



Designation: D8446 – 22

Standard Test Method for Water Vapor Content in Compressed Air Using Electronic Moisture Analyzers¹

This standard is issued under the fixed designation D8446; 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.

1. Scope

1.1 This test method covers the determination of the water vapor content in compressed air using portable or in-situ electronic moisture analyzers. Such analyzers commonly use sensing cells based on phosphorus pentoxide, P_2O_5 , aluminum oxide, Al_2O_3 , or silicon piezoelectric-type cells or laser-based technologies.

1.2 This test method is applicable for the range of condensation temperatures from $-80\text{ }^\circ\text{C}$ to $60\text{ }^\circ\text{C}$.

1.3 Testing is often performed at reduced pressure from the full pressure of the system or source of compressed air depending on the capability of the specific analyzer. Testing above 2000 kPa may introduce additional uncertainty because of changes in the relationship between water vapor pressure and actual moisture content at elevated pressures.

1.4 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

¹ This test method is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.13 on Compressed Air Quality.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- D1356 Terminology Relating to Sampling and Analysis of Atmospheres
- D4178 Practice for Calibrating Moisture Analyzers
- D4230 Test Method for Measuring Humidity with Cooled-Surface Condensation (Dew-Point) Hygrometer
- D5454 Test Method for Water Vapor Content of Gaseous Fuels Using Electronic Moisture Analyzers
- D7904 Test Method for Determination of Water Vapor (Moisture Concentration) in Natural Gas by Tunable Diode Laser Spectroscopy (TDLAS)

3. Terminology

3.1 *Definitions*—For definitions of other terms used in this test method, refer to Terminology D1356.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *capacitance-type cell, n*—this cell typically uses aluminum coated with aluminum oxide, Al_2O_3 , as part of a capacitor.

3.2.1.1 *Discussion*—The dielectric Al_2O_3 film changes the capacity of the capacitor in relation to the water vapor present. Silicone cells also operate on this principal by reporting a capacitance change when adsorbing or desorbing water vapor.

3.2.2 *dew point, n*—temperature (at a specified pressure) at which liquid water will start to condense from the water vapor present as measured over water.

3.2.2.1 *Discussion*—The term “dew point” is often used to include “frost point” (see 3.2.4) when generally referring to the water content based upon this principle, but there are unique values for each for temperatures below $0\text{ }^\circ\text{C}$.

3.2.3 *electrolytic-type cell, n*—this cell is composed of two noble metal electrode wires coated with phosphorus pentoxide, P_2O_5 .

3.2.3.1 *Discussion*—A bias voltage is applied to the electrodes and water vapor chemically reacts generating a current between the electrodes proportional to the reaction with the water vapor present.

3.2.4 *frost point, n*—temperature (at a specified pressure) at which liquid water will start to condense from the water vapor present as measured over ice.

3.2.5 *laser-type cell, n*—consists of a sample cell with an optical head mounted on one end and a mirror mounted on the

other; however, some models will not need a mirror to reflect the light wavelength emitted from the laser.

3.2.5.1 *Discussion*—The optical head contains a near infrared (NIR) laser that emits light at a wavelength known to be absorbed by the water molecule. Mounted with the laser is a detector sensitive to NIR wavelength light. Light from the laser passes through the far end and returns to the detector in the optical head. A portion of the emitted light, proportional to the concentration of the water molecules present, is absorbed as the light transits the sample cell and returns to the detector.

3.2.6 *resistance-type cell, n*—similar to capacitance-type cells, some manufacturers make a resistance-based cell, based on a lithium chloride and the carbon resistance film layer.

3.2.6.1 *Discussion*—The conducting film of the resistive hygrometer is sandwiched between metal electrodes. The resistance of the conducting film varies with the change in the value of humidity present in the surrounding air. The change in the value of resistance is measured by applying the alternating current to the bridge.

3.2.7 *water content, n*—water content is customarily expressed in terms of dew point or frost point, °C, at a specific pressure, or the nonmetric term of parts per million (PPM).

3.2.7.1 *Discussion*—For moisture in air, parts per million can be stated in terms of volume (PPM_v) or molecular weight (PPM_w).

3.3 Symbols:

ATM—atmospheric pressure at sea level equivalent to 1013.25 mbar or 101.325 kPa

e—vapor pressure of water vapor in moist air

e_i—saturation pressure of water vapor in equilibrium with the plane surface of ice

e_w—saturation pressure of water vapor in equilibrium with the plane surface of water

M_T—molecular weight of total (for subject gas mixture)

M_w—molecular weight of water vapor

P—sample pressure, kPa or Pa

T—air temperature, °C

T_d—thermodynamic dew point temperature

T_f—thermodynamic frost point temperature

4. Summary of Test Method

4.1 A sample of compressed air is connected to a hygrometer with an electronic cell that measures moisture content of the air as it passes through the cell. The principle of the measurement is based on the type of cell that is used. The compressed air is regulated down to an acceptable pressure and flow rate based on the manufacturer's rating of the hygrometer, as necessary.

4.2 For comparison purposes, moisture content measured as dew point/frost point at pressures up to 2000 kPa (20 bara) can be calculated for the equivalent moisture content at atmospheric pressure, 100 kPa (1 bara). Details are provided in Section 13.

4.3 **Appendix X1** provides some guidance for selecting a hygrometer technology for specific ranges of expected dew point, level of uncertainty, and other application-specific needs covered in this test method.

5. Significance and Use

5.1 Water vapor is ubiquitous and a basic contaminant in compressed air. It cannot be eliminated but shall be controlled. Knowledge of the vapor content of compressed air is important for industrial processes to ensure that compressors that generate compressed air are functioning properly and equipment and systems that use the compressed air will function properly and maintain high reliability. This test method describes the measurement of water vapor using direct readout electronic instrumentation. Measurements are provided as dew point/frost point and calculations of related unitless quantities (ppm) are provided. Sampling techniques and warnings are provided to reduce false readings caused by contamination from the sampling method. Dry compressed air typically has a frost point between $-80\text{ }^{\circ}\text{C}$ and $-40\text{ }^{\circ}\text{C}$ (0.5 PPM_v to 127 PPM_v) at atmospheric pressure.

5.2 Measurement of moisture in compressed air can be done after regulating the pressure down to ATM or measured at elevated pressure up to the full system pressure. When measurements are made of the actual dew point (for example, condensation) or the related property of vapor pressure, the value of the dew point (and vapor pressure) is directly affected by the sample pressure since the vapor pressure is a component of the total pressure. The relationship between vapor pressure and moisture content (and dew point) is well defined below 5 MPa, but at greater pressures, additional study needs to be done to define this relationship.

5.3 Electronic moisture analyzers are also used for measuring moisture levels in other gases, including gaseous fuels. See Test Method **D5454**. In addition, tunable diode laser spectroscopy (TDLAS) is another technology that may be applicable to detecting moisture in compressed air. This technology is already being used in gases. See Test Method **D7904**.

6. Interferences

6.1 Other contaminants in air such as particles (dust/dirt) or volatile gases may contaminate electronic analyzers and lead to inaccurate readings. These types of interferences may increase over time with usage of the analyzer. If these conditions exist, decrease time between calibrations or verification of instrument or both.

6.2 Since water vapor is ubiquitous, connection of sample lines, connection points between the air to be tested, and the instrument analyzer shall be cleared of water vapor before taking test readings. The material of the connection line may retain moisture and slowly release water vapor into the test connections leading to false readings, so the type of materials used and the size and condition of the internal surface areas need to be considered before testing.

7. Apparatus

7.1 *Dew-point hygrometers*, specifically designed for industrial applications are available commercially. These instruments vary in design and analysis principles but typically have several common features. Instruments may have internal flow, filtering or pressure regulation, or sample piping connections to provide control and protection from the high pressures and

pressure fluctuations from the compressed air source. Follow the manufacturer’s instructions for pressure and flowrate limitations and filtering so as not to damage the test instrument and obtain inaccurate readings.

7.2 Portable or laboratory hygrometers are connected to the compressed air to be tested via a sample test rig and hoses. A permanently installed hygrometer/probe may be installed in a test loop that is part of the facility system and exposed to the system air stream with manual or electronic isolation valves. A schematic arrangement of a typical test rig and connection of a dew-point hygrometer to a compressed air source is shown in Fig. 1.

NOTE 1—Some hygrometers may incorporate pressure sensing, flow meters, filters, and isolation valves within the meter housing, negating the need for some external test rig components.

7.3 Hygrometers may be designed to measure dew point at full system pressure or limited to operating at low pressures (for example, 690 kPa or less). Since dew point is a function of pressure, the hygrometer electronics may be programmed to convert the measured value to an equivalent dew point at another pressure (for example, 101.3 kPa (1 ATM)) or a moisture content unit that is not dependent on pressure (for example, PPM_v). Follow the manufacturer’s instructions for pressure limitations and built in conversion logic. See Section 13 for more information on conversion calculations.

7.4 When measuring low dew points (<30 PPM_v), select test rig materials that have low-moisture absorption/desorption properties. In Table 1, materials that are recommended and materials that should be avoided are listed.

7.5 Sample test rig temperature fluctuations will cause moisture absorption/desorption between the sample test rig and

TABLE 1 Recommended Test Rig Materials

Recommended	Not Recommended
<ul style="list-style-type: none"> Stainless steel (300 series) Polytetrafluoroethylene (PTFE)-coated flexible hose 	<ul style="list-style-type: none"> Stainless steel (400 series) Rubber hose or thin walled plastic flexible tubing Copper, brass tubing

the sampled gas. Therefore, the temperature of the sample test rig should be at least 10 °C above the measured dew point of the gas.

8. Hazards

8.1 Ensure all mechanical connections are properly connected and tightened.

8.2 Only connect to compressed air systems with piping, tubing, and fittings that are rated for the maximum level of pressure in the compressed air source.

8.3 Ensure the instrument is isolated from the compressed air source by a regulating valve if the test instrument is not rated for the source pressure.

8.4 For instruments not designed to take readings at system pressure being sampled, take precautions to monitor the pressure introduced to the meter. A large pressure spike or flow rate may damage the meter and cause false readings.

8.5 Compressed air is a stored energy source and, therefore, can be dangerous if not handled properly. Wear proper personal protective equipment (PPE) when working with compressed air.

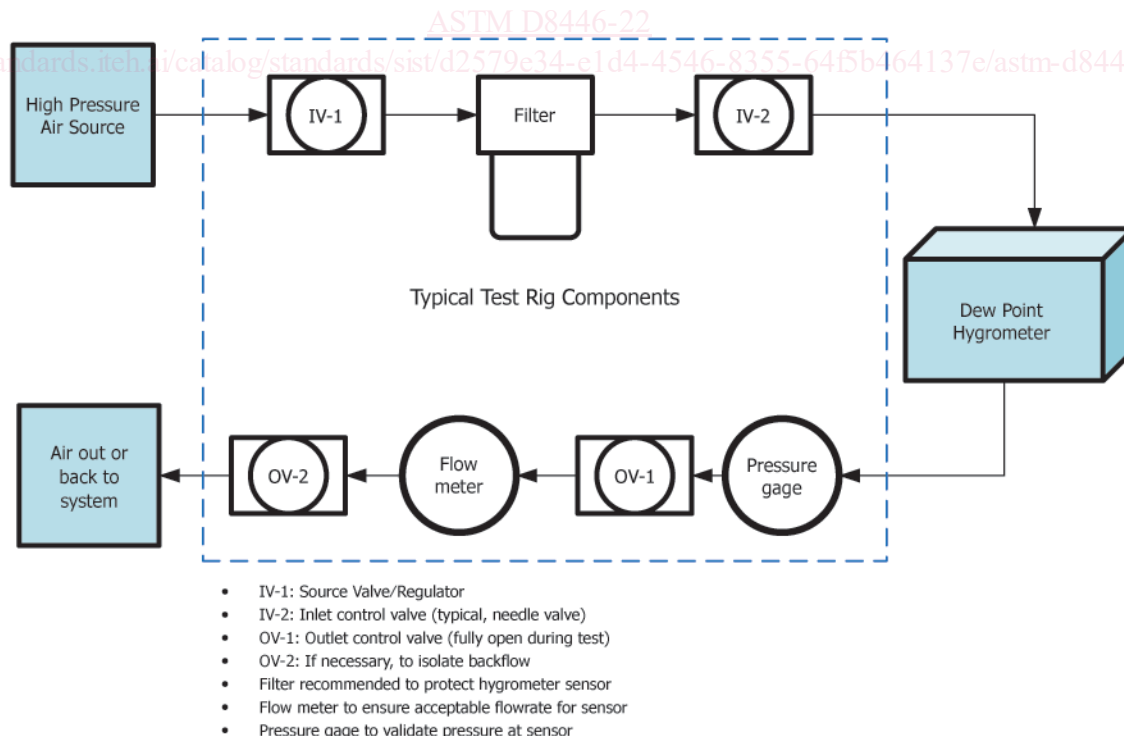


FIG. 1 Sample Test Rig and Hygrometer Connected to a Compressed Air Source

8.6 Release of compressed air can cause high noise levels and hearing damage.

8.7 Never release compressed air into or onto the human body.

9. Sampling, Test Specimens, and Test Units

9.1 Moisture testing may be done with hygrometers that are permanently installed in an air system or portable hygrometers that are connected to a portable or fixed system or located in a test facility where the gas is connected to a fixed instrument via a test board. In each case, connecting lines shall be thoroughly flushed with the gas to be tested to ensure residual moisture is removed from the test connections. In each case, control the pressure and flow rate to the levels acceptable for the instrument in use. In some cases, it may be necessary to take a dew point at a defined flow rate. This can be accomplished by splitting the sample and the exhaust lines to ensure both the dew point meter and exhaust line receive adequate flow.

9.2 For portable hygrometers, connect the sampling test rig to the compressed air source with appropriate fittings. Ensure the test connections are tight and no compressed air is leaking out of the test rig upstream of the hygrometer. Before attaching the hygrometer to the test rig, bleed off compressed air to clear the line of residual moisture. This may take several minutes to remove residual moisture adequately. When complete, shut the valve just upstream of the hygrometer connection. After connecting the hygrometer to the test rig, purge the meter and lines before measurement to ensure the meter is exposed to the air to be sampled.

9.3 When testing is accomplished at ambient pressure, the expansion of the compressed air will cause the temperature of the sample air and test rig to drop. The temperature of the air in the test rig and meter must be higher than the measured dew point temperature to prevent condensation in the sample lines and false readings.

10. Preparation of Apparatus

10.1 The test rig and hygrometer should be kept in a dry storage location with test connections closed/capped. Before use, purge the test rig and hygrometer with dry nitrogen (or dry air). An alternate method of storage is to keep the meter connected to a dry gas source.

10.2 Verify that the calibration of the hygrometer is within the periodicity defined by the calibration laboratory.

NOTE 2—It is recommended that instrument validation be conducted on a periodic basis between calibrations to ensure that instrument is working properly. See Section 11.

11. Calibration and Periodic Validation

11.1 Calibration of the test instrument shall be done before use by an accredited calibration laboratory. Standards used in calibration shall be traceable to national standards. Calibration periodicities should be set such that instruments (or sensors) are not typically significantly out of calibration when recalibrated. Since this test method covers several different types of instruments, the calibration periods may be different from one type of instrument to another. A maximum calibration period-

icity of one year is recommended. A calibration certificate shall be provided by the calibration laboratory with data that support calibration traceability. Practice D4178 provides guidance on a calibration technique and preparation of standards of known water content.

11.2 Validation of the hygrometer before use is recommended to ensure proper operation in between calibrations. Validation does not replace calibration and is not intended to validate the accuracy of the hygrometer over the operating range; rather, it is a means to identify an instrument that has been damaged or lost sensitivity since the previous calibration. There are multiple methods to validate the operation or accuracy of a test instrument and each activity should decide on a method that is appropriate based on a risk assessment of their specific needs. Example methods of validation are:

11.2.1 *Method 1*—Instruments may be validated by comparison to a compressed gas water vapor standard, a moist gas generator validated by another hygrometer, or a permeation-tube-based gas generator.

11.2.2 *Method 2*—Validation may be done by comparison of two calibrated instruments in parallel to an air source with stable humidity. If available, select a hygrometer that is based on a different measurement principle (for example, condensation) than the hygrometer that is being validated.

11.2.3 For Validation Methods 1 and 2, the user should develop acceptance criteria that are based on the statistical analysis of past results and risk tolerance for uncertainty in the final test result. Precision and bias information provided in Section 15 may also be used to develop a user acceptance tolerance level for validation.

11.2.4 Validation records should be tracked to identify the reliability of the instrument over time in between calibration cycles. The periodicity of validation may vary based on the frequency of use.

12. Procedure

12.1 This section provides a general outline for taking a dew point reading. Follow the manufacturer's instructions for operating the hygrometer, which may vary depending on the features and operational modes of the specific hygrometer in use.

12.2 *Sample Preparation*—Connect the sample line to the compressed air source with appropriate fittings. Ensure the test connections are tight and there are no noticeable leaks. Leaks may be detected by soap bubble methods (preferred) or by sound (audible or ultrasonic). See 7.2 and Fig. 1 for an example of a typical test rig. Use as short a sample line as is practical. Purge the sample line before connecting the hygrometer to the sample line.

12.2.1 Purge times may vary based on instrument, length of sample line, and initial dew point of the sensor. Follow the manufacturer's instructions for recommended purge times.

12.3 Ensure all valves are closed and connect the sample line to the test rig/hygrometer.

12.4 Open the source valve, then the hygrometer outlet valve (if applicable), and then the hygrometer inlet valve. Set