Instrumentation and control apparatus in Explosive Atmospheres:

The following Guidance has been prepared to give assistance to personnel working in industries where intrinsic safety forms the basis of protection from ignition of an explosive atmosphere. It does not claim to give legal advice but may give technical information to assist in the safe installation of intrinsically safe circuits. Certain terms used here will not be familiar to all readers but will be generally known by personnel working in industry with intrinsically safe apparatus.

In general instrumentation and control devices for explosive atmospheres fall into two technology groups:

- Devices where the energy required to measure, or control is high enough to create a spark or heat that would ignite a flammable atmosphere in which case the protection method employed is Ex d or Ex e. Devices such as flow meters, level transmitters and valve positioners fall into this group.
- Devices where, through the control of energy and where the energy consumption of the device is sufficiently low that it will not dissipate enough energy to ignite a flammable mixture. In this case the protection measure deployed is a system protection measure known as Ex i (or EExi) or intrinsic safety.

Intrinsic Safety EEx i & Ex i

Intrinsic Safety is recognised widely as a low energy system of explosion protection, typical of electronic control and instrumentation circuits.

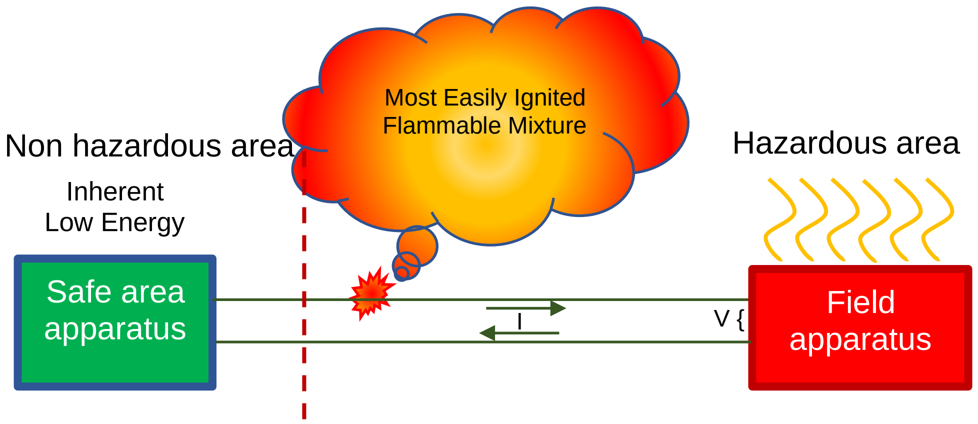

Figure 1

Standards

There are numerous standards, both national and international, that define or reference intrinsic safety. Table 1 presents in inexhaustive list of the relevant standards.

Table 1 Inexhaustive list of Standards relevant to Intrinsically safe apparatus,

I.S. EN 60079-11: 2012	Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i"
I.S. EN 60079-25: 2010	Explosive atmospheres - Part 25: Intrinsically safe electrical systems
IEC 60079-27: 2008	Explosive atmospheres – Part 27: Fieldbus intrinsically safe concept (FISCO)
I.S. EN60079-14: 2013	Explosive atmospheres - Part 14: Electrical installations design, selection and erection
I.S. EN60079-17: 2014	Explosive atmospheres - Part 17: Electrical installations inspection and maintenance

Definition

I.S. EN 60079-11 defines an intrinsically safe circuit as:

> *"A type of protection based on the restriction of electrical energy within apparatus and of interconnecting wring exposed to the potentially explosive atmosphere to a level below that which can cause ignition by either sparking or heating effects."*

Equipment Protection Levels for intrinsically safe systems are:

Zones of use:	EPL
O, 1 & 2	(Ex ia) (based on traditional approach)
1 & 2	(Ex ib)
2	(Ex ic)

Principles of Intrinsic Safety

Safety in an intrinsically safe (IS) circuit is achieved by maintaining very low energy levels such that electrical sparks, if they occur, will have insufficient energy to ignite the most easily ignitable concentration of a flammable mixture nor will there be sufficient energy to produce hot surfaces.

Low levels of power and thermal energy are achieved by limiting the voltage and current supplied to the apparatus in the hazardous area. It is of paramount importance that low levels of voltage and current are not exceeded under any condition normal or fault condition.

Circuit parameters including voltage, current, resistance, inductance, capacitance and thermal dissipation are all factors that have to be considered in the design of an IS circuit. Consultation of the characteristic ignition curves given in the construction standard (I.S. EN 60079-11: 2012 or equivalent) and the application of an appropriate safety factor, will ensure that safe values are established for these parameters during the design stage.

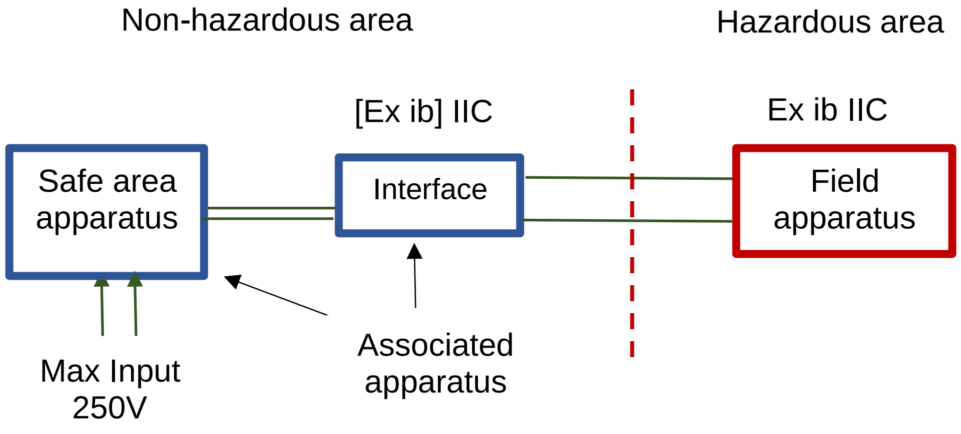

Figure 2

A typical Intrinsically Safe system that comprises of a safe area apparatus, safe-to-hazardous area interface, cables, junction boxes and field (hazardous) area apparatus, must be designed in such a way as to prevent the possibility of particular faults occurring (Figure 2). As opposed to other methods of explosion protection, **intrinsic safety is a system approach which applies to the complete circuit and not to any one component only.** Safe area apparatus, the interface, connected to hazardous area field apparatus and interconnecting cables, are collectively referred to as "**associated apparatus"** and with the exclusion of "simple devices" should have a - declaration of conformity in accordance with the relevant European product legislation, Directive 2014/34/EU. and will generally require certification from an independent third party called a Notified Body.

Associated apparatus, such as the interface will usually be marked with square brackets [Ex ia] llC, to indicate that they are not to be mounted in a hazardous area. Associated apparatus may be used in the hazardous area if installed in accordance with another method of explosion protection, e.g. enclosed within flameproof Ex d enclosure. In addition, power supplies may also be installed in flameproof or pressurised Ex p enclosures if installed in the hazardous area. An overall "Descriptive System Document" should be prepared to document the design intent of the installation and to record the intrinsically safe energy calculations.. Only the equipment specified in the system documentation may be installed in the system. This Descriptive System Document could form part of the Explosion Protection Document (EPD) as required by the 2007 Safety Health and Welfare at Work (General Application) Regulations (Part 8).

The power supply apparatus/source parameters such as voltage (Ui), Current (Ii) and power (Pi), which is connected to the non-IS terminals of associated apparatus, must not exceed the values Ui Ii or Pi of those given on the ATEX certificate of the associated apparatus.

Advantages of Intrinsic Safety are:

a. Live maintenance is possible

b. Cost effective — certified enclosures not required and ordinary wiring may be used

c. Safe — low voltage not harmful to personnel

d. Can be used in Zone 0

Interface types (associated apparatus)

There are generally two technologies available for the Interface Barrier: the Zener shunt diode barrier and the galvanic isolator barrier. The interface prevents high energy levels entering the hazardous area.

The Zener Barrier

The faults which can occur in an IS systems are either overvoltage or overcurrent, and mitigation against these conditions is afforded by the use of an interface, typically a Zener barrier. The interface, which is connected between the safe area and hazardous area apparatus (See Fig 2), is normally located in the safe area and as close as practical to the boundary with the hazardous area. Alternatively, it may be located in the hazardous area if installed in a flameproof enclosure.

The construction of a Zener barrier should be assessed in terms of its individual components in as shown in Figure 3 below.

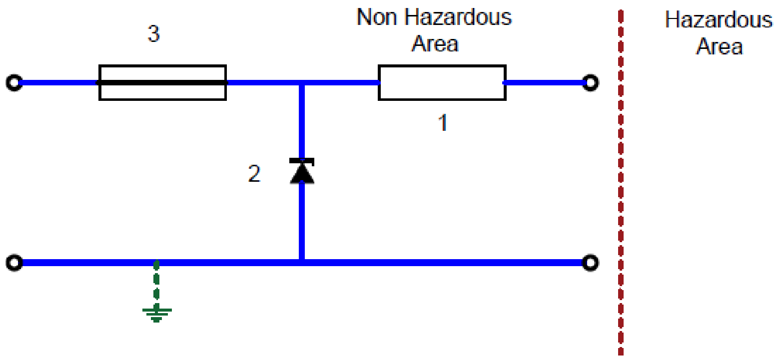

Figure 3

A simple Zener barrier has three principal components, (1) a resistor, (2) a Zener diode, and (3) a fuse, all of which must have infallible properties. Infallibility, in respect to the current limiting resistor, requires that resistance value will be higher or open-circuit in the event of it failing. To ensure infallibility is satisfied, one should only use a quality wire-wound or metal film resistor, which should not operate at more than two thirds of its rated current, voltage and power for a specified temperature range.

The purpose of the Zener diode is to limit the voltage available to the apparatus in the hazardous area and as a single item, is not considered to be an infallible component, and must also be operated at only two thirds of its rated current, voltage and power. For infallibility to be satisfied, the Zener diode is required to fail to a short-circuit. Diode failure to a higher resistance or open circuit could allow higher then permitted voltage levels into the hazardous area.

Note: Manufacturers tests have demonstrated that diodes almost always fail to a short-circuit state, but this cannot be guaranteed. The infallibility of Zener diodes can only be considered when two or more diodes are connected in parallel.

The purpose of the fuse is to protect the Zener diode, not to protect against short circuits in the hazardous are and is located at the input (safe) end of the Zener barrier. The use of a sand-filled ceramic type fuses capable of operating properly even when exposed to a prospective fault-current of up to 4000 A will ensure infallibility of the fuse. Non ceramic fuses when they rupture can experience vaporisation which can allow the fuse to continue to conduct.

The standard- I.S. EN 60079-25 requires that all the components of the barrier including the fuse are encapsulated to deter repair or replacement. The repair of Zener barriers, even by the manufacturer, is not permissible.

Note: Categories (levels of protection), 'ia', 'ib' and 'ic', are described on the following page but with regard to the infallibility of components, this applies to 'ia' and 'ib', but is not applicable to 'ic'. Additionally, for level of protection 'ic' the two thirds safety factor applies only to the power rating; it does not apply to the voltage and current, provided the rated values are not exceeded.

Zener Barrier Operation

When a short-circuit event occurs in the hazardous area apparatus, or across the IS wiring, the series resistor in the Zener barrier will choke the short-circuit current (Isc) to a safe level such that the integrity of the system is maintained (

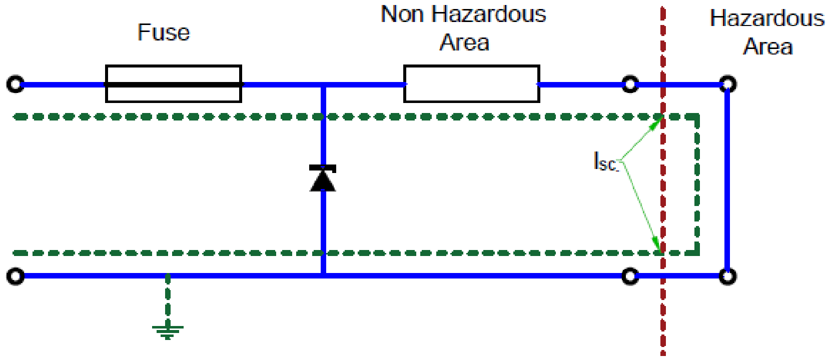

Figure 4

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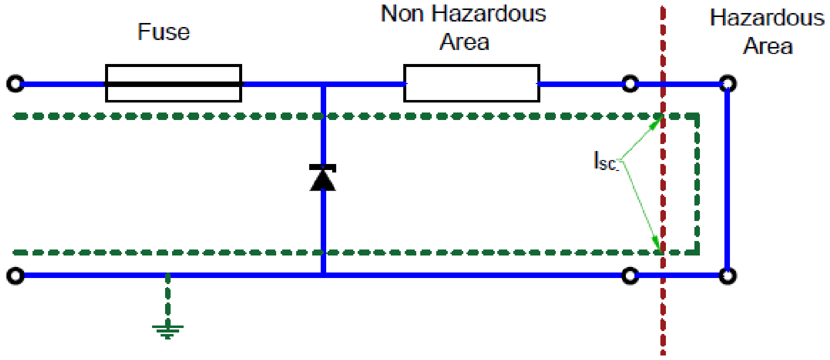


Figure 4

Likewise, if a voltage greater than the normal maximum voltage of the IS system is applied to the input terminals of the Zener barrier, this will trigger the Zener diode to conduct, and the resulting fault current will be shunted to earth. The excessive voltage is, therefore, prevented from reaching the apparatus in the hazardous area as illustrated in (**Error! Reference source not found.**).

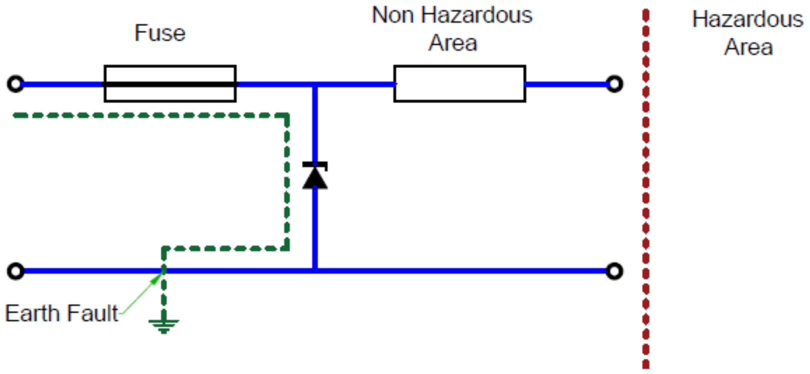


Figure 5

Levels of protection for IS

There are three levels of protection, namely 'ia', 'ib' and 'ic', the level of safety provided by each being dependant on the number component failures to be considered.

Protection level, 'ic', is the simplest of devices where no faults are considered in order to maintain safety. Protection level, 'ib' will maintain safety in the event of one fault occurring. Protection, 'ia', is required to maintain safety should two simultaneous faults occur. Therefore, to maintain safety with one or two faults in a Zener barrier (interface), additional Zener diodes are required since they are the components most likely to fail.

Since the occurrence of faults or the use of infallible components are not a consideration for the level of protection 'ic', apparatus marked 'ic' are only suitable for use in zone 2.

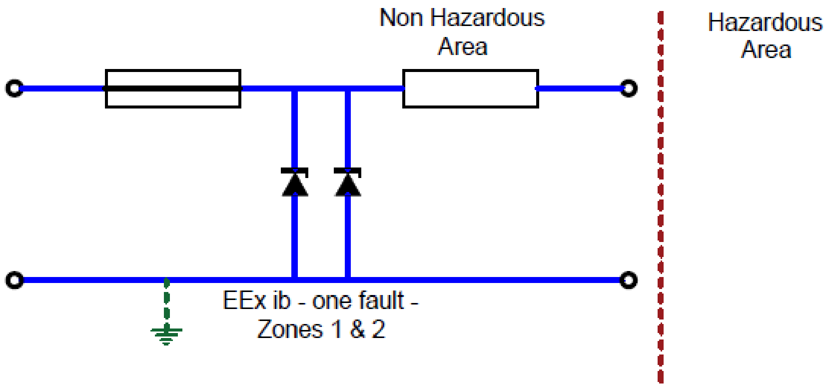


Figure 6

To assure safety with one fault present, the addition of a second Zener diode, connected in parallel with the first, will satisfy the requirements of category 'ib' intrinsic safety (Figure 6). Category 'ib' intrinsic safety may be used in Zones 1 & 2, but not Zone 0,

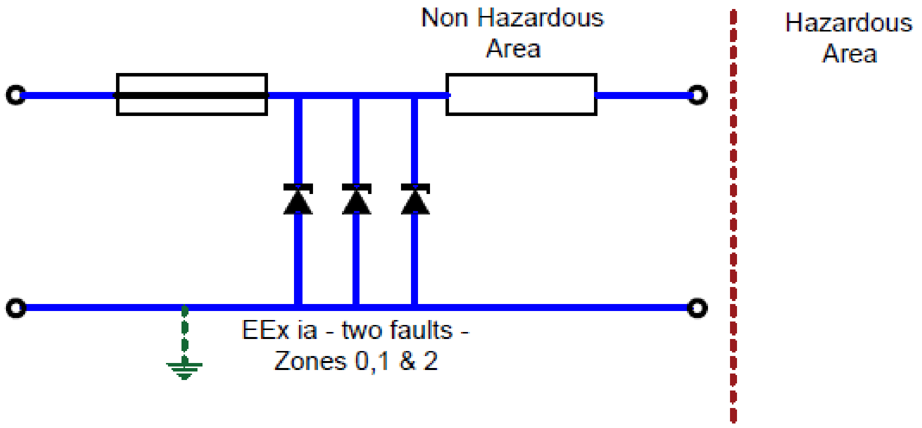


Figure 7

To satisfy the conditions for category 'ia' intrinsic safety in which safety is assured with two faults, a third Zener diode connected in parallel will be required (Figure 7). Category 'ia' intrinsic safety is permitted in Zones 0, 1 and 2.

Note 1: To verify if the fuse of a Zener barrier has blown a simple test is to disconnect both the input and output connections and measure the resistance between the input and output terminals.

Note 2: Associated equipment in the non-hazardous area connected to Equipment in the hazardous area must be compatible i.e. the same group and level of protection. Example: a Zener barrier was marked [Ex ib] IIC and the equipment in the hazardous area marked Ex ia IIC, the level of protection of the system would be reduced to Ex ib IIC.

Minimum Ignition Current Curves

To ensure operational safety it is necessary to limit the current and voltage in an IS circuit, therefor the design of the circuit will be based on the minimum ignition current curves given in the construction standard (I.S. EN 60079-11: 2012 or equivalent) and reproduced in Figure 8 Minimum Ignition Current Curve Resistive Circuits

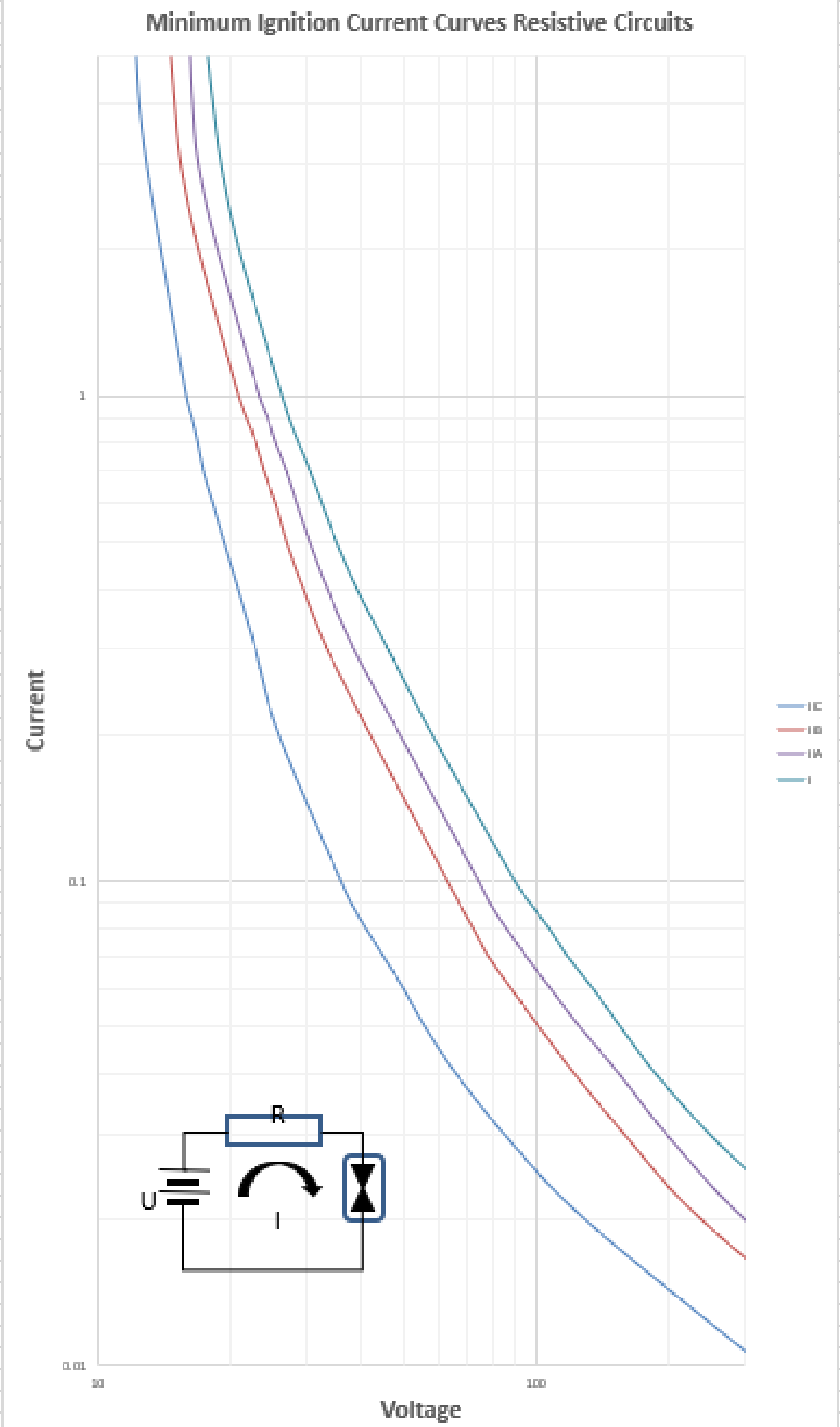


Figure 8 Minimum Ignition Current Curve Resistive Circuits

Resistive Circuits

In a purely resistive circuit of known voltage, the maximum circuit current can be determined from the graph, which enables selection of the correct interface.

For example, a purely resistive circuit for use in a IIC hazard, it is intended that a 28V, 300 Ω Zener barrier will be used. A 10% safety factor must be applied to the voltage of this device since a rise in its temperature may raise the triggering voltage of the Zener diodes. Applying the safety factors of 28V x 1.1 = 30.8 V, which is then located on the horizontal (voltage) axis of the graph. Tracing a line from 30.8V vertically towards the IIC curve, and tracing a line horizontally from the intersection with the curve towards the vertical (current) axis, provides a safe current of 140 mA. A safety factor of 1.5 must be applied to this value, resulting in 140mA x 0.666 = 93.33 mA. By applying ohm's law, 28V ÷ 93.33 mA = 300 Ω, equivalent to the resistance of the chosen Zener barrier. The calculation has confirmed that the 28V, 300 Ω interface is suitable for maintaining the integrity of the IS circuit in a IIC hazard.

Simple Apparatus

In the previous calculated circuit, the spark energy of an IS circuit, during normal or fault conditions, will be insufficient to cause ignition of a surrounding hazard. The introduction of a switch, which in normal operation produces sparks and does not dissipate power, will not alter the situation, and in fact, any device which is resistive by nature and non-energy storing may, theoretically, be added to the circuit without jeopardising the integrity of intrinsic safety.

Devices such as these are referred to as ***"simple apparatus"*** Simple apparatus includes switches, junction boxes, terminals, potentiometers and simple semiconductor devices. They may also include sources of stored energy, for example, capacitors and inductors having well defined parameters, consideration of these values must be assessed during the design stage of an IS installation. Sources of generated energy, typically thermocouples, loadcells and photocells, may also be assessed as simple apparatus providing, they do not generate more than 1.5 V, 100mA and 25 mW. Capacitance or inductance in these devices must also be considered during the design stage of an installation.

Enclosures

The minimum IP rating for enclosures in IS circuits is IP20, however environmental conditions may require a higher rating., Enclosures used as junction boxes must be marked that they contain IS circuits as illustrated in figure 10

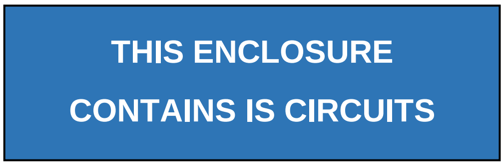


Figure 9 Intrinsic Safe Label for Enclosure

Alternatively, enclosures containing Safe Area components, for example, a Zener barrier (non-IS input /IS output) may utilise a flameproof enclosure in a hazardous area. The marking on such an enclosure would be, for example, Ex d [ia].

Energy Storage

Energy storing devices such as inductors and capacitors pose a risk to the integrity an IS system. Energy can be charged in these devices over a period of time and then released in a higher amplitude surge at a break in the IS cables due to a fault or live disconnection at terminals. Regardless of the design constraints on voltage and current this surge may occur resulting in ignition of a surrounding flammable atmosphere. It is therefore important to counteract this potential surge at the design stage. Field apparatus which has the potential to store energy is termed 'non-simple' and is required to be certified.

Cables between the interface and the apparatus in the hazardous area, will have appreciable inductance and capacitance, especially long runs which must be considered at the design stage. Cables will store energy under normal operating conditions and this energy may increase under fault conditions. The loop voltage will influence which parameter of the loop is predominant, for example a low voltage of 5 V will develop an inductive charge, but at 28V, the charge will be capacitive

In a system where only simple apparatus is used, the inductance and capacitance present in the loop can be attributed to the cables only, and parameters will be negligible if the cable runs are short. To determine the electrical parameters capacitance C_c, inductance L_c and L_c/R_c for typical instrument cables with twisted or adjacent cores there are three possible methods.

a. Obtaining the worst-case parameters from the cable manufacturer, or

b. Measurement of the parameters using a sample of the cable, or

c. Adoption of the following values —

Inductance, (L_c)	1 pH/m
Capacitance, (C_c)	200 pF/m
Inductance/resistance ratio (L/R_c)	30 H/Ω

It is important that the combined inductance and capacitance of the field apparatus and cables does not exceed the values of the interface specified by the manufacturer.

Evaluation of Cable Parameters

Inductance

To determine the maximum inductance of the interconnecting cables the maximum available source current from the interface has to be established., ether from the manufacturers data sheet or by calculation. I.e., assuming an interface with a maximum output of 28 V and 300 Ω resistance, the maximum source current Is:

$$28\ \text{V} / 300\ \Omega = 93.33\ \text{mA}$$

Applying a safety factor of 1.5:

$$1.5 \times 93.33 = 140\ \text{mA}$$

Assuming the cable is connected to simple apparatus in the hazardous area, the maximum inductance is determined to be approximately 4.0 mH. This value is found by projecting vertically form 140 mA on the current axis, and then horizontally towards the inductance axis form the point of contact on the IIC curve Figure 10 Inductive Circuit Curves for Group Il.

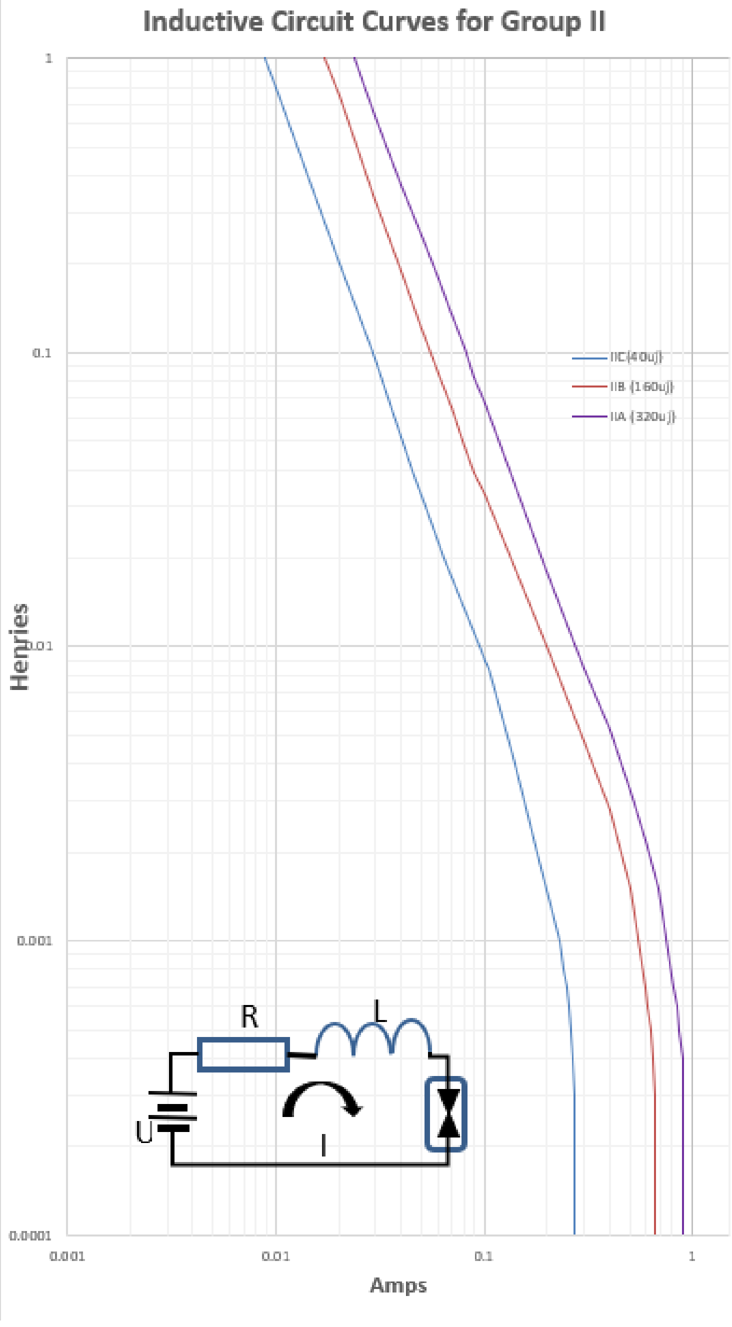


Figure 10 Inductive Circuit Curves for Group II

Capacitance

The procedure for capacitance circuits is exactly the same. A safety factor of 1.5 is applied to the Zener barrier voltage of 28 V.

i.e. 1.5 x 28 V = 42 V

Using the IIC curve in the graph in Figure 11 Capacitive Circuit Curves for Group II, the maximum safe capacitance for the interconnecting cables, assuming that connection is to 'simple apparatus' in the hazardous area, is found to be 0.08 µF approximately.

Comparison of the above values with the data provided by the cable manufacturer will establish of the interconnecting cable run is satisfactory.

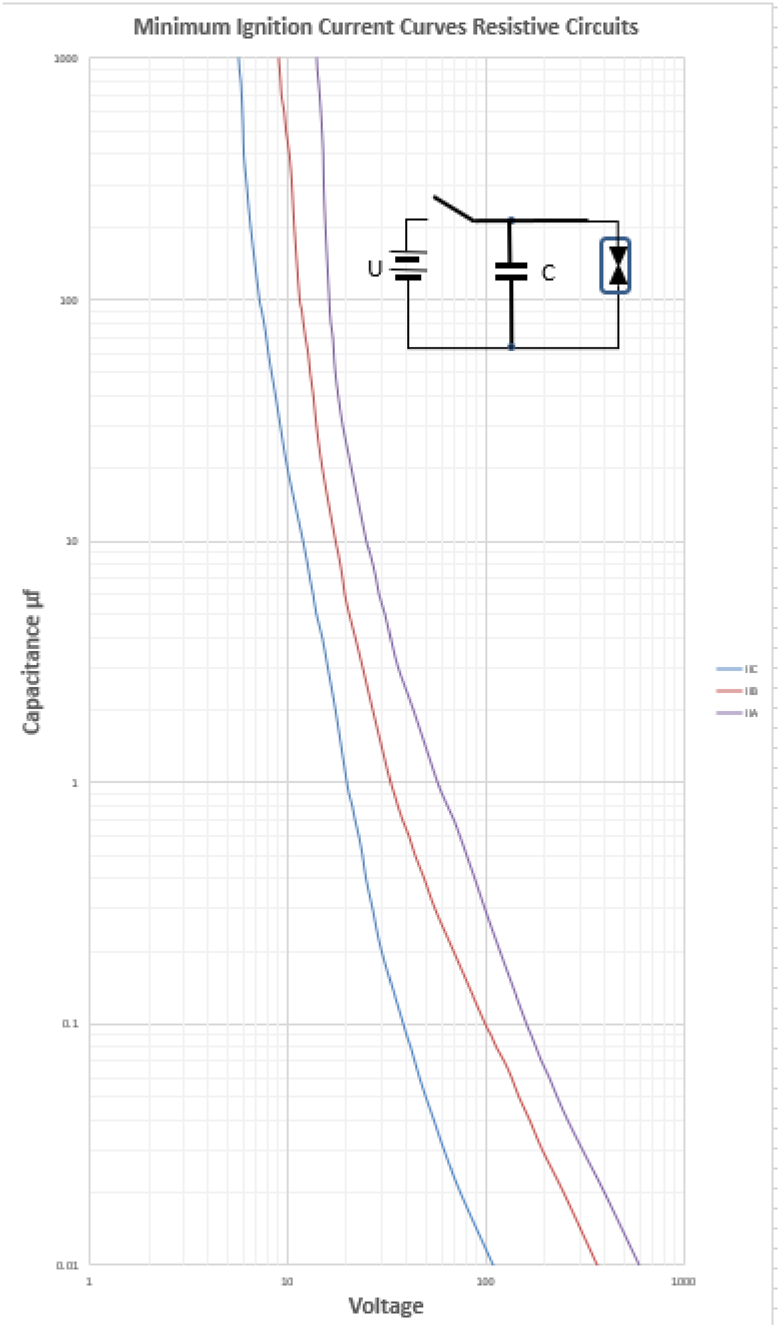


Figure 11 Capacitive Circuit Curves for Group II

Earthing

An essential factor in maintaining the security of IS circuits, particularly when Zener barriers are used is a dedicated high-integrity earth. If Galvanic isolators are deployed, a high-integrity earth is not essential as they operate on a different principle. However earthing may be required for interference suppression.

It is required that earth bars on which Zener barriers are mounted are connected directly to the main earth point via separate earthing conductors and are insulated from the surrounding metalwork. To facilitate earth resistance tests, which must be periodically carried out, it is good practice to use two cables, each secured at separate points at either end of the barrier earth bar to the main earth point. The resistance between the barrier earth bar and the main earth point should be no greater than 1 Ω. It is typical to have values of 0.1 Ω.

The earth conductors must be insulated, along its entire length so that contact with the plant metalwork is avoided: Where the risk of damage is high, mechanical protection for the cables should be provided.

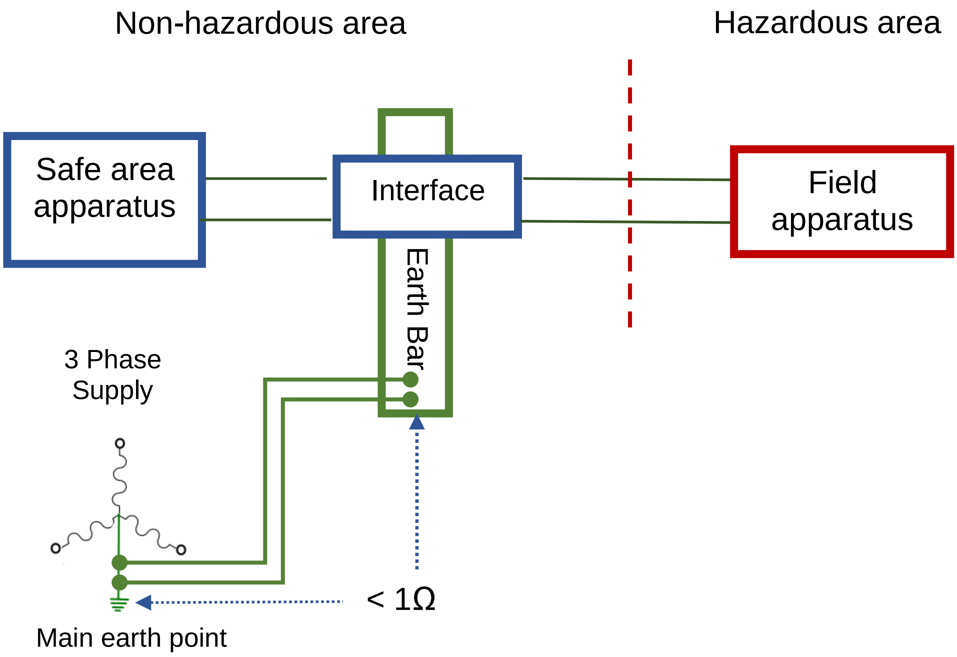
The earth conductors must be capable of carrying the maximum fault current and have an appropriate cross-sectional area (CSA) of the following:

a. At least two separate $1.5mm^2$ (minimum) copper conductors, or

b. At least one $4mm^2$ (minimum) copper conductor.

Note: The IS circuit in the hazardous area must be capable of a 500V insulation resistance test to earth.

Earthing and Bonding



Galvanic Isolation

While Zener barriers are still in use across many industrial sites, they have specific limitations:

a. A direct connection exists between the hazardous and safe area circuits and earth, which places a constraint on the rest of the system.
b. A dedicated high-integrity earth is necessary to divert fault currents away from the hazardous area.
c. Hazardous area apparatus must withstand a 500 V insulation resistance test to earth.

Galvanic Isolation interfaces typically, relays, optic isolators and transformers devices overcome these difficulties. Since there is no direct connection between the hazardous and non-hazardous area, an IS earth is not required and earthing of, cable screens may be carried out at the plant or the enclosure earth.

Relay/Transformer Isolation

In the relay/transformer circuit, isolation between the hazardous and safe areas is maintained by the use of a *high integrity component* approved transformer and *high integrity component* approved relay. The physical design of these devices ensures that high voltage invasion of the IS circuit will be prevented from reaching the hazardous area apparatus.

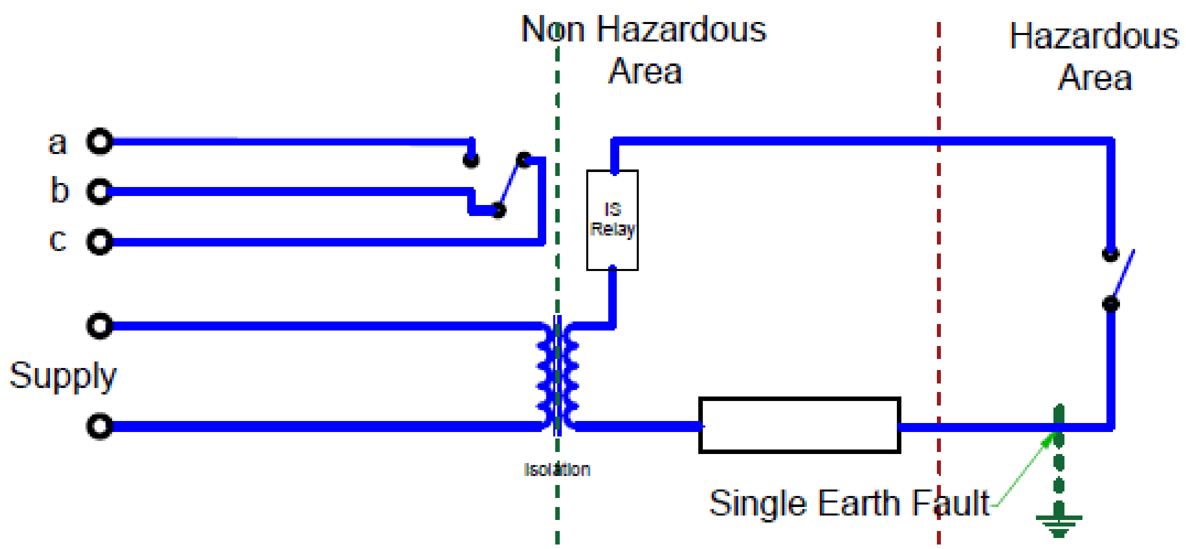


Figure 12

Opto-coupler/Transformer Isolation

The Opto-coupler/Transformer Isolation approach comprises a high integrity component certified opto-isolator and high integrity component approved transformer. Light (or infrared) emitted from the LED when it is forward biased falls onto the phototransistor which is shielded from external light. The optocoupler drives a relay in the safe area to replicate the switch condition in the hazardous area.

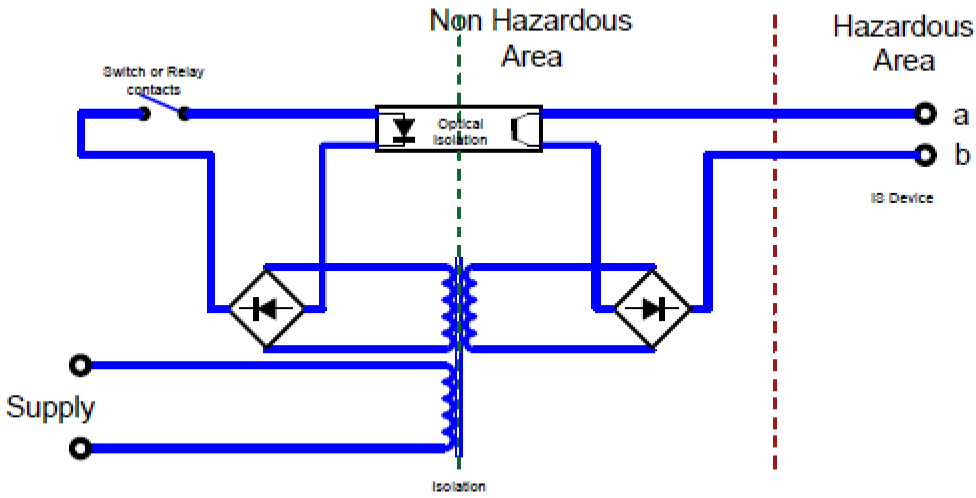


Figure 13

Installation of IS Apparatus

The apparatus which makes up an IS installation, i.e. associated apparatus/interfaces field apparatus, is required to be certified by a notified body that they have been manufactured in accordance with (IS EN 60079-25). Such apparatus, including interconnecting cables, must be installed in accordance with the manufacturer's instructions and with regard to the recommendations in IS EN 60079-14. Existing installations may, however have been installed in accordance with earlier codes of practice such BS 5345.

Within the manufactures instructions are the output characteristics of the safe area apparatus, which must be evaluated when designing an intrinsically safe circuit. The output characteristics tend to be linear, trapezoidal or rectangular depending on type of apparatus.

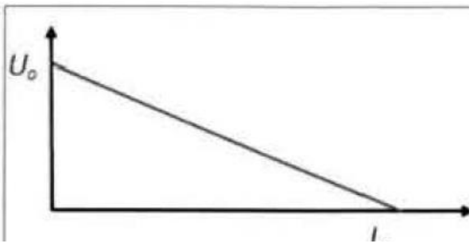
Applicability of the Limit Curves

Curves in figure 8, 11 &12, are only of limited applicability.

The values L_o and C_o from these curves have been experimentally determined independent of each other and no account has been made for the presence of both L and C simultaneously in a real circuit. It is therefore necessary to determine L_o and C_o in case of non-linear circuits?

Output Characteristics

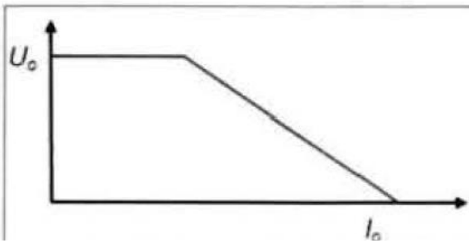
Linear characteristic



• $P_o = \frac{1}{4} U_o I_o$

Limit curves of EN 60079-11 are applicable: L_o or C_o

Trapezoidal characteristic

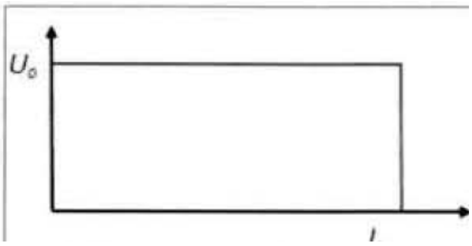


• $\frac{1}{4} U_o I_o < P_o < U_o I_o$

Limit curves of EN 60079-11 are not applicable.

Determination of L_o and C_o experimentally, by using PTB-report ThEx-10 (EN 60079-25

Rectangular characteristic



• $P_o = U_o I_o$

Limit curves of EN 60079-11 are not applicable.

Determination of L_o and C_o experimentally, by using PTB-report ThEx-10 (EN 60079-25)

L_o and C_o in Case of Non-Linear Sources

Determination of L_o and C_o in case of non-linear sources:

To determine L_o and C_o in the case of non-linear outputs there are two choices available to the designer:

• Application of PTB-report ThEx-10 (or IS EN 60079-25. Annex C)

• PTB-software i-spark

Whichever option is chosen the advantage is that both procedures already consider the simultaneous presence of lumped inductance and capacitance: L_o and C_o.

Difficulty of Mixed Circuits

Real circuits comprise L and C simultaneously. This applies to all circuits due to inductance L' and capacitance C' per unit length of cable and the respective L and C found in the safe and hazardous area apparatus. These are defined as distributed and lumped reactance's

Distributed and Lumped Reactance’s

Distributed Reactance’s:

Inductance and capacitance per unit length L' and C’ of cable.

Lumped Reactance’s

Hazardous area electronic components reactance’s L_i and C_i

IS EN 60079-14, Edition 4.0, 2007

IS EN 60079-14, Edition 4.0, 2007 contains a "new" procedure to evaluate the total reactance’s of an intrinsically safe loop:

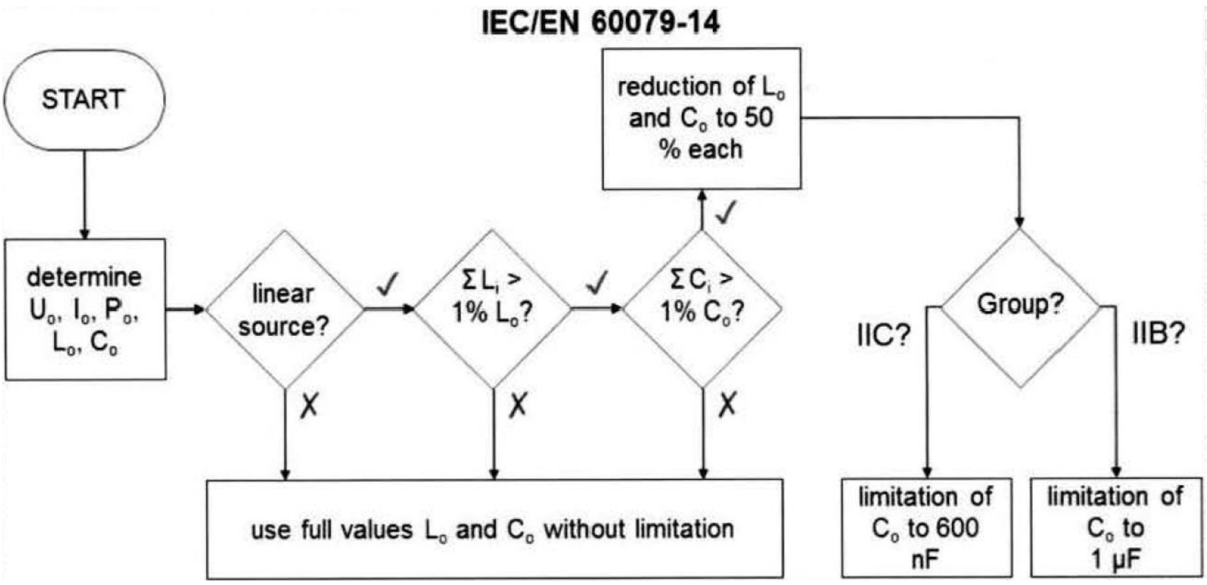
• Application of the 50 %-Rule” to calculate reduced L_o and C_o values if the output of the source is not linear

• Presently described in chapter 16 (“additional requirements, i")

• Since 2008/2009 adapted to all national editions (IS, BS, SS, DIN. OVE/ONORM. SN etc.)

- Simultaneous presence of L_i and C_i permissible under certain circumstances.

Flow-Chart: 50 % Rule



Attention: the application of the 50 % rule only makes sense in case of linear sources - this note is missing in the present edition of EN 60079-14:2014!

Example 1: L_i and C_i without Reduction

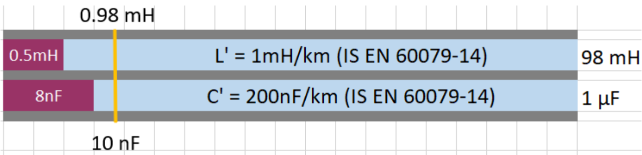
In this example, the safe area apparatus has a linear output, the cable values are taken from I.S. EN 60079-14 and the reactances of the hazardous area apparatus are relatively low.

Associated Apparatus			
U_o	=	13	V
I_o	=	19	mA
P_o	=	62	mW
L_o	=	98	mH
C_o	=	1	µF

Cable			
l	=	?	V
L'	=	1	mA
C'	=	200	mW
L_c	=	?	mH
C_c	=	?	µF

Intrinsically Safe Apparatus			
U_i	=	18	V
I_i	=	30	mA
P_i	=	100	mW
L_i	=	0.5	mH
C_i	=	8	nF

- The output characteristics is linear: ¼ U_o I_o = 61.75 mW = 62 mW
- L_o and C_o are applicable to IIC
- The cable parameters are based on generic values of IS EN 60079-14



Calculation of the maximum permissible cable length:

- As L_i and C_i do not exceed 1 % of L_o and C_o No reduction of L_o and C_o required.
- $\ell_{inductive}$ = (98 mH – 0.5 mH) + 1 mH/km = 97.5 km
- $\ell_{capacitive}$ = (1 µF - 8 nF) + 200 nF/km = 4.96 km

Therefore, the maximum permissible length of cable is 4.96km

Example 2: L_i and C_i without Reduction

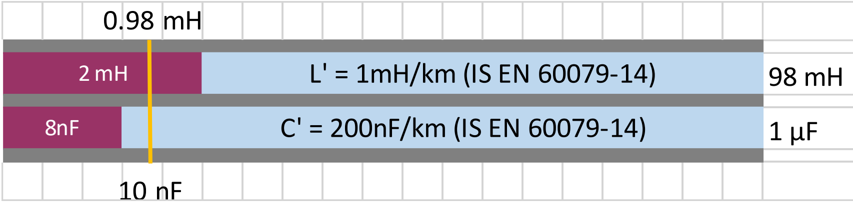
In this example the safe are apparatus has a linear output, the cable values are those from IS EN 60079-14 and the inductive reactance of the hazardous area apparatus exceeds 1% of L_o.

Associated Apparatus			
U_o	=	13	V
I_o	=	19	mA
P_o	=	62	mW
L_o	=	98	mH
C_o	=	1	µF

Cable			
l	=	?	V
L'	=	1	mA
C'	=	200	mW
L_c	=	?	mH
C_c	=	?	µF

Intrinsically Safe Apparatus			
U_i	=	18	V
I_i	=	30	mA
P_i	=	100	mW
L_i	=	2	mH
C_i	=	8	nF

- The output characteristics is linear: ¼ U_o I_o = 61.75 mW = 62 mW
- L_o and C_o are applicable to IIC
- The cable parameters are based on generic values of IS EN 60079-14



Calculation of the maximum permissible cable length:

It should be noted L_i exceeds 1% of L_o but C_i do not exceed 1 % of C_o No reduction of L_o and C_o required as the output characteristics are linear.

- $\ell_{inductive}$ = (98 mH – 2 mH) + 1 mH/km = 96 km
- $\ell_{capacitive}$ = (1 µF - 8 nF) + 200 nF/km = 4.96 km

Again, in this example the lumped capacitive reactance determines the maximum length of cable to 4.96km.

Example 3: L_i and C_i with Reduction

In this example the safe are apparatus has a linier output, the cable values are those from IS EN 60079-14 and both inductive capacitive reactance of the hazardous area apparatus exceeds 1% of L_o & L_c.

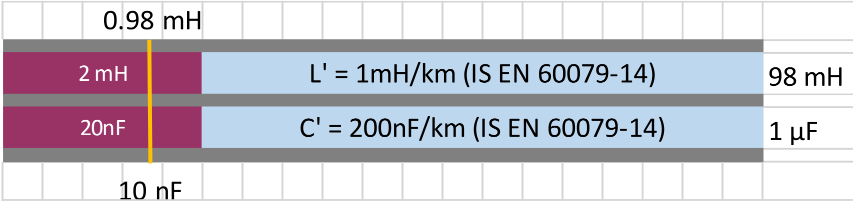
Associated Apparatus			
U_o	=	13	V
I_o	=	19	mA
P_o	=	62	mW
L_o	=	98	mH
C_o	=	1	µF

Cable			
l	=	?	V
L'	=	1	mA
C'	=	200	mW
L_c	=	?	mH
C_c	=	?	µF

Intrinsically Safe Apparatus			
U_i	=	18	V
I_i	=	30	mA
P_i	=	100	mW
L_i	=	2	mH
C_i	=	20	nF

Remarks

- The output characteristics is linear: ¼ U_o I_o = 61.75 mW = 62 mW
- L_o and C_o are applicable to IIC
- The cable parameters are based on generic values of I.S. EN 60079-14



Calculation of the maximum permissible cable length:

- Both L_i and C_i exceeds 1% of L_o and C_o

Reduction of L_o and C_o to 50% of the initial values required.

- $\ell_{inductive}$ = (49 mH – 2 mH) + 1 mH/km = 47 km
- $\ell_{capacitive}$ = (500 nF - 20 nF) + 200 nF/km = 2.4 km

In this example the 50% rule has and lumped capacitive reactance determines the maximum length of cable to 2.4 km.

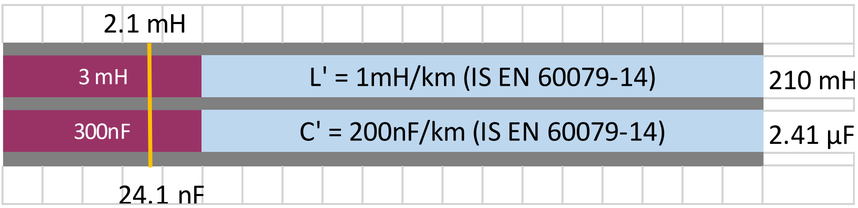
Example 4: L_i and C_i with Reduction

In this example the safe are apparatus has a linier output, the cable values are those from I.S. EN 60079-14 and both inductive capacitive reactance of the hazardous are apparatus exceeds 1% of L_o & L_c.

Associated Apparatus				Cable				Intrinsically Safe Apparatus			
U_o	=	10.5	V	l	=	?	V	U_i	=	18	V
I_o	=	13	mA	L'	=	1	mA	I_i	=	30	mA
P_o	=	34	mW	C'	=	200	mW	P_i	=	100	mW
L_o	=	210	mH	L_c	=	?	mH	L_i	=	3	mH
C_o	=	2.41	µF	C_c	=	?	µF	C_i	=	30	nF

Remarks

- The output characteristics is linear: ¼ U_o I_o = 34.125mW = 34 mW
- L_o and C_o are applicable to IIC
- The cable parameters are based on generic values of I.S. EN 60079-14



Calculation of the maximum permissible cable length:

- Both L_i and C_i exceeds 1% of L_o and C_o

Reduction of L_o and C_o to 50% of the initial values is required.

Limitation of the reduced capacitance to 600 nF (IIC) or 1 µF (IIB)

- $\ell_{inductive}$ = (105mH – 3 mH) + 1 mH/km = 102km
- $\ell_{capacitive}$ = (600 nF - 30 nF) + 200 nF/km = 3.85 km

In this example the 50% rule has and lumped capacitive reactance determines the maximum length of cable to 3.85 km.

The rule requires the designer to give due consideration of the relationship between U_o and C_o as well as I_o and L_o!

Example 5: L_i and C_i with Reduction

In this example the safe are apparatus has a linear output. However the L_o and C_o values are much lower, the cable values are those from I.S. EN 60079-14 and both inductive capacitive reactance of the hazardous are apparatus exceeds 1% of L_o & L_c.

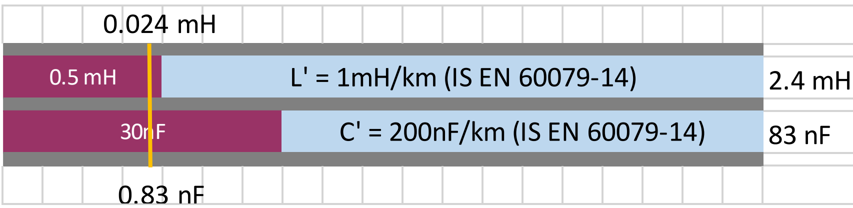
Associated Apparatus			
U_o	=	28	V
I_o	=	120	mA
P_o	=	840	mW
L_o	=	2.4	mH
C_o	=	83	nF

Cable			
I	=	?	V
L'	=	1	mA
C'	=	200	mW
L_c	=	?	mH
C_c	=	?	µF

Intrinsically Safe Apparatus			
U_i	=	30	V
I_i	=	150	mA
P_i	=	1000	mW
L_i	=	0.5	mH
C_i	=	30	nF

Remarks

- The output characteristics is linear: ¼ U_o I_o = 840 mW = 34 P_o
- L_o and C_o are applicable to IIC
- The cable parameters are based on generic values of I.S. EN 60079-14



Calculation of the maximum permissible cable length:

- Both L_i and C_i exceeds 1% of L_o and C_o

Reduction of L_o and C_o to 50% of the initial values required.

- ℓinductive = (1.02mH – 0.5 mH) + 1 mH/km = 700m

• ℓcapacitive = (41.5 nF - 30 nF) + 200 nF/km = 57.5 km

In this example the 50% rule and lumped reactances determines the maximum length of cable to 700m. it can be seen the L_o and C_o have a big impact on loop design and lumped reactance has a greater influence then lumped capacitance in determining maximum permissible cable length.

Requirements for IS Cables

According to relevant standards, intrinsically Safe cables must be capable of withstanding 500Va.c. or 750Vd.c. test voltages between conductors and earth, conductors and screens and screens and earth. The conductors are required to be insulated with elastomeric or thermoplastic insulation which has a minimum thickness of 0.2mm. The conductors of cables in the hazardous area, and this includes the individual strands of finely stranded cables, must have a diameter not less than 0. Imm. Separation of the individual strands of cables must be prevented by, for example, the use of core-end ferrules. Though not a mandatory requirement, the colour of IS cables (and terminals) is generally light blue. Alternatively, mineral insulated cable may be used.

Mechanical Protection

The interconnecting cables of an IS circuit are required to have an overall sheath in order to maintain the integrity of the system, i.e. to prevent contact with cables of other circuits, or earth, as a result of damage, and to ensure the circuit parameters in terms of inductance and capacitance are not exceeded.

Armouring or screening of cables for mechanical protection is not required except for IS circuits with multi-core cables in Zone 0.

Segregation of IS and Non-IS Circuits

Segregation of IS and non-IS circuits in both hazardous and non-hazardous areas is required, to avoid the possibility of higher voltages from non-IS circuits interacting with IS circuits. Segregation may be achieved by any one of the following methods.

- Adequate separation distance between IS circuit cables and non-IS circuit cables, or
- Positioning of the IS circuit cables such as to guard against the risk of mechanical damage (separate containment), or
- The use of armoured, metal sheathed, or screened cables for either the IS or non-IS cables.

It is not permitted for multi-core cables to carry both IS circuits and non-IS circuits.

Where IS cables and the cables of other circuits share the same duct, bundle or tray, segregation by means of an insulated or earthed metal partition is required. Separation is not necessary if either the IS cables or the cables of the non IS circuit are armoured, screened or metal sheathed. The armouring of cables should be securely bonded to the plant earth.

Unused Cable Cores

Where multi-core cables have one or more unused cores, either of the following termination methods may be used to maintain the integrity of the installation.

- Connected to separate terminals at both ends so that the cores are insulated from one another and earth, or
- Connected to the same earth point, if applicable, as used by the IS circuits in the cable, typically a Zener barrier earth-bar. The unused cores at the other end of the cable, however, must be insulated from each other and earth by means of suitable terminals.

Cable Screens

Where the interconnecting cables of IS circuits have overall screens, or groups of conductors with individual screens, it is required that the screens are earthed as specified in the loop diagram for the installation, at one point only, which is usually the Zener barrier earth bar. If, however, the IS circuit is isolated from earth, connection of the screen to the equipotential bonding system should be made at one point only.

Overall screens are required to be insulated from the external metalwork, i.e. cable tray etc.

Induced Voltage

IS circuits must be installed using methods that avoid external electric or magnetic fields affecting them. In general, induced voltage in IS interconnecting cables is unlikely, but may occur if the IS cables are installed parallel to and in close proximity to single-core cables carrying heavy current, or overhead power lines. To overcome this difficulty best practice requires adequate segregation between the different circuits, in addition to as the use of screens and/or twisted cores.

Marking of Cables

In order that IS Cables may be easily identified, the sheath or core insulation of IS circuit cables may be coloured light blue. To avoid confusion, light blue cables must not be used for other types of circuits in the vicinity.

Where IS circuits and non-IS circuits share the same enclosure, e.g. switchgear, distribution apparatus, measuring and control cabinets, etc., appropriate measures must be implemented to distinguish between the two types of circuit, and avoid confusion where a blue neutral conductor may be present. These measures are:

- Combining the IS cores in a common light blue harness,
- Labelling,
- Clear arrangement and spatial separation.

Multi-core Cables

It is NOT permissible for IS and non-IS circuits to be run in the same multi-core cable, however more than one IS circuit may be run in a multi-core cable. The conductor insulation must have adequate radial thickness but not less than 0.2mm and be capable of withstanding a rms a.c. test voltage equal to twice the nominal voltage of the IS circuit but not less than 500V. For each IS circuit in a multi-core cable the cores are required to be adjacent to one another for the entire length of a cable. If, however, a cable has, for example, individually screened pairs, then ideally each circuit should be connected to cores from the same screen and not to cores within other screens. An exception to this applies where an IS circuit requires a triple screened cable, i.e. three cores within a screen, but a cable with screened pairs only is available. This screened pair cable may be used where two adjacent screened pairs are utilised, with the spare unused core dealt with as specified in 'Unused cores' on the previous page. Connection to earth of this core, if required, should be at the same point as other earthed cores in the circuit as detailed in the hook-up diagram.

Test Requirements (multi-core cables)

Multi-core cables must be capable of withstanding the following dielectric tests.

500V r.m.s (or 750Vd.c.) applied across the cores connected together and the cable screens and/or armouring connected together.

For multi-core cables not having screens for individual circuits, 1000V r.m.s (or 1500Vd.c.) applied across half the cores which are connected together and the remaining cores which are also connected together.

The methods used for the above tests are required to be carried out as specified in a relevant cable standard, but where no method is specified, tests must comply with 10.6 of IS EN 60079-11.

Fault Conditions (multi-core cables)

The type of multi-core cable used in IS installations will have an influence on faults, if any, which may be taken into consideration.

- Type A cable: If the IS circuits are individually screened with a minimum surface area coverage of 60%, no faults between circuits are taken into consideration.
- Type B cable: If the cable is fixed and protected against mechanical damage and none of its circuits has a maximum voltage greater than 60V, no faults between circuits are taken into consideration.
- Type C cable: For this cable type, but without the requirements specified for Type A and Type B cables, two short-circuits between conductors and up to four simultaneous open-circuits of conductors have to be considered. No faults need be considered if all the circuits in the cable are identical and have a safety factor of four times that required for categories 'ia' or 'ib'.

Where multi-core cables do not comply with the requirements specified above (in page 17), the number of short-circuits between conductors and simultaneous open-circuits of conductors has no limit.

Clearance Distances

The clearance distance between the bare parts of cable conductors, connected to terminals, and earth or other conducting parts should not be less than 3mm.

The clearance between the bare parts of cable conductors of separate IS circuits connected to terminals should not be less than 6mm.

Where IS and non-IS circuits occupy the same enclosure there must be adequate separation between the two circuit types. This may be achieved by either:

- 50mm clearance between the IS and non-IS terminals. The terminals and wiring should be positioned such that contact between the circuits is not likely should a wire from either circuit become detached.

- An insulated partition or earth metal partition located between the IS and non-IS terminals. The partition must reach to within 1.5mm of the enclosure walls, or maintain at least 50mm creepage between the terminals in all directions around the partition.

Test Instruments

IS electrical test instruments are available for testing installations in the presence of flammable gases. Such instruments will have output parameters not in excess of 1.2V, 0. IA, 25mW and not capable of storing more than 20pJ of energy. It must be remembered, however, there exists the possibility that the parameters, inductance and capacitance, of the circuits under test may be large enough to modify the spark energy produced at the test probes of the instruments and cause ignition of the surrounding flammable gases. Testing in the presence of flammable gases, therefore, requires careful consideration of the circuits to be tested.

Sample Intrinsic calculation and Descriptive System Document:

CAH Limited	IS SYSTEM CERTIFICATION		Document No:
	Discriptive System Document		IS Cal X-000
	Project No	IRL250002021356	
	Building:	Oxy Plant	Sheet: 1 of 5
	Plant:	Pernise	

icate of Conformity for Intrinsically Safe Equipment to be used in Potentially Explosive Atmosp

Loop Description :	TempTransmitter			
Certifying Authority :	CAH Limited			
This System is Certified :	II 1 G Ex ia IIC T6			
Hazardous Area Classification for Building & Plant	External Zone	Internal Zone	Apparatus Group	Temperature Group
	1	0	IIC	T4

Certification

Equipment				Certification	
Barrier	11	Manufacturer:	Pepperl+Fuchs	Certification	PTB 00 ATEX 2080
Term:	A	Type:	KFD2-SR2-Ex2.W		
1. Field - Instrument	3	Manufacturer:	Baumer	Certification	TUV 07 ATEX 347151x
	a	Type:	17-9955-0		
2. Field - Instrument		Manufacturer:		Certification	
		Type:			
3. Field - Instrument		Manufacturer:		Certification	
		Type:			

Interconnection Diagram (See Appendix A1)	2	Maximum installed cable length	85 m

Permissible Interconnecting Cables.

The Capacitance and Inductance OR L/R ratio of the interconnecting cables must not exceed the following values :

Capacitance in (nF)	Inductance or L/R Ratio (mH)	(µH/ohm)	Max Cable Length
110.00	0.1	0	151

SYSTEM SAFE FOR USE IN HAZARDOUS AREA	YES

I.S. SYSTEM CERTIFICATE APPROVAL

	Print Name	Signed	Date
Author	John Smith		12 March 2022
Checked			
Approved			

The use of this System will normally be the subject of National Legislation and/or Installation codes
This Certificate and its schedule should always be reproduced in its totality.

Rev / Date	0		Date	1	Date	2	Date	3	Date	4	Date
Description	For Construction										
Made By	John Smith		12/03/2022								
Checked By											
Approved By											

CAH Limited	IS SYSTEM CERTIFICATION DATA SHEET		Document No: IS Cal [illegible]
	Project No	IRL250002021356	
	Building:	Oxy Plant	Sheet: 2 of 5
	Plant:	Pernise	

I.S. SYSTEM CERTIFICATION DATA SHEET

Power Source

Manufacturer:	Pepperl+Fuchs	Certificate N	PTB 00 ATEX 2080
Type:	KFD2-SR2-Ex2.W		

Limiting Parameter		Values from Certificate	Units
C_o	max external capacitance	150	nF
L_o	max external inductance	0.20	mH
L/R_o	max external L/R ratio	0.25	μH/Ohm
U_o	max open circuit voltage	10.5	Vdc
I_o	max output current	13.0	mA
P_o	max output power or matched pow	0.34	W

Cables

Description:	Pairs	Size (mm2)	Cable Specification	Units
	1	0.75	BS5308	
l_o	Max run length in meters		85	m
$R_{(c)}$	resistance per km		26	Ohm/km
$C_{(c)}$	capacitance per meter		200	nF/km
$L_{(c)}$	inductivity per metre		1	mH/km
L/R_o	L/R ratio		25	mH/Ohm
C_C	Capacitance (max)		145	nF
R_C	Resistance		22	Ω
L_C	Inductance (max)		0.19	mH

Hazardous Area Apparatus

Manufacturer:		[illegible]			
Model No:		[illegible]			
Certificate No:		[illegible] ATEX [illegible]			Units
C_i	effective capacitance	5			nF
L_i	effective inductance	0.015			mH
U_i	max input voltage	30			Vdc
I_i	max input current	100			mA
P_i	max input power	0.75			W
R_i	Calcualted Resistance	[illegible]			Ω
L_i / R_i		[illegible]			μH/Ω

Requirments for Safety:

Current / Cable Size	≤	Defined in ET105 2011	YES
C_o	≥	$C_i + C_C$	YES
L_o	≥	$L_i + L_C$	YES
U_o	≤	U_i	YES
I_o	≤	I_i	YES
P_o	≤	P_i	YES
L/R_o	≥	L_i/R_i	YES
SYSTEM MEETS SAFETY DEVICE REQUIREMENTS			YES

Rev / Date	0	Date	1	Date	2	Date	3	Date	4	Date
Description	For Construction									
Made By	John Smith	12/05/2022								
Checked By										
Approved By										

CAH Limited	**IS SYSTEM CERTIFICATION DATA SHEET**	Document No: IS Cal X-000
	Project No: IRL250002021356	
	Building: Ozg Plant	Sheet: 3 of 5
	Plant: Pernise	

When two or more field instruments are joined to a power source to form a system, the resultant installation carries the sub-grouping and categorisation of the worst item of apparatus.
e.g. II 1G [EEx ia] IIC T4 + II 2G [EEx ib] IIB T5 Will result in a system classification of II 2G [EEx ib] IIB T5

Industry Group		
I	Mining U/Ground	N/A
II	Surface industry	Best
III	Dust - Fibres	Worst

Equipment			
3D	22	Dust	Worst
3G	2	Gas	Worst
2D	21	Dust	
2G	1	Gas	
1D	20	Dust	Best
1G	0	Gas	Best

Protection		
ib	21, 22	Worst
ib	1, 2	Best
ia	20, 21, 22	Worst
ia	0, 1, 2	Best

Apparatus		
IIA	Propane	Worst
IIB	Ethylene	
IIC	Hydrogen	Best
IIIA	Combust	Worst
IIIB	Non conductive	
IIIC	Conductive	Best

Temprature		
T1	450	Worst
T2	300	
T3	200	
T4	135	
T5	100	
T6	85	Best

Resultant Classification

Equipment		Equipment Category			Protection Method		Apparatus Group	Temp. Rating
Vendor:	Pepperl+Fuchs	II	(1)	G	Ex	ia Ga	IIC	T6
Model:	KFD2-SR2-Ex2.W							
Vendor:	Baumer	II	1	G	Ex	ia	IIC	T5/T6
Model:	17-9955-0							
Vendor:								
Model:								
Vendor:								
Model:								
Resultant Classification		II	1	G	Ex	ia	IIC	T6

Note 4

Remarks / Restriction Conditions (X)

NOTES

1. Matched Power (linear) Po = (Uo*Io)/4. For a barrier this can be expressed as Uo*Uo/(4*R) e.g. for a 28V, 300Ohm barrier where a field short circuit gives 93mA results: Po = 784/1200 = 0.6533 W
2. The maximum external L/R Ratio for the Power Source or the cable is not obligatory for calculating the safety of the circuit
3. A simple apparatus is a device that does not GENERATE or STORE more than 1.2V, 0.1A, 20micro J or 25mW under normal or fault conditions, or is capable of dissipating not more than 1.3W on a matched power basis
4. Check with manufacturer for the use of instruments certified ia or ib in a dust hazard if equipment category does not stipulat

Rev / Date	0	Date	1	Date	2	Date	3	Date	4	Date
Description	For Construction		0		0		0		0	
Made By	John Smith	12/03/2022								
Checked By										
Approved By										

CAH Limited	**IS SYSTEM CERTIFICATION DATA SHEET**		Document No: IS Cal Z-000
	Project No:	IRL250002021356	
	Building:	Oxy Plant	Sheet: 4 of 5
	Plant:	Pernise	

APPLICABLE TAG NUMBERS /LOOPS

Tag No:	Drawing Number	Rev added	Tag No:	Drawing Number	Rev added
TE 751 K	P&ID 2021301A	b			
TE 752 K	P&ID 2021301A	b			
TE 753 K	P&ID 2021301A	b			
TE 754 K	P&ID 2021301A	b			

Rev / Date	0	Date	1	Date	2	Date	3	Date	4	Date
Description	For Construction									
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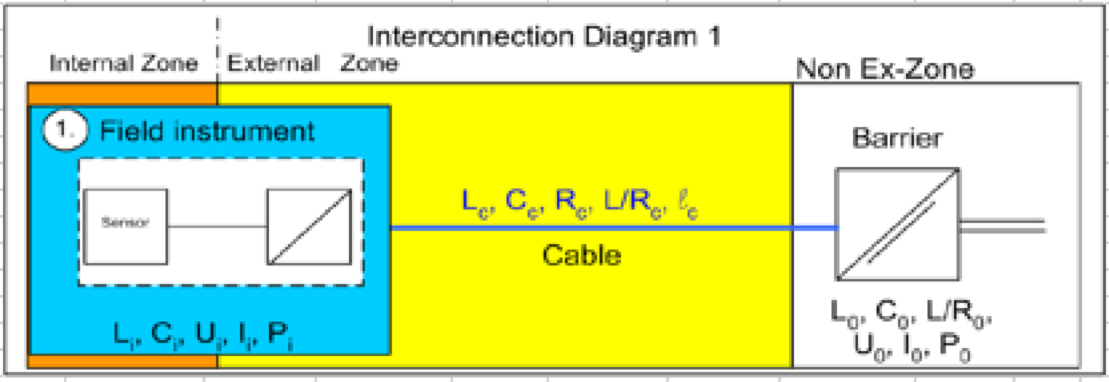
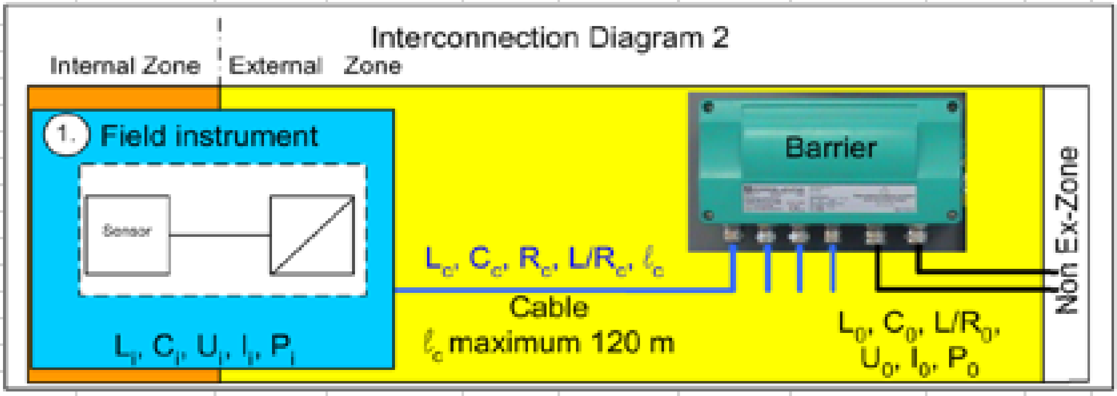
Checked By										
Approved By										

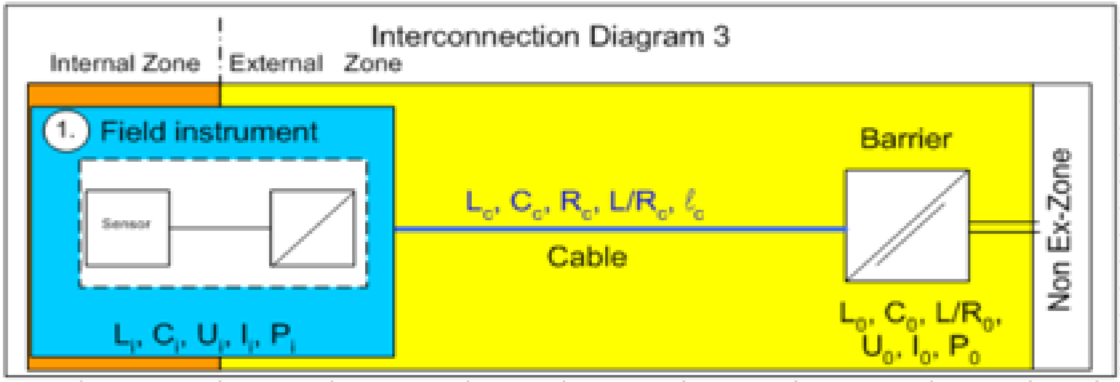
CAH Limited	**IS SYSTEM CERTIFICATION DATA SHEET**		Document No: IS Cal X-###
	Project No:	IRL250002021356	
	Building:	Oxy Plant	Sheet: 5 of 5
	Plant:	Pernise	

ATEX Barrier	Datasheet Cable	ATEX Fiel Instrument 1	ATEX Fiel Instrument 1	ATEX Fiel Instrument 1
Pepperl+Fuchs	BS5308	Baumer	0	0

Interconnect Diagrams







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