UL 80079-20-2

STANDARD FOR SAFETY

Explosive Atmospheres – Part 20-2: Material Characteristics – Combustible Dusts Test Methods

UL Standard for Safety for Explosive Atmospheres – Part 20-2: Material Characteristics – Combustible Dusts Test Methods, UL 80079-20-2

First Edition, Dated May 11, 2020

Summary of Topics

This revision of ANSI/UL 80079-20-2 dated September 10, 2020 is an editorial correction to replace "ANSI/UL 80079-20-1" with "ANSI/UL 80079-20-2" in the ANSI logo. No other changes have been made.

ANSI/UL 80079-20-2 is an adoption of ISO/IEC 80079-20-2 (first edition, issued by ISO/IEC February 2016 including corrigendum 1 issued March 2017). UL 80079-20-2 is an IEC-based UL standard with US Differences.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

No Text on This Page

MAY 11, 2020
(Title Page Reprinted: September 10, 2020)

UL 80079-20-2

Standard for Explosive Atmospheres – Part 20-2: Material Characteristics – Combustible Dusts Test Methods

First Edition

May 11, 2020

This ANSI/UL Standard for Safety consists of the First Edition including revisions through September 10, 2020.

The most recent designation of ANSI/UL 80079-20-2 as an American National Standard (ANSI) occurred on May 11, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

Preface (UL)

This UL Standard is based on ISO/IEC Publication 80079-20-2: First edition, Explosive atmospheres – Part 20-2: Material characteristics – Combustible dusts test methods as revised by corrigendum 1 issued March 2017. ISO/IEC publication 80079-20-2 is copyrighted by the IEC.

This edition has been issued to satisfy UL Standards policy.

This is the UL 80079-20-2 Standard for Safety for Explosive Atmospheres – Part 20-2: Material Characteristics – Combustible Dusts Test Methods

Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

The following people served as members of STP 60079 and participated in the review of this standard:

NAME	COMPANY
*B. Zimmermann, Chair	R Stahl Inc.
*T. Adam	FM Approvals LLC
R. Allen	Honeywell Inc.
*J. Anderson	Thermon Mfg. Co.
D. Ankele	UL LLC
P. Becker	nVent
S. Bihler-Lopez	CML Inc.
S. Blais	Emerson/Appleton Group
K. Boegli	KBB Consulting
R. Brownlee	Pepperl + Fuchs Inc.
D. Burns	Shell P&T — Innovation / R&D
R. Chalmers	Industrial Scientific Corp.
*C. Coache	National Fire Protection Association
*M. Cole	Hubbell Canada LP
D. Cook	Shelby County Department of Development Services
M. Coppler	Det Norske Veritas Certification Inc.
*R. Deadman	UL LLC
M. Dona	Consultant
T. Dubaniewicz	NIOSH
*G. Edwards	Det-Tronics
M. Egloff	Montana Tech, University of Montana
M. Ehrmann	R Stahl Inc
D. El Tawy	Siemens Energy
*A. Engler	Det Norske Veritas DNV
M. Fillip	National Oilwell Varco
W. Fiske	Intertek
Z. Fosse	DEKRA Certification Inc

NAME	COMPANY
G. Gurinder	Gurinder Garcha Consulting
D. Grady	Talema Group
R. Holub	DuPont
E. Hong	Solar Turbines Inc.
P. House	Thermon Mfg. Co.
D. Jang	National Research Council Canada
*B. Johnson	Thermon Mfg. Co.
R. Johnson	Source IEC
*P. Kelly	UL LLC
S. Kiddle	ABB Inc
A. Kreider	Phoenix Contact Development & Manufacturing Inc.
*J. Kuntscher	Thermon Mfg Co.
S. Lambaz	Littelfuse Inc.
W. Lawrence	FM Approvals LLC
E. Leubner	Eaton's Crouse-Hinds Business
W. Lowers	WCL Corp.
*N. Ludlam	FM Approvals Ltd.
E. Massey	ABB Motors and Mechanical Inc.
W. McBride	Northern Electric Co.
T. Michalski	Killark Electric Mfg. Co.
J. Miller	Detector Electronics Corp.
*O. Murphy	Honeywell Inc.
D. Nedorostek	Bureau of Safety & Environmental Enforcement (BSEE)
A. Page	Bud Page Consultant Inc.
R. Parks	National Instruments
L. Ricks	ExVeritas North America LLC
P. Rigling	Eaton Elecric Ltd – MTL
*K. Robinson	Occupational Safety and Health Adm.
J. Ruggieri	General Machine Corp.
S. Sam	Tundra Oil & Gas
*J. Scheller	ABB Motor and Mechanical Inc.
P. Schimmoeller	CSA Group
*T. Schnaare	Rosemount Inc.
R. Seitz	ARTECH Engineering
S. Sharma	Lindsay Corp.
K. Singh	Ex Safet Services and Solutions
G. Sitnik	MET Laboratories Inc.
J. Sotherden	Eatons Crouse-Hinds Business
G. Steinman	Thomas & Betts
*R. Teather	Det Norske Veritas Certification Inc.
L. Vlagea	General Monitors
D. Wechsler	American Chemistry Council
N. Wienhold	Rosemount Inc.
R. Wigg	E-x Solutions International Pty Ltd.
*K. Wolf	Intertek
T. Woods	Baker Hughes, A GE Co.

NAME	COMPANY
R. Zalosh	Firexplo

* Non-voting member

No Text on This Page

National Differences

National Differences from the text of International Electrotechnical Commission (IEC) Publication 80079-20-2, Explosive Atmospheres – Part 20-2: Material Characteristics – Combustible Dusts Test Methods, copyright 2016, are indicated by notations (differences) and are presented in bold text.

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

DR – These are National Differences based on the **national regulatory requirements**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.***Deletion / Delete*** - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

No Text on This Page

FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPLOSIVE ATMOSPHERES – Part 20-2: Material characteristics – Combustible dusts test methods

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). 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. 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 IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard ISO/IEC 80079-20-2 has been prepared by subcommittee 31M: Nonelectrical equipment and protective systems for explosive atmospheres, of IEC 31: Equipment for explosive atmospheres.

It is published as a double logo standard.

This first edition cancels and replaces the first edition of IEC 61241-2-1 published in 1994, the first edition of IEC 61241-2-2 published in 1993 and the first edition of IEC 61241-2-3 published in 1994, combining the requirements into a single document, and is considered to constitute a technical revision.

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

FDIS	Report on voting
31M/102/FDIS	31M/108/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table. In ISO, the standard has been approved by 15 P-members out of 21 having cast a vote.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

"A list of all parts in the IEC 60079 series, under the general title *Explosive atmospheres*, as well as the International Standard 80079 series, can be found on the IEC website."

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore. iec. ch" in the data related to the specific publication. At this date, the publication will be

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

The contents of the corrigendum of March 2017 have been included in this copy.

Significant changes with respect to
IEC 61241-2-1:1994, IEC 61241-2-2:1993 and IEC 61241-2-3:1994

		Type		
Explanation of the significance of the changes	**Clause**	**Minor and editorial changes**	**Extension**	**Major technical changes**
Normative references	2	X		
Terms and Definitions	3	X		
Dust sample Requirements	4	X		
Combustible Dust Determination	5	X		
Procedure for Characterisation of combustible dust or combustible flying	6	X		
Test methods for determination of a combustible dust or a combustible flying	7	X		
MIT of a dust cloud	8.1	X		
MIT of a dust layer	8.2	X		
MIE of a dust/air mixture	8.3	X		
Tests on resistivity	8.4	X		
Measurement of temperature distribution on the surface of the hot plate	Annex A	X		
Godbert-Greenwald oven	Annex B	X		
Examples of spark-generating systems	Annex C	X		
Vertical tube apparatus	Annex D	X		
20-litre sphere	Annex E	X		

Significant changes with respect to IEC 61241-2-1:1994, IEC 61241-2-2:1993 and IEC 61241-2-3:1994 Continued on Next Page

Significant changes with respect to IEC 61241-2-1:1994, IEC 61241-2-2:1993 and IEC 61241-2-3:1994 Continued

		Type		
Explanation of the significance of the changes	Clause	Minor and editorial changes	Extension	Major technical changes
BAM oven	Annex F	X		
Data for dust explosion characteristics	Annex G	X		
1 m^3 vessel	Annex H	X		

No Text on This Page

EXPLOSIVE ATMOSPHERES – Part 20-2: Material characteristics – Combustible dusts test methods

1 Scope

1DV DR *Modification of Clause 1 to replace with the following:*

This standard ~~part of ISO/IEC 80079~~ describes the test methods for the identification of combustible dust and combustible dust layers in order to permit classification of areas where such materials exist for the purpose of the proper selection and installation of electrical and mechanical equipment for use in the presence of combustible dust in accordance with the National Electrical Code, NFPA 70.

The standard atmospheric conditions for determination of characteristics of combustible dusts are:

• temperature –20 °C to +60 °C,

• pressure 80 kPa (0,8 bar) to 110 kPa (1,1 bar) and

• air with normal oxygen content, typically 21 % v/v.

The test methods defined do not apply to:

• recognized explosives, propellants (e. g. gunpowder, dynamite), or substances or mixtures of substances which may, under some circumstances, behave in a similar manner or

• dusts of explosives and propellants that do not require atmospheric oxygen for combustion, or to pyrophoric substances.

2 Normative references

2DV DR *Modification of Clause 2 to replace with the following:*

~~None.~~

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NFPA 70, *National Electrical Code (NEC)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
combustible dust
finely divided solid particles, 500 µm or less in nominal size, which may form explosive mixtures with air at standard atmospheric pressure and temperatures

Note 1 to entry: This includes dust and grit as defined in ISO 4225.

Note 2 to entry: The term 'solid particles' is intended to address particles in the solid phase but does not preclude a hollow particle.

3.1.1
conductive dust
combustible metal dusts and other combustible dusts with electrical resistivity equal to or less than 1×10^3 Ω·m

Note 1 to entry: Metal dust is treated as conductive dust because it is assumed that surface oxidation cannot be depended upon to always ensure electrical resistivity greater than 1×10^3 Ω·m

3.1.2
non-conductive dust
combustible dust with electrical resistivity greater than 1×10^3 Ω·m

3.2
combustible flyings
solid particles, including fibres, where one dimension is greater than 500 µm in nominal size, which may form an explosive mixture with air at standard atmospheric pressure and temperature

Note 1 to entry: The ratio of length to width is 3 or more.

Note 2 to entry: Examples of flyings include carbon fibre, rayon, cotton (including cotton linters and cotton waste), sisal, jute, hemp, cocoa fibre, oakum and baled waste kapok.

3.3
explosive dust atmosphere
mixture with air, under atmospheric conditions, of combustible substances in the form of dust, fibres, or flyings which, after ignition, permits self-sustaining propagation

3.4
minimum ignition temperature of a dust layer
lowest temperature of a hot surface at which ignition occurs in a dust layer under specified test conditions

3.5
minimum ignition temperature of a dust cloud
lowest temperature of a hot surface on which the most ignitable mixture of the dust with air is ignited under specified test conditions

3.6
minimum ignition energy (of a combustible dust/air mixture)
lowest electrical energy stored in a capacitor which upon discharge is sufficient to effect ignition of the most sensitive dust/air mixture under specified test conditions

4 Dust sample requirements

4.1 Receipt of sample for testing

A material safety data sheet or equivalent with the sample.

The test material shall be provided in suitable packaging, labelled according to relevant guidelines labelled according to relevant guidelines, and appropriate transportation.

NOTE It is usual to provide a quantity of at least 0,5 kg for testing. If sample preparation is required this may be insufficient. If only a smaller volume of material is available then the full range of testing may not be possible.

4.2 Characterisation of sample

The sample shall be representative of the material as it appears in the entire process operated.

NOTE Many unit operations such as extract systems will separate dust into finer fractions than seen in the main processing equipment and this is accounted for when taking the sample.

If the sample is not representative of the material as found in the process then sample preparation shall be carried out to apply the worst case conditions.

At least the following information about the sample shall be provided:

– minimum particle size,

– median particle size,

– maximum particle size,

– particle distribution,

– moisture content, and

– method of determination (e.g. optical methods or sieving).

If the applicant cannot provide usable data then this shall be determined separately.

4.3 Preparation of sample

If it is not possible to test the sample as received, or if the sample is no longer representative of the process material then it may be necessary to condition or alter the sample for testing. This may include

– grinding/sieving,

– drying and

– humidifying.

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.

NOTE 1 Sample preparation such as grinding and sieving, or drying can alter the material characteristics. Where finer fractions are present in a facility it is appropriate to take fractions of less than 63 µm to give the most easily ignitable mixtures. When the sample is a mixture of substances, the sample preparation can result in a change to the sample's composition.

NOTE 2 The presence of solvents can become altered in the sample preparation process.

4.4 Test conditions

The tests shall be carried out at standard atmospheric temperature of 20 $^{+10}_{-10}$ °C and standard atmospheric pressure of 80 kPa to 110 kPa (0,8 bar to 1,1 bar) unless otherwise specified.

5 Combustible dusts and combustible flyings determination

5.1 Test sequence

The sequence followed for the determination of the material properties of combustible dust and combustible flyings is given in 5.2, Clause 6 and Figure 1, Figure 2 and Figure 3.

NOTE 1 Refer also to the information referenced in Annex G.

NOTE 2 Testing in the Hartman tube is a screening method. The test procedure can be directly started with the 20 litre sphere or the GG Oven.

5.2 Tests to determine whether material is a combustible dust or combustible flying

5.2.1 Visual inspection

Make a visual inspection of the test material (by microscope if necessary) to determine whether the material consists of combustible flyings:

• If the material consists of combustible flyings with dust then continue the test procedure in a Hartmann tube (see 5.2.3) to determine whether the combination of the two is combustible dust.

• If the material consists only of combustible flyings then continue the test procedure in a Hartmann tube (see 5.2.3) to determine whether it is combustible flyings.

5.2.2 Determine particle distribution

For material which does not contain combustible flyings check the particle size distribution:

• If there are no particles less than 500 µm in size then the material is not a combustible dust.

• If there are any particles less than 500 µm in size then continue the test procedure in a Hartmann tube to determine whether it is a combustible dust.

5.2.3 Ignition test in the Hartmann tube

5.2.3.1 Test in a Hartmann tube with a spark (see 7.1):

1) If ignition occurs, the material is a combustible dust or a combustible flying (proceed to the procedure for characterisation of combustible dust or combustible flying (see Clause 6)).

2) If no ignition occurs:

a) proceed to a Hartmann tube with a hot coil ignition source (see 7.1);

b) it can be assumed that the minimum ignition energy is greater than 1 J and the test material is hard to ignite.

5.2.3.2 Test in a Hartmann tube with a hot coil ignition source (see 7.1):

1) If ignition occurs, the material is a combustible dust or a combustible flying, (proceed to the procedure for the characterisation of combustible dust or combustible flying (see Clause 6).

2) If no ignition occurs:

a) proceed to the test in the 20-litre sphere (see 7.2);

b) it can be assumed that the minimum ignition energy is greater than 10 J.

5.2.4 Ignition test in the 20-litre sphere

Test in the 20-litre sphere (see 7.2):

• If ignition occurs the material is a combustible dust or a combustible flying (proceed to procedure for characterisation of combustible dust or combustible flying (see Clause 6)).

• If no ignition occurs then the material is not a combustible dust or a combustible flying and the testing procedure is completed.

NOTE Although the material does not form explosive mixtures with air, it can still ignite as a combustible dust layer.

If there is insufficient material available for testing in a 20-litre sphere then testing in the Godbert-Greenwald (GG) oven at 1 000 °C is an acceptable alternative (see 7.3):

• If no ignition occurs at 1 000 °C then the material is not a combustible dust or a combustible flying.

• If there is an ignition at 1 000 °C then the material should be subject to further verification in the 20-litre sphere before declaring it combustible or non-combustible.

6 Procedure for characterisation of combustible dust or combustible flying

The following is the procedure for the characterisation of combustible dust or combustible flying:

– test for dust cloud minimum ignition temperature (MIT) (see Clause 8):

a) GG oven (see 8.1.2) or

b) BAM oven (see 8.1.3)

– test for dust layer MIT (see 8.2);

– est for minimum ignition energy (MIE) of dust cloud (see 8.3);

– test for resistivity of bulk dust (see 8.4).

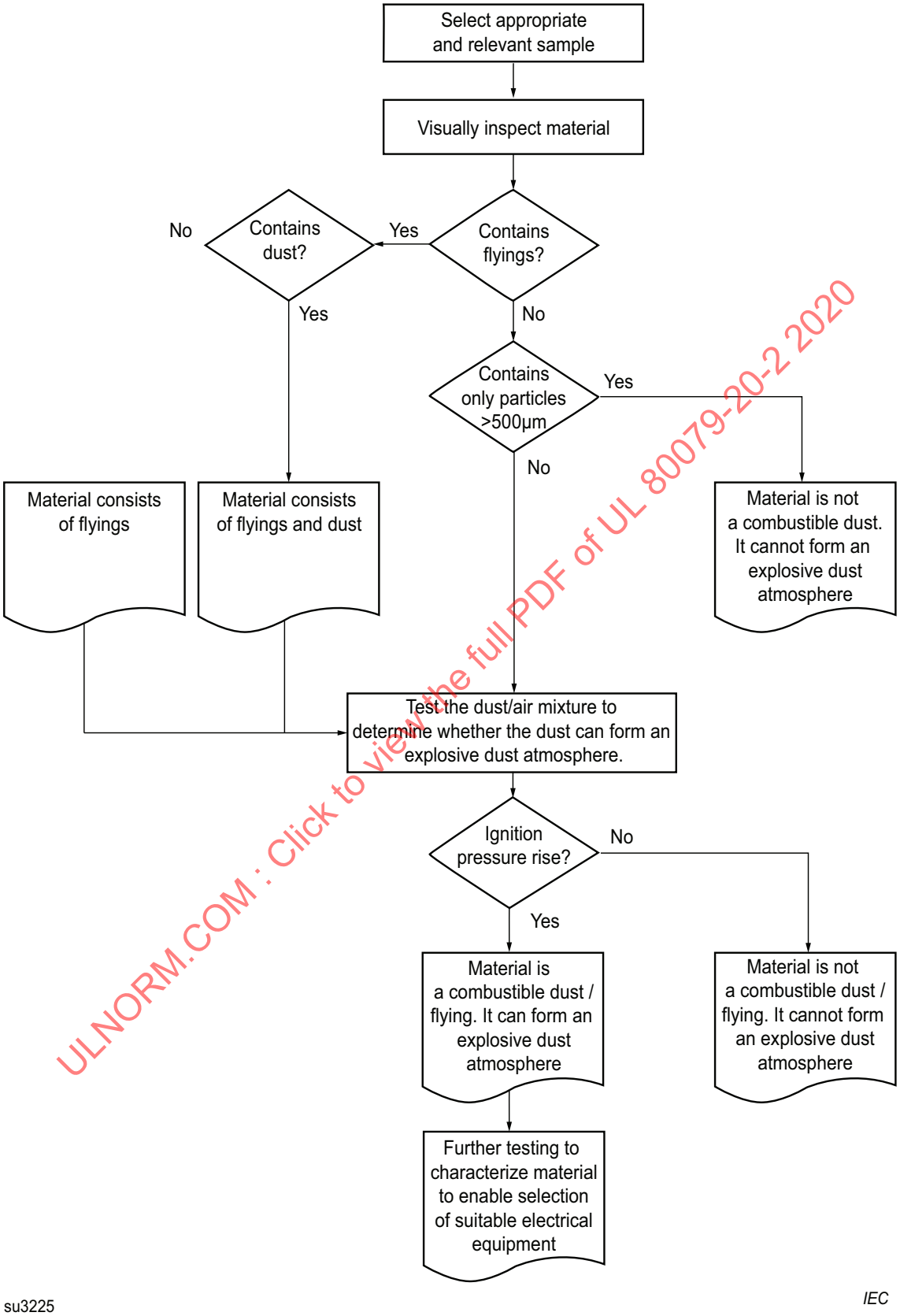


Figure 1

Protocol for characterisation of combustible dust or combustible flying

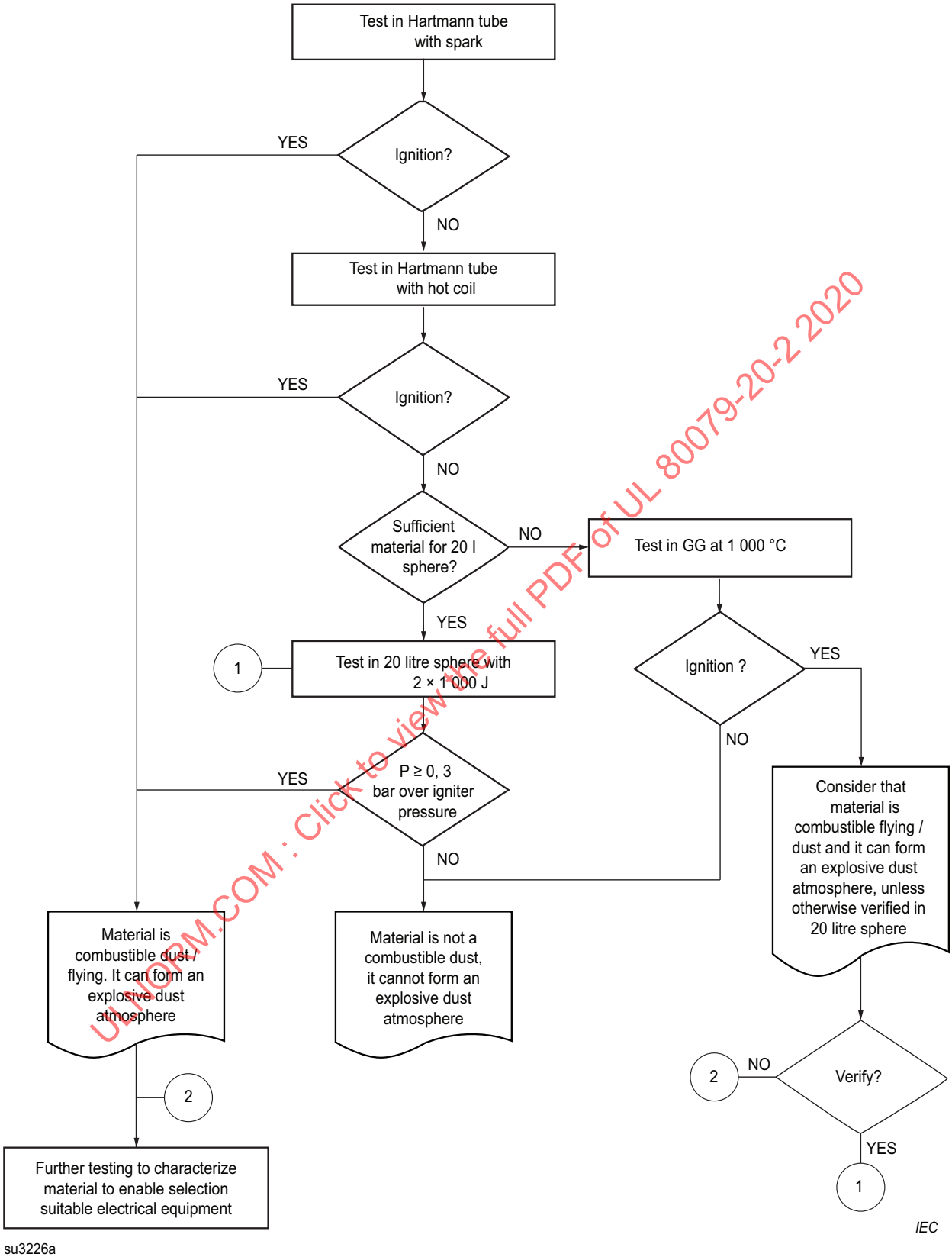


Figure 2

Tests to define ability to form explosive dust atmosphere (combustible dust/combustible flyings)

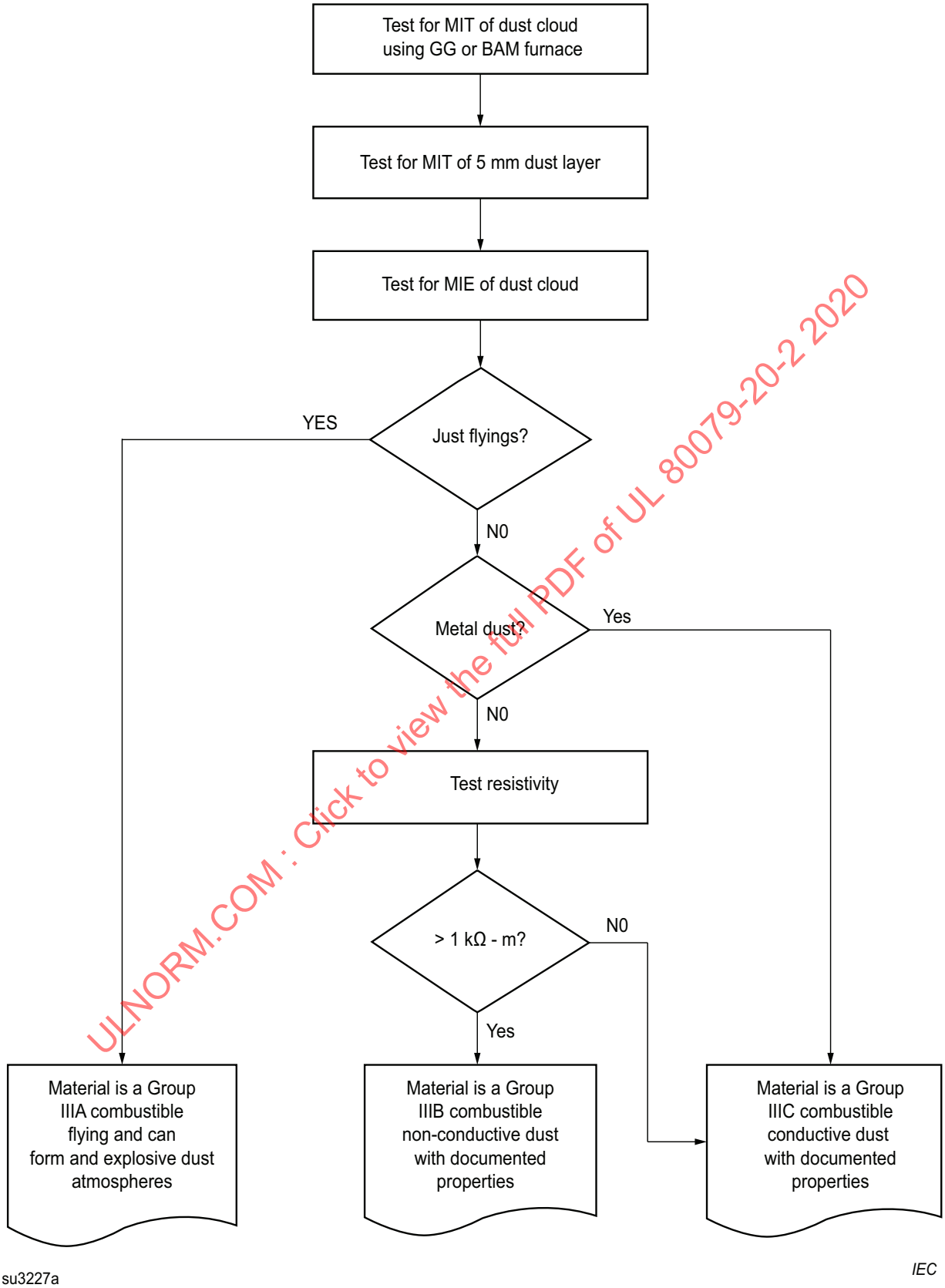


Figure 3

Tests to characterise combustible dust or combustible flying

7 Test methods for determination of whether a material is a combustible dust or a combustible flying

7.1 Modified Hartmann tube

7.1.1 General

Dust is dispersed in a tube to form a dust cloud, and ignition trials are attempted with two different ignition sources.

7.1.2 Test equipment

The test equipment consists of a vertical tube closed at the bottom with a dispersion cup (volume approximately 1,2 l, internal diameter (70 ± 5) mm).

As ignition sources

– a continuous induction spark (electrode gap of approximately 4 mm, with a transformer rated approximately 15 kV, and approximately 0,2 kVA),

– a glowing coil (wire diameter approximately 1,2 mm, wire length approximately 470 mm, coil diameter approximately 11 mm and wire temperature at least 1 000 °C).

The vertical separation between the bottom of the dispersion cup and the ignition source is approximately 100 mm.

A detailed description of suitable equipment can be found in Annex D.

7.1.3 Test procedure

The test sample is deposited in the dispersion cup and dispersed with a blast of air (50 cm^3, 700 kPa to 800 kPa gauge). The dust concentration is varied over a wide range from 250 g/m^3 to 1500 g/m^3 (typically 250 g/m^3, 500 g/m^3, 750 g/m^3, 1 000 g/m^3 and 1 500 g/m^3) and the behaviour is visually observed. The different quantities are each tested once, but repeated dispersions are made for at least 3 attempts.

If a flame propagates from the ignition source, the test material is a combustible dust or combustible flying.

If no ignitions are observed with the spark ignition source, then the coil ignition source is used. Testing may be stopped immediately after an ignition is observed.

If it is unclear, whether ignition has been observed then the 20-litre sphere test shall be used.

NOTE 1 In the case of high density materials such as metals higher concentrations (e.g. up to 2 500 g/m^3) are used.

NOTE 2 Deposits on the coil can result in localised smouldering or burning, which is not considered as ignition.

7.2 20-litre sphere

7.2.1 General

Dust is dispersed in a pressure resistant closed apparatus (20-litre sphere) to form a dust cloud under standard conditions of pressure and temperature. Ignition trials are attempted with pyrotechnic igniters.

As an alternative method, the 1 m^3 vessel can be used (see Annex H).

7.2.2 Test equipment

The standard test apparatus to determine dust cloud combustibility is a spherical explosion pressure resistant vessel of 20 litres.

The main components of the test apparatus are:

• spherical explosion vessel;

• dust dispersion system (rebound nozzle);

• ignition source (2 × 1 000 J pyrotechnical igniters);

• control unit;

• pressure measuring system with two sensors (± 10 kPa);

• dispersion overpressure p_z = (2 000 ± 100) kPa;

• initial temperature T_i = (20 ± 5) °C (water cooling).

A detailed description of suitable equipment can be found in Annex E.

NOTE 1 For flyings and very coarse materials other nozzles are typically used (see Annex E).

NOTE 2 The particle size of friable materials can be affected by the dispersing system.

7.2.3 Test procedure

Explosion tests with defined dust/air mixtures shall be carried out according to the following procedure. The test material is dispersed in the explosion vessel by an air blast such that a homogeneous dust cloud is created. Prior to the air blast the explosion vessel is evacuated to a level such that immediately after dispersion the internal pressure of the vessel shall be equal to standard atmospheric pressure.

The dust concentration is varied over a wide range from 250 g/m^3 to 1 500 g/m^3 (typically 250 g/m^3, 500 g/m^3, 750 g/m^3, 1 000 g/m^3 and 1 500 g/m^3) and the pressure increase is measured. The different concentrations shall each be tested at least once.

The required amount of the dust is placed in the dust container. The bulk volume of the dust shall not exceed 3/4 of the dust container allowing proper pressurization. The amount of the dust in the dust container has to be completely dispersed into the 20-litre-sphere. The container is then pressurized to an overpressure of 2 000 kPa.

Before starting the test procedure the temperature inside the vessel shall be measured and recorded.

After dispersion of dust the pressure in the 20-litre sphere shall be at atmospheric pressure. The actual pressure in the 20-litre sphere at the moment of ignition (initial pressure p_i) shall be measured and recorded.

The delay between the initiation of the dust dispersion and the activation of the ignition source (ignition delay t_v) shall be 60 ± 5 ms. The pressure is recorded as a function of time. From the pressure/time curve

the explosion pressure p_{ex} is determined by taking the arithmetic mean of the maximum values measured by the pressure sensors (see Annex E).

If the difference in the pressures measured by the different pressure sensors is more than 10 kPa of the mean, the accuracy of the sensors shall be checked and the measurements repeated.

An ignition of the dust (dust explosion) shall be considered to have taken place, if an overpressure is detected which is equal to or greater than the overpressure created by the ignition source alone in air plus 30 kPa.

If an ignition occurs, then the test material is a combustible dust or combustible flying, and testing may be stopped.

If no ignition occurs for all concentrations it is not a combustible dust or combustible flying.

In the case of high density materials such as metals, higher concentrations (e.g. up to 2 500 g/m^3) are permitted to be used.

After each test, the explosion vessel shall be cleaned.

7.3 Alternative method to 20-litre sphere for small test material quantities

7.3.1 General

Small quantities of dust are blown through a heated vertical tube (GG oven) at a temperature of 1 000 °C and ignition is detected by visual inspection.

7.3.2 Test equipment

The main components of the test apparatus are

• a furnace capable of achieving a wall temperature of 1 000 °C,

• a dust dispersion system including an air reservoir of 500 ml and

• a temperature control unit.

A detailed description of suitable equipment can be found in Annex B.

7.3.3 Test procedure

The test material is dispersed in the furnace by an air blast.

The dust quantity is varied from 0,3 g to 0,5 g.

The dust is dispersed with air at pressures varying between 10 kPa and 50 kPa.

If a burst of flame is seen below the end of the furnace tube the test material is a combustible dust or a combustible flying.

If a burst of flame is not seen below the end of the furnace tube the test material is not a combustible dust or combustible flying.

In case of uncertainties in the detection of flames the test material shall be considered to be a combustible dust or combustible flying. The ultimate determination shall be from a 20-litre sphere test as described in 7.2.

NOTE In the case of high density materials such as metals, higher quantities (e.g. up to 5,0 g) are typically used.

8 Test methods for combustible dust determinations

8.1 MIT of a dust cloud

8.1.1 General

There are two methods for measuring the MIT of the dust cloud outlined below, the GG furnace in 8.1.2 or the BAM furnace in 8.1.3.

8.1.2 GG furnace

8.1.2.1 General

Small quantities of dust are blown vertically downward through a heated furnace and ignition is detected by visual inspection.

8.1.2.2 Test equipment

The main components of the test apparatus are as shown in 7.3.1.

8.1.2.3 Test procedure

The test material is dispersed in the furnace by an air blast.

The dust quantity is varied over a wide range from 0,05 g to 0,5 g (typically 0,1 g, 0,2 g and 0,3 g). The dust is dispersed with air at pressures varying between 10 and 50 kPa (typically 10 kPa, 20 kPa, 30 kPa and 50 kPa).

In the absence of preliminary information the first test should be performed at a furnace wall temperature of 500 °C, with a quantity of 0,3 g and an air pressure of 30 kPa.

If no ignition is observed at this temperature the temperature should be increased in steps of 50 K until 600 °C is reached.

Once ignition is obtained, vary the mass of test material and the dispersion pressure of the air until the most vigorous ignition is apparent. Then using the same mass and dispersion pressure carry out further tests with the temperature reduced in steps of 20 K until no ignition is obtained after 10 attempts. If ignition still occurs at 300 °C reduce the temperature in steps of 10 K.

When no ignition is obtained using this temperature reduction procedure, test again at this temperature using lower and higher values of test material mass and air pressure. If necessary the temperature is reduced further until no ignition is obtained after 10 attempts.

If a burst of flame is seen below the end of the furnace tube this shall be considered as an ignition.

NOTE 1 In the case of high density materials such as metals, higher quantities (e.g. up to 5 g) and higher pressures are typically used.

Recording of test results the minimum ignition temperature is recorded as the lowest temperature of the furnace at which ignition was obtained using the above procedure minus 20 K for furnace temperatures above 300 °C and minus 10 K for furnace temperatures at or below 300 °C.

If no ignition is obtained even when the furnace temperature is at 600 °C this fact shall be stated in the report noting that this is the maximum temperature obtainable in the GG oven.

NOTE 2 There is no prohibition of using temperatures in excess of 600 °C.

8.1.3 BAM furnace

8.1.3.1 General

Small quantities of dust are blown horizontally through a heated furnace on a deflection surface and ignition is detected by visual inspection.

8.1.3.2 Test equipment

The main components of the test apparatus are:

– a furnace capable of achieving a wall temperature of at least 600 °C;

– a dust dispersion system with a rubber bulb and dust dispersion tube; and

– a temperature control unit.

An example of typical equipment can be found in Annex F.

8.1.3.3 Test procedure

The test material is dispersed in the furnace by an air blast.

The dust quantity is varied over a wide range from 0,5 ml to 2,0 ml (typically 0,5 ml, 1,0 ml, 1,5 ml and 2,0 ml). For dust cloud generation dust is dispersed from a tube filled with dust due to an air jet generated with a rubber bulb.

In the absence of preliminary information the first test should be performed at a furnace wall temperature of 500 °C with a volume of typically 1,0 ml.

If no ignition is observed within 10 s after dispersion at this temperature, the temperature should be increased in steps of 50 K and repeated until 600 °C is reached.

If ignition is obtained within 10 s after dispersion, further tests have to be carried out with the same volume and the temperature reduced in steps of 50 K until no ignition is obtained after 3 attempts. If this temperature is above 300 °C, testing is continued until a temperature is found which causes ignition, but which is as a maximum of 20 K higher than the highest temperature at which no ignition occurred. For a temperature at or below 300 °C, testing is continued until a temperature is found which causes ignition, but which is as a maximum of 10 K higher than the highest temperature at which no ignition occurred. In a next step, tests are performed with 10 K (or 20 K if > 300 °C) lower temperature using lower and higher values of test material volume. If necessary the temperature is reduced further in 10 K (or 20 K if > 300 °C) steps until no ignition is obtained after 3 attempts for each volume.

If a flame is seen in the furnace this shall be considered as an ignition. Single sparks are not considered as an ignition.

8.1.3.4 Recording of test results

the minimum ignition temperature is recorded as the lowest temperature of the furnace at which ignition was obtained using the above procedure minus 20 K for furnace temperatures above 300 °C and minus 10 K for furnace temperatures at or below 300 °C.

If no ignition is obtained even when the furnace temperature is at 600 °C this fact shall be stated in the report noting that this is the maximum temperature obtainable in the BAM furnace. If no ignition is obtained and the maximum test temperature was below 600 °C the maximum temperature at which no ignition is obtained shall be stated in the report too.

8.2 Test for MIT of dust layer

8.2.1 General

The apparatus consists of a heated plate and a dust ring.

8.2.2 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. 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, as depicted in Annex A. This requirement shall be satisfied at nominal surface temperatures of 200 °C and 350 °C. The variance across the surface is to be checked periodically, but not for every test;

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 accuracy of ± 3 K;

NOTE The maximum deviation from the nominal surface temperature shall not exceed 8 K due to points c) and e).

f) a thermocouple shall be connected to a temperature recorder to record the temperature of the surface during a test.

8.2.3 Dust layers

The dust layer shall be formed without compression of the layer. The layer shall then be levelled by drawing a straight edge across the top of the ring. Any excess should be swept away.

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. 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.

NOTE The same apparatus can be used for measuring the ignition temperatures of layers with depths greater than 5 mm. The layer ignition temperatures for thicker layers (e.g. 12,7 mm) can be estimated by interpolation between experimentally determined points or extrapolation for a number of test thicknesses.

8.2.4 Dust layer temperature

The temperature shall be measured within the layer at a height of between 2 mm and 3 mm from the surface of the plate, at the centre of the dust layer at a location centered on the dust ring ± 10 mm. This temperature shall be measured at 1 min intervals over the test period.

NOTE An infrared camera is often used as an additional detection system for the temperature rise or glowing.

8.2.5 Ambient temperature measurements

The ambient temperature shall be measured 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.

8.2.6 Dust layer temperature test method

The apparatus shall be set up 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 8.2.2. The metal ring shall be filled with the dust to be tested and levelled off. The recording of the dust layer temperature shall then be started.

The test shall be continued until it is ascertained either that the layer has ignited, or has heated above the plate temperature without igniting (self-heating) and is subsequently cooling down.

Ignition shall be considered to have occurred if:

a) visible glowing or flaming is observed; or

b) a temperature of 450 °C is measured in the dust layer; or

c) a temperature rise of 250 K above the temperature of the heated plate is measured in the dust layer.

If, after a period of 30 min, no further temperature increase is apparent the test should be terminated and repeated at a higher temperature. If ignition 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 in the layer, but which is no more than 10 K higher than a temperature which fails to cause ignition.

Tests shall be repeated with fresh layers of dust until a minimum ignition temperature of the dust layer has been determined. This shall be the lowest temperature of the plate, rounded down to the nearest integral multiple of 10 °C, at which ignition occurs in a layer of given thickness. If the lowest temperature at which ignition occurs is already an integral multiple of 10 K, it is not rounded down by 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.

8.2.7 Recording of results

The report shall state that the determination of minimum ignition temperature of the dust layer has been carried out in accordance with this standard.

The ignition tests shall be reported in the manner shown in Table 1 (showing results in descending order of surface temperature rather than in the order in which tests were performed):

Table 1
Example of ignition test report

Depth of layer mm	Surface temperature °C	Result of test	Time to ignition or to reach the highest value of temperature without ignition min	Max. temperature in dust layer
5	180	Ignition	16	196
	170	Ignition	36	193
	160	No ignition	40	154
	160	No ignition	38	156
	160	No ignition	42	152
	150	No ignition	62	141

The ignition temperature shall be recorded in accordance with 8.2.6 for each depth of layer.

In the example given in Table 1 the minimum ignition temperature for the 5 mm layer would be recorded as 170 °C.

Tests in which the heated surface temperature differed by more than ± 20 K from the recorded minimum ignition temperature need not be reported.

The test report shall then include a brief description of the nature of the combustion following ignition, noting especially behaviour such as unusually rapid combustion or violent decomposition. Factors likely to affect the significance of the results shall also be reported; these include difficulties in the preparation of layers, distortion of layers during heating, decrepitation, melting and evidence of flammable gas generated during heating of the dust.

8.3 Method for determining minimum ignition energy of dust/air mixtures

8.3.1 General

A test apparatus is described in this standard to measure the minimum ignition energy of a dust/ air mixture by an electrically generated high-voltage d.c. spark.

8.3.2 Test equipment

8.3.2.1 Spark generation circuit

Annex C describes some suitable forms of circuit, all of which shall have the following characteristics:

– the inductance of the discharge circuit shall be 1 mH to 2 mH except when the data is to be used for the assessment of electrostatic discharges with low inductance when the inductance of the discharge circuit shall not exceed 25 µH;

– the ohmic resistance of the discharge circuit shall be as low as possible and not more than 5 Ω;

– the electrode material shall be stainless steel, brass, copper or tungsten;

– electrode diameter and shape: (2,0 ± 0,5) mm. Electrodes with rounded tips can be used to reduce corona effects that can occur with pointed electrodes, and which may give incorrect values of spark energy. If pointed electrodes are used, corona effects should be carefully considered;

– the electrode gap shall be 6 mm minimum;

– capacitors shall be of the low-inductance type, resistant to surge current;

– the capacitance of the electrode arrangement shall be as low as possible; and

– insulation resistance between the electrodes shall be sufficiently high to prevent leakage currents.

NOTE Typically, a minimum resistance between the electrodes of 10^{12} Ω is used for a minimum ignition energy of 1 mJ, and 10^{10} Ω for a minimum ignition energy of 100 mJ.

8.3.2.2 Test vessel for determination of minimum ignition energies by electrically generated high-voltage d.c. sparks

The recommended vessel is the modified Hartmann tube (see Figure 4). Other vessels can be used, provided that the calibration requirements in 8.3.3 are met.

A modified Hartmann tube made of transparent material with a volume of 1,2 l is used as the explosion vessel. The dust dispersion system at the base of the tube is of the "mushroom-shaped" type around which the sample is loosely scattered. A blast of compressed air at 700 kPa overpressure is used to disperse the dust in the glass cylinder where it is ignited by a spark between two electrodes.

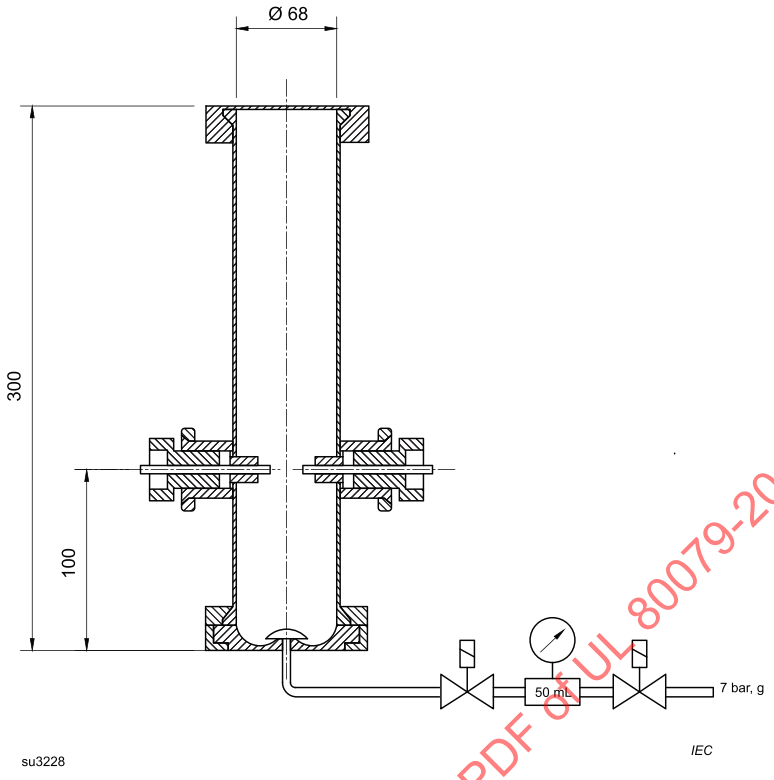


Figure 4

Modified Hartmann tube

8.3.3 Test procedure

The combustible dust to be tested is uniformly dispersed in air at atmospheric pressure and temperature and the dust/air mixture is subjected to a spark discharge from a charged capacitor.

The energy value of the discharge is calculated from the formula:

$$W = 0,5\ C \times U^2$$

where

W is the stored energy in joules (J);

C is the total discharge capacitance, in farads (F);

U is the voltage of the charged capacitor in volts (V).

NOTE 1 At spark energies above 100 mJ, the spark resistance can become so small that the circuit resistance is no longer negligible compared with the spark resistance, particularly when the circuit contains an inductance coil of the order of 1 mH. In such cases the net spark energy can be obtained from the equation:

$$W = \int I(t)\ U(t)dt$$

where

I(t) is the spark current, and

U(t) is the spark voltage; both of which are obtained by measurement.

NOTE 2 Further information relative to the calculation of spark energies is contained in Annex C.

It is necessary to take account of the following possible influences on the test:

– Ignition delay time (i.e. turbulence);

– dust concentration;

– voltage to which the capacitor is charged;

– value of the capacitor;

– inductance of the discharge circuit;

– ohmic resistance of the discharge circuit; and

– materials and dimensions of the electrodes and the gap between the electrodes.

To limit the expense of testing, every apparatus uses electrodes composed of a specific material with standardized dimensions and minimum electrode gap. The ohmic resistance of the discharge circuit shall be kept as low as possible.

The optimum dust concentration and the lowest turbulence level cannot be obtained in one step. Therefore an iterative procedure is required of which the main steps are as follows:

• Step 1

– Start with a value of ignition energy that will reliably cause ignition of a given concentration in air of the dust being tested. Reduce the spark energy in steps (e. g. by 50 %) at the given dust concentration until the dust cloud does no longer ignite in any of 10 tests at a given energy.

• Step 2

– Continue the procedure varying the dust concentration (750 mg, 1 200 mg, 2 000 mg, 3 000 mg) at the lowest energy found in Step 1. If for any dust concentration an ignition occurs, then repeat Step 1 at that concentration.

• Step 3

– Repeat the procedure by this combination of spark energy and dust concentration varying the delay time (60 ms, 120 ms and 180 ms) until the highest energy is found where no ignition occurs.

The minimum ignition energy, W_{min} (MIE), lies between the highest energy, W_1, at which ignition fails to occur and the lowest energy, W_2, at which ignition occurs.

$$W_1 < W_{min} < W_2$$

8.3.4 Calibration for determination of minimum ignition energies (MIE) by electrically generated high-voltage d.c. sparks

Calibration tests shall be carried out on validated reference dust.

The dust dispersion parameters, including ignition delay time, shall be noted.

8.3.5 Recording of test results

Where the test has been carried out in accordance with this standard, the test report shall provide

– total inductance of the discharge circuit;

– highest energy W_1 at which ignition does not occur; and

– lowest energy W_2 at which ignition is obtained.

8.4 Test on resistivity

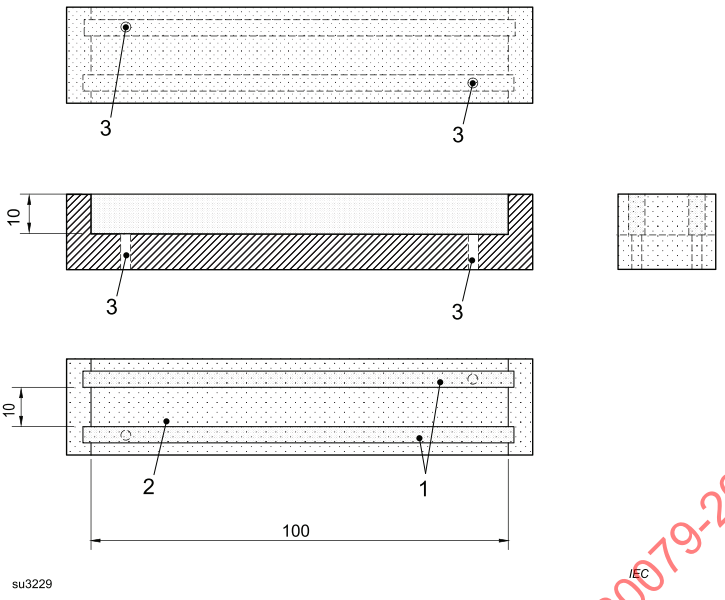
8.4.1 General

The powder resistivity shall be measured according to the following procedure.

A constant volume of powder is filled in a specific measuring cell with two electrodes. The resistance between both electrodes is measured.

8.4.2 Test equipment

A measuring cell consisting of two opposite electrodes of polished stainless steel bars, 10 mm in height, 100 mm in length and 10 mm distance, mounted together with two opposite walls of insulating bars, 10 mm in height, on an insulating base, shall be used (see Figure 5). The thickness of the electrodes shall be between 5 mm and 10 mm. The resistance R between the electrodes shall exceed 100 TΩ. The exact values of the dimensions of the cell have to be known for the geometric correction factor in 8.4.3.



Key

1 stainless steel

2 PTFE

3 plug connector

Figure 5

Measuring cell for powder resistivity

The electrodes are connected to a teraohm meter. The teraohm meter shall be regularly checked with a high resistance of known value. A guard shield electrode may be placed over the measuring cell without contacting the electrodes to minimise electric noise. During the test, the voltage shall be sufficiently steady so that the charging current due to voltage fluctuation will be negligible compared with the current flowing through the test sample.

8.4.3 Test procedure

The measurement procedure is as follows:

a) pour a quantity of the original untreated test dust between the test electrodes;

b) remove excess dust by running a straight-edge along the top of the stainless steel bars;

c) measure the resistance *R* of the filled test cell between the electrodes with the following values of d.c. voltage applied for 10 s: (105 ± 10) V, (500 ± 25) V, (1 000 ± 50) V. The same sample of dust in the test cell may be used for all the tests at any one of the values of voltage. If no constant measuring value is reached after 10 s the measuring time shall be elongated to (65 ± 5) s.

NOTE In most cases, a test voltage of (105 ±10) V is sufficient. Higher voltages can lead to unwanted physical or chemical effects however some types of dust might show conductivity at higher voltages.

d) calculate the resistivity ρ at all test voltages from the equation

$$\rho = 0,001 \times R \times H \times W / L$$

where

ρ is the resistivity in Ω·m,

H is the height of the electrode in mm,

W is the length of the electrode in mm and

L is the space between electrodes in mm;

e) repeat steps b) to d) twice and calculate the average value.

8.4.4 Recording of test results

A resistivity of 1×10^3 Ω·m or less shall be a Group IIIC conductive dust. A resistivity greater than 1×10^3 Ω·m shall be a Group IIIB non-conductive dust.

9 Test report

The following details are typically included in the report of the material characteristics identified for the sample tested:

– sample designation (name and chemical description if not implicit in the name);

– sample origin or source;

– sample pre-treatment;

– characteristics data for particle size distribution and moisture content if available and not already given by pre-treatment procedures;

– material form (combustible flying or combustible dust);

– environmental conditions at the time of the test (temperature, pressure, humidity);

– test results determined according to this standard;

- combustible dust or flying/ non-combustible dust or flying;
- MIT layer, MIT cloud, MIE, resistivity;
- dust explosion group;

– date, lab, operator;

– description of test equipment used;

– calibration of equipment (according to national standards);

– signature of person responsible for the test.

Annex A
(normative)

Measurement of temperature distribution on the surface of the hot plate

Figure A.1 illustrates the measurement of temperature distribution on the surface of the hot plate. Maximum temperature difference over the whole plate shall be 5 K. The maximum deviation from set-point temperature shall be 8 K.

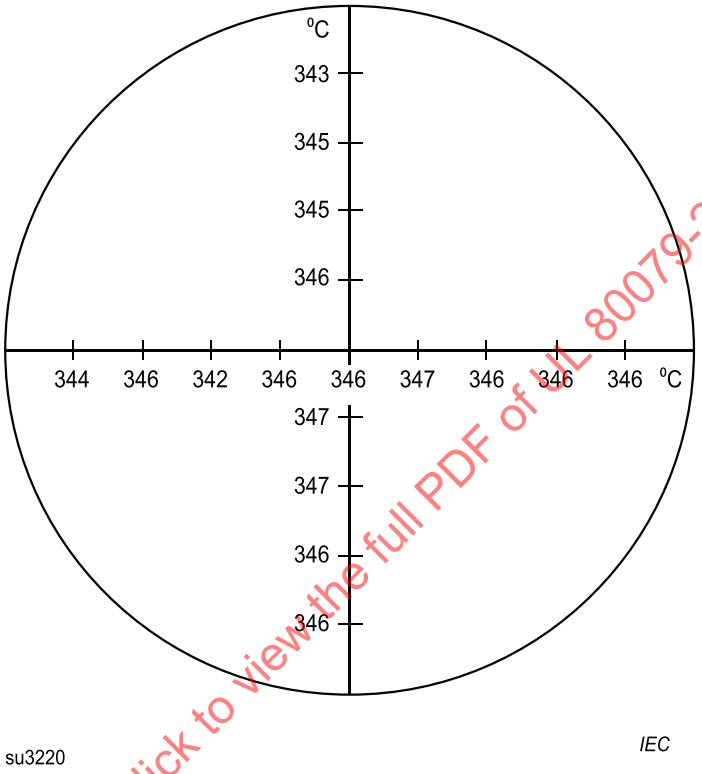


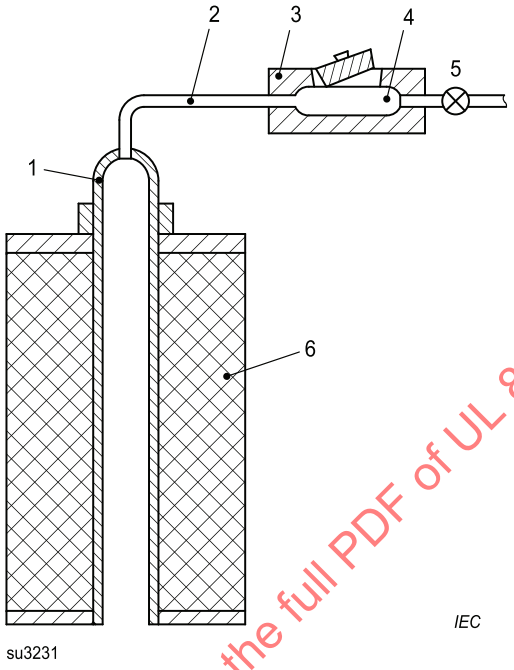
Figure A.1

Typical surface temperature distribution (method A)

Annex B
(informative)

Godbert-Greenwald oven (GG)

The length of the borosilicate glass tube in the GG oven is 210 mm ±10 mm (see Figure B.1).



Key

1 dust dispersion chamber
2 dust
3 solenoid valve
4 glass tubing
5 tube
6 insulation

Figure B.1

Vertical cross-section through the Godbert-Greenwald oven

Annex C
(informative)

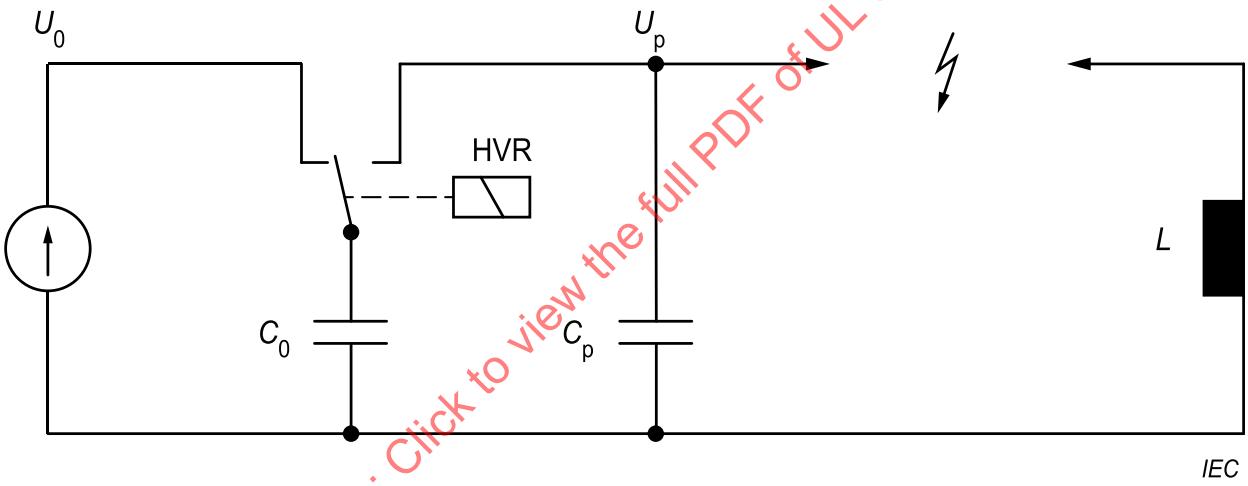
Examples of spark-generating systems

C.1 General

Clauses C.2, C.3, C.4 and C.5 contain descriptions of four designs of spark-generating circuit suitable for use in this test. With any of these examples it is possible to use different explosion vessels, provided that the dust dispersion is optimized and that suitable precautions are taken in order to prevent side-effects occurring in comparatively large vessels from electrostatic charging phenomena during the dispersion of the dust. These phenomena include additional charging/discharging of the capacitor.

If the storage capacitor is decoupled from the electrode during the charging process, the effect of the decrease in voltage that will occur due to the increase in capacitance when the connection to the electrode is made should be taken into account in calculating the spark energy. In all calculations of energy the total capacitance of the discharge circuit should be used, and the voltage at the time of discharge.

Figure C.1 illustrates the general arrangement of the test apparatus.



su3232

Key

U_0 charging voltage
U_p discharge voltage
C_0 storage capacitance
C_p parasitic capacitance
L inductance (additional)
HVR high-voltage relay

Figure C.1

Circuit – Triggering by high-voltage relay, using a two-electrode system

For very low energies the unavoidable parasitic capacity of the electrode arrangement is in the same order of magnitude as the value of the storage capacitor. Therefore the parasitic capacity is to be kept constant and the voltage of the spark is calculated as follows:

$$U_p = U_0 \times C_0 / (C_0 + C_p)$$

This results in a spark energy E according to the following equation:

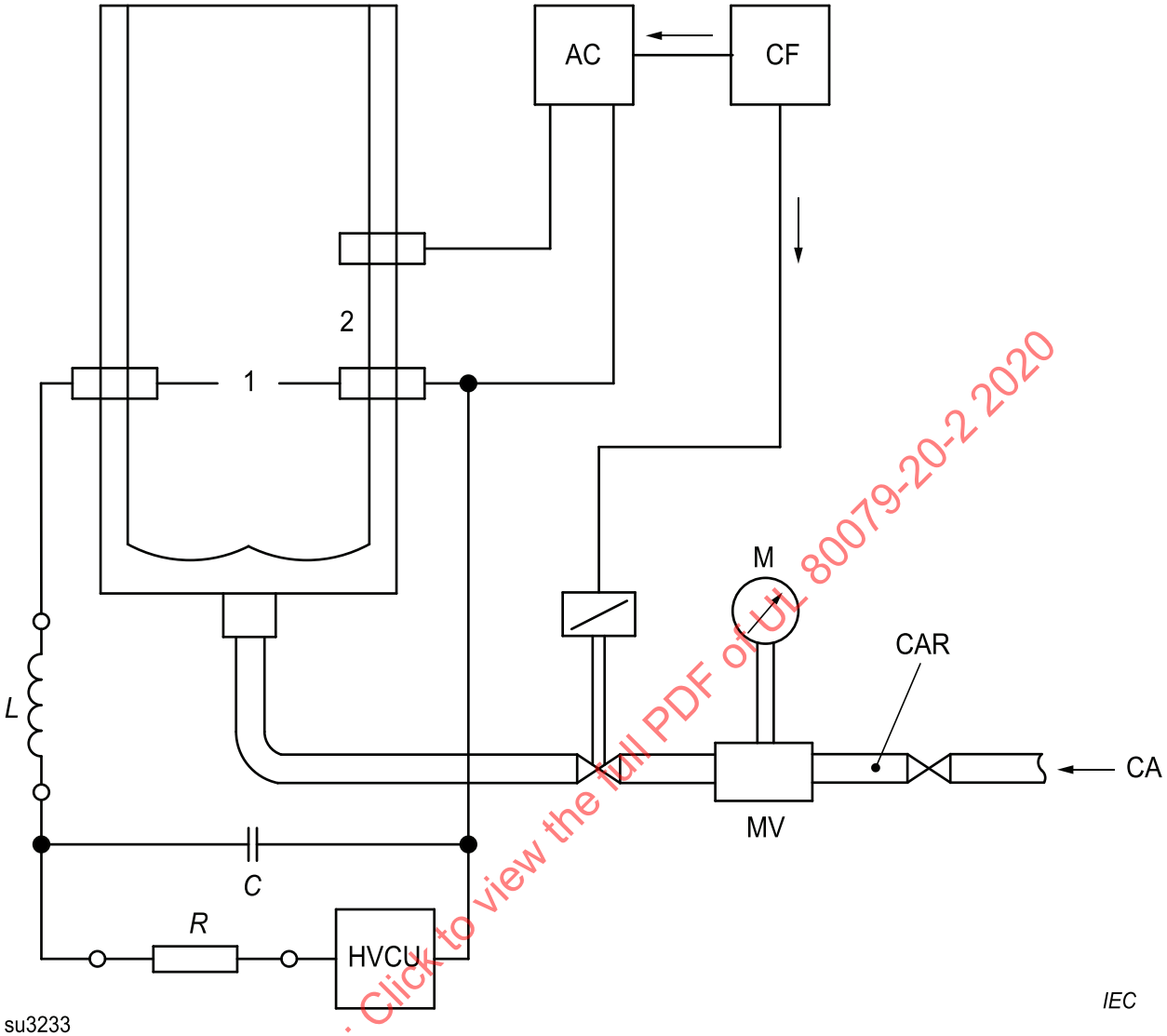
$$E = 0,5 \times (C_0 + C_p) \times U_p{}^2$$

The storage capacitor C_0 acquired the charge $Q_0 = U_0 \times C_0$. After switching of the relay “HVR”, the charge is retained, but the voltage U_0 is lowered to U_p.

This triggering circuit is suitable only for very low energies of the spark. For energies above 10 mJ the high voltage relay is not able to handle the high discharge current.

C.2 Triggering by auxiliary spark using three-electrode system

Figure C.2 illustrates the general arrangement of the test apparatus.



Key

1 main spark gap
2 auxiliary electrode
AC auxiliary circuit
CF control facility
CAR compressed air reservoir
CA compressed air
M manometer
MV magnetic valve
V shut-off valve
C test capacitor
HVCU charging unit
L inductance
R charging resistance

Figure C.2

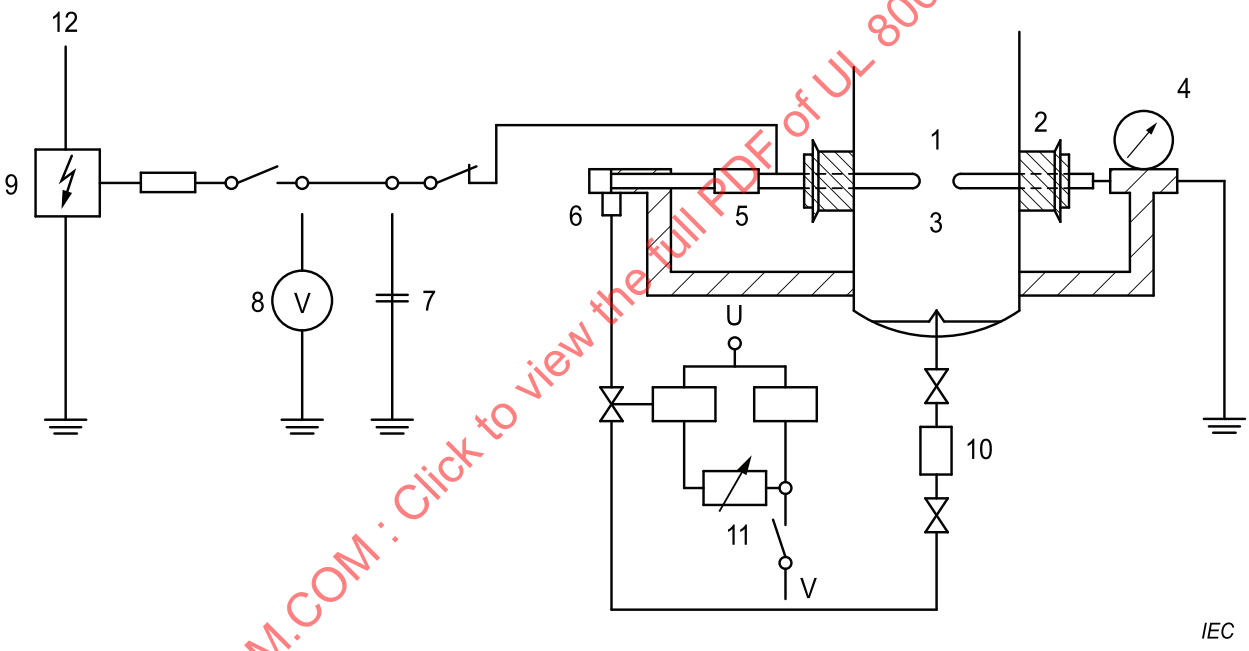
Apparatus for determining the minimum ignition energies of dust (schematic) – Triggering by auxiliary spark using three-electrode system

The essential component is a three-electrode spark gap. The two electrodes forming the main spark gap (1) are 3,2 mm in diameter, their ends being reduced to a diameter of 2,0 mm over a length of 20 mm. The free end of the auxiliary electrode (2) is angled toward the main spark gap, the length of this angled portion being 20 mm. This electrode arrangement is installed in an open-top Hartmann tube and is also suitable for installation in other explosion vessels.

Following the introduction into the mixture-generating device of the desired quantity of dust, the tube is placed in position. The test capacitor C (20 pF to 10 000 pF), which stores the ignition energy, is charged by means of the high-voltage charging unit HVCU across the charging resistance *R* which limits the charging current to 1 mA. The attempts to ignite the dust/air mixture are initiated by means of the control facility CF. Initiation of each attempt involves, first of all, triggering the device which disperses the dust into suspension, followed, after a predetermined interval, by the auxiliary spark and, with it, the triggering of the main spark discharge by the test capacitor. The energy of the auxiliary circuit is limited to not more than one-tenth of the energy of the main discharging circuit.

C.3 Triggering by electrode movement

Figure C.3 illustrates the general arrangement of the test apparatus.



Key

1 open-top Hartmann tube
2 PTFE stoppers
3 electrodes
4 micrometer screw
5 PTFE insulating piece
6 double-acting pneumatic piston
7 capacitor
8 electrostatic voltmeter
9 high-voltage generator (5 to 10 kV)
10 pressure vessel
11 timing device

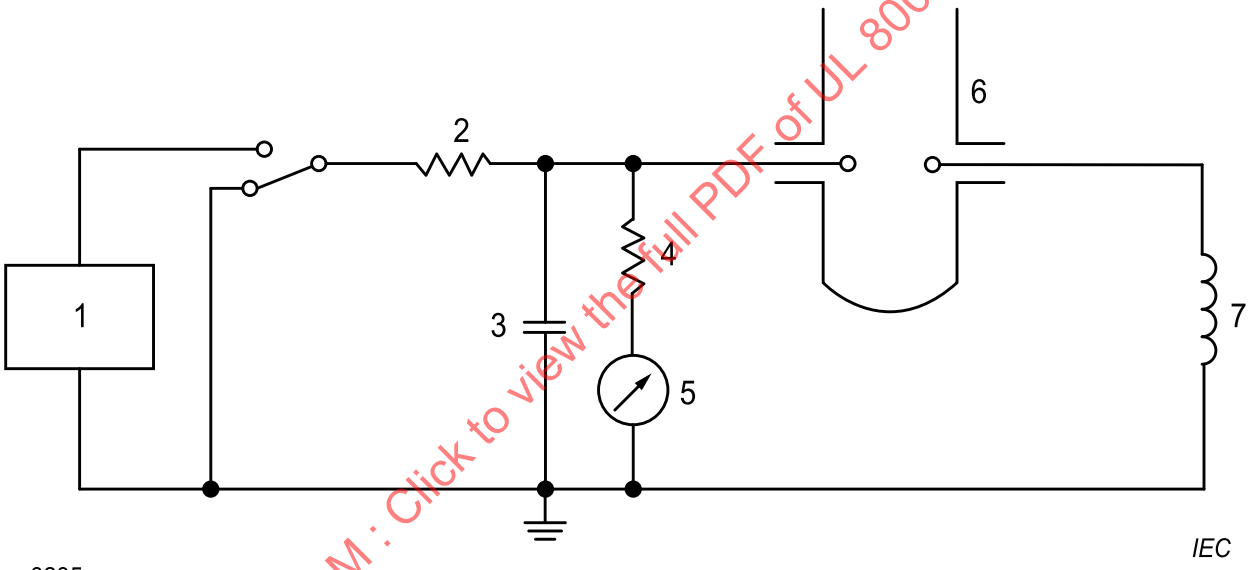
Figure C.3

Apparatus for determining the minimum ignition energies of dust (schematic) – Triggering by electrode movement

PTFE stoppers (2) are fitted into the two electrode mounting ports in an open-top Hartmann tube (1). These stoppers are bored in order to receive the electrodes (3) in a manner permitting them to be moved. One of the electrodes, which is at earth potential, is attached to the measuring rod of a micrometer screw (4). The yoke of the micrometer is shortened, and is fastened to the modified Hartmann tube. The other electrode, to which the high voltage is applied, is attached to the pushrod of a controllable, double-acting pneumatic piston (6) (piston nominal diameter: 35 mm; operating pressure: 600 kPa) which has a working travel of 10 mm, attachment being through a PFTE insulating piece (5). The high-voltage electrode is electrically connected to a capacitor (7) with a value between 26 pF and 311 µF. The voltage to which this capacitor is charged is indicated by means of an electrostatic voltmeter (8). After disconnecting the high-voltage generator (9) from the capacitor circuit, air is released electro-pneumatically from the pressure vessel (10) in which it is stored under pressure in such a way as to form a dust/air mixture by dispersing the dust in suspension. After a delay, which is set with the aid of a timing device (11), the high-voltage electrode is shot into the position defining the spark-gap length, the energy stored in the capacitor then being liberated at the spark gap.

C.4 Triggering by voltage increase (trickle-charging circuit)

Figure C.4 illustrates the general arrangement of the test apparatus.



Key

1 d.c. voltage source
2 current-limiting resistor
3 capacitor
4 decoupling resistor
5 electrostatic volt meter
6 inductance of 1 mH

Figure C.4

Apparatus for determining the minimum ignition energies of dust (schematic) – Triggering by voltage increase

The trickle-charging circuit is one of the simplest methods for producing sparks of known energy which are required for determining the minimum ignition energy of dust/air mixtures.

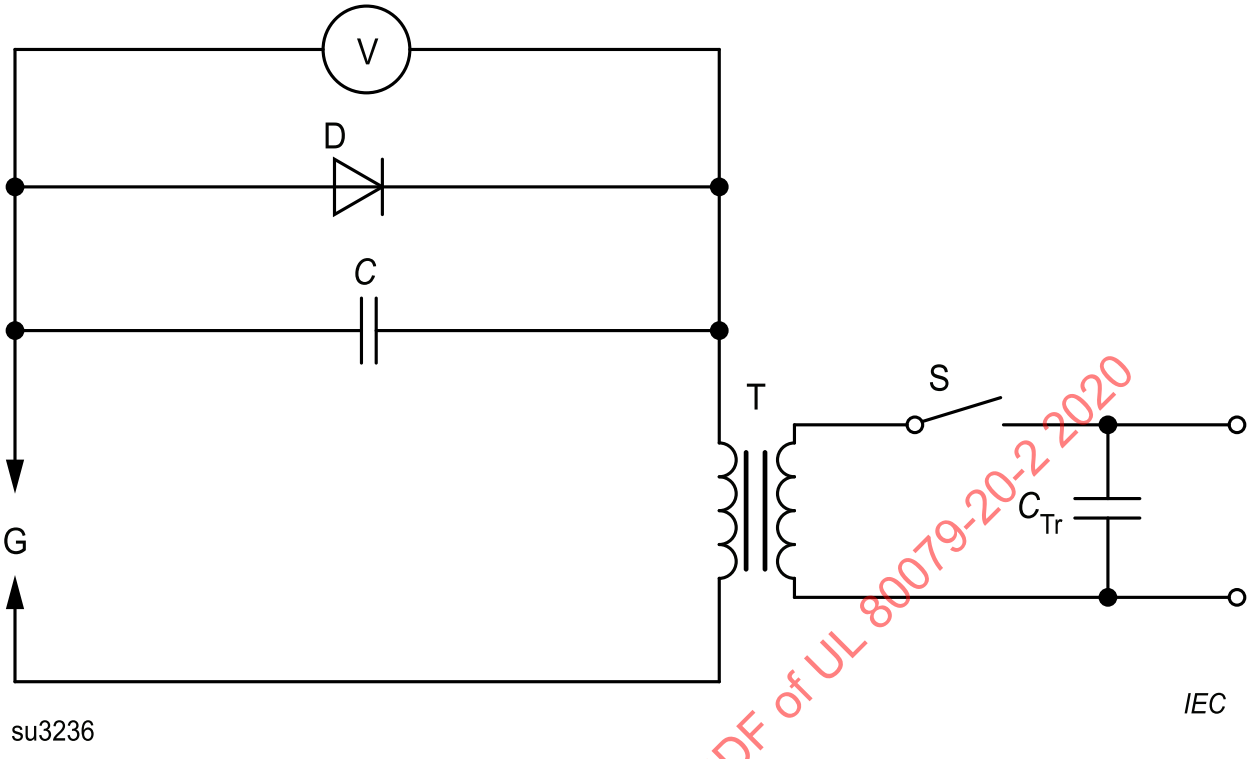
A high-voltage d.c supply slowly raises the potential of the capacitor until a spark occurs. The cycle is then repeated, giving a series of sparks, each of the same energy. A current-limiting resistor with a value between 10^8 Ω and 10^9 Ω is included in the circuit. The potential across the capacitor is measured by an electrostatic voltmeter with a decoupling resistor in series having a value between 10^8 Ω and 10^9 Ω. Sparks of any energy level from 1 mJ upwards can be readily produced using this circuit by varying the value of the capacitor and, if necessary, the discharge voltage.

The settings for sparks of the required energy are determined before any dust is placed in the ignition chamber. A capacitor of the appropriate value is chosen and a voltage in the range 10 kV to 30 kV selected. The voltage and electrode separation are then adjusted by trial until sparks of the required energy, given by 0,5 CU^2 occur at the electrodes. In this expression, U is the voltage at which the spark occurs and C is the total capacitance at the high-voltage electrode, which can be measured using normal a. c. bridge methods. In order to make an ignition test, the high-voltage electrode is earthed and the required quantity of the prepared dust is placed in the dispersion cup. The d. c. voltage supply is then switched into the circuit, and, as sparks start to pass between the electrodes, the dust is dispersed by an air jet. It is noted whether ignition occurs and whether the flame propagates away from the spark gap.

The first tests are usually performed with a high-spark energy typically 500 mJ. If there is an ignition, the spark energy is then reduced in steps, and the test repeated until ignition does not occur, as described in 8.3.

C.5 Triggering by auxiliary spark, using normal two-electrode system – Trigger transformer in discharge circuit

Figure C.5 illustrates the general arrangement of the test apparatus.



Key

C main capacitor

C_{Tr} trigger circuit capacitor

D diode

S switch

T transformer

G spark gap

Figure C.5

Apparatus for determining the minimum ignition energies for dust (schematic) – Trigger transformer in discharge circuit

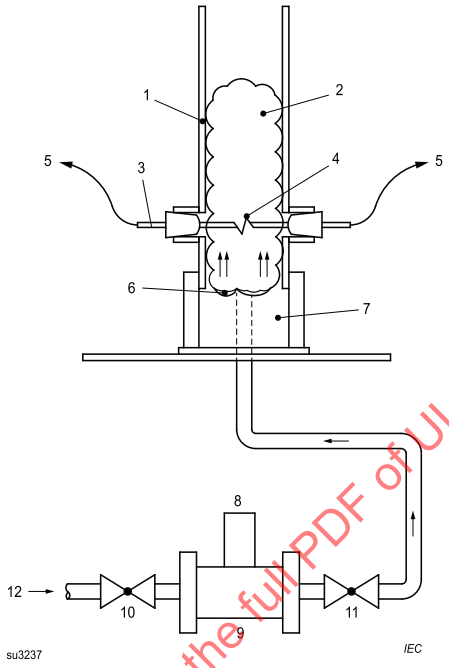
This circuit cannot be used for tests without inductance. *C* is the discharge capacitor, having an initial voltage of *U*. By having a range of capacitors from 40 pF and downwards in steps of a factor of 10, and variable voltage from 1 000 V downwards (400 V to 500 V is a practical minimum level), a wide selection of 0,5 CU^2 values is available. Initiation of spark discharge at the desired moment, which is essential if synchronization of spark discharge with the formation of a transient dust cloud is required, is accomplished by means of the trigger circuit in which the capacitor C_{Tr} a switch S, and the primary coil of the trigger transformer T constitute the essential elements. By closing the switch, a high-voltage pulse of approximately 15 kV peak value is induced in the secondary coil of the transformer, causing breakdown of the spark gap G, and thereby discharge of the main capacitor *C*. Experience has shown that it is very difficult to reduce the energy input to the spark gap by the trigger spark below 2 mJ to 5 mJ. For this reason, this trigger principle is only applicable to spark energies above 5 mJ.

The net spark energies generated for various combinations of *C* and *U* are determined in the conventional way by measuring current and voltage at the spark gap as functions of time and integrating the power-versus-time curve. The function of the diode D is to produce unidirectional discharges only. The self-inductance of the secondary coil of the trigger transformer should be 1 mH to 2 mH.

Annex D
(normative)

Vertical tube (modified Hartmann tube) apparatus

Figure D.1 illustrates the cross-sectional arrangement of a modified Hartmann tube apparatus.



Key

1 dispersion tube
2 dust cloud
3 electrode
4 spark gap
5 high voltage supply
6 test sample
7 dispersion cup
8 pressure gauge
9 air reservoir
10 solenoid valve
11 solenoid valve
12 air

Figure D.1
Vertical tube apparatus (modified Hartmann tube)

Annex E
(informative)

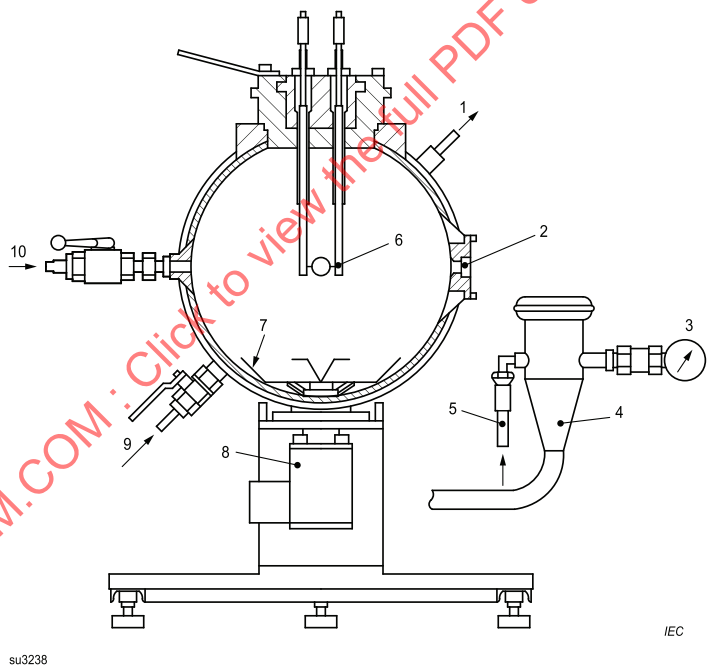
20-litre sphere

The explosion vessel is an explosion resistant sphere made of stainless steel, with an inner volume of 20 litres. A water jacket serves to dissipate the heat from the explosions. For testing, the dust is dispersed into the sphere from a pressurised dust container via the fast acting valve and a rebound nozzle. Figure E.2 and Figure E.3 illustrate such a rebound nozzle. The fast acting valve is pneumatically opened and closed by means of an auxiliary piston. The valves for the compressed air are activated electrically. The ignition source is located in the centre of the sphere. The pressure measuring system includes at least two pressure sensors, recording and control equipment (see Figure E.1). The explosion vessel should be designed to withstand an overpressure of at least 2 000 kPa. The vessel has means for establishing vacuum.

If it is not possible to adequately disperse the material with the rebound nozzle, alternative methods of testing the material are as follows:

– another nozzle, e.g. the mushroom cup shown in Figure E.4 can be used, or

– the material is to be sieved such that the particle size range is reduced to the point that it can be dispersed



Key

1 water outlet
2 pressure sensor
3 manometer
4 dust container (0,6 l)
5 air inlet
6 ignition source
7 rebound nozzle
8 fast acting valve
9 water inlet
10 outlet (air, reaction products)

Figure E.1

Test equipment 20-litre sphere (schematic)