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# SIMPLIFIED DESIGN OF LONG LINEAR VACUUM SYSTEMS

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No. 67

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SIMPLIFIED DESIGN OF LONG LINEAR VACUUM SYSTEMS

Summary

In the design of long linear vacuum systems, such as particle accelerators and beam transport systems, it is convenient and time saving to have a list showing the required spacing of vacuum pumps to maintain specified pressure drops for various combinations of tube diameters and outgassing rates. A computer program VAC was written to provide such a list. In this program the vacuum chamber tube diameter varies from 2" through 8", the outgassing rate varies from  $1 \times 10^{-10}$  through  $9 \times 10^{-7}$  torr  $\ell$ /sec  $\text{cm}^2$ , and the pressure drops were selected as 1, 3, 5, 7 and  $9 \times 10^{-6}$  torr.

After selecting the pump spacing from the list the required pump speed is calculated from  $S = Q/P$ .

Discussion

In designing a vacuum system for long particle accelerators and beam transport systems a simple approach is to first calculate the number and spacing of pump-out ports required to maintain the desired pressure drop along the vacuum pipe and then to size the pumps based on the outgassing rate of the vacuum chamber materials.

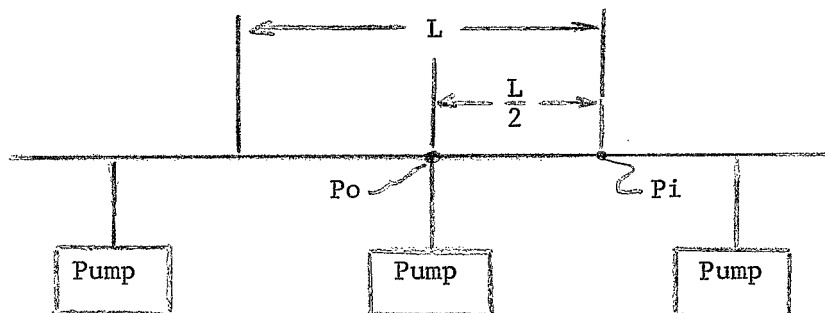


Figure 1.

Referring to Figure 1, for air at 20°C in the molecular flow region<sup>(1)</sup> the maximum pressure drop ( $P_i - P_o$ ) is given by

$$Q = C (P_i - P_o) = C \Delta P$$

where  $Q$  is the throughput (amount of gas pumped) in  $T\ell/\text{sec}$  and  $C$  is the conductance (resistance to "flow") between points  $P_i$  and  $P_o$  in  $\ell/\text{sec}$ . The pressure drop  $\Delta P$  is given in torr.

Knudsen<sup>(2)</sup> gives for the molecular conductance of a tube of constant cross section for air at 20°C

$$C = 62 \frac{KA^2}{BL} \ell/\text{sec}$$

where  $K$  = a dimensionless constant ( $K = 1$  for circular cross section),  $A$  is the cross-sectional area of the tube in  $\text{cm}^2$ ,  $B$  is the perimeter of the tube in  $\text{cm}$ , and  $L$  is the distance between pumps in  $\text{cm}$ .

If we consider the pressure drop along the length  $L/2$  and from

$$Q = (\pi D L/2) q$$

we have

$$Q = (\pi D L/2) q = C \Delta P = \frac{62 A^2}{BL} \Delta P$$

where  $D$  is the tube diameter in  $\text{cm}$  and  $q$  the specific outgassing rate of the vacuum tube in  $T\ell/\text{sec cm}^2$ .

Solving for  $\Delta P$

$$\Delta P = \frac{\pi}{124} \frac{DBqL^2}{A^2} \text{ torr}$$

and for a circular tube

$$\Delta P = \frac{1}{7.75} \frac{q L^2}{D^2} \text{ torr}$$

and the distance between pumps is

$$L = \left( 7.75 \frac{\Delta P D^2}{q} \right)^{1/2} \text{ cm}$$

---

(1) Molecular Flow Region  $\bar{P}D < 15\mu - \text{cm}$

Viscous Flow Region  $\bar{P}D > 500 \mu - \text{cm}$

or

$$L = (.0328) \left( 7.75 \frac{\Delta P D^2}{q} \right)^{1/2} \text{ft}$$

After L is known and the number of pumps determined the pumping speed of the pumps is calculated from  $S = Q_L/P$ ,  $Q_L$  being the outgassing from a tube of length L.

It must be noted that the pumping speed required is only adequate to handle the plane vacuum tube with a specific  $q$  and a given  $\Delta P$ . In general, however, additional elements are added to the vacuum system such as detection equipment, targets, large vacuum boxes, etc. and additional pumping capacity must be added to handle these added gas loads.

Listed on attached sheets is the computer output from the VAC program.

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(2) A. Guthrie and R.K. Wakerling, "Vacuum Equipment and Techniques", page 35, McGraw-Hill, 1949

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(I)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x 10 <sup>-10</sup> Tl/sec cm <sup>2</sup>	Press. Drop, ΔP x 10 <sup>-6</sup> Torr
	46.39	25.81	1.00	1.0000
	32.80	25.81	2.00	1.0000
	26.78	25.81	3.00	1.0000
	23.19	25.81	4.00	1.0000
	20.74	25.81	5.00	1.0000
	18.94	25.81	6.00	1.0000
	17.53	25.81	7.00	1.0000
	16.40	25.81	8.00	1.0000
	15.46	25.81	9.00	1.0000
	14.67	25.81	10.00	1.0000
	10.37	25.81	20.00	1.0000
	8.47	25.81	30.00	1.0000
	7.33	25.81	40.00	1.0000
	6.56	25.81	50.00	1.0000
	5.99	25.81	60.00	1.0000
	5.54	25.81	70.00	1.0000
	5.19	25.81	80.00	1.0000
	4.89	25.81	90.00	1.0000
	4.64	25.81	100.00	1.0000
	3.28	25.81	200.00	1.0000
	2.68	25.81	300.00	1.0000
	2.32	25.81	400.00	1.0000
	2.07	25.81	500.00	1.0000
	1.89	25.81	600.00	1.0000
	1.75	25.81	700.00	1.0000
	1.64	25.81	800.00	1.0000
	1.55	25.81	900.00	1.0000
	1.47	25.81	1000.00	1.0000
	1.04	25.81	2000.00	1.0000
	.85	25.81	3000.00	1.0000
	.73	25.81	4000.00	1.0000
	.66	25.81	5000.00	1.0000
	.60	25.81	6000.00	1.0000
	.55	25.81	7000.00	1.0000
	.52	25.81	8000.00	1.0000
	.49	25.81	9000.00	1.0000
	69.58	58.06	1.00	1.0000
	49.20	58.06	2.00	1.0000
	40.17	58.06	3.00	1.0000
	34.79	58.06	4.00	1.0000
	31.12	58.06	5.00	1.0000
	28.41	58.06	6.00	1.0000
	26.30	58.06	7.00	1.0000
	24.60	58.06	8.00	1.0000
	23.19	58.06	9.00	1.0000
	22.00	58.06	10.00	1.0000
	15.56	58.06	20.00	1.0000
	12.70	58.06	30.00	1.0000
	11.00	58.06	40.00	1.0000
	9.84	58.06	50.00	1.0000
	8.98	58.06	60.00	1.0000
	8.32	58.06	70.00	1.0000
	7.78	58.06	80.00	1.0000
	7.33	58.06	90.00	1.0000
	6.96	58.06	100.00	1.0000
	4.92	58.06	200.00	1.0000
	4.02	58.06	300.00	1.0000
	3.48	58.06	400.00	1.0000
	3.11	58.06	500.00	1.0000
	2.84	58.06	600.00	1.0000

(2)

Length, L  
(ft)Dia. D  
(cm<sup>2</sup>)Outgassing Rate, q  
x 10<sup>-4</sup> l/sec cm<sup>2</sup>Pres. Drop  
x 10<sup>-6</sup> Torr

Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x 10 <sup>-4</sup> l/sec cm <sup>2</sup>	Pres. Drop x 10 <sup>-6</sup> Torr
2.46	58.06	800.00	1.0000
2.32	58.06	900.00	1.0000
2.20	58.06	1000.00	1.0000
1.56	58.06	2000.00	1.0000
1.27	58.06	3000.00	1.0000
1.10	58.06	4000.00	1.0000
.98	58.06	5000.00	1.0000
.90	58.06	6000.00	1.0000
.83	58.06	7000.00	1.0000
.78	58.06	8000.00	1.0000
.73	58.06	9000.00	1.0000
92.77	103.23	1.00	1.0000
65.60	103.23	2.00	1.0000
53.56	103.23	3.00	1.0000
46.39	103.23	4.00	1.0000
41.49	103.23	5.00	1.0000
37.87	103.23	6.00	1.0000
35.06	103.23	7.00	1.0000
32.80	103.23	8.00	1.0000
30.92	103.23	9.00	1.0000
29.34	103.23	10.00	1.0000
20.74	103.23	20.00	1.0000
16.94	103.23	30.00	1.0000
14.67	103.23	40.00	1.0000
13.12	103.23	50.00	1.0000
11.98	103.23	60.00	1.0000
11.09	103.23	70.00	1.0000
10.37	103.23	80.00	1.0000
9.78	103.23	90.00	1.0000
9.28	103.23	100.00	1.0000
6.56	103.23	200.00	1.0000
5.36	103.23	300.00	1.0000
4.64	103.23	400.00	1.0000
4.15	103.23	500.00	1.0000
3.79	103.23	600.00	1.0000
3.51	103.23	700.00	1.0000
3.28	103.23	800.00	1.0000
3.09	103.23	900.00	1.0000
2.93	103.23	1000.00	1.0000
2.07	103.23	2000.00	1.0000
1.69	103.23	3000.00	1.0000
1.47	103.23	4000.00	1.0000
1.31	103.23	5000.00	1.0000
1.20	103.23	6000.00	1.0000
1.11	103.23	7000.00	1.0000
1.04	103.23	8000.00	1.0000
.98	103.23	9000.00	1.0000
115.97	161.29	1.00	1.0000
82.00	161.29	2.00	1.0000
66.95	161.29	3.00	1.0000
57.98	161.29	4.00	1.0000
51.86	161.29	5.00	1.0000
47.34	161.29	6.00	1.0000
43.83	161.29	7.00	1.0000
41.00	161.29	8.00	1.0000
38.66	161.29	9.00	1.0000
36.67	161.29	10.00	1.0000
25.93	161.29	20.00	1.0000
21.17	161.29	30.00	1.0000
18.34	161.29	40.00	1.0000
16.40	161.29	50.00	1.0000
14.97	161.29	60.00	1.0000



(3)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, g x10 <sup>-10</sup> Tl/sec cm <sup>2</sup>	Press. Drop, ΔP x 10 <sup>-6</sup> Torr
	13.86	161,29	70,00	1,0000
	12.97	161,29	80,00	1,0000
	12.22	161,29	90,00	1,0000
	11.60	161,29	100,00	1,0000
	8.20	161,29	200,00	1,0000
	6.70	161,29	300,00	1,0000
	5.80	161,29	400,00	1,0000
	5.19	161,29	500,00	1,0000
	4.73	161,29	600,00	1,0000
	4.38	161,29	700,00	1,0000
	4.10	161,29	800,00	1,0000
	3.87	161,29	900,00	1,0000
	3.67	161,29	1000,00	1,0000
	2.59	161,29	2000,00	1,0000
	2.12	161,29	3000,00	1,0000
	1.83	161,29	4000,00	1,0000
	1.64	161,29	5000,00	1,0000
	1.50	161,29	6000,00	1,0000
	1.39	161,29	7000,00	1,0000
	1.30	161,29	8000,00	1,0000
	1.22	161,29	9000,00	1,0000
	139.16	232,26	1,00	1,0000
	98.40	232,26	2,00	1,0000
	80.34	232,26	3,00	1,0000
	69.58	232,26	4,00	1,0000
	62.23	232,26	5,00	1,0000
	56.81	232,26	6,00	1,0000
	52.60	232,26	7,00	1,0000
	49.20	232,26	8,00	1,0000
	46.39	232,26	9,00	1,0000
	44.01	232,26	10,00	1,0000
	31.12	232,26	20,00	1,0000
	25.41	232,26	30,00	1,0000
	22.00	232,26	40,00	1,0000
	19.68	232,26	50,00	1,0000
	17.97	232,26	60,00	1,0000
	16.63	232,26	70,00	1,0000
	15.56	232,26	80,00	1,0000
	14.67	232,26	90,00	1,0000
	13.92	232,26	100,00	1,0000
	9.84	232,26	200,00	1,0000
	8.03	232,26	300,00	1,0000
	6.96	232,26	400,00	1,0000
	6.22	232,26	500,00	1,0000
	5.68	232,26	600,00	1,0000
	5.26	232,26	700,00	1,0000
	4.92	232,26	800,00	1,0000
	4.64	232,26	900,00	1,0000
	4.40	232,26	1000,00	1,0000
	3.11	232,26	2000,00	1,0000
	2.54	232,26	3000,00	1,0000
	2.20	232,26	4000,00	1,0000
	1.97	232,26	5000,00	1,0000
	1.80	232,26	6000,00	1,0000
	1.66	232,26	7000,00	1,0000
	1.56	232,26	8000,00	1,0000
	1.47	232,26	9000,00	1,0000
	162.35	316,13	1,00	1,0000
	114.80	316,13	2,00	1,0000
	93.73	316,13	3,00	1,0000
	81.18	316,13	4,00	1,0000
	72.61	316,13	5,00	1,0000

(4)

Length, L  
(ft)Dia. D  
(cm<sup>2</sup>)Outgassing Rate, q  
 $\times 10^{-10}$  Torr/sec cm<sup>2</sup>Press. Drop,  $\Delta P$   
 $\times 10^{-6}$  Torr

Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q $\times 10^{-10}$ Torr/sec cm <sup>2</sup>	Press. Drop, $\Delta P$ $\times 10^{-6}$ Torr
66.28	316.13	6.00	1.0000
61.36	316.13	7.00	1.0000
57.40	316.13	8.00	1.0000
54.12	316.13	9.00	1.0000
51.34	316.13	10.00	1.0000
36.30	316.13	20.00	1.0000
29.64	316.13	30.00	1.0000
25.67	316.13	40.00	1.0000
22.96	316.13	50.00	1.0000
20.96	316.13	60.00	1.0000
19.40	316.13	70.00	1.0000
18.15	316.13	80.00	1.0000
17.11	316.13	90.00	1.0000
16.24	316.13	100.00	1.0000
11.48	316.13	200.00	1.0000
9.37	316.13	300.00	1.0000
8.12	316.13	400.00	1.0000
7.26	316.13	500.00	1.0000
6.63	316.13	600.00	1.0000
6.14	316.13	700.00	1.0000
5.74	316.13	800.00	1.0000
5.41	316.13	900.00	1.0000
5.13	316.13	1000.00	1.0000
3.63	316.13	2000.00	1.0000
2.96	316.13	3000.00	1.0000
2.57	316.13	4000.00	1.0000
2.30	316.13	5000.00	1.0000
2.10	316.13	6000.00	1.0000
1.94	316.13	7000.00	1.0000
1.82	316.13	8000.00	1.0000
1.71	316.13	9000.00	1.0000
185.54	412.90	1.00	1.0000
131.20	412.90	2.00	1.0000
107.12	412.90	3.00	1.0000
92.77	412.90	4.00	1.0000
82.98	412.90	5.00	1.0000
75.75	412.90	6.00	1.0000
70.13	412.90	7.00	1.0000
65.60	412.90	8.00	1.0000
61.85	412.90	9.00	1.0000
58.67	412.90	10.00	1.0000
41.49	412.90	20.00	1.0000
33.88	412.90	30.00	1.0000
29.34	412.90	40.00	1.0000
26.24	412.90	50.00	1.0000
23.95	412.90	60.00	1.0000
22.18	412.90	70.00	1.0000
20.74	412.90	80.00	1.0000
19.56	412.90	90.00	1.0000
18.55	412.90	100.00	1.0000
13.12	412.90	200.00	1.0000
10.71	412.90	300.00	1.0000
9.28	412.90	400.00	1.0000
8.30	412.90	500.00	1.0000
7.57	412.90	600.00	1.0000
7.01	412.90	700.00	1.0000
6.56	412.90	800.00	1.0000
6.18	412.90	900.00	1.0000
5.87	412.90	1000.00	1.0000
4.15	412.90	2000.00	1.0000
3.39	412.90	3000.00	1.0000
2.93	412.90	4000.00	1.0000

(5)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, g x10 <sup>-8</sup> Torr sec cm <sup>2</sup>	Press. Drop, ΔP x10 <sup>-3</sup> Torr
	2.62	412.90	5000.00	1.0000
	2.40	412.90	6000.00	1.0000
	2.22	412.90	7000.00	1.0000
	2.07	412.90	8000.00	1.0000
	1.96	412.90	9000.00	1.0000
	80.34	25.81	1.00	3.0000
	56.81	25.81	2.00	3.0000
	46.39	25.81	3.00	3.0000
	40.17	25.81	4.00	3.0000
	35.93	25.81	5.00	3.0000
	32.80	25.81	6.00	3.0000
	30.37	25.81	7.00	3.0000
	28.41	25.81	8.00	3.0000
	26.78	25.81	9.00	3.0000
	25.41	25.81	10.00	3.0000
	17.97	25.81	20.00	3.0000
	14.67	25.81	30.00	3.0000
	12.70	25.81	40.00	3.0000
	11.36	25.81	50.00	3.0000
	10.37	25.81	60.00	3.0000
	9.60	25.81	70.00	3.0000
	8.98	25.81	80.00	3.0000
	8.47	25.81	90.00	3.0000
	8.03	25.81	100.00	3.0000
	5.68	25.81	200.00	3.0000
	4.64	25.81	300.00	3.0000
	4.02	25.81	400.00	3.0000
	3.59	25.81	500.00	3.0000
	3.28	25.81	600.00	3.0000
	3.04	25.81	700.00	3.0000
	2.84	25.81	800.00	3.0000
	2.68	25.81	900.00	3.0000
	2.54	25.81	1000.00	3.0000
	1.80	25.81	2000.00	3.0000
	1.47	25.81	3000.00	3.0000
	1.27	25.81	4000.00	3.0000
	1.14	25.81	5000.00	3.0000
	1.04	25.81	6000.00	3.0000
	.96	25.81	7000.00	3.0000
	.90	25.81	8000.00	3.0000
	.85	25.81	9000.00	3.0000
	120.51	58.06	1.00	3.0000
	85.22	58.06	2.00	3.0000
	69.58	58.06	3.00	3.0000
	60.26	58.06	4.00	3.0000
	53.90	58.06	5.00	3.0000
	49.20	58.06	6.00	3.0000
	45.55	58.06	7.00	3.0000
	42.61	58.06	8.00	3.0000
	40.17	58.06	9.00	3.0000
	38.11	58.06	10.00	3.0000
	26.95	58.06	20.00	3.0000
	22.00	58.06	30.00	3.0000
	19.06	58.06	40.00	3.0000
	17.04	58.06	50.00	3.0000
	15.56	58.06	60.00	3.0000
	14.40	58.06	70.00	3.0000
	13.47	58.06	80.00	3.0000
	12.70	58.06	90.00	3.0000
	12.05	58.06	100.00	3.0000
	8.52	58.06	200.00	3.0000
	6.96	58.06	300.00	3.0000

(6)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> Tl/sec. cm <sup>2</sup>	Press. Drop ΔP x10 <sup>-6</sup> Torr
	6.03	58.06	400.00	3.0000
	5.39	58.06	500.00	3.0000
	4.92	58.06	600.00	3.0000
	4.56	58.06	700.00	3.0000
	4.26	58.06	800.00	3.0000
	4.02	58.06	900.00	3.0000
	3.81	58.06	1000.00	3.0000
	2.69	58.06	2000.00	3.0000
	2.20	58.06	3000.00	3.0000
	1.91	58.06	4000.00	3.0000
	1.70	58.06	5000.00	3.0000
	1.56	58.06	6000.00	3.0000
	1.44	58.06	7000.00	3.0000
	1.35	58.06	8000.00	3.0000
	1.27	58.06	9000.00	3.0000
	160.69	103.23	1.00	3.0000
	113.62	103.23	2.00	3.0000
	92.77	103.23	3.00	3.0000
	80.34	103.23	4.00	3.0000
	71.86	103.23	5.00	3.0000
	65.60	103.23	6.00	3.0000
	60.73	103.23	7.00	3.0000
	56.81	103.23	8.00	3.0000
	53.56	103.23	9.00	3.0000
	50.81	103.23	10.00	3.0000
	35.93	103.23	20.00	3.0000
	29.34	103.23	30.00	3.0000
	25.41	103.23	40.00	3.0000
	22.72	103.23	50.00	3.0000
	20.74	103.23	60.00	3.0000
	19.21	103.23	70.00	3.0000
	17.97	103.23	80.00	3.0000
	16.94	103.23	90.00	3.0000
	16.07	103.23	100.00	3.0000
	11.36	103.23	200.00	3.0000
	9.28	103.23	300.00	3.0000
	8.03	103.23	400.00	3.0000
	7.19	103.23	500.00	3.0000
	6.56	103.23	600.00	3.0000
	6.07	103.23	700.00	3.0000
	5.68	103.23	800.00	3.0000
	5.36	103.23	900.00	3.0000
	5.08	103.23	1000.00	3.0000
	3.59	103.23	2000.00	3.0000
	2.93	103.23	3000.00	3.0000
	2.54	103.23	4000.00	3.0000
	2.27	103.23	5000.00	3.0000
	2.07	103.23	6000.00	3.0000
	1.92	103.23	7000.00	3.0000
	1.80	103.23	8000.00	3.0000
	1.69	103.23	9000.00	3.0000
	200.86	161.29	1.00	3.0000
	142.03	161.29	2.00	3.0000
	115.97	161.29	3.00	3.0000
	100.43	161.29	4.00	3.0000
	89.83	161.29	5.00	3.0000
	82.00	161.29	6.00	3.0000
	75.92	161.29	7.00	3.0000
	71.01	161.29	8.00	3.0000
	66.95	161.29	9.00	3.0000
	63.52	161.29	10.00	3.0000
	44.91	161.29	20.00	3.0000

(7)	Length, L (ft)	(cm <sup>2</sup> )	$\times 10^{-10}$ Tl/sec cm <sup>2</sup>	$\times 10^{-8}$ Torr
	36.67	161,29	30,00	3,0000
	31.76	161,29	40,00	3,0000
	28.41	161,29	50,00	3,0000
	25.93	161,29	60,00	3,0000
	24.01	161,29	70,00	3,0000
	22.46	161,29	80,00	3,0000
	21.17	161,29	90,00	3,0000
	20.09	161,29	100,00	3,0000
	14.20	161,29	200,00	3,0000
	11.60	161,29	300,00	3,0000
	10.04	161,29	400,00	3,0000
	8.98	161,29	500,00	3,0000
	8.20	161,29	600,00	3,0000
	7.59	161,29	700,00	3,0000
	7.10	161,29	800,00	3,0000
	6.70	161,29	900,00	3,0000
	6.35	161,29	1000,00	3,0000
	4.49	161,29	2000,00	3,0000
	3.67	161,29	3000,00	3,0000
	3.18	161,29	4000,00	3,0000
	2.84	161,29	5000,00	3,0000
	2.59	161,29	6000,00	3,0000
	2.40	161,29	7000,00	3,0000
	2.25	161,29	8000,00	3,0000
	2.12	161,29	9000,00	3,0000
	241.03	232,26	1,00	3,0000
	170.43	232,26	2,00	3,0000
	139.16	232,26	3,00	3,0000
	120.51	232,26	4,00	3,0000
	107.79	232,26	5,00	3,0000
	98.40	232,26	6,00	3,0000
	91.10	232,26	7,00	3,0000
	85.22	232,26	8,00	3,0000
	80.34	232,26	9,00	3,0000
	76.22	232,26	10,00	3,0000
	53.90	232,26	20,00	3,0000
	44.01	232,26	30,00	3,0000
	38.11	232,26	40,00	3,0000
	34.09	232,26	50,00	3,0000
	31.12	232,26	60,00	3,0000
	28.81	232,26	70,00	3,0000
	26.95	232,26	80,00	3,0000
	25.41	232,26	90,00	3,0000
	24.10	232,26	100,00	3,0000
	17.04	232,26	200,00	3,0000
	13.92	232,26	300,00	3,0000
	12.05	232,26	400,00	3,0000
	10.78	232,26	500,00	3,0000
	9.84	232,26	600,00	3,0000
	9.11	232,26	700,00	3,0000
	8.52	232,26	800,00	3,0000
	8.03	232,26	900,00	3,0000
	7.62	232,26	1000,00	3,0000
	5.39	232,26	2000,00	3,0000
	4.40	232,26	3000,00	3,0000
	3.81	232,26	4000,00	3,0000
	3.41	232,26	5000,00	3,0000
	3.11	232,26	6000,00	3,0000
	2.88	232,26	7000,00	3,0000
	2.69	232,26	8000,00	3,0000
	2.54	232,26	9000,00	3,0000
	281.20	316,13	1,00	3,0000

(8)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> T <sub>h</sub> /sec cm <sup>2</sup>	x 10 <sup>-6</sup> Torr
	198.84	316.13	2.00	3.0000
	162.35	316.13	3.00	3.0000
	140.60	316.13	4.00	3.0000
	125.76	316.13	5.00	3.0000
	114.80	316.13	6.00	3.0000
	106.28	316.13	7.00	3.0000
	99.42	316.13	8.00	3.0000
	93.73	316.13	9.00	3.0000
	88.92	316.13	10.00	3.0000
	62.88	316.13	20.00	3.0000
	51.34	316.13	30.00	3.0000
	44.46	316.13	40.00	3.0000
	39.77	316.13	50.00	3.0000
	36.30	316.13	60.00	3.0000
	33.61	316.13	70.00	3.0000
	31.44	316.13	80.00	3.0000
	29.64	316.13	90.00	3.0000
	28.12	316.13	100.00	3.0000
	19.88	316.13	200.00	3.0000
	16.24	316.13	300.00	3.0000
	14.06	316.13	400.00	3.0000
	12.58	316.13	500.00	3.0000
	11.48	316.13	600.00	3.0000
	10.63	316.13	700.00	3.0000
	9.94	316.13	800.00	3.0000
	9.37	316.13	900.00	3.0000
	8.89	316.13	1000.00	3.0000
	6.29	316.13	2000.00	3.0000
	5.13	316.13	3000.00	3.0000
	4.45	316.13	4000.00	3.0000
	3.98	316.13	5000.00	3.0000
	3.63	316.13	6000.00	3.0000
	3.36	316.13	7000.00	3.0000
	3.14	316.13	8000.00	3.0000
	2.96	316.13	9000.00	3.0000
	321.37	412.90	1.00	3.0000
	227.24	412.90	2.00	3.0000
	185.54	412.90	3.00	3.0000
	160.69	412.90	4.00	3.0000
	143.72	412.90	5.00	3.0000
	131.20	412.90	6.00	3.0000
	121.47	412.90	7.00	3.0000
	113.62	412.90	8.00	3.0000
	107.12	412.90	9.00	3.0000
	101.63	412.90	10.00	3.0000
	71.86	412.90	20.00	3.0000
	58.67	412.90	30.00	3.0000
	50.81	412.90	40.00	3.0000
	45.45	412.90	50.00	3.0000
	41.49	412.90	60.00	3.0000
	38.41	412.90	70.00	3.0000
	35.93	412.90	80.00	3.0000
	33.88	412.90	90.00	3.0000
	32.14	412.90	100.00	3.0000
	22.72	412.90	200.00	3.0000
	18.55	412.90	300.00	3.0000
	16.07	412.90	400.00	3.0000
	14.37	412.90	500.00	3.0000
	13.12	412.90	600.00	3.0000
	12.15	412.90	700.00	3.0000
	11.36	412.90	800.00	3.0000
	10.71	412.90	900.00	3.0000

(9)

Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> T%/sec cm <sup>2</sup>	Pres. Drop, ΔP x10 <sup>-6</sup> Torr
10.16	412.90	1000.00	3.0000
7.19	412.90	2000.00	3.0000
5.87	412.90	3000.00	3.0000
5.08	412.90	4000.00	3.0000
4.54	412.90	5000.00	3.0000
4.15	412.90	6000.00	3.0000
3.84	412.90	7000.00	3.0000
3.59	412.90	8000.00	3.0000
3.39	412.90	9000.00	3.0000
103.72	25.81	1.00	5.0000
73.34	25.81	2.00	5.0000
59.88	25.81	3.00	5.0000
51.86	25.81	4.00	5.0000
46.39	25.81	5.00	5.0000
42.34	25.81	6.00	5.0000
39.20	25.81	7.00	5.0000
36.67	25.81	8.00	5.0000
34.57	25.81	9.00	5.0000
32.80	25.81	10.00	5.0000
23.19	25.81	20.00	5.0000
18.94	25.81	30.00	5.0000
16.40	25.81	40.00	5.0000
14.67	25.81	50.00	5.0000
13.39	25.81	60.00	5.0000
12.40	25.81	70.00	5.0000
11.60	25.81	80.00	5.0000
10.93	25.81	90.00	5.0000
10.37	25.81	100.00	5.0000
7.33	25.81	200.00	5.0000
5.99	25.81	300.00	5.0000
5.19	25.81	400.00	5.0000
4.64	25.81	500.00	5.0000
4.23	25.81	600.00	5.0000
3.92	25.81	700.00	5.0000
3.67	25.81	800.00	5.0000
3.46	25.81	900.00	5.0000
3.28	25.81	1000.00	5.0000
2.32	25.81	2000.00	5.0000
1.89	25.81	3000.00	5.0000
1.64	25.81	4000.00	5.0000
1.47	25.81	5000.00	5.0000
1.34	25.81	6000.00	5.0000
1.24	25.81	7000.00	5.0000
1.16	25.81	8000.00	5.0000
1.09	25.81	9000.00	5.0000
155.58	58.06	1.00	5.0000
110.01	58.06	2.00	5.0000
89.83	58.06	3.00	5.0000
77.79	58.06	4.00	5.0000
69.58	58.06	5.00	5.0000
63.52	58.06	6.00	5.0000
58.81	58.06	7.00	5.0000
55.01	58.06	8.00	5.0000
51.86	58.06	9.00	5.0000
49.20	58.06	10.00	5.0000
34.79	58.06	20.00	5.0000
28.41	58.06	30.00	5.0000
24.60	58.06	40.00	5.0000
22.00	58.06	50.00	5.0000
20.09	58.06	60.00	5.0000
18.60	58.06	70.00	5.0000

(10)

Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> Tl/sec cm <sup>2</sup>	Pres. Drop, ΔP x10 <sup>-6</sup> Torr
16.40	58.06	90.00	5.0000
15.56	58.06	100.00	5.0000
11.00	58.06	200.00	5.0000
8.98	58.06	300.00	5.0000
7.78	58.06	400.00	5.0000
6.96	58.06	500.00	5.0000
6.35	58.06	600.00	5.0000
5.88	58.06	700.00	5.0000
5.50	58.06	800.00	5.0000
5.19	58.06	900.00	5.0000
4.92	58.06	1000.00	5.0000
3.48	58.06	2000.00	5.0000
2.84	58.06	3000.00	5.0000
2.46	58.06	4000.00	5.0000
2.20	58.06	5000.00	5.0000
2.01	58.06	6000.00	5.0000
1.86	58.06	7000.00	5.0000
1.74	58.06	8000.00	5.0000
1.64	58.06	9000.00	5.0000
207.45	103.23	1.00	5.0000
146.69	103.23	2.00	5.0000
119.77	103.23	3.00	5.0000
103.72	103.23	4.00	5.0000
92.77	103.23	5.00	5.0000
84.69	103.23	6.00	5.0000
78.41	103.23	7.00	5.0000
73.34	103.23	8.00	5.0000
69.15	103.23	9.00	5.0000
65.60	103.23	10.00	5.0000
46.39	103.23	20.00	5.0000
37.87	103.23	30.00	5.0000
32.80	103.23	40.00	5.0000
29.34	103.23	50.00	5.0000
26.78	103.23	60.00	5.0000
24.79	103.23	70.00	5.0000
23.19	103.23	80.00	5.0000
21.87	103.23	90.00	5.0000
20.74	103.23	100.00	5.0000
14.67	103.23	200.00	5.0000
11.98	103.23	300.00	5.0000
10.37	103.23	400.00	5.0000
9.28	103.23	500.00	5.0000
8.47	103.23	600.00	5.0000
7.84	103.23	700.00	5.0000
7.33	103.23	800.00	5.0000
6.91	103.23	900.00	5.0000
6.56	103.23	1000.00	5.0000
4.64	103.23	2000.00	5.0000
3.79	103.23	3000.00	5.0000
3.28	103.23	4000.00	5.0000
2.93	103.23	5000.00	5.0000
2.68	103.23	6000.00	5.0000
2.48	103.23	7000.00	5.0000
2.32	103.23	8000.00	5.0000
2.19	103.23	9000.00	5.0000
259.31	161.29	1.00	5.0000
183.36	161.29	2.00	5.0000
149.71	161.29	3.00	5.0000
129.65	161.29	4.00	5.0000
115.97	161.29	5.00	5.0000
105.86	161.29	6.00	5.0000
98.01	161.29	7.00	5.0000



(11)

Length, L  
(ft.)

Dia. D  
(cm<sup>2</sup>)

Outgassing rate, q  
x10<sup>-10</sup> Tl/sec cm<sup>2</sup>

Press. Drop, ΔP  
x 10<sup>-8</sup> Torr

91.68	161.29	8.00	5.0000
86.44	161.29	9.00	5.0000
82.00	161.29	10.00	5.0000
57.98	161.29	20.00	5.0000
47.34	161.29	30.00	5.0000
41.00	161.29	40.00	5.0000
36.67	161.29	50.00	5.0000
33.48	161.29	60.00	5.0000
30.99	161.29	70.00	5.0000
28.99	161.29	80.00	5.0000
27.33	161.29	90.00	5.0000
25.93	161.29	100.00	5.0000
18.34	161.29	200.00	5.0000
14.97	161.29	300.00	5.0000
12.97	161.29	400.00	5.0000
11.60	161.29	500.00	5.0000
10.59	161.29	600.00	5.0000
9.80	161.29	700.00	5.0000
9.17	161.29	800.00	5.0000
8.64	161.29	900.00	5.0000
8.20	161.29	1000.00	5.0000
5.80	161.29	2000.00	5.0000
4.73	161.29	3000.00	5.0000
4.10	161.29	4000.00	5.0000
3.67	161.29	5000.00	5.0000
3.35	161.29	6000.00	5.0000
3.10	161.29	7000.00	5.0000
2.90	161.29	8000.00	5.0000
2.73	161.29	9000.00	5.0000
311.17	232.26	1.00	5.0000
220.03	232.26	2.00	5.0000
179.65	232.26	3.00	5.0000
155.58	232.26	4.00	5.0000
139.16	232.26	5.00	5.0000
127.03	232.26	6.00	5.0000
117.61	232.26	7.00	5.0000
110.01	232.26	8.00	5.0000
103.72	232.26	9.00	5.0000
98.40	232.26	10.00	5.0000
69.58	232.26	20.00	5.0000
56.81	232.26	30.00	5.0000
49.20	232.26	40.00	5.0000
44.01	232.26	50.00	5.0000
40.17	232.26	60.00	5.0000
37.19	232.26	70.00	5.0000
34.79	232.26	80.00	5.0000
32.80	232.26	90.00	5.0000
31.12	232.26	100.00	5.0000
22.00	232.26	200.00	5.0000
17.97	232.26	300.00	5.0000
15.56	232.26	400.00	5.0000
13.92	232.26	500.00	5.0000
12.70	232.26	600.00	5.0000
11.76	232.26	700.00	5.0000
11.00	232.26	800.00	5.0000
10.37	232.26	900.00	5.0000
9.84	232.26	1000.00	5.0000
6.96	232.26	2000.00	5.0000
5.68	232.26	3000.00	5.0000
4.92	232.26	4000.00	5.0000
4.40	232.26	5000.00	5.0000
4.02	232.26	6000.00	5.0000

(12)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q $\times 10^{-10}$ Torr/sec. cm <sup>2</sup>	Press. Drop, $\Delta P$ $\times 10^{-6}$ Torr
	3.72	232.26	7000.00	5.0000
	3.48	232.26	8000.00	5.0000
	3.28	232.26	9000.00	5.0000
	363.03	316.13	1.00	5.0000
	256.70	316.13	2.00	5.0000
	209.59	316.13	3.00	5.0000
	181.51	316.13	4.00	5.0000
	162.35	316.13	5.00	5.0000
	148.21	316.13	6.00	5.0000
	137.21	316.13	7.00	5.0000
	128.35	316.13	8.00	5.0000
	121.01	316.13	9.00	5.0000
	114.80	316.13	10.00	5.0000
	81.18	316.13	20.00	5.0000
	66.28	316.13	30.00	5.0000
	57.40	316.13	40.00	5.0000
	51.34	316.13	50.00	5.0000
	46.87	316.13	60.00	5.0000
	43.39	316.13	70.00	5.0000
	40.59	316.13	80.00	5.0000
	38.27	316.13	90.00	5.0000
	36.30	316.13	100.00	5.0000
	25.67	316.13	200.00	5.0000
	20.96	316.13	300.00	5.0000
	18.15	316.13	400.00	5.0000
	16.24	316.13	500.00	5.0000
	14.82	316.13	600.00	5.0000
	13.72	316.13	700.00	5.0000
	12.84	316.13	800.00	5.0000
	12.10	316.13	900.00	5.0000
	11.48	316.13	1000.00	5.0000
	8.12	316.13	2000.00	5.0000
	6.63	316.13	3000.00	5.0000
	5.74	316.13	4000.00	5.0000
	5.13	316.13	5000.00	5.0000
	4.69	316.13	6000.00	5.0000
	4.34	316.13	7000.00	5.0000
	4.06	316.13	8000.00	5.0000
	3.83	316.13	9000.00	5.0000
	414.89	412.90	1.00	5.0000
	293.37	412.90	2.00	5.0000
	239.54	412.90	3.00	5.0000
	207.45	412.90	4.00	5.0000
	185.54	412.90	5.00	5.0000
	169.38	412.90	6.00	5.0000
	156.81	412.90	7.00	5.0000
	146.69	412.90	8.00	5.0000
	138.30	412.90	9.00	5.0000
	131.20	412.90	10.00	5.0000
	92.77	412.90	20.00	5.0000
	75.75	412.90	30.00	5.0000
	65.60	412.90	40.00	5.0000
	58.67	412.90	50.00	5.0000
	53.56	412.90	60.00	5.0000
	49.59	412.90	70.00	5.0000
	46.39	412.90	80.00	5.0000
	43.73	412.90	90.00	5.0000
	41.49	412.90	100.00	5.0000
	29.34	412.90	200.00	5.0000
	23.95	412.90	300.00	5.0000
	20.74	412.90	400.00	5.0000
	18.55	412.90	500.00	5.0000

(13)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> Torr/sec cm <sup>2</sup>	Press Drop, ΔP x10 <sup>-6</sup> Torr
	16.94	412.90	600.00	5.0000
	15.68	412.90	700.00	5.0000
	14.67	412.90	800.00	5.0000
	13.83	412.90	900.00	5.0000
	13.12	412.90	1000.00	5.0000
	9.28	412.90	2000.00	5.0000
	7.57	412.90	3000.00	5.0000
	6.56	412.90	4000.00	5.0000
	5.87	412.90	5000.00	5.0000
	5.36	412.90	6000.00	5.0000
	4.96	412.90	7000.00	5.0000
	4.64	412.90	8000.00	5.0000
	4.37	412.90	9000.00	5.0000
1	22.73	25.81	1.00	7.0000
	86.78	25.81	2.00	7.0000
	70.86	25.81	3.00	7.0000
	61.36	25.81	4.00	7.0000
	54.88	25.81	5.00	7.0000
	50.10	25.81	6.00	7.0000
	46.39	25.81	7.00	7.0000
	43.39	25.81	8.00	7.0000
	40.91	25.81	9.00	7.0000
	38.81	25.81	10.00	7.0000
	27.44	25.81	20.00	7.0000
	22.41	25.81	30.00	7.0000
	19.40	25.81	40.00	7.0000
	17.36	25.81	50.00	7.0000
	15.84	25.81	60.00	7.0000
	14.67	25.81	70.00	7.0000
	13.72	25.81	80.00	7.0000
	12.94	25.81	90.00	7.0000
	12.27	25.81	100.00	7.0000
	8.68	25.81	200.00	7.0000
	7.09	25.81	300.00	7.0000
	6.14	25.81	400.00	7.0000
	5.49	25.81	500.00	7.0000
	5.01	25.81	600.00	7.0000
	4.64	25.81	700.00	7.0000
	4.34	25.81	800.00	7.0000
	4.09	25.81	900.00	7.0000
	3.88	25.81	1000.00	7.0000
	2.74	25.81	2000.00	7.0000
	2.24	25.81	3000.00	7.0000
	1.94	25.81	4000.00	7.0000
	1.74	25.81	5000.00	7.0000
	1.58	25.81	6000.00	7.0000
	1.47	25.81	7000.00	7.0000
	1.37	25.81	8000.00	7.0000
	1.29	25.81	9000.00	7.0000
1	84.09	58.06	1.00	7.0000
1	30.17	58.06	2.00	7.0000
1	06.28	58.06	3.00	7.0000
	92.04	58.06	4.00	7.0000
	82.33	58.06	5.00	7.0000
	75.15	58.06	6.00	7.0000
	69.58	58.06	7.00	7.0000
	65.09	58.06	8.00	7.0000
	61.36	58.06	9.00	7.0000
	58.21	58.06	10.00	7.0000
	41.16	58.06	20.00	7.0000
	33.61	58.06	30.00	7.0000
	29.11	58.06	40.00	7.0000

(14)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> Torr/sec cm <sup>2</sup>	Press Drop, ΔP x 10 <sup>-6</sup> Torr
	26.03	58.06	50.00	7.0000
	23.77	58.06	60.00	7.0000
	22.00	58.06	70.00	7.0000
	20.58	58.06	80.00	7.0000
	19.40	58.06	90.00	7.0000
	18.41	58.06	100.00	7.0000
	13.02	58.06	200.00	7.0000
	10.63	58.06	300.00	7.0000
	9.20	58.06	400.00	7.0000
	8.23	58.06	500.00	7.0000
	7.52	58.06	600.00	7.0000
	6.96	58.06	700.00	7.0000
	6.51	58.06	800.00	7.0000
	6.14	58.06	900.00	7.0000
	5.82	58.06	1000.00	7.0000
	4.12	58.06	2000.00	7.0000
	3.36	58.06	3000.00	7.0000
	2.91	58.06	4000.00	7.0000
	2.60	58.06	5000.00	7.0000
	2.38	58.06	6000.00	7.0000
	2.20	58.06	7000.00	7.0000
	2.06	58.06	8000.00	7.0000
	1.94	58.06	9000.00	7.0000
	245.45	103.23	1.00	7.0000
	173.56	103.23	2.00	7.0000
	141.71	103.23	3.00	7.0000
	122.73	103.23	4.00	7.0000
	109.77	103.23	5.00	7.0000
	100.21	103.23	6.00	7.0000
	92.77	103.23	7.00	7.0000
	86.78	103.23	8.00	7.0000
	81.82	103.23	9.00	7.0000
	77.62	103.23	10.00	7.0000
	54.88	103.23	20.00	7.0000
	44.81	103.23	30.00	7.0000
	38.81	103.23	40.00	7.0000
	34.71	103.23	50.00	7.0000
	31.69	103.23	60.00	7.0000
	29.34	103.23	70.00	7.0000
	27.44	103.23	80.00	7.0000
	25.87	103.23	90.00	7.0000
	24.55	103.23	100.00	7.0000
	17.36	103.23	200.00	7.0000
	14.17	103.23	300.00	7.0000
	12.27	103.23	400.00	7.0000
	10.98	103.23	500.00	7.0000
	10.02	103.23	600.00	7.0000
	9.28	103.23	700.00	7.0000
	8.68	103.23	800.00	7.0000
	8.18	103.23	900.00	7.0000
	7.76	103.23	1000.00	7.0000
	5.49	103.23	2000.00	7.0000
	4.48	103.23	3000.00	7.0000
	3.88	103.23	4000.00	7.0000
	3.47	103.23	5000.00	7.0000
	3.17	103.23	6000.00	7.0000
	2.93	103.23	7000.00	7.0000
	2.74	103.23	8000.00	7.0000
	2.59	103.23	9000.00	7.0000
	306.82	161.29	1.00	7.0000
	216.95	161.29	2.00	7.0000
	177.14	161.29	3.00	7.0000

(15)

Length, L  
(ft)

Dia. D  
(cm<sup>2</sup>)

Outgassing Rate, q  
x10<sup>-10</sup> Torr/sec cm<sup>2</sup>

Press. Drop, ΔP  
x10<sup>-6</sup> Torr

153.41	161.29	4.00	7.0000
137.21	161.29	5.00	7.0000
125.26	161.29	6.00	7.0000
115.97	161.29	7.00	7.0000
108.48	161.29	8.00	7.0000
102.27	161.29	9.00	7.0000
97.02	161.29	10.00	7.0000
68.61	161.29	20.00	7.0000
56.02	161.29	30.00	7.0000
48.51	161.29	40.00	7.0000
43.39	161.29	50.00	7.0000
39.61	161.29	60.00	7.0000
36.67	161.29	70.00	7.0000
34.30	161.29	80.00	7.0000
32.34	161.29	90.00	7.0000
30.68	161.29	100.00	7.0000
21.70	161.29	200.00	7.0000
17.71	161.29	300.00	7.0000
15.34	161.29	400.00	7.0000
13.72	161.29	500.00	7.0000
12.53	161.29	600.00	7.0000
11.60	161.29	700.00	7.0000
10.85	161.29	800.00	7.0000
10.23	161.29	900.00	7.0000
9.70	161.29	1000.00	7.0000
6.86	161.29	2000.00	7.0000
5.60	161.29	3000.00	7.0000
4.85	161.29	4000.00	7.0000
4.34	161.29	5000.00	7.0000
3.96	161.29	6000.00	7.0000
3.67	161.29	7000.00	7.0000
3.43	161.29	8000.00	7.0000
3.23	161.29	9000.00	7.0000
368.18	232.26	1.00	7.0000
260.34	232.26	2.00	7.0000
212.57	232.26	3.00	7.0000
184.09	232.26	4.00	7.0000
164.65	232.26	5.00	7.0000
150.31	232.26	6.00	7.0000
139.16	232.26	7.00	7.0000
130.17	232.26	8.00	7.0000
122.73	232.26	9.00	7.0000
116.43	232.26	10.00	7.0000
82.33	232.26	20.00	7.0000
67.22	232.26	30.00	7.0000
58.21	232.26	40.00	7.0000
52.07	232.26	50.00	7.0000
47.53	232.26	60.00	7.0000
44.01	232.26	70.00	7.0000
41.16	232.26	80.00	7.0000
38.81	232.26	90.00	7.0000
36.82	232.26	100.00	7.0000
26.03	232.26	200.00	7.0000
21.26	232.26	300.00	7.0000
18.41	232.26	400.00	7.0000
16.47	232.26	500.00	7.0000
15.03	232.26	600.00	7.0000
13.92	232.26	700.00	7.0000
13.02	232.26	800.00	7.0000
12.27	232.26	900.00	7.0000
11.64	232.26	1000.00	7.0000
8.23	232.26	2000.00	7.0000

(16)

Length, L  
(ft)Dia. D  
(cm<sup>2</sup>)Outgassing Rate, q  
x 10<sup>-3</sup> Tl/sec cm<sup>2</sup>Press Drop  
x10<sup>-6</sup> Torr

6.72	232.26	3000.00	7.0000
5.82	232.26	4000.00	7.0000
5.21	232.26	5000.00	7.0000
4.75	232.26	6000.00	7.0000
4.40	232.26	7000.00	7.0000
4.12	232.26	8000.00	7.0000
3.88	232.26	9000.00	7.0000
429.54	316.13	1.00	7.0000
303.73	316.13	2.00	7.0000
248.00	316.13	3.00	7.0000
214.77	316.13	4.00	7.0000
192.10	316.13	5.00	7.0000
175.36	316.13	6.00	7.0000
162.35	316.13	7.00	7.0000
151.87	316.13	8.00	7.0000
143.18	316.13	9.00	7.0000
135.83	316.13	10.00	7.0000
96.05	316.13	20.00	7.0000
78.42	316.13	30.00	7.0000
67.92	316.13	40.00	7.0000
60.75	316.13	50.00	7.0000
55.45	316.13	60.00	7.0000
51.34	316.13	70.00	7.0000
48.02	316.13	80.00	7.0000
45.28	316.13	90.00	7.0000
42.95	316.13	100.00	7.0000
30.37	316.13	200.00	7.0000
24.80	316.13	300.00	7.0000
21.48	316.13	400.00	7.0000
19.21	316.13	500.00	7.0000
17.54	316.13	600.00	7.0000
16.24	316.13	700.00	7.0000
15.19	316.13	800.00	7.0000
14.32	316.13	900.00	7.0000
13.58	316.13	1000.00	7.0000
9.60	316.13	2000.00	7.0000
7.84	316.13	3000.00	7.0000
6.79	316.13	4000.00	7.0000
6.07	316.13	5000.00	7.0000
5.55	316.13	6000.00	7.0000
5.13	316.13	7000.00	7.0000
4.80	316.13	8000.00	7.0000
4.53	316.13	9000.00	7.0000
490.90	412.90	1.00	7.0000
347.12	412.90	2.00	7.0000
283.42	412.90	3.00	7.0000
245.45	412.90	4.00	7.0000
219.54	412.90	5.00	7.0000
200.41	412.90	6.00	7.0000
185.54	412.90	7.00	7.0000
173.56	412.90	8.00	7.0000
163.63	412.90	9.00	7.0000
155.24	412.90	10.00	7.0000
109.77	412.90	20.00	7.0000
89.63	412.90	30.00	7.0000
77.62	412.90	40.00	7.0000
69.42	412.90	50.00	7.0000
63.38	412.90	60.00	7.0000
58.67	412.90	70.00	7.0000
54.88	412.90	80.00	7.0000
51.75	412.90	90.00	7.0000
49.09	412.90	100.00	7.0000

(17)	(ft)	(cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> T <sub>0</sub> /sec cm <sup>2</sup>	Press Drop, ΔP x10 <sup>-8</sup> Torr
	34.71	412.90	200.00	7.0000
	28.34	412.90	300.00	7.0000
	24.55	412.90	400.00	7.0000
	21.95	412.90	500.00	7.0000
	20.04	412.90	600.00	7.0000
	18.55	412.90	700.00	7.0000
	17.36	412.90	800.00	7.0000
	16.36	412.90	900.00	7.0000
	15.52	412.90	1000.00	7.0000
	10.98	412.90	2000.00	7.0000
	8.96	412.90	3000.00	7.0000
	7.76	412.90	4000.00	7.0000
	6.94	412.90	5000.00	7.0000
	6.34	412.90	6000.00	7.0000
	5.87	412.90	7000.00	7.0000
	5.49	412.90	8000.00	7.0000
	5.17	412.90	9000.00	7.0000
	139.16	25.81	1.00	9.0000
	98.40	25.81	2.00	9.0000
	80.34	25.81	3.00	9.0000
	69.58	25.81	4.00	9.0000
	62.23	25.81	5.00	9.0000
	56.81	25.81	6.00	9.0000
	52.60	25.81	7.00	9.0000
	49.20	25.81	8.00	9.0000
	46.39	25.81	9.00	9.0000
	44.01	25.81	10.00	9.0000
	31.12	25.81	20.00	9.0000
	25.41	25.81	30.00	9.0000
	22.00	25.81	40.00	9.0000
	19.68	25.81	50.00	9.0000
	17.97	25.81	60.00	9.0000
	16.63	25.81	70.00	9.0000
	15.56	25.81	80.00	9.0000
	14.67	25.81	90.00	9.0000
	13.92	25.81	100.00	9.0000
	9.84	25.81	200.00	9.0000
	8.03	25.81	300.00	9.0000
	6.96	25.81	400.00	9.0000
	6.22	25.81	500.00	9.0000
	5.68	25.81	600.00	9.0000
	5.26	25.81	700.00	9.0000
	4.92	25.81	800.00	9.0000
	4.64	25.81	900.00	9.0000
	4.40	25.81	1000.00	9.0000
	3.11	25.81	2000.00	9.0000
	2.54	25.81	3000.00	9.0000
	2.20	25.81	4000.00	9.0000
	1.97	25.81	5000.00	9.0000
	1.80	25.81	6000.00	9.0000
	1.66	25.81	7000.00	9.0000
	1.56	25.81	8000.00	9.0000
	1.47	25.81	9000.00	9.0000
	208.74	58.06	1.00	9.0000
	147.60	58.06	2.00	9.0000
	120.51	58.06	3.00	9.0000
	104.37	58.06	4.00	9.0000
	93.35	58.06	5.00	9.0000
	85.22	58.06	6.00	9.0000
	78.90	58.06	7.00	9.0000
	73.80	58.06	8.00	9.0000
	69.58	58.06	9.00	9.0000

(18)	Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> Tl/sec cm <sup>2</sup>	Press. Drop, ΔP x10 <sup>-8</sup> Torr
	66.01	58.06	10.00	9.0000
	46.68	58.06	20.00	9.0000
	38.11	58.06	30.00	9.0000
	33.00	58.06	40.00	9.0000
	29.52	58.06	50.00	9.0000
	26.95	58.06	60.00	9.0000
	24.95	58.06	70.00	9.0000
	23.34	58.06	80.00	9.0000
	22.00	58.06	90.00	9.0000
	20.87	58.06	100.00	9.0000
	14.76	58.06	200.00	9.0000
	12.05	58.06	300.00	9.0000
	10.44	58.06	400.00	9.0000
	9.34	58.06	500.00	9.0000
	8.52	58.06	600.00	9.0000
	7.89	58.06	700.00	9.0000
	7.38	58.06	800.00	9.0000
	6.96	58.06	900.00	9.0000
	6.60	58.06	1000.00	9.0000
	4.67	58.06	2000.00	9.0000
	3.81	58.06	3000.00	9.0000
	3.30	58.06	4000.00	9.0000
	2.95	58.06	5000.00	9.0000
	2.69	58.06	6000.00	9.0000
	2.49	58.06	7000.00	9.0000
	2.33	58.06	8000.00	9.0000
	2.20	58.06	9000.00	9.0000
	278.32	103.23	1.00	9.0000
	196.80	103.23	2.00	9.0000
	160.69	103.23	3.00	9.0000
	139.16	103.23	4.00	9.0000
	124.47	103.23	5.00	9.0000
	113.62	103.23	6.00	9.0000
	105.19	103.23	7.00	9.0000
	98.40	103.23	8.00	9.0000
	92.77	103.23	9.00	9.0000
	88.01	103.23	10.00	9.0000
	62.23	103.23	20.00	9.0000
	50.81	103.23	30.00	9.0000
	44.01	103.23	40.00	9.0000
	39.36	103.23	50.00	9.0000
	35.93	103.23	60.00	9.0000
	33.27	103.23	70.00	9.0000
	31.12	103.23	80.00	9.0000
	29.34	103.23	90.00	9.0000
	27.83	103.23	100.00	9.0000
	19.68	103.23	200.00	9.0000
	16.07	103.23	300.00	9.0000
	13.92	103.23	400.00	9.0000
	12.45	103.23	500.00	9.0000
	11.36	103.23	600.00	9.0000
	10.52	103.23	700.00	9.0000
	9.84	103.23	800.00	9.0000
	9.28	103.23	900.00	9.0000
	8.80	103.23	1000.00	9.0000
	6.22	103.23	2000.00	9.0000
	5.08	103.23	3000.00	9.0000
	4.40	103.23	4000.00	9.0000
	3.94	103.23	5000.00	9.0000
	3.59	103.23	6000.00	9.0000
	3.33	103.23	7000.00	9.0000
	3.11	103.23	8000.00	9.0000



(19)	Length, L (FT)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, g x10 <sup>-10</sup> T <sub>0</sub> /sec cm <sup>2</sup>	Press Drop, ΔP x 10 <sup>-6</sup> Torr
	2.93	103.23	9000.00	9.0000
	347.90	161.29	1.00	9.0000
	246.00	161.29	2.00	9.0000
	200.86	161.29	3.00	9.0000
	173.95	161.29	4.00	9.0000
	155.58	161.29	5.00	9.0000
	142.03	161.29	6.00	9.0000
	131.49	161.29	7.00	9.0000
	123.00	161.29	8.00	9.0000
	115.97	161.29	9.00	9.0000
	110.01	161.29	10.00	9.0000
	77.79	161.29	20.00	9.0000
	63.52	161.29	30.00	9.0000
	55.01	161.29	40.00	9.0000
	49.20	161.29	50.00	9.0000
	44.91	161.29	60.00	9.0000
	41.58	161.29	70.00	9.0000
	38.90	161.29	80.00	9.0000
	36.67	161.29	90.00	9.0000
	34.79	161.29	100.00	9.0000
	24.60	161.29	200.00	9.0000
	20.09	161.29	300.00	9.0000
	17.39	161.29	400.00	9.0000
	15.56	161.29	500.00	9.0000
	14.20	161.29	600.00	9.0000
	13.15	161.29	700.00	9.0000
	12.30	161.29	800.00	9.0000
	11.60	161.29	900.00	9.0000
	11.00	161.29	1000.00	9.0000
	7.78	161.29	2000.00	9.0000
	6.35	161.29	3000.00	9.0000
	5.50	161.29	4000.00	9.0000
	4.92	161.29	5000.00	9.0000
	4.49	161.29	6000.00	9.0000
	4.16	161.29	7000.00	9.0000
	3.89	161.29	8000.00	9.0000
	3.67	161.29	9000.00	9.0000
	417.48	232.26	1.00	9.0000
	295.20	232.26	2.00	9.0000
	241.03	232.26	3.00	9.0000
	208.74	232.26	4.00	9.0000
	186.70	232.26	5.00	9.0000
	170.43	232.26	6.00	9.0000
	157.79	232.26	7.00	9.0000
	147.60	232.26	8.00	9.0000
	139.16	232.26	9.00	9.0000
	132.02	232.26	10.00	9.0000
	93.35	232.26	20.00	9.0000
	76.22	232.26	30.00	9.0000
	66.01	232.26	40.00	9.0000
	59.04	232.26	50.00	9.0000
	53.90	232.26	60.00	9.0000
	49.90	232.26	70.00	9.0000
	46.68	232.26	80.00	9.0000
	44.01	232.26	90.00	9.0000
	41.75	232.26	100.00	9.0000
	29.52	232.26	200.00	9.0000
	24.10	232.26	300.00	9.0000
	20.87	232.26	400.00	9.0000
	18.67	232.26	500.00	9.0000
	17.04	232.26	600.00	9.0000
	15.78	232.26	700.00	9.0000

(20)

Length, L  
(ft)Dia. D  
(cm<sup>2</sup>)Outgassing Rate, q  
x10<sup>-10</sup> Tl/sec cm<sup>2</sup>Press. Drop, ΔP  
x10<sup>-6</sup> Torr

Length, L (ft)	Dia. D (cm <sup>2</sup> )	Outgassing Rate, q x10 <sup>-10</sup> Tl/sec cm <sup>2</sup>	Press. Drop, ΔP x10 <sup>-6</sup> Torr
14.76	232.26	800.00	9.0000
13.92	232.26	900.00	9.0000
13.20	232.26	1000.00	9.0000
9.34	232.26	2000.00	9.0000
7.62	232.26	3000.00	9.0000
6.60	232.26	4000.00	9.0000
5.90	232.26	5000.00	9.0000
5.39	232.26	6000.00	9.0000
4.99	232.26	7000.00	9.0000
4.67	232.26	8000.00	9.0000
4.40	232.26	9000.00	9.0000
487.05	316.13	1.00	9.0000
344.40	316.13	2.00	9.0000
281.20	316.13	3.00	9.0000
243.53	316.13	4.00	9.0000
217.82	316.13	5.00	9.0000
198.84	316.13	6.00	9.0000
184.09	316.13	7.00	9.0000
172.20	316.13	8.00	9.0000
162.35	316.13	9.00	9.0000
154.02	316.13	10.00	9.0000
108.91	316.13	20.00	9.0000
88.92	316.13	30.00	9.0000
77.01	316.13	40.00	9.0000
68.88	316.13	50.00	9.0000
62.88	316.13	60.00	9.0000
58.21	316.13	70.00	9.0000
54.45	316.13	80.00	9.0000
51.34	316.13	90.00	9.0000
48.71	316.13	100.00	9.0000
34.44	316.13	200.00	9.0000
28.12	316.13	300.00	9.0000
24.35	316.13	400.00	9.0000
21.78	316.13	500.00	9.0000
19.88	316.13	600.00	9.0000
18.41	316.13	700.00	9.0000
17.22	316.13	800.00	9.0000
16.24	316.13	900.00	9.0000
15.40	316.13	1000.00	9.0000
10.89	316.13	2000.00	9.0000
8.89	316.13	3000.00	9.0000
7.70	316.13	4000.00	9.0000
6.89	316.13	5000.00	9.0000
6.29	316.13	6000.00	9.0000
5.82	316.13	7000.00	9.0000
5.45	316.13	8000.00	9.0000
5.13	316.13	9000.00	9.0000
556.63	412.90	1.00	9.0000
393.60	412.90	2.00	9.0000
321.37	412.90	3.00	9.0000
278.32	412.90	4.00	9.0000
248.93	412.90	5.00	9.0000
227.24	412.90	6.00	9.0000
210.39	412.90	7.00	9.0000
196.80	412.90	8.00	9.0000
185.54	412.90	9.00	9.0000
176.02	412.90	10.00	9.0000
124.47	412.90	20.00	9.0000
101.63	412.90	30.00	9.0000
88.01	412.90	40.00	9.0000
78.72	412.90	50.00	9.0000
71.86	412.90	60.00	9.0000

(21)

Length, L  
(ft)Dia. D  
(cm<sup>2</sup>)Outgassing Rate, q  
 $\times 10^{-10}$  Torr/sec cm<sup>2</sup>Press Drop,  $\Delta P$   
 $\times 10^{-6}$  Torr

66.53	412.90	70.00	9.0000
62.23	412.90	80.00	9.0000
58.67	412.90	90.00	9.0000
55.66	412.90	100.00	9.0000
39.36	412.90	200.00	9.0000
32.14	412.90	300.00	9.0000
27.83	412.90	400.00	9.0000
24.89	412.90	500.00	9.0000
22.72	412.90	600.00	9.0000
21.04	412.90	700.00	9.0000
19.68	412.90	800.00	9.0000
18.55	412.90	900.00	9.0000
17.60	412.90	1000.00	9.0000
12.45	412.90	2000.00	9.0000
10.16	412.90	3000.00	9.0000
8.80	412.90	4000.00	9.0000
7.87	412.90	5000.00	9.0000
7.19	412.90	6000.00	9.0000
6.65	412.90	7000.00	9.0000
6.22	412.90	8000.00	9.0000
5.87	412.90	9000.00	9.0000