Electrical apparatus for potentially explosive atmospheres — Group I — Intrinsically safe systems —

Part 1: Construction and testing

The European Standard EN 50394-1:2004 has the status of a British Standard

ICS 29.260.20

British Standards

National foreword

This British Standard is the official English language version of EN 50394-1:2004.

The UK participation in its preparation was entrusted by Technical Committee GEL/31, Electrical apparatus for use in explosive atmospheres, to Subcommittee GEL/31/13, Intrinsically safe apparatus, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

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English version

Electrical apparatus for potentially explosive atmospheres – Group I – Intrinsically safe systems Part 1: Construction and testing

Matériels électriques pour atmosphères explosibles –
Système de sécurité intrinsèque du groupe I
Partie 1: Construction et essais

Elektrische Betriebsmittel für explosionsgefährdete Bereiche –
Gruppe I: Eigensichere Systeme
Teil 1: Konstruktion und Prüfung

This European Standard was approved by CENELEC on 2003-10-01. 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.

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

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Ref. No. EN 50394-1:2004 E

Foreword

This European Standard was prepared jointly by a mining working group, convened under SC 31-3, Intrinsically safe apparatus and systems "i", of Technical Committee CENELEC TC 31, Electrical apparatus for explosive atmospheres.

The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 50394-1 on 2003-10-01.

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)	2004-10-01
- latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2006-10-01

This European Standard was prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association to set down requirements for the design and construction of equipment in support of the essential safety and health requirements described in the European Directive 94/9/EC "Equipment and protective systems intended for use in potentially explosive atmospheres".

Contents

Introduction

When the European Directive 94/9/EC came into force on 1 March 1996, the requirements relating to intrinsically safe electrical systems were identified as requiring revision.

The EU Commission issued the following interpretation, following a request from CENELEC TC 31:

"a) intrinsically safe systems are not protective systems as defined in Article 1(3b) of the directive. They can be equipment, as defined in Article 1(3a), or components, as defined in Article 1(3c) and are in such cases within the scope of the directive;

b) intrinsically safe systems have to undergo the relevant conformity assessment procedures of the directive, if they are placed on the market as a complete system and, therefore, to be considered as equipment or components;

c) in case an intrinsically safe system comprises several separate products, which are designed to be assembled by the user, each single product, which is within the scope of the directive and placed on the market separately, has to undergo the relevant conformity assessment procedure of the directive;

d) the resulting system has to be seen as an installation and it is, as such, not subject to the procedures and requirements of the directive. This does not exclude that there might be national regulations related to the use of intrinsically safe systems, which have to be applied. In this context the use of EN 50039 could be useful."

As a result of the above interpretation, CENELEC SC 31-3 decided to produce a revised version of EN 50039 with separate parts for mining (Group I) and non-mining industries (Group II). Accordingly, this standard is the mining industry document dealing with the construction and testing of Group I intrinsically safe systems.

1 Scope

1.1 This European Standard contains the requirements for construction and testing of Group I intrinsically safe electrical systems intended for use, as a whole or in part, in atmospheres susceptible to firedamp.

1.2 This European Standard supplements EN 50020, the requirements of which apply to electrical apparatus used in intrinsically safe electrical systems.

It is intended to apply to

– systems placed on the market by a manufacturer or their authorised representative, or
– systems assembled by the user, using products separately conforming with EN 50020.

NOTE If the user intends to assemble a system using a product not conforming with EN 50020, then the user assumes the responsibilities of the system manufacturer and needs to follow the conformity assessment procedure.

1.3 This European Standard does not deal with the selection of suitable equipment, or the installation of intrinsically safe electrical apparatus, associated electrical apparatus, to form an intrinsically safe electrical system.

NOTE National Regulations may impose additional requirements for the selection, installation and use of intrinsically safe systems in mines.

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.

Publication	Title
EN 50014	Electrical apparatus for potentially explosive atmospheres - General requirements
EN 50020	Electrical apparatus for potentially explosive atmospheres - Intrinsic safety ‘i’
EN 50303	Group I Category M1 equipment intended to remain functional in atmospheres endangered by firedamp and/or coal dust

3 Definitions

For the purpose of this European Standard, the following definitions apply. They supplement the definitions, which are given in EN 50014, EN 50020, and EN 50303.

3.1
intrinsically safe electrical system
interconnected items of electrical apparatus, described in a descriptive system document, in which the circuits or parts of circuits intended to be used in potentially explosive atmospheres, are intrinsically safe circuits

3.2
conformity-assessed intrinsically safe electrical system
a complete system placed on the market, conforming with 3.1 which has undergone the relevant conformity assessment procedures and complies with the requirements of this standard

3.3
user constructed intrinsically safe electrical system
a system conforming with 3.1 and assembled by the user comprising products separately conforming to EN 50020 (which may consist of associated apparatus, intrinsically safe apparatus and/or simple apparatus and interconnecting wiring supplied from one or more linear power supplies or a power supply with trapezoidal/non-linear output characteristic) for which an assessment report has been issued confirming that the complete electrical system complies with this standard

3.4
descriptive system document
a document prepared by the system designer in which the items of electrical apparatus, their electrical parameters and the parameters for the interconnecting wiring are specified

NOTE The term “system designer” is intended to describe the person, who is responsible for the intrinsic safety of the system.

3.5
equipment Group I category M1 in accordance with EN 50014
equipment designed and, where necessary, equipped with additional special means to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a very high level of protection. Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines endangered by firedamp and/or combustible dust. Equipment in this category is intended to remain functional, even in the event of rare incidents relating to equipment, with an explosive atmosphere present, and is characterised by means of protection such that

a) either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection, or

b) the requisite level of protection is assured in the event of two faults occurring independently of each other.

NOTE At the present time, only “level of protection ‘ia’ ”, meets the requirement of (b) above.

3.6
equipment Group I category M2 in accordance with EN 50014
equipment designed to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a high level of protection. Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines likely to be endangered by firedamp and/or combustible dust. This equipment is intended to be de-energised in the event of an explosive atmosphere. The means of protection relating to equipment in this category assure the requisite level of protection during normal operation and also in the case of more severe operating conditions, in particular those arising from rough handling and changing environmental conditions

NOTE The definitions in 3.5 and 3.6 above are an extract of the definitions in EN 50014.

3.7
accessories
passive components such as terminal boxes, junction boxes, plugs, sockets, and switches

3.8
linear power supply
a power source from which the available output current is determined by a resistor. The output voltage decreases linearly as the output current increases

3.9
power supply with trapezoidal output characteristics
a power source from which the available output current is determined by a resistor. The output voltage is controlled by the addition of a zener diode clamp on the output terminals (see Annex E for more detail)

3.10
non-linear power supply
a power source where the output voltage and output current have a non-linear relationship. For example a supply with a constant voltage output up to constant current limit controlled by semiconductors

3.11
maximum cable capacitance (C_c)
maximum capacitance of the interconnecting cable that can be connected into an intrinsically safe circuit without invalidating intrinsic safety

3.12
maximum cable inductance (L_c)
maximum inductance of the interconnecting cable that can be connected into an intrinsically safe circuit without invalidating intrinsic safety

3.13
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

4 Categories of intrinsically safe electrical systems (in accordance with EN 50014)

Each part of an intrinsically safe electrical system shall meet the requirements for either category M1 or M2, depending upon whether it is intended for operation in an explosive atmosphere or a potentially explosive atmosphere respectively. The complete system need not necessarily be in an single category, providing it is clear which parts relate to which category as outlined in 4.1 and 4.2 below.

NOTE Intrinsically safe systems, or parts thereof, may have different categories to those of the intrinsically safe electrical apparatus and associated electrical apparatus included in the system or part thereof.

4.1 Category M1

Parts of intrinsically safe electrical systems are of category M1 if they comply with either

a) the requirements applicable to electrical apparatus of “level of protection ‘ia’” (see 5.1 of EN 50020), or

b) the requirements of EN 50303 as they apply to intrinsically safe apparatus/circuits.

The faults shall be applied to the electrical system as an entity and not to each item of electrical apparatus in the system.

4.2 Category M2

Parts of intrinsically safe electrical systems are of category M2 if they comply with the requirements applicable to electrical apparatus of at least “level of protection ‘ib’" (see 5.1 of EN 50020); but the fault shall be applied to the electrical system as an entity and not to each item of electrical apparatus in the system

5 Interconnecting wiring/cables used in an intrinsically safe electrical system

5.1 The electrical parameters and all characteristics of the interconnecting wiring specific to an intrinsically safe electrical system, insofar as intrinsic safety depends on them, shall be specified in the descriptive system document. Interconnecting wiring/cables shall meet the requirements of Annex A.

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.

5.2 A multicore cable shall not contain any intrinsically and non-intrinsically safe circuits at the same time.

5.3 Where a multicore cable is to be used, the descriptive system document shall identify which of the cables described in A.3.3 are to be used.

6 Accessories for intrinsically safe electrical systems

Accessories shall comply with the following requirements:

– Clauses 6 and 7 of EN 50014;
– Clause 6 and 12.2 of EN 50020 if their construction can affect the intrinsic safety of that system. Such accessories shall be shown on the descriptive system document.

7 Type tests and assessment

7.1 General

7.1.1 Group I conformity-assessed intrinsically safe systems shall be subjected to type tests and assessment in accordance with EN 50020, but taking into account the specific requirements of this European Standard.

7.1.2 Where a system contains apparatus, which does not separately conform to EN 50020 or is not simple apparatus then that system shall be assessed/tested as a whole. The system shall be analysed as if it is a single apparatus, taking into account faults within the apparatus and failures within the field wiring as listed in 7.2.

NOTE It is recognised 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 when apparatus conforming to EN 50020 is being used. This is an alternative solution to the more usual straightforward comparison of input and output characteristics of the separately assessed/tested apparatus.

7.1.3 Where a system contains only apparatus conforming to EN 50020 and simple apparatus, 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 linear source of power then the output parameters of the power source take into account the possible cable failures, and consequently these need not be further considered. Annex C contains further details of the analysis of these simple circuits.

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

7.1.5 Annex E gives further details of the analysis of a system which contains a power supply with a trapezoidal output characteristic.

7.1.6 If an intrinsically safe system contains more than one source of power and one or more of these sources is non-linear, the assessment method described in Annex D cannot be used. Annex F explains how the system analysis can be done if the combination contains non-linear power supplies.

7.1.7 Where an apparatus has a well-defined inductance and resistance either by virtue of its assessment or construction then the safety of the inductive aspects of the system utilising a linear power source shall be confirmed by the process defined in Annex G.

7.1.8 Where simple apparatus can possibly interconnect separate intrinsically safe circuits, for example a resistance thermometer with two separate resistance windings then the interconnected circuits shall be assessed as a single circuit.

7.1.9 Figure 1 illustrates the principles of system analysis.

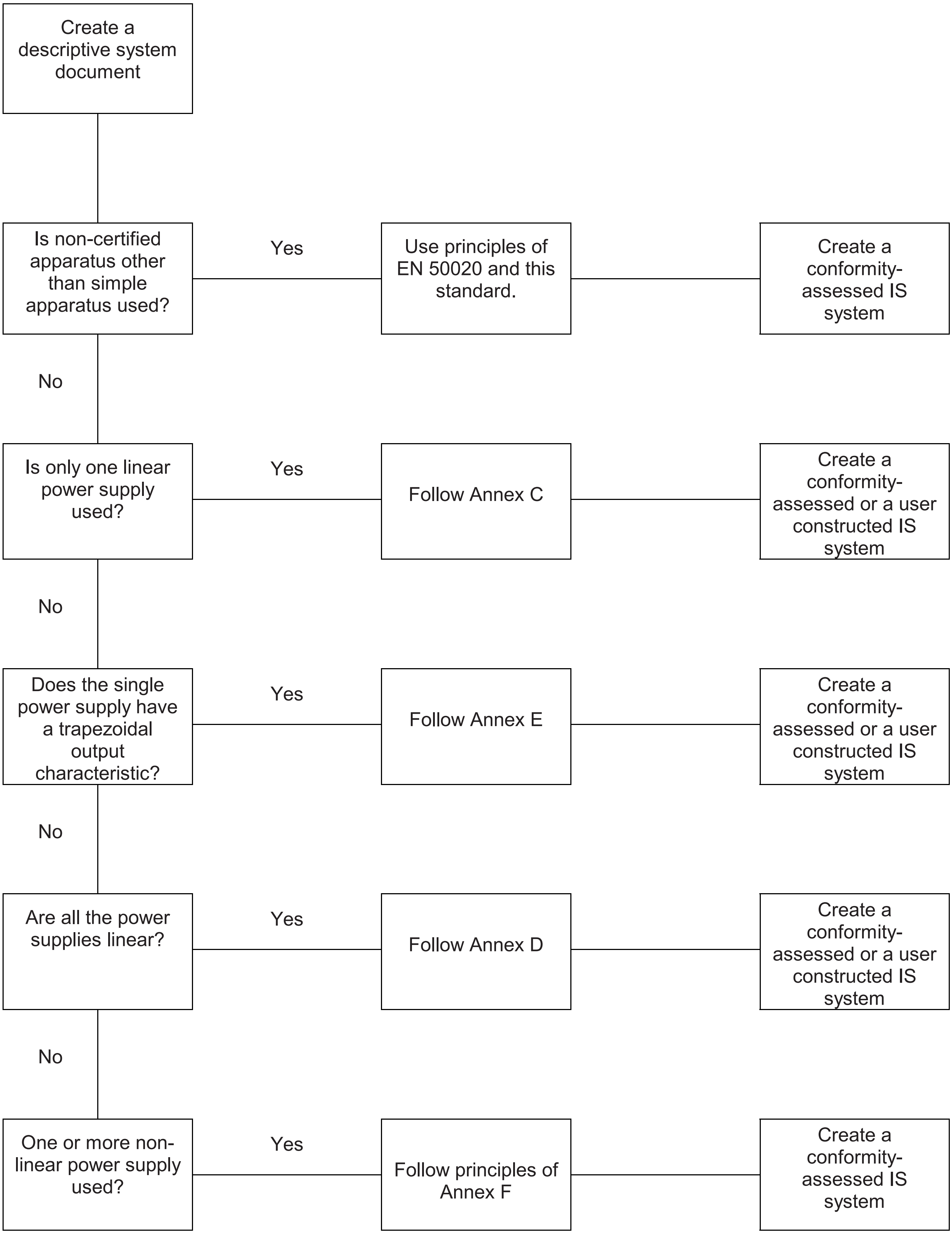


Figure 1 - Systems analysis flowchart

7.2 Assessment of systems having multicore cables containing one or more circuits

Cable faults to be taken into consideration will depend upon the type of multicore cable used. (see Annex A for details of the types of cable, and Table 1 for summary of requirements) The following subclauses detail the cable faults to be considered for each type of cable.

7.2.1 Type A cable

No failures between circuits shall be taken into consideration if each circuit is enclosed in an individual conducting screen.

7.2.2 Type B cable

No failures between circuits shall be taken into consideration if no circuit contained within the cable has a peak voltage exceeding 60 V.

7.2.3 Type C cable

In addition to the application of 4.1 or 4.2, it is necessary to take into consideration up to two connections between conductors and, simultaneously, up to four open circuits of conductors. In the case of identical circuits, failures shall not be taken into consideration provided that each circuit passing through the cable has a safety factor of four times that required by 4.1 or 4.2.

Table 1 - Summary of interconnecting cable requirements

Cable type	Core-insulation A.2	Dielectric-test A.1, A.3.1	Conducting screens A.3.2	Additional conditions	Faults to be considered
A	Yes	Yes	Yes	None	None
B	Yes	Yes	No	Fixed and protected, < 60 V	None
C	Yes	Yes	No	None	2 short circuits 4 open circuits
C	Yes	Yes	No	Each circuit with 4 x normal safety factor	None

8 Marking of intrinsically safe electrical systems

All apparatus within the system shall be readily identifiable. In the case of simple apparatus a traceable plant identification label is acceptable.

Each item of electrical apparatus in an intrinsically safe electrical system shall be marked as specified in EN 50014 either by virtue of its separate compliance with EN 50020 or system compliance with this standard.

In addition, these systems shall be marked by the holder of the system certificate in a strategic position with the test/assessment reference and the letters “SYST”.

NOTE The system marking should normally appear on or adjacent to the principal item of electrical apparatus in the system or at the interface between the intrinsically safe and non-intrinsically safe circuits.

9 Descriptive system document

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

The minimum requirements for a descriptive system document are:

a) a block diagram of the system identifying all the items of apparatus including simple apparatus and their interconnections within the system;

b) a statement of the system category and ambient temperature of the system. Alternatively, if different parts of the system have different categories/ambient temperatures then the separate parts shall be clearly identified;

c) the requirements and permitted parameters of the interconnecting cables/wiring shall be specified. Except in the special circumstances when the fault count required by a type C multicore has been considered then a note shall be included on the block diagram of the descriptive system document stating "*where the interconnecting cable utilises part of a multicore containing other intrinsically safe circuits then the multicore must be in accordance with the requirements of a multicore type A or B as specified in Annex A of EN 50394-1*";

d) points which are intended to be connected to an earth or reference point shall be identified. Points which are considered to be earthed because of failure to meet the 500 V insulation test should also be identified;

e) each descriptive system document shall have a unique identification;

f) the documentation shall be signed and dated by the system designer.

Annex B comprises an example of a typical diagram which illustrates the requirements of a descriptive system document.

10 Instructions

In addition to the requirements of EN 50014, the system shall be accompanied by a copy of the descriptive system document.

Annex A
(normative)

Requirements for cables

A.1 Dielectric strength testing

Any testing to show conformity with the requirements of A.2 and A.3.1 shall be carried out by the manufacturer of the cable. The voltage tests shall be carried out by a method specified in an appropriate cable standard. Where no such method is available, the tests shall be carried out as follows:

– where the specified dielectric tests use an a.c. voltage, it shall be of substantially sinusoidal waveform and be at a frequency of between 48 Hz and 62 Hz, and derived from a transformer of at least 500 VA output;

– a d.c. voltage can be used for the dielectric testing, provided that the value of the d.c. voltage is 1,4 times that specified for a.c. testing;

– the voltage shall be increased steadily to the specified value in a period of not less than 10 s and then maintained at this value for at least 60 s. No breakdown of the dielectric shall occur.

A.2 General construction

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.

Only insulated cables, whose conductor-earth, conductor-screen and screen-earth test voltages are at least 500 V a.c. (r.m.s.), shall be used in intrinsically safe circuits.

A.3 Multicore cables containing more than one intrinsically safe circuit.

A.3.1 Dielectric test on an assembled cable

In addition to the requirements of A.2, the assembled cable shall withstand dielectric strength test of 1 000 V a.c. (r.m.s.) between a bundle comprising one half of the cable cores joined together and a bundle comprising the other half of the cable cores joined together.

A.3.2 Conducting screens

When conducting screens provide individual protection for 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.

A.3.3 Types of multicore cables (see 5.3)

Type A cable - one which complies with A.1, A.2, A.3.1, A.3.2;

Type B cable - one which complies with A.1, A.2, A.3.1, is fixed and effectively protected against damage;

Type C cable - one which complies with A.1, A.2, A.3.1.

Annex B
(informative)

Typical descriptive system drawing

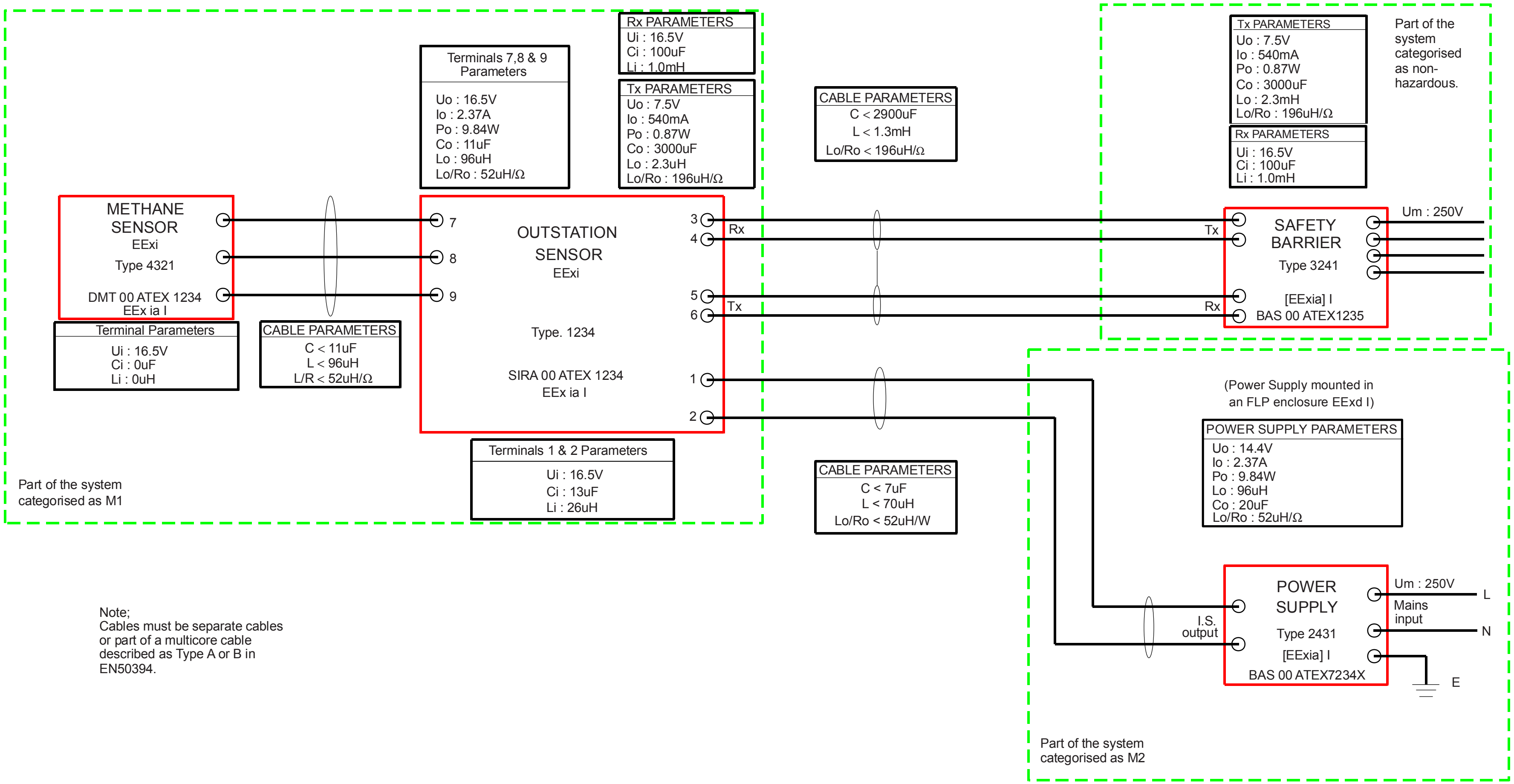


Figure B.1

Typical IS System Descriptive System Document

Annex C
(normative)

Assessment of a simple intrinsically safe system

This simple analysis is only applicable when the system considered uses one linear source of power.

The process of determining the acceptability of the simple system, which is illustrated by the example of Figure C.1 shall be as follows:

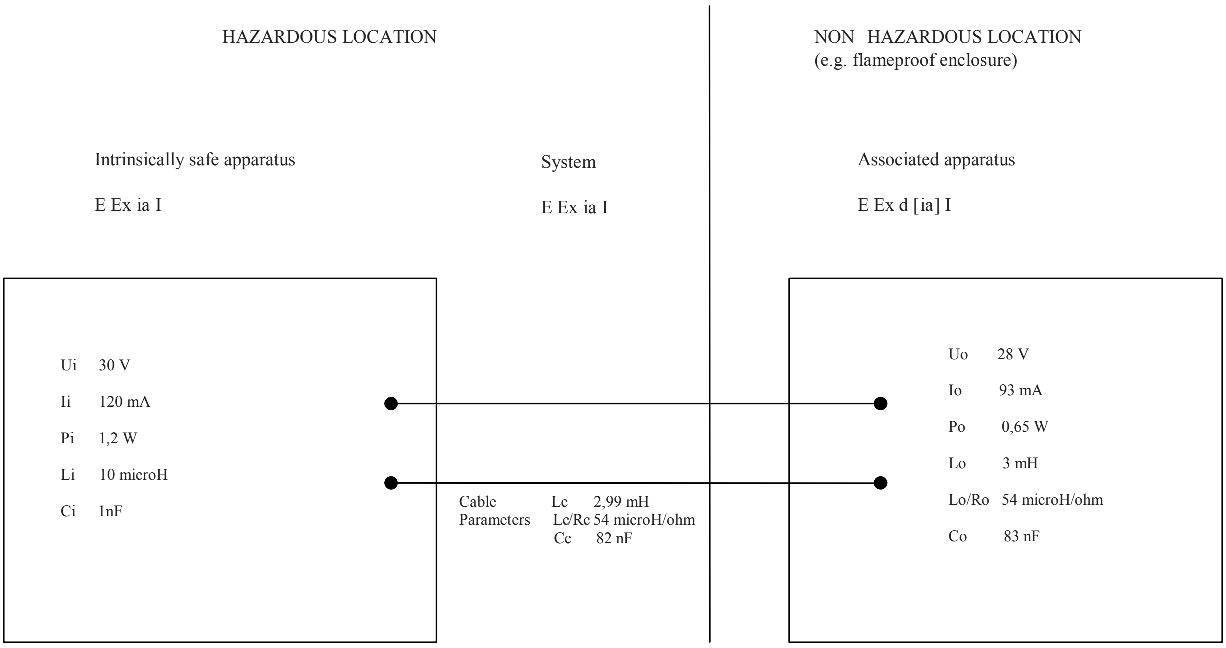


Figure C.1 – Interconnection of intrinsically safe apparatus with associated apparatus

a) determine the level of protection of the system by comparing the two pieces of apparatus separately conforming to EN 50020. It is permitted for different parts of the system to have different levels of protection. In these circumstances the descriptive system document should clearly define the separate parts of the circuit;

b) check that the voltage current and power parameters are compatible i.e. the permissible input parameters of the intrinsically safe apparatus are not less than the output parameters of the associated apparatus. Where the effective input resistance of the intrinsically safe apparatus is specified then the calculation of the permitted input current may include this parameter. In the example illustrated there is no problem;

c) the permitted cable capacitance [C_c] is the permitted capacitance for the source of power [C_o] less the effective input capacitance of the intrinsically safe apparatus [C_i];

d) the permitted cable inductance [L_c] is the permitted inductance for the source of power [L_o] less the effective input inductance of the intrinsically safe apparatus [L_i];

e) where the power supply is a resistance limited linear power source, the maximum external inductance to resistance ratio (L_c/R_c) shall be calculated using the following formula (from 6.3.3 of EN 50020). This formula takes account of a 1,5 factor of safety on current and shall not be used where *Ci* for the output terminals of the apparatus exceeds 1% of *Co*.

$$\frac{L_0}{R_0} = \frac{8eR_i + (64e^2R_i^2 - 72U_o^2\, eL_i)^{½}}{4{,}5\, U_o^2} \ \mu\text{H}/\Omega$$

where

e is the minimum spark-test apparatus ignition energy in microjoules, and is 525 for Group I apparatus,

R_i is the minimum output resistance of the power source, in ohms,

U_o is the maximum open circuit voltage, in volts

L_i Is the maximum inductance present at the power source terminals, in henries.

If $L_i = 0$

Then $$\frac{L_0}{R_0} = \frac{32eR_i}{9U_0^2} \ \mu\text{H}/\Omega$$

Where the intrinsically safe apparatus has a low inductance, as in the example, the permissible L_o/R_o ratio would remain unchanged. If the inductance of the intrinsically safe apparatus is greater than 5 % of the permitted output inductance L_o of the source of power then a revised L_o/R_o shall be calculated. This calculation may use the resistance of the inductance if this is known. The permitted L_o/R_o ratio of the interconnecting cable is then the lower of these two values.

Some sources of power can be bi-directional, for example shunt diode safety barriers intended for alternating current signals. In these circumstances the effect of both polarity outputs shall be considered.

Annex D
(normative)

Assessment of circuits with more than one linear 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.

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 EN 50020, 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.

D.1 Series combinations

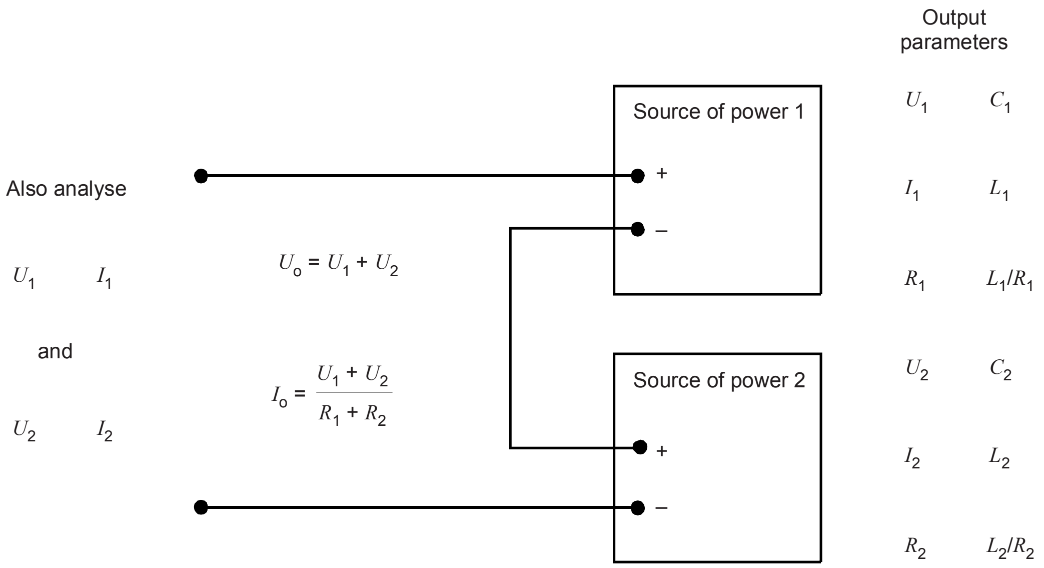


Figure D.1 – Sources of power connected in series

Figure D.1 illustrates the usual series combination. This series situation results in the open circuit voltage being $U_o = U_1 + U_2$ but the possibility of the voltage being $U_1 - U_2$ is not considered. In considering the safety of the system three voltages U_1, U_2 and U_0 are considered together with their corresponding currents I_1 and I_2 and the combined current $I_0 = [U_1 + U_2]/[R_1 + R_2]$.

Each of the three equivalent circuits has to be assessed for safety using the Table A.1 of EN 50020. The value of L_0, L_0/R_0 and C_0 must then be established for each circuit and the most onerous value used together with its relevant equivalent circuit.

A factor of safety of 1,5 shall be used in determining these values in all circumstances.

NOTE Where the two voltages add, the capacitive figure will be decided by the combined circuit. However, the inductance and the *L/R* ratio may be determined by one of the separate circuits being considered on its own.

The matched power available from each of the equivalent circuits should be determined.

D.2 Parallel combinations

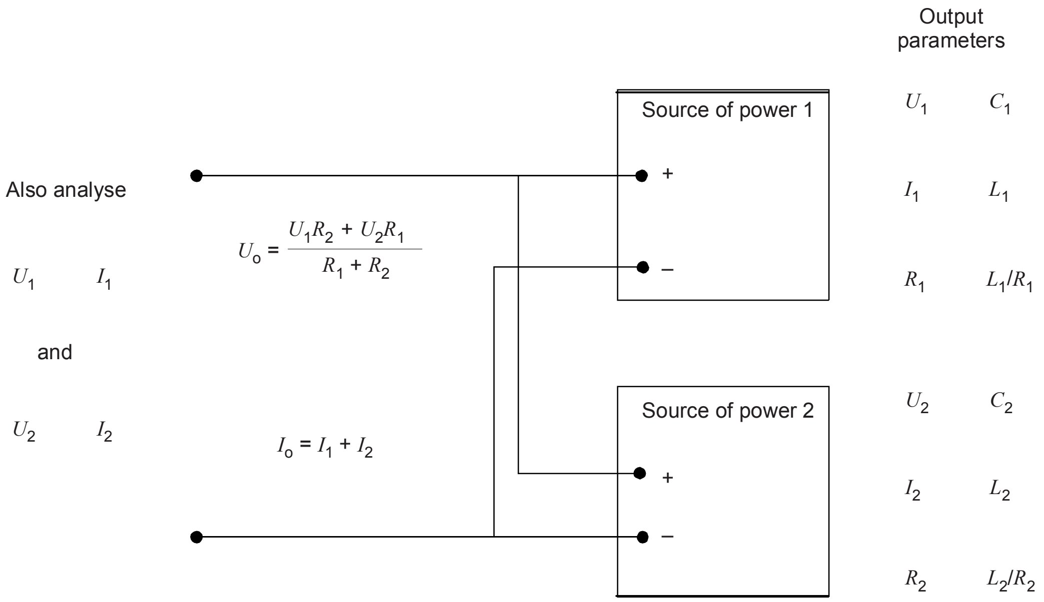


Figure D.2 – Sources of power connected in parallel

When the sources of power are connected in parallel as in Figure D.2 then the three currents I_1, I_2 and I_0 have to be considered with their corresponding voltages U_1, U_2, and U_0.

Each of the three equivalent circuits has to be assessed for safety using the Table A.1 of EN 50020. The values L_0, L_0/R_0 and C_0 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 should be determined.

D.3 Indeterminate combinations

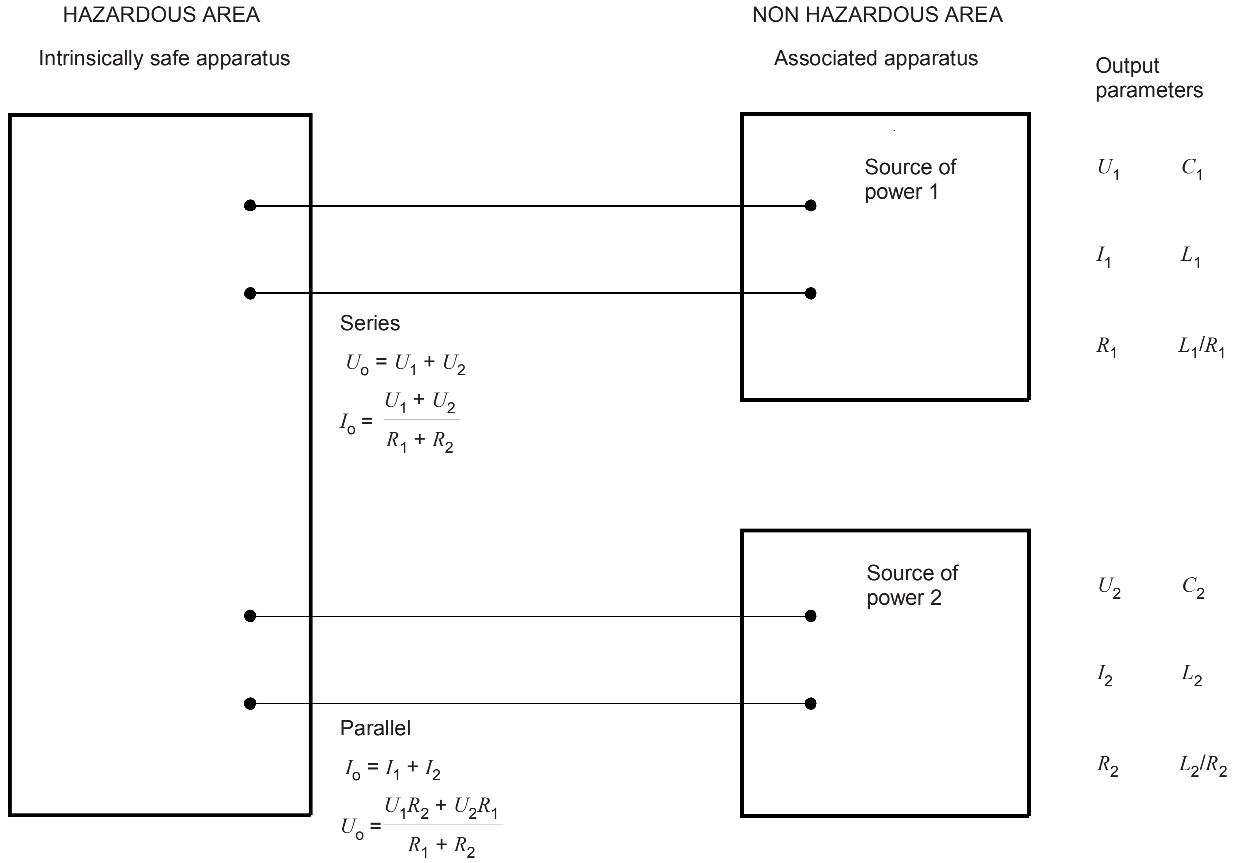


Figure D.3 – Sources of power not deliberately connected

Where two sources of power are connected to the same intrinsically safe circuit, as in Figure D.3, and their interconnections are not well defined by reliable interconnections 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 have to be evaluated, following both the procedures set out in D.1 and D.2. The most onerous output parameters and equivalent circuits have to be utilized in establishing the integrity of the intrinsically safe system.

D.4 Further considerations

The hazardous area apparatus may contain a source of power which results in the apparatus having significant 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 then these circuits can be used as if there was a single source of power and the procedure already discussed in Annex C used to establish whether the system as a whole is acceptably safe.

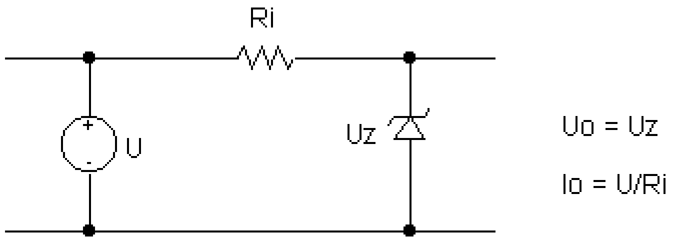
NOTE When two or more sources of power with different output voltages are interconnected then the resultant circulating current can cause additional dissipation in the regulating circuits and this needs consideration.

Annex E
(normative)

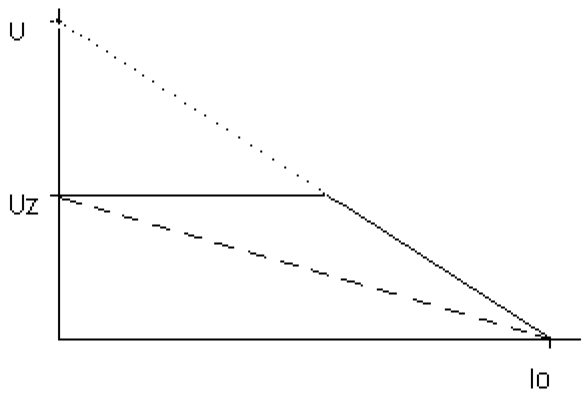
Trapezoidal power supplies

A power supply with a trapezoidal output characteristic is formed by applying shunt voltage limitation to a resistively limited voltage source (i.e. a linear source):

Typical circuit:



Typical output characteristic:



Generally, the trapezoidal characteristic (solid line) has a higher power output than the corresponding linear source shown by the hashed line having output parameters of $U_o = U_z$ and I_o.

The trapezoidal output cannot be analytically assessed for spark ignition capability using the ignition data in EN 50020, the supply will generally need to be subjected to an ignition test.

Cable Parameters:

The maximum external capacitance C_o and inductance L_o can be based on the output voltage U_o and short-circuit current Io respectively. The maximum external inductance to resistance ratio L_o/R_o is based on the current and resistance which achieves maximum power transfer into the cable load.

To simplify calculations, the cable resistance is taken as equal to R_i and the maximum current into the cable is therefore equal to $U/2R_i$.

The maximum permitted inductance is obtained from the ignition data curves in EN 50020 at a current of (1,5 x $U/2R_i$) and this is then divided by the resistance R_i to give the required *L/R* ratio, usually expressed in microHenries/Ohm.

Annex F
(normative)

Non-linear power supplies

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

Where linear and non-linear circuits are to be interconnected, the assessment of the combination into a system should be carried out by an authorized test house.

Annex G
(normative)

Verification of inductive parameters

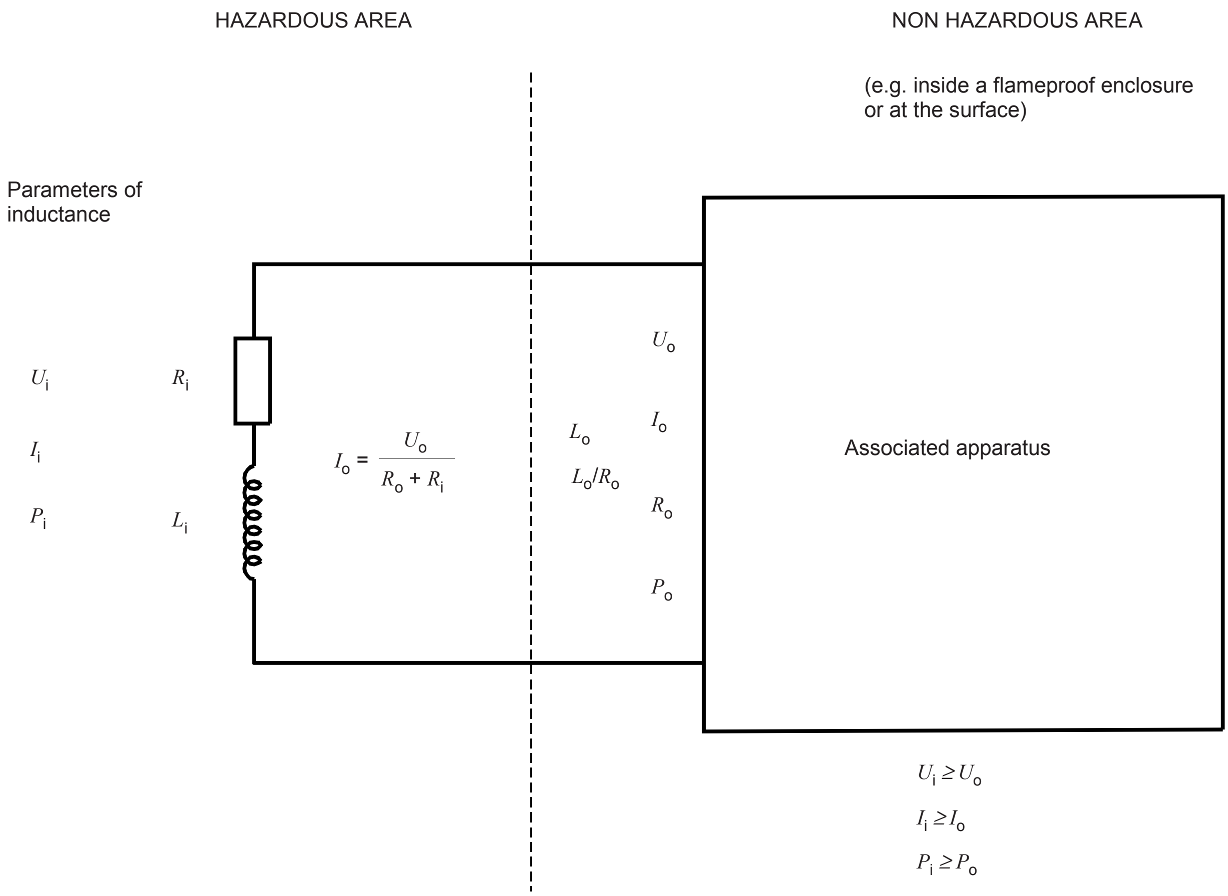


Figure G.1 - Typical inductive circuit

Figure G.1 illustrates an example of a system utilising a linear source of supply which is to be analyzed

where

R_i is the inherent resistance of the inductive coil. If the coil resistance is supplemented by an additional resistor, then that resistor must meet the criteria of an infallible resistor,

R_0 is the output resistance of the linear source of power, that is U_0/I_0.

If L_i is less than L_0 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_0/R_0 of the power source then the system is acceptable and the permitted *L/R* ratio of the cable remains L_0/R_0

NOTE Where a power supply uses the lowest value of current limiting resistor permitted by Table A.1 of EN 50020 then there is no permitted inductance for a cable without taking into consideration the cable resistance and L_0 equals zero.

If the inductive apparatus does not meet either of these two requirements then a more extensive analysis should be undertaken as follows:

a) determine the current, which will flow through the inductance. In the circuit illustrated this would be $U_0/(R_0 + R_i)$;

b) multiply this current by 1,5 and use the inductive curves in EN 50020 for Group I to determine the maximum permitted inductance L_{max};

c) if L_{max} is less than the inductance of the coil L_i then the circuit is not acceptable;

d) 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_0;

e) if required, the 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_0

$$\frac{L_c}{R_c} = \frac{8eR + (64e^2R^2 - 72U_o^2\, eL)^{½}}{4,5\, U_o^2} \text{ H/}\Omega$$

where

e is the spark-test apparatus ignition energy in joules for Group I apparatus, 525 µJ;

R is the total circuit resistance ($R_0 + R_i$), in ohms;

U_0 is the maximum open circuit voltage, in volts;

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

The permitted *L/R* ratio of the system cable is whichever is the smaller of this calculated value and the L_0/R_0 ratio of the source of power.

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

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