JIS

JAPANESE INDUSTRIAL STANDARD

The code number of this Standard changed from JIS C 0080 to the following from 20 March 2004.

JIS C 60695-6-30:2001

Translated and Published by
Japanese Standards Association

JIS C 0080 : 2001

(IEC 60695-6-30 : 1996)

(RCJ/JSA)

Fire hazard testing—Part 6 : Guidance and test methods on the assessment of obscuration hazard of vision caused by smoke opacity from electrotechnical products involved in fires—Section 30 : Small scale static method—Determination of smoke opacity—Description of the apparatus

ICS 13.220.40; 19.040; 29.020; 31.020

Reference number : JIS C 0080 : 2001 (E)

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal of establishing a Japanese Industrial Standard from the Reliability Center for Electronic Components of Japan (RCJ)/ the Japanese Standards Association (JSA), with a draft of Industrial Standard based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

Date of Establishment: 2001-11-20

Date of Public Notice in Official Gazette: 2001-11-20

Investigated by: Japanese Industrial Standards Committee

Standards Board

Technical Committee on Electricity Technology

JIS C 0080:2001, First English edition published in 2003-02

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

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Printed in Japan

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Fire hazard testing—Part 6 : Guidance and test methods on the assessment of obscuration hazard of vision caused by smoke opacity from electrotechnical products involved in fires— Section 30 : Small scale static method— Determination of smoke opacity— Description of the apparatus

Introduction This Japanese Industrial Standard has been prepared based on the first edition of **IEC 60695-6-30** *Part 6 : Guidance and test methods on the assessment of obscuration hazard of vision caused by smoke opacity from electrotechnical products involved in fires—Section 30 : Small scale static method—Determination of smoke opacity—Description of the apparatus* published in 1996 without modifying the technical contents.

Portions underlined with dots in this Standard are the matters not included in the original International Standard.

1 Scope This Standard describes the apparatus, calibration procedures and basic experimental procedures for the determination of the specific optical density of smoke produced by materials exposed vertically to a radiant heat source with or without the application of a pilot flame. The test specimens are of a defined size. The determination of the optical density is carried out in a pressure controlled chamber previously calibrated with reference materials.

This method is applicable to solid, non-metallic flat test specimens only. It is not suitable for use with non-planar specimens, e.g. insulated wire and cable, because it is not possible to obtain a homogeneous distribution of heat flux with such products.

This Standard does not provide a classification system for the behaviour of materials.

Materials which melt and flow away from the direct impingement of heat flux may not provide reproducible results and this method is not applicable.

Virtually all non-metallic materials, including those used in electrotechnical products, emit smoke when exposed to heat. Among the hazards associated with fire, smoke causes human and material damage and impairs fire fighting. Consequently, a reduction in the rate of generation of opaque smoke produced by materials/products during a fire reduces damage to equipment, facilitates evacuation of people and emergency services intervention.

WARNING : Appropriate safety measures are to be taken as toxic and harmful effluents may be produced by pyrolysis or combustion of test specimens.

Remarks : The International Standard corresponding to this Standard is as follows.

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In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21**.

IEC 60695-6-30 : 1996 *Fire hazard testing—Part 6 : Guidance and test methods on the assessment of obscuration hazard of vision caused by smoke opacity from electrotechnical products involved in fires—Section 30 : Small scale static method—Determination of smoke opacity—Description of the apparatus* (IDT)

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. Concerning the indication of the year of coming into effect given to these referred standards, only the edition of indicated year constitutes the provision of this Standard but the revision and amendment made thereafter are not applied.

IEC 60584-1 : 1977 *Thermocouples—Part 1 : Reference tables* Amendment 1 (1989)

IEC 60584-2 : 1982 *Thermocouples—Part 2 : Tolerances*

IEC 60695-1-1 : 1999 *Fire hazard testing—Part 1-1 : Guidance for assessing the fire hazard of electrotechnical products : General guidance*

IEC 60695-4 : 1993 *Fire hazard testing—Part 4 : Terminology concerning fire tests*

ISO 1923 : 1981 *Cellular plastics and rubbers—Determination of linear dimensions*

3 Definitions For the purposes of this Standard, the following definitions taken from **IEC 60695-4** apply:

3.1 opacity (of smoke) The ratio (I/T) of incident luminous flux (I) to transmitted luminous flux (T) through smoke, under specified test conditions.

3.2 optical density (of smoke) [log (I/T)] The common logarithm of the opacity of smoke.

Remarks : In this Standard (D) is used to represent the optical density of smoke.

3.3 specific optical density, D_s A measure of the smoke produced by a test specimen of a material or a product, taking into account the optical density and factors characteristic of the specified test method.

Remarks : Specific optical density is a dimensionless number.

4 Principle A test specimen, mounted vertically, is exposed to a controlled thermal radiation in a pressure controlled chamber, with or without the application of a pilot flame.

A photometric system is used to measure the opacity of the smoke generated.

5 Apparatus This apparatus is able to measure a maximum specific optical density of 528 with the moveable filter in place, and 924 without this filter.

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A description of the test apparatus is given in annex A (figures A.1 to A.8).

The details of construction are given in annex B.

The calibration procedure and suggestions for maintenance are given in annex C.

Two examples of the test apparatus are given in annex D.

5.1 Test chamber

5.1.1 The test chamber has a nominal volume of 0.51 m^3 and the following internal dimensions:

— width: 914 mm ± 3 mm

— depth: 610 mm ± 3 mm

— height: 914 mm ± 3 mm

The interior surfaces shall be suitable for periodic cleaning and resistant to corrosion.

Remarks : Example of panel construction: interior surface made of enamelled steel, core panels made of thermally insulating material, exterior surface made of galvanized steel.

5.1.2 When closed, the chamber shall be capable of maintaining positive pressure during test periods, in accordance with **6.3**. A water manometer is suitable for measuring the chamber pressure.

A blow-out sheet of aluminium foil approximately 0.04 mm thick is used to cover an aperture in the floor of the chamber, to provide protection against a sudden increase in pressure. Before installing, carefully degrease, clean and wipe the floor of the chamber around the aperture.

Care shall be taken not to wrinkle the foil so that no leakage develops at any creases.

A stainless steel grid can be placed over the aluminium foil to protect it.

A stainless steel receptacle can be placed under the specimen holder to collect flow from melting specimen which might damage the aluminium foil.

5.1.3 An exhaust system complying with safety environment regulations shall be connected to the smoke outlet.

5.1.4 A thermocouple shall be fixed to the centre of the inner surface of the wall opposite the door to measure the inside temperature (see clause **B.8**).

5.2 Furnace (radiant heat source) (see figure A.2 and clause **B.1**) The furnace is a ceramic tube with an inside diameter of approximately 76.2 mm, containing an electric heating element (see figure A.2) and constructed and positioned as described in clause **B.1**.

The furnace and its support are positioned so that the distance between the heating element and the test specimen surface is 76.2 mm ± 1.0 mm.

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The furnace operation shall be permanently monitored by means of an appropriate system.

The output from the furnace shall be controlled such that the radiance level is maintained within the specified limits of 25 kW/m² ± 0.5 kW/m² averaged over a 38.1 mm diameter circle at the centre of the test specimen position (see annex C).

5.3 Test specimen holder and support

5.3.1 The test specimen holder (see figure A.4 and clause **B.2**) is placed on a support attached to the furnace support so that the centre of the test specimen can be moved by an appropriate device along the centreline of the furnace.

5.3.2 A blank specimen holder, consisting of a refractory plate 76.2 mm × 76.2 mm shall be located in front of the furnace opening, whenever the furnace is energized, except during testing or calibration.

The refractory plate is held against the lips of the front of the test specimen holder by a spring and retaining rod.

Remarks : A plate with a nominal density of between 800 kg/m³ and 970 kg/m³ and a minimum thickness of 10 mm has been found satisfactory.

5.4 Gas burner (see clause **B.4**) During flaming exposure tests, a burner with a row of six tubes is fixed so that the tips of the horizontal tubes are centred 6.4 mm ± 1.5 mm above the lower opening of the test specimen holder (*N* dimension in figure A.4) and 6.4 mm ± 0.85 mm away from the test specimen area (*M* dimension in figure A.4).

The fuel used shall be a mixture of propane (purity 95 % or better) and air at flowrates of 50 cm³/min ± 5 cm³/min and 500 cm³/min ± 25 cm³/min respectively. The flow-rates are adjusted by needle valves and measured by two flow meters.

5.5 Photometric system (see figure A.5 and clause **B.5**) The photometric system consists of a light source and photodetector oriented vertically to reduce measurement variations resulting from stratification of the smoke.

The photometric system shall ensure the recording of optical densities over 6 sensitivity ranges for the measurement of the transmittance factors comprised between 0.000 1 % and 100 %.

The photometer shall have an accuracy of better than ± 0.3 % of the maximum reading on any sensitivity range. The output of the photodetector is connected to a recording device.

5.5.1 The light source is an incandescent tungsten filament lamp (nominally 6.5 V) mounted in a light-tight box separated from the test chamber by a window located in the floor, heated to about 50 °C in order to prevent condensation.

This box shall contain the necessary optics to provide a collimated light beam of 38.1 mm diameter passing vertically through the chamber.

5.5.2 The photodetector is a photomultiplier tube with a dark current of less than 1 nA and an S-4 spectral sensitivity response in accordance with the ILC(1), located

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at the top of the chamber opposite the light source in a light-tight box isolated from the test chamber by a window located in the ceiling. A converging lens shall be used to focus the beam on the detector. A removable neutral filter with a nominal optical density of 2, is used to extend the range of measurements of the optical density.

Note (1) ILC: International Lighting Commission

5.6 Measuring and recording devices A data recorder shall be available to measure:

— the radiometer output voltage when calibrating the furnace (see **6.1**):

— the photodetector output voltage during the tests (see **5.5.2**).

6 Calibration and verification Before any calibration or test, the temperature of the rear wall panel of the test chamber shall be stabilized at 33 °C ± 4 K, the apparatus cleaned of any residues from previous tests, and flushed with air for at least 2 min.

6.1 Furnace calibration The furnace shall be calibrated using the following procedure.

Remove the burner, mount the radiometer in the furnace in the stand-by position and connect to the electrical and gas services.

Place the blank test specimen holder in position in front of the furnace. Move the radiometer in front of the furnace by displacing the blank test specimen holder against the stop on the supporting framework, and check the accuracy of the radiometer alignment relative to the furnace opening using the 38.1 mm gauge, and make any necessary adjustments (see figure C.1).

Remarks : This test is sensitive to small variations in the position of the radiometer and of test specimens relative to the radiant heat source. The furnace gauge can also be used for checking the position of specimen holders.

Return the radiometer and blank test specimen holder to their former positions, bring the apparatus to its normal operating condition with the chamber wall temperature remaining steady at 33 °C ± 4 K, and move the radiometer to be in front of the furnace by displacing the blank test specimen holder against the stop.

With the chamber door closed, the inlet vent open and the exhaust vent closed, supply air to the radiometer cooler to maintain the radiometer body temperature at 93 °C ± 3 K. Monitor the radiometer output to determine when equilibrium has been reached, and then adjust the furnace, as necessary, to give a steady voltage reading corresponding to the calibrated value equivalent to a steady-state irradiance of 25 kW/m² ± 0.5 kW/m². Allow about 10 min between adjustments to the furnace to ensure that the radiometer has reached equilibrium. If the door is opened for any reason during calibration, wait sufficient time after closing the door to allow thermal equilibrium to be reached before taking the final voltage reading.

At the end of the calibration procedure, return the blank specimen holder to the position in front of the furnace, turn off the radiometer cooling air supply and remove the radiometer from the test chamber.

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6.2 Verification of the optical device (see **C.1.3**) The accuracy and linearity of the photometer shall be confirmed by placing standard neutral density filters (described in **C.1.3.2**) in the light path. These filters shall cover the whole aperture of the optical system and the specific optical density values measured by the photometer shall be ± 5 % of the calibrated values.

Remarks : In order to confirm the specified rated values of specific optical density given at 600 nm the light transmittance of these filters can be checked by spectrometric analysis in the range 400 nm to 900 nm, because the light source has a wide spectral distribution. Hence, the specific optical density measured with this filter may not be accurate, but comparable from one laboratory to another, if the spectral distribution of the lamps is identical.

6.3 Verification of the chamber air-tightness The chamber tightness shall be verified periodically by a leakage rate test using a U-shaped manometer (see figure A.8 and clause **B.9**). The pressure inside the chamber shall be raised to approximately 76 mm of water by introducing compressed air through a gas sampling port on the top of the chamber.

The time for the pressure to fall to 50 mm of water, determined using a stopwatch, shall not be less than 5 min.

7 Verification of the performance of the apparatus by the use of reference materials Two reference materials shall be used to check the correct operation of the apparatus and the test procedure:

— alpha cellulose paper (reference SRM 1006) for the non-flaming test (see remarks),

— a sheet of plastic material (reference SRM 1007) for the flaming test (see remarks).

Remarks : These reference materials can be obtained from the Office of Standards Reference Materials [National Institute of Standards and Technology (NIST), Gaithersburg, MD USA].

7.1 Test specimens Prior to testing, all the test specimens of the reference materials shall be conditioned in accordance with instructions given by the certificate for each reference materials; with all faces in contact with air.

The test specimen shall be 76.2 mm × 76.2 mm.

The thickness of each test specimen shall be measured in accordance with **ISO 1923**, and a batch with at least six test specimens prepared in which the thickness range is less than 0.1 mm.

After conditioning, each specimen shall be prepared as follows: Using a flat base, lay the sample face-upwards on the dull side of a piece of aluminium foil approximately 0.04 mm thick, and of sufficient size that will fold up over the edges and cover 6 mm to 10 mm around the face of the specimen. Carefully fold the foil over the edges and onto the specimen face to achieve a close fit and minimum wrinkling (some preliminary diagonal cuts at the corners may help to reduce wrinkling). Avoid puncturing the foil.

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Cut the top and side overlaps so as to expose the 65 mm × 65 mm test area, leaving the bottom flap to be turned down into the trough of the specimen holder as a chute for test debris after insertion. Avoid damaging the specimen face when cutting the foil. With some hard materials it may be possible to trim the foil against the aperture of the specimen holder, after insertion.

Insert the specimen into the specimen holder and back it with a 75 mm square piece of non-combustible insulating board of over-dry density of 850 kg/m^3 ± 100 kg/m^3, with a nominal thickness of 12.5 mm, then insert the spring and retaining clip.

For specimens greater than 16 mm thick an adjustable clip is used. Cut the foil around the specimen holder aperture, if required, and form the chute into the specimen holder trough.

7.2 Preparation of the apparatus The windows of the photometric system shall be cleaned before each test.

Remarks : Alcohol is a suitable product.

Switch on the light source and all the measuring devices and allow to stabilise.

If testing in the flaming mode, adjust the air and propane flowrates as specified in **5.4** and ignite the burner. If testing in the non-flaming mode, remove the burner and allow the burner to stabilise at its calibration setting (see **6.1**).

Install a No. 2 density filter in the detector and connect the photometer to the recording system. Adjust the system to read zero when the detector is covered, and a full-scale reading on the least sensitive scale when the detector is exposed (100 % transmittance).

7.3 Procedure The test specimen is exposed to the radiant heat flux emitted by the furnace. The average heat flux at the surface of the test specimen shall be 25 kW/m^2 ± 0.5 kW/m^2.

Test material reference: SRM 1006—no pilot burner application

Test material reference: SRM 1007—pilot flame applied

Open the inlet vent damper and shut the exhaust vent damper (see annex D). Place the test specimen holder, with the test specimen on the slide fixed on the support furnace, next to the blank test specimen holder. Move the test specimen holder in front of the furnace displacing the blank specimen holder.

Start the data recording system to record the percentage of light transmission (T) and time.

Shut the inlet vent damper when the light transmission starts to decrease.

In the event of an pressure higher than 150 mm of water, open the exhaust vent for a short time to reduce the pressure to a safe level. During the test adjust the sensitivity of the recorder so that readings are between 10 % and 100 % of full scale.

If the light transmission falls below 0.01 %, cover the observation window to avoid any light entering from outside and withdraw the range extension filter from the light path in order to multiply the sensibility range by 100. Re-insert the range extension filter whenever the transmission factor exceeds 0.01 %.

After an exposure of 20 min extinguish the burner, if used, and move the test specimen holder so that the blank test specimen holder is in front of the furnace.

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Flush the effluent out of the chamber by opening the inlet and exhaust vents. Monitor the level of light transmission until a constant value of the light transmission (T_c) is reached, and record this value. At the end of each test (with a pilot flame) extinguish the burner. After each test, clean the two optical windows.

7.4 Test results For this chamber the specific optical density, D_s is given as follows:

$$D_s = G\,[\log_{10}(100/T) + F]$$

where

$$G = V/AL$$

with: V = volume of the close chamber (m^3);

A = exposed area of the test specimen (m^2);

L = length of the light path through the smoke (m);

T = percent of light transmittance as read from the light-sensing instrument;

F = optical density of the filter, depending on the following:

$1/F$ = 0, if the optical system is not equipped with a moveable filter, or if the moveable filter is in the light path at the time that T is being measured;

$2/F$ = the known optical density of the filter, if the filter is not in the light path at the time that T is being measured. In this case, the D_s value as obtained from table A.1, is corrected by adding or subtracting the value of the correction factor as determined according to the method described in **C.1.3.3**.

Calculate the maximum specific optical density value (D_m) which corresponds to the minimum light transmission.

For each series of tests, express the results as the average of the values obtained for three test specimens if the maximum value D_m is less than 1.5 times the minimum value and for six test specimens if it exceeds 1.5 times.

Check if the calculated value D_m and the thickness correspond with the range of values quoted in NIST (NBS)(2) certificate.

The value of the specific optical density, calculated at the end of the test after the pilot flame has been extinguished and the smoke flushed out of the chamber, is denoted as D_c.

$$D_s\,(\text{corr}) = D_m - D_c$$

Note (2) NBS: National Bureau of Standards, USA. The present NIST (National Institute of Standards and Technology).

Remarks : To account for deposits of soot or other particles on the optical systems located inside the chamber, the value of the corrected maximum specific optical density, D_s(corr), is obtained by subtracting the value of the specific optical density at the end of the test, D_c, from the maximal value of the specific optical density, D_m.

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