.9 \, K \, D_2^2 \sqrt{\rho_1 h_w}$.

Thus,

$$K = \frac{\text{pounds per hour}}{358.9 \, D_2^2 \sqrt{\rho_1} \sqrt{h_w}} = \frac{1,336,150}{358.9 \times 36.9151 \times 7.8937 \times 20.657}$$

$= .6185$.