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Standard Test Methods for
Water Vapor Content of Electrical Insulating Gases by Measurement of Dew Point[1]

This standard is issued under the fixed designation D 2029; 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 These test methods describe the determination of the water vapor content of electrical insulating gases by direct or indirect measurement of the dew point and the calculation of the water vapor content.

1.2 The following four test methods are provided:

1.2.1 *Method A* describes the automatic chilled mirror method for measurement of dew point as low as – 73°C (–99°F).

1.2.2 *Method B* describes the manual chilled mirror or dew cup method for measurement of dew point as low as – 73°C (–99°F).

1.2.3 *Method C* describes the adiabatic expansion method for measurement of dew point as low as – 62°C (–80°F).

1.2.4 *Method D* describes the capacitance method for measurement of dew point as low as – 110°C (–166°F).

1.3 *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. For specific warnings, see 8.1.1, 9.2, 10.1.2 and 10.2.5.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]
D 1933 Specification for Nitrogen Gas as an Electrical Insulating Material
D 2472 Specification for Sulfur Hexafluoride
D 3283 Specification for Air as an Electrical Insulating Material

3. Terminology

3.1 *Definitions:*

3.1.1 *dew point,, n*—the temperature to which a gas must be cooled at constant pressure and constant water vapor content in order for saturation to occur. Any further cooling usually results in formation of the first drop of dew.

3.1.2 *hygroscopic,, adj*—readily taking up and retaining moisture.

4. Summary of Test Methods

4.1 *Method A*—The automatic chilled mirror method uses the chilled mirror dew point condensation principle to determine the water vapor content in gas mixtures. An internal mirror, which is in the path of the test gas, is automatically cooled. Internal electronics sense the presence of moisture on the mirror. The device then automatically brings itself to equilibrium and provides a direct reading of dew point temperature.

4.2 *Method B*—This method uses the same basic condensation principle in 4.1; however, the manual chilled mirror method uses a mixture of acetone and ice or other cooling media to manually chill the dew cup polished surface which acts as the mirror.

4.3 *Method C*—Adiabatic expansion uses a process in which the test gas is cooled rapidly to determine dew point temperature. This rapid exhausting of the test gas to atmosphere results in an expansion and cooling of the gas. If the cooling is sufficient to reduce the temperature of the gas to or below the dew point, water vapor will condense out in the form of a fine mist or fog. Successive trials will determine the minimum initial pressure that will produce a fog. From this, the dew point temperature can be calculated.

4.3.1 The relationship between pressure and temperature during adiabatic expansion is as follows:

$$T_F = T_I[P_F/P_I]^{[K-1/K]}$$

where:
K = ratio of specific heats for a given gas,
T_F = final temperature,
T_I = initial temperature,
P_F = final pressure, and
P_I = initial pressure.

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4.4 *Method D*—The capacitance method uses a moisture sensor, typically aluminum oxide or silicon oxide, which changes its electrical output with the amount of water vapor to which it is exposed.

5. Significance and Use

5.1 Certain gases have excellent dielectric and electric arc interruption characteristics which make their use in electrical installations very desirable.

5.2 Water content, as the test parameter, is of great importance in determining the dielectric effectiveness of the gas. Under certain conditions, water may condense and become a conducting liquid resulting in a catastrophic dielectric breakdown of the insulation. The water content of these insulating gases as expressed by dew point is listed in Specifications D 1933, D 2473, and D 3283.

5.3 Once the dew point is determined, a conversion to moisture content may be performed using Table 1. Once moisture content is known, the lowest temperature at which gas insulated equipment can be safely operated can usually be determined by reviewing manufacturers' specifications for the equipment.

5.4 The dew point of the test gas is independent of the gas temperature but does depend on its pressure. Many moisture measurement test instruments are sensitive to pressure, and display moisture values at the instrument inlet pressure and not necessarily at the pressure of the system being sampled. It is therefore important to account for this condition to avoid serious measurement errors.

6. Interferences

6.1 *Tubing*:

6.1.1 Most new metal tubing contains oil deposits on the interior walls due to the manufacturing process. This residue should be removed before using these lines for gas sampling.

6.1.2 Tubing should be free of leaks, since even a pinhole leak will result in a false indication (higher dew point), due to the partial pressure of water vapor in the atmosphere.

6.1.3 When the gas being tested is extremely dry [dew point below approximately − 40°C (−40°F)], results can be misleading until the moisture adsorbed in the system (tubing, regulators, etc.) has been removed by purging with the test gas. At this point, all moisture present within the system should be due to that contained in the test gas.

6.2 When testing gases that contain readily liquefiable impurities, it must be kept in mind that the dew point that is measured by condensation type instruments may be due to these impurities rather than to water. Under these conditions, the measured dew point is not an indication of the water content of the gas.

6.3 Measurement of water vapor in very dry gases is complicated by four considerations, as follows:

6.3.1 For Methods A, B, and C, the relatively large volume of gas required to deposit sufficient water vapor to create the "dew".

6.3.2 For Methods A, B, and C, that under very dry condition, the possibility exists to condense the test gas prior to deposition of moisture on the mirror.

6.3.3 For Methods A, B, C, and D, that the measuring system (instrument and tubing) must not entrain moisture. If any moisture is entrained, several hours may be required for the gas being measured to come into equilibrium with the measuring system.

6.3.4 For Methods B and C, the sensitivity of the human eye in determining exactly when the dew first forms.

7. General Requirements

7.1 *Methods A, B, and C*—Any properly constructed dew point apparatus may be used that provides a means to satisfy the following basic requirements:

7.1.1 Control the flow of gas entering and leaving the apparatus while the apparatus is at a temperature at least 2°C (3.6°F) above the dew point of the gas.

7.1.2 Control the cooling rate of a chamber in the apparatus through which the flowing gas passes to a temperature low enough to cause water vapor to condense from the gas.

7.1.3 Detect the deposition of dew on the cold portion of the apparatus and measure the temperature at which dew is formed.

7.1.4 Ensure that the test gas is at or near atmospheric pressure and is isolated from contamination from other gases.

7.2 *Method D*—Any properly constructed capacitive type moisture sensor may be used that provides a means to satisfy the following basic requirements:

7.2.1 Expose the sensor to a gas that is at a temperature at least 10°C (18°F) above the dew point of the gas.

7.2.2 Measure the partial vapor pressure of water in a gas by means of a capacitive type sensor.

7.3 These test methods provide for several techniques, each utilizing different types of apparatus for measuring dew point. The techniques in these test methods are provided for general information and are not intended as a substitute for manufacturer's instructions. When using any instrument, the manufacturer's instructions should be followed to ensure proper and safe operation.

8. Apparatus

8.1 *General*:

8.1.1 *Tubing*—Although not true of all applications, stainless steel, glass, and nickel alloy tubing are the best possible nonhygroscopic materials and should be used for low dew point applications − 18 to − 73°C (0 to − 100°F). Copper and aluminum alloys, as well as stabilized polypropylene tubing, are acceptable above − 29°C (−20°F) dew point. (**Warning**— All materials will adsorb moisture to some extent; therefore, the internal surface of apparatus, tubing, and fittings should be minimized to enable the system to dry out more quickly and achieve equilibrium sooner. However, it should be noted that when one switches from measurement of a high dew point to a lower dew point [that is, 0 to − 60°C (32 to − 76°F)] copper tubing might take 1 h or more to desorb the moisture from the previous sample, whereas stainless steel will equilibrate in approximately 10 min.)

8.1.2 Although not a requirement, the addition of a chart recorder to various automated systems makes determining when the system has reached equilibrium much easier.

TABLE 1 Relationship Between Dew Point and Moisture Content of Gases

NOTE 1—With a known dew point which is indicated by the dew point indicator or recorder, the moisture content can be read directly from the table. The table shows the amount of water in air or other gas at various dew points at a pressure of 1 atm (14.7) psi.

Dew Point		Moisture Content			Dew Point		Moisture Content		
°C	°F	lb/1000 ft³	mg/L	volume[A] percent	°C	°F	lb/1000 ft³	mg/L	volume[A] percent
50	122.0	5.16	82.7	12.2	−16	3.2	0.079	1.27	0.149
49	120.2	4.92	78.9	11.6	−17	1.4	0.072	1.16	0.136
48	118.4	4.69	75.1	11.0	−18	−0.4	0.066	1.06	0.123
47	116.6	4.48	71.9	10.5	−19	−2.2	0.060	0.965	0.112
46	114.8	4.26	68.4	9.95	−20	−4.0	0.055	0.882	0.102
45	113.0	4.06	65.0	9.45	−21	−5.8	0.050	0.809	0.093
44	111.2	3.88	62.1	8.99	−22	−7.6	0.046	0.733	0.084
43	109.4	3.69	59.1	8.52	−23	−9.4	0.042	0.666	0.076
42	107.6	3.52	56.4	8.10	−24	−11.2	0.038	0.608	0.069
41	105.8	3.34	53.5	7.67	−25	−13.0	0.035	0.556	0.063
40	104.0	3.18	50.9	7.27	−26	−14.8	0.031	0.506	0.057
39	102.2	3.02	48.4	6.89	−26	−16.6	0.028	0.454	0.057
38	100.4	2.87	46.0	6.54	−28	−18.4	0.025	0.411	0.046
37	98.6	2.74	43.8	6.20	−29	−20.2	0.023	0.377	0.042
36	96.8	2.60	41.6	5.87	−30	−22.0	0.021	0.343	0.038
35	95.0	2.46	39.4	5.55	−31	−23.8	0.019	0.307	0.034
34	93.2	2.34	37.4	5.25	−32	−25.6	0.017	0.273	0.030
33	91.4	2.22	35.6	4.96	−33	−27.4	0.015	0.246	0.027
32	89.6	2.11	33.8	4.70	−34	−29.2	0.014	0.229	0.025
31	87.8	2.00	32.0	4.44	−35	−31.0	0.013	0.202	0.022
30	86.0	1.89	30.3	4.19	−36	−32.8	0.012	0.185	0.020
29	84.2	1.84	29.2	4.01	−37	−34.6	0.010	0.167	0.018
28	82.4	1.69	27.1	3.7	−38	−36.4	0.0093	0.149	0.016
27	80.6	1.60	25.7	3.52	−39	−38.2	0.0082	0.131	0.014
26	78.8	1.52	24.4	3.33	−40	−40.0	0.0074	0.119	0.0127
25	77.0	1.44	23.0	3.12	−41	−41.8	0.0068	0.107	0.0113
24	75.2	1.35	21.7	2.94	−42	−43.6	0.0060	0.096	0.0102
23	73.4	1.28	20.6	2.78	−43	−45.4	0.0054	0.086	0.0090
22	71.6	1.21	19.4	2.61	−44	−47.2	0.0047	0.076	0.0080
21	69.8	1.14	18.3	2.46	−45	−49.0	0.0042	0.068	0.0071
20	68.0	1.08	17.3	2.31	−46	−50.8	0.0038	0.061	0.0063
19	66.2	1.02	16.3	2.17	−47	−52.6	0.0034	0.054	0.0056
18	64.4	0.961	15.4	2.04	−48	−54.4	0.0031	0.049	0.0050
17	62.6	0.899	14.4	1.91	−49	−56.2	0.0027	0.043	0.0044
16	60.8	0.855	13.7	1.80	−50	−58.0	0.0024	0.038	0.0039
15	59.0	0.799	12.8	1.68	−51	−59.8	0.0021	0.034	0.0034
14	57.2	0.749	12.0	1.57	−52	−61.6	0.0019	0.030	0.0030
13	55.4	0.706	11.3	1.48	−53	−63.4	0.0017	0.027	0.0027
12	53.6	0.668	10.7	1.39	−54	−65.2	0.0014	0.023	0.0023
11	51.8	0.620	9.94	1.29	−55	−67.0	0.0013	0.021	0.0021
10	50.0	0.584	9.37	1.21	−56	−68.8	0.0011	0.018	0.0018
9	48.2	0.547	8.76	1.13	−57	−70.6	0.0010	0.016	0.0016
8	46.4	0.516	8.27	1.06	−58	−72.4	0.00087	0.014	0.0014
7	44.6	0.482	7.73	0.988	−59	−74.2	0.00075	0.012	0.0012
6	42.8	0.452	7.25	0.924	−60	−76.0	0.00069	0.011	0.0011
5	41.0	0.424	6.79	0.861	−61	−77.8	0.00059	0.0095	0.00092
4	39.2	0.399	6.36	0.804	−62	−79.6	0.00052	0.0083	0.00080
3	37.4	0.370	5.94	0.748	−63	−81.4	0.00046	0.0073	0.00070
2	35.6	0.346	5.55	0.696	−64	−83.2	0.00040	0.0064	0.00061
1	33.8	0.323	5.18	0.649	−65	−85.0	0.00035	0.0056	0.00053
0	32.0	0.302	4.84	0.602	−66	−86.8	0.00030	0.0048	0.00045
−1	30.2	0.280	4.49	0.556	−67	−88.6	0.00027	0.0043	0.00040
−2	28.4	0.258	4.14	0.511	−68	−90.4	0.00022	0.0036	0.00034
−3	26.6	0.238	3.81	0.470	−69	−92.2	0.00019	0.0031	0.00029
−4	24.8	0.220	3.52	0.431	−70	−94.0	0.00017	0.0027	0.00025
−5	23.0	0.202	3.24	0.396	−71	−95.8	0.00015	0.0024	0.00022
−6	21.2	0.186	2.98	0.364	−72	−97.6	0.00013	0.0021	0.00019
−7	19.4	0.171	2.74	0.333	−73	−99.4	0.00011	0.0018	0.00016
−8	17.6	0.158	2.53	0.306	−74	−101.2	0.00009	0.0015	0.00014
−9	15.8	0.145	2.32	0.280	−75	−103.0	0.00008	0.0013	0.00012
−10	14.0	0.134	2.14	0.257	−76	−104.8	0.00007	0.0011	0.00010
−11	12.2	0.122	1.96	0.235	−77	−106.6	0.00006	0.0010	0.00009
−12	10.4	0.113	1.81	0.215	−78	−108.4	0.00005	0.0008	0.00007
−13	8.6	0.103	1.65	0.196	−79	−110.2	0.00004	0.0007	0.00006
−14	6.8	0.095	1.52	0.179	−80	−112.0	0.00004	0.0006	0.00005
−15	5.0	0.086	1.38	0.163	−81	−113.8	0.00003	0.0005	0.00004

[A]Vapor pressures in atmospheres at various dew points can be obtained by dividing the values for "volume percent" in this table by 100. Calculations for this table were made by using the International Critical Table values for the vapor pressure of ice and liquid water. The vapor pressure of liquid water was used for values from 50 to 0°C. The vapor pressure of ice was used from 0 to − 81°C.