

THE PERMEABILITIES OF THREE POROUS GRAPHITES

Final Report

to

National Aeronautics and Space Administration
Hampton, Virginia

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Task Order 2

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THE PERMEABILITIES OF THREE POROUS GRAPHITES

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INTRODUCTION

This is the final report under Task Order 2 of Contract NAS 1-5448 for a project to determine the permeabilities of three porous graphites, Grades 25, 45, and 60. The shipping labels identified the specimens as Grades A, B, and C and these designations have been followed throughout this report. Permeabilities of these graphites were measured from room temperature to 1000°F using both nitrogen and helium as the permeating gases.

APPARATUS AND PROCEDURE

A schematic of the permeability apparatus is shown in Figure 1. Gas was supplied to the specimen from a commercial gas cylinder. The upstream pressure was regulated at 2 to 6 inches of mercury by means of a pressure regulator and a throttling valve. Flow rate was measured with a wet test meter. The total pressure drop through the specimen was measured with a mercury manometer. The specimen was heated in a tubular resistance furnace and its temperature measured by two thermocouples inserted in radially drilled holes in the housing. Power input to the heater was controlled by an autotransformer. Before entering the wet test meter, the gas was cooled to room temperature by passing it through a cooling coil immersed in ice water.

The specimen, which was one inch in diameter by approximately $\frac{1}{4}$ inch thick, was mounted in a stainless steel housing as shown in Figure 2. The specimen was mounted on a shoulder approximately $\frac{1}{64}$ inch wide, so that the effective flow diameter was 0.9375 inch. On the upstream side, the specimen holder was bored out to a diameter of 1.50 inches and the annulus between the specimen and the holder was filled with a sealing compound. For the high temperature runs Sauereisen No. 31 cement was used as a sealant. To verify

the sealing qualities of the Sauereisen cement, some evaluations were made on each of the three graphites from room temperature to 500°F using a silicone rubber (Dow Corning RTV-731 Silastic) as the sealant. The silicone rubber had been employed with prior success in room temperature permeability measurements.

Initially, some difficulty was experienced in obtaining a satisfactory seal with the Sauereisen cement due to shrinkage and cracking of the cement on curing. In some cases a satisfactory seal at room temperature would fail at temperatures in the vicinity of 1000°F, as evidenced by a sudden increase in the flow through the specimen. After some experimentation, a satisfactory seal was obtained over the full temperature range by filling the annulus about $\frac{3}{4}$ full with a dry mix of the Sauereisen, allowing it to cure for 24 hours at room temperature, then applying a fairly wet wash of the cement on the surface. A brass washer was mounted on the surface of the cement while it was still wet. This washer reduced the exposed area of the sealant and served as a secondary seal.

Knife edges and copper gaskets were used to seal the specimen holder within the housing.

During the runs the following data were recorded:

1. Barometric pressure, in. Hg
2. Upstream pressure, in. Hg
3. Flow rate, cm³/sec
4. Specimen temperature, °F
5. Temperature at wet test meter, °F
6. Room temperature, °F
7. Downstream pressure (measured at inlet to wet test meter), in. H₂O.

The procedure in making the runs was as follows: The system was purged for about one hour to saturate the gas in the wet test meter. The upstream pressure was adjusted to the desired level and the temperature allowed to stabilize before taking data. All runs were made in both nitrogen and helium. When changing from one gas to the other the system was purged for about 30 minutes before taking a reading. Four readings were taken at each pressure level to monitor that steady state conditions had been obtained.

The admittance of the specimen was calculated using the equation

$$K_{mv} = \frac{P_m L Q_m}{\Delta P} \quad (1)$$

where

P_m = mean pressure in specimen

Q_m = flow rate through specimen based on mean pressure, cm^3/sec

L = thickness of specimen, cm

A = cross sectional area of specimen, cm^2

ΔP = pressure drop across specimen

Since the flow rate was measured at the meter, it had to be corrected for conditions at the specimen. This was performed using the continuity equation as follows:

$$W = \rho AV = \rho Q = \text{constant} \quad (2)$$

where

ρ = gas density

A = flow area

V = velocity

from the perfect gas law

$$\rho = \frac{P}{RT} \quad (3)$$

where

R = the gas constant

T = absolute temperature

then substituting in equation (2)

$$\left(\frac{P_m Q_m}{RT_m} \right)_{\text{specimen}} = \left(\frac{PQ}{RT} \right)_{\text{meter}} \quad (4)$$

then

$$P_m Q_m = PQ \Big)_{\text{meter}} \left(\frac{T_{\text{specimen}}}{T_{\text{meter}}} \right) \quad (5)$$

Thus, the flow rates measured at the wet test meter were corrected to the flow rates that existed for the pressures and temperatures at the specimen.

DATA AND RESULTS

The data for Graphite A are shown in Figure 3 and Tables 1 and 2. As shown in Figure 3, the values at room temperature ranged from about 2200 cm²/sec for nitrogen to about 3100 cm²/sec for helium. At 1000°F the values all agreed within about 10 percent, averaging about 3000 cm²/sec.

The data for Graphite B are shown in Figures 4 and 5 and Tables 3, 4, and 5. As shown in the figures the curves exhibited about the same character as those for Graphite A, the lowest values at room temperature being measured in nitrogen at an upstream pressure of 6 in. Hg. At 1000°F the lowest values were for helium. At both temperatures the values ranged from about 1150 cm²/sec to 1500 cm²/sec.

The data for Graphite C are shown in Figure 6 and Tables 6, 7, and 8. This graphite exhibited the lowest permeabilities of the three grades tested, the values ranging from about 340 to 480 cm²/sec at room temperature, and from 250 to 380 cm²/sec at 1000°F.

To investigate the flow characteristics at higher pressure drops, some evaluations were made at room temperature on a specimen of Graphite B. For these determinations the wet test meter was replaced with a rotameter which, although less accurate than the wet test meter, did permit the measurement of higher flows. The data are shown in Figure 7 and Table 9. Observe that the admittance generally increased with increasing pressure. The type of flow can be determined from a log-log plot of PQ versus PΔP. From the theory of flow through porous media, the product PQ is directly proportional to PΔP, i. e., the slope of the curve is unity if the flow in the pores is laminar. If turbulent flow exists, the flow rate is proportional to the $\frac{1}{2}$ power of PΔP (slope = 0.5). For the transition region in which both types of flow exist, the exponent, or slope of the curve, will fall between 0.5 and unity.¹

Such a plot is presented in Figure 8, showing that over the range of pressures covered the flow is laminar for both gases, possibly approaching turbulent flow for nitrogen at the upper end.

DISCUSSION

In general, the permeability varies with pressure and temperature in a fashion that is indicative of the type of flow through the specimen. The admittance, K_{mv} , can be represented as the sum of two terms, as follows:

$$K_{mv} = K_0 \sqrt{RT} + K_1 \frac{P_m}{\eta} \quad (5)$$

where η is the viscosity of the gas.

The first term represents the molecular portion and the second term the viscous portion. If viscous flow predominates, the curve increases linearly with pressure and decreases with temperature because of the viscosity effect. If molecular flow predominates, the admittance will remain constant with pressure and increase with an increase in temperature, provided K_0 remains constant. Reference to Figure 7 shows that for Graphite B at room temperature and at mean pressures below about 35 in. Hg, corresponding to upstream gage pressures below 6 in. Hg, the admittance for both gases decreased or remained constant with pressure. Hence, flow was predominantly molecular. The data for Graphites A and B, shown in Figures 3 through 5, also exhibited this trend at room temperature, while at 1000°F there was some pressure effect, suggesting viscous flow at the higher temperature. For Graphite C, the permeability increased with increasing pressure and decreased with increasing temperature, suggesting viscous flow over the full temperature range.

It appears that for all conditions of the tests, flow was laminar.

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REFERENCES

1. Creutz, E.: Turbulent and Transition Gas Flow in Porous Media. Nuclear Science and Engineering, Vol. 20, 1964, pp. 28-44.

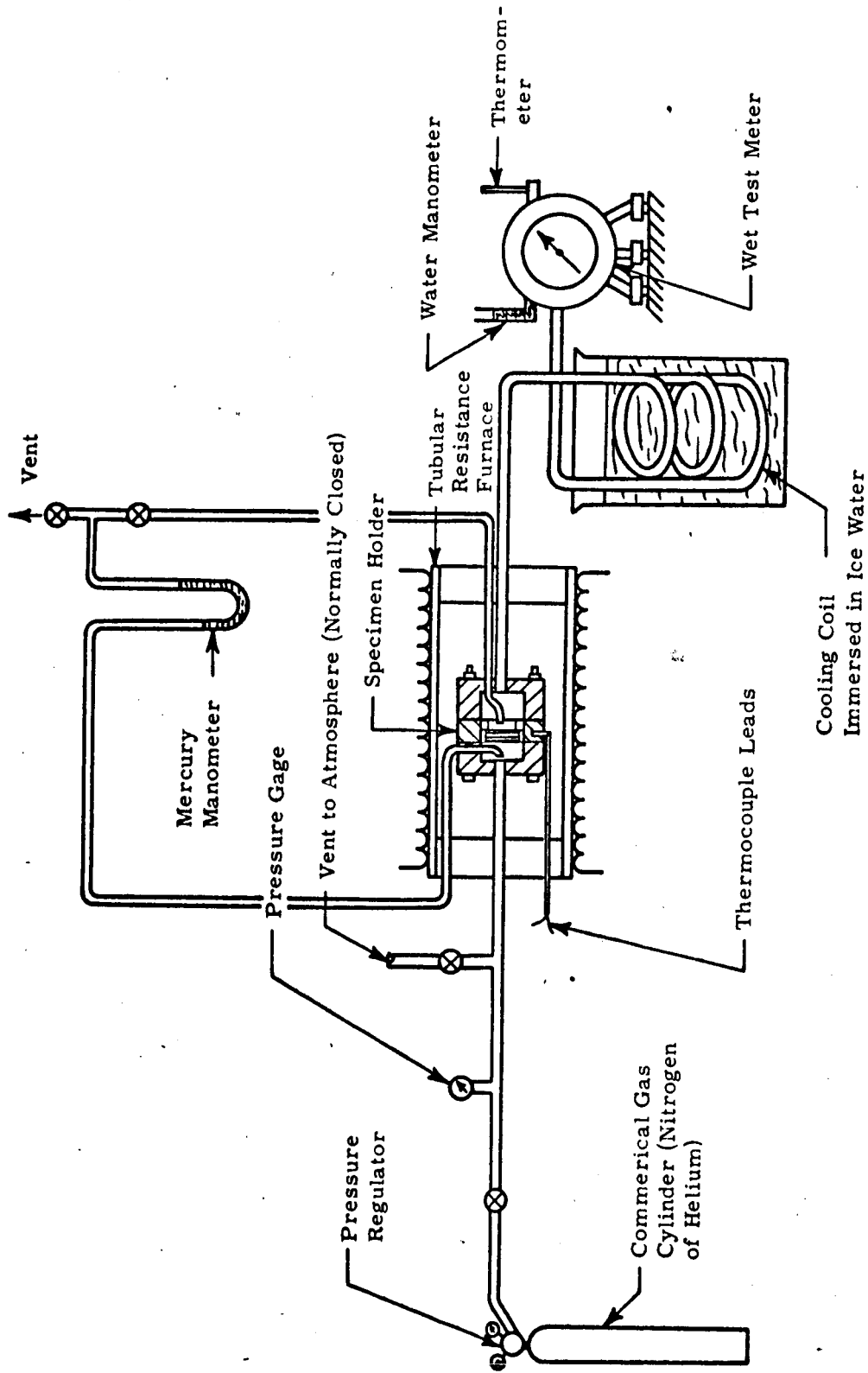


Figure 1. Schematic of the Permeability Apparatus

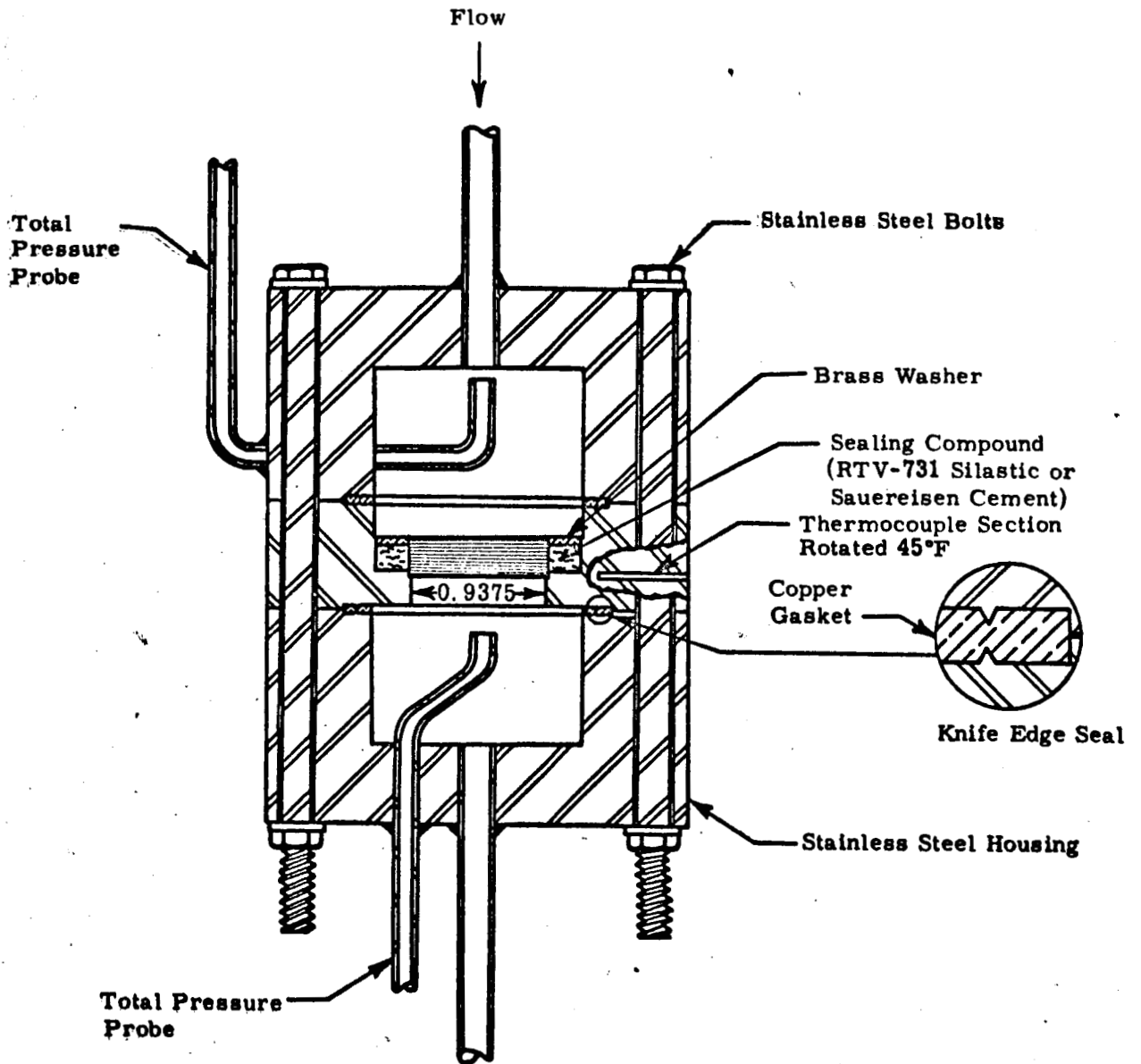


Figure 2. Details of Permeability Specimen Holder

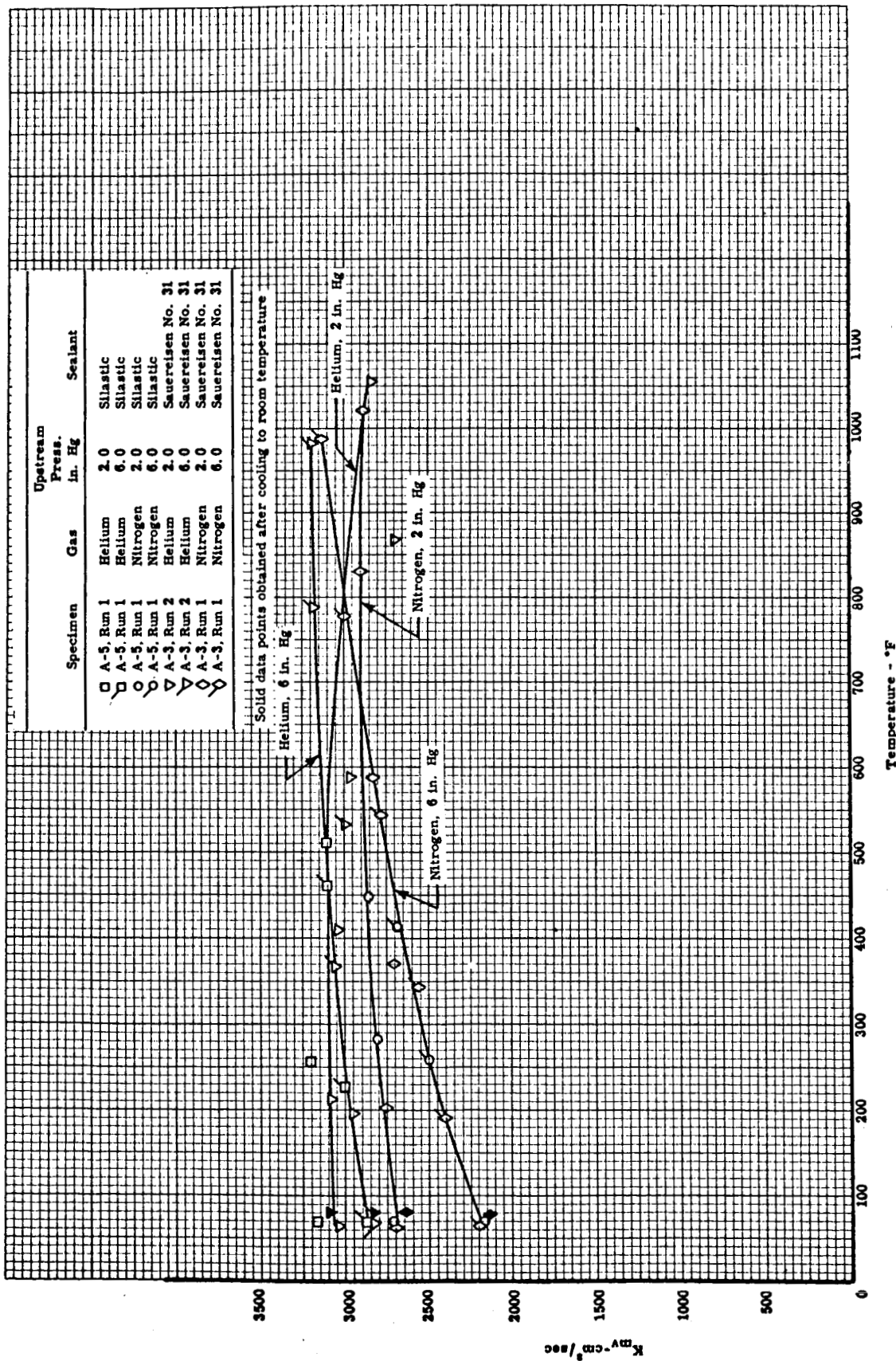


Figure 3. The permeability of porous graphite Type A

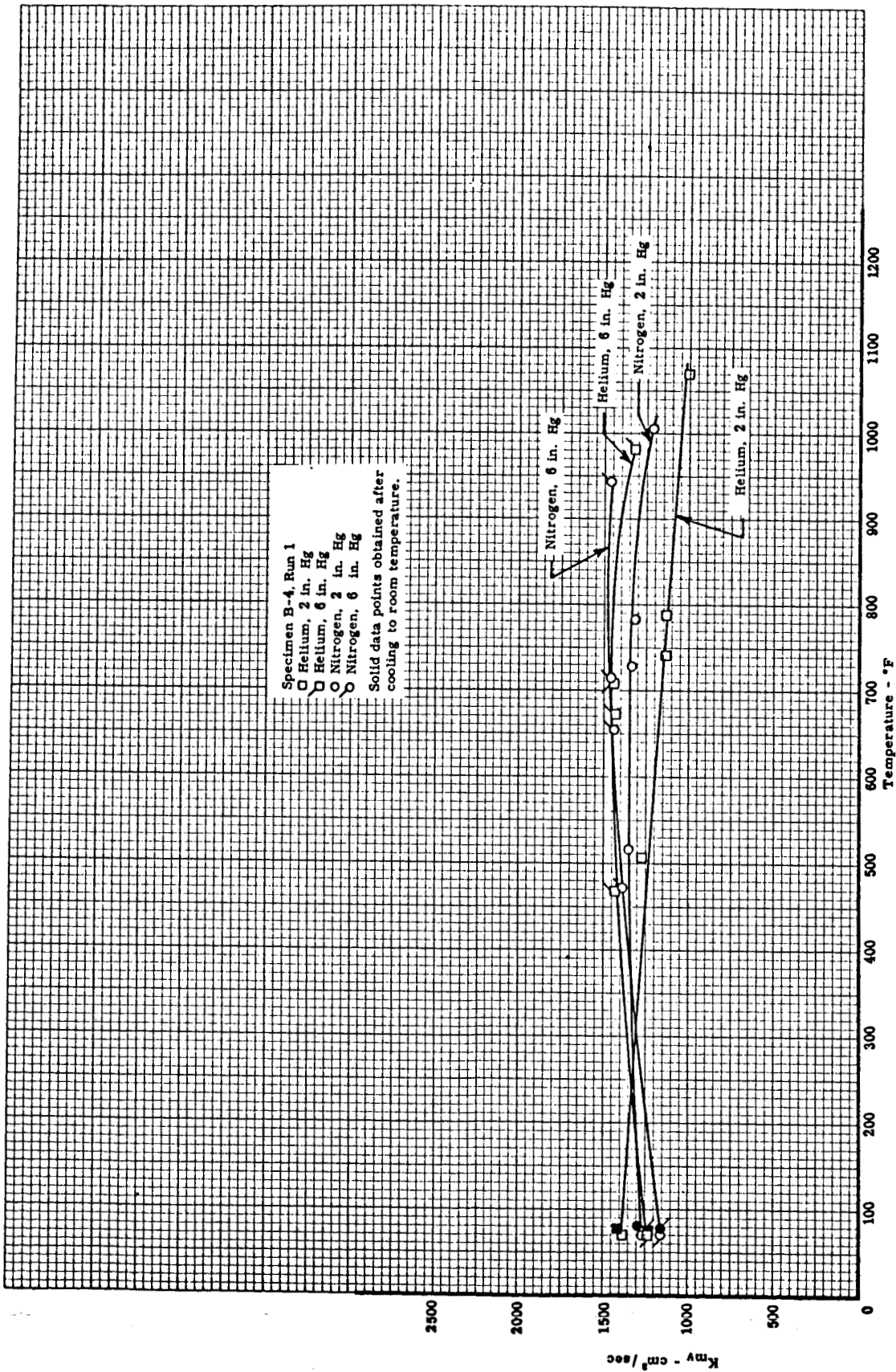


Figure 4. The permeability of porous graphite Type B

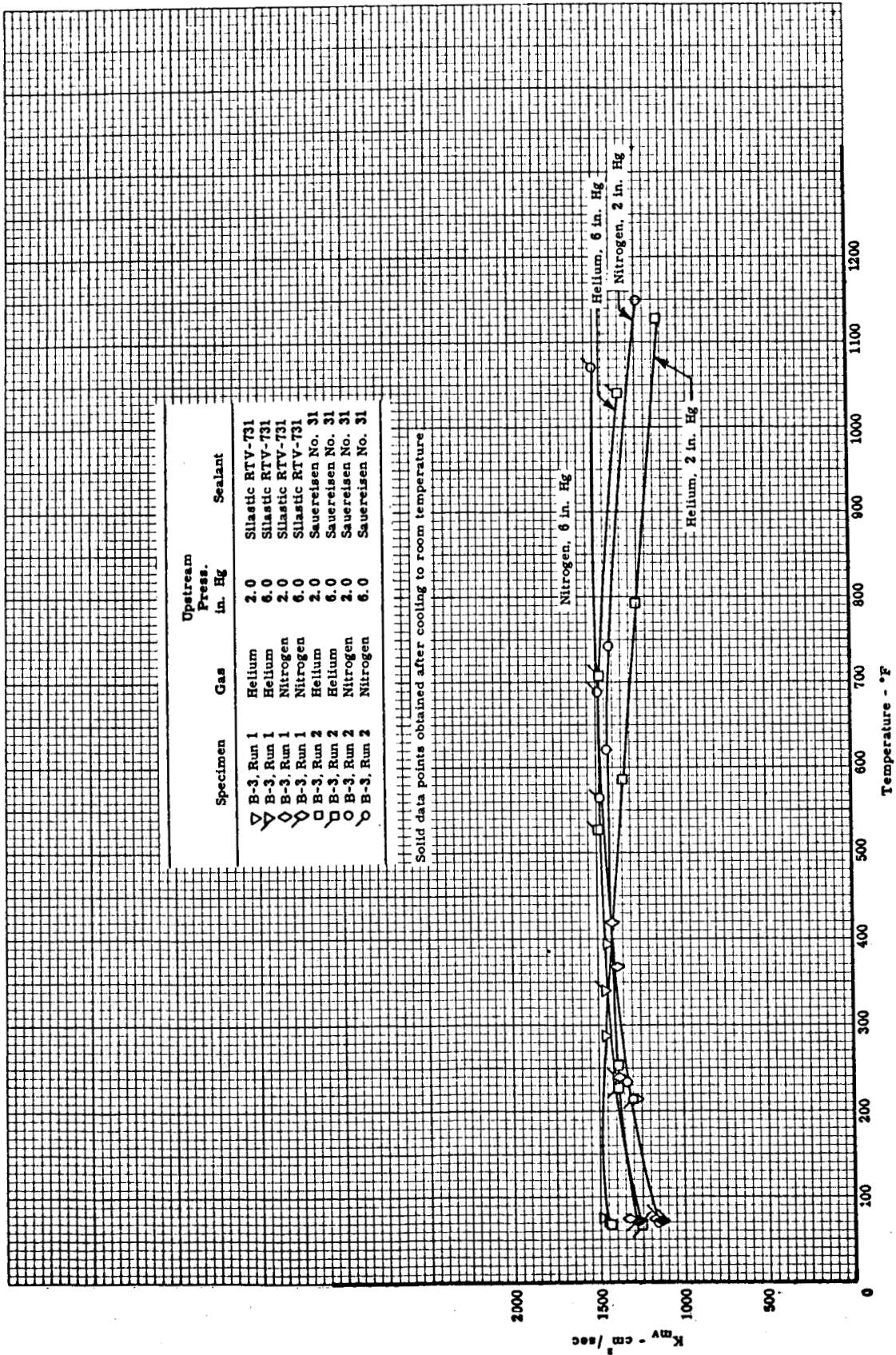


Figure 5. The permeability of porous graphite Type B

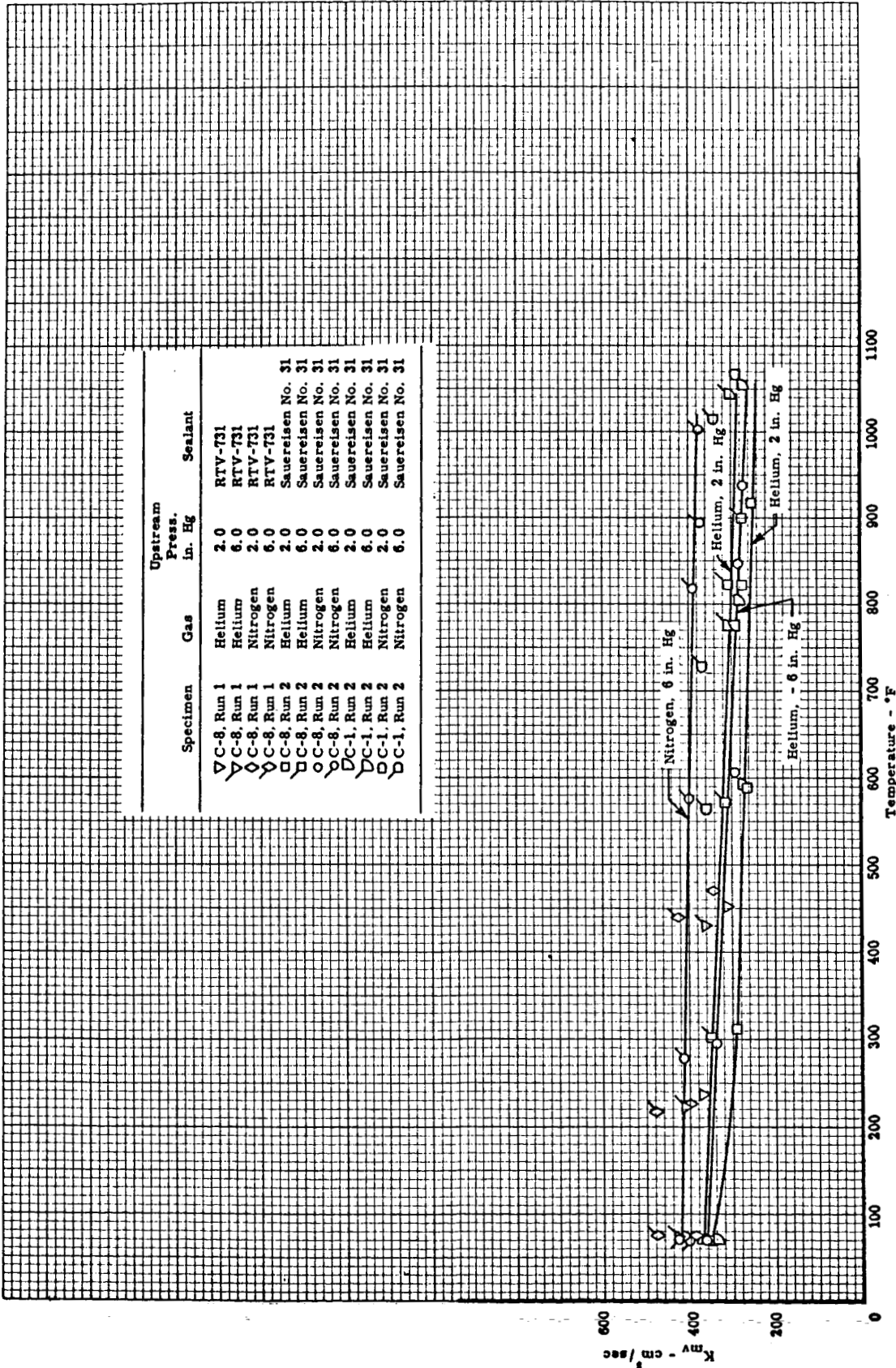


Figure 6. The permeability of porous graphite Type C

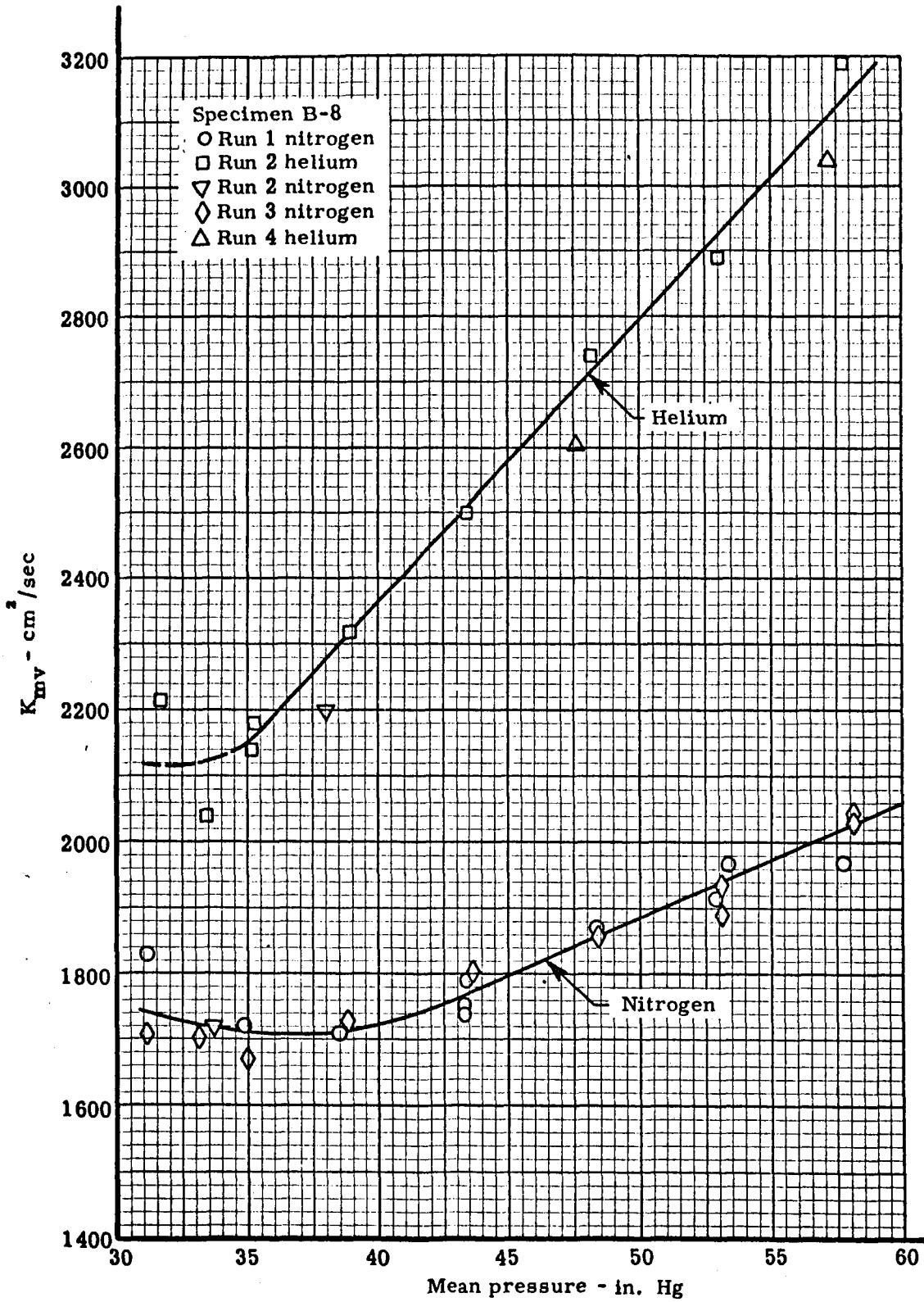


Figure 7. Permeability of Graphite B at room temperature showing effect of pressure

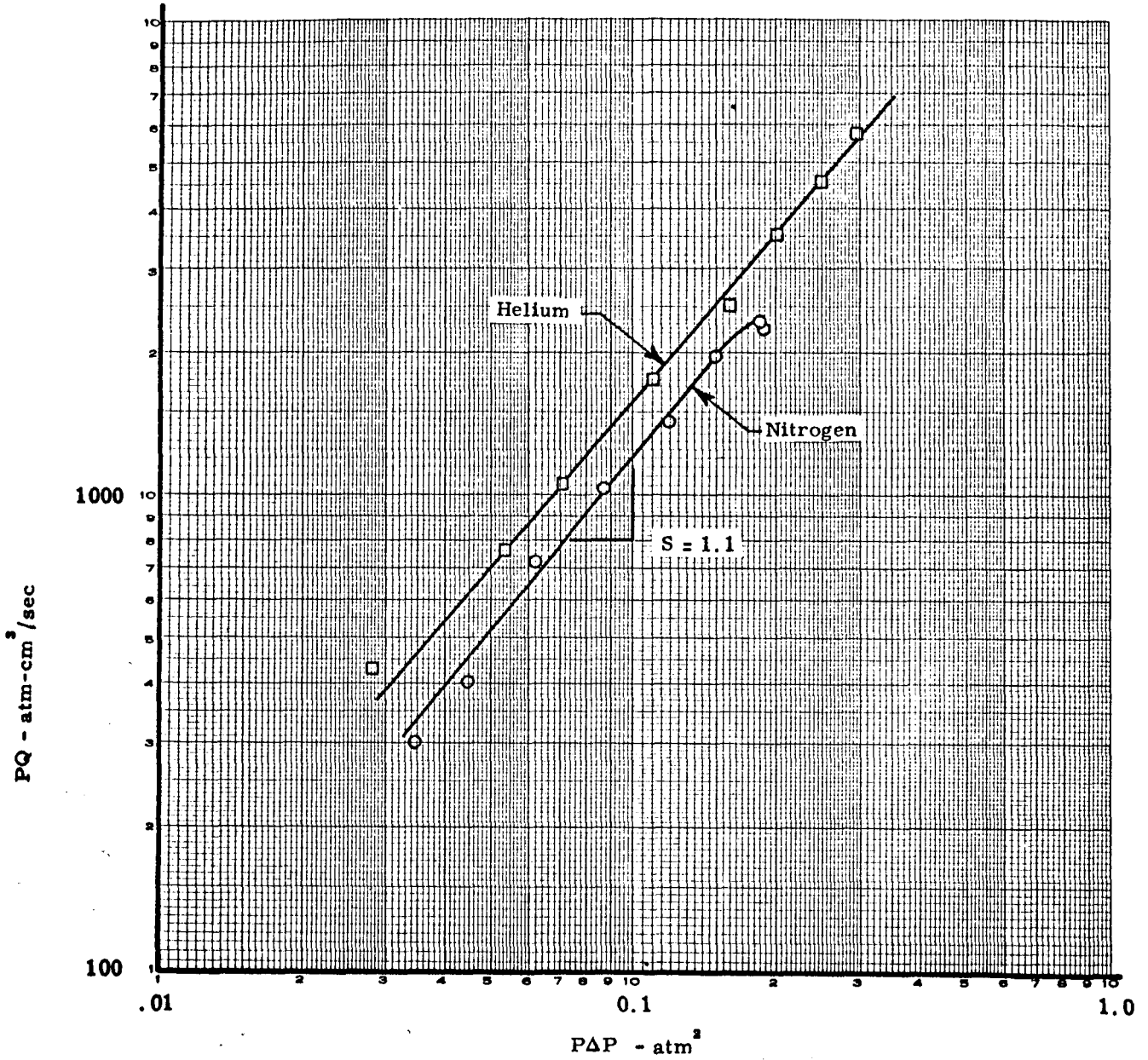


Figure 8. Product PQ in $\text{atm-cm}^3/\text{sec}$, versus $P\Delta P$ in atm^2 for Graphite B, Specimen 7

TABLE I
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN A-3, RUN 3

Time	Permeating gas	Atm. press. P ₀ in. Hg	Upstream gage press. P ₁ in. Hg	Downstream gage press. P ₂ in. Hg ^(s)	Pressure drop through specimen in. Hg	Mean press. P _m in. Hg	Temperature, °F		Flow rate cm ³ /sec ^(c)	K _{inv} cm ³ /sec	Remarks
							Spec.	Meter			
Begin Purge 12:00, Read											
1:50	nitrogen	30.15	2.0	0.055	.37	31.97	64.5	69.0	225.1	2700	
1:57	nitrogen	30.15	6.0	0.220	.53	35.73	64.5	69.0	417.2	3200	
Begin Purge 2:05, Read											
2:25	helium	30.15	2.0	0.037	.56	31.87	66.0	69.0	393.3	3040	
2:29	helium	30.15	6.0	0.184	1.23	35.53	66.0	68.5	806.8	2840	
4:15	helium	30.12	2.0	0.037	.68	31.78	211	68.5	380.2	3080	
4:28	helium	30.12	6.0	0.171	1.40	35.42	195	68.0	769.5	2960	
Begin Purge 4:32, Read											
4:52	nitrogen	30.12	2.0	0.051	.44	31.90	201	68.0	215.5	2780	
5:05	nitrogen	30.12	6.0	0.206	.90	35.67	190	67.8	403.4	2410	
Purge overnight with helium, Read											
7:51 a. m.	helium	30.25	2.0	0.029	.82	31.83	409	72.0	350.1	3040	
8:10	helium	30.25	6.0	0.154	1.65	35.43	366	70.5	741.2	3060	
Begin Purge 8:16, Read											
8:36	nitrogen	30.25	2.0	0.051	.53	31.98	370	65.5	209.2	2710	
8:51	nitrogen	30.25	6.0	0.199	1.00	35.75	342	70.0	389.0	2570	
11:04	nitrogen	30.25	2.0	0.048	.62	31.94	587	70.0	204.6	2830	
11:20	nitrogen	30.25	6.0	0.184	1.13	35.68	542	70.0	380.6	2780	
Begin Purge 11:25, Read											
12:36	helium	30.25	2.0	0.029	.96	31.77	588	69.2	330.0	2960	
12:50	helium	30.25	6.0	0.140	1.87	35.31	531	69.0	687.3	3000	
2:45	helium	30.20	2.0	0.029	1.16	31.62	869	68.5	287.2	2700	
2:57	helium	30.20	6.0	0.132	2.23	35.06	787	68.5	690.6	3180	
Begin Purge 3:00, Read											
3:20	nitrogen	30.20	2.0	0.044	.73	31.83	830	68.2	199.7	2900	
3:43	nitrogen	30.20	6.0	0.164	1.27	35.56	777	68.0	373.0	3000	
4:40	nitrogen	30.16	2.0	0.044	.81	31.75	1021	68.2	192.9	2890	
4:53	nitrogen	30.16	6.0	0.176	1.40	35.46	989	68.2	367.8	3140	
Begin Purge 5:00, Read											
5:18	helium	30.16	2.0	0.018	1.30	31.51	1055	68.2	254.8	2840	
5:31	helium	30.16	6.0	0.268	2.48	34.92	981	68.2	661.6	3180	
Power off 5:33											
7:45 a. m.	helium	30.28	2.0	0.059	.56	32.00	80	71.0	391.1	3100	
7:50	helium	30.28	6.0	0.191	1.25	35.65	80	70.5	795.4	2830	
Begin Purge 7:55, Read											
8:37	nitrogen	30.28	2.0	0.059	.38	32.09	80	70.5	226.5	2640	
8:41	nitrogen	30.28	6.0	0.110	.84	35.66	78	70.0	406.8	2140	

1. Used Sauerelsa No. 31 Cement for seal.
2. Specimen thickness: 0.252 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 2
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN A-5, RUN 1

Time	Permeating gas	Atm. press. P _a in. Hg	Upstream gage press. P ₁ in. Hg	Downstream gage press. P ₂ in. Hg ^(a)	Pressure drop through specimen in. Hg	Mean press. P _m in. Hg	Temperature, °F		Flow rate cm ³ /sec ^(b)	K _{mv} cm ³ /sec	Remarks
							Spec.	Meter			
Begin Purge											
8:10, Read	helium	30.12	2.0	0.015	.55	31.85	70.0	70.0	403.4	3173	
10:30	helium	30.12	6.0	0.007	1.23	35.48	70.0	70.0	818.4	2880	
10:24											
Begin Purge											
10:35, Read											
11:13	nitrogen	30.12	2.0	0.059	.37	31.94	70.0	69.2	231.7	2716	
11:16	nitrogen	30.12	6.0	0.221	.84	35.70	70.0	69.2	417.7	2170	
2:05	nitrogen	30.06	2.0	0.051	.48	31.82	282	68.5	221.9	2810	
2:18	nitrogen	30.06	6.0	0.213	.95	35.58	259	68.0	403.4	2500	
Begin Purge											
2:22, Read											
2:47	helium	30.06	2.0	0.037	.70	31.71	256	67.5	382.7	3210	
2:59	helium	30.06	6.0	0.007	1.46	35.33	228	67.0	777.9	3000	
4:26	helium	30.06	2.0	0.029	.90	31.81	514	67.0	350.5	3110	
4:36	helium	30.06	6.0	0.015	1.77	35.18	461	66.8	729.8	3110	
Begin Purge											
4:40, Read											
5:03	nitrogen	30.06	2.0	0.051	.55	31.78	448	66.5	211.3	2860	
5:18	nitrogen	30.06	6.0	0.199	1.05	35.53	411	66.0	390.2	2660	

1. Used RTV-731 Silastic Sealant
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 3
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN B-3, RUN 1

Time	Permeating gas	Atm. press. P _a in. Hg	Upstream gage press. P ₁ in. Hg	Downstream gage press. P ₂ (s) in. Hg	Pressure drop through specimen in. Hg	Mean press. P _m in. Hg	Temperature, °F		Flow rate ^a cm ³ /sec ^(b)	K _{mv} cm ³ /sec	Remarks
							Spec.	Meter			
Begin Purge 9:50, Read											
12:32	nitrogen	30.07	2.0	0.051	.70	31.72	73.5	67.00	210	1322	Room temperature 73.5°F
12:40	nitrogen	30.07	6.0	0.199	1.50	35.32	73.5	66.75	397	1172	
Begin Purge 12:49, Read											
1:35	helium	30.07	2.0	0.040	1.00	31.57	73.5	66.75	339	1493	
1:40	helium	30.07	6.0	0.077	2.50	34.82	73.5	66.25	730	1290	
4:00	helium	30.00	2.0	0.037	1.25	31.37	288	67.75	298	1466	
4:27	helium	30.00	6.0	0.129	2.83	34.58	238	66.50	686	1399	
Begin Purge 4:32, Read											
4:48	nitrogen	30.00	2.0	0.044	.82	31.59	238	66.25	198	1391	Room temperature 73°F
5:14	nitrogen	30.00	6.0	0.187	1.66	35.12	214	66.00	382	1286	
10:57	nitrogen	30.01	2.0	0.040	.96	31.53	418	66.00	188	1419	
11:24	nitrogen	30.01	6.0	0.173	1.85	35.08	368	65.50	373	1385	
Begin Purge 11:29, Read											
12:30	helium	30.01	2.0	0.015	1.33	31.34	394	66.00	273	1446	Power off 12:57
12:55	helium	30.01	6.0	0.114	3.03	34.49	340	65.00	666	1458	
Begin Purge 9:10, Read											
10:14	helium	30.00	2.0	0.033	1.00	31.50	71.0	70.00	337	1465	Room temperature 70°F
10:20	helium	30.00	6.0	0.114	2.50	34.75	69.0	69.75	730	1268	
Begin Purge 10:24, Read											
12:21	nitrogen	30.00	2.0	0.048	.70	31.65	69.0	69.25	210	1303	
12:28	nitrogen	30.00	6.0	0.195	1.50	35.25	69.0	69.00	394	1146	

1. Used RTV-731 Silastic Sealant
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 4
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN B-3, RUN 2

Time	Permeating gas	Atm. press. P ₁ in. Hg	Upstream gage press. P ₁ in. Hg	Downstream gage press. P ₂ in. Hg (°)	Pressure drop through specimen in. Hg	Mean press. P _m in. Hg	Temperature, °F		Flow rate (4) cm ³ /sec	K _{mv} cm ³ /sec	Remarks
							Spec.	Meter			
Begin Purge											
11:05, Read											
3:57	nitrogen	29.96	2.0	0.048	.70	31.61	69.0	73.00	208	1279	
4:02	nitrogen	29.96	6.0	0.195	1.48	35.22	69.0	73.00	399	1166	Room temperature 72°F
Begin Purge											
4:06, Read											
4:30	helium	29.96	2.0	0.026	1.00	31.46	68.0	73.00	336	1442	
4:33	helium	29.96	6.0	0.132	2.47	34.72	68.0	72.75	724	1262	
12:15	helium	29.98	2.0	0.018	1.23	31.36	251	72.75	294	1382	Power on 4:35 p. m.
12:28	helium	29.98	6.0	0.125	2.80	34.58	226	72.00	692	1366	
Begin Purge											
12:32, Read											
1:37	nitrogen	29.98	2.0	0.040	.82	31.57	232	71.00	194	1337	
1:50	nitrogen	29.98	6.0	0.187	1.66	35.15	214	71.00	390	1300	
7:43	nitrogen	30.01	2.0	0.033	1.10	31.46	620	71.25	179	1437	Room temperature 71°F
7:58	nitrogen	30.01	6.0	0.158	2.10	34.96	584	71.00	370	1481	
Begin Purge											
8:02, Read											
8:58	helium	30.01	2.0	0.011	1.45	31.28	586	71.00	235	1349	
9:11	helium	30.01	6.0	0.092	3.40	34.31	527	70.75	628	1493	
3:16	helium	29.91	2.0	0.011	1.58	31.12	792	73.75	196	1257	Room temperature 75°F
3:29	helium	29.91	6.0	0.077	3.75	34.03	708	73.25	584	1478	
Begin Purge											
3:33, Read											
4:18	nitrogen	29.91	2.0	0.026	1.17	31.32	741	73.50	170	1416	
4:33	nitrogen	29.91	6.0	0.151	2.25	33.68	686	73.25	359	1490	
7:50	nitrogen	30.00	2.0	0.018	1.46	31.27	1149	74.00	139	1244	Room temperature 74.25°F
8:03	nitrogen	30.00	6.0	0.121	2.73	34.63	1070	74.00	329	1503	
Begin Purge											
8:07, Read											
9:48	helium	30.00	2.0	0.004	1.80	31.10	1128	74.75	157	1122	
10:03	helium	30.00	6.0	0.055	4.42	33.79	1039	74.25	490	1352	Power off 10:04, Slow purge, during cooldown
Begin Purge											
8:45, Read											
9:56	helium	29.93	2.0	0.022	1.00	31.43	70.25	70.50	332	1437	
10:01	helium	29.93	6.0	0.129	2.50	34.68	70.25	70.00	718	1247	Room temperature 70.25°F
Begin Purge											
10:04, Read											
10:38	nitrogen	29.93	2.0	0.048	.70	31.58	70.25	70.50	332	1287	
10:43	nitrogen	29.93	6.0	0.195	1.50	35.18	70.25	70.00	390	1132	

1. Used Sauereisen No. 31 Cement for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 5
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN B-4, RUN 1

Time	Permeating gas	Atm. press. P _a in. Hg	Upstream gage press. P ₁ in. Hg.	Downstream gage press. P ₂ in. Hg (s)	Pressure drop through specimen in. Hg	Mean press. P _m in. Hg	Temperature, °F		Flow rate cm ³ /sec (μ)	K _{mv} cm ³ /sec	Remarks
							Spec.	Meter			
Begin Purge											
9:35, Read											
9:51	helium	30.09	2.0	0.026	1.00	31.59	70	70.0	318	1384	Room temperature 71°F
9:56	helium	30.09	6.0	0.121	2.48	34.85	70	70.0	703	1237	
Begin Purge											
10:00, Read											
10:20	nitrogen	30.09	2.0	0.048	.70	31.74	88	70.0	204	1269	Room temperature 72°F
10:24	nitrogen	30.09	6.0	0.195	1.48	35.35	68	70.0	393	1182	
1:34	nitrogen	30.00	2.0	0.033	1.03	31.48	517	71.0	174	1349	
1:54	nitrogen	30.00	6.0	0.092	2.0	35.00	472	70.0	362	1384	
Begin Purge											
1:58, Read											
2:27	helium	30.00	2.0	0.011	1.40	31.30	508	70.0	225	1273	Room temperature 71°F
2:41	helium	30.00	6.0	0.092	2.27	34.36	469	70.0	614	1431	
4:46	helium	30.02	2.0	0.007	1.57	31.23	787	71.0	176	1142	
5:00	helium	30.02	6.0	0.077	2.75	34.14	708	70.0	567	1448	
Begin Purge											
5:05, Read											
5:25	nitrogen	30.02	2.0	0.026	1.16	31.44	729	70.0	159	1335	Slow nitrogen purge over night Room temperature 70°F
5:48	nitrogen	30.02	6.0	0.151	2.23	34.90	655	69.0	350	1442	
7:58	nitrogen	30.08	2.0	0.026	1.20	31.48	783	70.0	165	1318	
8:13	nitrogen	30.08	6.0	0.147	2.28	34.94	713	70.0	345	1463	
Begin Purge											
8:18, Read											
8:50	helium	30.08	2.0	0.011	1.56	31.30	742	70.0	180	1138	Room temperature 71°F
9:04	helium	30.08	6.0	0.081	2.68	34.24	673	69.0	562	1426	
12:39	helium	30.06	2.0	0.007	1.75	31.18	1069	71.0	140	1002	
12:54	helium	30.06	6.0	0.062	4.30	33.91	981	70.0	478	1316	
Begin Purge											
12:58, Read											
1:31	nitrogen	30.06	2.0	0.022	1.36	31.38	1005	70.0	138	1219	Power off 1:46, slow nitrogen purge over night, Room temp. 69°F
1:45	nitrogen	30.06	6.0	0.132	2.56	34.78	944	70.0	324	1462	
7:52	nitrogen	30.12	2.0	0.044	.70	31.77	80	69.0	204	1296	
7:56	nitrogen	30.12	6.0	0.195	1.50	35.37	79	69.0	391	1164	
Begin Purge											
8:00, Read											
8:25	helium	30.12	2.0	0.026	1.00	31.62	76	69.0	321	1417	Gas off
8:29	helium	30.12	6.0	0.121	2.48	34.88	74	69.0	697	1240	

1. Used Sauerisen No. 31 Cement for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 6
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN C-8, RUN 1

Time	Permeating gas	Atm. press. P ₁ in. Hg	Upstream gage press. P ₁ in. Hg	Downstream gage press. P ₂ in. Hg (s)	Pressure drop through specimen in. Hg	Mean press. P _m in. Hg	Temperature, °F		Flow rate q cm/sec (s)	K _{mv} cm/sec	Remarks
							Spec.	Meter			
Begin Purge 8:10, Read 9:12 9:17	nitrogen	29.96	2.0	0.018	1.48	31.22	75.0	73.50	133	389	Room temperature 75°F
	nitrogen	29.96	6.0	0.107	2.80	34.86	75.0	73.25	308	478	
Begin Purge 9:20, Read 10:00 10:04 2:25 2:40	helium	29.96	2.0	0.007	1.69	31.11	75.0	73.75	160	410	Room temperature 75.25°F
	helium	29.96	6.0	0.040	4.36	33.78	75.0	73.50	431	428	
	helium	29.88	2.0	0.004	1.80	30.98	236	74.25	119	372	
	helium	29.88	6.0	0.033	4.80	33.48	222	74.00	358	412	
Begin Purge 2:43, Read 3:25 3:40 10:54 11:11	nitrogen	29.88	2.0	0.015	1.60	31.08	226	74.00	115	399	Room temperature 70°F
	nitrogen	29.88	6.0	0.088	3.20	34.28	216	74.00	280	480	
	nitrogen	29.94	2.0	0.007	1.75	31.06	469	70.25	80	347	
	nitrogen	29.94	6.0	0.070	4.10	33.89	439	70.00	239	428	
Begin Purge 11:16, Read 11:51 12:08	helium	29.94	2.0	0.004	1.85	31.01	453	70.00	77	310	Power off 12:11 Helium off 12:11
	helium	29.94	6.0	0.018	5.30	33.29	430	69.75	266	365	
Begin Purge 11:35, Read 12:35 12:39	helium	30.08	2.0	0.007	1.70	31.23	69.0	69.50	155	396	Room temperature 69°F
	helium	30.08	6.0	0.044	4.40	33.88	69.0	69.50	423	418	
Begin Purge 12:43, Read 1:10 1:14	nitrogen	30.08	2.0	0.018	1.50	31.33	69.0	70.00	132	383	
	nitrogen	30.08	6.0	0.107	2.90	34.83	69.0	70.00	302	454	

1. Used RTV-731 Silastic Sealant for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 7
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN C-8, RUN 2

Time	Permeating gas	Atm. press. P _a in. Hg	Upstream gage press. P ₁ in. Hg	Downstream gage press. P ₂ (s) in. Hg	Pressure drop through specimen in. Hg	Mean press. P _m in. Hg	Temperature, °F		Flow rate (4) cm ³ /sec	K _{mv} cm ³ /sec	Remarks
							Spec.	Meter			
Begin Purge 8:45, Read											
9:45	nitrogen	30.13	2.0	0.018	1.80	31.38	70.0	70.00	125	363	Room temperature 70°F
9:50	nitrogen	30.13	4.0	0.099	3.00	34.63	70.0	70.00	295	430	
Begin Purge 9:55, Read											
10:20	helium	30.13	2.0	0.007	1.70	31.28	70.0	70.00	146	374	Power on 10:28
10:25	helium	30.13	6.0	0.037	4.60	33.83	70.0	70.00	398	377	
2:48	helium	30.04	2.0	0.004	1.85	31.11	323	75.50	86	295	Room temperature 81°F
3:04	helium	30.04	6.0	0.022	5.23	33.42	303	75.75	295	349	
Begin Purge 3:08, Read											
3:55	nitrogen	30.04	2.0	0.011	1.70	31.19	295	77.00	94	338	Room temperature 83°F
4:10	nitrogen	30.04	6.0	0.077	3.70	34.19	277	77.00	257	415	
8:20	nitrogen	30.02	2.0	0.004	1.80	31.12	608	82.50	62	294	
8:39	nitrogen	30.02	6.0	0.051	4.50	33.77	576	82.25	216	399	
Begin Purge 8:44, Read											
9:14	helium	30.02	2.0	0.004	1.90	31.07	588	81.25	60	265	Room temperature 76°F
9:31	helium	30.02	6.0	0.011	5.50	33.27	571	81.00	211	317	
2:36	helium	29.90	2.0	0.004	1.90	30.95	824	78.00	51	275	
2:56	helium	29.90	6.0	0.011	5.45	33.07	823	78.00	168	306	
Begin Purge 3:01, Read											
3:31	nitrogen	29.90	2.0	0.004	1.85	30.97	846	77.50	50	283	Room temperature 72°F
3:51	nitrogen	29.90	6.0	0.048	4.90	33.45	817	77.25	186	391	
8:26	nitrogen	29.92	2.0	0.004	1.85	30.99	934	72.25	45	276	
8:48	nitrogen	29.92	6.0	0.048	5.10	33.37	894	72.50	173	374	
Begin Purge 8:53, Read											
9:25	helium	29.92	2.0	0.004	1.94	30.95	916	72.50	44	254	
10:05	helium	29.92	6.0	0.007	5.70	33.07	889	72.25	145	279	
Begin Purge 1:17, Read											
2:15	nitrogen	29.88	6.0	0.051	5.20	33.28	1003	72.50	167	382	Power off 2:18, Slow purge over night
8:15	nitrogen	29.89	2.0	0.018	1.50	31.14	69.0	68.00	125	360	
8:21	nitrogen	29.89	6.0	0.121	3.00	34.39	69.0	68.00	293	424	
Begin Purge 8:24, Read											
9:04	helium	29.89	2.0	0.007	1.70	31.04	69.0	68.00	145	368	
9:09	helium	29.89	6.0	0.037	4.60	33.59	69.0	67.75	395	371	

1. Used Saureisen No. 31 Cement for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 8
THE PERMEABILITY OF POROUS GRAPHITE SPECIMEN C-1, RUN 2

Time	Permeating gas	Atm. press. P_a in. Hg	Upstream gage press. P_1 in. Hg	Downstream gage press. P_2 (s) in. Hg	Pressure drop through specimen in. Hg	Mean press. P_m in. Hg	Temperature, °F		Flow rate cm ³ /sec ⁽⁴⁾	K_{mv} cm ² /sec	Remarks
							Spec.	Meter			
Begin Purge											
10:53, Read	helium	30.13	2.0	0.004	1.76	31.25	70	69.0	138	341	Room temperature 70°F
11:53	helium	30.13	6.0	0.033	4.70	33.73	69	69.0	384	356	
Begin Purge											
12:03, Read	nitrogen	30.13	2.0	0.011	1.50	31.38	69	69.0	122	354	Power on 12:34
12:31	nitrogen	30.13	6.0	0.074	3.13	34.56	69	69.0	289	403	
7:34	nitrogen	30.10	6.0	0.033	4.67	33.80	562	70.0	201	361	
Begin Purge											
7:39, Read	helium	30.10	2.0	0.004	1.90	31.15	590	70.0	61	277	Power up 8:29 Room temperature 70°F
8:00	helium	30.10	6.0	0.007	5.54	33.33	569	70.0	203	310	
10:30	helium	30.14	2.0	none	1.90	31.19	308	71.0	52	284	
10:55	helium	30.14	6.0	0.007	5.64	33.32	775	71.0	172	309	
Begin Purge											
11:00, Read	nitrogen	30.14	2.0	0.004	1.85	31.21	776	71.0	54	296	Power up 11:54 Room temperature 71°F
11:25	nitrogen	30.14	6.0	0.029	4.97	33.65	727	71.0	188	369	
3:16	nitrogen	30.06	2.0	none	1.90	31.11	1067	71.0	45	286	
3:40	nitrogen	30.06	6.0	0.018	5.48	33.32	1016	71.0	156	344	
Begin Purge											
3:45, Read	helium	30.06	2.0	none	1.94	31.09	1055	71.0	43	276	Power off 4:44 Slow helium purge over night, room temp 69°F
4:15	helium	30.06	6.0	0.004	5.70	33.21	1044	71.0	142	306	
4:40	helium	30.08	2.0	0.004	1.75	31.20	92	69.0	134	341	
7:19	helium	30.08	6.0	0.029	4.77	33.69	77	69.0	381	353	
Begin Purge											
7:25, Read	nitrogen	30.08	2.0	0.011	1.50	31.33	79	69.0	122	360	
7:58	nitrogen	30.08	6.0	0.070	3.16	34.49	79	69.0	286	399	

1. Used Sauereisen No. 31 Cement for seal.
2. Specimen thickness: 0.253 in.
3. Measured at inlet to wet test meter.
4. Measured at wet test meter.

TABLE 9
THE PERMEABILITY OF SPECIMEN B-8 AT ROOM TEMPERATURE AND VARIOUS PRESSURES

Time	Gas	Atm press. in. Hg	Upstream press. in. Hg	Pressure drop through specimen in. Hg	Mean press. in. Hg	Press. at flowmeter inlet in. Hg	Flow rate cm ³ /sec	K _{mv} cm ³ /sec	Remarks
Run 1									
9:20	N ₂	29.41	2.0	.45	31.18	.25	192	1831	Room temperature 72°F
	N ₂	29.41	6.0	1.05	34.93	.70	382	1720	
	N ₂	29.41	9.8	1.45	38.53	1.10	563	1713	
	N ₂	29.41	14.8	1.80	43.31	1.70	718	1792	
	N ₂	29.41	14.9	1.85	43.38	1.75	714	1738	
	N ₂	29.41	20.0	2.20	48.31	2.50	894	1874	
	N ₂	29.41	24.8	2.55	52.93	3.20	1036	1915	
	N ₂	29.41	25.2	2.55	53.33	3.30	1061	1967	
9:40	N ₂	29.41	29.9	2.95	57.83	4.10	1200	1968	
Run 2									
12:35	N ₂	30.08	2.0	.80	31.68	.20	405	2215	Room temperature 65°F
12:40	He	30.08	4.0	1.45	33.35	.30	693	2098	
	He	30.08	6.0	1.85	35.15	.50	914	2182	
	He	30.08	6.0	1.85	35.10	.50	896	2139	
	He	30.08	10.0	2.60	38.78	.90	1348	2320	
	He	30.08	15.0	3.25	43.45	1.50	1778	2497	
	He	30.08	20.0	3.75	48.20	2.20	2205	2743	
	He	30.08	25.0	4.25	52.95	2.90	2576	2888	
1:00	He	30.08	30.0	4.60	57.78	3.75	3004	3193	
Run 3									
8:45	N ₂	29.50	2.0	.50	31.25	.30	199	1713	Room temperature 70°F
	N ₂	29.50	4.0	.80	33.10	.45	314	1701	
	N ₂	29.50	6.0	1.05	34.97	.65	402	1688	
	N ₂	29.50	10.0	1.45	38.77	1.10	588	1731	
	N ₂	29.50	15.0	1.85	43.57	1.70	740	1804	
	N ₂	29.50	20.0	2.25	48.37	2.45	904	1855	
	N ₂	29.50	25.0	2.55	53.22	3.20	1044	1936	
	N ₂	29.50	25.1	2.55	53.32	3.20	1020	1889	
	N ₂	29.50	30.0	2.85	58.07	4.10	1193	2033	
9:35	N ₂	29.50	30.0	2.85	58.07	4.10	1199	2042	
Run 4									
11:05	He	29.50	10.0	2.65	38.17	.90	1328	2200	Room temperature 70°F
	He	29.50	20.0	3.80	47.60	2.15	2166	2606	
11:20	He	29.50	30.0	4.70	57.15	3.70	2975	3036	