UNCLASSIFIED

AAEC/E. 18.

DISCHARGE COEFFICIENTS FOR THE NO.1 SODIUM LOOP VENTURI METER

by

R.C. Cairns

SUMMARY

Discharge coefficients for the Venturi meter designed for use on the No. 1 Sodium Loop are reported for throat Reynolds numbers up to 298,000.

TABLE OF CONTENTS

(1) INTRODUCTION

It was necessary to design a Venturi meter for measuring the flow rate of the sodium for the No. 1 Sodium Loop. A Venturi meter was selected because this gives minimum pressure losses and because the meter is completely drainable.

In Venturis the discharge coefficient can be influenced by any roughness of the inner surfaces or sharpness of edges. Although the Venturi was smooth machined and examined for imperfections after manufacture, it was necessary to determine the discharge coefficients over the Reynolds number range intended for the sodium.

The British Standard Code on Flow Measurement, (2), does not cover Venturi meters for pipe sizes less than 2–in. diameter. This code is at present being revised. For systems with pipe sizes less than 2 inches diameter, some workers, (4), have used a Venturi designed for a 2–in. pipe, but this is not good practice.

The A.S.M.E. Research Publication on Fluid Meters, (1), also being revised, gives coefficients of discharge for Herschel design Venturi tubes as small as ½ inch x ¼ inch. These coefficients had to be checked for the Venturi to be used on the Sodium Loop.

(2) EXPERIMENTAL

The Venturi, made of stainless steel, was designed according to the A.S.M.E. Research Publication, and a diagram of the meter is shown in fig. (1). The upstream and downstream diameters were fixed by the 1–in. o.d. x 16 s.w.g. tube to be used either side of the Venturi. The ratio of throat diameter to upstream diameter, β, was selected to give almost 200 inches water gauge pressure differential for the maximum sodium flow of 10 gallons per minute at 932°F with the Venturi at a temperature of 750°F.

The pressure drops across the Venturi for various flow rates were determined using clean water, and the equipment built for pumping tungsten–water suspensions, (3). The Venturi meter was installed in place of the measuring tube. The experimental procedure was identical to that used for the tungsten–water experiments.

The maximum throat Reynolds number for the sodium at 750°F is 298,000. To enable the coefficient of discharge at this Reynolds number to be determined, water up to 50°C was circulated to reduce the water viscosity.

(3) RESULTS AND DISCUSSION

The results and calculated data are given in Table (1). The coefficient of discharge, C_D, was obtained from the ratio of actual flow to the theoretical flow. The theoretical flow rate was found from, (1).

$$w = 358.9 \left(\frac{D_2^2}{\sqrt{1 - \beta^4}} \right) \sqrt{\rho \; h_w}$$

where w = theoretical flow rate, lb/hr.

D_2 = throat diameter, in.

$\beta = \frac{D_2}{D_1}$

D_1 = upstream diameter, in.

ρ = density of water at line temperature, lb/cu.ft.

h_w = differential, inches of water at 68°F.

The throat Reynolds number, Re_t, was found from –

$$Re_t = \frac{d_2 G}{\mu}$$

where d_2 = throat diameter, ft.

G = mass velocity in throat, lb/(hr.)(sq.ft.)

μ = viscosity, lb/(ft.)(hr.)

Values of C_D versus Re_t are plotted in fig. (2). The line shows the curve for a Venturi with identical dimensions calculated from the A.S.M.E. data. The dashed line above 150,000 Reynolds number is an extrapolation of the A.S.M.E. line. The agreement throughout is very good.

(4) CONCLUSION

The Venturi meter designed for use for throat Reynolds numbers up to 298,000 for sodium gives normal discharge coefficients. For this meter the effects of roughness are negligible. No significant deviation from the coefficients of discharge calculated from the A.S.M.E. data is expected as long as the sodium wets the stainless steel.

(5) ACKNOWLEDGMENTS

Acknowledgments are due to Mr. K.S. Turner and Mr. E. Lee who carried out the experimental work, and Mr. R.B. Beer who prepared the diagrams.

(6) REFERENCES

1. A.S.M.E. Research Publication, "Fluid Meters", Part 1, 4th Edition, 1937.

2. British Standard Code, "Flow Measurement", B.S. 1042: 1943.

3. Cairns, R.C., and Turner, K.S., "Studies of Small Particle Suspensions for L.M.F.R. Part I – Fluid Flow with Suspensions Simulating the U–Na System", AAEC/E.5, Aug., 1957.

4. Hitchon, J.W., and Murdock, R., "The Pumping of Aqueous Thoria Slurries", A.E.R.E. CE/M 189, 1957.

TABLE I

EXPERIMENTAL AND CALCULATED DATA

$D_1 = 0.873$ in. actual, $D_2 = 0.376$ in. actual, $\frac{1}{\sqrt{1-\beta^4}} = 1.018$

Run No.	Discharge	Time Secs.	Temp °C	Actual Rate lb./hr.	G x 10^{-7} lb/(hr.)(sq. ft.)	Re_t	Deflection	
							cms.	h_w inches
	cu. ft.						Hg	
3.3	2.187	63.0	20	7787	1.010	130,000	77.0	380.4
7	2.101	67.4	23	6991	.9067	126,000	61.8	305.4
8	2.197	74.6	23.5	6599	.8559	120,000	55.2	272.7
9	2.042	73.4	24.5	6235	.8087	116,000	49.5	244.6
10	2.052	77.4	25	5940	.7704	111,000	44.6	220.4
11	2.087	83.6	25.5	5594	.7255	107,000	39.6	195.7
12	2.113	92.0	26	5148	.6677	99,000	33.8	167.1
13	2.017	95.4	26.5	4738	.6145	92,000	29.1	143.8
4.1	2.008	55.2	16	8168	1.059	125,000	84.3	416.6
2	2.109	69.2	16.5	6844	.8877	105,000	59.8	295.5
3	1.922	75.4	17	5724	.7424	89,000	41.2	203.6
5	2.070	94.2	18.5	4932	.6397	79,000	31.1	153.6
6	2.168	121.0	19.5	4021	.5215	66,000	21.2	104.8
7	1.907	123.4	20	3466	.4495	58,000	15.7	77.58
8	2.087	175.2	20.5	2672	.3466	45,300	9.5	46.94
	lb.							
9	23.69	35.2	22	2422	.3141	42,600	7.7	38.04
10	24.16	41.8	22	2080	.2698	36,600	5.8	28.65
11	21.26	49.6	26	1543	.2001	29,600	3.3	16.30
							CCl_4	
12	20.96	53.8	27	1403	.1820	27,500	55.9	13.14
13	20.57	67.6	28.5	1095	.1420	22,200	34.8	8.18
14	19.66	75.8	29	934	.1211	19,100	25.0	5.874
15	20.61	89.8	29.5	826	.1071	17,100	20.0	4.701
16	19.66	98.0	30	722	.0937	15,200	15.1	3.549

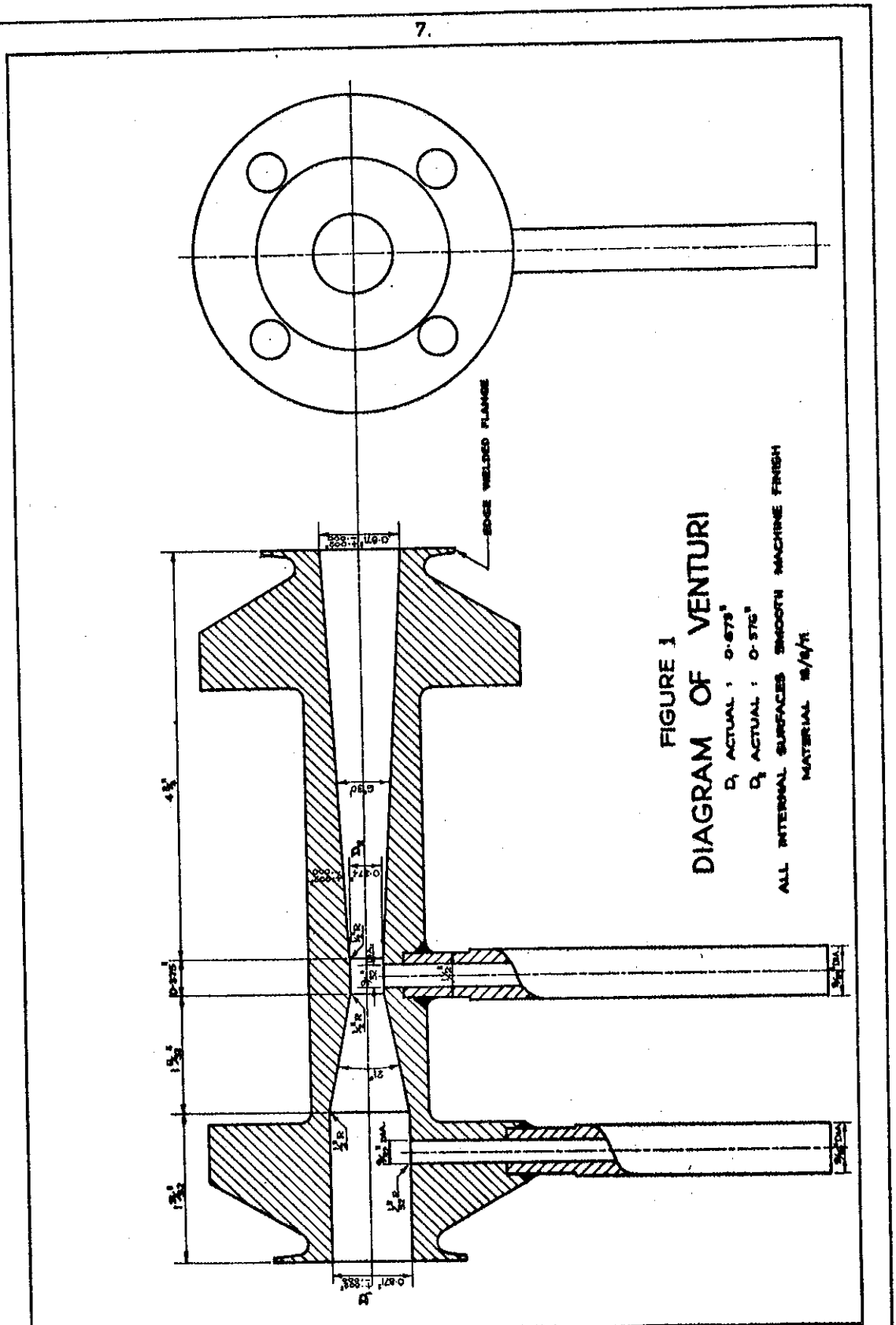
TABLE (1) (CONTD.)

Run No.	Discharge	Time Secs.	Temp °C	Actual Rate lb./hr.	G x 10^{-7} lb/(hr,) (sq.ft,)	$\dot{R}e_t$	Def cms.
	lb						CC14
4.17	20.01	119.0	30	605	.0785	12,700	10.4
18	20.17	148.4	30.5	489	.0635	10,400	6.9
19	19.37	176.4	31	395	.0513	8,500	4.5
20	18.89	222.0	31.5	306	.0397	6,600	3.0
	cu.ft.						Hg
5.1	2.152	57.6	22	8380	1.087	147,000	88.0
2	2.078	62.0	22.5	7519	.9752	134,000	71.2
3	2.143	78.0	23	6162	.7992	111,000	48.0
4	2.163	89.0	23	5450	.7069	98,000	39.8
5	2.109	109.0	24	4336	.5624	80,000	24.6
6	2.087	121.6	24.5	3846	.4998	72,000	19.1
7	1.978	149.2	25	2972	.3855	56,000	13.0
8	2.007	170.8	25.5	2630	.3411	50,000	9.2
	lb.						
9	25.88	40.6	14.5	2294	.2975	33,400	6.9
10	24.26	42.0	16	2079	.2696	31,500	5.4
							CCl_4
11	23.76	53.4	17	1602	.2078	24,800	71.2
12	21.35	59.4	18	1294	.1678	20,500	46.8
13	24.05	78.2	18.5	1107	.1436	17,800	35.4
14	22.21	90.4	19	884	.1147	14,400	22.0
15	23.71	104.0	20	821	.1064	13,700	19.2
16	20.64	112.8	20.5	659	.0854	11,200	12.5
17	22.92	166.2	21	496	.0644	8,500	7.0
18	20.70	178.4	21.5	418	.0542	7,200	5.1

TABLE (1) (CONTD).

Run No.	Discharge	Time Secs.	Temp. °C	Actual Rate lb/hr.	G x 10^{-7} lb/(hr.) (sq. ft.)	Re_t	Deflection	
							cms.	h_w inches
	c u.ft.						Hg	
5.19	2.147	51.8	44.5	9223	1.196	257,000	108.0	533.7
20	2.170	52.6	35.5	9215	1.195	216,000	106.0	523.8
6.1	2.012	55.0	49.0	8132	1.055	245,000	83.1	410.7
2	2.017	54.0	29.5	8359	1.084	173,000	87.4	431.9
3	2.041	55.4	25.5	8256	1.071	157,000	85.6	423.0
	lb.						C_6H_5C1	
4	17.10	141.6	19.5	435	.0564	7,200	20.5	1.309
5	13.71	145.2	21	340	.0441	5,800	18.5	7939
6	11.44	141.6	22.5	291	.0377	5,200	13.7	5879
7	7.203	143.8	23.5	181	.0234	3,290	5.8	2488
8	6.000	158.4	23	136	.0177	2,460	3.2	1373
	cu.ft.						Hg	
9	2.148	49.0	50.0	9727	1.262	298,000	117.5	580.6

NOTE – Four figure calculated data shown in the tables were used to avoid cumulative


EDGE WELDED FLANGE
FIGURE 1
DIAGRAM OF VENTURI
D_1 ACTUAL : 0·673"
D_2 ACTUAL : 0·376"
ALL INTERNAL SURFACES SMOOTH MACHINE FINISH
MATERIAL 18/8/Ti

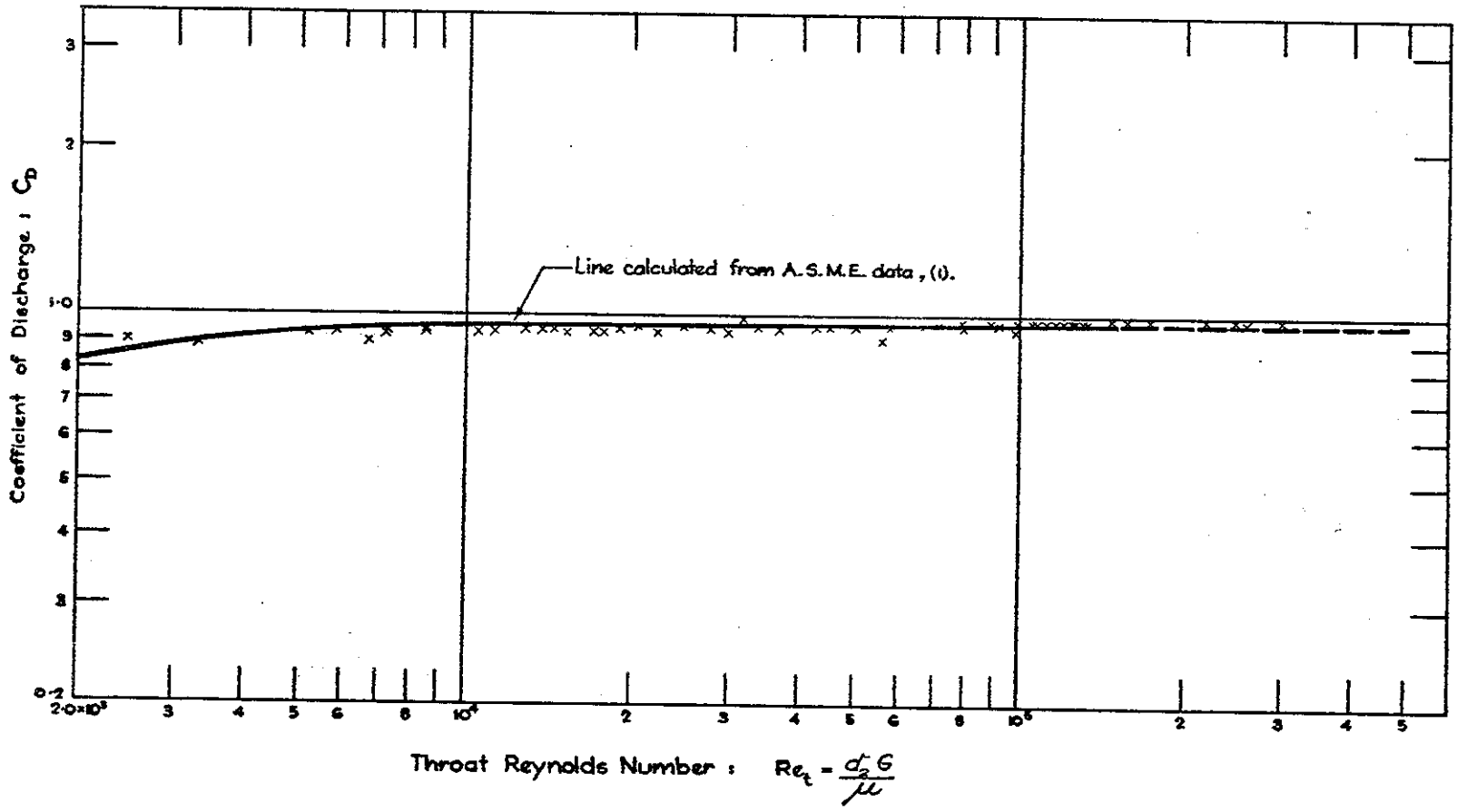


FIGURE 2 : Coefficient of Discharge versus Throat Reynolds Number for the Venturi.