Designation: G 26 – 96

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
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Standard Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[1]

This standard is issued under the fixed designation G 26; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers the basic principles and operating procedure for water- or light-exposure apparatus, or both, employing a xenon-arc light source.

NOTE 1—This practice combines the practices previously referred to as G 26 and G 27. Practice G 27, for Operating Xenon-Arc Type Apparatus for Light Exposure of Nonmetallic Materials[2], has been discontinued since it is now covered in this edition of G 26 under Test Methods C and D.

1.2 This practice does not specify the exposure conditions best suited for the material to be tested, but is limited to the method of obtaining, measuring, and controlling the conditions and procedures of the exposure. Sample preparation, test conditions, and evaluation of results are covered in ASTM methods or specifications for specific materials.

1.3 This practice includes four test methods:

1.3.1 *Test Method 1*—Continuous exposure to light and intermittent exposure to water spray.

1.3.2 *Test Method 2*—Alternate exposure to light and darkness and intermittent exposure to water spray.

1.3.3 *Test Method 3*—Continuous exposure to light without water spray. Exposure conditions are characteristic of those specified by AATCC Test Method 16E 1976.

1.3.4 *Test Method 4*—Alternate exposure to light and darkness without water spray. Exposure conditions characteristic of those natural conditions experienced when exposing are in accordance with Practice G 24.

1.4 The values stated in SI units are to be regarded as the standard. The inch-pound equivalents of the SI units may be approximate.

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

2. Referenced Documents

2.1 *ASTM Standard:*

D 859 Test Methods for Silica in Water[2]

D 1293 Test Methods for pH of Water[2]

D 4517 Test Method for Low-Level Total Silica in High Purity Water by Flameless Atomic Absorption[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[4]

G 24 Practice for Conducting Natural Light Exposures Under Glass[5]

2.2 *AATCC Standard:*

Method 16 Colorfastness to Light[6]

2.3 *CIE Standard:*

No. 20 Recommendations for the Integrated Irradiance and the Spectral Distribution of Simulated Solar Radiation for Testing Purposes[7]

2.4 *ISO Standard:*

Gray Scale[8]

3. Significance and Use

3.1 Several types of apparatus with different exposure conditions are available for use. No single operating procedure for light-exposure apparatus with and without water can be specified as a direct simulation of natural exposure. This practice does not imply expressly or otherwise an accelerated weathering test.

3.2 Since the natural environment varies with respect to time, geography, and topography, it may be expected that the effects of natural exposure will vary accordingly. All materials are not affected equally by the same environment. Results obtained by use of this practice should not be represented as equivalent to those of any natural weathering test until the degree of quantitative correlation has been established for the material in question.

3.3 Variations in results may be expected among instruments of different types or when operating conditions among similar type instruments vary within the accepted limits of this practice. Therefore, no reference should be made to results from use of this practice unless accompanied by the report form shown in Fig. 1 or unless otherwise specified in a referenced procedure.

[1] This practice is under the jurisdiction of ASTM Committee G-3 on Durability of Nonmetallic Materials and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Environmental Tests.

Current edition approved Jan. 1, 1996. Published April 1996. Originally published as E 239 – 64 T. Redesignated G 26 in 1970. Last previous edition G 26 – 95.

[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Annual Book of ASTM Standards*, Vol 11.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 06.01.

[6] Available from The Secretary, American Association of Textile Chemists and Colorists, P.O. Box 12215, Research Triangle Park, NC 27709.

[7] Available from Secretary, U.S. National Committee, CIE, National Institute of Standards and Technology, Gaithersburg, MD 20899.

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

Laboratory ____________________
Material ____________________
G 26 Test Method No. ____________________
Reference Standard Used: ____________________
Other ASTM Test No. __________ Method No. __________
Exposure Apparatus: ASTM Type ____________________
Mfr. Model __________ Serial No. __________
Light Source: Water-Cooled ___W, Air-Cooled ___W
Method Used to Regulate Wattage to Lamp ____________________
Optical Filters: Type __________, Age __________ h
Spectral Irradiance: __________W/m² at __________nm
Irradiation Units: __________kJ/m² How Monitored: __________
Elapsed Exposure Time: ______h
Exposure Conditions: Program ______h
Light ______min Dark ______min

Black-Panel Temperature	___°C (°F)	
Air Temperature	___°C (°F)	
Dry Bulb Temperature	___°C (°F)	___°C (°F)
Relative Humidity	___%	___%
Specimen Water Spray	___min cycle	___min cycle
Specimen Nonspray	___min cycle	___min cycle

Specimen Spray Water Type: ____________________
Specimen Spray Nozzle Type: Mfg. Designation ____________________
Specimen Relocation Procedure During Exposure: ____________________

Identify properties to be determined on test specimens and identify test procedures or methods used for property measurement.

Operator/Date: ____________________
Supervisor/Date: ____________________
Company: ____________________

FIG. 1 Report Form

4. Apparatus

4.1 *Water-Cooled Type:*[9]

4.1.1 The apparatus employed should utilize a water-cooled xenon-arc lamp as the source of radiation and should be one of the following general types, or their equivalent:

4.1.1.1 *Type A*—An exposure apparatus in which the source of radiant energy shall be a water-cooled xenon-arc vertically located at the central axis of either a 508-mm (20-in.) diameter vertical specimen rack, or of a 648-mm (25.5-in.) diameter inclined rack. Means shall be provided for automatic programming of temperature and cycles. Means shall be provided for adjustment of relative humidity. The specimen rack shall rotate at 1 ± 0.1 rpm.

NOTE 2—In the commercial descriptions of the four types, the term "cycle" is defined as each time interval of light, darkness, and water spray that is specified differently in accordance with the different testing methods.

4.1.1.2 *Type AH*—The exposure apparatus shall be identical to Type A except it shall have automatic humidity control.

4.1.1.3 *Type B*—An exposure apparatus in which the source of radiant energy shall be a water-cooled xenon-arc vertically located at the central axis of a 960-mm (37.75-in.) diameter specimen rack. Means shall be provided for automatic programming of temperature and cycles. Means may be provided for adjustment of humidity. The specimen rack shall rotate at 1 ± 0.1 rpm.

4.1.1.4 *Type BH*—The exposure apparatus shall be similar to Type B except it shall have automatic humidity control.

[9] Available from Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, IL 60613 and from Suga Test Instruments Co., Ltd, 4-14, Shinjuku 5-chome, Shinjuku-Ku, Tokyo, 160, Japan.

4.1.2 The xenon-arcs employed shall be of the "long arc" water-cooled type operated through suitable reactance transformers and electrical equipment from a 50 or 60-Hz power supply. They shall employ cylindrical inner and outer optical filters to direct the flow of cooling water and to simulate a designed spectral energy distribution.

4.1.2.1 For the purpose of this practice, the xenon-arc lamp shall consist of a quartz xenon burner tube and one of the following optical filter combinations as recommended by the manufacturer:

(*a*) Borosilicate glass inner and outer optical filter to simulate the spectral power distribution (SPD) of natural daylight throughout the actinic region.

(*b*) Infrared absorbing glass inner optical filter with quartz outer optical filter to simulate the SPD of natural daylight (300 to 1000 nm).

(*c*) Borosilicate glass inner optical filter with soda lime glass outer optical filter to simulate the SPD of natural daylight (actinic wavelengths) filtered through window glass.

(*d*) Infrared absorbing glass inner and outer optical filter to simulate the SPD of natural daylight (310 to 1000 nm) filtered through window glass.

(*e*) Quartz inner and outer optical filter to approximate sunlight intensities unfiltered by the earth's atmosphere.[9]

4.1.2.2 To prevent loss in levels of irradiance due to excessive solarization and to prevent possible breakage caused by stresses in optical filters exposed to high-intensity UV energy, inner optical filters shall be replaced periodically. Suggested intervals are 300 and 400 h for Types A and B, respectively. The outer optical filter shall be replaced after 1500 and 2000 h for Types A and B, respectively.

4.1.3 Distilled or deionized water should be recirculated past the burner at a flow rate sufficient to remove excess heat. Passing water through a cartridge demineralizer installed in the recirculation line just ahead of the lamp minimizes contamination of the quartz envelope of the burner. A heat-exchange unit should be used to cool the recirculated lamp water.

4.1.4 Since xenon-arc lamps, like all gas discharge lamps, will have a progressive drop in radiation output with continued use, and since optical filters will change in their transmission characteristics, provision shall be made in the apparatus (automatically or manually) for progressively increasing the wattage of the lamp to minimize changes in the intensity of the radiation at the face of the sample. The greatest change in both the xenon burner tube and optical filters occurs in the first 20 h of use. For this reason, burners and optical filters preaged by the instrument manufacturer are recommended for critical testing when a more rapidly changing rate of intensity is undesirable. For routine testing on a comparative basis, the 20 h of preaging may be omitted.

4.1.5 Many nonmetallic materials are selectively absorbing. The energy that a molecule absorbs depends upon the wavelength of the incident radiation.[10] It is desirable to monitor the level of irradiance of the photochemically effective wavelengths if intercomparisons are to be made among samples not exposed simultaneously. Samples may then be exposed to known amounts of irradiation, the time integral of irradiance.

4.1.5.1 Where radiometers capable of monitoring discrete portions of a continuous spectrum are available, exposure to a mutually agreed-upon level of irradiation may be specified as the exposure interval in place of a time interval.

(*a*) When using the optical filter combination described in 4.1.2.1 (*a*), the suggested minimum spectral irradiance levels are:

.2 $W/m^2/nm$ band at 320 nm
.35 $W/m^2/nm$ band at 340 nm
.5 $W/m^2/nm$ band at 380 nm
.75 $W/m^2/nm$ band at 420 nm

(*b*) When using the optical filter combination described in 4.1.2.1 (*c*), the suggested minimum spectral irradiance levels are:

.2 $W/m^2/nm$ band at 340 nm
.45 $W/m^2/nm$ band at 380 nm
.7 $W/m^2/nm$ band at 420 nm

(*c*) Operating at the suggested minimum levels approximates the average daily solar irradiance under ideal conditions. It is about half of the maximum values for total irradiance on a horizontal plane when the sun is at 90° altitude as reported in CIE No. 20. When irradiance is monitored and periodic manual adjustment of wattage is made to compensate for changes of intensity, no lamp assembly should be used that cannot maintain the minimum level of irradiance within a 10 % tolerance at the monitored wavelength. Irradiation expressed as joules per square metre is the product of irradiance × exposure time in seconds.

4.1.5.2 Xenon-arc type equipment not having a radiometer shall be operated with periodic increases in wattage to minimize any drift in levels of irradiation. Such intervals shall be established by the parties concerned or follow the suggested schedule below in 4.1.5.2 (*a*).

NOTE 3—The use of suggested wattage steps does not imply that irradiance will be maintained at levels equivalent to those obtained when employing a light monitor. They are intended as a guide to minimize the reduction of UV intensity with maximum lamp longevity when using either Test Method A or C for 2.5, 6, or 6.5-kW lamps, respectively.

(*a*) The following are the suggested wattage settings for each exposure interval of a 2500-W xenon burner tube based upon the average performance of xenon burner tubes with borosilicate filters:

Time, h	Power, W
0 to 20	1600
20 to 200	1800
200 to 400	2000
400 to 600	2250
600 to 800	2500
800 to 1000	2600
1000 to 1200	2800
1200 to 1500	3000

(*b*) The following are the suggested wattage settings for each exposure interval of a 6000-W xenon burner tube based upon the performance of xenon burner tubes with borosilicate filters in Test Method A:

Time, h	Power, W
0 to 20	min
20 to 100	4750
100 to 250	5000
250 to 400	5250
400 to 550	5500
550 to 700	6000
700 to 850	6500
850 to 1000	7000

(*c*) The following are the suggested wattage settings for each exposure interval of a 6500-W xenon burner tube based upon the average performance of xenon burner tubes with borosilicate filters in Test Method A:

Time, h	Power, W
0 to 20	min
20 to 100	5500
100 to 200	6000
200 to 500	6200
500 to 1000	6500
1000 to 1500	7000
1500 to 2000	7500
2000 and over	8500

4.1.6 Specimens should be mounted on a rack rotating about the lamp at a distance such that the location of each specimen assures that the irradiance incident on its surface does not vary by more than 5 % from the average. Figure 2 illustrates a rack meeting this condition.

4.1.7 Any apparatus that does not comply with the condition of 4.1.6 shall not have a variation in irradiance exceeding 10 % of the average, and may require specimen rearrangement during exposure, in accordance with the test procedure, in order to minimize the variability in radiant exposure.

4.1.8 Testing temperatures should be measured and regulated on the basis of a black panel thermometer unit mounted on the specimen rack so that the face of the unit is in the same relative position and is subjected to the same influences as the test specimens. The black panel thermometer unit should consist of a stainless steel panel about 70 by 50 by 0.95 mm (2.750 by 5.875 by 0.0375 in.), to which a stainless steel bimetallic dial-type thermometer is mechani-

[10] Hawkins, W.L., ed., "Polymer Stabilization," *Wiley-Interscience*, 1972. p. 166.

cally fastened. This thermometer should have a stem approximately 4 mm (0.16 in.) in diameter with a 44.5-mm (1.75-in.) dial. The sensitive portion extending about 38 mm (1.5 in.) from the end of the stem should be located in the center of the panel approximately 64 mm (2.5 in.) from the top and approximately 48 mm (1.875 in.) from the bottom of the panel. The face of the panel with the thermometer stem attached should be finished with a baked-on black infrared-absorbing coating having good resistance to light.

4.1.8.1 A thermocouple or resistance bulb thermometer mounted at the center face of the black panel, which provides temperature values equivalent to the dial thermometer, may be substituted.

4.1.9 A blower unit in the base of the apparatus should provide a flow of air through the test chamber and over the test specimens. Control of specimen and black-panel temperature should be accomplished by thermostatic control of the temperature of the constant volume of air from the blower. Black-panel temperatures should be read through the window in the test chamber door without opening the door.

4.1.10 Apparatus operated as a light- and water-exposure test shall be equipped with a specimen spray unit as illustrated in Figs. 3 and 4. All components of the specimen spray unit should be fabricated from stainless steel, plastic, or other material that does not contaminate the water. Apparatus operated only as a light-exposure test are not required to have the specimen spray unit or, if present, it should not be used.

4.1.11 Types A, AH, BH, and some Type B apparatus are equipped with an electrically operated vaporizing unit for adding moisture to the air as it passes through the conditioning chamber in the base section prior to its entry into the test chamber of the apparatus.

4.1.11.1 In Types A and B, the vaporizing unit, when manually turned on, may operate continuously while the apparatus is in operation. Type A and some Type B apparatus may be programmed to operate the vaporizer during a dark cycle only. The temperature of the water, with which the vaporizer is supplied, is not controlled. In Type B apparatus not supplied with a vaporizing unit, the relative humidity within the test chamber is governed by evaporation of water in the bottom of the chamber and from water emitted through the specimen spray unit.

4.1.11.2 In Types AH and BH apparatus, operation of the vaporizer is controlled automatically by a wet-bulb thermostat. The temperature of the water supplied to the vaporizer is regulated automatically by thermostatically-actuated electric immersion heaters. Control automatically shifts between two separate sets of thermostats as the arc lamp is turned on and off by the program control unit.

4.1.12 In Types A, B, AH, and BH apparatus containing vaporizing units, relative humidity is determined from wet- and dry-bulb thermometers located in the air stream at the vaporizer's point of exit from the test chamber.

4.1.12.1 Determine the relative humidity for Type B apparatus not equipped with a vaporizing unit from wet- and dry-bulb thermometers mounted in holders on the specimen rack so that their sensitive portions are in the same relative position as the face of the test specimen but shielded from the radiation.

4.1.12.2 Any apparatus with a vaporizing unit operated with the unit and immersion heaters turned off will provide essentially the same conditions of relative humidity as are produced in Type B apparatus without a vaporizing unit.

4.1.13 The apparatus shall include means for measuring the following:

4.1.13.1 Wattage of the xenon-arc lamp,

4.1.13.2 Irradiance at the specimen rack,

4.1.13.3 Black-panel temperature,

4.1.13.4 Dry-bulb temperature (test chamber),

4.1.13.5 Wet-bulb temperature (test chamber),

4.1.13.6 Exposure interval, and

4.1.13.7 Water spray pressure when applicable.

4.1.14 Where specified, the apparatus shall include means for regulating or controlling the following:

4.1.14.1 Wattage of the xenon lamp,

4.1.14.2 Irradiance or irradiation, or both, at the specimen rack,

4.1.14.3 Temperature (test chamber),

4.1.14.4 Relative humidity (test chamber),

4.1.14.5 Light-dark-spray-humidity-temperature cycles, and

4.1.14.6 Water spray pressure when applicable.

4.2 *Air-Cooled Type:*[11]

4.2.1 The apparatus employed shall use an air-cooled xenon-arc lamp as the source of radiation and should be one of the following types, or their equivalent:

4.2.1.1 *Type C*—Air-cooled xenon-arc apparatus, 1500 W, 158-mm (6.2-in.) diameter specimen rack, with automatic programming of cycles and humidity. The specimen rack should rotate at 5.2 ± 0.1 rpm.

4.2.1.2 *Type D*—Air-cooled xenon-arc apparatus, 4500 W, 360-mm (14.2-in.) diameter specimen rack, with automatic programming of temperature, cycles, and humidity. The specimen rack should rotate at 3.7 ± 0.1 rpm.

4.2.1.3 *Type E*—Air-cooled xenon-arc apparatus, three lamps operating simultaneously at 4500 W each, 610-mm (24.1-in.) diameter specimen rack, with automatic programming of temperature, cycles, and humidity. The specimen rack should rotate at 2.0 ± 0.1 rpm.

4.2.2 The xenon arcs employed in Types C and D should be of the medium-pressure, air-cooled type and one or more optical filters shall be fitted between the light source and the samples to filter out undesired wavelengths of radiation. A combination of optical filters recommended by the manufacturer shall be used to simulate (*1*) sunlight in the open, (*2*) sunlight behind window glass, or (*3*) any other simulated solar irradiation condition desired.

4.2.3 All gas discharge lamps have a progressive drop in radiant output with continued use. For Types C and D, it is recommended to exchange the IR-optical filters for new ones after 3500 h of use. Answering the purpose, not all seven IR-optical filters of the filter lantern should be exchanged at the same time but each should be exchanged after it has been running for 3500 h. For Type E which has three lamps, one lamp should be replaced every 500 h to minimize the overall drop in radiant output. For Type E, the three partial preaged filters should be cleaned monthly and replaced after five years of normal usage.

[11] Available from Heraeus DSET Laboratory, Inc., 45601 N. 47th Ave., Phoenix, AZ 85027-7042.

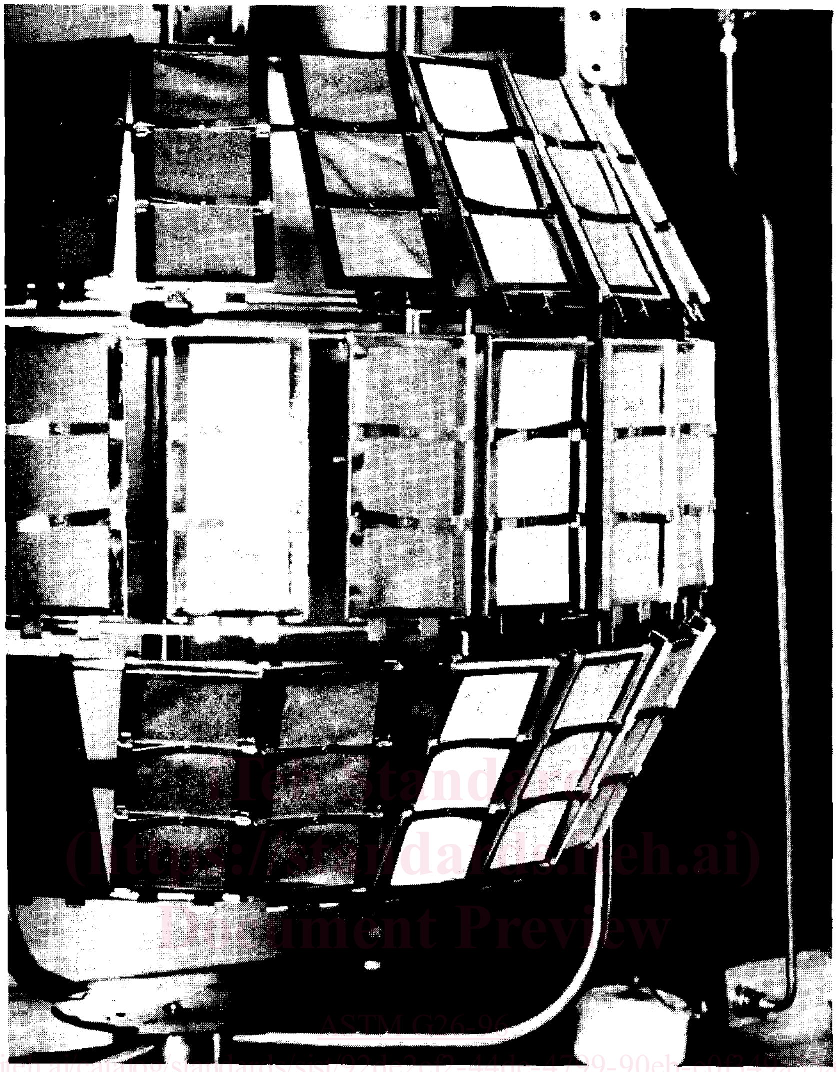


FIG. 2 Three-Tiered Specimen Rack

4.2.4 Specimen holders should rotate around the arc, describing a cylindrical surface, so that specimens may face, or be turned opposite to, the arc. No part of the specimens shall be above or below the ends of the arc. Repositioning of specimens in upper, center, or lower positions can improve the uniformity of intensity of the exposure.

4.2.5 Testing temperatures should be measured and regulated on the basis of a black-panel thermometer unit that is mounted so that the face of the unit is in the same relative position and is subjected to the same influences as the test specimens. The black-panel thermometer unit should consist of a stainless steel panel approximately 48 by 200 by 1 mm (1.9 by 8.0 by 0.04 in.), to which a stainless steel bimetallic dial-type thermometer is mechanically fastened. The temperature at the center of the panel should be sensed by the thermometer. The face of the panel should be finished with a baked-on black glossy enamel having good stability to light.

4.2.6 A blower unit in the base of the apparatus shall provide a flow of air through the test chamber and over the test specimens. Control of the specimen and the black-panel temperature should be accomplished by thermostatic control of the temperature of the constant volume of air from the blower. Black-panel temperature should be read through the window in the test chamber door without opening the door.

4.2.7 The apparatus should be equipped with a system to spray the specimens uniformly with water. This system should be of stainless steel, plastic, or other material that does not react with or contaminate the water employed.

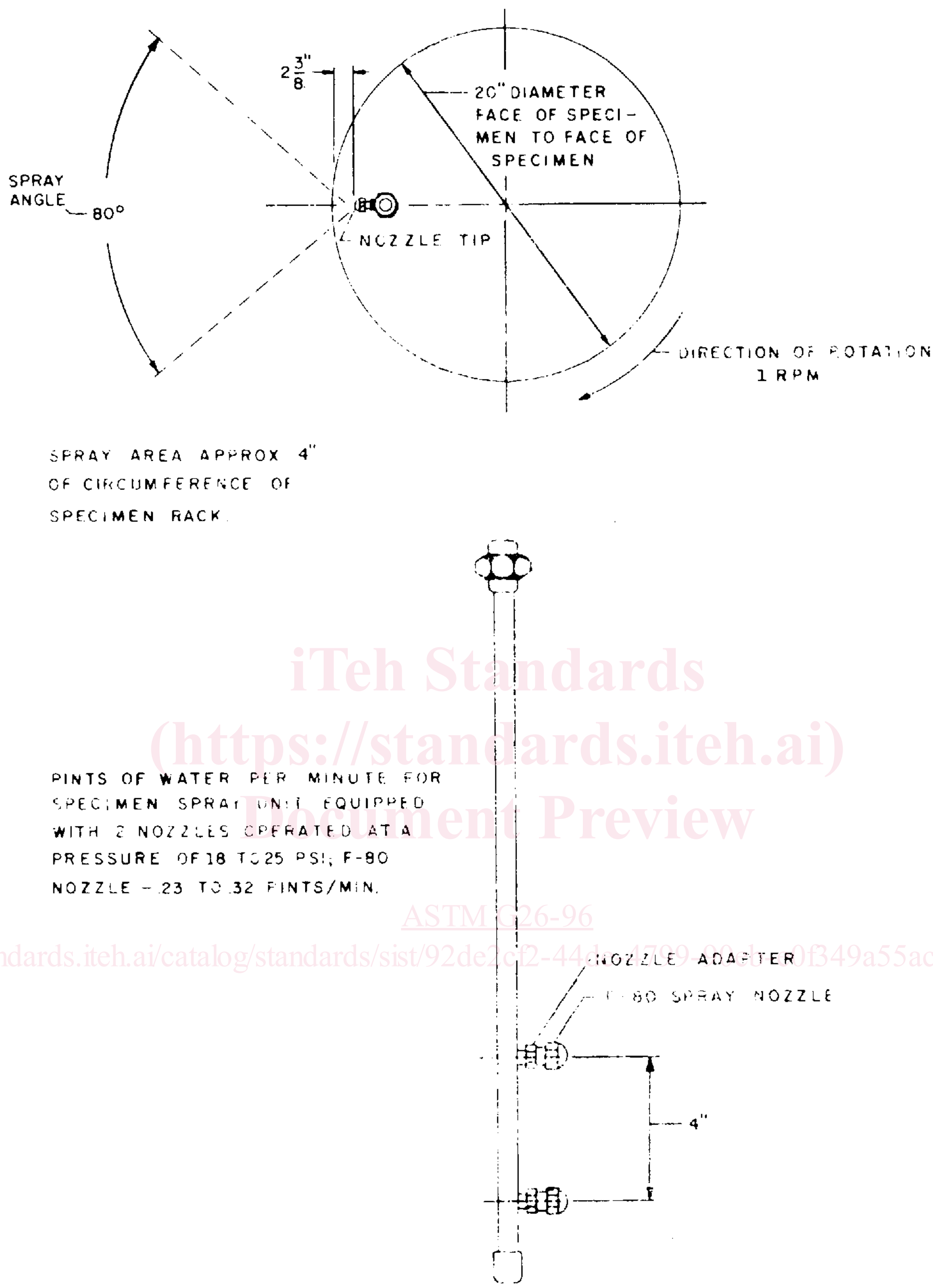
4.2.8 Relative humidity in the test chamber should be measured and controlled by a contact hygrometer. Water should be vaporized and diffused to enrich the air with moisture and produce the required humidity.

4.2.9 The apparatus shall include equipment necessary for measuring and controlling the same parameters as listed for water-cooled xenon arcs.

5. General Procedure

5.1 Check to be sure the apparatus is operating properly at the start of each test. Check the lamp operation at 100-h intervals to be sure the burner tube and optical filters are clean and that they have not exceeded the maximum recommended period of use.

5.2 Program the instrument to operate in the continuous light-on mode without water spray. Fill the specimen rack



Metric Equivalents

2⅜ in.	60.325 mm
4 in.	101.6 mm
20 in.	508 mm
18 psi	124 kPa
25 psi	172 kPa
0.23 pt	0.109 liter
0.32 pt	0.152 liter

FIG. 3 Specimen Spray Arrangement for Type A and AH Apparatus

with blanks and the black-panel thermometer. Operate the instrument in this mode while regulating the chamber dry-bulb temperature to provide the desired black-panel temperature of 63 ± 3°C (145 ± 5°F).

5.3 When the chamber dry-bulb temperature has been regulated, adjust instruments with automatic humidity control to the desired relative humidity (Types C, D, and E) or to the chamber wet-bulb temperature (Types A and B) at the