Part II

PHYSICAL PROPERTIES

EVALUATION OF COMPOUNDS AND MATERIALS

Compressibility of Helium at −10° to 130°F. and Pressures to 4000 P.S.I.A.

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To compute discharge volumes of cylinders containing Grade A helium (nominally 99.995% pure), accurate compressibility data for helium must be known. Several persons have presented data for helium at pressures to approximately 135 atm. (*1-4*), but these pressures are too low to cover the present range of interest. The Whittaker Report (*6*) presents computed data to high pressures, but the figures do not agree with those of other workers. Probably the best source for such information is an article by Wiebe, Gaddy, and Heins (*7*) who obtained compressibility data for helium by using small-volume calibrated pipets, from −70° to 200° C., at pressures to 1000 atm. These figures are reliable, but extensive interpolation would be required to obtain the information needed for the presently desired temperature and pressure range. Thus, using a different experimental method than Wiebe's, the compressibility of helium was studied at seven temperatures from −10° to 130° F. and at pressures to 4000 p.s.i.a.

APPARATUS AND MATERIALS

The Burnett (*1*) method was used. The procedure was recently studied by Pfefferle, Goff, and Miller (*5*), who presented an improved method for treating the data. The accuracy in using this apparatus is estimated conservatively at 0.1%. In the present work, temperatures were maintained within ±0.05° F. of the desired value and pressures were measured to the nearest 0.01 p.s.i.a.

EXPERIMENTAL DATA AND RESULTS

Data of this study are presented in Table I. Each isotherm generally yields ten pairs of Z and P values. Plots of Z *vs.* P for each isotherm were drawn, and all were observed to be linear. The experimental information was fitted to the linear equation

$$Z = 1 + BP \qquad (1)$$

in which Z = the compressibility factor PV/RT, and P is the pressure in p.s.i.a. The virial coefficient B, or slope of the linear plot, was evaluated for each isotherm by the simplified least-squares relation

$$B = \frac{\Sigma (Z - 1)}{\Sigma P} \qquad (2)$$

These B values were used in Equation 1 to obtain calculated Z values. The per cent deviation of the calculated values, compared with the experimental data, are given in Table I for each pressure, and averages are indicated for each isotherm. Greatest deviation for any individual pressure was 0.22%, at 130° F.

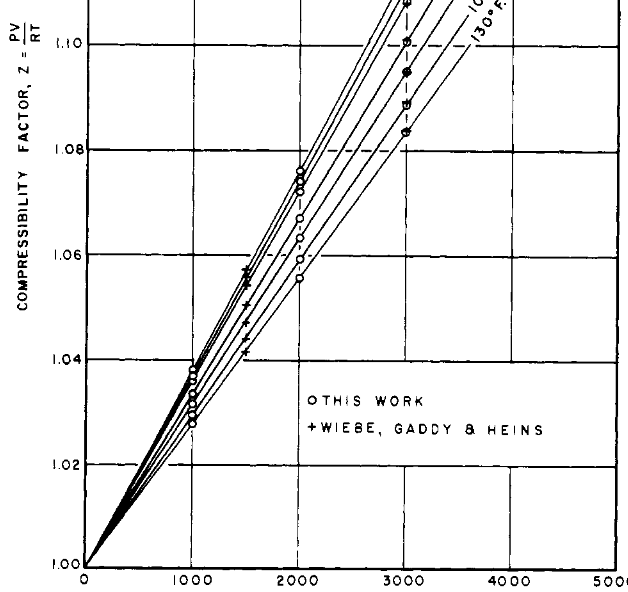


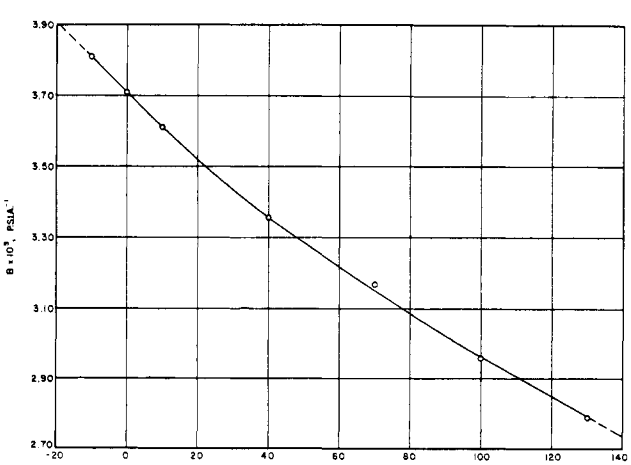
Figure 1. Experimental compressibility data for helium

Table 1. Isothermal Compressibility Data for Pure Helium, Showing Comparisons between Experimental and Calculated Values

	P.S.I.A.	Compressibility Factor, Z^a Exptl.	Compressibility Factor, Z^a Calcd.	% Dev.
-10° F.	4007.8	1.1525	1.1527	+0.02
$B = 3.8108 \times 10^{-5}$	2658.5	1.1016	1.1013	-0.03
	1790.1	1.0688	1.0682	-0.06
	1216.5	1.0466	1.0464	-0.02
	832.33	1.0317	1.0317	...
	572.02	1.0217	1.0218	+0.01
	394.30	1.0148	1.0150	+0.02
	272.39	1.0101	1.0104	+0.03
	188.49	1.0072	1.0072	...
	130.53	1.0050	1.0050	...
				Av. ±0.02
0° F.	3998.1	1.1481	1.1483	+0.02
$B = 3.7092 \times 10^{-5}$	2655.4	1.0988	1.0985	-0.03
	1788.6	1.0665	1.0663	-0.02
	1216.4	1.0452	1.0451	-0.01
	832.49	1.0308	1.0309	+0.01
	572.26	1.0210	1.0212	+0.02
	394.56	1.0144	1.0146	+0.02
	272.62	1.0101	1.0101	...
	188.65	1.0072	1.0070	-0.02
				Av. ±0.02
+10° F.	3950.2	1.1425	1.1427	+0.02
$B = 3.6124 \times 10^{-5}$	2627.6	1.0951	1.0949	-0.02
	1771.5	1.0639	1.0640	+0.01
	1206.0	1.0437	1.0436	-0.01
	825.75	1.0298	1.0298	...
	567.81	1.0204	1.0205	+0.01
	391.61	1.0141	1.0141	...
	270.59	1.0097	1.0098	+0.01
	187.28	1.0070	1.0068	-0.02
				Av. ±0.01
+40° F.	4040.3	1.1359	1.1356	-0.03
$B = 3.3550 \times 10^{-5}$	2693.8	1.0913	1.0904	-0.08
	1818.5	1.0615	1.0610	-0.05
	1238.4	1.0417	1.0415	-0.02
	848.38	1.0283	1.0285	+0.02
	583.61	1.0192	1.0196	+0.04
+40° F.	402.53	1.0130	1.0135	+0.05
$B = 3.3550 \times 10^{-5}$	278.22	1.0089	1.0093	+0.04
	192.56	1.0062	1.0065	+0.03
	133.39	1.0043	1.0045	+0.02
				Av. ±0.04
+70° F.	4004.4	1.1268	1.1269	+0.01
$B = 3.1683 \times 10^{-5}$	2679.9	1.0850	1.0849	-0.01
	1809.8	1.0574	1.0573	-0.01
	1234.0	1.0390	1.0391	+0.01
	846.14	1.0266	1.0268	+0.02
	582.43	1.0183	1.0185	+0.02
	401.95	1.0126	1.0127	+0.01
	277.90	1.0089	1.0088	-0.01
	192.38	1.0064	1.0061	-0.03
	133.22	1.0042	1.0042	...
				Av. ±0.01
+100° F.	4069.3	1.1210	1.1204	-0.05
$B = 2.9597 \times 10^{-5}$	2723.9	1.0812	1.0806	-0.05
	1844.4	1.0549	1.0546	-0.03
	1258.6	1.0373	1.0373	...
	863.42	1.0253	1.0256	+0.03
	594.47	1.0172	1.0176	+0.04
	410.33	1.0117	1.0121	+0.04
	283.74	1.0080	1.0084	+0.04
	196.48	1.0058	1.0058	...
				Av. ±0.03
+130° F.	3990.8	1.1089	1.1113	+0.22
$B = 2.7882 \times 10^{-5}$	2678.2	1.0753	1.0747	-0.06
	1816.5	1.0510	1.0506	-0.04
	1241.0	1.0346	1.0346	...
	852.10	1.0237	1.0238	+0.01
	587.01	1.0162	1.0164	+0.02
	405.33	1.0112	1.0113	+0.01
	280.35	1.0078	1.0078	...
	194.14	1.0057	1.0054	-0.03
	134.53	1.0042	1.0038	-0.04
	93.30	1.0036	1.0026	-0.10
				Av. ±0.05

[a] Computed by Equation $Z = 1 + BP$, where B has the value indicated and P is expressed in p.s.i.a.

Figure 2. Virial coefficient, B, for helium



and 3990 p.s.i.a. All other calculated Z values differed from the experimental in the range 0.05 to -0.10%. Greatest average value was ±0.05% for the 130° F. isotherm.

Figure 1 is a plot of the computed values of Z for helium, *vs.* pressure, for the seven isotherms studied. Data obtained by Wiebe, Gaddy, and Heins (7) are included for comparison. The variation of the virial coefficient B, with temperature, for helium is shown in Figure 2. The plot permits the calculation of Z for any temperature between -10° and 130° F.

These computations have been used by the Helium Activity in preparing charts showing true discharge volumes of cylinders and tank cars. The Bureau hopes the information will be useful in missile engineering and in designing gas-cooled reactors.

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