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An American National Standard

Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation[1]

This standard is issued under the fixed designation D 5374; 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 These test methods cover procedures for evaluating the characteristics of forced-convection ventilated electrically-heated ovens, operating over all or part of the temperature range from 20°C above the ambient temperature to 500°C and used for thermal endurance evaluation of electrical insulating materials.

1.2 These test methods are based on IEC Publication 216-4-1, and are technically identical to it. This compilation of test methods and an associated specification, D 5423, have replaced Specification D 2436.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 2436 Specification for Forced-Convection Laboratory Ovens for Electrical Insulation[2]

D 5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation[3]

2.2 *Other Document:*

IEC Publication 216-4-1 Guide for the Determination of Thermal Endurance Properties of Electrical Insulating Materials, Part 4—Aging Ovens, Section 1—Single-Chamber Ovens[4]

3. Terminology

3.1 Refer to the terminology section of Specification D 5423.

4. Significance and Use

4.1 It is essential that ovens used for thermal evaluation of insulating materials be capable of maintaining uniform conditions of temperature and air circulation over the extended periods of time that are required for conducting these tests. Specification D 5423 specifies the permissible deviations from absolute uniformity that have been generally accepted internationally for these ovens. These test methods include procedures for measuring these deviations and other specified characteristics of the ovens.

5. Apparatus

5.1 *Multi-Point Recording Potentiometer*, having provisions for at least nine iron-constantan or chromel-alumel thermocouples, with scale readings to 0.1°C or less. Use of a data processor or a data logger may be helpful in reducing the number of calculations required.

5.2 *Calibrated Iron-Constantan or Chromel-Alumel Thermocouples*, using 0.5-mm diameter or smaller wire and having a junction size not over 2.5 mm long. If calibrated thermocouples are not available, thermocouples made from a single spool of thermocouple wire may be used provided that, when placed within 10 mm of each other without touching in an oven chamber at 200°C, they give values for temperature that do not differ from each other by more than 0.2°C.

5.3 A temperature measuring system other than thermocouples and a potentiometer may be used, provided that the sensitivity, accuracy, and response time are at least equivalent to that of the equipment described above, and that the objectives of 6.2.3 relative to minimization of heat conduction effects can be met.

5.4 *Thermal Lag Time Specimen*, consisting of a solid brass cylinder, 10 mm in diameter and 55 mm long, with one junction of a differential thermocouple soldered to the surface midway between the ends. The other junction of the thermocouple must be capable of being moved at least 80 mm away from the brass cylinder. An appropriate temperature indicator (as in 5.1, or other) must be provided for indication of temperature differences to the nearest 0.1°C as measured by the differential thermocouple.

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[1] These test methods are under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.17 on Thermal Characteristics.

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[2] Discontinued 1994; see *1993 Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 10.02.

[4] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

5.5 *Watt-Hour Meter*, of the appropriate voltage and phase, capable of reading to the nearest 1.0 Wh or less.

6. Procedures

6.1 *Rate of Ventilation*:

6.1.1 *Summary of Test Method*—The rate of ventilation is calculated using determinations of (*1*) the average power required to maintain the oven at a given temperature with its ports open and (*2*) the average power required to maintain the oven at the same temperature with its ports closed. The test is conducted at 100°C and at the maximum temperature at which the oven may be used.

6.1.2 Seal all openings into the oven, including, but not necessarily limited to, the vent ports, door, thermometer ports, and the space around the blower shaft (if the blower motor is mounted externally).

6.1.3 Install a watt-hour meter, as described in 5.5, in the oven electrical supply line.

6.1.4 Install a temperature sensor, such as a thermometer, 2 m to 3 m away from the oven, at least 1 m away from any solid object, and approximately level with the oven air intake. Use the oven temperature indicator to measure the internal temperature of the oven.

6.1.5 Raise the oven temperature to 100 ± 2°C. When the temperature of the oven has stabilized, measure the consumption of power over a measured period of 30 to 40 min. Begin and end the measuring period at corresponding points of the cyclic temperature fluctuation; for example, the moment when the heaters are switched on by the thermostat in the case of an "on/off" control. Measure and record the room temperature, which must not vary by more than 2°C during the test.

6.1.6 Remove the seals to restore the oven to its normal operating condition. If necessary, adjust the vents and dampers to positions estimated to provide the specified rate of ventilation.

6.1.7 Repeat 6.1.5. The average ambient air temperature must be within 2°C of the average ambient temperature measured in 6.1.5.

6.1.8 Calculate the rate of ventilation in the oven using the following equation:

$$N = 3.59\ (P_2 - P_1)/(V \cdot \rho \cdot \Delta T) \quad (1)$$

where:

N = number of air changes per hour,

P_1 = average power consumption, with no ventilation, obtained by dividing the energy consumption determined from the watt-hour meter readings by the duration of the test in hours, *W*,

P_2 = average power consumption during ventilation, calculated in the same manner, *W*,

V = total volume of air circulated within the oven, m^3(see Note 1),

ρ = density of the ambient room air during the test, kg/m^3(see Note 2), and

ΔT = difference in temperature between the oven and the ambient room temperature, °C.

NOTE 1—This volume includes space outside the testing chamber. The amount of this additional space depends on the physical design of the oven.

NOTE 2—The density of air at one atmosphere and 20°C is 1.205 kg/m^3.

6.1.9 If the rate of ventilation is not within the specified limits for the oven, adjust the vents and dampers and repeat 6.1.7 through 6.1.8.

6.1.10 Repeat 6.1.2 through 6.1.9, except heat the oven to the maximum temperature at which the oven may be used.

6.1.11 Report the following information:

6.1.11.1 Identification of the oven,

6.1.11.2 Date and location of test,

6.1.11.3 Test temperatures, and

6.1.11.4 Rate of ventilation at each temperature.

6.2 *Temperature Variation, Gradient, and Fluctuation*:

6.2.1 *Summary of Test Method*—Simultaneous temperature measurements are made at nine points in the oven chamber over a period of time to determine the time and space variations of temperature. The time variation (temperature fluctuation) and the space variation (temperature gradient) can be reported separately from temperature variation, which is the combination of the two.

6.2.2 Set the vents and dampers in the oven to the settings needed for the specified range of rate of ventilation.

6.2.3 Install nine thermocouples in the oven chamber (see 5.1 and 5.2). Place one thermocouple in each of the eight corners of the chamber 50 to 60 mm from each wall, and the ninth thermocouple within 25 mm of the geometric center of the chamber. Leave at least 300 mm of wire for each thermocouple within the oven chamber, in order to minimize effects of heat conduction along the wire.

6.2.4 Bring the oven to the selected operating temperature and allow it to stabilize for a minimum of 16 h.

6.2.5 Measure the temperatures indicated by the nine thermocouples to 0.1°C a sufficient number of times during one complete temperature variation cycle to permit the determination of the maximum, minimum, and mean temperatures of each thermocouple during one cycle. Ambient room temperature must not vary by more than a total of 10°C, and supply voltage to the oven must not vary by more than a total of 5 % during this measuring period.

6.2.5.1 Calculate the average of the nine mean temperatures to 0.1°C and record as the set temperature of the oven.

6.2.5.2 Calculate the difference between the highest maximum temperature and the lowest minimum temperature determined in 6.2.5 and record as the temperature variation.

6.2.5.3 Calculate the difference between the highest temperature and the lowest temperature at any specific time during the temperature cycle, and record as the temperature gradient.

6.2.5.4 Determine which thermocouple has the greatest difference between maximum temperature and minimum temperature over the temperature cycle and record difference as the temperature fluctuation.

6.2.6 Maintain the oven at the same operating temperature for five days after the end of the stabilization period, and after the measurement of temperatures specified in 6.2.5. Maintain ambient room temperature and supply voltage within the limits in 6.2.5 during the entire period. Repeat the measurements and calculations in 6.2.5 daily.

6.2.7 For routine monitoring of oven characteristics, for example, as recommended in Appendix X1 of Specification D 5423, the stabilization time specified in 6.2.4 may be reduced to 8 h, and the length of the test period following the initial temperature measurements specified in 6.2.6 may be reduced to 24 h (one day), with a single repetition of the temperature measurements. In case of doubt or dispute, use the longer time periods.

6.2.8 Report the following information:

6.2.8.1 Identification of the oven,

6.2.8.2 Date and location of test,

6.2.8.3 Calculated set temperature for each measurement,

6.2.8.4 Temperature variation for each measurement, and

6.2.8.5 If specified, temperature gradient and temperature fluctuation for each measurement.

6.3 *Thermal Lag Time*:

6.3.1 *Summary of Test Method*—A defined brass bar specimen is placed in the heated oven, and the difference between its temperature and the oven air temperature is plotted against time. The thermal lag time is the time in seconds required for the temperature difference to be reduced to 10 % of the maximum observed temperature difference.

6.3.2 Heat the oven to 200 ± 5°C and allow it to stabilize for at least 1 h. Stabilize a brass bar specimen (5.4) at room temperature for at least 1 h.

6.3.3 Without turning off the oven, open the door(s) of the oven 90°. Quickly hang the specimen in the geometric center of the oven, using a heat-resistant nonmetallic cord. The orientation of the axis of the specimen is not significant. Suspend the other junction of the thermocouple 80 to 100 mm from the brass bar. Leave the oven door(s) open for a total of 60 ± 1 s, then close the oven. Record the temperature difference, as indicated by the two junctions of the differential thermocouple, at least once every 10 s until the maximum temperature difference has been obtained. Continue recording at least once every 30 s until the temperature difference has dropped below 10 % of maximum.

6.3.4 Plot the recorded temperature values against the time in seconds since closing the oven.

6.3.5 Divide the maximum temperature difference by ten and record as T_{10}. Then record as the thermal lag time the time in seconds, taken from the plot of temperature difference versus time, for the temperature difference to reach T_{10}, after the time of maximum temperature difference.

6.3.6 Report the following information:

6.3.6.1 Identification of the oven,

6.3.6.2 Date and location of the test,

6.3.6.3 Set temperature of the oven, and

6.3.6.4 The determined thermal lag time, in seconds.

7. Precision and Bias

7.1 The precision of the individual methods given herein has not been determined, and no activity is planned to determine the precision.

7.2 The bias of the individual methods is largely dependent upon the accuracy of temperature measurement attainable using the available apparatus.

8. Keywords

8.1 forced-convection; ovens; set temperature; temperature fluctuation; temperature gradient; thermal endurance evaluation; thermal lag time; ventilated; ventilation rate