



Standard Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature¹

This standard is issued under the fixed designation D 1142; 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 attachment² 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 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.

¹ This test method is under the jurisdiction of ASTM Committee D-3 on Gaseous Fuels, and is the direct responsibility of Subcommittee D03.05 on Determination of Special Constituents of Gaseous Fuels.

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² Several pieces of apparatus for this purpose are commercially available. Information concerning this apparatus is available from ASTM Headquarters.

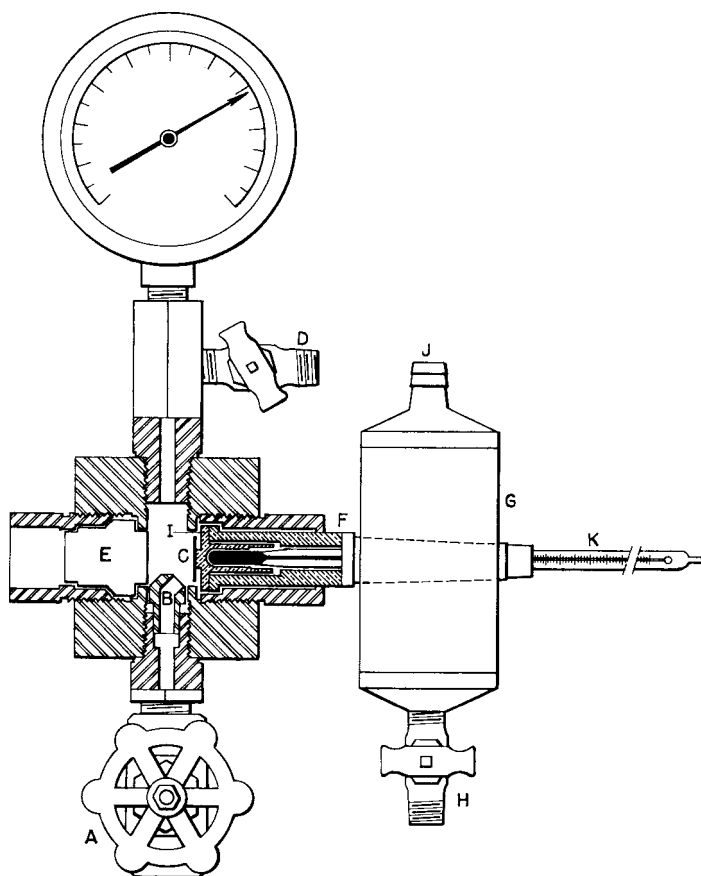


FIG. 1 Bureau of Mines Dew-Point Apparatus

4.2 The Bureau of Mines type of dew-point apparatus³ 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 It will be noted 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 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 reported³ to permit a determination with a

³ 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.

precision (reproducibility) of $\pm 0.2^\circ\text{F}$ ($\pm 0.1^\circ\text{C}$) and with an accuracy of $\pm 0.2^\circ\text{F}$ ($\pm 0.1^\circ\text{C}$) 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 $\pm 0.5^\circ\text{F}$ (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 $1^\circ\text{F}/\text{min}$ ($.5^\circ\text{C}/\text{min}$) 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.

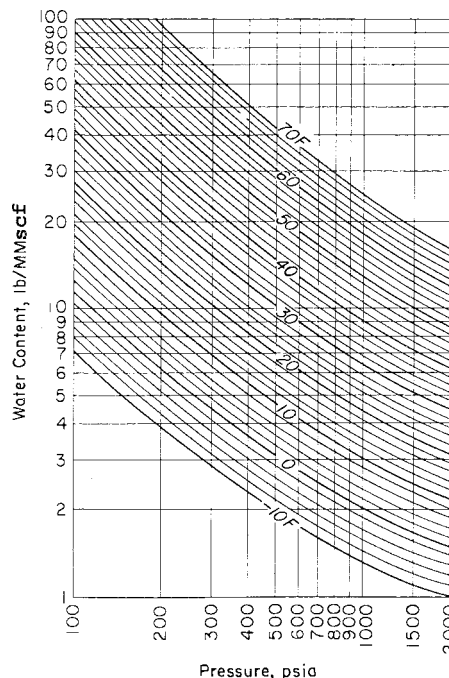


FIG. 2 Equilibrium Water Vapor Content of Natural Gases

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:

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

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, $^\circ\text{F}$,

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:

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 ft ³ /lb	Temperature, °F	Vapor Pressure of Liquid Water, psia	Specific Volume of Saturated Water Vapor, ft ³ /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. ⁴ 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.

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

What is the water-vapor content million ft³ 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 ft³/lb, from which:

$$w = (1/2731.9) = 0.000\ 3660\ \text{lb/ft}^3,$$

and

$$W = 0.000\ 3660 \times 10^6 \times (14.7/15.0) \times [(460 + 37)/(460 + 60)] \\ = 342.8\ \text{lb/million ft}^3$$

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 ft³/lb from which $W_{\text{ice, 5F}} = 0.000\ 086\ 6$, but the observed water dew point was in equilibrium with subcooled liquid water at 5°F. From Table 2 (data from International Critical Tables⁴), 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,

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

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.⁵ 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 ft³,

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 34475 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. 2.⁶ 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 inter-laboratory test program and encourages interested parties to contact the Staff Manager, Committee D-3, ASTM Headquarters.

8. Keywords

8.1 gaseous fuels; natural gas

⁴ *International Critical Tables*, Vol III, National Research Council, McGraw-Hill Book Co., Inc., New York, NY, pp. 210–211, 1928.

⁵ 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.

⁶ 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, 3424 S. State St., Chicago, IL 60616.

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.

TABLE 3 Equilibrium Water Vapor Contents of Natural Gases Above the Critical Temperatures
(lb/million ft³ where $P_b = 14.7$ psia, $t_b = 60^\circ\text{F}$)

Temperature, °F	Total Pressure, psia										
	14.7	100	200	300	400	500	600	700	800	900	1000
-40	9.1	1.5	0.88	0.66	0.55	0.49	0.44	0.41	0.39	0.37	0.36
-38	10.2	1.7	0.98	0.73	0.61	0.54	0.49	0.45	0.43	0.41	0.39
-36	11.5	1.9	1.1	0.80	0.68	0.59	0.54	0.50	0.47	0.45	0.43
-34	12.8	2.1	1.2	0.90	0.74	0.65	0.59	0.55	0.51	0.49	0.47
-32	14.4	2.4	1.3	0.99	0.82	0.72	0.65	0.60	0.57	0.54	0.51
-30	16.0	2.6	1.5	1.1	0.91	0.79	0.72	0.66	0.62	0.59	0.56
-28	17.8	2.9	1.6	1.2	1.0	0.87	0.79	0.72	0.68	0.64	0.61
-26	19.8	3.2	1.8	1.3	1.1	0.96	0.86	0.79	0.74	0.70	0.67
-24	22.0	3.6	2.0	1.5	1.2	1.1	0.95	0.87	0.81	0.77	0.73
-22	24.4	4.0	2.2	1.6	1.3	1.2	1.0	0.95	0.89	0.84	0.80
-20	27.0	4.4	2.4	1.8	1.5	1.3	1.1	1.0	0.97	0.92	0.87
-18	30.0	4.9	2.7	2.0	1.6	1.4	1.2	1.1	1.1	1.0	0.95
-16	33.1	5.4	3.0	2.2	1.8	1.5	1.4	1.2	1.2	1.1	1.0
-14	36.7	5.9	3.3	2.4	1.9	1.7	1.5	1.4	1.3	1.2	1.1
-12	40.5	6.5	3.6	2.6	2.1	1.8	1.6	1.5	1.4	1.3	1.2
-10	44.8	7.2	4.0	2.9	2.3	2.0	1.8	1.6	1.5	1.4	1.3
-8	49.3	7.9	4.3	3.1	2.5	2.2	1.9	1.8	1.6	1.5	1.5
-6	54.6	8.7	4.7	3.4	2.8	2.4	2.1	1.9	1.8	1.7	1.6
-4	59.8	9.5	5.2	3.7	3.0	2.6	2.3	2.1	1.9	1.8	1.7
-2	65.7	10.4	5.7	4.1	3.3	2.8	2.5	2.3	2.1	2.0	1.9
0	72.1	11.4	6.2	4.5	3.6	3.1	2.7	2.5	2.3	2.1	2.0
2	79.1	12.5	6.8	4.9	3.9	3.3	3.0	2.7	2.5	2.3	2.2
4	86.8	13.7	7.4	5.3	4.3	3.6	3.2	2.9	2.7	2.5	2.4
6	95.1	15.0	8.1	5.8	4.6	4.0	3.5	3.2	2.9	2.7	2.6
8	104	16.4	8.8	6.3	5.1	4.3	3.8	3.4	3.2	3.0	2.8
10	114	17.9	9.6	6.9	5.5	4.7	4.1	3.7	3.4	3.2	3.0
12	124	19.5	10.5	7.5	6.0	5.1	4.5	4.0	3.7	3.5	3.3
14	136	21.3	11.4	8.1	6.5	5.5	4.8	4.5	4.0	3.7	3.5
16	148	23.2	12.4	8.8	7.0	5.9	5.2	4.7	4.3	4.0	3.8
18	161	25.2	13.5	9.6	7.6	6.4	5.7	5.1	4.7	4.4	4.1
20	176	27.4	14.6	10.4	8.2	7.0	6.1	5.5	5.1	4.7	4.4
22	191	29.8	15.9	11.3	8.9	7.5	6.6	5.9	5.5	5.1	4.8
24	208	32.4	17.2	12.2	9.7	8.2	7.2	6.4	5.9	5.5	5.1
26	226	35.1	18.7	13.2	10.5	8.8	7.7	6.9	6.3	5.9	5.5
28	246	38.1	20.2	14.3	11.3	9.5	8.3	7.5	6.8	6.3	5.9
30	276	41.3	21.9	15.4	12.2	10.3	9.0	8.0	7.4	6.8	6.4
32	289	44.7	23.7	16.7	13.2	11.1	9.7	8.7	7.9	7.3	6.9
34	313	48.4	25.6	18.0	14.2	11.9	10.4	9.3	8.5	7.9	7.4
36	339	52.4	27.7	19.4	15.3	12.9	11.2	10.0	9.2	8.5	7.9
38	367	56.6	29.9	20.1	16.5	13.9	12.1	10.8	9.8	9.1	8.5
40	396	61.1	32.2	22.6	17.8	14.9	13.0	11.6	10.6	9.8	9.1
42	428	66.0	34.8	24.4	19.2	16.0	13.9	12.5	11.3	10.5	9.8
44	462	71.2	37.5	26.2	20.6	17.2	15.0	13.4	12.2	11.2	10.5
46	499	76.7	40.3	28.2	22.2	18.5	16.1	14.4	13.1	12.0	11.2
48	538	82.6	43.4	30.3	23.8	19.9	17.3	15.4	14.0	12.9	12.0
50	80	89.0	46.7	32.6	25.6	21.3	18.5	16.5	15.0	13.8	12.9
52	624	95.7	50.2	35.0	27.4	22.9	19.8	17.7	16.1	14.8	13.8
54	672	103	54.0	37.6	29.4	24.5	21.3	18.9	17.2	15.8	14.7
56	721	111	57.9	40.3	31.5	26.7	22.8	20.3	18.3	16.9	15.7
58	776	119	62.1	43.2	33.8	28.1	24.4	21.7	19.6	18.0	16.8
60	834	128	66.6	46.3	36.2	30.1	26.1	23.2	21.0	19.3	17.9
62	895	137	71.4	49.6	38.7	32.2	27.9	24.7	22.4	20.6	19.1
64	960	147	76.5	53.1	41.4	34.4	29.8	26.4	23.9	22.0	20.4
66	1 030	157	81.8	56.8	44.3	36.8	31.8	28.2	25.5	23.4	21.8
68	1 100	168	87.6	60.7	47.3	39.3	33.9	30.1	27.2	25.0	23.2
70	1 180	180	93.7	65.0	50.6	42.0	36.2	32.1	29.0	26.6	24.7
72	1 260	192	100	69.4	54.0	44.8	38.6	34.2	30.9	28.4	26.3
74	1 350	206	107	74.0	57.6	47.7	41.1	36.4	32.9	30.2	28.0
76	1 440	220	114	79.0	61.4	50.9	43.8	38.8	35.0	32.1	29.8
78	1 540	235	122	84.2	65.5	54.2	46.7	41.3	37.3	34.2	31.7

TABLE 3 *Continued*

Temperature, ° F	Total Pressure, psia										
	14.7	100	200	300	400	500	600	700	800	900	1000
80	1 650	250	130	89.8	69.7	57.5	49.7	44.0	39.7	36.3	33.6
82	1 760	267	138	95.6	74.2	61.4	52.8	46.7	42.1	38.6	36.7
84	1 870	285	148	102	79.0	65.3	56.2	49.7	44.8	41.0	37.9
86	2 000	303	157	108	84.1	69.5	59.7	52.8	47.6	43.5	40.3
88	2 130	323	167	115	89.4	73.8	63.5	56.1	50.5	46.2	42.7
90	2 270	344	178	123	95.0	78.5	67.4	59.5	53.6	49.0	45.3
92	2 410	366	189	130	101	83.3	71.5	63.1	56.8	51.9	48.0
94	2 570	389	201	138	107	88.4	75.9	67.0	60.3	55.0	50.9
96	2 730	413	214	147	114	93.8	80.5	71.0	63.9	58.3	53.9
98	2 900	439	227	156	121	99.5	85.3	75.2	67.6	61.8	57.0
100	3 080	466	241	166	128	105	90.4	79.7	71.6	65.4	...
102	3 270	495	256	176	136	112	95.8	84.4	75.9	69.2	...
104	3 470	525	271	186	144	118	101	89.3	80.2	73.1	...
106	3 680	557	287	197	152	125	107	94.5	84.9	77.4	...
108	3 900	589	304	209	161	133	114	99.9	89.7	81.7	...
110	4 130	624	322	221	170	140	120	106	94.7	86.3	...
112	4 380	661	341	234	180	148	127	112	100	91.2	...
114	4 640	700	360	247	191	157	134	118	106	96.2	...
116	4 910	740	381	261	201	165	142	124	112	102	...
118	5 190	783	403	276	213	175	149	131	118	107	...
120	5 490	828	426	292	225	185	158	139	124	113	...
122	5 800	874	449	308	237	195	166	146	131	119	...
124	6 130	923	474	325	250	205	175	154	138	125	...
126	6 470	974	500	343	264	216	185	162	145	132	...
128	6 830	1030	528	361	278	228	195	171	153	139	...
130	7 240	1090	559	382	294	241	206	181	162	147	...
132	7 580	1140	585	400	308	252	215	189	169	154	...
134	7 990	1200	617	422	324	266	227	199	178	162	...
136	8 470	1270	653	446	343	281	240	210	188	171	...
138	8 880	1330	684	468	359	294	251	220	197	179	...
140	9 360	1410	721	492	378	310	264	231	207	188	...
142	9 830	1480	757	517	397	325	277	243	217	197	...
144	10 400	1560	799	545	419	343	292	256	229	207	...
146	10 900	1640	840	573	440	360	307	269	240	218	...
148	11 500	1720	882	602	462	378	322	282	252	229	...

TABLE 4 Equilibrium Water Vapor Contents of Natural Gases Above the Critical Temperatures
 (lb/million ft³ where $P_b = 14.7$ psia, $t_b = 60^\circ\text{F}$)

Temperature, °F	Total Pressure, psia									
	14.7	100	200	300	400	500	600	700	800	900
150	12 100	1810	928	633	486	397	338	296	264	240
152	12 700	1910	975	665	510	417	355	311	277	252
154	13 300	2000	1020	697	534	437	372	325	290	263
156	14 000	2100	1070	732	561	458	390	341	305	276
158	14 700	2200	1130	767	588	480	409	357	319	289
160	15 400	2300	1180	802	615	502	427	374	333	302
162	...	2410	1230	841	644	526	447	391	349	316
164	...	2540	1300	883	676	552	469	410	366	332
166	...	2650	1350	922	706	576	490	428	382	346
168	...	2780	1420	967	740	604	514	449	400	363
170	...	2910	1490	1010	775	633	538	470	419	379
172	...	3040	1550	1060	810	661	562	491	437	396
174	...	3190	1630	1110	847	691	587	513	457	414
176	...	3330	1700	1160	885	722	613	535	477	432
178	...	3480	1780	1210	925	754	640	559	498	451
180	...	3640	1860	1260	967	789	670	585	521	471
182	...	3800	1940	1320	1010	821	697	609	542	491
184	...	3980	2030	1380	1060	860	730	637	567	513
186	...	4150	2120	1440	1100	897	761	664	591	535
188	...	4340	2210	1500	1150	936	794	693	617	558
190	...	4520	2300	1570	1200	974	827	721	642	581
192	...	4720	2410	1630	1250	1020	863	753	670	606
194	...	4920	2510	1700	1300	1060	900	785	698	631
196	...	5140	2620	1780	1360	1110	938	818	728	658
198	...	5350	2730	1850	1410	1150	976	851	757	684
200	...	5570	2840	1930	1470	1200	1020	885	788	712
202	...	5810	2960	2010	1530	1250	1060	922	821	741
204	...	6050	3080	2090	1600	1300	1100	960	854	771
206	...	6310	3210	2180	1660	1350	1150	999	889	803
208	3340	2270	1730	1400	1190	1040	924	835
210	3480	2360	1800	1460	1240	1080	961	868
212	3620	2450	1870	1520	1290	1120	999	902
214	3760	2550	1950	1580	1340	1160	1040	937
216	3910	2650	2020	1640	1390	1210	1080	973
218	4060	2760	2100	1710	1450	1260	1120	1010
220	4220	2860	2180	1780	1500	1310	1160	1050
222	4390	2980	2270	1840	1560	1360	1200	1090
224	4560	3090	2350	1910	1620	1410	1250	1130
226	4730	3200	2440	1990	1680	1460	1300	1170
228	4910	3330	2540	2060	1750	1520	1350	1220
230	5100	3460	2630	2140	1810	1580	1400	1260
240	4160	3170	2570	2180	1890	1680	1510
250	3770	3060	2590	2250	2000	1800

TABLE 5 Equilibrium Water Vapor Contents of Natural Gases Above the Critical Temperatures
(lb/million ft³ where $P_b = 14.7$ psia, $t_b = 60^\circ\text{F}$)

Temperature, °F	Total Pressure, psia								
	1000	1500	2000	2500	3000	3500	4000	4500	5000
100	60.4	45.4	37.9	33.3	30.3	28.2	26.6	25.3	24.3
102	63.9	47.9	40.0	35.5	32.0	29.7	28.0	26.6	25.6
104	67.5	50.6	42.1	37.0	33.6	31.2	29.4	28.0	26.9
106	71.4	53.4	44.5	39.1	35.5	32.9	31.0	29.5	28.3
108	75.4	56.4	46.9	41.1	37.3	34.6	32.6	31.0	29.7
110	79.6	59.4	49.4	43.3	39.3	36.4	34.2	32.5	31.2
112	84.1	62.7	52.1	45.6	41.4	38.3	36.0	34.2	32.8
114	88.7	66.1	54.8	48.0	43.4	40.2	37.8	35.9	34.4
116	93.6	69.7	57.7	50.5	45.7	42.3	39.8	37.8	36.2
118	98.7	73.4	60.7	53.1	48.0	44.4	41.7	39.6	37.9
120	104	77.3	63.9	55.9	50.5	46.7	43.8	41.6	39.8
122	110	81.3	67.2	58.7	53.0	49.0	45.9	43.6	41.7
124	116	85.6	70.7	61.7	55.7	51.4	48.2	45.7	43.7
126	122	89.9	74.2	64.7	58.4	53.9	50.5	47.8	45.7
128	128	94.7	78.0	68.0	61.3	56.6	53.0	50.2	48.0
130	135	99.8	82.1	71.5	64.4	59.4	55.6	52.6	50.3
132	141	104	85.8	74.7	67.3	62.0	58.1	55.0	52.5
134	149	110	90.1	78.4	70.6	65.0	60.9	57.6	55.0
136	157	116	94.9	82.5	74.2	68.3	63.9	60.3	57.7
138	164	121	99.2	86.2	77.5	71.3	66.7	63.1	60.2
140	173	127	104	90.4	81.3	74.7	69.9	66.0	63.0
142	181	133	109	94.6	85.0	78.1	73.0	69.0	65.8
144	191	140	115	99.3	89.2	81.9	76.5	72.3	68.9
146	200	147	120	104	93.0	85.7	80.0	75.6	72.0
148	210	154	126	109	97.6	89.6	83.6	78.9	75.6
150	220	161	132	114	102	93.8	87.5	82.5	78.6
152	231	169	138	119	107	98.0	91.4	86.2	82.1
154	242	177	144	125	112	102	95.4	89.9	85.6
156	253	185	151	130	117	107	100	94.0	89.4
158	265	194	158	136	122	112	104	98.0	93.2
160	277	202	165	142	127	116	108	102	97.1
162	290	211	172	149	133	122	113	107	101
164	304	221	180	155	139	127	118	111	106
166	317	231	188	162	145	132	123	116	110
168	332	242	196	169	151	138	128	121	115
170	348	253	205	177	158	144	134	126	120
172	363	263	214	184	165	150	139	131	124
174	379	275	223	192	171	156	145	136	130
176	396	287	233	200	178	163	151	142	135
178	413	299	243	208	186	169	157	148	140
180	432	313	253	217	194	177	164	154	146
182	449	325	263	226	201	184	170	160	152
184	470	340	275	236	210	191	177	167	158
186	490	354	286	245	218	199	184	173	164
188	511	369	298	256	227	207	192	180	171
190	531	384	310	266	236	215	199	187	177
192	554	400	323	277	246	224	207	194	184
194	578	417	336	288	256	233	215	202	191
196	602	434	350	299	266	242	224	210	199
198	626	451	364	311	276	251	232	218	206
200	651	469	378	323	286	260	241	226	213
202	678	488	393	336	298	271	251	235	222
204	705	507	408	349	309	281	260	243	230
206	734	528	425	363	321	292	270	253	238
208	763	548	441	377	334	303	280	262	248
210	793	569	458	390	346	314	290	271	256
212	824	591	475	405	359	325	301	281	266
214	856	614	493	420	372	337	312	291	275
216	889	637	512	436	386	350	323	302	285
218	924	662	532	453	401	363	335	313	296

TABLE 5 *Continued*

Temperature, °F	Total Pressure, psia								
	1000	1500	2000	2500	3000	3500	4000	4500	5000
220	959	687	551	469	415	376	347	324	306
222	996	713	572	487	431	390	360	336	318
224	1030	739	593	504	446	404	372	348	328
226	1070	767	615	523	462	418	386	360	340
228	1110	795	637	542	479	433	400	373	352
230	1150	824	660	561	495	448	413	385	363
240	1380	985	787	668	589	532	490	456	430
250	1640	1170	932	790	695	628	577	538	506

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