Designation: D1142 – 95(Reapproved 2006)

Standard Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature[1]

This standard is issued under the fixed designation D1142; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the water vapor content of gaseous fuels by measurement of the dew-point temperature and the calculation therefrom of the water vapor content.

NOTE 1—Some gaseous fuels contain vapors of hydrocarbons or other components that easily condense into liquid and sometimes interfere with or mask the water dew point. When this occurs, it is sometimes very helpful to supplement the apparatus in Fig. 1 with an optical attachment that uniformly illuminates the dew–point mirror and also magnifies the condensate on the mirror. With this attachment it is possible, in some cases, to observe separate condensation points of water vapor, hydrocarbons, and glycolamines as well as ice points. However, if the dew point of the condensable hydrocarbons is higher than the water vapor dew point, when such hydrocarbons are present in large amounts, they may flood the mirror and obscure or wash off the water dew point. Best results in distinguishing multiple component dew points are obtained when they are not too closely spaced.

NOTE 2—Condensation of water vapor on the dew-point mirror may appear as liquid water at temperatures as low as 0 to −10°F (−18 to −23°C). At lower temperatures an ice point rather than a water dew point likely will be observed. The minimum dew point of any vapor that can be observed is limited by the mechanical parts of the equipment. Mirror temperatures as low as −150°F (−100°C) have been measured, using liquid nitrogen as the coolant with a thermocouple attached to the mirror, instead of a thermometer well.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *saturated water vapor or equilibrium water–vapor content*—the water vapor concentration in a gas mixture that is in equilibrium with a liquid phase of pure water that is saturated with the gas mixture. When a gas containing water vapor is at the water dew-point temperature, it is said to be saturated at the existing pressure.

2.1.2 *specific volume—of a gaseous fuel*, the volume of the gas in cubic feet per pound.

2.1.3 *water dew-point temperature— of a gaseous fuel*, the temperature at which the gas is saturated with water vapor at the existing pressure.

3. Significance and Use

3.1 Generally, contracts governing the pipeline transmission of natural gas contain specifications limiting the maximum concentration of water vapor allowed. Excess water vapor can cause corrosive conditions, degrading pipelines and equipment. It can also condense and freeze or form methane hydrates causing blockages. Water–vapor content also affects the heating value of natural gas, thus influencing the quality of the gas. This test method permits the determination of water content of natural gas.

4. Apparatus

4.1 Any properly constructed dew-point apparatus may be used that satisfies the basic requirements that means must be provided:

4.1.1 To permit a controlled flow of gas to enter and leave the apparatus while the apparatus is at a temperature at least 3°F above the dew point of the gas.

4.1.2 To cool and control the cooling rate of a portion (preferably a small portion) of the apparatus, with which the *flowing* gas comes in contact, to a temperature low enough to cause vapor to condense from the gas.

4.1.3 To observe the deposition of dew on the cold portion of the apparatus.

4.1.4 To measure the temperature of the cold portion on the apparatus on which the dew is deposited, and

4.1.5 To measure the pressure of the gas within the apparatus or the deviation from the known existing barometric pressure.

4.1.6 The apparatus should be constructed so that the "cold spot," that is, the cold portion of the apparatus on which dew

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[1] This test method is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.05 on Determination of Special Constituents of Gaseous Fuels.

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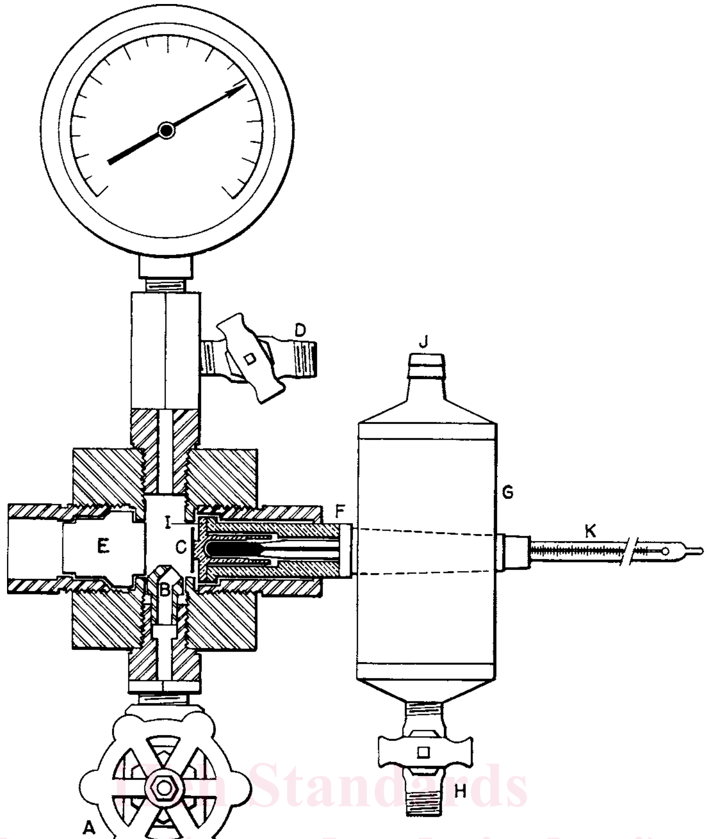

FIG. 1 Bureau of Mines Dew-Point Apparatus

is deposited, is protected from all gases other than the gas under test. The apparatus may or may not be designed for use under pressure.

4.2 The Bureau of Mines type of dew-point apparatus[2] shown in Fig. 1 fulfills the requirements specified in 4.1. Within the range of conditions in Section 1, this apparatus is satisfactory for determining the dew point of gaseous fuels. Briefly, this apparatus consists of a metal chamber into and out of which the test gas is permitted to flow through control valves *A* and *D*. Gas entering the apparatus through valve *A* is deflected by nozzle *B* towards the cold portion of the apparatus, *C*. The gas flows across the face of *C* and out of the apparatus through valve *D*. Part *C* is a highly polished stainless steel "target mirror," cooled by means of a copper cooling rod, *F*. The mirror, *C*, is silver-soldered to a nib on the copper thermometer well fitting, *I*, which is soft-soldered to the cooling rod, *F*. The thermometer well is integral with the fitting, *I*. Cooling of rod *F* is accomplished by vaporizing a refrigerant such as liquid butane, propane, carbon dioxide, or some other liquefied gas in the chiller, *G*. The refrigerant is throttled into the chiller through valve *H* and passes out at *J*. The chiller body is made of copper and has brass headers on either end. The lower header is connected with the upper header by numerous small holes drilled in the copper body through which the vaporized refrigerant passes. The chiller is attached to the cooling rod, *F*, by means of a taper joint. The temperature of the target mirror, *C*, is indicated by a calibrated mercury-in-glass thermometer, *K*, whose bulb fits snugly into the thermometer well. Observation of the dew deposit is made through the pressure-resisting transparent window, *E*.

4.2.1 Note that only the central portion of the stainless steel target mirror, *C*, is thermally bonded to the fitting, *I*, through which *C* is cooled. Since stainless steel is a relatively poor thermal conductor, the central portion of the mirror is thus maintained at a slightly lower temperature than the outer portion, with the result that the dew first appears on the central portion of the mirror and its detection is aided materially by the contrast afforded. The arrangement for measuring the temperature of the target mirror, *C*, also should be noted. The temperature is read with a thermometer or RTD, *K*, inserted in the cooling rod, *F*, so that the bulb of the temperature measuring device is entirely within the thermometer well in fitting, *I*. The stud to which the stainless steel mirror is silver-soldered is a part of the base of the thermometer well, and as there is no metallic contact between the thermometer well and the cooling tube, other than through its base, the thermometer or RTD indicates the temperature of the mirror rather than some compromise temperature influenced by the

[2] Deaton, W. M., and Frost, E. M., Jr., "Bureau of Mines Apparatus for Determining the Dew Point of Gases Under Pressure," *Bureau of Mines Report of Investigation 3399*, May 1938.

temperature gradient along the cooling tube as would be the case if this type of construction were not used. The RTD will include suitable electronics and display.

4.2.2 Tests with the Bureau of Mines type of dew-point apparatus are reported[2] to permit a determination with a precision (reproducibility) of ±0.2°F (±0.1°C) and with an accuracy of ±0.2°F (±0.1°C) when the dew-point temperatures range from room temperature to a temperature of 32°F (0°C). It is estimated that water dew points may be determined with an accuracy of ±0.5°F (0.3°C) when they are below 32°F (0°C) and not lower than 0°F (−17.8°C), provided ice crystals do not form during the determination.

5. Procedure

5.1 *General Considerations*—Take the specimen so as to be representative of the gas at the source. Do not take at a point where isolation would permit condensate to collect or would otherwise allow a vapor content to exist that is not in equilibrium with the main stream or supply of gas, such as the sorption or desorption of vapors from the sampling line or from deposits therein. The temperature of the pipelines leading the specimen directly from the gas source to the dew-point apparatus, and also the temperature of the apparatus, shall be at least 3°F (1.7°C) higher than the observed dew point. The determination may be made at any pressure, but the gas pressure within the dew-point apparatus must be known with an accuracy appropriate to the accuracy requirements of the test. The pressure may be read on a calibrated bourdon-type pressure gage; for very low pressures or more accurate measurements, a mercury-filled manometer or a dead-weight gage should be used.

5.2 *Detailed Procedure for Operation of Bureau of Mines Dew-Point Apparatus*—Introduce the gas specimen through valve *A* (Fig. 1), opening this valve wide if the test is to be made under full source pressure (Note 3), and controlling the flow by the small outlet valve, *D*. The rate of flow is not critical but should not be so great that there is a measurable or objectionable drop in pressure through the connecting lines and dew-point apparatus. A flow of 0.05 to 0.5 ft^3/min (1.4 to 14 L/min) (measured at atmospheric pressure) usually will be satisfactory. With liquefied refrigerant gas piped to the chiller throttle valve, *H*, "crack" the valve momentarily, allowing the refrigerant to vaporize in the chiller to produce suitable lowering in temperature of the chiller tube, *F*, and target mirror, *C*, as indicated by the thermometer, *K*. The rate of cooling may be as rapid as desired in making a preliminary test. After estimating the dew-point temperature, either by a preliminary test or from other knowledge, control the cooling or warming rate so that it does not exceed 1°F/min (0.5°C/min) when this temperature is approached. For accurate results, the cooling and warming rates should approximate isothermal conditions as nearly as possible. The most satisfactory method is to cool or warm the target mirror stepwise. Steps of about 0.2°F (0.1°C) allow equilibrium conditions to be approached closely and favor an accurate determination. When dew has been deposited, allow the target mirror to warm up at a rate comparable to the recommended rate of cooling. The normal warming rate usually will be faster than desired. To reduce the rate, "crack" valve *H* momentarily at intervals to supply cooling to the cooling tube, *F*. Repeat the cooling and warming cycles several times. The arithmetic average of the temperatures at which dew is observed to appear and disappear is considered to be the observed dew point.

NOTE 3—If the water–vapor content is to be calculated as described in 6.2, the gas specimen should be throttled at the inlet valve, *A*, to a pressure within the apparatus approximately equal to atmospheric pressure. The outlet valve may be left wide open or restricted, as desired. The pressure existing within the apparatus must, however, be known to the required accuracy.

6. Calculation

6.1 If an acceptable chart showing the variation of water-vapor content with saturation or water dew-point temperatures over a suitable range of pressures for the gas being tested is available, the water-vapor content may be read directly, using the observed water dew-point temperature and the pressure at which the determination was made.

6.2 If such a chart is not available, the water–vapor content of the gas may be calculated from the water dew-point temperature and the pressure at which it was determined (see Note 3), as follows:

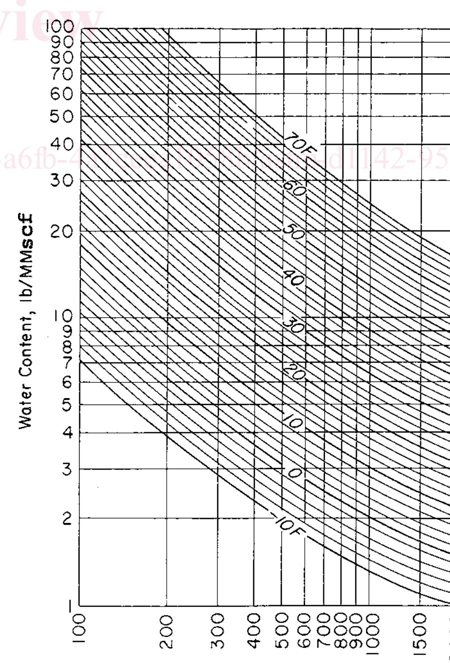

FIG. 2 Equilibrium Water Vapor Content of Natural Gases

$$W = w \times 10^{6} \times \left(P_b/P \times \left(T/T_b\right)\right) \quad (1)$$

where:

W = lb of water/million ft^3 of gaseous mixture at pressure P_b and temperature T_b;
w = weight of saturated water vapor, lb/ft^3, at the water dew-point temperature, that is, the reciprocal of the specific volume of saturated vapor (see Table 1);
P_b = pressure-base of gas measurement, psia;
P = pressure at which the water dew point of gas was determined, psia;
t = observed water dew-point temperature, °F;
T = Rankine (absolute Fahrenheit scale) water dew point, t + 460, at pressure P; and
T_b = base temperature of gas measurement, t_b + 460.

NOTE 4—*Example 1:*

Given: Water dew point = 37°F at 15.0-psia pressure.

What is the water–vapor content million ft^3 of gas (gas measurement base of 60°F and 14.7-psia pressure)?

From Table 1 the specific volume of saturated water at 37°F is 2731.9 ft^3/lb, from which:

$$w = (1/2731.9) = 0.000\ 366\ 0 \text{ lb/ft}^3$$

and

$$W = 0.000\ 366\ 0 \times 10^{6} \times (14.7/15.0) \times [(460 + 37)/(460 + 60)] = 342.8 \text{ lb/million ft}^3$$

Example 2:

Given: Water dew point = 5°F at 14.4 psia.

From Table 2, the specific volume of saturated water vapor with respect to ice at 5°F is 11 550 ft^3/lb from which $W_{ice,\ 5F}$ = 0.000 086 6, but the observed water dew point was in equilibrium with subcooled liquid water at 5°F. From Table 2 (data from International Critical Tables[3]), the vapor pressures of subcooled liquid water and of ice at 5°F (−15°C) are 1.436 mm and 1.241 mm Hg, respectively.

Since the vapor pressure of subcooled liquid water is greater than ice at the same temperature, the weight per cubic foot of water vapor in equilibrium with liquid water will be proportionately larger than the value calculated from the specific volume read from the table, which is for equilibrium with ice.

Hence,

$$W_{liq.,\ 5F} = W_{ice\ 5F} \times (1.436/1.241) = 0.000\ 086\ 6 \times 1.157 = 0.000\ 100\ 2$$

and

$$W = 0.000\ 100\ 2 \times 10^{6} \times (14.7/14.4) \times [(460 + 5)/[460 + 60)] = 91.5 \text{ lb/million ft}^3$$

6.3 A correlation of the available data on the equilibrium water content of natural gases has been reported by Bukacek.[4] This correlation is believed to be accurate enough for the requirements of the gaseous fuels industry, except for unusual situations where the dew point is measured at conditions close to the critical temperature of the gas. The correlation is a modified form of Raoult's law having the following form:

$$W = (A/P) + B \quad (2)$$

where:

W = water–vapor content, lb/million ft^3;
P = total pressure, psia;
A = a constant proportional to the vapor pressure of water; and
B = a constant depending on temperature and gas composition.

NOTE 5—Values of B were computed from available data on methane, methane-ethane mixtures, and natural gases.

6.3.1 Table 2 lists values of the constants A and B for natural gases in the temperature range from −40 to 460°F (−40 to 238°C).

6.3.2 Tables 3-5 list values of water–vapor content from −40 to 250°F (−40° to 121°C) and from 14.7 to 5000 psia (101 to 34 475 kPa), covering the range of most natural gas processing applications.

6.3.3 A convenient graphical representation of the data in Tables 3-5 is illustrated in Fig. 2.[5] The moisture content values given can be corrected to base conditions other than 14.7 psia (101 kPa) and 60°F (15.5°C) by the same equations given in Table 2.

7. Precision and Bias

7.1 No precision data is available for this test method, however, the Committee is interested in conducting an interlaboratory test program and encourages interested parties to contact the Staff Manager, Committee D03, ASTM Headquarters.

8. Keywords

8.1 gaseous fuels; natural gas

[3] *International Critical Tables*, Vol III, National Research Council, McGraw-Hill Book Co., Inc., New York, 1928, pp. 210–211.

[4] Bukacek, R. F., "Equilibrium Moisture Content of Natural Gases," *Research Bulletin 8*, Institute of Gas Technology, 1955. Reports work sponsored by the Pipeline Research Committee of the American Gas Association.

[5] Complete sets of these charts covering the entire range of pressures and temperatures of Tables 3-5 may be purchased from the Institute of Gas Technology, 1700 S. Mount Prospect Rd., Des Plaines, IL 60018.

TABLE 1 Vapor Pressures and Specific Volumes of Saturated Water Vapor at Various Temperatures[A]

Temperature, °F	Vapor Pressure of Liquid Water		Vapor Pressure of Ice		Specific Volume of Saturated Water Vapor ft³/lb	Temperature, °F	Vapor Pressure of Liquid Water, psia	Specific Volume of Saturated Water Vapor, ft³/lb
	mm Hg	psia	mm Hg	psia				
0	1.139	0.022 02	0.958	0.018 52	14 810			
1	1.195	0.023 11	1.010	0.019 53	14 080	51	0.184 85	1 644.2
2	1.251	0.024 19	1.063	0.020 56	13 400	52	0.191 82	1 587.6
3	1.310	0.025 33	1.120	0.021 66	12 750	53	0.199 01	1 533.2
4	1.373	0.026 55	1.180	0.022 82	12 140	54	0.206 44	1 480.9
5	1.436	0.027 77	1.241	0.024 00	11 550	55	0.214 11	1 430.6
6	1.505	0.029 10	1.308	0.025 29	11 000	56	0.222 03	1 382.2
7	1.573	0.030 42	1.374	0.026 57	10 480	57	0.230 21	1 335.6
8	1.647	0.031 85	1.446	0.027 96	9 979	58	0.238 65	1 290.9
9	1.723	0.033 32	1.521	0.029 41	9 507	59	0.247 36	1 247.8
10	1.807	0.034 94	1.599	0.030 92	9 060	60	0.256 35	1 206.3
11	1.883	0.036 41	1.681	0.032 51	8 636	61	0.265 62	1 166.4
12	1.970	0.038 09	1.767	0.034 17	8 234	62	0.275 19	1 128.0
13	2.057	0.039 78	1.856	0.035 89	7 851	63	0.285 06	1 091.0
14	2.149	0.041 56	1.950	0.037 71	7 489	64	0.295 24	1 055.4
15	2.247	0.043 45	2.050	0.039 64	7 144	65	0.305 73	1 021.1
16	2.345	0.045 35	2.151	0.041 59	6 817	66	0.316 55	988.03
17	2.450	0.047 37	2.260	0.043 70	6 505	67	0.327 70	956.19
18	2.557	0.049 44	2.373	0.045 89	6 210	68	0.339 20	925.51
19	2.607	0.051 63	2.489	0.048 13	5 929	69	0.351 05	895.94
20	2.785	0.053 85	2.610	0.050 47	5 662	70	0.363 26	867.44
21	2.907	0.056 21	2.740	0.052 98	5 408	71	0.375 84	839.97
22	3.032	0.058 63	2.872	0.055 54	5 166	72	0.388 79	813.48
23	3.163	0.061 16	3.013	0.058 26	4 936	73	0.402 14	787.94
24	3.299	0.063 79	3.160	0.061 10	4 717	74	0.415 88	763.31
25	3.433	0.066 38	3.310	0.064 01	4 509	75	0.430 04	739.55
26	3.585	0.069 32	3.471	0.067 12	4 311	76	0.444 61	716.62
27	3.735	0.072 22	3.636	0.070 31	4 122	77	0.459 61	694.51
28	3.893	0.075 28	3.810	0.073 67	3 943	78	0.475 05	673.16
29	4.054	0.078 39	3.989	0.077 14	3 771	79	0.490 94	652.56
30	4.224	0.081 68	4.178	0.080 79	3 608	80	0.507 29	632.68
31	4.397	0.085 02	4.373	0.084 56	3 453	81	0.524 11	613.48
32	4.579	0.088 66	4.579	0.088 54	3 301.9	82	0.541 42	594.95
33	...	0.092 30	...	...	3 178.0	83	0.559 22	577.05
34	...	0.096 07	...	...	3 059.2	84	0.577 53	559.76
35	...	0.099 98	...	...	2 945.5	85	0.596 36	543.07
36	...	0.104 04	...	...	2 836.4	86	0.615 73	526.94
37	...	0.108 23	...	...	2 731.9	87	0.635 63	511.35
38	...	0.112 58	...	...	2 631.7	88	0.656 09	496.29
39	...	0.117 08	...	...	2 535.7	89	0.677 13	481.73
40	...	0.121 73	...	...	2 443.5	90	0.698 74	467.66
41	...	0.126 55	...	...	2 355.1	91	0.720 95	454.06
42	...	0.131 54	...	...	2 270.3	92	0.743 77	440.91
43	...	0.136 70	...	...	2 188.9	93	0.767 22	428.19
44	...	0.142 04	...	...	2 110.8	94	0.791 30	415.89
45	...	0.147 56	...	...	2 035.8	95	0.816 04	403.99
46	...	0.153 28	...	...	1 963.8	96	0.841 44	392.48
47	...	0.159 18	...	...	1 894.6	97	0.867 53	381.35
48	...	0.165 28	...	...	1 828.2	98	0.894 31	370.58
49	...	0.171 59	...	...	1 764.4	99	0.921 80	360.15
50	...	0.178 12	...	...	1 703.1	100	0.950 03	350.06

[A]The values for vapor pressure, from 0 to 32°F, were calculated from data in the International Critical Tables.[3] All other values were taken from Harr, Gallagher, and Kell, "NBS/NRC Steam Tables," National Standard Reference Data System, 1984, p. 9. Data on specific volumes of saturated water vapor from 0 to 32°F were obtained from Goff, J. A., and Gratch, S., " Low-Pressure Properties of Water from −160 to 212°F," *Heating, Piping, and Air Conditioning*, Vol 18, No. 2, Feb. 1946, pp. 125–136.

TABLE 2 Values of Constants *A* and *B*
(Base Conditions = 14.7 psia, 60°F)

Temperature, °F	*A*	*B*	Temperature, ° F	*A*	*B*	Temperature, °F	*A*	*B*
–40	131	0.22	70	17 200	7.17	180	357 000	74.8
–38	147	0.24	72	18 500	7.85	182	372 000	77.2
–36	165	0.26	74	19 700	8.25	184	390 000	79.9
–34	184	0.28	76	21 100	8.67	186	407 000	82.7
–32	206	0.30	78	22 500	9.11	188	425 000	85.8
–30	230	0.33	80	24 100	9.57	190	443 000	88.4
–28	256	0.36	82	25 700	10.0	192	463 000	91.4
–26	285	0.39	84	27 400	10.5	194	483 000	94.8
–24	317	0.42	86	29 200	11.1	196	504 000	97.7
–22	352	0.45	88	31 100	11.6	198	525 000	101
–20	390	0.48	90	33 200	12.2	200	547 000	104
–18	434	0.52	92	35 300	12.7	202	570 000	108
–16	479	0.56	94	37 500	13.3	204	594 000	111
–14	530	0.60	96	39 900	14.0	206	619 000	115
–12	586	0.64	98	42 400	14.6	208	644 000	119
–10	648	0.69	100	45 100	15.3	210	671 000	122
–8	714	0.74	102	47 900	16.0	212	698 000	126
–6	786	0.79	104	50 800	16.7	214	725 000	130
–4	866	0.85	106	53 900	17.5	216	754 000	134
–2	950	0.91	108	57 100	18.3	218	785 000	139
0	1 050	0.97	110	60 500	19.1	220	816 000	143
2	1 150	1.04	112	64 100	20.0	222	848 000	148
4	1 260	1.11	114	67 900	20.9	224	881 000	152
6	1 380	1.19	116	71 800	21.8	226	915 000	157
8	1 510	1.27	118	76 000	22.7	228	950 000	162
10	1 650	1.35	120	80 400	23.7	230	987 000	166
12	1 810	1.44	122	84 900	24.7	232	1 020 000	171
14	1 970	1.54	124	89 700	25.8	234	1 060 000	177
16	2 150	1.64	126	94 700	26.9	236	1 100 000	182
18	2 350	1.74	128	100 000	28.0	238	1 140 000	187
20	2 560	1.85	130	106 000	29.1	240	1 190 000	192
22	2 780	1.97	132	111 000	30.3	242	1 230 000	198
24	3 030	2.09	134	117 000	31.6	244	1 270 000	204
26	3 290	2.22	136	124 000	32.9	246	1 320 000	210
28	3 570	2.36	138	130 000	34.2	248	1 370 000	216
30	3 880	2.50	140	137 000	35.6	250	1 420 000	222
32	4 210	2.65	142	144 000	37.0	252	1 470 000	229
34	4 560	2.81	144	152 000	38.5	254	1 520 000	235
36	4 940	2.98	146	160 000	40.0	256	1 570 000	242
38	5 350	3.16	148	168 000	41.6	258	1 630 000	248
40	5 780	3.34	150	177 000	43.2	260	1 680 000	255
42	6 240	3.54	152	186 000	44.9	280	2 340 000	333
44	6 740	3.74	154	195 000	46.6	300	3 180 000	430
46	7 280	3.96	156	205 000	48.4	320	4 260 000	548
48	7 850	4.18	158	215 000	50.2	340	5 610 000	692
50	8 460	4.42	160	225 000	52.1	360	7 270 000	869
52	9 110	4.66	162	236 000	54.1	380	9 300 000	1090
54	9 800	4.92	164	248 000	56.1	400	11 700 000	1360
56	10 500	5.19	166	259 000	58.2	420	14 700 000	1700
58	11 300	5.48	168	272 000	60.3	440	18 100 000	2130
60	12 200	5.77	170	285 000	62.5	460	22 200 000	
62	13 100	6.08	172	298 000	64.8			
64	14 000	6.41	174	312 000	67.1			
66	15 000	6.74	176	326 000	69.5			
68	16 100	7.10	178	341 000	72.0			

NOTE 1—To correct *A* and *B* to other base conditions, multiply each by:

$$(P_b/14.7) \times [519.6/(t_b+459.6)] \times (0.998/Z_b)$$

where:

P_b = absolute base pressure, psia;
t_b = base temperature, °F; and
Z_b = compressibility factor under base conditions.