BS EN 60079-25:2010

*Incorporating corrigendum September 2013*

BSI Standards Publication



# Explosive atmospheres

## Part 25: Intrinsically safe electrical systems

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## National foreword

This British Standard is the UK implementation of EN 60079-25:2010, incorporating corrigendum September 2013. It is identical to IEC 60079-25:2010. It supersedes BS EN 60079-25:2004 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee EXL/31, Equipment for explosive atmospheres, to Subcommittee EXL/31/2, Intrinsically safe apparatus.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.



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**Compliance with a British Standard cannot confer immunity from legal obligations.**

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| 31 October 2013 | Implementation of CENELEC corrigendum September 2013: Supersession information on CENELEC title and foreword pages updated |

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

# EN 60079-25

October 2010

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Supersedes EN 60079-25:2004 and EN 50394-1:2004

English version



## Explosive atmospheres - Part 25: Intrinsically safe electrical systems (IEC 60079-25:2010)

Atmosphères explosives - Partie 25: Systèmes électriques de sécurité intrinsèque (CEI 60079-25:2010)

Explosionsfähige Atmosphäre - Teil 25: Eigensichere Systeme (IEC 60079-25:2010)

This European Standard was approved by CENELEC on 2010-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Ref. No. EN 60079-25:2010 E

## Foreword

The text of document 31G/202/FDIS, future edition 2 of IEC 60079-25, prepared by SC 31G, Intrinsically-safe apparatus, of IEC TC 31, Equipment for explosive atmospheres, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60079-25 on 2010-10-01.



This European Standard supersedes EN 60079-25:2004 and EN 50394-1:2004.

The significant changes with respect to EN 60079-25:2004 are:

– extension of the scope from Group II to Groups I, II and III;

– introduction of level of protection "ic";

– addition of requirements for cables and multi-core cables;

– reference to EN 60079-11 regarding the termination of intrinsically safe circuits;

– requirements for the assessment of an expanded and clarified intrinsically safe system regarding level of protection "ic", simple apparatus and faults in multi-core cables;

– introduction of predefined systems and merging of the system requirements for FISCO from EN 60079-27;

– addition of requirements for simple intrinsically safe systems containing both lumped inductance and lumped capacitance;

– addition of a method for testing the electrical parameters of cables;

– additional information for the use of simple apparatus in systems.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

The following dates were fixed:

| | | |
|---|---|---|
| – latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2011-07-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2013-10-01 |

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EC Directive 94/9/EC. See Annex ZZ.

Annexes ZA and ZZ have been added by CENELEC.

## Endorsement notice

The text of the International Standard IEC 60079-25:2010 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 60529 NOTE Harmonized as EN 60529.

# Annex ZA
(normative)

## Normative references to international publications with their corresponding European publications



The following referenced documents are indispensable for the application 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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

| Publication | Year | Title | EN/HD | Year |
|---|---|---|---|---|
| IEC 60060-1 | - | High-voltage test techniques - Part 1: General definitions and test requirements | EN 60060-1 | - |
| IEC 60079-0 | - | Explosive atmospheres - Part 0: Equipment - General requirements | EN 60079-0 | - |
| IEC 60079-11 | 2006 | Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i" | EN 60079-11 | 2007 |
| IEC 60079-14 | 2007 | Explosive atmospheres - Part 14: Electrical installations design, selection and erection | EN 60079-14 | 2008 |
| IEC 60079-15 | - | Explosive atmospheres – Part 15: Equipment protection by type of protection "n" | EN 60079-15 | - |
| IEC 60079-27 | 2008 | Explosive atmospheres - Part 27: Fieldbus intrinsically safe concept (FISCO) | EN 60079-27 | 2008 |
| IEC 61158-2 | - | Industrial communication networks - Fieldbus specifications - Part 2: Physical layer specification and service definition | EN 61158-2 | - |
| IEC 61241-0 | - | Electrical apparatus for use in the presence of combustible dust - Part 0: General requirements | EN 61241-0 | - |
| IEC 61241-11 | - | Electrical apparatus for use in the presence of combustible dust - Part 11: Protection by intrinsic safety 'iD' | EN 61241-11 | - |

# Annex ZZ
(informative)

## Coverage of essential requirements of the directive 94/9/EC



This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers only the following essential safety requirements out of those given in Annex II of the EC Directive 94/9/EC:

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive concerned.

WARNING: Other requirements and other EC Directives may be applicable to the products falling within the scope of this standard.

| ESR | Equivalent requirement in EN 60079-25:2010 |
|---|---|
| 1.0.1 | fundamental basis of standard |
| 1.0.2 | Fundamental principle of intrinsic safety technique applied throughout this standard and apparatus standard EN 60079-11 and EN 60079-0 |
| 1.0.3 | Requirement primarily met by apparatus standard EN 60079-11 and the maintenance requirements specified in EN 60079-14 and EN 60079-17. |
| 1.0.4 | EN 60079-0 Clause 5, Subclauses 6.1, 6.2, 7.2 and 7.3 |
| 1.0.5 | Clause 14, EN 60079-0 Clause 29 and Foreword |
| 1.0.6 a | Clause 4 |
| 1.1.1 | EN 60079-0 Clause 8.1 |
| 1.1.3 | EN 60079-0 Clause 7, 8, 12 |
| 1.2.1 | The system and apparatus standards represent the latest state of the art |
| 1.2.2 | Requirement met by apparatus standard, EN 60079-0 Clause 13 and clause 13.2 of this standard |
| 1.2.4 | Clause 5 also covers Group III, details in EN 60079-0 and EN 60079-11 |
| 1.2.6 | Covered by EN 60079-11 |
| 1.3.1 | Sparks and hot surfaces covered in Clause 13 and in EN 60079-11. Other potential ignition sources covered in EN 60079-0 |
| 1.3.2 | EN 60079-0, Subclause 7.4 |
| 1.3.3 to 1.3.5 | EN 60079-0 |
| 1.4 | EN 60079-0 and EN 60079-11 |
| 2.0.1 and 2.0.2 | 'ia' apparatus and systems in accordance with EN 60079-11 and this standard meet the 'two fault' criterion (M1) and 'ib' apparatus and systems in accordance with EN 60079-11 and this standard meet the 'one fault' criterion (M2) and the other criterions |
| 2.1.1 and 2.1.2 | 'ia' apparatus and systems in accordance with EN 60079-11/EN 61241-11 and this standard meet the 'two fault' criterion (1G and 1D) and the other criterions |
| 2.2.1 and 2.2.2 | 'ib' apparatus and systems in accordance with EN 60079-11/EN 61241-11 and this standard meet the 'one fault' criterion (2G and 2D) and the other criterions |
| 2.3.1 and 2.3.2 | 'ic' apparatus and systems in accordance with EN 60079-11/EN 61241-11 and this standard meet the 'safe in normal operation' criterion (3G and 3D) and the other criterions |

CONTENTS

# EXPLOSIVE ATMOSPHERES –

## Part 25: Intrinsically safe electrical systems



## 1 Scope

This part of IEC 60079 contains the specific requirements for construction and assessment of intrinsically safe electrical systems, type of protection "i", intended for use, as a whole or in part, in locations in which the use of Group I, II or III apparatus is required.

NOTE 1 This standard is intended for use by the designer of the system who may be a manufacturer, a specialist consultant or a member of the end-user's staff.

This standard supplements and modifies the general requirements of IEC 60079-0 and the intrinsic safety standard IEC 60079-11. Where a requirement of this standard conflicts with a requirement of IEC 60079-0 or IEC 60079-11, the requirement of this standard takes precedence.

This standard supplements IEC 60079-11, the requirements of which apply to electrical apparatus used in intrinsically safe electrical systems.

The installation requirements of Group II or Group III systems designed in accordance with this standard are specified in IEC 60079-14.

NOTE 2 Group I installation requirements are presently not provided in IEC 60079-14.

## 2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-11:2006, *Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"*

IEC 60079-14:2007, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

IEC 60079-15, *Electrical apparatus for explosive gas atmospheres – Part 15: Construction, test and marking of type of protection "n" electrical apparatus*

IEC 60079-27:2008, *Explosive atmospheres – Part 27: Fieldbus intrinsically safe concept (FISCO)*

IEC 61158-2, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61241-0, *Electrical apparatus for use in the presence of combustible dust – Part 0: General requirements*

IEC 61241-11, *Electrical apparatus for use in the presence of combustible dust – Part 11: Protection by intrinsic safety 'iD'*



# 3 Terms, definitions and abbreviations

## 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions, specific to intrinsically safe electrical systems, apply. They supplement the terms and definitions which are given in IEC 60079-0 and IEC 60079-11.

**3.1.1**
**intrinsically safe electrical system**
assembly of interconnected items of electrical apparatus, described in a descriptive system document, in which the circuits or parts of circuits, intended to be used in an explosive atmosphere, are intrinsically safe circuits

**3.1.2**
**certified intrinsically safe electrical system**
intrinsically safe electrical system conforming to 3.1.1 for which a certificate has been issued confirming that the electrical system complies with IEC 60079-25

**3.1.3**
**uncertified intrinsically safe electrical system**
intrinsically safe electrical system conforming to 3.1.1 for which the knowledge of the electrical parameters of the items of certified intrinsically safe electrical apparatus, certified associated apparatus, simple apparatus and the knowledge of the electrical and physical parameters of the interconnecting wiring permit the unambiguous deduction that intrinsic safety is preserved

**3.1.4**
**descriptive system document**
document in which the items of electrical apparatus, their electrical parameters and those of the interconnecting wiring are specified

**3.1.5**
**system designer**
person who is responsible for the descriptive system document, has the necessary competence to fulfil the task and who is empowered to enter into the commitments on behalf of his employer

**3.1.6**
**maximum cable capacitance**
$C_c$
maximum capacitance of the interconnecting cable that can be connected into an intrinsically safe circuit without invalidating intrinsic safety

**3.1.7**
**maximum cable inductance**
$L_c$
maximum inductance of the interconnecting cable that can be connected into an intrinsically safe circuit without invalidating intrinsic safety

**3.1.8**
**maximum cable inductance to resistance ratio**
$L_c/R_c$
maximum value of the ratio inductance ($L_c$) to resistance ($R_c$) of the interconnecting cable that can be connected into an intrinsically safe circuit without invalidating intrinsic safety

**3.1.9**
**linear power supply**
power source from which the available output current is determined by a resistor; the output voltage decreases linearly as the output current increases

**3.1.10**
**non-linear power supply**
power supply where the output voltage and output current have a non-linear relationship

NOTE For example, a supply with a constant voltage output that can reach a constant current limit controlled by semiconductors.

### 3.2 Abbreviations

FISCO Fieldbus Intrinsically Safe Concept
FNICO Fieldbus Non-Incendive Concept

## 4 Descriptive system document

A descriptive system document shall be created for all systems. The descriptive system document shall provide an adequate analysis of the safety achieved by the system.

NOTE Annex E comprises examples of typical diagrams, which illustrate the requirements of the descriptive system document.

The minimum requirements are as follows:

a) block diagram of the system listing all the items of apparatus within the system including simple apparatus and the interconnecting wiring. An example of such a diagram is shown in Figure E.1;
b) a statement of the group subdivision (for Groups II and III), the level of protection for each part of the system, the temperature classification, and the ambient temperature rating in accordance with Clauses 5, 6 and 7;
c) the requirements and permitted parameters of the interconnecting wiring in accordance with Clause 8;
d) details of the earthing and bonding points of the systems in accordance with Clause 11. When surge protection devices are used, an analysis in accordance with Clause 12 shall also be included;
e) where applicable, the justification of the assessment of apparatus as simple apparatus in accordance with IEC 60079-11 shall be included;
f) where the intrinsically safe circuit contains several pieces of intrinsically safe apparatus the analysis of the summation of their parameters shall be available. This shall include all simple apparatus and certified intrinsically safe apparatus;
g) a unique identification of the descriptive system document shall be created;
h) the system designer shall sign and date the document.

NOTE The descriptive system’s drawing is not the same as the Control Drawing referred to in IEC 60079-11.

## 5 Grouping and classification

Intrinsically safe electrical systems shall be placed in a Group I, Group II or Group III as defined in IEC 60079-0. Groups II and III intrinsically safe electrical systems as a whole or parts thereof shall be given a further subdivision of the Group as appropriate.

Apparatus within Groups II and III intrinsically safe electrical system, intended for use in explosive gas or dust atmospheres, shall be given a temperature class or maximum surface temperature in accordance with IEC 60079-0, IEC 60079-11, IEC 61241-0 and IEC 61241-11 as applicable.

NOTE 1 In Group II and Group III intrinsically safe electrical systems, or parts thereof, the subdivisions A, B, C may be different from those of the particular intrinsically safe electrical apparatus and associated electrical apparatus included in the system.

NOTE 2 Different parts of the same intrinsically safe electrical system may have different subdivisions (A, B, C). The apparatus used may have different temperature classes and different ambient temperature ratings.



## 6 Levels of protection

### 6.1 General

Each part of an intrinsically safe electrical system intended for use in an explosive atmosphere will have a level of protection of “ia”, “ib” or “ic” in accordance with IEC 60079-11. The complete system need not necessarily have a single level of protection.

NOTE 1 For example, where an instrument is primarily an “ib” instrument but which is designed for the connection of an “ia” sensor, such as a pH measuring instrument with its connected probe, the part of the system up to the instrument is “ib” and the sensor and its connections “ia”.

NOTE 2 An “ia” field instrument powered via an “ib” associated apparatus would be considered as an “ib” system.

NOTE 3 A system may be “ib” in normal operation with external power, but when power is removed under defined safety circumstances (ventilation failure) then the system could become “ia” under back up battery power. The level of protection will be clearly defined for foreseeable circumstances.

Clause 13 contains details of the required assessment.

### 6.2 Level of protection “ia”

Where the requirements applicable to electrical apparatus of level of protection “ia” (see IEC 60079-11) are satisfied by an intrinsically safe system or part of a system considered as an entity, then that system or part of a system shall be placed in level of protection “ia”.

### 6.3 Level of protection “ib”

Where the requirements applicable to electrical apparatus of level of protection “ib” (see IEC 60079-11) are satisfied by an intrinsically safe system or part of a system considered as an entity, then that system or part of a system shall be placed in level of protection “ib”.

### 6.4 Level of protection “ic”

Where the requirements applicable to electrical apparatus level of protection “ic” (see IEC 60079-11) are satisfied by an intrinsically safe system or part of a system considered as an entity, then the system or part of a system shall be placed in level of protection “ic”.

## 7 Ambient temperature rating

Where part or all the intrinsically safe system is specified as being suitable for operation outside the normal operating temperature range of –20 °C and +40 °C, this shall be specified in the descriptive system document.

## 8 Interconnecting wiring / cables used in an intrinsically safe electrical system

The electrical parameters of the interconnecting wiring upon which intrinsic safety depends and the derivation of these parameters shall be specified in the descriptive system document. Alternatively, a specific type of cable shall be specified and the justification for its use included in the documentation. Cables for the interconnecting wiring shall comply with the relevant requirements of Clause 9.

Where relevant, the descriptive system document shall also specify the permissible types of multi-core cables as specified in Clause 9, which each particular circuit may utilize. In the particular case where faults between separate circuits have not been taken into account, then a note shall be included on the block diagram of the descriptive system document stating the following: “where the interconnecting cable utilizes part of a multi-core cable containing other intrinsically safe circuits, then the multi-core cable shall be in accordance with the requirements of a multi-core cable type A or B, as specified in Clause 9 of IEC 60079-25”.

A multi-core cable containing circuits classified as level of protection “ia”, “ib” or “ic” shall not contain non-intrinsically safe circuits.

“ic” multi-core cables may contain more than one intrinsically safe “ia”, “ib” or “ic” circuit subject to the applicable faults specified in Clause 13.

NOTE Multi-core cables not complying with type A or B are permitted if the specific combination of circuits is examined against the requirements of IEC 60079-11.

Intrinsically safe “ic” circuits shall only be run together with intrinsically safe “ia” and “ib” circuits provided they are run in a multi-core cable of type A or type B specified in 9.5.

## 9 Requirements of cables and multi-core cables

### 9.1 General

The diameter of individual conductors or strands of multi-stranded conductors within the hazardous area shall not be less than 0,1 mm.

Only insulated cables with insulation capable of withstanding a dielectric test of at least 500 V a.c. or 750 V d.c. shall be used in intrinsically safe circuits.

NOTE This clause is not intended to prevent the use of bare conductors in a signalling system and these should be considered as simple apparatus and not interconnecting wiring.

### 9.2 Multi-core cables

The radial thickness of the insulation of each core shall be appropriate to the conductor diameter and the nature of the insulation with a minimum of 0,2 mm.

Multi-core cables shall be capable of withstanding a dielectric test of at least:

a) 500 V r.m.s. a.c. or 750 V d.c. applied between any armouring and/or screen(s) joined together and all the cores joined together.
b) 1 000 V r.m.s. a.c. or 1 500 V d.c. applied between a bundle comprising one half of the cable cores joined together and a bundle comprising the other half of the cores joined

together. This test is not applicable to multi-core cables with conducting screens for individual circuits.

The dielectric strength test shall be carried out in accordance with an appropriate cable standard or dielectric strength tests of IEC 60079-11.



### 9.3 Electrical parameters of cables

The electrical parameters ($C_c$ and $L_c$ or $C_c$ and $L_c/R_c$) for all cables used within an intrinsically safe system shall be determined according to a), b) or c):

a) the most onerous electrical parameters provided by the cable manufacturer;

b) electrical parameters determined by measurement of a sample, with the method of testing electrical parameters of cables given in Annex G;

c) where the interconnection comprises two or three cores of a conventionally constructed cable (with or without screen), 200 pF/m and either 1 µH/m or an inductance to resistance ratio ($L_c/R_c$) calculated by dividing 1 µH by the manufacturers specified loop resistance per meter. Alternatively, for currents up to $I_o$ = 3 A an $L/R$ ratio of 30 µH/Ω may be used.

Where a FISCO or FNICO system is used, the requirements for the cable parameters shall comply with Annex I.

### 9.4 Conducting screens

Where conducting screens provide protection for separate intrinsically safe circuits in order to prevent such circuits becoming connected to one another, the coverage of those screens shall be at least 60 % of the surface area.

### 9.5 Types of multi-core cables

#### 9.5.1 General

Multi-core cables shall be classified as either type A, type B or type C for the purposes of applying faults and assessing the safety of the cabling within an intrinsically safe system. The cable types are specified in 9.5.2, 9.5.3, and 9.5.4.

The use of multi-core cables that do not comply with the requirements for types A, B, or C is not permitted.

#### 9.5.2 Type A cable

A cable whose construction complies with 9.1, 9.2, 9.3 and has conducting screens providing individual protection for each intrinsically safe circuit according to 9.4.

#### 9.5.3 Type B cable

A cable whose construction complies with 9.1, 9.2 and 9.3, is fixed and effectively protected against damage and does not contain any circuit with a maximum voltage $U_o$ exceeding 60 V.

#### 9.5.4 Type C cable

A cable whose construction complies with 9.1, 9.2 and 9.3.

## 10 Termination of intrinsically safe circuits

Intrinsically safe systems that contain junction boxes or marshalling cubicles where intrinsically safe circuits are terminated shall comply with the terminal requirements in the facilities for the connection of external circuits of IEC 60079-11.

## 11 Earthing and bonding of intrinsically safe systems

In general, an intrinsically safe circuit shall either be fully floating or bonded to the reference potential associated with a hazardous area at one point only. The level of isolation required (except at that one point) is to be designed to withstand a 500 V insulation test in accordance with the dielectric strength requirement of IEC 60079-11. Where this requirement is not met, the circuit shall be considered to be earthed at that point. More than one earth connection is permitted on a circuit, provided that the circuit is galvanically separated into sub-circuits, each of which has only one earth point.

Screens shall be connected to earth or the structure in accordance with IEC 60079-14. Where a system is intended for use in an installation where significant potential differences (greater than 10 V) between the structure and the circuit can occur, the preferred technique is to use a circuit galvanically isolated from external influences such as changes in ground potential at some distance from the structure. Particular care is required where part of the system is intended to be used in Zone 0 or Zone 20 locations or when the system has a very high level of protection so as to conform to EPL Ma requirements.



The descriptive system document should clearly indicate which point or points of the system are intended to be connected to the plant reference potential and any special requirements of such a bond. This may be achieved by adding a reference to IEC 60079-14 in the descriptive system document.

NOTE IEC 60079-14 does not apply to electrical installations in mines susceptible to firedamp.

## 12 Protection against lightning and other electrical surges

Where a risk analysis shows that an installation is particularly susceptible to lightning or other surges, precautions shall be taken to avoid the possible hazards.

If part of an intrinsically safe circuit is installed in Zone 0 in such a way that there is a risk of developing hazardous or damaging potential differences within Zone 0, a surge protection device shall be installed. Surge protection is required between each conductor of the cable including the screen and the structure where the conductor is not already bonded to the structure. The surge protection device shall be installed outside but as near to the boundary of Zone 0 as is practicable, preferably within 1 m.

Surge protection for apparatus in Zones 1 and 2 shall be included in the system design for highly susceptible locations.

The surge protection device shall be capable of diverting a minimum peak discharge current of 10 kA (8/20 μs impulse according to IEC 60060-1 for 10 operations). The connection between the protection device and the local structure shall have a minimum cross-sectional area equivalent to 4 $mm^2$ copper. The cable between the intrinsically safe apparatus in Zone 0 and the surge protection device shall be installed in such a way that it is protected from lightning. Any surge protection device introduced into an intrinsically safe circuit shall be suitably explosion protected for its intended location.

The use of surge protection devices which interconnect the circuit and the structure via non-linear devices such as gas discharge tubes and semiconductors is not considered to adversely affect the intrinsic safety of a circuit, provided that in normal operation the current through the device is less than 10 μA.

NOTE If insulation testing at 500 V is carried out under well-controlled conditions, then it may be necessary to disconnect the surge suppression devices to prevent them invalidating the measurement.

Intrinsically safe systems utilizing surge suppression techniques shall be supported by an adequately documented analysis of the effect of indirect multiple earthing, taking into account the criteria set out above. The capacitance and inductance of the surge suppression devices shall be considered in the assessment of the intrinsically safe system.

Annex F illustrates some aspects of the design of surge protection of an intrinsically safe system.



## 13 Assessment of an intrinsically safe system

### 13.1 General

Where a system contains apparatus which does not separately conform to IEC 60079-11, then that system shall be analysed as a whole, as if it were an apparatus. A level of protection “ia” system shall be analysed in accordance with the level of protection “ia” criteria of IEC 60079-11. A level of protection “ib” system shall be analysed in accordance with the level of protection “ib” criteria of IEC 60079-11. A level of protection “ic” system shall be analysed in accordance with the level of protection “ic” criteria of IEC 60079-11. In addition to the faults within the apparatus, the failures within the field wiring listed in 13.4 shall also be taken into account.

NOTE It is recognized that applying faults to the system as a whole is less stringent than applying faults to each piece of apparatus; nevertheless, this is considered to achieve an acceptable level of safety.

Where all the necessary information is available, it is permissible to apply the fault count to the system as a whole even when apparatus conforming to IEC 60079-11 is being used. This is an alternative solution to the more usual straightforward comparison of input and output characteristics of the separately analysed or tested apparatus. Where a system contains only separately analysed or tested apparatus conforming to IEC 60079-11, the compatibility of all the apparatus included in the system shall be demonstrated. Faults within the apparatus have already been considered and no further consideration of these faults is necessary. Where a system contains a single source of power, the output parameters of the power source take into account opening, shorting and earthing of the external interconnecting cable, and consequently these failures do not need to be further considered. Annex A contains further details of the analysis of these simple circuits.

When a system contains more than one linear source of power, then the effect of the combined sources of power shall be analysed. Annex B illustrates the analysis to be used in the most frequently occurring combinations.

If an intrinsically safe system contains more than one source of power, and one or more of these sources are non-linear, the assessment method described in Annex B cannot be used. For this kind of intrinsically safe system, Annex C explains how the system analysis can be conducted if the combination contains a single non-linear power supply.

Figure 1 illustrates the principles of the system’s analysis.

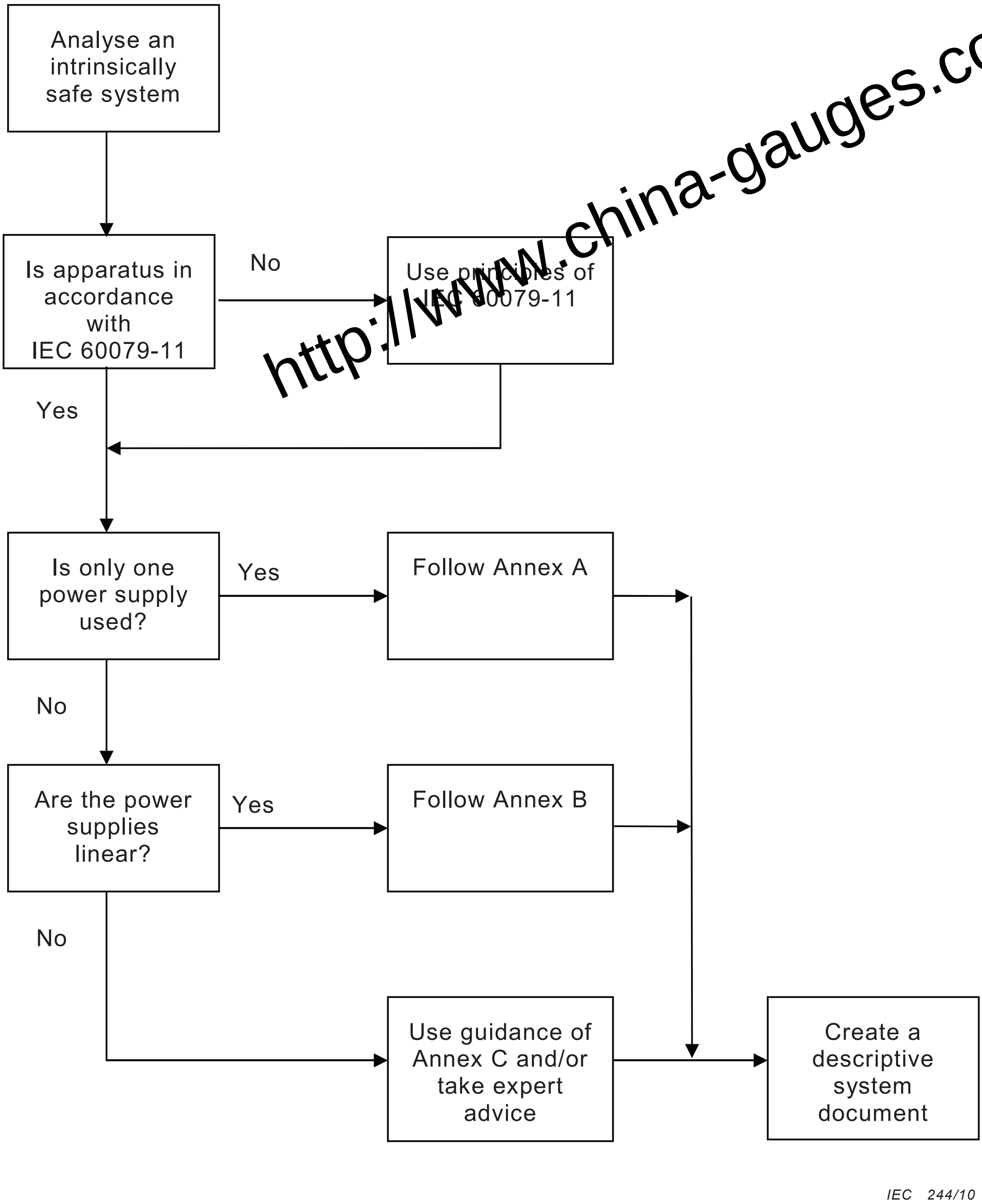




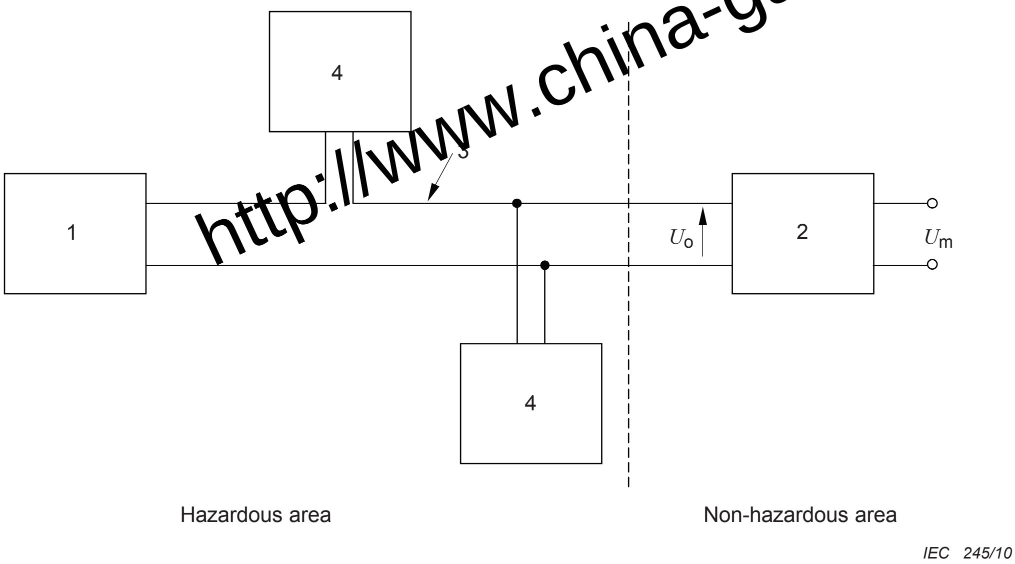

**Figure 1 – Systems analysis**

### 13.2 Simple apparatus

Switches, terminals, terminal boxes, plugs and sockets complying with the simple apparatus requirements of IEC 60079-11, may be added to a system without modifying the safety assessment. The possible heating effects on simple apparatus shall be considered. When other types of simple apparatus consisting of energy storing components for example capacitors or inductors complying with IEC 60079-11 are added to a system, the safety assessment shall take into account their electrical parameters. A typical system using simple apparatus is shown in Figure 2.

Where simple apparatus are intended to contain several separate intrinsically safe circuits, e.g. connectors, plugs and sockets or a resistance thermometer with two separate resistance windings, the separation requirements of IEC 60079-11 apply. If they do not conform, then the interconnected circuits shall be assessed as a single intrinsically safe circuit.






Key
1 certified intrinsically safe apparatus
2 certified associated intrinsically safe apparatus
3 cable
4 simple apparatus

**Figure 2 – Typical system using simple apparatus**

### 13.3 Analysis of inductive circuits

Where an apparatus has a well-defined inductance and resistance either by virtue of its documentation or construction, then the safety of the inductive aspects of the system shall be confirmed by the process defined in Annex D.

### 13.4 Faults in multi-core cables

#### 13.4.1 Type of multi-core cables

The faults, if any, which shall be taken into consideration in multi-core cables used within intrinsically safe electrical systems depend upon the type of cable used. The following sub-clauses detail the cable faults to be assessed for each type of cable.

#### 13.4.2 Type A cable

No faults between circuits shall be taken into consideration if the cable complies with 9.5.2.

#### 13.4.3 Type B cable

No faults between circuits shall be taken into consideration if the cable complies with 9.5.3.

#### 13.4.4 Type C cable

The combination of faults comprising of two short circuits between conductors and simultaneously up to four open circuits of conductors that result in the most onerous condition if the cable complies with 9.5.4.

All circuits in a multi-core cable subject to damage shall adopt the level of protection of the circuit with the lowest level of protection.

### 13.5 Type verifications and type tests

Where it is necessary to carry out type verifications and/or type tests to establish that a system is adequately safe, then the methods specified in IEC 60079-11 shall be used.



## 14 Marking

All apparatus within the system shall be readily identifiable. The minimum requirement is that the relevant descriptive system document shall be readily traceable. One acceptable technique is a clear instrument loop number, which identifies the loop documentation, which in turn lists the descriptive system document.

Where a system is assessed as a whole and is found to conform to IEC 60079-11, each piece of apparatus shall be marked in accordance with that standard.

## 15 Predefined systems

A system and all of its individual devices may be predefined and previously assessed in such a way that the interconnection of the individual devices and cables is sufficiently well known. In such cases, the assessment requirements of this standard can be simplified. One such predefined system is the FISCO system, the assessment of a FISCO system is set forth in Annex I.

# Annex A
(informative)

## Assessment of a simple intrinsically safe system



The majority of intrinsically safe systems are simple systems, containing a single source of power in associated apparatus connected to a single piece of field mounted intrinsically safe apparatus. This standard uses the combination of the temperature transmitter and the intrinsically safe interface shown in Annex E to illustrate the method of analysis.

The initial requirement is to establish the safety data of the two pieces of apparatus in the circuit. This data can be derived from a copy of the certificate, instructions or control drawing, which should be available to the system designer. In particular, any specific conditions of use should be taken into account in the system design. Precisely what information is transferred to the system drawing is determined by the necessity for the system analysis to be clearly justified and for it to be relatively simple to create the particular installation drawing from this reference drawing.

The compatibility of the two pieces of apparatus is established by comparison of the data of each apparatus. The sequence is usually as follows.

a) Compare equipment grouping. If they differ then the system takes the least sensitive classification. For example, if one device is IIC and the other IIB then the system becomes IIB. It is usual for a source of power certified as IIC to have permissible output parameters ($L_o$, $C_o$ and $L_o/R_o$) for IIB and IIA equipment groups as well. If these larger values are used then the parameters used determine the system gas group.

b) Compare levels of protection. If they differ then the system assumes the lowest level of protection. For example, if a device is "ia" and the other "ib" then the system becomes "ib". A source of power which is certified "ib" may also have different output parameters for use in "ic" circuits. If these values are used in the system design then the system becomes "ic":

c) Determine the temperature classification of the equipment mounted in the hazardous area. Apparatus may have different temperature classifications for different conditions of use (usually dependent on ambient temperature or $I_i$, $U_i$ and $P_i$) and the relevant one should be selected and recorded. Furthermore, it should be noted that it is the apparatus which is temperature classified, not the system.

d) The permissible ambient temperature range of each piece of apparatus should be recorded.

e) The voltage ($U_o$), current ($I_o$) and power ($P_o$) output parameters of the source of power should be compared with the input parameters ($U_i$, $I_i$ and $P_i$) of the field device, and the output parameters should not exceed the relevant input parameters. Occasionally the safety of the field device is completely specified by only one of these parameters. In these circumstances the unspecified parameters are not relevant.

f) Determine the permitted cable parameters.

   The permitted cable capacitance ($C_c$) is derived by subtracting the input capacitance of the field device ($C_i$) from the permitted output capacitance of the source of power ($C_o$), that is

$$C_c = C_o - C_i.$$

   The permitted cable inductance ($L_c$) is derived by subtracting the input inductance of the field device ($L_i$) from the permitted output inductance of the source of power ($L_o$), that is

$$L_c = L_o - L_i.$$

   The permitted $L/R$ ratio of the cable ($L_c/R_c$) is easily determined provided that the input inductance of the field device is negligible ($L_i$ less than 1 % of $L_o$). $L_c/R_c$ is then taken to be equal to that of the source of power $L_o/R_o$. If the inductance of the field device is significant then the equation given in Annex D can be used to calculate the permitted $L_c/R_c$ if this is thought to be desirable. Fortunately, this is not a frequently occurring requirement.

Where a system contains both lumped capacitances and lumped inductances the interaction of these may increase the risk of ignition capable sparks. This concern is confined to fixed inductance and capacitance and not to the distributed parameters of a cable. Consequently, on those rare occasions when **both** the lumped inductance (the sum of $L_i$ of the source of power and the field devices) and the lumped capacitance (the sum of $C_i$ of the source of power and the field devices) are greater than 1 % of the respective output parameters of the source of power $L_o$ and $C_o$ then the permissible output parameters are both to be divided by two. However, the maximum external capacitance $C_o$ derived by using this simple rule shall be limited to a maximum value of 1 μF for Group IIB and 600 nF for Group IIC. It should be stressed that this reduction in output parameters is only applicable on very rare occasions since it is unusual for field devices to have **both** inductive and capacitive input parameters which are significantly large. Frequently, $L_i$ and $C_i$ of a power source are not quoted in the documentation and in these circumstances it can be assumed that they are negligible. There is no suggestion that it is considered necessary to go back and check the safety documentation on existing installations for this most recent requirement. However, new analyses should take this remote possibility into account.

To summarise, it must be checked that either the lumped capacitance or inductance is less than 1 % of the respective output parameters. If it is, then the original calculation is valid. If **both** parameters are greater than 1 % of the output parameters then $C_o$ and $L_o$ of the system should be reduced by a factor of two.

Where a source of power is certified “ia” or “ib” then the permitted output parameters $L_o$, $C_o$ and $L_o/R_o$ are derived using a factor of safety of 1,5 on $U_o$ or $I_o$ respectively. When such a source of power is used in an “ic” circuit, the permitted output parameters may be derived using a unity safety factor. This results in a significant change, which usually removes the necessity to consider cable parameters in detail. Accurate values can be ascertained using the methods and tables in the apparatus standard. An acceptable conservative technique is to multiply the output parameters by two, which normally removes any concern about cable parameters.

g) Check that the level of insulation from earth is acceptable, or that the system earthing requirements are satisfied.

If these criteria are all satisfied, the compatibility of the two pieces of apparatus has been established. A convenient way of recording the analysis is to create a table. The following example (see Table A.1) uses the values from the typical system’s drawing (see Figure E.1) and compares the intrinsically safe interface and the temperature transmitter.

**Table A.1 – Simple system analysis**

| Step | Item | I.S. interface | Temperature transmitter | System |
|---|---|---|---|---|
| a) | Equipment group | IIC | IIC | IIC |
| b) | Level of protection | ia | ia | ia |
| c) | Temperature classification | not applicable | T4 | |
| d) | Ambient temperature | −20 °C to +60 °C | −40 °C to +80 °C | |
| e) | Parameter comparison | | | |
| | Voltage | $U_o$: 28 V | $U_i$: 30 V | √ |
| | Current | $I_o$: 93 mA | $I_i$: 120 mA | √ |
| | Power | $P_o$: 650 mW | $P_i$: 1 W | √ |
| f) | Cable parameters | | | |
| | Capacitance | $C_o$: 83 nF | $C_i$: 3 nF | $C_c$: 80 nF |
| | Inductance | $L_o$: 4,2 mH | $L_i$: 10 µH | $L_c$: 4,2 mH |
| | $L/R$ ratio | $L_o/R_o$: 54 µH/Ω | | $L_c/R_c$: 54 µH/Ω |
| g) | Earthing | Isolated | Isolated | Isolated |

# Annex B
(normative)

## Assessment of circuits with more than one source of power



This analysis is only applicable when the power sources considered use a linear resistive limited output. It is not applicable to power sources using other forms of current limitation.

IEC 60079-14 contains a simplified procedure of determining the maximum system voltages and currents in intrinsically safe circuits with more than one associated apparatus with linear current/voltage characteristics which gives conservative results, which ensure a safe installation and may be used as an alternative to this annex.

Where there is more than one source of power and the interconnections are made under controlled conditions so as to provide adequate segregation and mechanical stability in accordance with IEC 60079-11, then the interconnections are considered to fail to open and short circuit but not so as to reverse the connections or to change a series into a parallel connection or a parallel connection into a series one. Interconnections made within a rack or panel constructed in a location with adequate quality control and test facilities are an example of the degree of integrity required.

Figure B.1 illustrates the usual series combination. This series situation results in the open circuit voltage $U_o$ being $U_1 + U_2$ but the possibility of the voltage being $U_1 - U_2$ is not considered. Considering the safety of the system, three voltages $U_1$, $U_2$ and $U_o = U_1 + U_2$ are considered together with their corresponding currents $I_1$ and $I_2$ and the combined

$$I_o = \frac{U_1 + U_2}{R_1 + R_2}$$

Each of the three equivalent circuits has to be assessed for safety using the table showing the permitted short-circuit current corresponding to the voltage and the apparatus group of IEC 60079-11. The value of $L_o$, or optionally $L_o/R_o$ and $C_o$ shall then be established for each circuit and the most onerous value used together with its relevant equivalent circuit.

For level of protection “ia” and “ib” a factor of safety 1,5 shall be used in determining these values in all circumstances. For “ic” a safety factor of 1,0 is sufficient

NOTE Where the two voltages add, the combined circuit will determine the capacitive figure. However, the inductance and if applicable the $L_o/R_o$ ratio may be determined by one of the separate circuits being considered on its own. The minimum inductance does not always coincide with the maximum circuit current and the minimum $L_o/R_o$ ratio, if used, may not be coincident with the minimum inductance.

The matched power available from each of the equivalent circuits shall be determined. The matched power of the combined circuit is the sum of the power available from each circuit only when the sources have the same output current.

When the sources of power are connected in parallel as in Figure B.2, then the three currents $I_1$, $I_2$ and $I_o = I_1 + I_2$ have to be considered with their corresponding voltages $U_1$, $U_2$ and

$$U_o = \frac{U_1 R_2 + U_2 R_1}{R_1 + R_2}$$

Each of the three equivalent circuits has to be assessed for safety using the table showing the permitted short-circuit current corresponding to the voltage and the apparatus group of IEC 60079-11. The values $L_o$, or optionally $L_o/R_o$ and $C_o$ have to be established for each circuit and the most onerous value used together with its relevant equivalent circuit. The matched power available from each of the three equivalent circuits shall also be established. The matched power of the combined circuit is the sum of the power available from each circuit only when the sources have the same output voltage.

Where two sources of power are connected to the same intrinsically safe circuit and their interconnections are not well defined by reliable interconnections as illustrated in Figure B.3, there is a possibility that the sources of power can be connected in both series and parallel. In these circumstances, all the possible equivalent circuits shall be evaluated, following both the procedures set out. The most onerous output parameters and equivalent circuits shall be utilized in establishing the integrity of the intrinsically safe system.

The hazardous area apparatus may contain a source of power, which results in the apparatus having output parameters, for example from internal batteries. When this occurs, the analysis of the system shall include the combination of this source of power with any source of power in the associated apparatus. Such an analysis shall normally include the reversal of the interconnection because of the possible failure of the field wiring.

Having established the representative equivalent circuits, these circuits can be used as if there was a single source of power, and the procedure already discussed in Annex A can be used to establish whether the system as a whole is acceptably safe.

When two or more sources of power with different output voltages are interconnected the resultant circulating current can cause additional dissipation in the regulating circuits. Where the circuits have conventional resistive current limiting, the additional dissipation is not considered to adversely affect intrinsic safety.

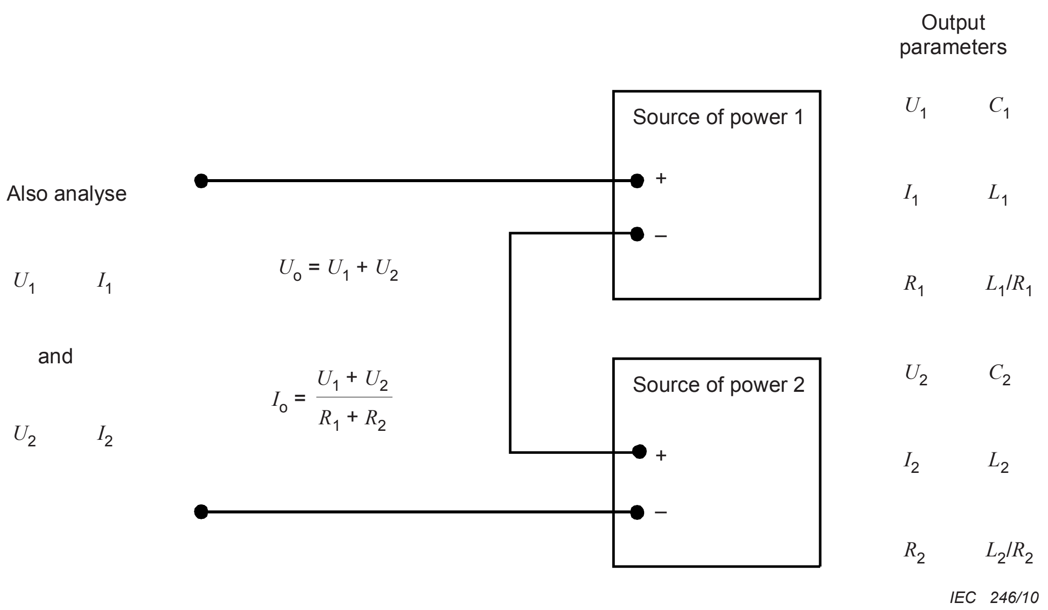



**Figure B.1 – Sources of power connected in series**

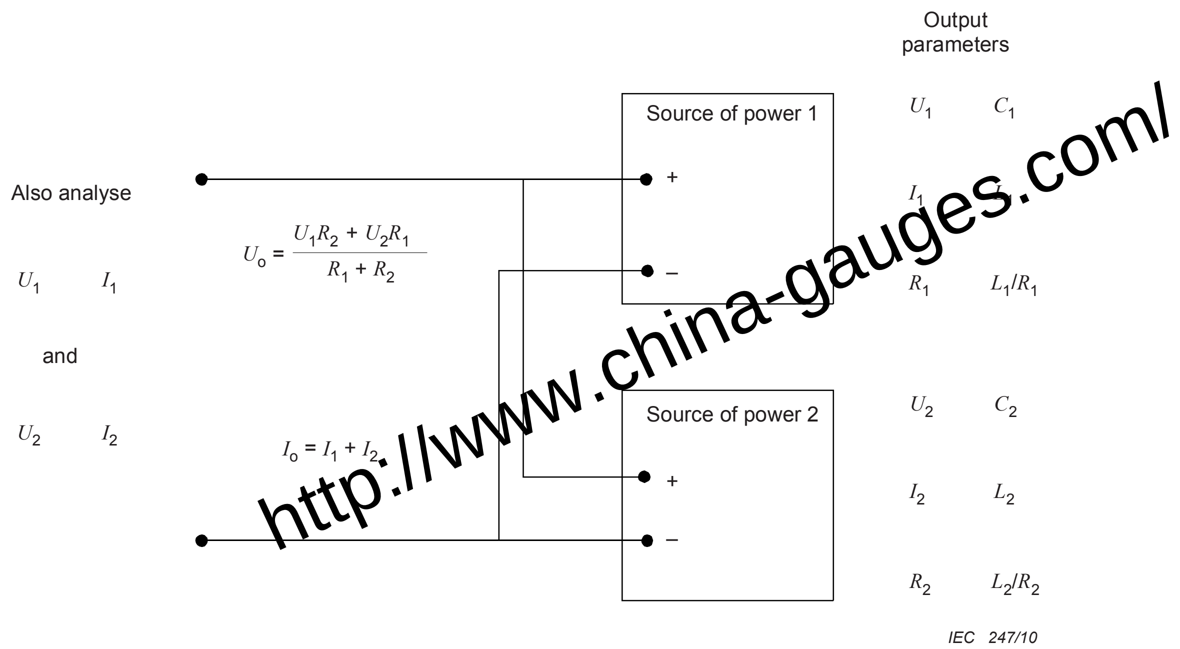
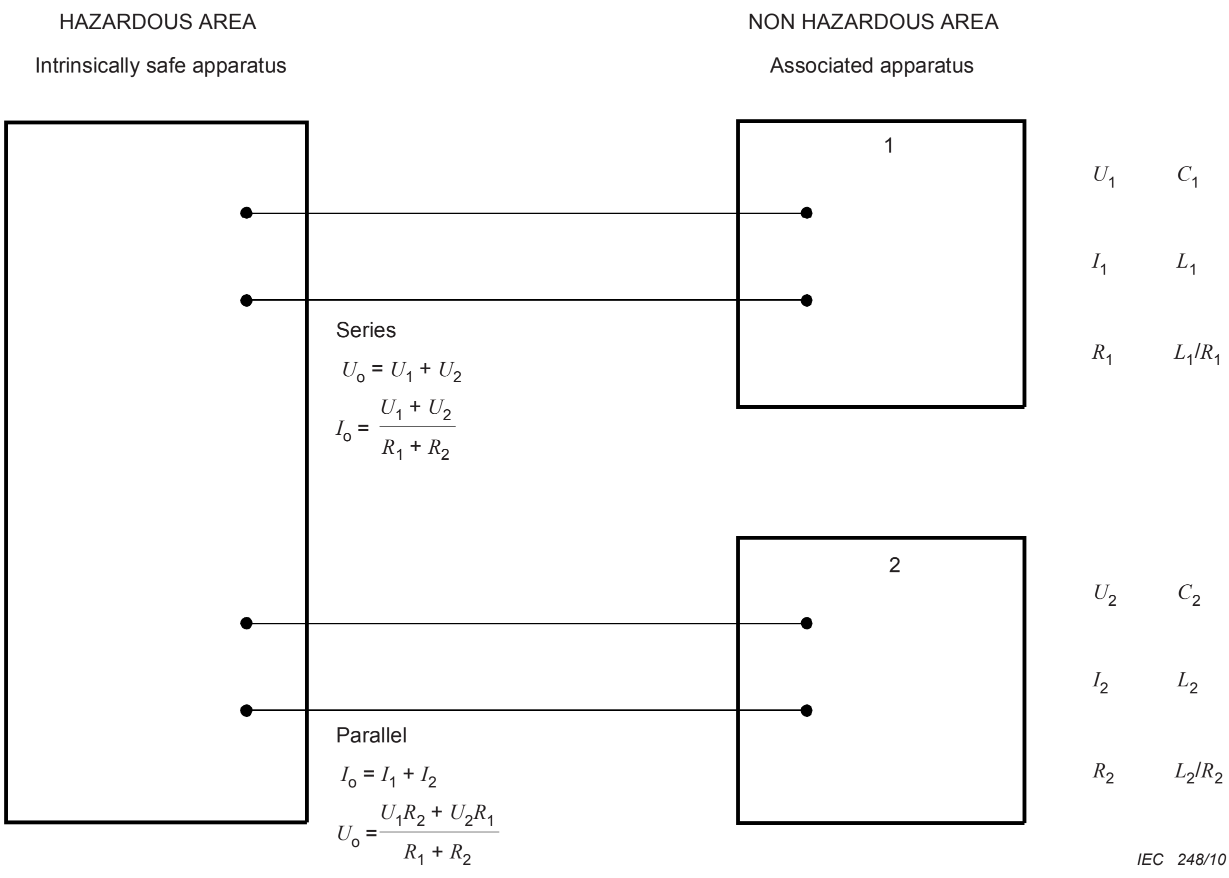



**Figure B.2 – Sources of power connected in parallel**




**Key**

1 source of power 1

2 source of power 2

**Figure B.3 – Sources of power not deliberately connected**

# Annex C
(informative)

# Interconnection of non-linear and linear intrinsically safe circuits

## C.1 General

This subject has been under active consideration for some considerable time and is still developing. It is the best knowledge currently available and is included so that wider experience of its use can be obtained.

The design and application of non-linear power supplies requires specialist knowledge and access to appropriate test facilities. Where the system designer is satisfied that a particular source of power is adequately safe it is permissible to design a system in accordance with this standard. Any particular conditions relating to such a system should be clearly stated in the accompanying documentation.

Where a safety analysis of a combination of power supplies using non-linear outputs is carried out, the interaction of the two circuits may cause a considerable increase in the dissipation in the regulating circuit components. This factor should be taken into account. It is recommended to have only one power supply containing regulating semiconductors combined with linear and/or trapezoidal sources.

The installation rules in IEC 60079-14 permit the operator in control of a hazardous area to combine several intrinsically safe circuits by interconnection. This also includes the case where several associated apparatus (that is, active in normal operation or only under fault conditions) are involved (see IEC 60079-14). Where this is done, it is not required to involve a certification body, test laboratory or an authorized engineer if a calculated or test-based proof of the intrinsic safety of the interconnection is carried out.

The test-based proof should be performed using the standard spark test apparatus in accordance with IEC 60079-11 considering the safety factor of the combined electrical apparatus. In this case, certain fault conditions leading to the most unfavourable ignition conditions, the ‘worst case’ approach, should be taken into account. Thus, this method of proof often meets with difficulties in practice and is usually reserved for a certification body or a test laboratory.

An assessment by calculation of the interconnection can be carried out easily at least for resistive circuits, if the electrical sources involved have a linear internal resistance as shown in Figure C.1a. In this case, the ignition limit curves in IEC 60079-11 apply and the method described in IEC 60079-14, for the verification of intrinsically safe circuits with more than one associated apparatus with linear current/voltage characteristics; or the characteristics of Figure C.7 and Figure C.8 of this standard can be used.

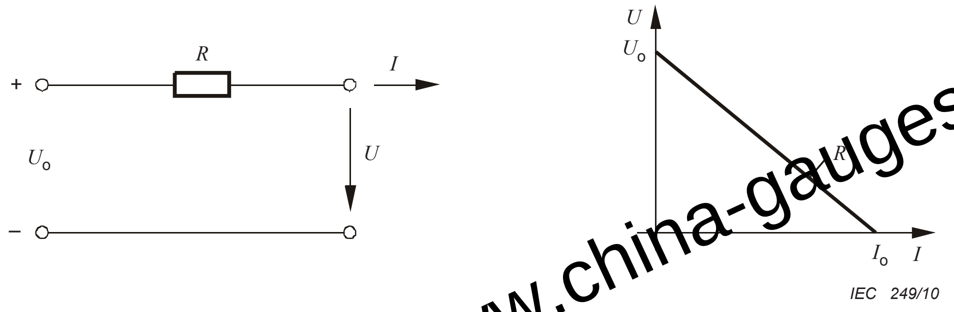





**Figure C.1a – Linear characteristics**

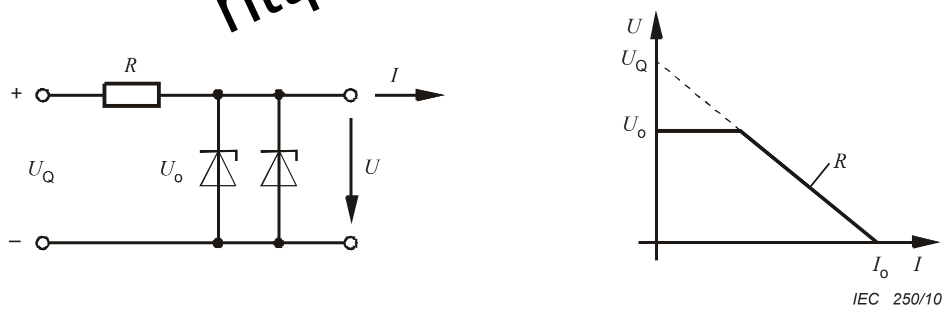



**Figure C.1b – Trapezoidal characteristics**

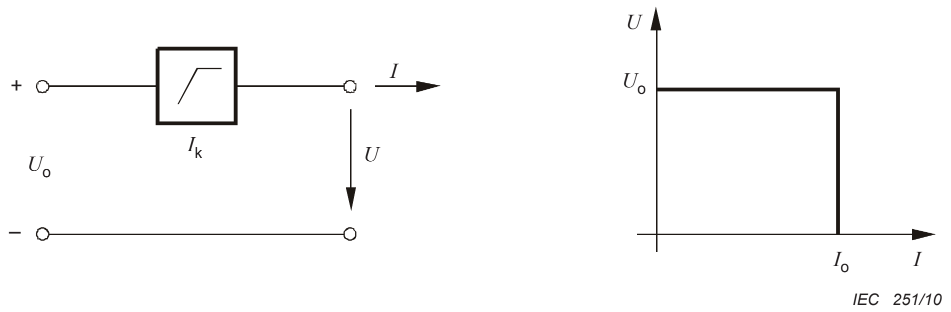



**Figure C.1c – Rectangular characteristics**

**Figure C.1 – Equivalent circuit and output characteristic of resistive circuits**

The first step is to evaluate the new maximum values of voltage and current resulting from combining the associated apparatus. If the associated apparatus are combined as shown in Figure C.2a, there is a series connection. The maximum open-circuit voltage values, $U_o$, of the individual sub-assemblies are added and the maximum value of the short-circuit currents, $I_o$, of the sub-assemblies is taken. In an arrangement like that in Figure C.2c, there is a parallel connection. The short-circuit currents are added while the greatest value of the open-circuit voltage is taken.

If the arrangement of the apparatus is not clearly defined with respect to the polarity (as in Figure C.2e), then there may be a series or parallel connection depending on the fault condition considered. In this case, voltage addition and current addition should be assumed for both, but separately. The most unfavourable values have to be taken as a basis.

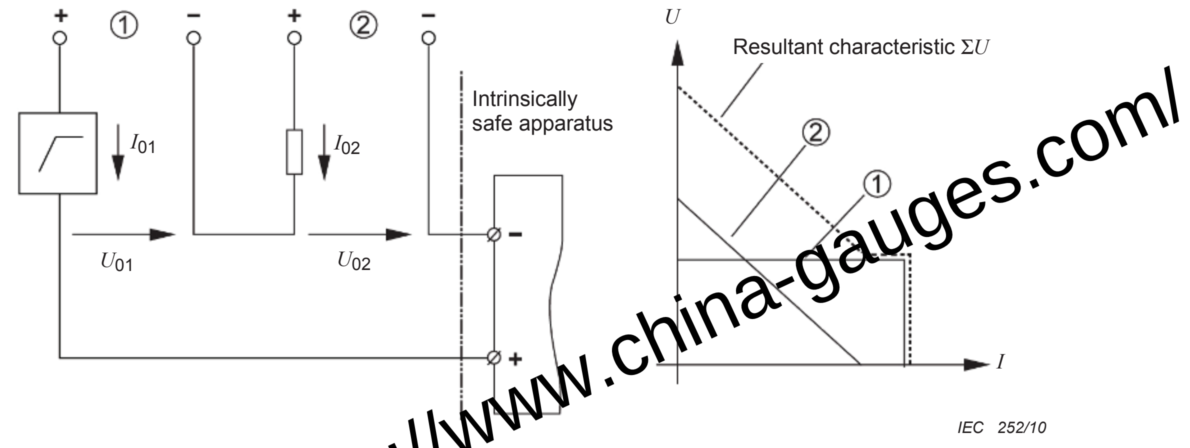





**Figure C.2a – Series connection with voltage addition**

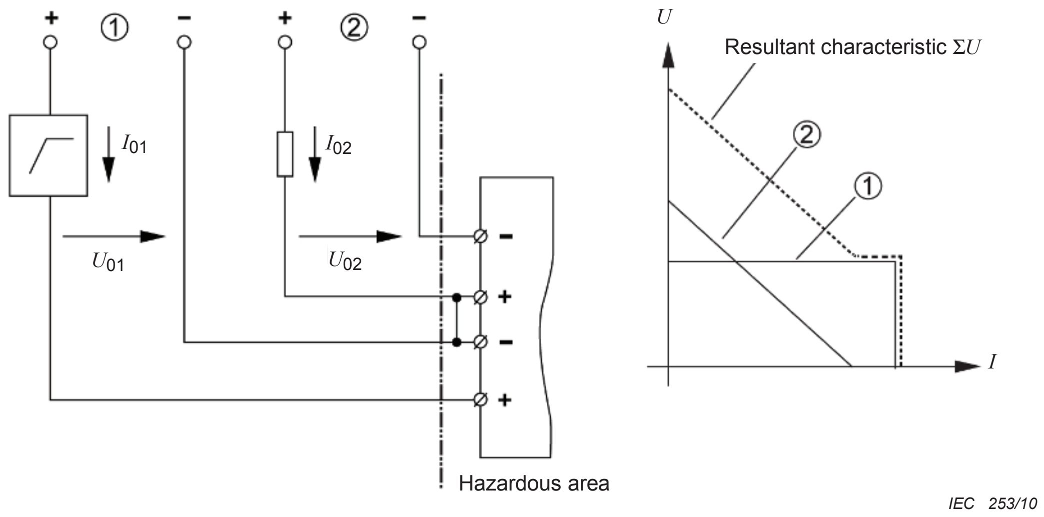



**Figure C.2b – Series connection with voltage addition and possibly current addition**

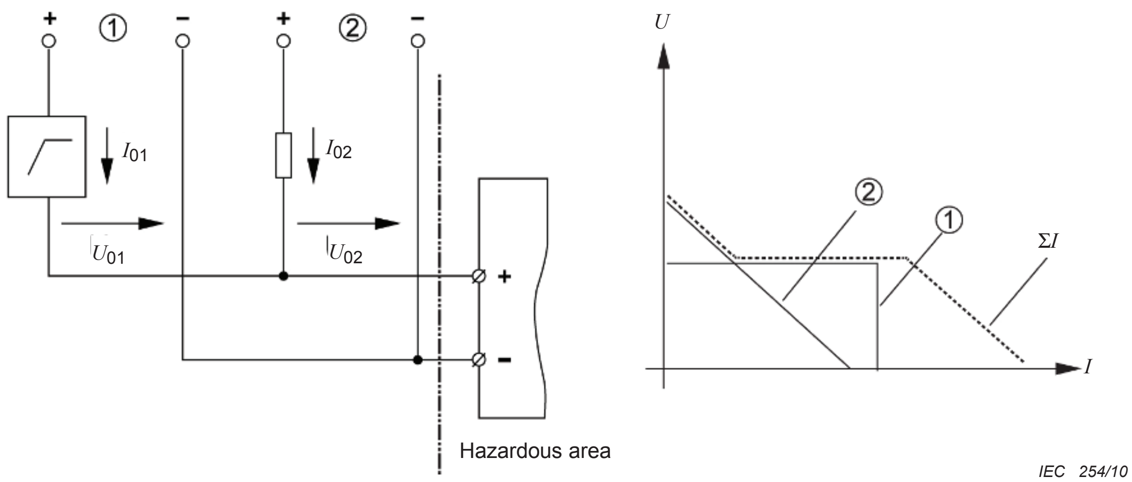



**Figure C.2c – Parallel connection with current addition**

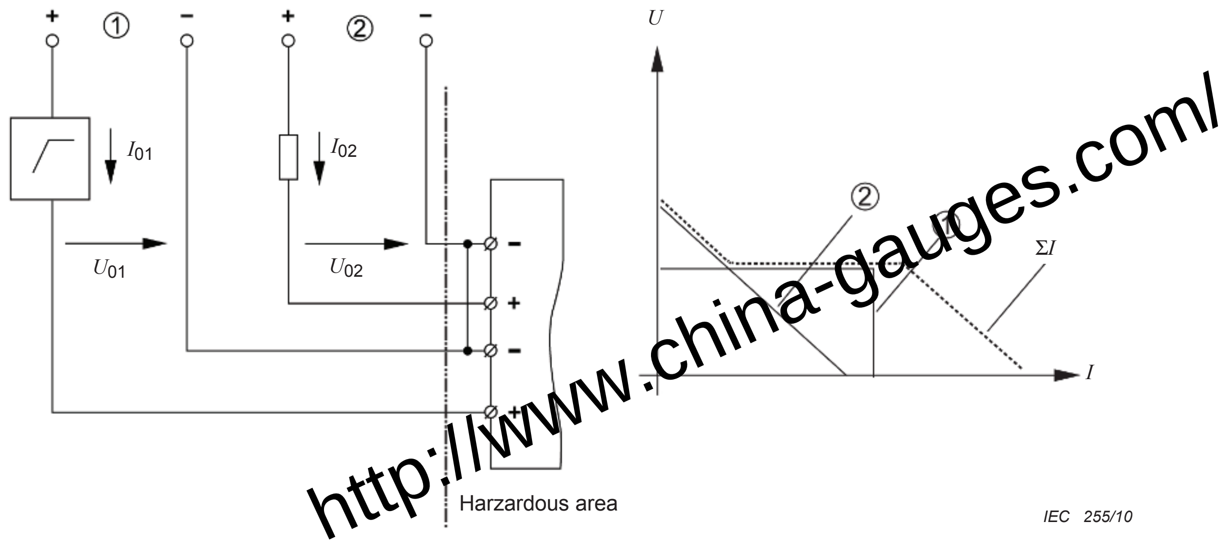




**Figure C.2d) – Parallel connection with current and possibly voltage addition**

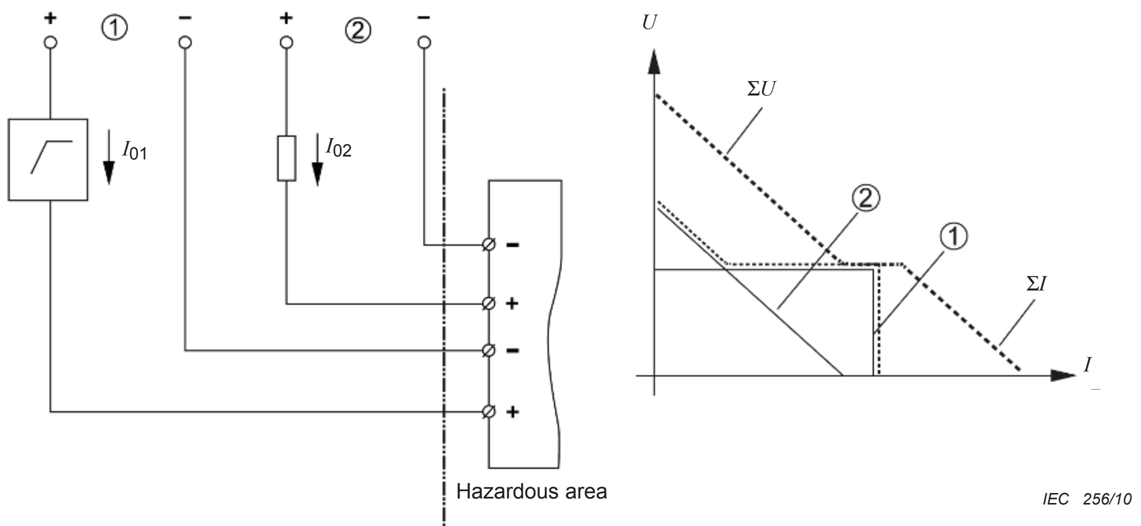



**Figure C.2e – Series or parallel connection with current and voltage addition**

**Figure C.2 – Current and/or voltage addition for interconnections**

After determining the new maximum values of current and voltage, the intrinsic safety of the combined circuit should be checked by means of the ignition limit curves given in IEC 60079-11, taking account of the safety factor for the resistive circuit, and the new maximum permissible values of external inductance $L_o$ and capacitance $C_o$ should be determined. Here, however, the procedure introduced in IEC 60079-14, for the verification of intrinsically safe circuits with more than one associated apparatus with linear current/voltage characteristics, shows a weakness, caused by the following:

– the maximum permissible inductances are valid only for a maximum voltage of 24 V;

– the occurrence of both inductance and capacitance is not taken into account.

If proceeding on the basis of open-circuit voltages and short-circuit currents only, the safety factor obtained really decreases from the desired value of 1,5 to approximately 1,0 in the voltage range above 20 V. This seems to be acceptable, since the interconnection in accordance with IEC 60079-14 can only meet level of protection “ib” generally, even if all the individual apparatus conforms to level of protection “ia”. However, in the case of low voltages, the safety factor can drop considerably below the value of 1,0. Such an approach is thus not effective with regard to safety.

If one or more active sources within one circuit have non-linear characteristics, evaluation on the basis of no-load voltages and short-circuit currents only cannot accomplish the original intention.

In practice, sources with trapezoidal shape (see Figure C.1b) are used and rectangular output characteristics (see Figure C.1c) occur often if electronic current-limiting devices are used. For such circuits, the ignition limit curves in IEC 60079-11 cannot be used. This standard therefore describes a method that allows the safety evaluation of the combination of networks including non-linear circuits by means of diagrams.

The procedure introduced here is applicable for Zone 1 and for equipment groups IIC and IIB. It should be emphasized that an instrument for the assessment of the interconnection is being proposed here; using it for defining intrinsic safety parameters of individual circuits or apparatus makes sense only in the case of simple rectangular or linear circuits.



## C.2 Basic types of non-linear circuits

### C.2.1 Parameters

Whilst assessing the intrinsic safety of active circuits, it is necessary to know the internal resistance and the source voltage. In the simplest case, the source can be characterized by two (constant) electrical values, either by the voltage $U_o$ and the internal resistance $R$ or by $U_o$ and the short-circuit current $I_o$ (see Figure C.1a). $U_o$ often is determined by zener diodes. $U_o$ and $I_o$ are maximum values that can occur under the fault conditions defined in IEC 60079-11. In the case of Figure C.1a, the characteristic is linear. Unfortunately, in practice, only a few circuits can be represented in this simple way.

A battery, for example, fitted with an external current limiting resistor has no constant internal resistance. Likewise, the source voltage changes as a function of the degree of charge. In order to study the behaviour of such practical circuits, they are represented by their simpler equivalent circuits that should obviously not be less capable of causing ignition than the actual circuit. In the above case of a battery, one would take the maximum open circuit as $U_o$ and the external resistance as $R$ as in Figure C.1a. This equivalent circuit voltage has a linear characteristic.

Non-linear circuits can also be reduced, usually to the two basic types shown in Figures C.1b and C.1c. The source with trapezoidal characteristic (Figure C.1b) consists of a voltage source, a resistance and additional voltage limiting components (for example, zener diodes) at the output terminals. The rectangular characteristic of Figure C.1c has the current limited by an electronic current regulator.

If one considers the output power of the different networks, it becomes obvious that different ignition limit values should apply, since the igniting spark is also a load and its matching to the source feeding it should be taken into account. The maximum available power from the source shown in Figure C.1a is

$P_{max} = 0{,}25\ U_o \times I_o$

and for the trapezoidal characteristic (Figure C.1b):

$P_{max} = 0{,}25\ U_Q \times I_o$ (for $U_o > 0{,}5 \times U_Q$), or

$P_{max} = U_o \times (U_Q - U_o)/R$ (for $U_o \leq 0{,}5 \times U_Q$).

The trapezoidal characteristic of Figure C.1b becomes the rectangular characteristic of Figure C.1c as $U_Q$ tends to infinity.

Here:

$P_{max} = U_o \times I_o$.

For the complete electrical description of a source, two parameters are needed for the linear and rectangular characteristics and three parameters for the trapezoidal characteristic (see Table C.1).



**Table C.1 – Parameters necessary to describe the output characteristic**

| Characteristic | Parameters necessary |
|---|---|
| Linear, Figure C.1a | $U_o$, $I_o$ or $U_o$, $R$ |
| Trapezoidal, Figure C.1b | $U_o$, $U_Q$, $R$ or $U_o$, $R$, $I_o$ or $U_o$, $U_Q$, $I_o$ |
| Rectangular, Figure C.1c | $U_o$, $I_o$ |

### C.2.2 Information given in the certificates, instructions or control drawing

The first step in any safety-oriented assessment should be the determination of the type of characteristic and associated electrical parameters of the individual circuits. Since the circuit arrangements and the internal construction of the apparatus are not normally known to the user or operator, they will have to trust the electrical data given in the certificate, instructions or control drawing.

The values given usually are as follows: open-circuit voltage (here named $U_o$) and short-circuit current (here named $I_o$) and normally the maximum available power $P_o$. It is often possible to conclude information about the type of characteristic from these values.

Example (maximum values):

$U_o$ = 12,5 V

$I_o$ = 0,1 A

$P_o$ = 313 mW

Because $P_o$ is one-quarter of the product of open-circuit voltage and short-circuit current, it can be deduced that in this example a linear characteristic (Figure C.1a) is effective.

Example (maximum values):

$U_o$ = 20,5 V

$I_o$ = 35 mA

$P_o$ = 718 mW

Here $P_o$ is the product of the open-circuit voltage and the short-circuit current, and hence a rectangular characteristic is given (Figure C.1c).

In certain cases, the values for power, current and voltage do not correspond to the above because the power rating is specified for the stationary case (heating effect of components connected subsequently) and the current or voltage values for the dynamic case (spark ignition) are given. In situations where there is a doubt, it is essential to verify which characteristic to take as the basis for the interconnection with respect to spark ignition.

In the case of a trapezoidal characteristic, the information in the test certificate is often not sufficient to determine the characteristic. The third parameter is missing (see Table C.1), either $U_Q$ or $R$.

When $R$ is given as the additional parameter, there is the least danger of confusion. Therefore $R$ will generally be given in the test certificates. The parameter $U_Q$ (Figure C.1b) can then be derived from $U_Q = I_o \times R$.

In most cases, the test certificate will also give the characteristic shape of any non-linear circuits.



An example may look as follows.

Maximum values (trapezoidal characteristic):

$U_o$ = 13,7 V

$I_o$ = 105 mA

$R$ = 438 Ω

$P_o$ = 1 010 mW

The characteristic represented is shown in Figure C.3a; Figure C.3b shows the safety equivalent circuit.

Calculation is as follows:

$U_Q = I_o \times R$ = 46 V and

$P_o = (U_Q - U_o) \times U_o/R$ = 1 010 mW

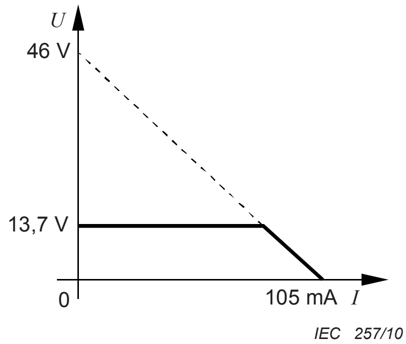



**Figure C.3a – Output characteristics**

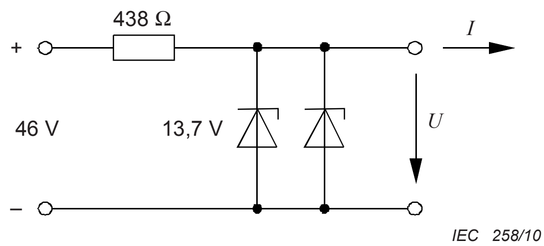



**Figure C.3b – Equivalent circuit**

**Figure C.3 – Output characteristic and equivalent circuit of a source with trapezoidal characteristic**

The data needed for the interconnection can be obtained from the information given in the certificate. If there is no data in the older certificates, the values should be obtained from the manufacturer of the apparatus.

In designing intrinsically safe circuits, an attempt should be made always to keep the interconnections and number of combined sub-assemblies low. This objective cannot always be achieved in practice, because it is also necessary to consider fault conditions. This means that some apparatus which are not acting in normal operation as sources have to be regarded as sources in the case of failures.



The passive inputs of devices, for example, measurement transducers, plotters etc, can, from the safety point of view, also act as active sources. Therefore the maximum values indicated in the certificates should be referred to. As a result, the operational characteristics of a circuit may deviate substantially from the safety characteristic. The values given in the certificates for open circuit voltage $U_o$ and short-circuit current $I_o$ for the circuit concerned are stated only for transient conditions in some cases. On the other hand, the power value applies for steady-state conditions which have to be considered for the temperature rise of connected components.

## C.3 Interconnection of intrinsically safe circuits with more than one source

### C.3.1 Determination of a resultant output characteristic

It is assumed that the output characteristics of the circuits making up the combination, and which are to be regarded as sources, are known (see Clause C.2). It is then necessary to ascertain from the type of interconnection whether, in normal operation and under fault conditions, it is necessary to consider the voltage sum, the current sum, or both current and voltage sums.

If the combined sources are connected in series and are not bonded, for example, to earth (Figure C.2a), then, irrespective of the polarity of the sources, voltage addition only is possible. The resultant output characteristic is conveniently found by graphical addition. Thus for each current value, the voltages of the individual sources are added. The dotted-line curve in Figure C.2 shows the resultant characteristics in the different cases.

In the series circuit shown in Figure C.2b, where there is a common connection of both voltage sources at the load, current addition can be excluded only if the polarity of both sources in the direction shown here is fixed with respect to safety (for example, for certain safety barriers). With sources which can change the polarity operationally or under fault conditions, both voltage and current addition should be considered (see Figure C.2e).

In the parallel arrangement of Figure C.2c, current addition is only possible if, with bipolar sources, two poles are connected in each case. Voltage addition is not possible in this case and the resultant characteristic is generated by graphical addition of individual current values.

If only one pole of each source is connected to that of the other (Figure C.2d), then voltage addition can be excluded only if the polarity of the sources as shown here is fixed regarding all circumstances (for example, with safety barriers). Otherwise, both voltage and current addition should be considered (see Figure C.2e).

If several circuits are connected to a circuitry in which arbitrary interconnections should be assumed (Figure C.2e), then, depending on the fault conditions considered, a parallel or series connection may be set up, so that both current and voltage addition, should be considered. Because both cases are not possible at the same time, the resultant characteristic for current addition and that for voltage addition should be constructed separately. This procedure is necessary also in all cases of doubt for the circuits in Figures C.2b and C.2d as well as with circuits with more than two conductors. The result so obtained will always be on the safe side.

### C.3.2 Safety assessment of the interconnection and determination of the maximum permissible capacitance and inductance

When the resultant characteristic for the combination circuit has been determined as detailed in C.3.1, the next step is analysis of the intrinsic safety. For this purpose, the diagrams given in Figures C.7 and C.8 are to be used. They show the permissible limit curve for linear source characteristics (dotted limit curve) and for rectangular characteristics (solid limit curve), with a given inductance and the new maximum values of current and voltage in the combined circuit. Further, curves are given to determine the highest permissible external capacitance for both cases. Table C.2 gives an overview.

**Table C.2 – Assignment of diagrams to equipment groups and inductances**

| Figure | Group | Permissible inductance $L_o$ |
|---|---|---|
| Figure C.7a | | 0,15 mH |
| Figure C.7b | | 0,5 mH |
| Figure C.7c | IIC | 1 mH |
| Figure C.7d | | 2 mH |
| Figure C.7e | | 5 mH |
| Figure C.8a | | 0,15 mH |
| Figure C.8b | | 0,5 mH |
| Figure C.8c | IIB | 1 mH |
| Figure C.8d | | 2 mH |
| Figure C.8e | | 5 mH |

To assess the intrinsic safety, first select the explosion group and then the total inductance required for the combination. If only small inductances (that is no lumped inductances, only short cable lengths) are concerned, then the diagram with the lowest inductance should be selected (i.e. Figure C.7a for Group IIC and Figure C.8a for Group IIB).

The resultant output characteristic is then plotted in the diagram concerned. If, in accordance with C.3.1 current and voltage additions are considered, then both resultant characteristics should be plotted.

It is now possible to determine directly whether the combination of sources together with the inductance for that diagram and the selected explosion group is intrinsically safe. The resultant sum characteristic should not intersect the limit curve for the rectangular source in the diagram at any point. In addition, the point in the diagram defined by the maximum voltage and the maximum current of the sum characteristic should be below the curve for the linear source.

The maximum permissible capacitance of the resulting circuit is found as the lowest value from the two $C_o$ limit curve families, being the highest $C_o$ value that is not intersected by the resultant output characteristic for the linear limit and for the rectangular limit. If a higher permissible capacitance $C_o$ is required for the purpose of an application, then this can be obtained by starting with a diagram for a lower inductance. The same approach can also be used where the resultant output characteristic intersects the curve for the inductive limit of the linear or rectangular source. If, even for the smallest inductance value in the diagrams (0,15 mH), the relevant limit curve(s) is exceeded in the IIC diagram, then the use of the IIB diagrams is recommended. If these limits are also exceeded, then the combination is not intrinsically safe for explosion Group IIB either.

### C.3.3 Supplementary comments about the procedure using output characteristics

The procedure described above in C.3.1 and C.3.2 for the safety assessment of interconnections of intrinsically safe circuits is based on fundamental research work and model calculations. The actual calculation method gives results differing from those in former report.

In future, somewhat larger capacitances are permissible in the small voltage range. For higher voltages the difference can be up to a factor of 3. In contrast to the diagrams in a former report, the limit curve for the purely resistive circuit is omitted in Figures C.7 and C.8; but it is inherently established through the inductive limits. Further, the limit curves for linear sources were inserted here. Apart from this, the graphic process remains the same in general.

The graphic method is based upon a reduction of the actual source characteristic in abstracted linear as well as rectangular sources and comparison with the associated limit curves. Only in the case where the actual source characteristic is either linear or rectangular can the safety factor be derived from the diagram with a guarantee to be exactly 1,5. In some of the more complex sources, it may be of benefit to construct an enveloping linear or rectangular characteristic and the safety factor is preserved. If both limit criteria are made use of, the actual safety factor can be slightly smaller (always greater than 1 however). This is a result of the reduction of the actual circuit conditions used in this simple graphic method. General expert opinion indicates that this is acceptable when considering Zone 1 installations.

When using the diagrams given in Figures C.7 and C.8, the interaction of inductance and capacitance (mixed circuit) is always covered. The procedure should be used also for the combination of purely linear circuits (output characteristic in accordance with Figure C.1a). The method specified does not distinguish between lumped inductances or capacitances and those derived from distributed cable parameters. When cables with transmission times of up to 10 µs occur, then the current view is that there is no need for this difference. The calculation based on concentrated elements lies on the safe side and does not, in contrast to earlier calculation methods, cause severe limitation in practice.

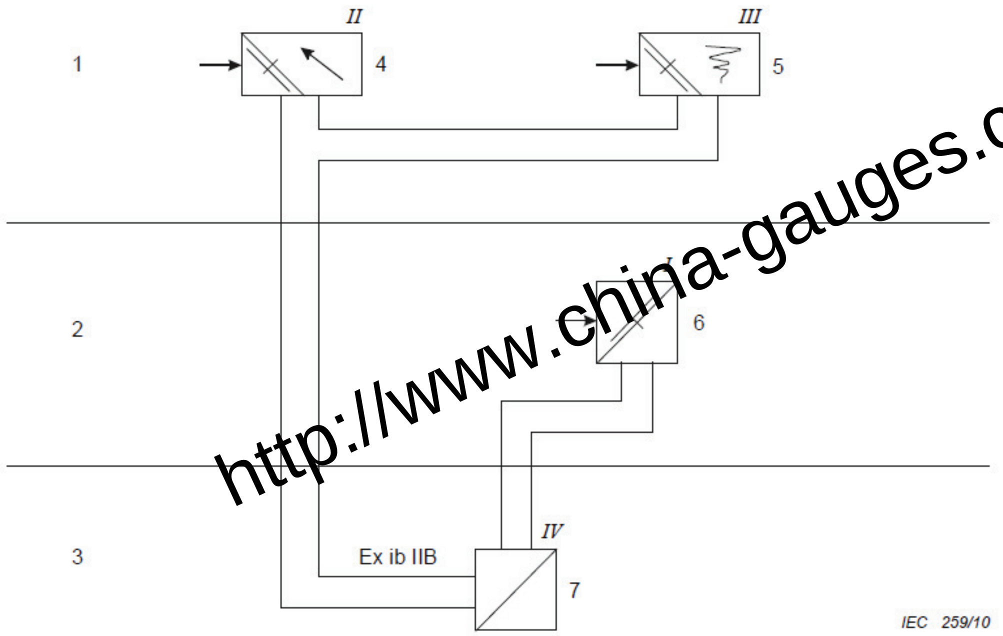
The advantage of this procedure is that all information relating to safety data can be taken from a single diagram. Nevertheless, an additional comparison of the maximum open-circuit voltage with the maximum capacitance in accordance with the permitted capacitance corresponding to the voltage and the apparatus group table in IEC 60079-11 should be made, because in certain cases the procedure described here gives a higher permissible capacitance. The values should then be taken from IEC 60079-11 because misunderstandings can arise otherwise.

The values obtained for the maximum permissible external inductance and capacitance are those for the total combination, that is the inductances and capacitances of all the individual devices, which are effective at the external terminals, should be considered.

The calculation procedure used for the diagrams shows no significant systematic deviations from the results obtained from the ignition tests during the research projects. It is known that the numerous experimental results have an uncertainty in the range of 10 %. The reason for this is the test method and the spark test apparatus itself. The method presented here is not estimated to have greater deviations.

## C.4 Illustration of the procedure using output characteristics by means of an example

In the example shown in Figure C.4, an analyser with an amplifier (IV) is located inside the hazardous area and supplied by an intrinsically safe power supply (I). The intrinsically safe amplifier output signal (0 to 20 mA signal) is fed to a display (II) and a plotter (III).






Current/voltage addition
interconnected circuit Ex ib IIB

$P_o$ = 1,9 W, $U_o$ = 28,7 V, $I_o$ = 264 mA

$L_o$ = 0,5 mH, $C_o$ = 400 nF

**Key**

1 control

2 switch room

3 field (hazardous area)

4 display operationally passive maximum values: 12 V, 133 mA, 0,4 W linear characteristic

5 recorder operationally passive maximum values: 1 V, 31 mA, 10 mW linear characteristic

6 power supply maximum values: Ex ib IIB 15,7 V. 100 mA, 1,57 W, $L_o$ ≤ 1 mH, $C_o$ ≤ 650 nF electronic current regulation rectangular characteristic

7 analyser with amplifier (intrinsically safe apparatus)

I intrinsically safe power supply

II display

III plotter

IV amplifier

**Figure C.4 – Example of an interconnection**

The analyser is an intrinsically safe apparatus; the power supply, the display and the plotter are associated apparatus within the meaning of IEC 60079-11. In normal operation, only the mains supply is effective as an active source, whilst display and plotter are passive. For safety analysis however, the highest possible values are taken as a basis which are found in the test certificates for the three devices when in a fault condition.

The following information is available.

I **Power supply**

Output with type of protection Ex ib IIB

Maximum values

$U_o$ = 15,7 V

$I_o$ = 100 mA

$P_o$ = 1,57 W

$L_o$ = 1 mH

$C_o$ = 650 nF

Rectangular output characteristic (Figure C.1c)



II **Display**

Input with type of protection Ex ib IIC

Maximum values

$U_o$ = 12 V

$I_o$ = 133 mA

$P_o$ = 0,4 W

$L_o$ = 1,8 mH

$C_o$ = 1,4 µF

Linear output characteristic (Figure C.1a)

III **Plotter**

Input with type of protection Ex ib IIC

Maximum values

$U_o$ = 1 V

$I_o$ = 31 mA

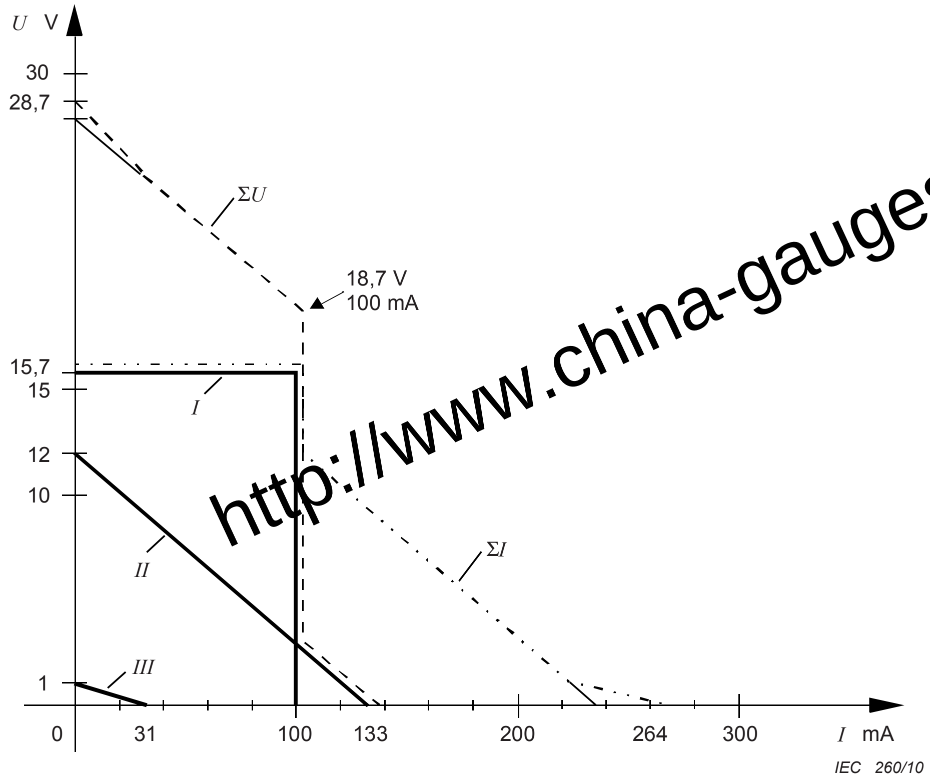
$P_o$ = 10 mW

$L_o$ = 36 mH

$C_o$ = 200 µF

Linear output characteristic (Figure C.1a)

With the circuit arrangement in Figure C.4, and depending on the fault conditions in the analyser, voltages or currents can be added as in Figure C.2e. The individual characteristics and the two sum characteristics for voltage and current addition are shown in Figure C.5.






**Key**

I power supply

II display

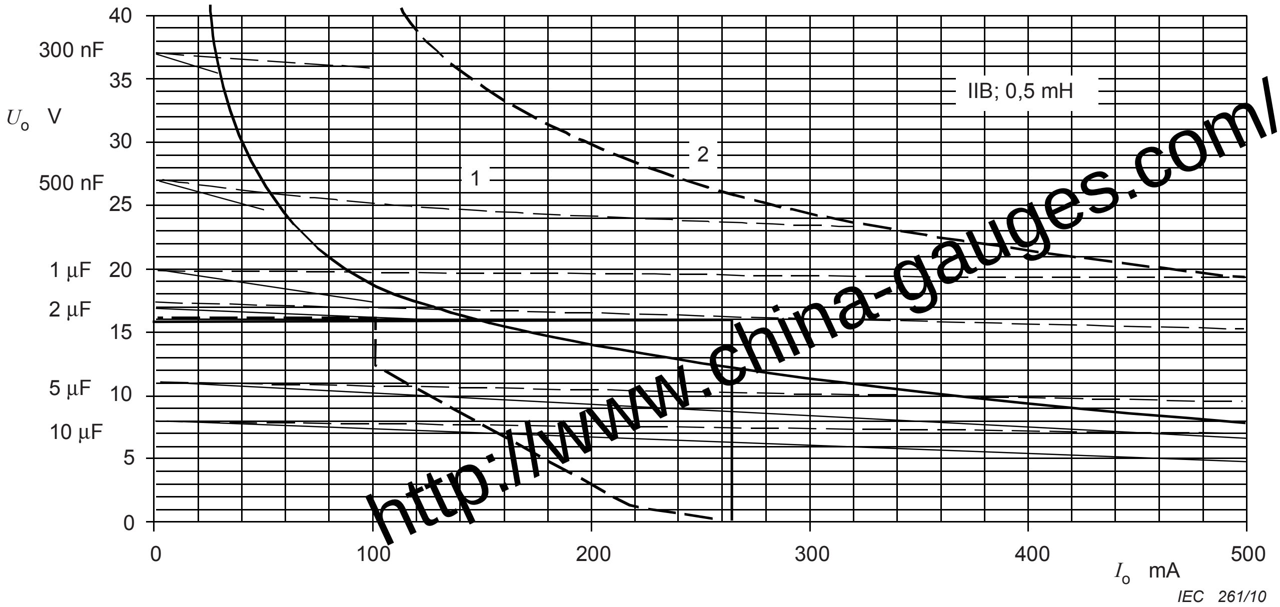
III plotter

**Figure C.5 – Sum characteristics for the circuit as given in Figure C.4**

In order to check the intrinsic safety, the two sum characteristics are drawn in Figure C.8b (explosion Group IIB, $L$ = 0,5 mH) (Figures C.6a and C.6b).

The corner point at 18,7 V and 100 mA in the voltage addition curve obviously is the critical point, it is nearest to the inductive limit of the rectangular source, but does not reach it. At this point the theoretically highest power of 1,9 W is reached.

Since both resultant characteristics of the combination do not intersect the inductive limit curves for the linear and rectangular sources in Figures C.6a and C.6b, the safety test has come out positively. For the maximum voltage (28,7 V) of the resultant characteristic in the present example, the maximum permissible capacitance of the combination from the family of curves in Figure C.6b can be read off to be 400 nF. If the permitted capacitance corresponding to the voltage and the apparatus group table of IEC 60079-11 is checked for the value 28,7 V Group IIB, the permissible value of capacitance is 618 nF which is higher than the value of 400 nF established here.



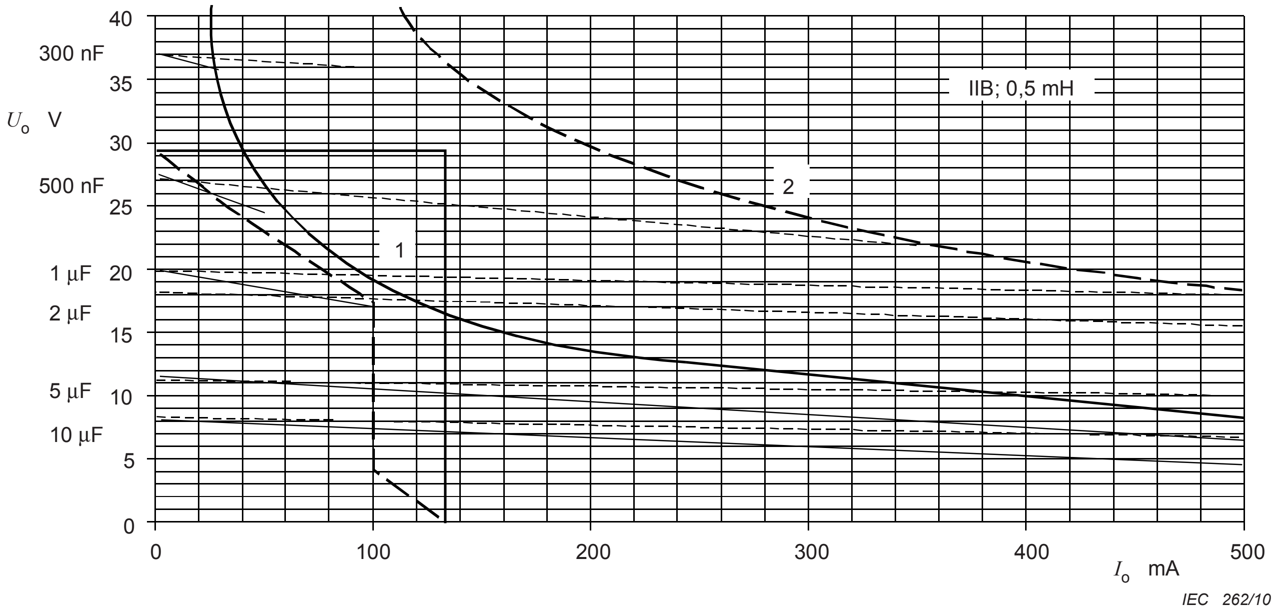



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.6a – Current addition**




**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.6b – Voltage addition**

**Figure C.6 – Current and/or voltage addition for the example given in Figure C.4**

The resultant values for the combination are as follows:

Explosion Group IIB

Maximum values

$U_o$ = 28,7 V

$I_o$ = 264 mA

$P_o$ = 1,9 W

$L_o$ = 0,5 mH

$C_o$ = 400 nF



Because, in the present example, the associated apparatus (power supply, display and plotter) have no effective inductance or capacitance values at the intrinsically safe inputs/outputs, the maximum values for capacitance and inductance may be used for the intrinsically safe apparatus (analyser) and for the interconnection cables.

## C.5 Summary

In the design and construction of measuring and process plant in the chemical and petrochemical industries, it is frequently necessary to combine several certified pieces of apparatus with intrinsically safe circuits.

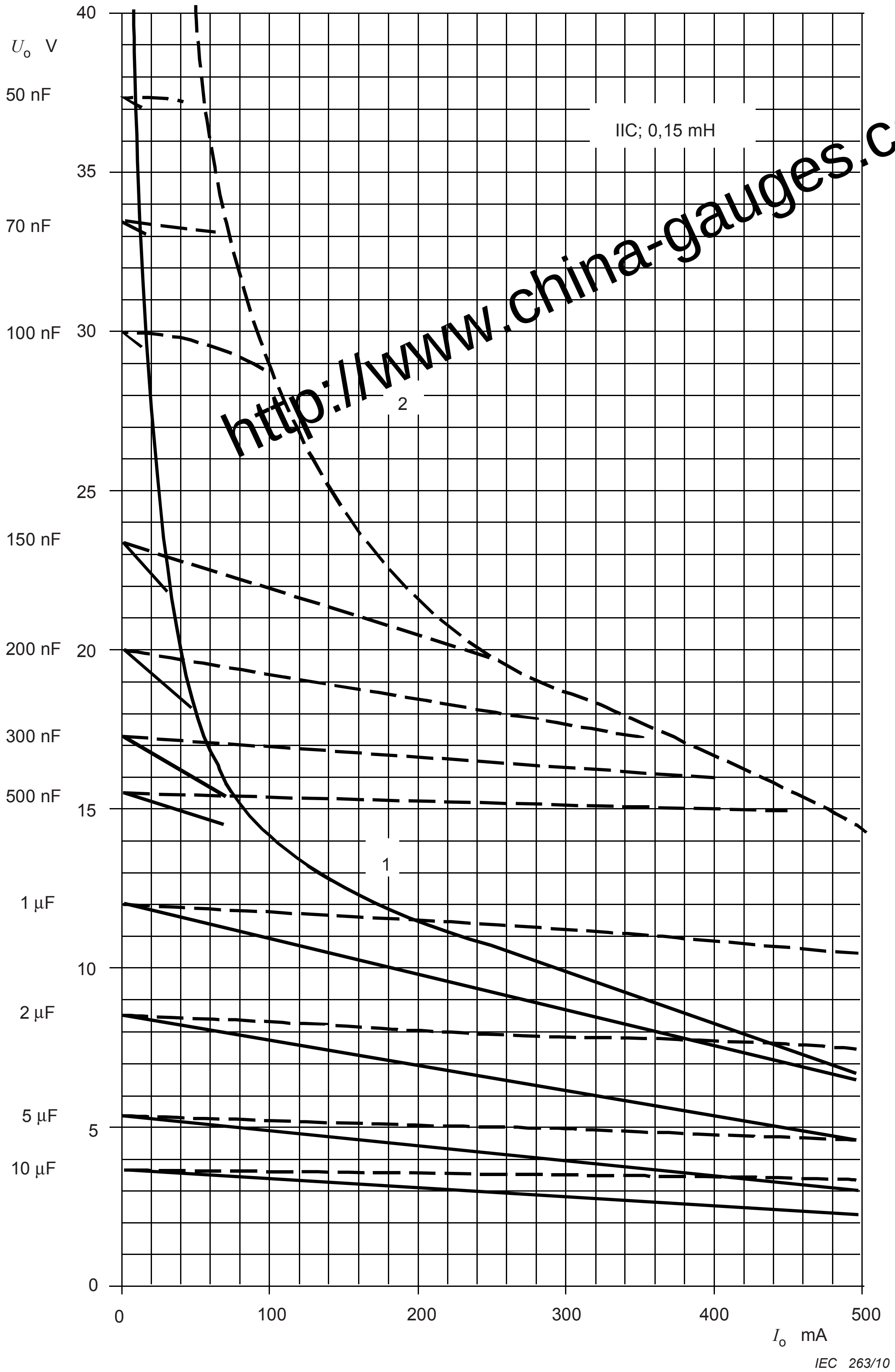
The installation rules of IEC 60079-14 permit the designer, constructor or operator of an electric installation in a hazardous area to handle such combinations at his own responsibility if a calculated or measured proof of the safety of the interconnection is carried out. Since the operator has, generally, no facility for a measured proof (the required equipment is not available to the operator), the operator is left with a suitable calculation procedure. IEC 60079-14 has up to now provided only a procedure that can be used exclusively for sources with purely linear internal resistance and even this does not always result in safe configurations. In practice however, sources with non-linear characteristic occur frequently, and up till now the combination of these were only possible with the support of a testing station.

A method was therefore developed which permits the safety assessment of the combination of networks with linear and non-linear circuits to be performed by means of diagrams. The procedure described here is applicable to explosion Groups IIB and IIC and for hazardous area Zone 1.

The basic part of the procedure is the graphical summation of the output characteristics of the intrinsically safe sources involved. The resultant characteristics are then plotted in a suitable diagram from which the intrinsic safety of the resistive, inductive, capacitive and combined circuits can be assessed (that is with a simultaneous inductive and capacitive load). A significant advantage of this procedure is that all information and boundary conditions relating to the safety data can be taken from just one diagram. The required safety factor of 1,5 is already incorporated into the diagrams.

## C.6 Diagrams

The diagram in Figure C.9 is included so that it may be used for copying onto a transparency. The self-calculated diagrams for voltage sum or current sum then can be drawn and laid upon the different limit diagrams (common scale versions) for assessment. On the following pages the limit diagrams in accordance with to Table C.2 are given both in a common scale and in optimized scale.



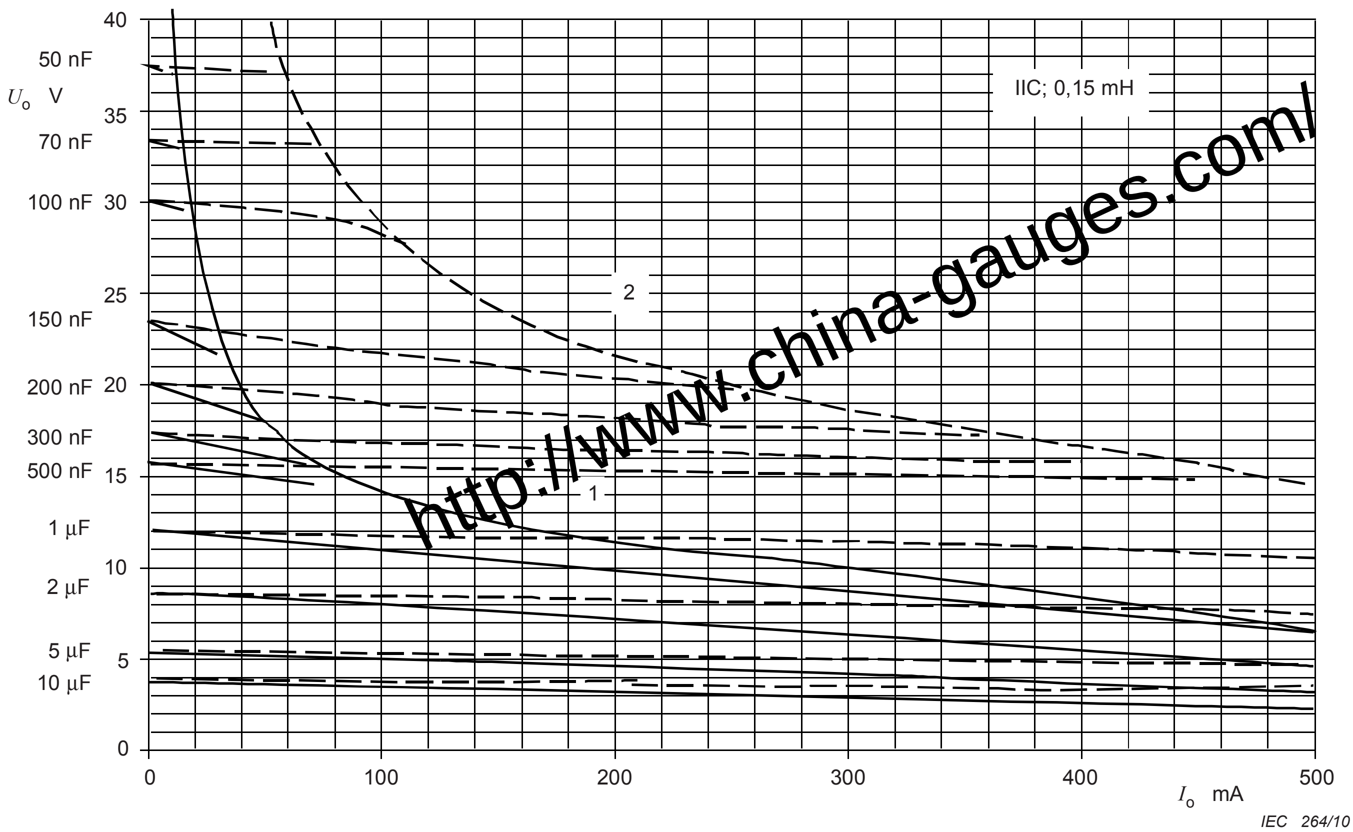



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7a – Diagram for 0,15 mH**



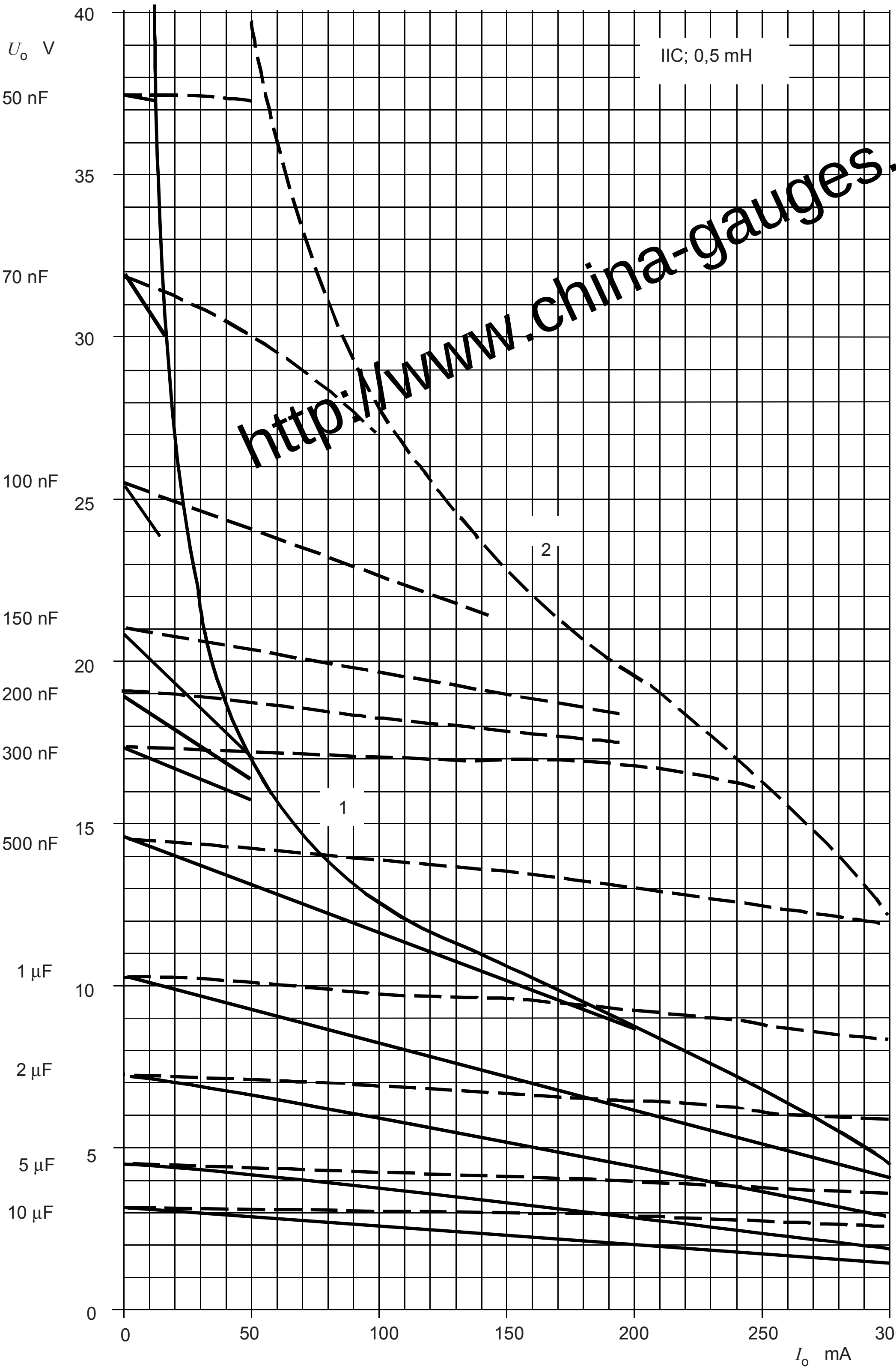



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7a – Diagram for 0,15 mH** *(continued)*




IEC 265/10

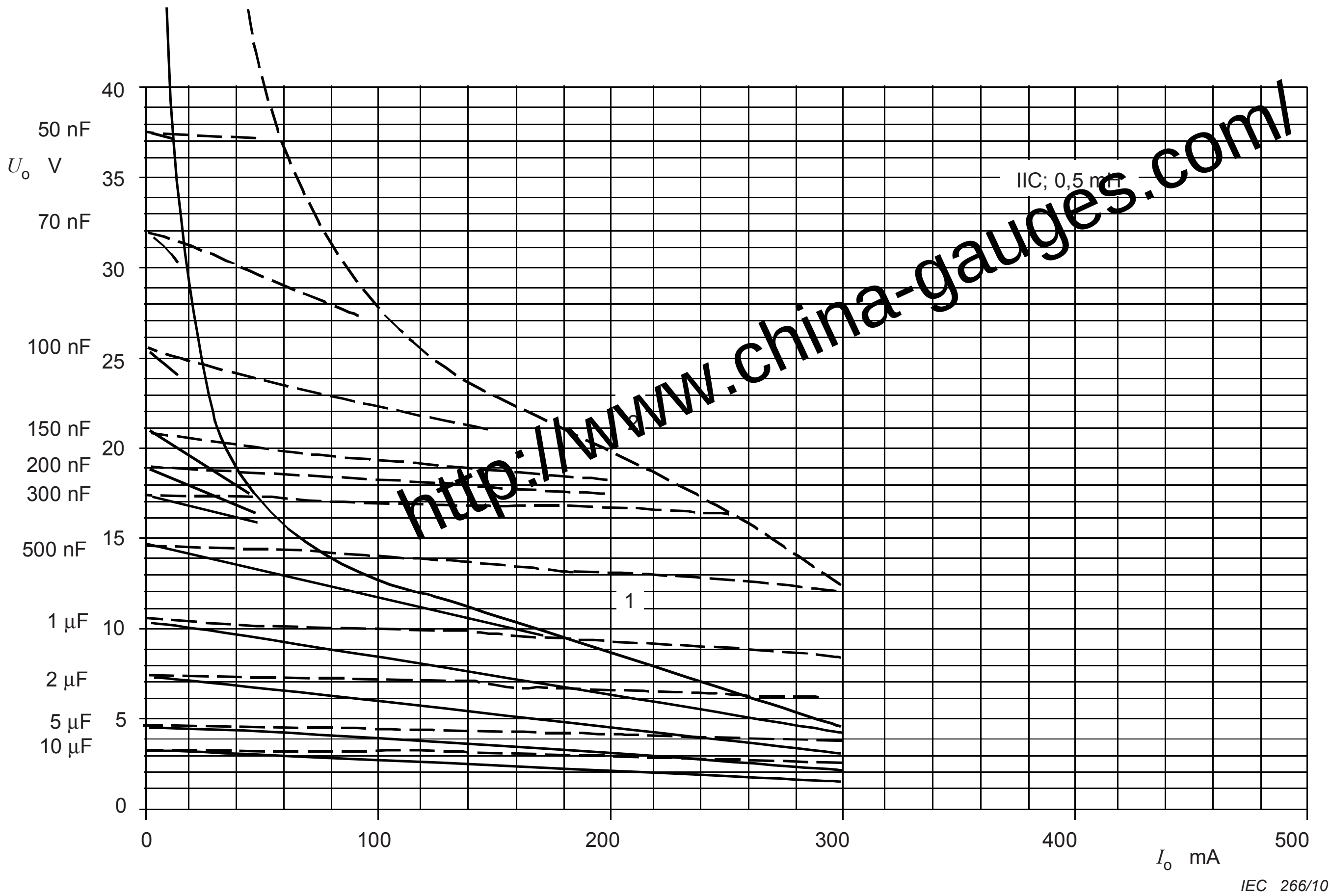


**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7b – Diagram for 0,5 mH**



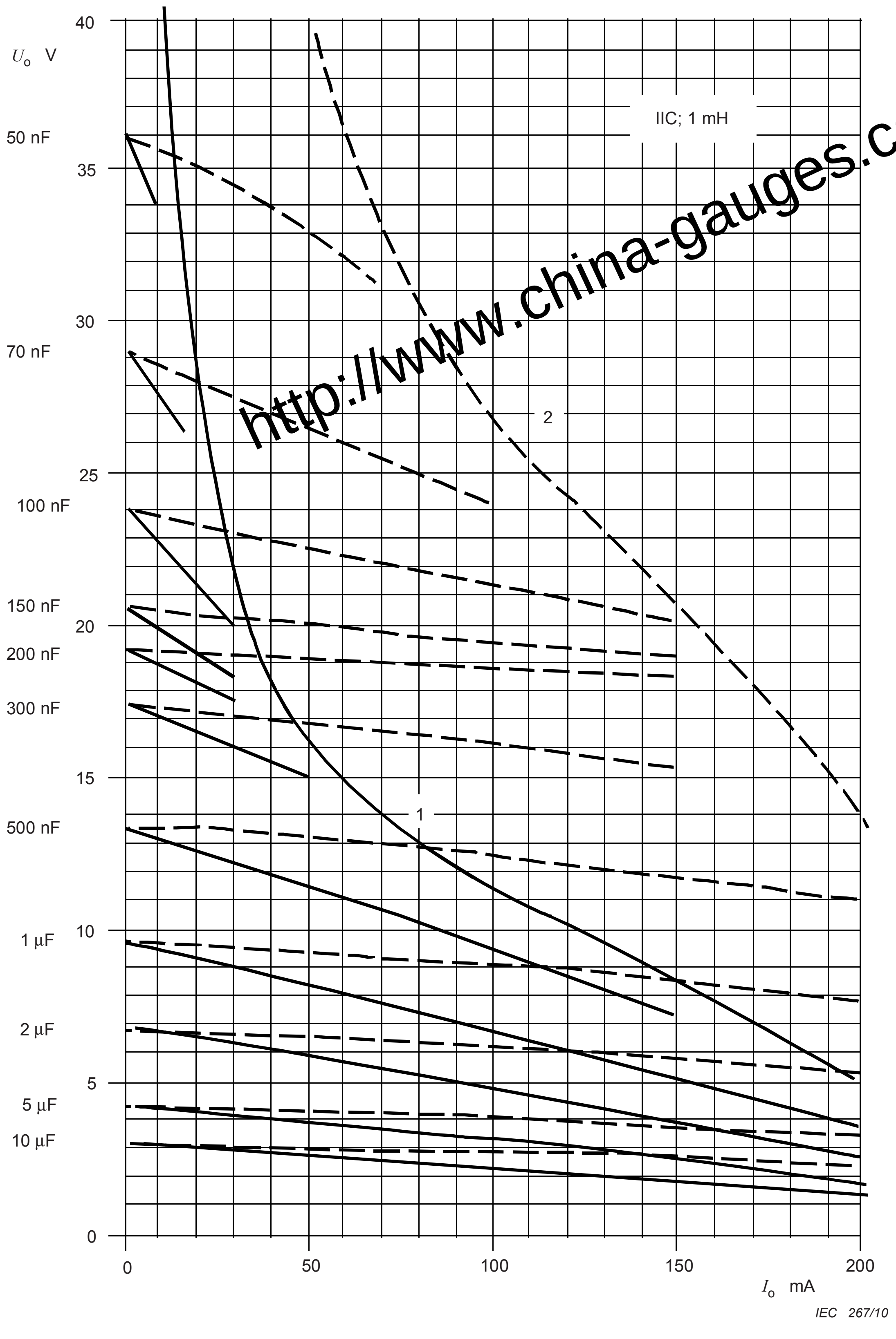


**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7b – Diagram for 0,5 mH** *(continued)*



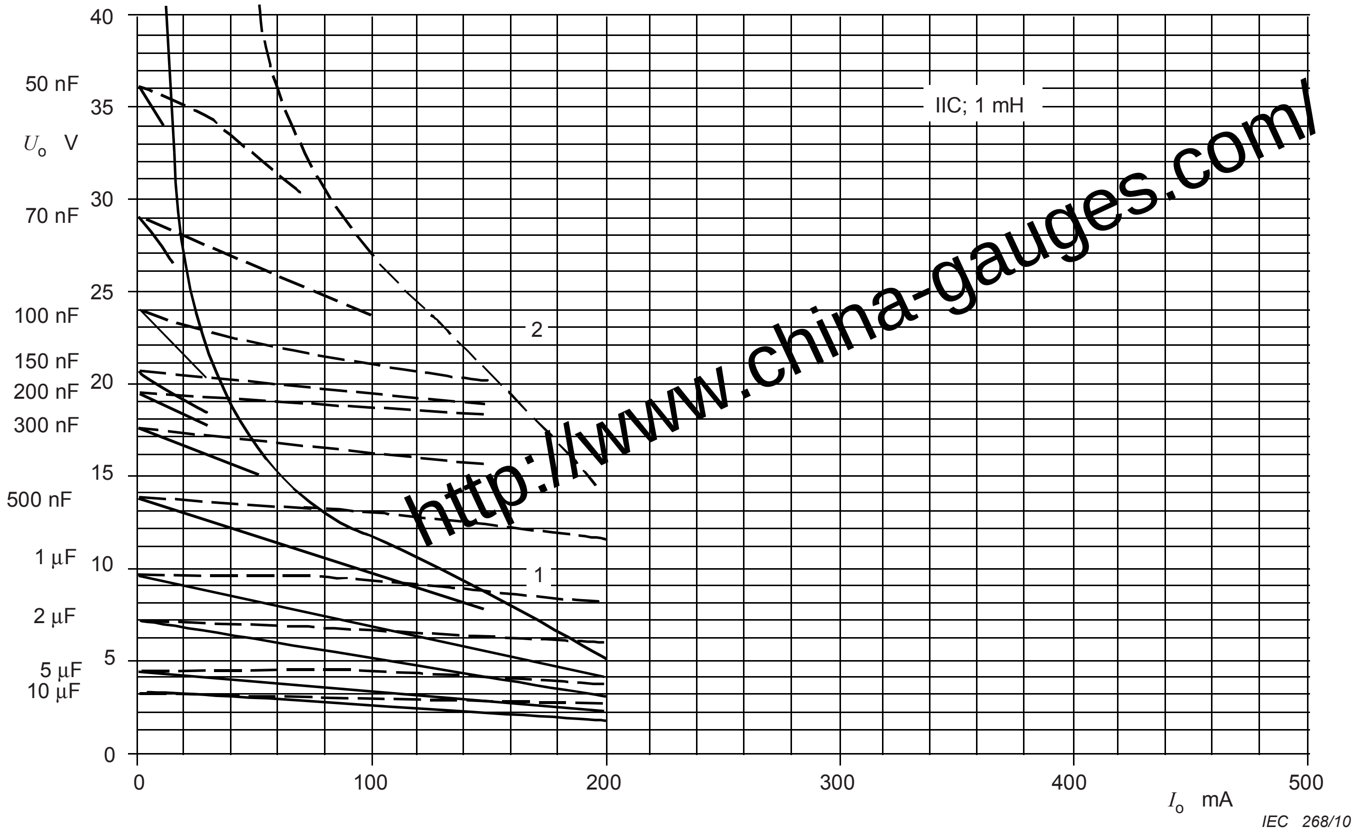


**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7c – Diagram for 1 mH**



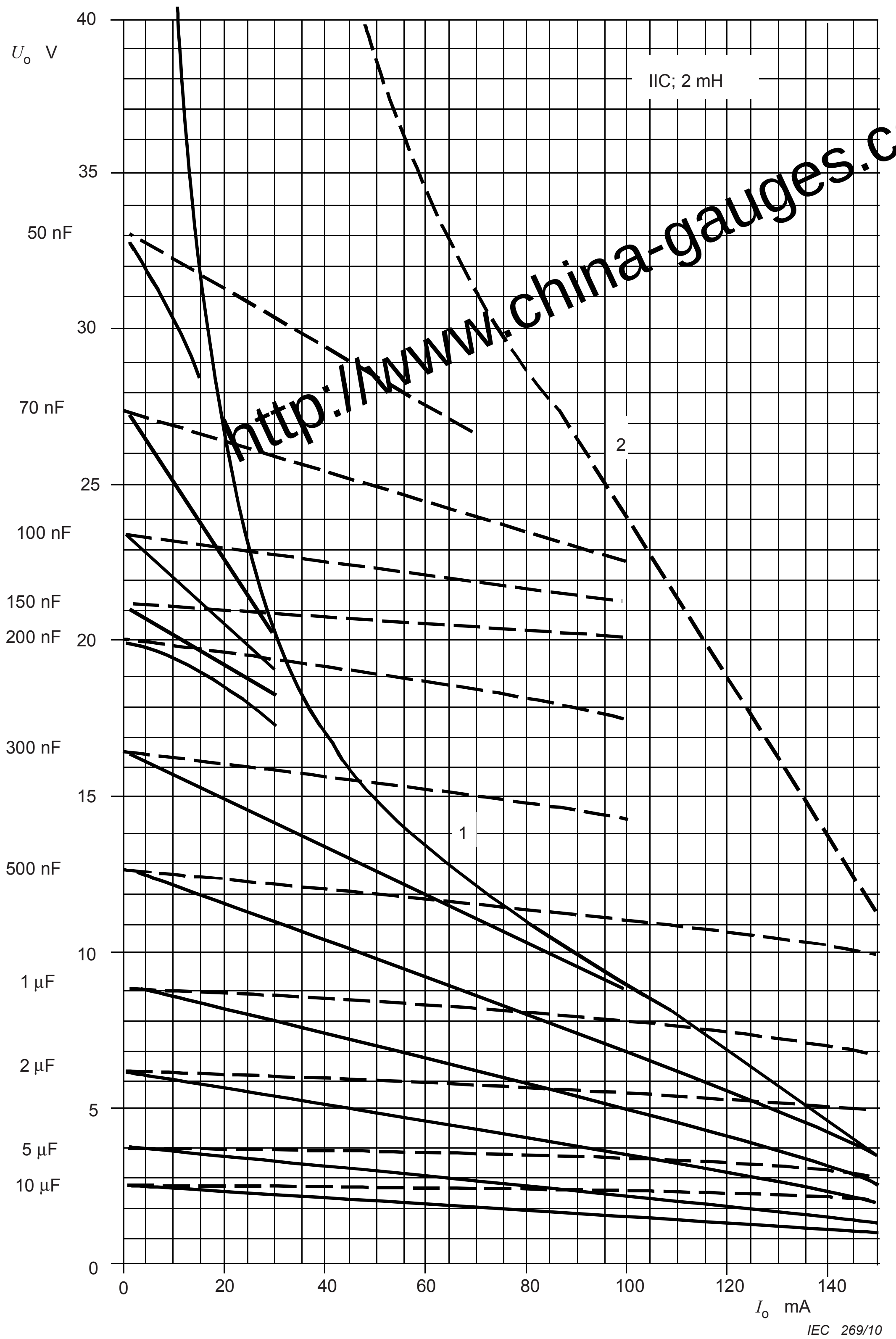



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7c – Diagram for 1 mH** *(continued)*



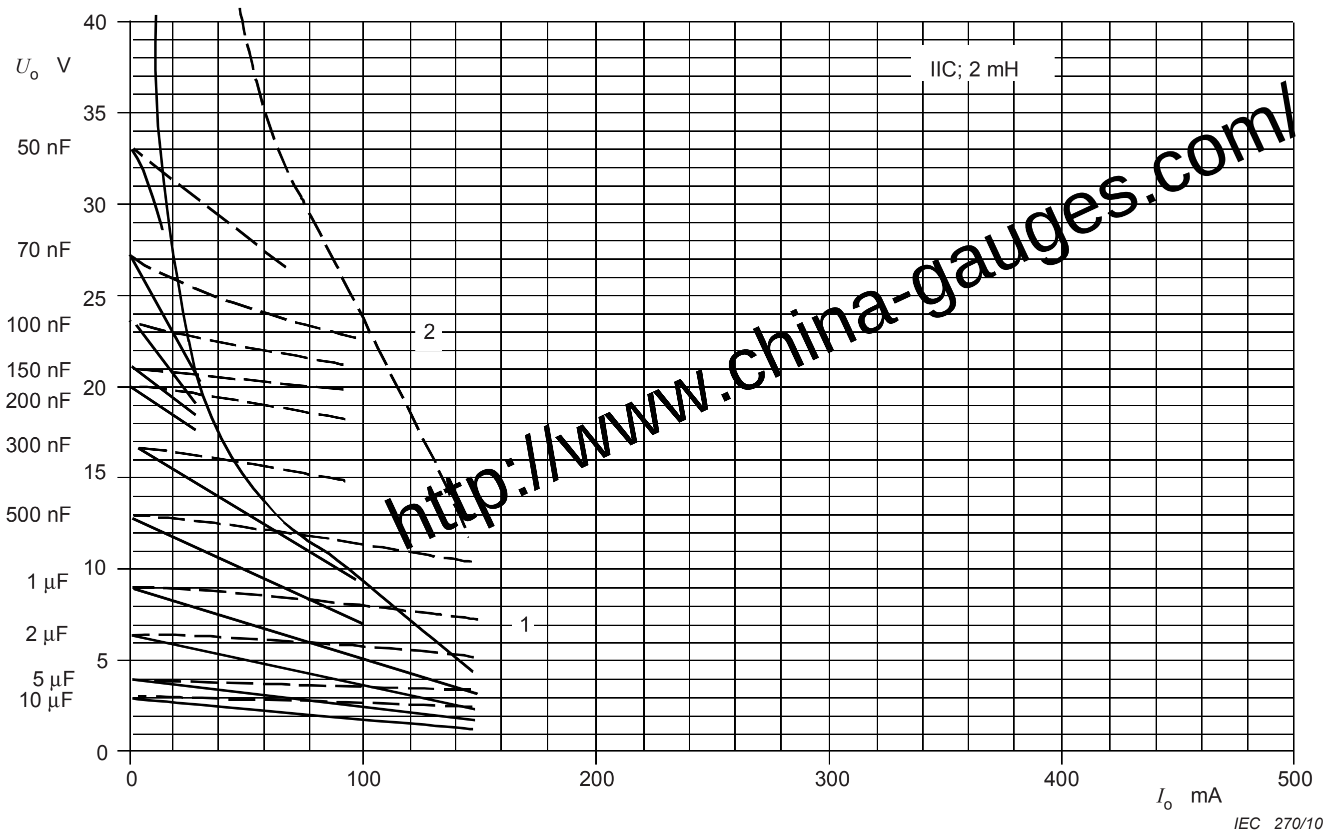



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7d – Diagram for 2 mH**



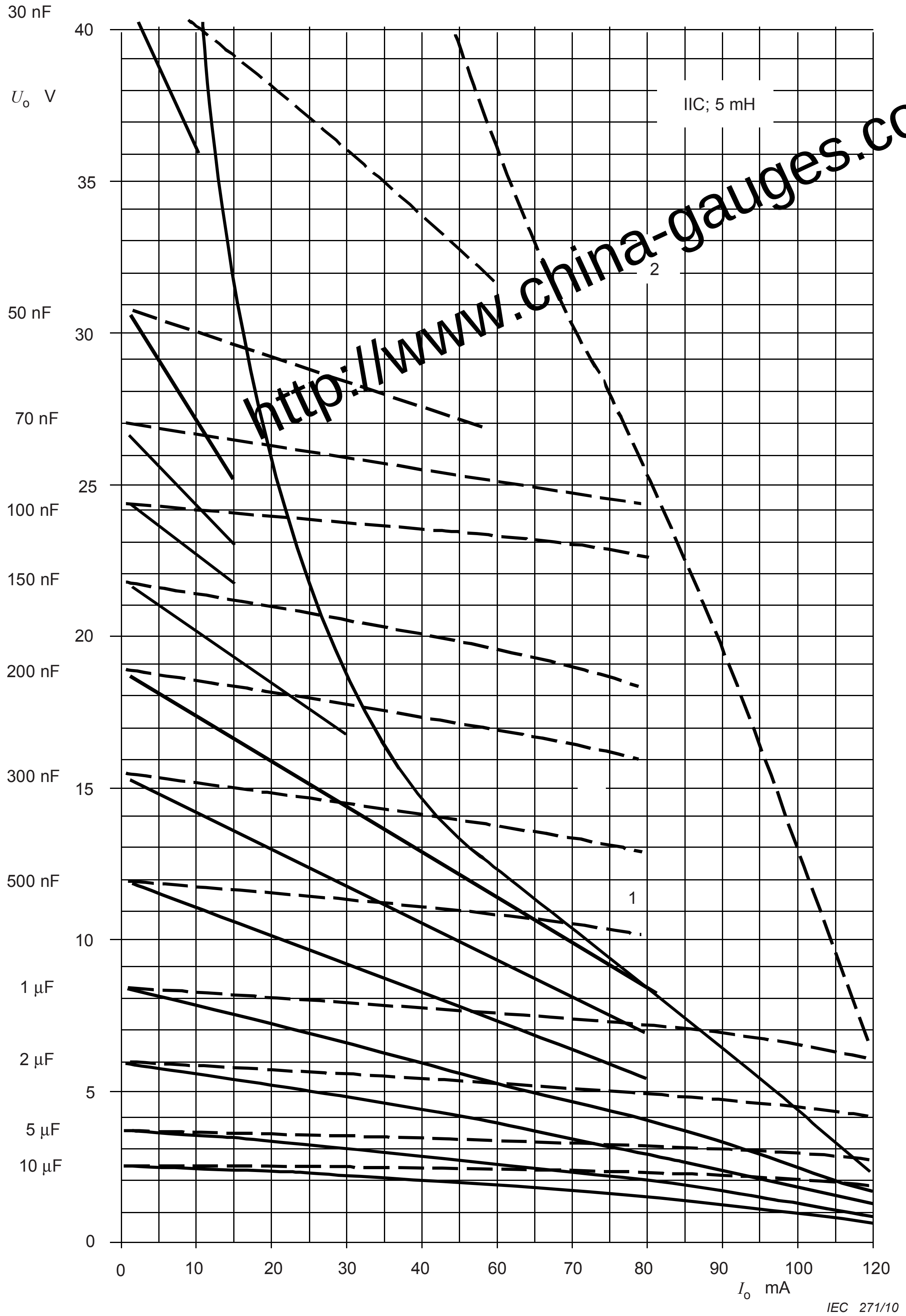



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7d – Diagram for 2 mH** *(continued)*






**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7e – Diagram for 5 mH**



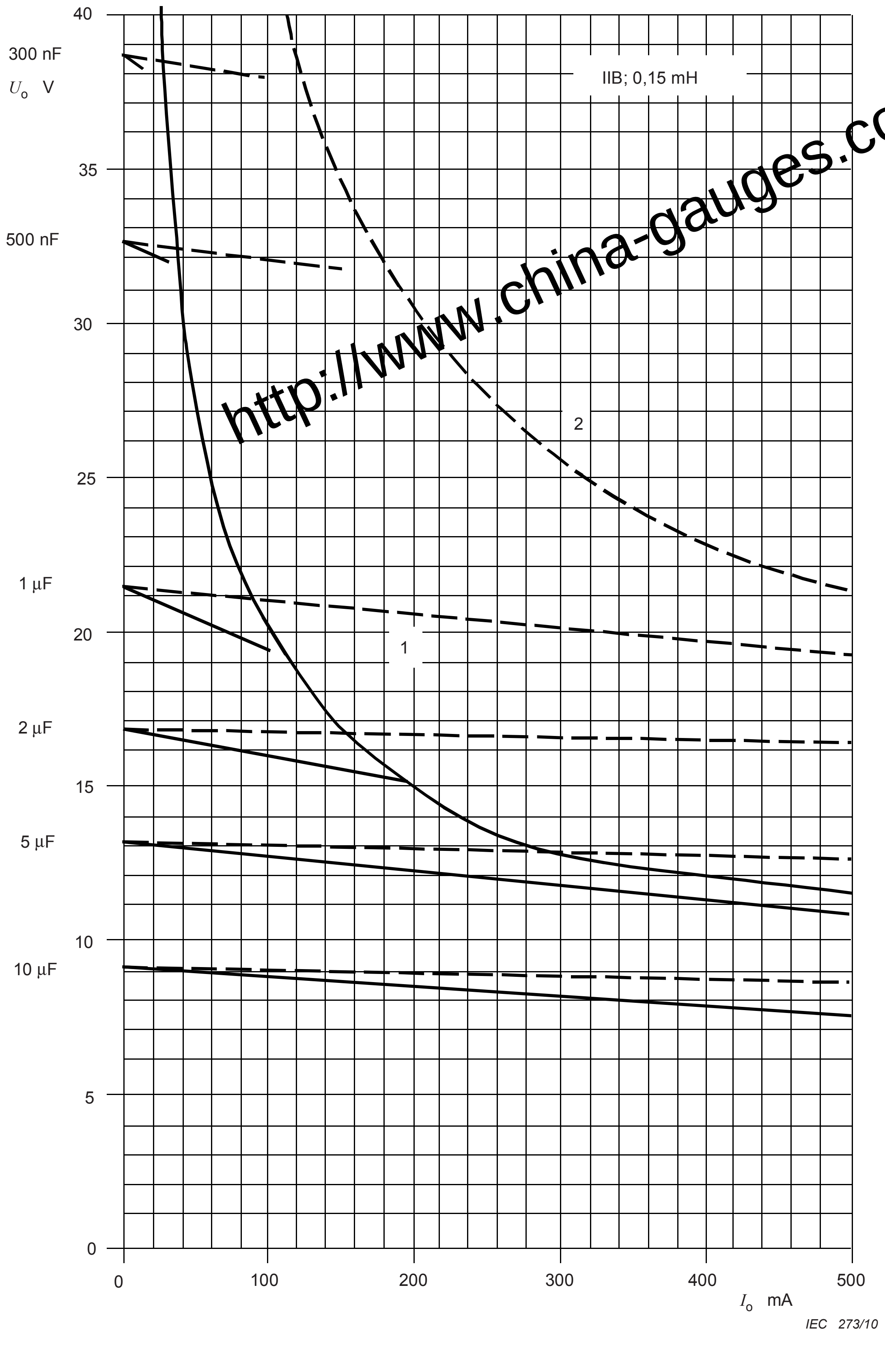

**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.7e – Diagram for 5 mH** *(continued)*

**Figure C.7 – Limit curve diagram for universal source characteristic – Group IIC**



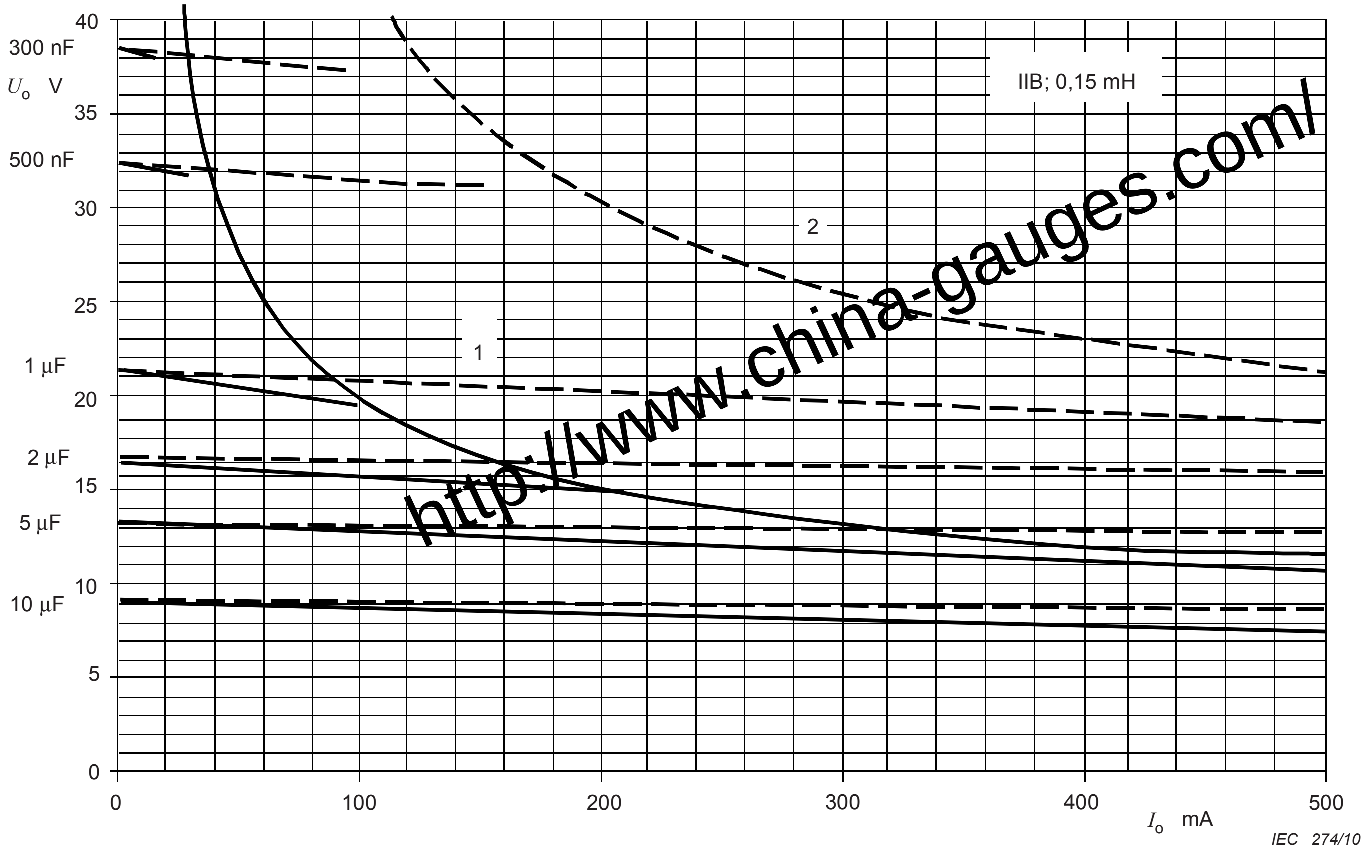



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8a – Diagram for 0,15 mH**



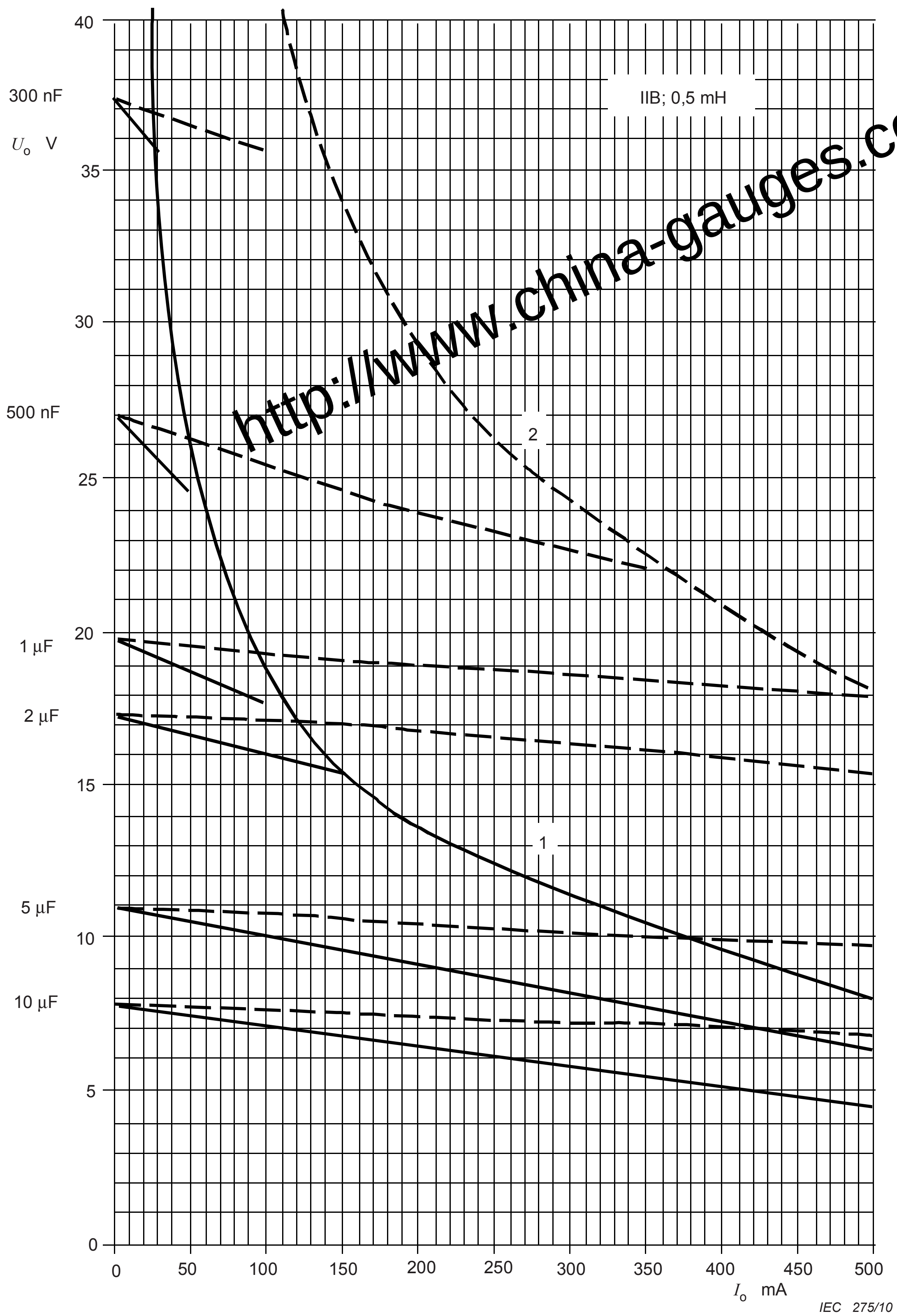


**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8a – Diagram for 0,15 mH** *(continued)*

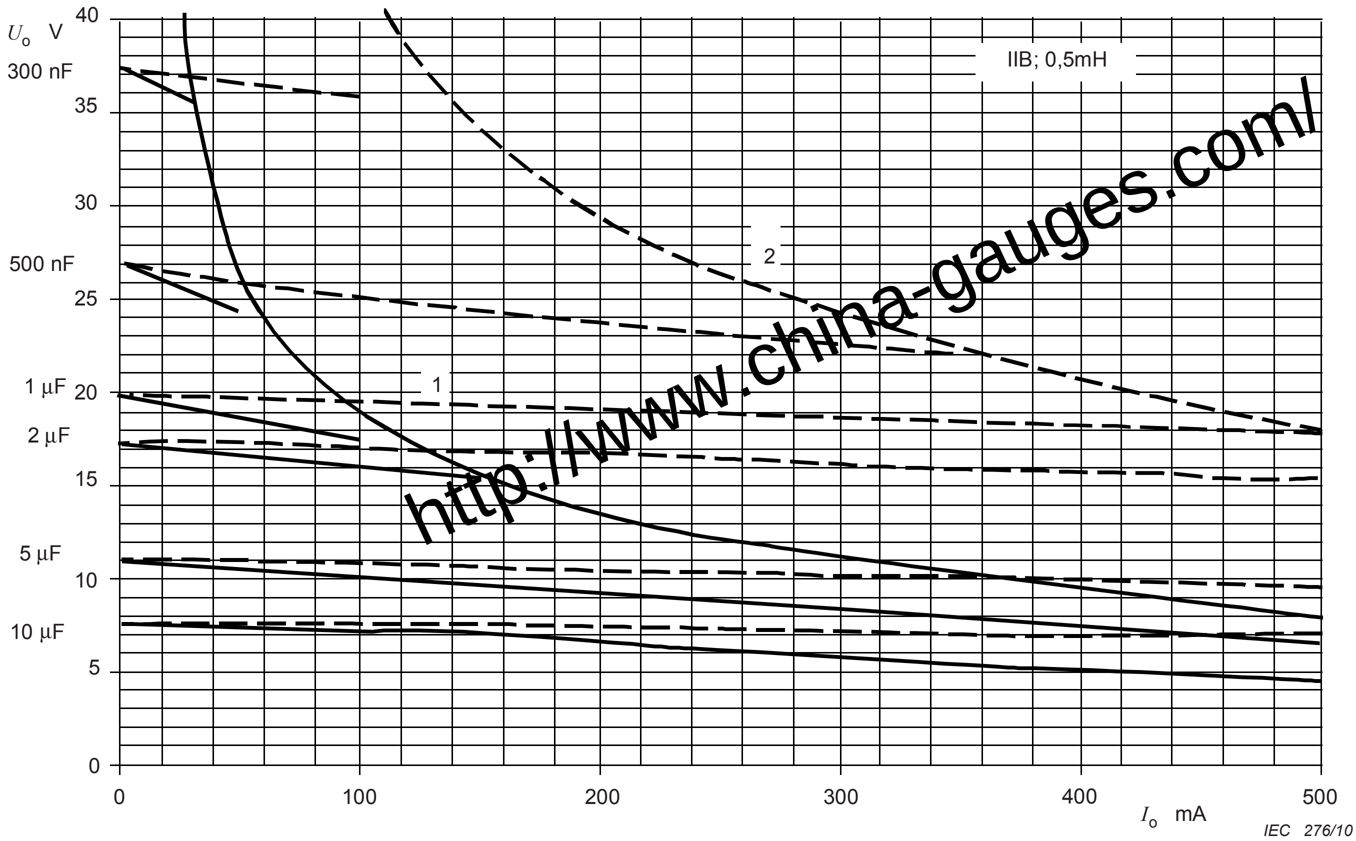



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8b – Diagram for 0,5 mH**

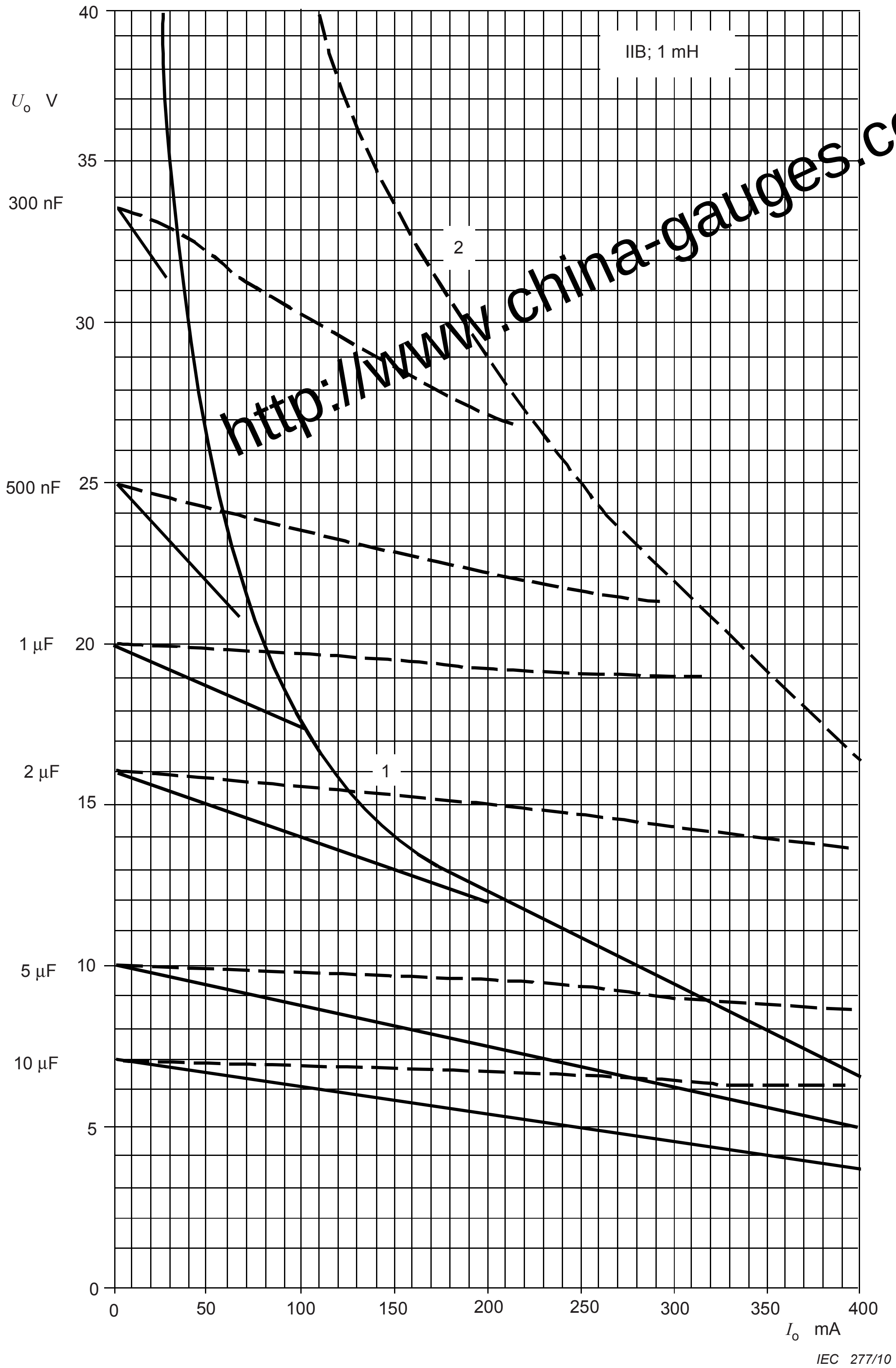



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8b – Diagram for 0,5 mH** *(continued)*



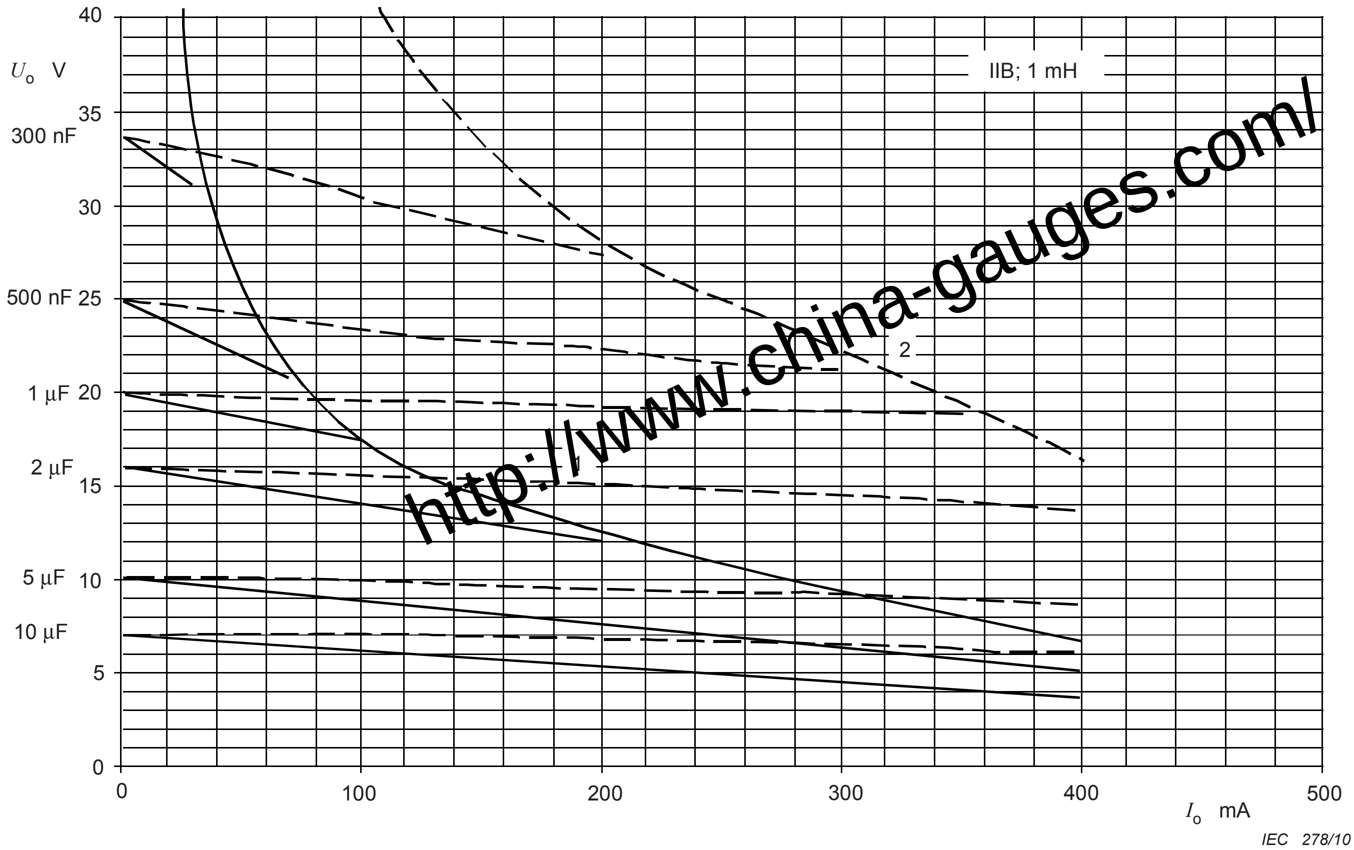



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8c – Diagram for 1 mH**



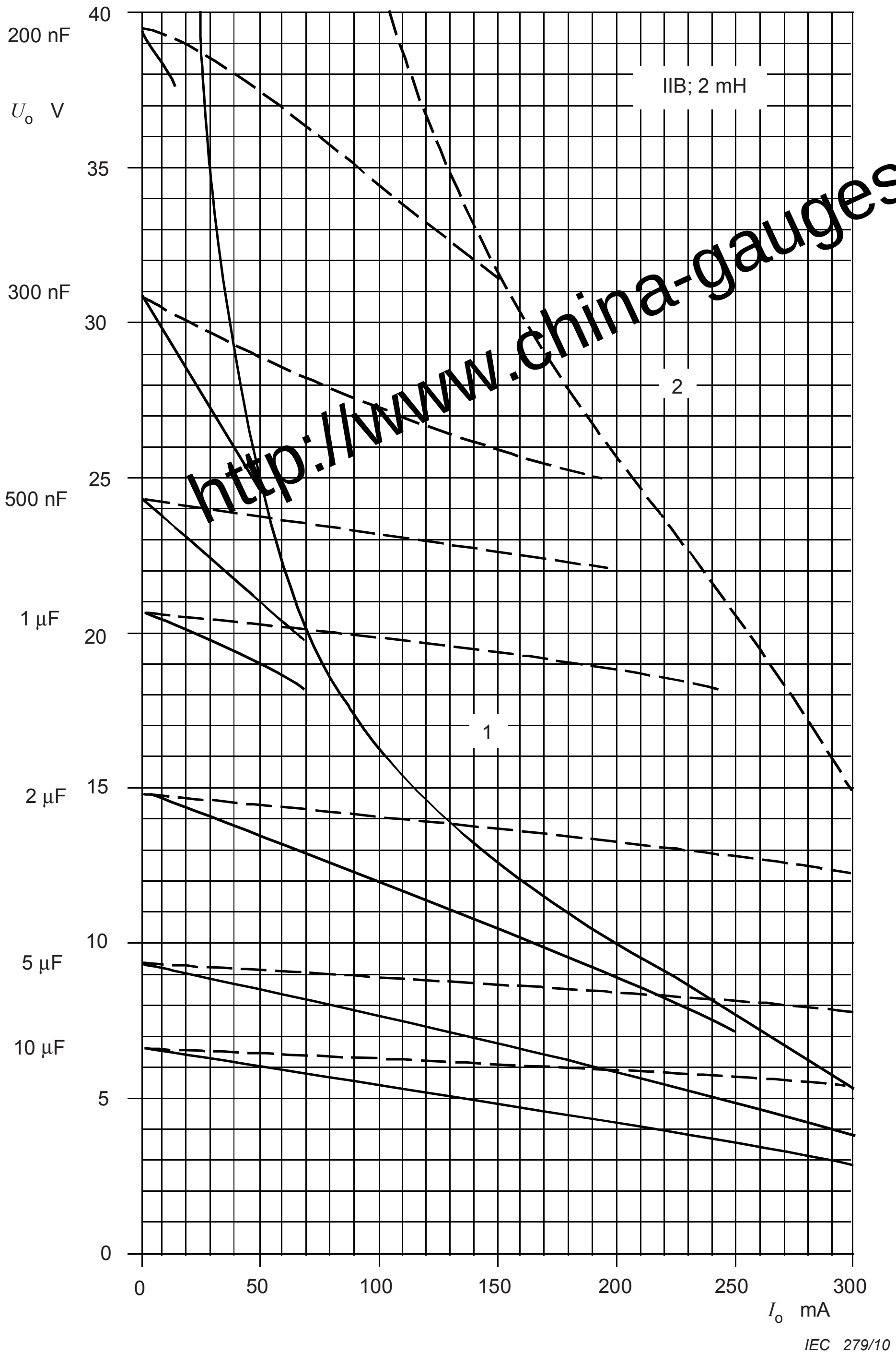



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8c – Diagram for 1 mH** *(continued)*



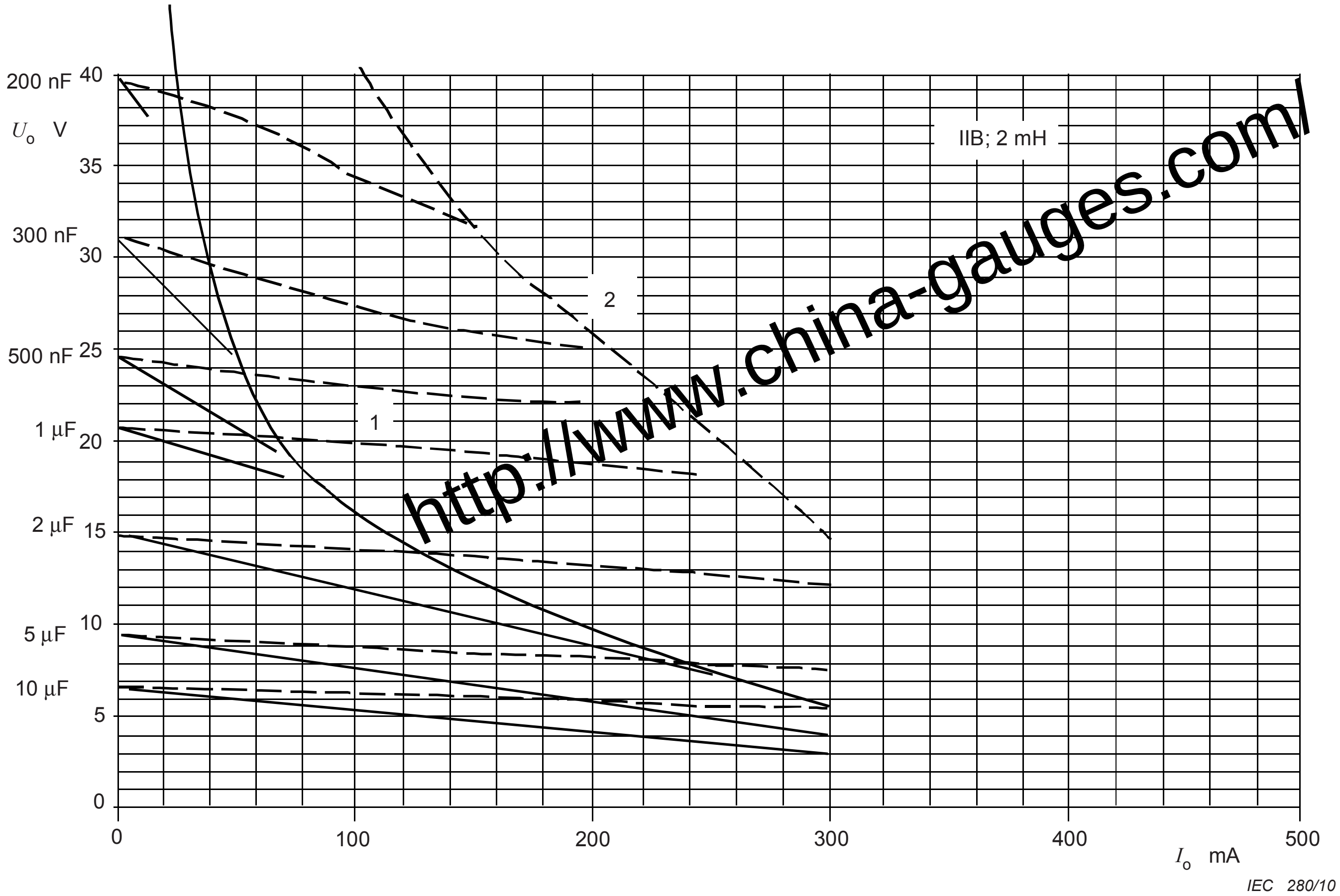



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8d – Diagram for 2 mH**



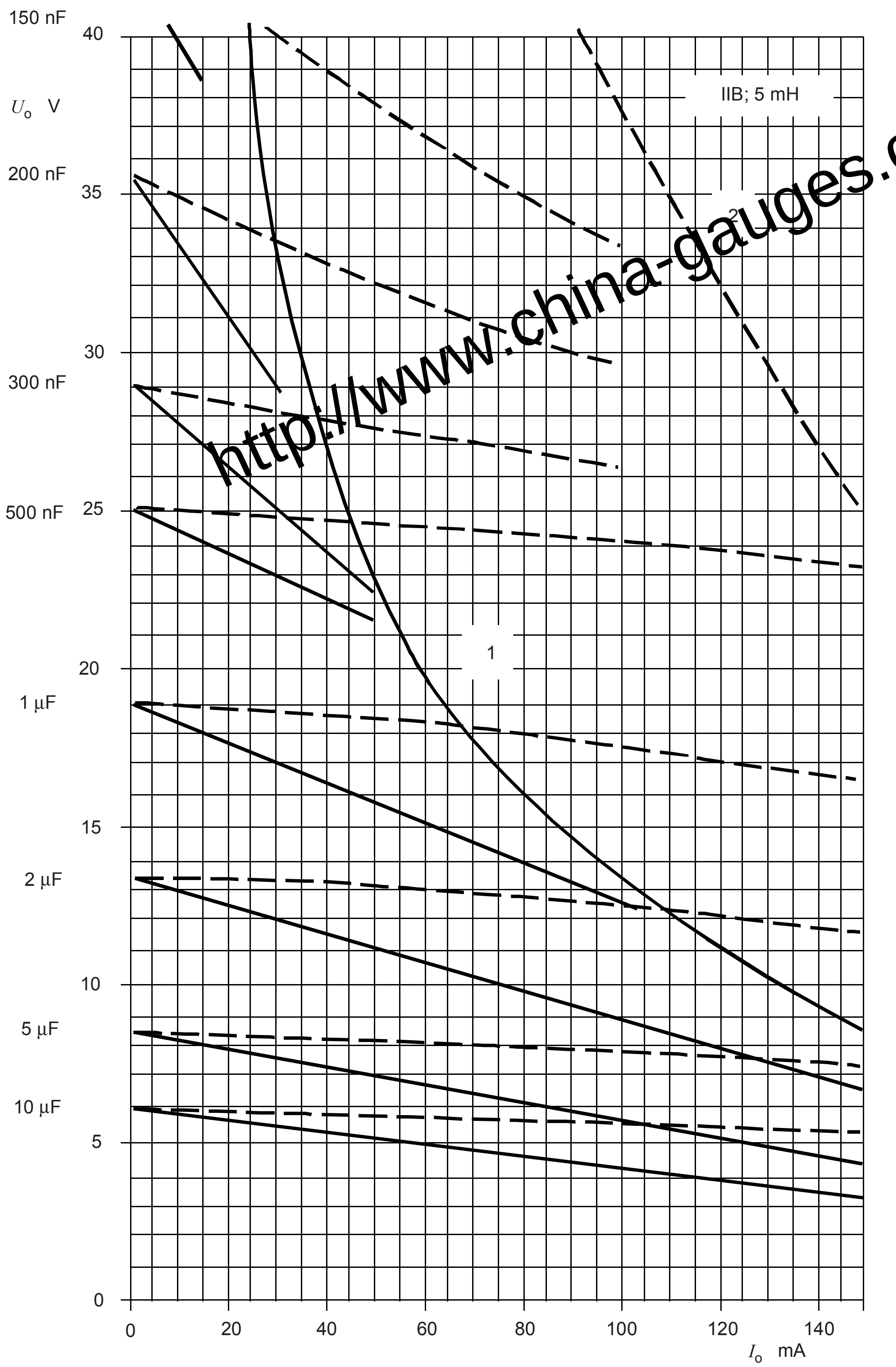



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8d – Diagram for 2 mH** *(continued)*



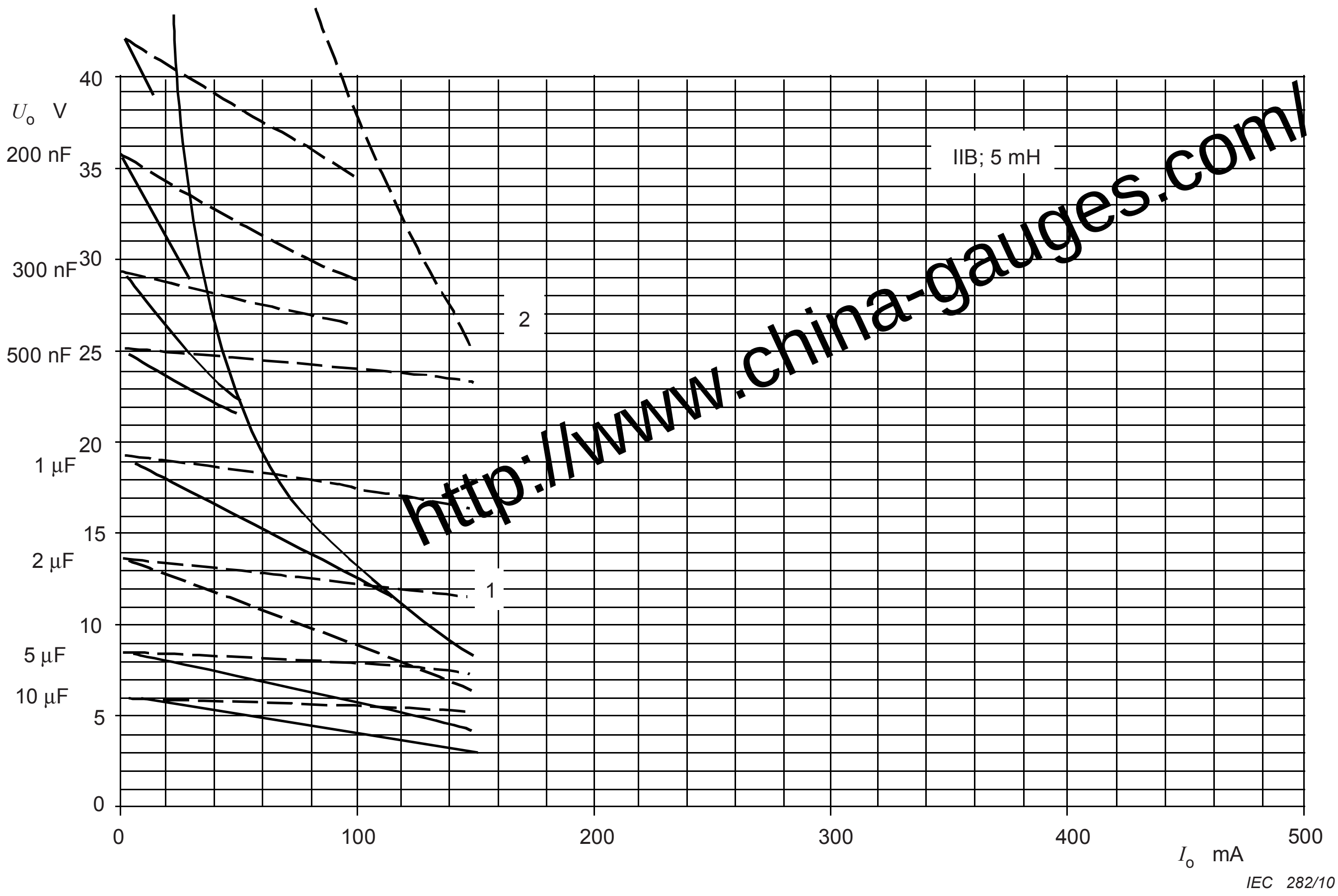



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8e – Diagram for 5 mH**





**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure C.8e – Diagram for 5 mH** *(continued)*

**Figure C.8 – Limit curve diagram for universal source characteristic – Group IIB**

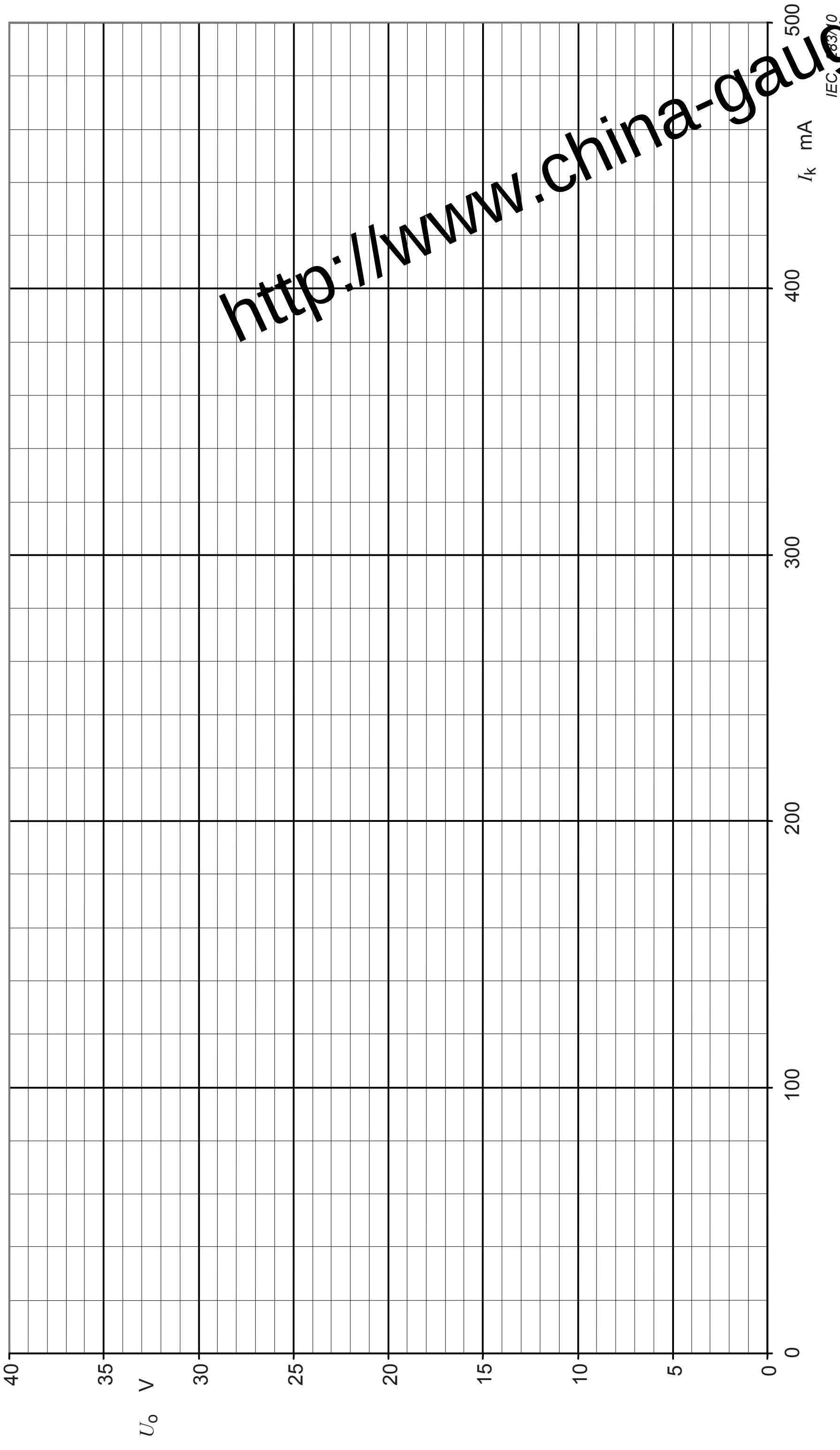



**Figure C.9 – Copy pattern for universal source diagrams**

# Annex D
(normative)

## Verification of inductive parameters



Figure D.1 illustrates the system being analysed.

$R_i$ is the inherent resistance of the inductive coil. If the coil resistance is supplemented by an additional resistor, then that resistor shall conform to the criteria of an infallible resistor.

$R_o$ is the output resistance of the linear source of power, that is $U_o/I_o$.

If $L_i$ is less than $L_o$, then the permitted inductance of the cable may be taken, as the difference between the two values and the system is acceptable.

If $L_i/R_i$ is less than the permitted $L_o/R_o$ of the power source, then the system is acceptable and the permitted $L/R$ ratio of the cable remains $L_o/R_o$.

NOTE 1 Where a power supply uses the lowest value of a current-limiting resistor determined from the permitted short-circuit current corresponding to the voltage and the apparatus group table of IEC 60079-11, there is no permitted inductance for a cable without taking into consideration the cable resistance, and $L_o$ equals zero.

If the inductive apparatus does not conform to either of these two requirements, then a more extensive analysis should be undertaken as follows.

Determine the current, which flows through the inductance. In the circuit illustrated, this is $I = U_o/(R_o + R_i)$.

Multiply this current by 1,5 and use the inductive curves in IEC 60079-11 appropriate to the required equipment group to determine the maximum permitted inductance $L_{max}$.

If $L_{max}$ is less than the inductance of the coil $L_i$, then the circuit is not acceptable.

If $L_{max}$ is greater than $L_i$ then the permitted cable inductance $L_c$ is the smaller of the two values $(L_{max} - L_i)$ or $L_o$.

If required, maximum inductance to resistance ratio of the cable ($L_c/R_c$), which may be connected in the system, shall be calculated using the following formula. This formula takes account of a 1,5 factor of safety on current and shall not be used where $C_i$ for the output terminals of the apparatus exceeds 1 % of $C_o$.

$$\frac{L_c}{R_c} = \frac{8eR + (64e^2R^2 - 72U_o^2eL)^{1/2}}{4{,}5U_o^2} \ \mu\text{H}/\Omega$$

where

$e$ is the minimum spark-test apparatus ignition energy in microjoules, and is for

- Group I apparatus: 525 μJ,
- Group IIA apparatus: 320 μJ,
- Group IIB apparatus: 160 μJ,
- Group IIC apparatus: 40 μJ;

$R$ is the total circuit resistance ($R_o + R_i$), in ohms;

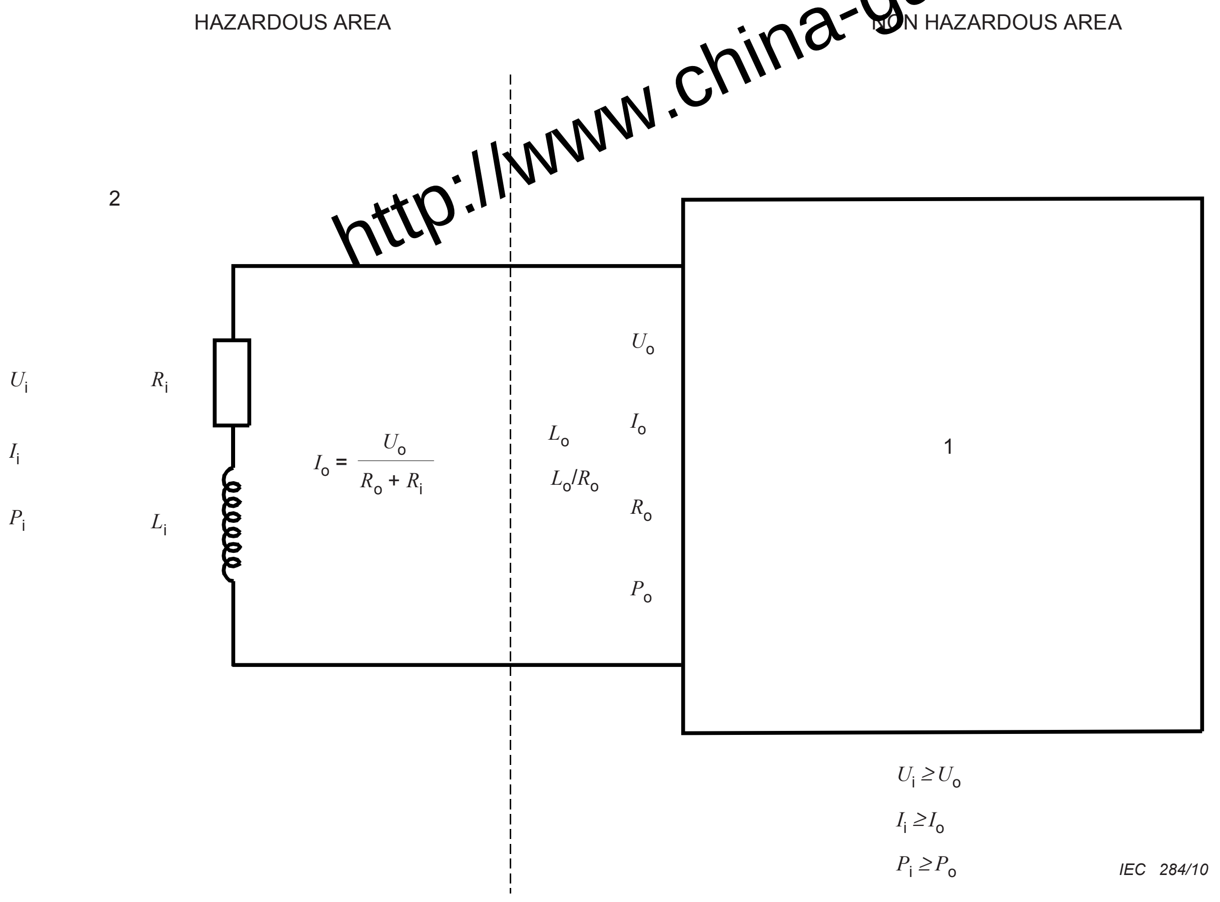
$U_o$ is the maximum open circuit voltage, in volts;

$L$ is the total circuit inductance ($L_i$ + internal inductance of power source) in henries;

The permitted $L_c/R_c$ ratio of the system cable is whichever is the smaller of this calculated value and the $L_o/R_o$ ratio of the source of power.

NOTE 2 In determining the temperature classification of such an inductor, the assumption is made that the coil resistance fails to the value permitting maximum power transfer.






**Key**

1 associated apparatus

2 parameters of inductance

**Figure D.1 – Typical inductive circuit**

# Annex E
(informative)

## A possible format for descriptive systems drawings and installation drawings



This annex is intended to illustrate the information that is considered desirable in preparing descriptive system drawings as shown in Figure E.1 and installation drawings as shown in Figure E.2. It is not intended to promote a particular format for these drawings or suggest that other methods of storing the information cannot be equally effective. The example illustrated was deliberately chosen because of its complexity and illustrates almost all facets of system design. The majority of applications are much simpler than this and comprise a single transmitter and interface.

The block diagram contains all the information necessary to confirm the status of the system, and to make possible the analysis described in Annexes A and B. The note on the RTD confirms that it is simple apparatus and that its temperature classification is determined by the local process temperature. The failure to comply with the 500 V insulation test means that it is regarded as being earthed at the point and hence relies on the galvanic isolation within the transmitter to satisfy the requirement of the circuit being earthed at one point only.

The transmitter is certified apparatus and has safety parameters specified for both the RTD input connections and the 4 mA to 20 mA output connections. The input capacitance marginally changes the permitted cable capacitance, and the permitted ambient temperature range ensures that the transmitter is suitable for plant mounting in most locations.

The galvanically isolated interface has well-defined output parameters which are used to determine the permitted cable parameters. The restrictive cable parameter is the 80 nF cable capacitance, which is highlighted in the note under the document number. The alternative parameter in Group IIB is given since this might be more relevant to a particular application.

The installation drawing is intended to convert the descriptive system drawing to the requirements of a particular installation. The assumption is made that the installing technician requires the information necessary to create an installation, which has already been correctly designed. The technician would only need access to the descriptive system drawing if he had some reason to doubt the adequacy of the installation. The installation drawing adds the junction box, which is simple apparatus and specifies the particular cables and glands to be used. In this case they are agreed company standards complying with the relevant requirements. The temperature classification of the RTD is clarified and specific instructions on the bonding of the cable screens are given. The level of information on this drawing should be adequate to permit subsequent inspections to be carried out.

It is important to reiterate that this annex illustrates only one method of presenting this information. The essential requirement is that the descriptive system document contains all the information, which enables an adequately safe system to be created. The installation document should contain the necessary information to enable a particular embodiment of that system to be safely installed in a specific location.

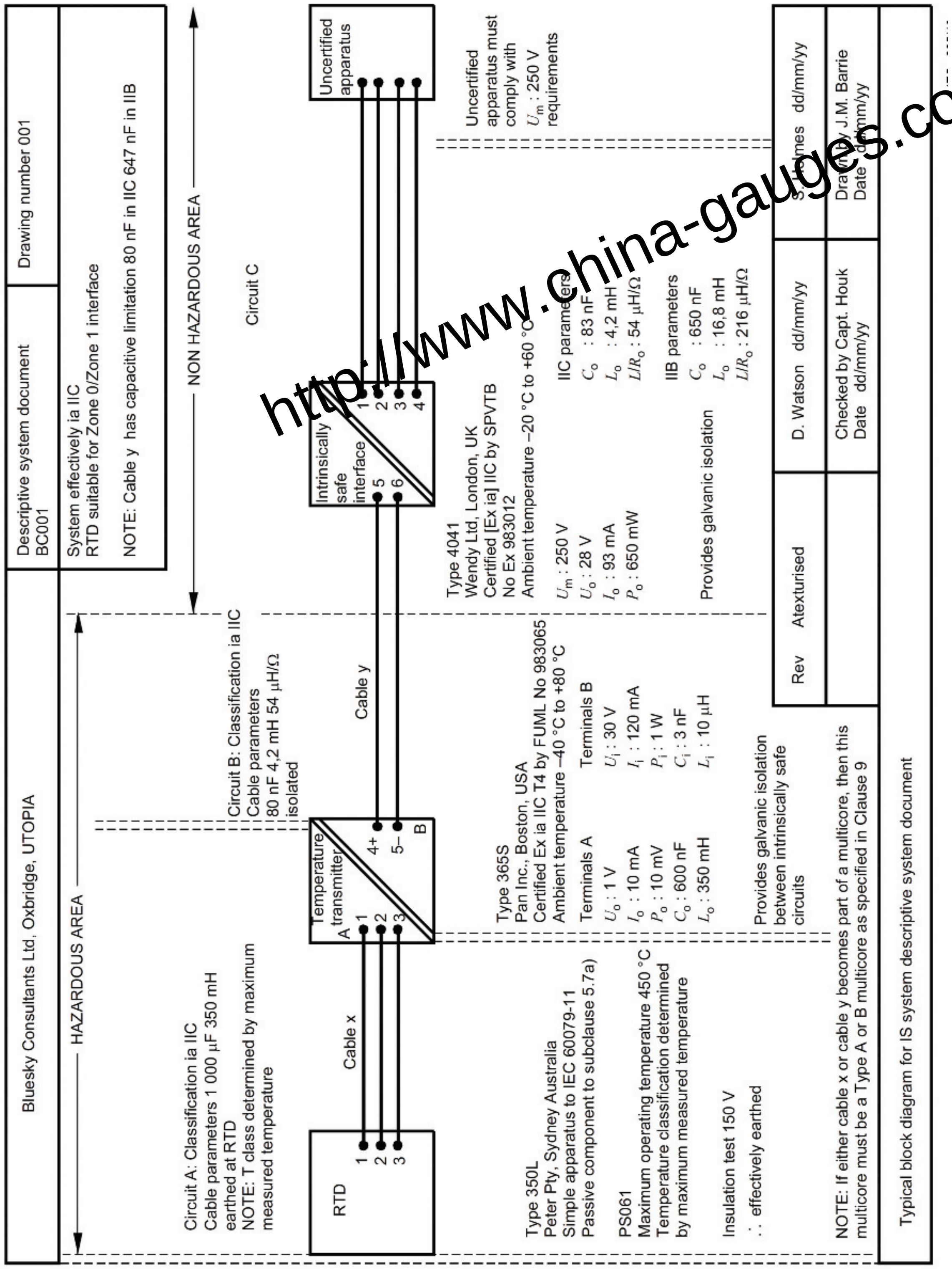





**Figure E.1 – Typical block diagram for IS system descriptive system document**

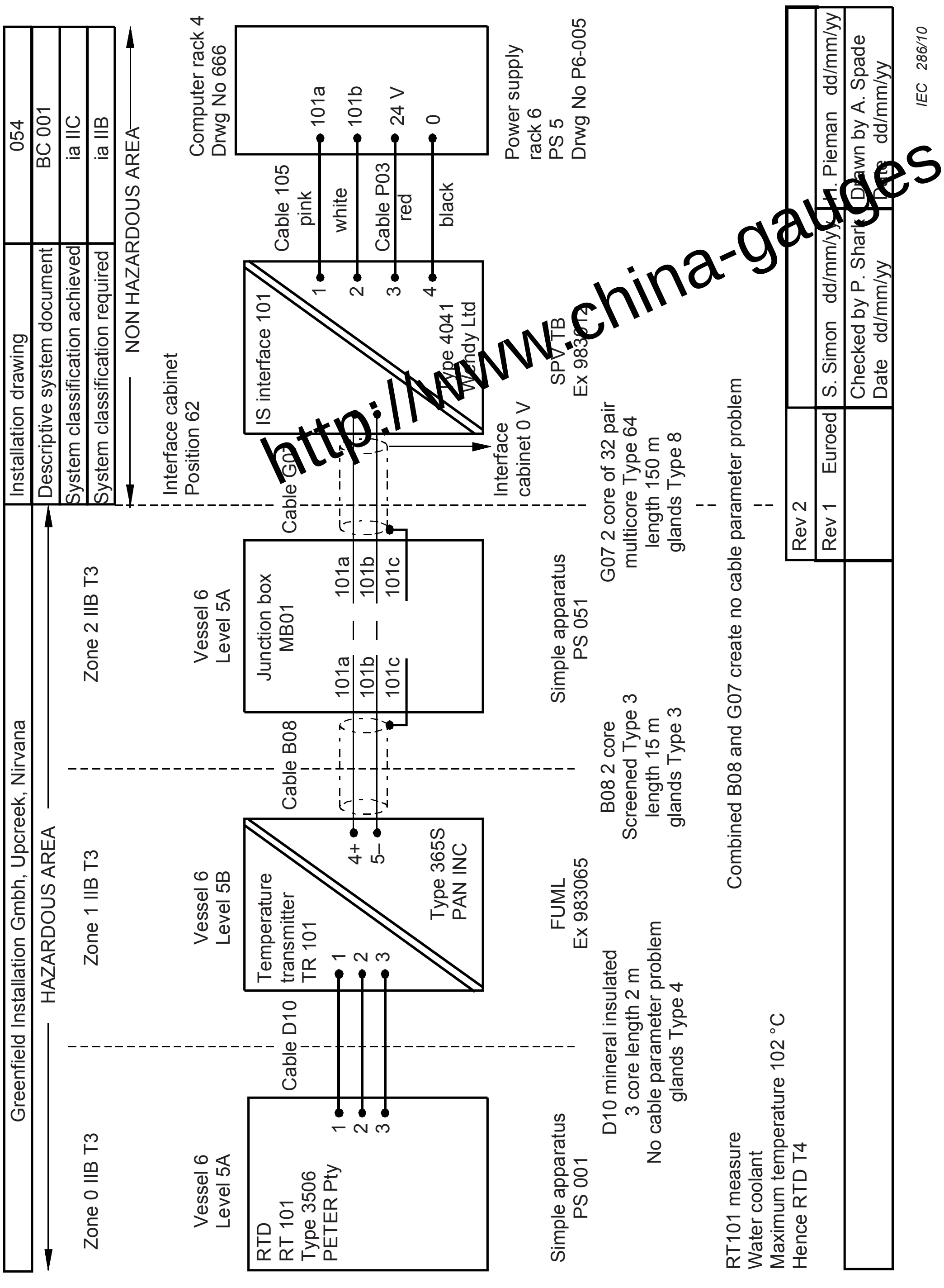





**Figure E.2 – Typical installation drawing for IS system**

# Annex F
(informative)

# Surge protection of an intrinsically safe circuit



## F.1 General

This annex illustrates a possible technique for protecting an intrinsically safe circuit from the surges induced by a nearby lightning strike. This type of protection is only applied when a risk analysis of the probability of a lightning strike and the consequences of such an event shows it to be necessary. The example is intended to demonstrate the necessary analysis; it is not the only possible solution.

## F.2 Installation to be protected

Figure F.1 illustrates a typical installation where the neutral is directly connected to an earth mat. Other bonding techniques are equally acceptable. The temperature-sensing element penetrates the Faraday cage of a storage tank containing a flammable material. The sensing element resistance is converted to 4 mA to 20 mA by a converter with internal isolation. This current is then fed into the computer-input network via a galvanic isolator. The combination of isolator, converter and the sensing element needs to be analysed as being an intrinsically safe system and is the system analysed in Annex E.

## F.3 Lightning induced surges

One possible scenario is lightning striking the tank at point X and the resultant current being dispersed via the foundations of the tank and the equipotential bonding of the installation. A transient voltage (typically 60 kV) would be developed between the tank top (X) and the bonding point of the computer ‘0’ volt (Y). The transient voltage would cause breakdowns of the galvanic isolator and the converter isolation and could create a side flash within the vapour space of the tank with a high probability of an explosion.

## F.4 Preventive measures

A surge suppressor can be mounted on the tank to protect the transmitter segregation thus preventing a potential difference within the tank. The surge suppresser is bonded to the tank to preserve the Faraday cage. The multi-element surge suppresser restricts the voltage excursion (60 V) to a level which can readily be absorbed by the transmitter isolation.

A second surge arrester is necessary to prevent the galvanic isolator and computer input circuits being damaged. This surge suppresser would normally be mounted in the safe area and connected as indicated. The resultant common-mode surge on the isolator would not overstress the isolation within the galvanic isolator.

The system is not intrinsically safe during the transient voltage but the high currents and voltages are removed from the highest hazard location within the tank and are present in the relatively secure location of the interconnecting cables.

The system is indirectly earthed (bonded) at two places and during the transient period the circulating current flowing is incendive. However, in normal operation the indirect earths are non-conducting and require a relatively high voltage (120 V) between the bonding connections of the surge suppression networks for any significant current to flow. Such a voltage should not exist for any significant time and hence the circuits are adequately safe.

## F.5 Supporting documentation

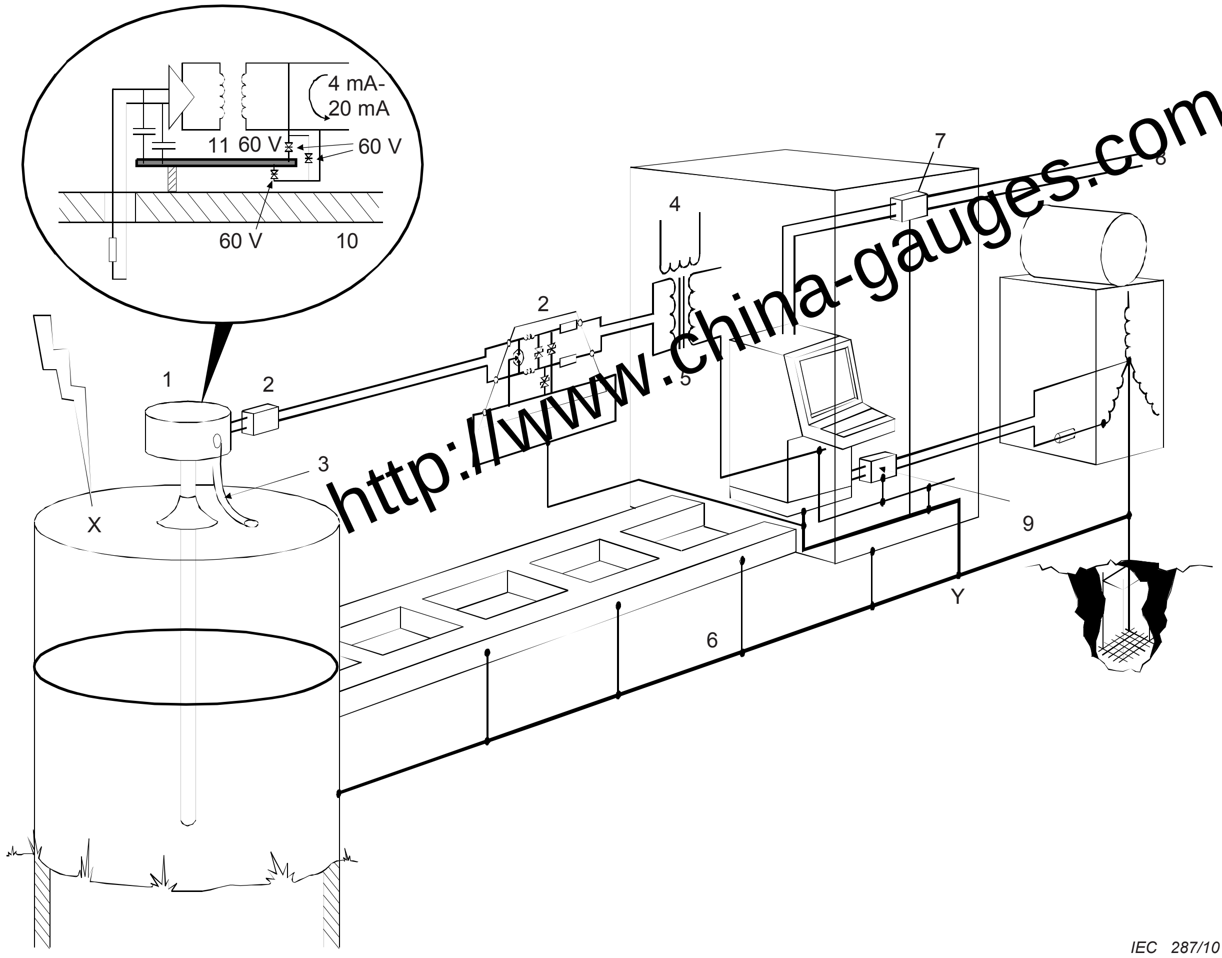
The descriptive system document should be modified to include the surge suppression networks fitted. Their effect in normal operation needs to be analysed taking into account their relevant characteristics, which may include small values of capacitance and inductance.

The indirect earthing in two places should be recorded and analysed and an argument of acceptability presented.

## F.6 Further protection

Where lightning is recognized as a significant problem, consideration should be given to fitting surge suppression to the mains supply to the instrumentation system. Mains borne surges could damage the galvanic isolators from the power supply or signal connections. Some degree of immunity is implicit in the normal requirements of compliance with EMC standards but this is not adequate against most lightning induced surges.

Similarly, the other possible invasion route along network interconnections requires some degree of surge protection.





**Key**

| | | | | | |
|---|---|---|---|---|---|
| 1 | converter | 5 | galvanic isolator | 9 | mains filter suppressor |
| 2 | surge suppressor | 6 | equipotential bond | 10 | tank shell |
| 3 | bonding strap | 7 | signal suppressor | 11 | instrument housing |
| 4 | mains supply | 8 | data link | | |

**Figure F.1 – Surge protection requirements of an instrument loop**

# Annex G
(normative)

# Testing of cable electrical parameters



## G.1 General

This annex describes the method of testing the electrical parameters of cables and multi-core cables specified for use within intrinsically safe systems.

## G.2 Measurements

The inductance and capacitance of a cable shall be measured using equipment operating at a frequency of 1 kHz ± 0,1 kHz and an accuracy of ±1 %. The resistance of the cable shall be measured using d.c. equipment with an accuracy of ±1 %. Results taken from a representative sample of cable with a minimum length of 10 m are acceptable. Measurements shall be taken at an ambient temperature of 20 °C to 30 °C.

NOTE The equipment for the measurement of inductance should be able to operate satisfactorily when measuring low inductance in the presence of significant resistance.

Where practicable, measurements of all the possible combinations of the cores which can result from open-circuiting and short-circuiting the separate ends of the cables shall be made. The maximum measured values of capacitance, inductance and the $L/R$ ratio shall be used as the cable parameters. Where there are a large number of cores, measurements shall only be made utilizing a representative sample of the combination of cores which will create the largest values of inductance and capacitance.

The maximum capacitance of the cable shall be determined by open-circuiting the remote end of the cable and measuring the capacitance of the combinations of the wires and screens which give the maximum value. For example, if a twin-pair screened cable is being measured, then the highest value will probably be measured between one core connected to the screen and the other core. That this is the highest value of capacitance shall be confirmed by measuring the other combination of cores and screen.

The maximum inductance shall be measured by connecting together the remote ends of the two cores. The value to be used shall be that configuration that gives the highest measurement. The d.c. resistance of this path is the resistance used in calculating the $L/R$ ratio of the cable.

Where the cable is loosely constructed, bending and twisting the cable a minimum of ten times shall not cause the cable parameters to vary by more than 2 %.

For the purpose of these measurements, the combination of faults which could connect separate conductors in series to effectively increase the length of cables shall not be considered. When measuring capacitance, any screens or unused cores shall be joined together and connected to one side of the circuit being measured.

## G.3 Multi-core cables

### G.3.1 General

Where the conductors utilized by a particular intrinsically safe circuit are readily identifiable within a multi-core, only the cable parameters related to those specific conductors shall be considered.

### G.3.2 Type A multi-core cables

When all the conductors utilized in a circuit are within one screen, only the interconnections of the conductors within that screen and to that screen shall be considered. Where the conductors are within more than one screen, measurement shall be made utilizing all the relevant conductors within the relevant screens.

### G.3.3 Type B multi-core cables

When the conductors utilized for a particular circuit can be clearly identified, measurement shall be made only on those conductors. Where a clear identification cannot be made, all the possible combinations of the conductors used in that particular intrinsically safe circuit shall be considered.

### G.3.4 Type C multi-core cables

Measurement shall be made on all conductors and any screens associated with the intrinsically safe systems which can be interconnected by the two short-circuit faults which have to be considered.

Where relevant conductors are not clearly identifiable, the testing shall be extended to the possible combinations of the total number of conductors and screens associated with the three interconnected circuits.

# Annex H
(informative)

# Use of simple apparatus in systems



## H.1 General

The intrinsic safety apparatus standard (IEC 60079-11) distinguishes between a complex apparatus, which normally requires some form of certification and simple apparatus which is not required to be certified. The intention is to permit the use of apparatus, which does not significantly affect the intrinsic safety of a system without the need for third party certification. There is an implication that it is possible to demonstrate that simple apparatus is obviously safe without recourse to the detailed application of the remainder of the standard. For example, if any current or voltage limiting components are necessary then the apparatus is not considered to be simple. In practice, it is relatively easy to decide which components are simple apparatus at the system design stage. If the decision is not easy then the apparatus is not simple.

NOTE Although it is not considered essential that simple apparatus is certified by a third party, it is not unusual for simple apparatus which is used in significant quantities to be certified. In these circumstances the apparatus is marked as required by the apparatus standard, but can be used in the same way as other simple apparatus.

The apparatus standard imposes limits of 1,5 V, 100 mA and 25 mW on the electrical parameters generated within simple apparatus. It is accepted that simple apparatus can be added to an intrinsically safe system without the necessity to recalculate the safety of the system. The combined effect of all pieces of simple apparatus, any intrinsically safe apparatus and any intrinsically safe associated apparatus should be taken into consideration. For example the use of one or two thermocouples in a system is permitted but a combination of a large number used in a single average temperature circuit might not meet this criterion.

The standard also allows capacitive and inductive components to be used in simple apparatus provided that these components are included in the system evaluation. It is not usual to include inductors or capacitors of significant size, but the simple apparatus concept does permit the use of small radio-frequency decoupling components without undertaking a further analysis of the system. A useful 'rule of thumb' is to ensure that the total capacitance and inductance added to the system is less than 1 % of the respective output parameters of the source of power and then their effect can be ignored. If **both** the added capacitance and inductance together with any other lumped capacitance in the circuit are greater than 1% of the specified output parameters of the source of power then the permitted output parameters should be halved as explained in Annex A.

It is also necessary to temperature classify simple apparatus, when it is intended to be mounted in the hazardous area. The apparatus standard allows a T6 temperature classification for switches, plugs, sockets and terminals used within their normal rating at an ambient temperature of not greater than 40 °C. In practice, it is not easy to design a system that can be used with gases requiring a T6 (85 ºC) temperature classification and a T4 (135 ºC) classification is normally the level achieved. The only gas listed in the available documentation requiring a T6 temperature classification is carbon disulfide ($CS_2$). A T4 temperature classification is therefore normally adequate. The T4 temperature classification of simple apparatus (with a surface area not less than 20 $mm^2$) normally relies on the input power being not greater than 1,3 W when the maximum ambient temperature required is 40 ºC. The corresponding powers for higher ambient temperatures are 1,2 W at 60 ºC and 1 W at 80 ºC. If this rule is not applicable then the possible maximum surface temperature has to be measured or assessed. If, for any reason, it is not obvious that the maximum surface temperature is considerably lower than 135 °C (say 100 ºC) then the apparatus is probably not simple.

Usually simple apparatus is isolated from earth and introduces no problem. The requirement is to satisfy a 500 V insulation test in accordance with the apparatus standard. Where this level of isolation is not present then the simple apparatus introduces an earth on to the system and the system design should take this into account.



## H.2 Use of apparatus with 'simple apparatus' input description

The other common use for the simple apparatus clause is to permit the use of certified apparatus with output parameters equivalent to simple apparatus to be added to an existing intrinsically safe circuit with only a minor change in the documentation. The most frequent uses of this technique are for test equipment, indicators and trip amplifiers.

Where more than one piece of apparatus with simple apparatus output characteristics is included in a circuit then care should be taken to ensure that the permitted simple apparatus parameters are not exceeded. Advantage can sometimes be taken of the fact that the output voltage only appears under fault conditions and that it is permitted to apply the fault count to the system as a whole. For example, if more than one piece of simple apparatus is connected in the circuit then it can be argued that only one piece of apparatus is considered to fail at any one time, and hence only the most adverse set of output parameters needs to be considered. This type of argument is acceptable in "ib" systems but needs to be carefully documented. For such an argument to be valid for "ia" systems detailed knowledge of the derivation of the output parameters is required. This type of information is not usually readily available and hence the technique is not normally applicable to "ia" systems. If it is known that the apparatus terminals are purely resistive in normal operation (as is frequently the case) then any number of these devices can be incorporated in an "ic" system.

# Annex I
(normative)

# FISCO systems



## I.1 General

This annex contains the details of the design of systems for use with the Fieldbus Intrinsically Safe Concept (FISCO). It is based on the concepts of Manchester encoded, bus powered systems designed in accordance with IEC 61158-2 which is the physical layer standard for Fieldbus installations.

The requirements of FISCO systems are determined by this standard, except as modified by this annex.

NOTE 1 Some apparatus certified before this standard was published but not necessarily complying with the electrical parameters of this standard may be marked "Suitable for FISCO systems". This apparatus may be accepted in a FISCO system, if the comparison of the electrical parameters $U_o$, $I_o$, $P_o$, with $U$i, $I_i$, $P_i$, demonstrate compatibility with the remainder of the system, conform to all the other requirements of this standard.

NOTE 2 A typical system is illustrated in Figure I.1

NOTE 3 Generally, "ic" FISCO systems are intended for use in Zone 2 locations. "ia" and "ib" FISCO systems are predominantly intended for use in Zone 1 locations. "ia" FISCO systems may enter Zone 0 locations if specifically permitted to do so by the documentation.

## I.2 System requirements

### I.2.1 General

A system is usually of the form illustrated in Figure I.1.

The cable used in the system shall comply with Clause 9 and shall have the following parameters:

- loop resistance $R_C$ 15 Ω/km to 150 Ω/km;
- loop inductance $L_C$ 0,4 mH/km to 1 mH/ km;
- capacitance $C_C$ 45 nF/km to 200 nF/km;
- maximum length of each spur cable 60 m in all equipment groups;
- maximum length of each trunk cable, including the length of all spurs, 1 km in IIC and 5 km in I, IIB and IIIC.

When cable, which complies with this annex, is used, no further consideration of cable parameters is necessary.

NOTE 1 Where multicore cables are used these should be type A or type B cables.

Where a system comprises

- one source of power,
- any number of field devices up to 32, and
- up to two terminators,

all complying with the requirements of this standard combined with a cable to the above specification, then that system shall be considered to be adequately safe.

All apparatus used in a FISCO system shall be of the same equipment group I, II or III appropriate for the systems intended use.

The system shall be allocated a level of protection (“ia”, ‘“ib” or “ic”) determined by the least onerous level of protection of the apparatus used in the system. The safety documentation should record the allocated level of protection.

Sub-systems of the system may have different levels of protection where this is justified by the assessment and recorded in the documentation. For example, an “ia” spur may be created from an “ib” trunk by the insertion of a suitably certified interface.

The terminator(s) shall be situated at the end(s) of the trunk. The power supply shall be located not more than 60 m from one end of the trunk. Where the power supply is connected via a spur, then that spur is restricted to a length of 60 m.

NOTE 2 The number of field devices, which can be connected to a spur, is restricted by operational constraints and the requirement of this annex, which restricts the number of field devices in a system to a maximum of 32.



Connection facilities and/or switches may be added to a system without modifying the safety assessment. Other types of simple apparatus complying with IEC 60079-11 may be connected to a FISCO system provided that the total inductance and capacitance of each simple apparatus is not greater than 10 μH and 5 nF respectively, and the total number of pieces of such simple apparatus plus field devices does not exceed 32.

The safety documentation may be simplified to a list of the equipment, together with relevant apparatus documentation used. The documentation should clearly identify the level of protection of each part of the system.

For Group II systems the equipment group of the power supply determines the equipment group of the system.

The temperature classification or maximum surface temperature, as appropriate, of each piece of apparatus shall be determined and recorded in the documentation. It is also necessary to confirm that the permitted ambient temperature rating of each piece of apparatus is suitable for its intended location.

## I.3 Additional requirements of “ic” FISCO systems

Apparatus designed and approved to the FNICO requirements of the first edition of IEC 60079-27[1] may be used in an “ic” FISCO system.

Field devices, terminators and other ancillaries complying with the requirements of intrinsic safety but not as FISCO apparatus may be used with a FISCO power supply in an “ic” FISCO system provided that they have input parameters of $U_i$ not less than 17,5 V and internal parameters of $L_i$ and $C_i$ not greater than 20 μH and 5 nF respectively.

Similarly, apparatus not approved as FISCO apparatus, but constructed in accordance with the requirements of IEC 60079-15 energy-limited (“nL”) apparatus and having input parameters of $U_i$ not less than 17,5 V and internal parameters of $L_i$ and $C_i$ not greater than 20 μH and 5 nF respectively, may be used in an “ic” FISCO system.

Where FNICO, intrinsically safe or energy-limited apparatus is used in an “ic” FISCO system, this should be indicated at the point of installation of that apparatus. A plant label marked “ic” FISCO system is an acceptable way of satisfying this requirement.

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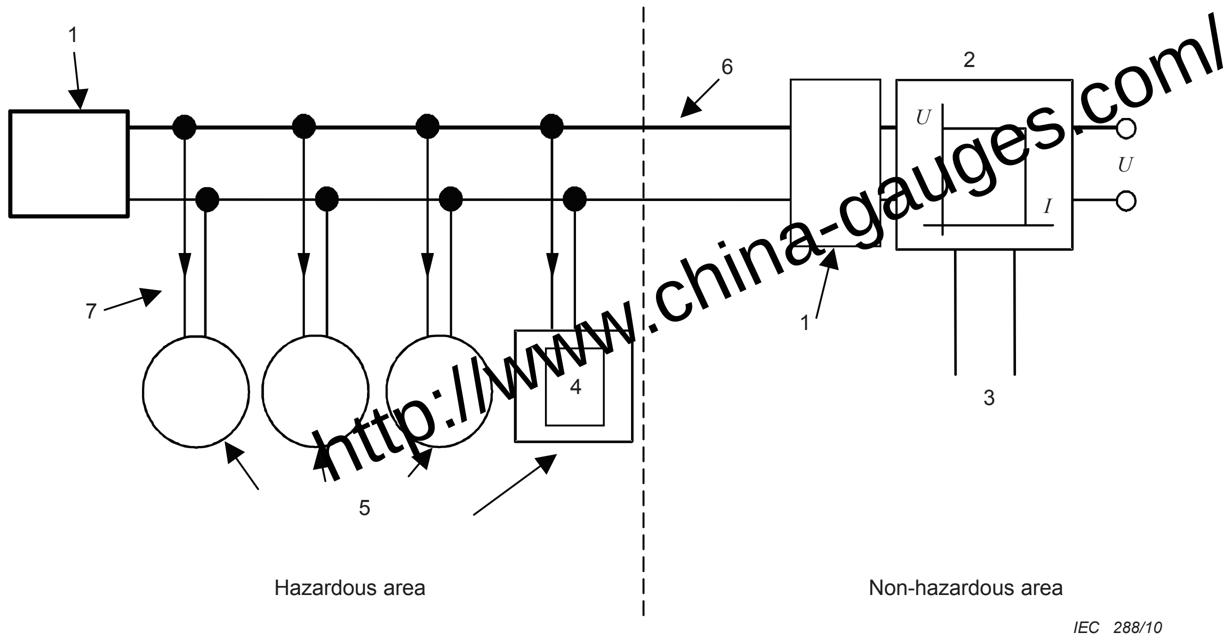
1 IEC 60079-27:2005, *Electrical apparatus for explosive gas atmospheres – Part 27: Fieldbus intrinsically safe concept (FISCO) and Fieldbus non-incendive concept (FNICO)*





**Key**

1 terminator

2 power supply

3 data

4 hand held terminal

5 field devices

6 trunk

7 spur

**Figure I.1 – Typical system**

## Bibliography

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

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