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SIMPLIFIED DESIGN OF LONG LINEAR VACUUM SYSTEMS

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Collider Accelerator Department

Brookhaven National Laboratory

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AGS DIVISION TECHNICAL NOTE

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 1×10^{-10} through 9×10^{-7} torr ℓ/sec cm^2, and the pressure drops were selected as 1, 3, 5, 7 and 9×10^{-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.

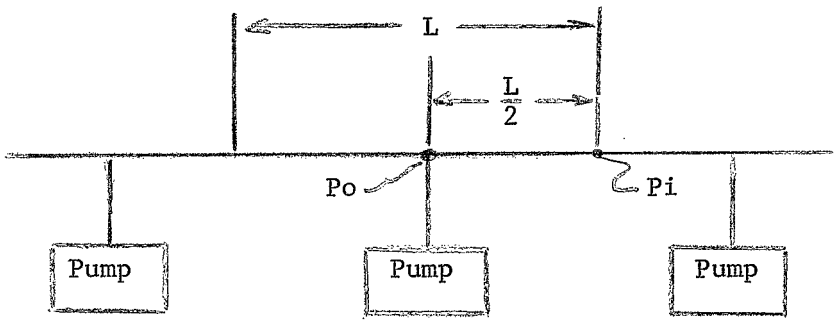

Figure 1.

Referring to Figure 1, for air at 20°C in the molecular flow region[1] the maximum pressure drop (Pi - Po) is given by

$$Q = C\ (Pi - Po) = C\ \Delta P$$

where Q is the throughput (amount of gas pumped) in Tℓ/sec and C is the conductance (resistance to "flow") between points Pi and Po in ℓ/sec. The pressure drop ΔP is given in torr.

Knudsen[2] 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 cm^2, B is the perimeter of the tube in cm, and L is the distance between pumps in 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 cm and q the specific outgassing rate of the vacuum tube in Tℓ/sec cm^2.

Solving for ΔP

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

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 $\bar{P}D < 15\mu$ - cm

Viscous Flow Region $\bar{P}D > 500\ \mu$ - 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 ΔP. 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^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Press. Drop, ΔP $x\ 10^{-6}$ 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^2)	Outgassing Rate, q $\times 10^{-10}$ Tl/sec cm^2	Pres. Drop, ΔP $\times 10^{-6}$ 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^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Press.Drop, ΔP $x\ 10^{-6}$ 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^2)	Outgassing Rate, q x 10^{-10} T ℓ/sec cm^2	Press. Drop, ΔP x10^{-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^2)	Outgassing Rate, g $x10^{-6}$ Tℓ/sec cm^2	Press. Drop, ΔP $x10^{-3}$ 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^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Press.Drop ΔP $x10^{-6}$ 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)	(cm²)	x10⁻¹⁰ Tℓ/sec cm²	Press. Drop, ΔP x10⁻⁶ 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^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	x 10^{-6} 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

Length, L (ft)	Dia. D (cm^2)	Outgassing Rate, q $x10^{-10}$ T//sec cm^2	Pres. Drop, ΔP $x10^{-6}$ 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^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Pres. Drop, ΔP $x10^{-6}$ 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^2)	Outgassing Rate,q $x10^{-10}$ Tℓ/sec cm^2	Press.Drop,ΔP x 10^{-6} 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^2)	Outgassing Rate, q $x10^{-10}$ Torr ℓ/sec cm^2	Press. Drop, ΔP $x10^{-6}$ 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

Length, L (ft)	Dia. D (cm^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Press Drop, ΔP $x10^{-6}$ 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
122.73	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
184.09	58,06	1,00	7,0000
130.17	58,06	2,00	7,0000
106.28	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^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Press Drop, ΔP $x\ 10^{-6}$ 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

Length, L (ft)	Dia. D (cm^2)	Outgassing Rate, q $x10^{-10}$ Tl/sec cm^2	Press.Drop, ΔP $x10^{-6}$ 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

Length, L (ft)	Dia. D (cm^2)	Outgassing Rate, q x 10^{-10} Tℓ/sec cm^2	Press Drop, ΔP x10^{-6} 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

(ℓt)	(cm^2)	Outgassing Rate, q $x10^{-10}$ T ℓ/sec cm^2	Press Drop, ΔP $x10^{-6}$ 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

Length, L (ft)	Dia. D (cm²)	Outgassing Rate, q x10⁻¹⁰ Tℓ/sec cm²	Press. Drop, ΔP x10⁻⁶ 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

Length, L (ft)	Dia. D (cm^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Press Drop, ΔP $x\ 10^{-6}$ 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

Length, L (ft)	Dia. D (cm^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Press. Drop, ΔP $x10^{-6}$ 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^2)	Outgassing Rate, q $x10^{-10}$ Tℓ/sec cm^2	Press Drop, ΔP $x10^{-6}$ 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