WSRC-TR-2001-00229

Eductor Performance Testing

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This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U.S. Department of Energy.

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Abstract

HB-Line uses eductors to pump the contents of the Recycle Tanks and the Filtrate Tanks to H Canyon. The eductors serve the functions of both pumping and diluting product bearing solutions. Dilution must be reliably controlled because of criticality concerns with H Canyon Tanks. Therefore, it is important to measure the performance characteristics of the eductors. An eductor (Schutte and Koerting, model 264, size ½", 316 stainless steel) identical to the eductors in HB Line Phase II was tested in the Thermal Fluids Laboratory (TFL) over the appropriate ranges of eductant pressure, suction head and discharge head. After testing, the eductor was engraved with the following equipment number, HBL-221000-HV-NPCP-EDR-NT-31/32. The performance data were successfully correlated using two equations, one for the flowrate of eductant and the other for the flowrate of suction fluid. Flowrates were within 10% of the flowrates published by the vendor.

Description of Eductor and Test Facility

Figures 1 and 2 are a cutaway view drawing of the eductor and a photograph of the eductor, respectively. A high velocity jet of eductant flows out of the nozzle, entraining flow from the suction connection of the eductor. Figures 3 and 4 are a drawing and a photograph of the test facility, respectively. The suction of the eductor was connected to 2" transparent pipe, the end of which was submerged in a tank of water placed on a 200 lb. scale (instrument number TR-30073). The high pressure side of the eductor was supplied with process water passing through a pressure regulator. The high pressure at the regulator was measured with a Bourdon pressure gage (no instrument number). The mixed effluent from the eductor flowed up a vertical section of pipe to establish an outlet head. There was a horizontal section of pipe, a tee, then a vertical section of pipe leading down to a collection tank on a 1000 lb. scale (TR-03603).

Times were measured with a stopwatch (TR-2269). Distances were measured with a tape measure. A plumb bob was used to assure vertical piping. All piping was made of 2" transparent PVC pipe. Two inch pipe was chosen so that the frictional pressure drop would be negligible. For example, the highest flowrate and longest length in the discharge line were 4.5 gpm and 7 feet, for a frictional pressure drop of less than 0.01 psid. Flowrates, and therefore, pressure drops were less in the suction pipe.

The two scales and the stopwatch are calibrated annually. The pressure gage was calibrated before and after the testing. The four preceding calibrations were performed traceable to NIST. The SRS Quality Assurance Program does not require the calibration of tape measures.

Testing

This test was initiated by a Technical Task Request [Posnick, 2001] and a Task Plan [Steimke, 2001a]. Testing was conducted according to a written procedure [Steimke, 2001b]. Water was both the eductant and the pumped fluid. The eductant water pressure, the suction head and the discharge head were varied in a test matrix. The eductant water pressures were 15, 25, 30, 35, 45 and 55 psig. The suction heads were 140", 170", 200" and 240". The discharge heads were 13", 36", 60" and 84". The measured quantities were the suction flowrate and the mixed discharge flowrate. The flowrate of eductant was equal to the mixed discharge flowrate minus the suction flowrate.

A simplified procedure follows. The piping was connected to give the requested suction height and distance height. The flow of process water was initiated and the requested pressure was set. The transparent suction pipe was observed until all air was drawn out of it by the eductor. Then simultaneously the weight on both scales was read and the stopwatch was started. The two weights were recorded in the laboratory notebook. After three minutes the weights on the two scales were again read and recorded.

Data Analysis

The suction flowrate was calculated as the weight loss from the suction tank divided by the density of water and the elapsed time. The mixed discharge flowrate was calculated in the same way except that it was a weight gain. The eductant flowrate was calculated as the difference between the mixed discharge flowrate and the suction flowrate. Heads measured in feet of water were converted to pressure drops in psid using the density of water.

Table 2 lists the experimental results. The uncertainty for the measured flows was +/- 1%. The uncertainty for the pressure was +/- 0.5 psig. The uncertainty for the heads was +/- 0.3". The eductant flowrate was correlated with the pressure drop across the nozzle in the eductor, which is the pressure of the process water supplied to the high pressure side of the eductor minus the pressure at the suction inlet of the eductor, as shown in the following equation.

$$DP_{noz} = P_{educ} + r\ g\ DH_{suc} \quad (1)$$

The terms r, g and DH_{suc} are eductant density, gravity and the suction head, respectively. The pressure drop across a nozzle is expected to be proportional to flowrate squared as is shown in Figure 5. The correlation follows where pressure drop and flowrate have units of psid and gpm, respectively.

$$DP_{noz} = 6.12\ F_{educ}^{2} \quad (2)$$

Steimke [1998] previously analyzed eductor vendor data and concluded that the correlation was

$$DP_{noz} = 0.813\ S\ F_{educ}^{2}/C_f^{2} \quad (3)$$

where S is equal to 1.0 for water and C_f is equal to 0.36 for a ½" eductor. Equation 3 simplifies to the following equation.

$$DP = 6.27\ F^{2} \quad (4)$$

noz educ

Equation 4 is only 2.5% different from Equation 1. Therefore, the nozzle pressure drop is close to that expected from the vendor data.

The eductor generates a pressure gain, which is the sum of the discharge head and the suction head.

$DP_{pump} = g\ (r_{suc}\ DH_{suc} + r_{dis}\ DH_{dis})$ (5)

The Pump Handbook (Karassik, 1976) recommended correlating eductor data in terms of head ratio, R_h , and mass flow ratio, R_w.

$R_h = DP_{noz} / DP_{pump}$ (6)

$R_w = M_{suc}/M_{educ} = (F_{suc}\ r_{suc}) / (F_{educ}\ r_{educ})$ (7)

For the current testing the densities of the eductant and the suction fluid were equal so R_w was equal to the ratio of the flows. A plot of R_h vs. R_w was determined to be less useful than a plot of $1/R_h$ vs. R_w , which appears as Figure 6 in the form of a pump curve. The equation of the line through the data follows.

$DP_{pump} / DP_{noz} = 0.327 – 0.219\ (F_{suc}\ r_{suc}) / (F_{educ}\ r_{educ})$ (8)

Figure 7 plots vendor data from Table 1 for a 1" eductor and eductant pressures of 20, 30, 40 and 50 psig in the same form. Equation 8 is also plotted. There is fairly good agreement between equation 8 and the vendor data.

References

1. J. W. Posnick, TTR #NMSS-HTS-2001-006, March 3, 2001
2. J. L. Steimke, "Measurement of Eductor Performance", Task #SRT-ETF-2001,00003, March 22, 2001.
3. J. L. Steimke, "Eductor Performance Testing", FP-887, April 11, 2001.
4. J. L. Steimke, "Analysis of Eductor Performance", WSRC-TR-98-00208, 1998.
5. I. J. Karassik, W. C. Krutzsch, W. H. Fraser and J. P. Messina, Pump Handbook, 1986.

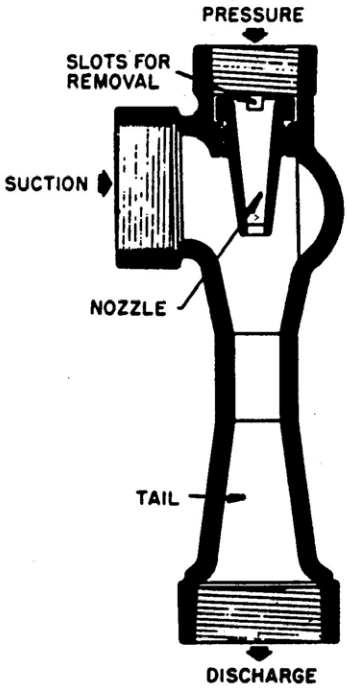


FIG. 1 General purpose eductor. (Schutte and Koerting)

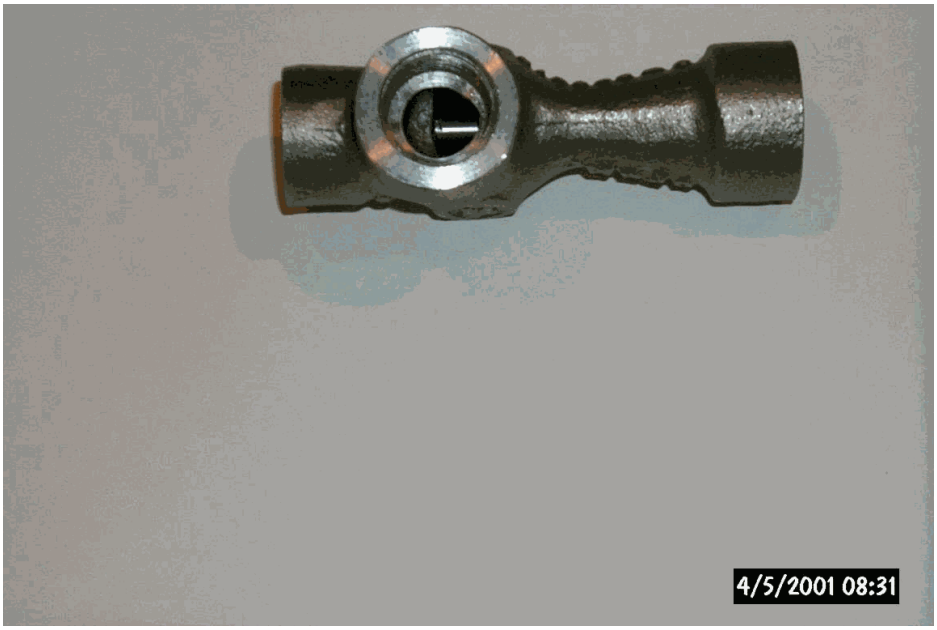


Figure 2. Photograph of Eductor

Figure 3. Test Stand for Measuring Eductor Performance

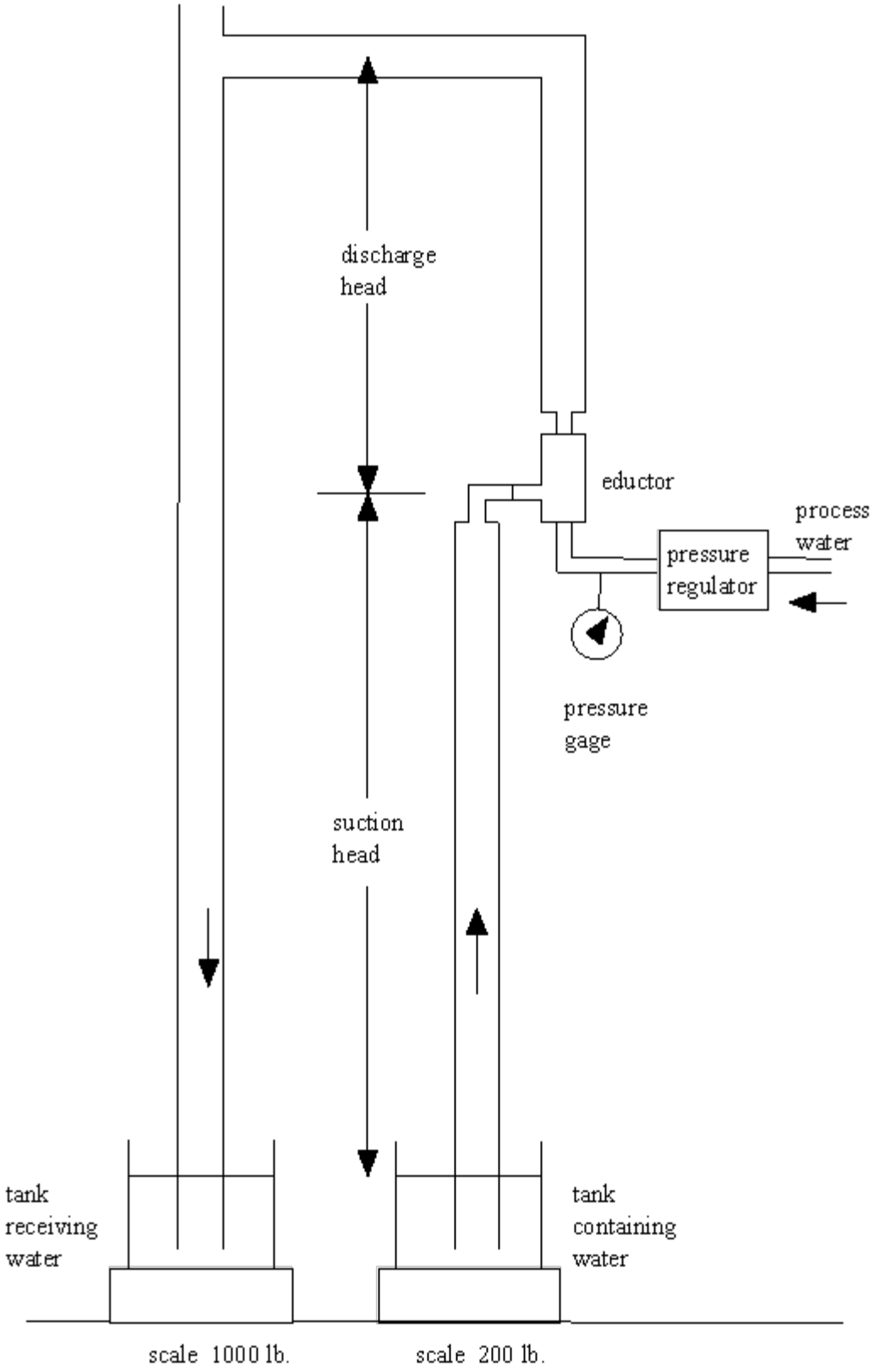
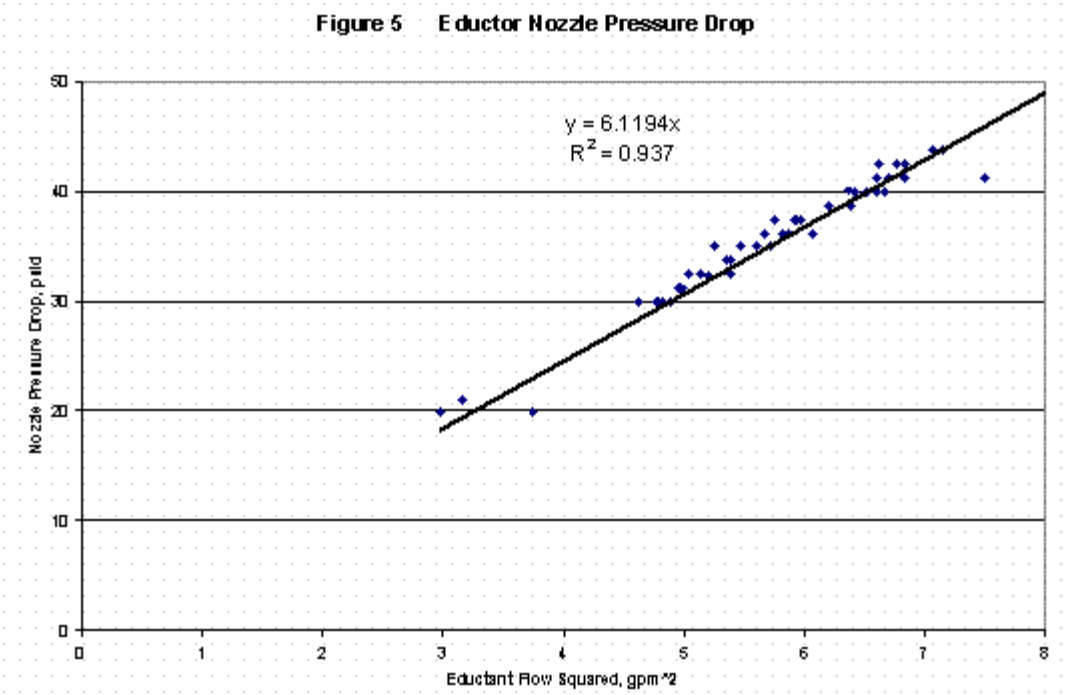


Figure 4. Photograph of Test Setup



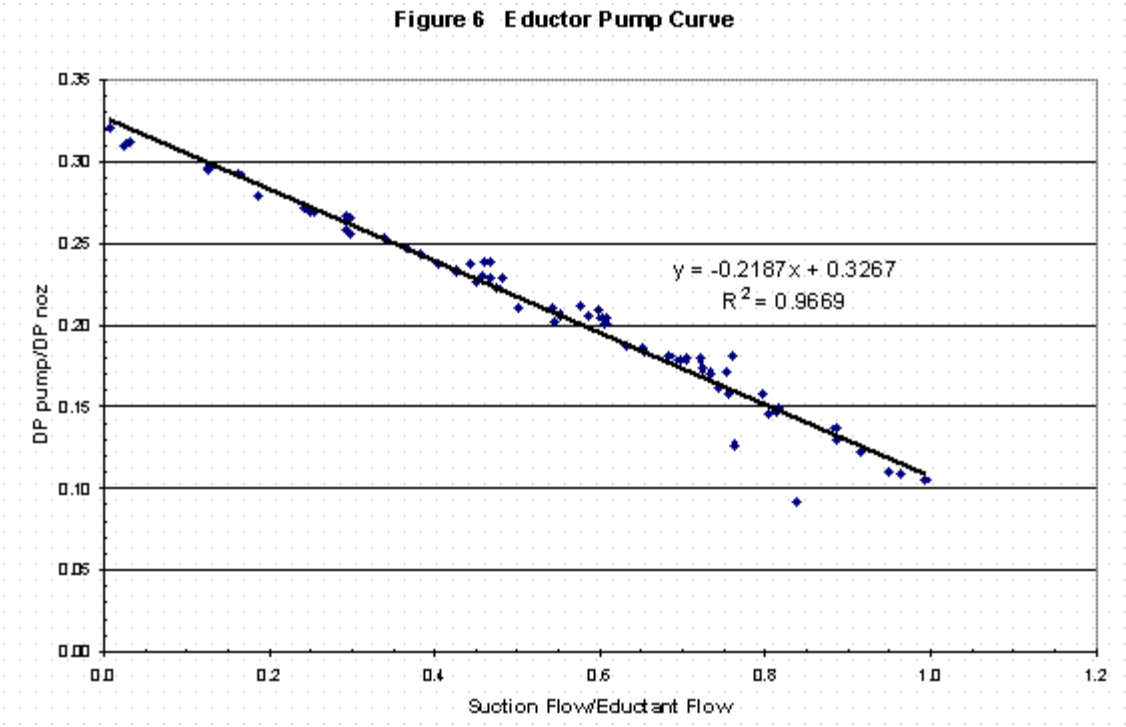


Figure 6 Eductor Pump Curve
y = -0.2187x + 0.3267
R 2 = 0.9669
DP pump/DP noz
Suction Flow/Eductant Flow
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.0
0.2
0.4
0.6
0.8
1.0
1.2

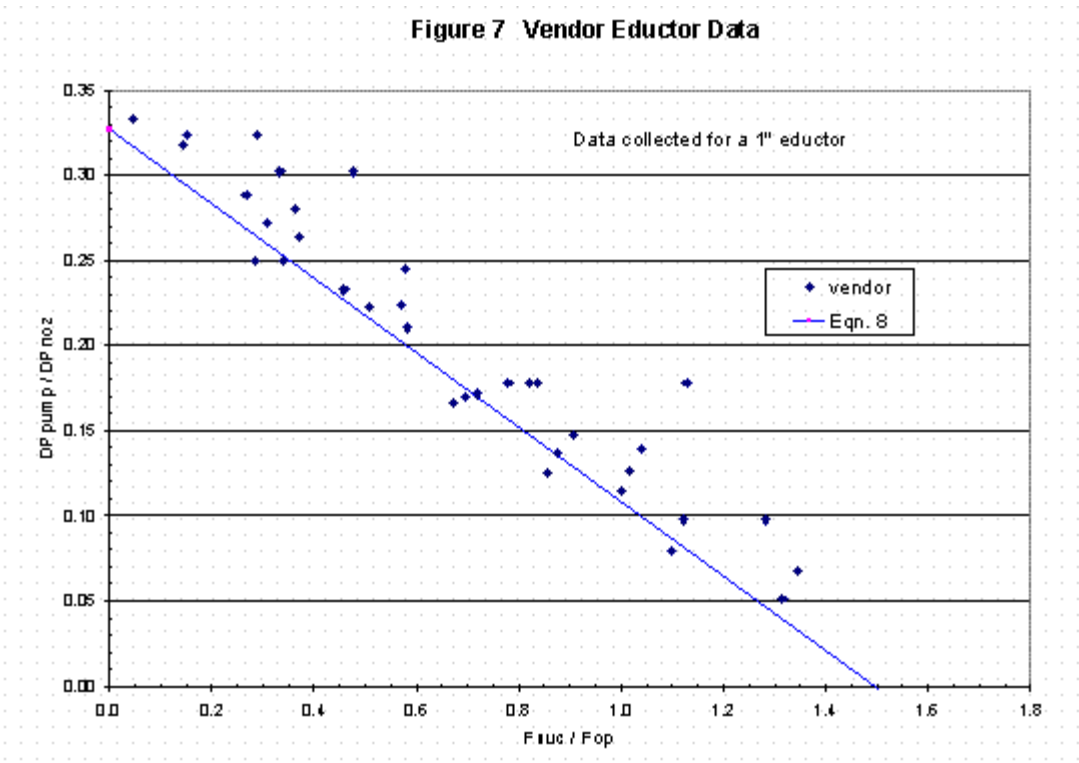


Figure 7 Vendor Eductor Data
Data collected for a 1" eductor
vendor
Eqn. 8
DP pump / DP noz
Fnuc / Fop
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

TABLE 1 Capacity Table of Standard 1-in (25.4-mm) Water-Jet Eductors, gpm*

Suction lift, ft (m)	Discharge pressure, lb/in² (bar) gage	Function	Operating water pressure, lb/in² (bar) gage							
			10 (0.69)	20 (1.4)	30 (2.1)	40 (2.8)	50 (3.4)	60 (4.1)	80 (5.5)	100 (6.9)
0 (0)	0 (0)	Suction	5.85	8.1	9.5	10.0	12.0	12.0	12.0	12.0
		Operating	3.55	5.0	6.1	7.1	7.9	8.7	10.0	11.0
	5 (0.34)	Suction	...	1.4	4.1	6.0	8.0	10.0	11.0	12.0
		Operating	...	4.9	6.1	7.0	7.9	8.6	10.0	11.0
	10 (0.69)	Suction	...	..	0.28	2.3	4.8	6.4	8.8	11.0
		Operating	...	..	5.9	6.8	7.8	8.5	9.8	11.0
	15 (1.0)	Suction	...	..	...	...	1.2	3.4	5.9	8.6
		Operating	...	..	...	...	7.7	8.4	9.8	11.0
	20 (1.4)	Suction	...	..	...	...	...	0.3	3.5	5.9
		Operating	...	..	...	...	...	8.2	9.7	11.0
	25 (1.7)	Suction	...	..	...	...	...	...	0.83	3.9
		Operating	...	..	...	...	...	...	9.6	11.0
	30 (2.1)	Suction	...	..	...	...	...	...	...	1.7
		Operating	...	..	...	...	...	...	...	11.0
5 (1.5)	0 (0)	Suction	4.4	6.8	8.6	9.6	11.0	11.0	12.0	12.0
		Operating	3.9	5.3	6.4	7.3	8.1	8.8	10.0	11.0
	5 (0.34)	Suction	...	1.5	3.2	5.0	7.0	9.0	11.0	11.0
		Operating	...	5.2	6.3	7.2	8.0	8.7	10.0	11.0
	10 (0.69)	Suction	...	..	...	1.9	3.6	5.6	8.6	10.0
		Operating	...	..	...	7.1	7.9	8.6	10.0	11.0
	15 (1.0)	Suction	...	..	...	...	1.1	2.6	5.8	8.3
		Operating	...	..	...	...	7.8	8.6	9.9	11.0
	20 (1.4)	Suction	...	..	...	...	...	...	3.3	5.6
		Operating	...	..	...	...	...	...	9.8	11.0
	25 (1.7)	Suction	...	..	...	...	...	...	0.47	3.6
		Operating	...	..	...	...	...	...	9.8	11.0
	30 (2.1)	Suction	...	..	...	...	...	...	...	1.5
		Operating	...	..	...	...	...	...	...	11.0
10 (3.0)	0 (0)	Suction	2.0	4.6	6.7	8.3	9.0	10.0	10.0	10.0
		Operating	4.2	5.5	6.6	7.4	8.2	9.0	10.0	11.0
	5 (0.34)	Suction	...	..	2.0	4.3	5.9	7.7	9.9	10.0
		Operating	...	..	6.5	7.4	8.2	8.9	10.0	11.0
	10 (0.69)	Suction	...	..	...	1.1	3.0	4.5	8.1	9.6
		Operating	...	..	...	7.3	8.1	8.8	10.0	11.0
	15 (1.0)	Suction	...	..	...	...	1.1	2.1	5.6	7.3
		Operating	...	..	...	...	8.0	8.7	10.0	11.0
	20 (1.4)	Suction	...	..	...	...	...	...	2.8	5.3
		Operating	...	.*	...	...	...	...	9.9	11.0
	25 (1.7)	Suction	...	..	...	...	...	...	...	2.8
		Operating	...	..	...	...	...	...	...	11.0
	30 (2.1)	Suction	...	..	...	...	...	...	...	1.1
		Operating	...	..	...	...	...	...	...	11.0
15 (4.6)	0 (0)	Suction	...	3.3	5.3	7.9	8.4	8.9	8.9	9.1
		Operating	...	5.7	6.8	7.6	8.4	9.1	10.0	12.0
	5 (0.34)	Suction	...	..	...	4.0	4.9	7.3	8.6	9.1
		Operating	...		...	7.6	8.3	9.0	10.0	11.0
	10 (0.69)	Suction	...	..	...	...	2.4	4.0	6.4	8.6
		Operating	...	..	...	...	8.2	9.0	10.0	11.0
	15 (1.0)	Suction	...	..	...	...	...	...	4.2	6.8
		Operating	...	..	...	...	...	...	10.0	11.0
	20 (1.4)	Suction	...	..	...	...	...	...	2.1	4.5
		Operating	...	..	...	...	...	...	10.0	11.0
	25 (1.7)	Suction	...	..	...	...	...	...	...	1.9
		Operating	...	..	...	...	...	...	...	11.0
20 (6.1)	0 (0)	Suction	...	2.0	4.0	6.4	7.8	7.8	7.8	7.8
		Operating	...	6.0	7.0	7.8	8.6	9.3	11.0	12.0
	5 (0.34)	Suction	...	..	...	2.8	3.9	6.3	7.8	7.8
		Operating	...	..	...	7.7	8.5	9.2	10.0	12.0
	10 (0.69)	Suction	...	..	...	...	1.2	3.1	5.7	7.1
		Operating	...	..	...	...	8.3	9.1	10.0	12.0
	15 (1.0)	Suction	...	..	...	...	...	...	3.6	5.4
		Operating	...	..	...	...	...	...	10.0	11.0
	20 (1.4)	Suction	...	..	...	...	...	...	1.4	3.8
		Operating	...	..	...	...	...	...	10.0	11.0
	25 (1.7)	Suction	...	..	...	...	...	...	...	1.5
		Operating	...	..	...	...	...	...	...	11.0

Relative capacities of standard sizes

Size eductor, in (mm)	½ (12.7)	¾ (19.1)	1 (25.4)	1½ (38.1)	2 (50.8)	2½ (63.5)	3 (76.2)	4 (102)	6 (152)
Capacity ratio	0.36	0.64	1.00	2.89	4.00	6.25	9.00	16.00	36.00

*gpm × 0.227 = m³/h.
SOURCE: Schutte and Koerting.

Table 2 TFL Data for 1/2" Model 264 Eductor

discharge head inches	suction head inches	eductant pressure psig	eductant flow gpm	suction flow gpm
13	138.0	25	2.15	1.64
13	138.0	30	2.29	1.59
13	138.5	35	2.58	2.28
36	137.8	25	2.21	1.32
36	138.0	30	2.37	1.67
36	138.5	35	2.53	2.02
60	137.5	25	2.19	0.97
60	138.3	30	2.29	1.38
60	138.0	35	2.57	1.79
84	137.0	25	2.18	0.64
84	137.5	30	2.39	1.15
84	138.0	35	2.55	1.55
60	138.0	25	2.19	1.01
60	138.5	30	2.34	1.42
60	139.0	35	2.52	1.82
13	169.5	25	2.23	1.29
13	170.5	30	2.46	1.61
13	171.0	35	2.61	1.95
36	169.5	25	2.22	1.04
36	170.0	30	na	1.34
36	170.0	30	2.41	1.41
36	170.5	35	2.57	1.76
60	169.0	25	2.23	0.67
60	169.5	30	2.38	1.11
60	170.5	35	2.74	1.49
84	167.5	25	2.23	0.36
84	169.5	30	2.42	0.82
84	170.3	35	2.59	1.23
13	205.5	25	2.32	0.89
13	206.0	30	2.44	1.22
13	206.5	35	2.61	1.70
36	205.5	25	2.25	0.57
36	206.0	30	2.40	1.02
36	206.8	35	2.61	1.44
60	204.8	25	2.27	0.28
60	205.0	30	2.43	0.72
60	206.0	35	2.60	1.17
84	205.0	30	2.44	0.45
84	206.5	35	2.57	0.94
84	204.0	25	2.28	0.02
13	241.0	25	2.31	0.56
13	242.0	30	2.49	1.01
13	242.8	35	2.66	1.44
36	240.5	25	2.32	0.30
36	241.8	30	2.53	0.74
36	242.5	35	2.67	1.22
36	243.3	45	2.92	1.84
36	244.5	55	3.17	2.39
36	171.0	45	2.87	2.31
36	172.0	55	3.13	2.87
13	167.5	15	1.78	0.04
13	171.8	45	2.86	2.54
13	172.5	55	3.19	3.07
13	135.5	15	1.72	0.43
13	140.0	45	2.92	2.77
13	140.5	55	3.51	2.94
36	136.0	15	1.94	0.06
36	139.8	45	2.83	2.16
36	140.0	55	3.11	3.09