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Electrical apparatus for use in the presence of combustible dust - Part 2: Test methods - Section 1: Methods for determining the minimum ignition temperatures of dust

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Partie 2:
Méthodes d'essai –
Section 1: Méthodes de détermination de la température minimale d'inflammation de la poussière

Electrical apparatus for use in the presence of combustible dust –

Part 2:
Test methods –
Section 1: Methods for determining the minimum ignition temperatures of dust

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL APPARATUS FOR USE IN THE PRESENCE OF COMBUSTIBLE DUST –

Part 2: Test methods – Section 1: Methods for determining the minimum ignition temperatures of dust

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

International Standard IEC 1241-2-1 has been prepared by sub-committee 31H: Apparatus for use in the presence of ignitable dust, of IEC technical committee 31: Electrical apparatus for explosive atmospheres.

The text of this standard is based on the following documents:

DIS	Report on voting
31H(CO)9	31H(CO)14

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

Annexes A and B form an integral part of this standard.

INTRODUCTION

This section of IEC 1241-2 describes methods for determining the minimum ignition temperature of dust which are:

- method A: Dust layer on a heated surface at a constant temperature (clause 4);

- method B: Dust cloud in a furnace at a constant temperature (clause 5).

Method A determines the minimum ignition temperature of a dust layer on a prescribed heated surface.

Method B determines the minimum ignition temperature of a dust cloud within a prescribed heated furnace.

The test methods are of a general nature, and may be used for purposes of comparison, but in certain industrial situations further tests may be necessary.

The methods for determining the minimum ignition temperatures are not suitable for use with recognized explosives, for example, gunpowder, dynamite, or mixtures of substances which may, under some circumstances, behave similarly.

Where there is doubt, an indication of the existence of a hazard due to explosive properties may be obtained by testing a very small quantity of the dust on a surface at 400 °C or higher, located remotely from the operator.

ELECTRICAL APPARATUS FOR USE IN THE PRESENCE OF COMBUSTIBLE DUST –

Part 2: Test methods – Section 1: Methods for determining the minimum ignition temperatures of dust

1 Scope

This section of IEC 1241-2 specifies two test methods for determining the minimum ignition temperatures of dust.

The methods are not suitable for use with substances having explosive properties.

Method A (clause 4) is applicable to the determination of the minimum temperature of a prescribed hot surface which will result in the decomposition and/or ignition of a layer of dust of a specified thickness deposited on it. The method is particularly relevant to industrial equipment with which dust is present on hot surfaces in thin layers exposed to the atmosphere.

Method B (clause 5) is applicable to the determination of the minimum temperature of a prescribed hot surface which will result in the ignition of a cloud of a given sample of dust or other particulate solid. The test is intended to be carried out as a complementary test after determining the minimum ignition temperature of a dust layer by method A of this standard.

NOTES concerning method B

1 Because the method of operation of the furnace gives short residence times for dust particles within it, this method of test is applicable to industrial equipment where dust is present as a cloud for a short time. This method of test is of small scale and the results are not necessarily representative of all industrial conditions.

2 The method is not applicable to dusts which may, over a longer period of time than provided for in the test method, produce from deposits gases generated during pyrolysis or smouldering.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section of IEC 1241-2. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this section of IEC 1241-2 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 565: 1990, *Test sieves – Metal wire cloth, perforated metal plate and electroformed sheet – Nominal sizes of opening*

ISO 4225: 1980: *Air quality – General aspects – Vocabulary*

3 Definitions

For the purpose of this section of IEC 1241-2, the following definitions apply:

3.1 **dust:** Small solid particles in the atmosphere which settle out under their own weight, but which may remain suspended in air for some time (includes dust and grit as defined in ISO 4225).

3.2 **ignition of a dust layer:** Ignition is considered to have occurred if glowing or flaming is initiated in the material, or a temperature of 450 °C or more, or a temperature rise of 250 K or more above the temperature of the prescribed hot surface, is measured in the test.

3.3 **minimum ignition temperature of a dust layer:** Lowest temperature of a hot surface at which ignition occurs in a dust layer of specified thickness on this hot surface.

NOTES

1 Because of the wide range of processes in industry, the ignition of dust layers may be dependent upon local conditions. This method of test is not necessarily representative of all industrial conditions, where account may need to be taken of such factors as the presence of thick layers of dust and of the distribution of temperature in the environment.

2 When carrying out this test, it is essential that all necessary precautions be taken to safeguard the health of personnel, for example, against the risk of fire, explosion, inhalation of smoke and any toxic products of combustion.

3.4 **ignition of a dust cloud:** Initiation of an explosion by the transfer of energy to a dust cloud in air.

3.5 **ignition temperature of a dust cloud:** Lowest temperature of the hot inner wall of a furnace at which ignition occurs in a dust cloud in air contained therein.

NOTE – When carrying out this test, it is essential that all necessary precautions be taken to safeguard the health of personnel, for example, against the risk of fire, explosion, inhalation of smoke and any toxic products of combustion.

4 Method A: Dust layer on a heated surface at a constant temperature

4.1 *Preparation of dust sample*

The sample shall be prepared so as to be homogeneous and representative of the dust received for consideration.

The dust sample to be tested shall, in general, be able to pass through a woven metal wire cloth or a square hole perforated plate test sieve with a nominal size of aperture of 200 µm (for supplementary sizes, see ISO 565). If it is necessary to test a coarser dust, passing a test sieve with a nominal size of aperture up to 500 µm, the fact shall be stated in the test report.

Any apparent changes noted in the properties of the dust during preparation of the sample, for example, by sieving or owing to temperature or humidity conditions, shall be stated in the test report.

4.2 *Test apparatus*

The apparatus is shown schematically in figure A.1. Essential details and performance requirements are given in the following subclauses. Methods of construction to enable these requirements to be met are described in annex A.

4.2.1 *Heated surface*

The heated surface shall consist of a circular metal plate and shall provide a working area of at least 200 mm in diameter and be not less than 20 mm in thickness. The plate shall be heated electrically and its temperature shall be controlled by a device for which the sensing element is a thermocouple mounted in the plate near the centre and with its junction within 1 mm ± 0,5 mm of the upper surface and in good thermal contact with the plate.

A similar thermocouple shall be mounted near the control thermocouple in a similar manner, and shall be connected to a temperature recorder to record the temperature of the surface during a test. The heated surface and its control device shall satisfy the following performance requirements:

a) the heated surface shall be capable of attaining a maximum temperature of 400 °C without a dust layer in position;

b) the temperature of the heated surface shall be constant to within ±5 K throughout the period of a test;

c) when the heated surface has reached a steady state, the temperature across the surface shall be uniform to within ±5 K when measured across two diameters at right angles, by the procedure described in annex B. This requirement shall be satisfied at nominal surface temperatures of 200 °C and 350 °C;

d) the temperature control shall be such that the recorded surface temperature does not change by more than ±5 K during the placing of the dust layer, and it shall be restored to within ±2 K of the previous value within 5 min of placing the dust layer;

e) temperature control and measurement devices shall be calibrated and shall have limits of inaccuracy of ±3 K.

4.2.2 *Dust layer thermocouple*

A fine thermocouple (0,20 mm to 0,25 mm diameter) of chromel-alumel or other suitable material shall be stretched across the heated surface, and parallel to it, at a height of between 2 mm and 3 mm from it with the junction over the centre of the plate. This thermocouple shall be connected to a temperature recorder in order to determine the behaviour of the dust layer during the test.

4.2.3 *Temperature measurements*

Temperature measurements using thermocouples shall be made either relative to a fixed reference junction or with automatic cold junction compensation. In either case, calibration shall satisfy the requirements of 4.2.1 e).

4.2.4 *Ambient temperature measurements*

The ambient temperature shall be measured by a thermometer placed not more than 1 m from the heated surface, but shielded from heat convection and radiation from the surface. The ambient temperature shall be within the range 15 °C to 35 °C.

4.2.5 *Dust layers*

Dust layers shall be prepared by filling the cavity formed by placing a metal ring of appropriate height on the heated surface and levelling the layer to the top of the ring. The ring shall have an internal diameter of nominally 100 mm and shall have slots at opposite ends of a diameter to clear the test thermocouple (figure A.2). The ring shall be left in place during a test.

A given dust shall be tested in a layer of 5,0 mm ± 0,1 mm depth. For predictive purposes (see 4.6) a second depth (such as 12,5 mm ± 0,1 mm or 15,0 mm ± 1 mm) is useful. Rings of appropriate depths will be required.

4.2.6 *Formation of dust layer*

The dust layer shall be formed without compressing it unduly. That is to say, the dust shall be put into the ring with a spatula and distributed mainly with sideways movement of the spatula until the ring is slightly overfilled. The layer shall then be levelled by drawing a straight edge across the top of the ring. Any excess should be swept away.

For each type of dust, a layer shall be formed in the above manner on a sheet of paper whose weight is known and weighed. The density shall be calculated from the mass of the dust and the filled volume of the ring, and shall be reported.

4.3 *Procedure*

4.3.1 *General*

Ignition in particulate or porous solids exposed to elevated temperatures is generally preceded by a more or less protracted period of self-heating (usually due to atmospheric oxidation). Depending on the temperature of exposure, self-heating may result in no more than a transient, though sometimes substantial, rise in temperature within the solid which does not lead to propagation of combustion. Further, the "induction period" for ignition, at temperatures near to the minimum required for ignition is usually many times greater than for ignition in dust clouds or in gases and vapours (minutes or hours rather than seconds). For both reasons the recognition of the minimum ignition temperature of dust layers is less straightforward than for dust clouds or for gases and vapours. It is necessary especially to be certain that failure to ignite at a given temperature is not merely because a test was terminated prematurely.

The occurrence of ignition in a layer of dust on a surface at a given temperature depends critically on the balance between the rate of heat generation ("self-heating") in the layer and the rate of heat loss to the surroundings. The temperature at which ignition of a given material occurs depends, therefore, on the thickness of the layer. Values determined for two or more thicknesses of a given dust may be used for predictive purposes (see 4.6).

Following the recommended procedure, ignition shall be considered to have occurred if:

a) visible glowing or flaming is observed (figure 3a), or

b) a temperature of 450 °C, is measured or

c) a temperature rise of 250 K above the temperature of the heated plate (figure 3c), is measured.

With regard to items b and c above, ignition shall not be considered to have occurred if it can be shown that the reaction does not propagate to glowing or flaming. The temperature shall be measured by thermocouple (see 4.2.2) It will usually be found that, provided the temperature of the heated surface is high enough, the temperature in the layer will slowly increase to a maximum value which may be in excess of the temperature of the heated surface and then slowly fall to a steady value below the temperature of the heated surface (figure 3b). This behaviour is evidence of self-heating in the dust layer and it may often be accompanied by a discoloration of the dust but without active and visible combustion of the layer. If the temperature of the heated surface is slightly higher, the temperature measured in the dust layer will continue to rise instead of passing through a maximum. Some materials exhibit more than one stage of self-heating, and it may sometimes be necessary to prolong the test in order to fully explore this possibility. With organic dust, combustion will usually take the form of charring followed by the appearance of smouldering with glowing which will progress through the layer and leave a residue of ash. With dust layers composed of certain divided metals, ignition may be characterized by the relatively sudden appearance of highly incandescent smouldering combustion progressing rapidly through the layer.

In the determination of the minimum ignition temperature for a layer of given thickness, repeated trials are carried out, using a fresh layer of dust each time and with up-and-down adjustments to the temperature of the heated surface until a temperature is found which is high enough to cause ignition in the layer but which is no more than 10 K higher than a temperature which fails to cause ignition. The highest temperature at which ignition fails to occur shall be confirmed by continuing the test long enough to establish that any self-heating is decreasing in rate; that is, the temperature at the point of measurement in the layer is decreasing to a steady value lower than the temperature of the heated surface.

4.3.2 *Method*

The apparatus shall be set up in a position free from draughts, and preferably under a hood capable of extracting smoke and fumes.

The temperature of the heated surface shall be adjusted to the desired value and shall be allowed to become steady within the prescribed limits of 4.2.1 b). A metal ring of the required height shall be placed centrally on the heated surface and this ring shall be filled with the dust to be tested and levelled off within a period of 2 min. The recorder for the dust layer thermocouple shall then be started.

The test shall be continued until it is ascertained either that the layer has ignited, either visually or by the thermocouple recording, or has self-heated without igniting and is subsequently cooling down.

If, after a period of 30 min, no self-heating is apparent the test should be terminated and repeated at a higher temperature. If ignition or self-heating occurs the test shall be repeated at a lower temperature, if necessary, prolonging the test beyond 30 min. Testing is continued until a temperature is found which is high enough to cause ignition or self-heating in the layer, but which is no more than 10 K higher than a temperature which fails to cause ignition or self-heating.

4.3.3 *Results*

Tests shall be repeated with fresh layers of dust until a minimum ignition temperature has been determined. This shall be the lowest temperature, rounded down to the nearest integral multiple of 10 °C, at which ignition occurs in a layer of given thickness. Where ignition has been deemed to occur, from readings of the test thermocouple (see 4.3.1), the minimum ignition temperature shall be the lowest such temperature, rounded down to the nearest integral multiple of 10 °C, less 10 K.

The highest value of temperature at which ignition does not occur, or is deemed not to occur, shall also be recorded. This temperature shall not be more than 10 K lower than the minimum temperature at which ignition does occur, or is deemed to occur, and it shall be confirmed by at least three tests.

For the purpose of this standard, the tests shall be discontinued if ignition of a dust layer does not occur below a heated surface temperature of 400 °C. This fact shall be reported as the result of the test.

Times to obtain ignition, or times to reach the maximum temperature in the case of no ignition, shall be measured to the nearest 5 min from the time of placing the dust layer on to the heated surface, and shall be reported.

Where a dust layer fails to ignite at a temperature of less than 400 °C, the maximum duration shall be reported.

4.4 *Test acceptance criteria*

Results obtained by the same operator on different days and results obtained in different laboratories shall be considered unsatisfactory if they give ignition temperatures differing by more than 10 K in either case.

The validity of test results may sometimes be poor for reasons associated with the physical nature of the dusts and the behaviour of layers during test. When this occurs it shall be reported (see 4.5) and all results shall be accepted as equally valid.