How to calculate an Intrinsically Safe loop approval; including the impact of using Ex ic (Zone 2) and gas group on cable lengths. Revised & updated Dec 2020

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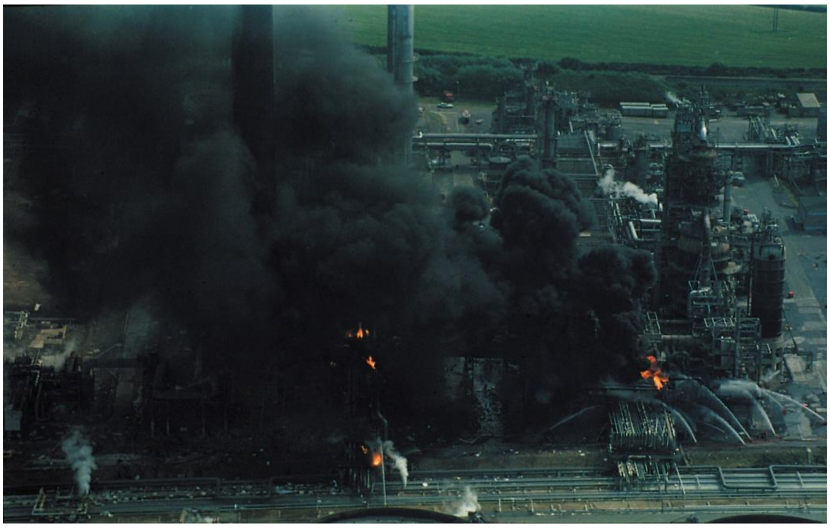
We all know what can happen when the correct techniques are not used when interfacing into the Hazardous Area. Using Intrinsic Safety (Ex i based on IEC/ SANS 60079-11; IEC/ SANS 60079-25), the energy in the hazardous area is limited to below the ignition energy of the gas present, thereby preventing explosions.



For an explosion, all three, gas/dust, oxygen and source of ignition (spark or heat) need to be present. There are several protection techniques to prevent ignition. For instrumentation, Intrinsic Safety Exi (electronic protection) & Flameproof Exd (mechanical protection) are most common. Intrinsic Safety works on the principle of removing the source of ignition. This can be achieved by using a Zener Barrier or Galvanic Isolator.

A zener barrier is a simple device where the voltage is limited by a zener diode and the current by a resistor. The fuse is there to protect the zener diode. The key to safety is the Intrinsically safe earth. Without it, there is no protection. If the input voltage increases above zener diode voltage, the zener conducts & the fuse blows. The zener barrier has to be replaced. In addition, the zener barrier has a volt drop across it under operating conditions so careful calculation must be done to ensure there is sufficient voltage at the field device.

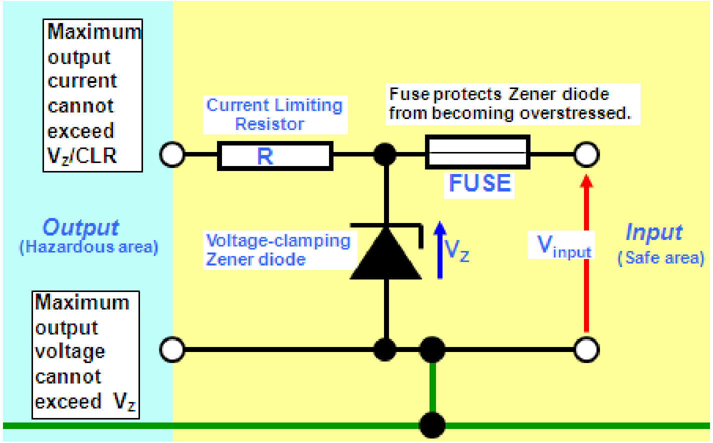


Figure 1. Zener barrier.

NOTE: USING ZENER BARRIERS WITHOUT AN IS EARTH IS NOT SAFE!

A Galvanic Isolator is an active device that energy limits without the dependence on the IS earth for safety. It also has the advantage of supplying higher voltage at the hazardous area terminals and allowing longer cable lengths. Isolators have local LED indication and most 4-20mA isolators transfer Hart communications.

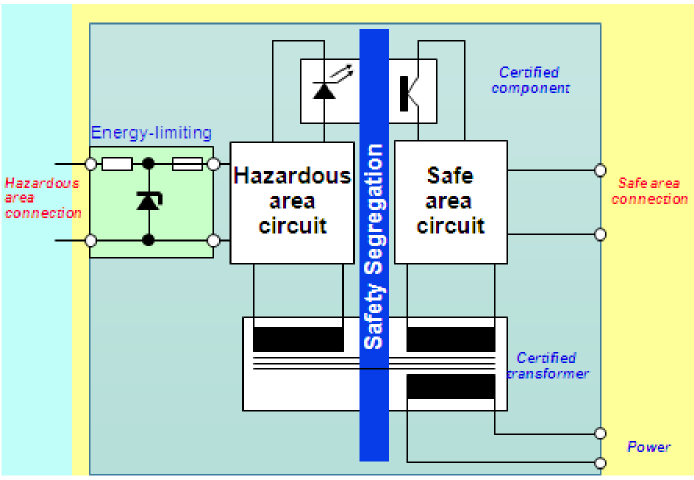


Figure 2. Galvanic Isolator

The principle for loop approval is the same for zener barriers & galvanic isolators, but first let's define Ex i and which hazardous zone they can be used in.

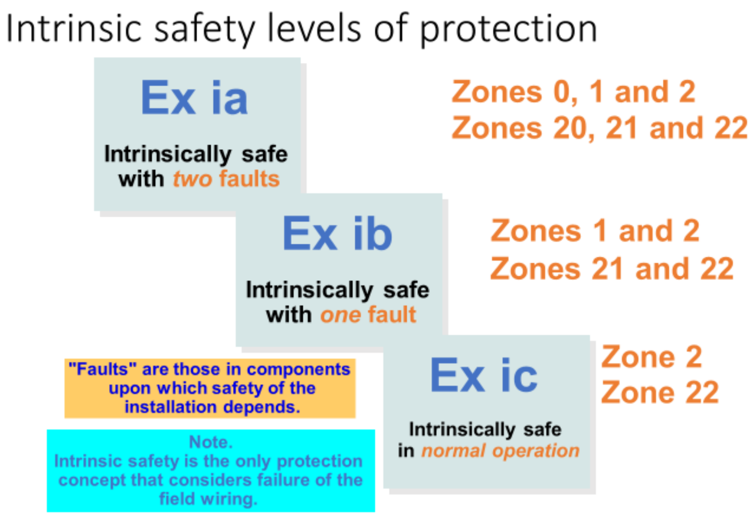


Figure 3. Exi vs zone.

As you can see from figure 4 below, the barrier/isolator has [Ex ia] IIC. The square brackets indicate that the barrier/isolator (mounted in safe area) can have connections to hazardous area. In this case Ex ia i.e. zone 0. IIC is the gas group. The field instrument (e.g. 4-20mA temperature transmitter) has Ex ia IIC T4. This means it can be located in zone 0 in gas group IIC. T4 is the maximum surface temperature of device (135°C).

The barrier/isolator has maximum output parameters for voltage, current and power Uo Io Po. These are maximum output values under fault conditions (known as Safety Description or entity parameters). The field device has maximum input parameters Ui Ii Pi which are the maximum values that can be applied under fault conditions and still be safe.

NOTE: FOR A SAFE LOOP ALL THREE INPUT PARAMETERS MUST BE GREATER THAN OR EQUAL TO OUTPUT PARAMETERS (Ui ≥ Uo, Ii ≥ Io, Pi ≥ Po)

NOTE: BARRIER/ISOLATOR SAFETY PARAMETERS SHOULD NOT BE CONFUSED WITH OPERATIONAL PARAMETERS.

To complete the system loop approval, the electrical stored energy (cabling) needs to be considered. Table A.2 in IEC/SANS 60079-11 lists the maximum capacitance Co against output voltage of the IS interface. IEC/SANS 60079-11 also state maximum inductance Lo. In the example below the maximum electrical stored energy that can be connected to the hazardous area terminals is Co 83nF Lo 4.2mH. The transmitter has internal capacitance and inductance, so maximum cable capacitance Cc = Co-Ci and maximum inductance Lc = Lo-Li. (Alternatively the cable L/R ratio can be used). The cable specification typically gives pF/m and µH/m allowing a calculation of maximum cable length.

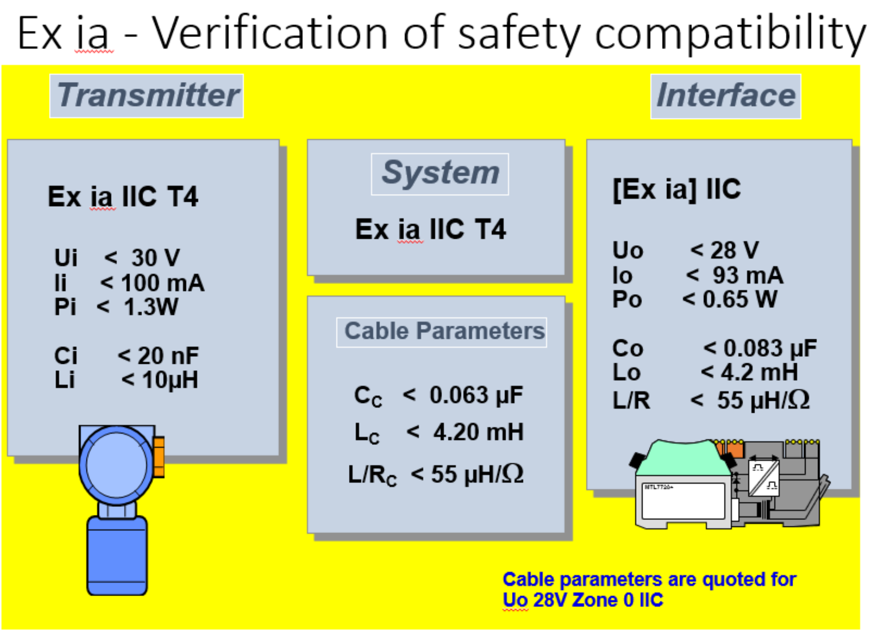


Figure 4. Instrument located in Zone 0 (or 1).

Based on this assessment, a system certificate or loop approval can be documented.

NOTE: INSERTING A BARRIER OR ISOLATOR WITH A NON-CERTIFIED (ACTIVE) FIELD DEVICE IS NOT SAFE!

Some field devices like thermocouples are defined as Simple Apparatus. A simple loop drawing is still required and an assessment of power/maximum surface temperature needs to be completed.

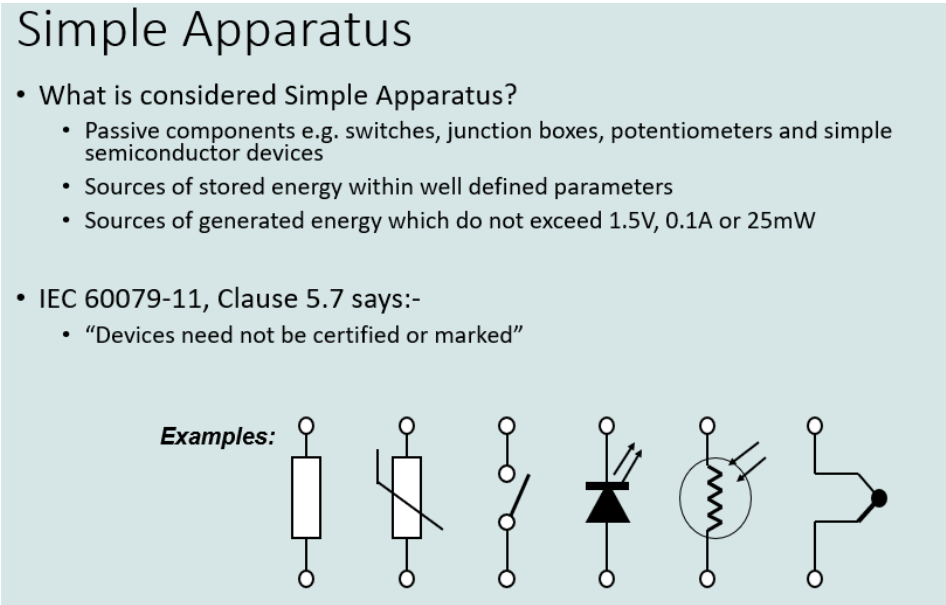


Figure 5. Simple apparatus.

Exic for Zone 2.

NOTE: IS LOOPS CERTIFIED Exia/Exib FOR ZONE 0/1 CAN BE USED IN ZONE 2. SOMETIMES THOUGH, CABLE LENGTHS ARE LIMITING.

Let's consider the impact of Exic and how to handle long cable runs in IS loops: ExnL (Energy Limiting) was a technique used for zone 2 which was effectively 'Intrinsic Safety in normal operation' i.e. with no safety factor required. ExnL has been reassigned as Exic in IEC/SANS60079-11 and IEC/SANS60079-25. Previously, although not spelt out in the standards, it was generally accepted practice to run ExnL loops in same trunking as IS loops. With the new standards, it is clear that Exic loops can be run in same multi-core or trunking as other Exi loops. This means that single multi-core (or trunking) can be used for IS instruments in Zone 0, 1 and 2. NOTE : Shared multicore must be Type A or B in accordance with system standard IEC/SANS60079-25, that is not subject to faults.

NOTE: Ex nL has been replaced by Ex ic for zone 2 in the standards. This means Intrinsic Safety can easily be used in zones 0, 1 & 2 and the wiring can be in same multi-core cable and/or trunking (IEC/SANS60079-14 6.12.2.6)!

6.12.2.6 Cables carrying more than one intrinsically safe circuit

The requirements of this sub clause are in addition to those of 6.12.2.2 to 6.12.2.5.

Cables could contain more than one intrinsically safe circuit. Circuits which are not intrinsically safe shall not be carried in the same cables with intrinsically safe circuits except as noted in 6.12.6. Intrinsically safe "ic" circuits are permitted to be running together with intrinsically safe "ia" and "ib" circuits provided they are run in a cable of Type A or Type B as specified in 6.12.2.7.

Another advantage of Ex ic is that the safety factor of 1.5 (as shown in Table A.2 of IEC /SANS60079-11) does not need to be applied to cable parameters allowing for longer cable runs.

Further on this topic: The CENLEC standard and subsequently the IEC standard changed the capacitive reference curves because of some tests done in Germany. This reduced the allowed cable capacitance from 2002.This impacts plants built between 1995 and 2002 based on earlier ATEX standards where longer cable runs were required.

For a standard 24V loop (Uo = 28V) this changed the Co from 130nF to 83nF, reducing the maximum cable length allowed. When these plants require a DCS upgrade and a new isolator is to be fitted, the IS loop calculation now fails.

How can we handle this? Firstly and importantly, there is a misconception that the Co values are defined by the design of barrier/isolator. The Co value is actually defined in IEC/SANS60079-11: 2011 Table A.2 page 96 .

– 96 – 60079-11 © IEC:2011

Table A.2 *(continued)*

Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
28,0	0,272	0,083	1,65	0,650	6,60	2,15	9,35	3,76

Figure 6. Permitted capacitance.

So any barrier/isolator with 28V safety description will have Co = 83nF (Zone 0/1; IIC). In practice this parameter will define the maximum allowable cable length.

Figure 4 shows an Exia loop with a Co=83nF. The max cable capacitance Cc=63nF. With a typical cable capacitance of 95nF/km, this would equate to maximum cable of 660m.

If the loop were Exic, the Co=272nF, so Cc=252nF would theoretically allow 2.5kms of cable. i.e. no longer a limiting factor. (The limiting factor in this system is likely to be operating voltage at the end of the cable being high enough for the transmitter to work). In Figure 7, you can see that the system is Exic certified.

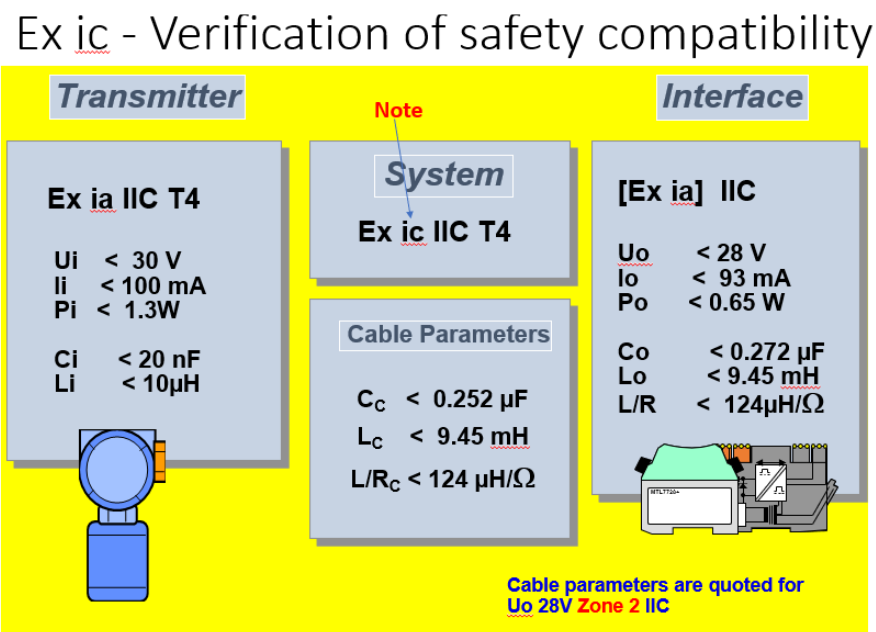


Figure 7. Field instrument in Zone 2.

For new installations requiring long cable runs, classifying the area as zone 2 (if possible) offers significant benefit.
For upgrading existing plants where the new loop approval fails, reclassify the hazardous area as zone 2, use Exic and make use of the higher Co value.

Exic offers some flexibility and for upgrades allows for upgrades of old control systems improving safety.

Now let's consider the impact of Gas Group on cable lengths for IS loops. If it is not possible to use Exic (i.e. zone 0 or 1), note that Gas Group also offers an option. Gas Group classification impacts Co parameter as per Figure 8.

Factors affecting max. cable lengths for IS loops
(IEC60079-11:2011 Table A2 pg. 96)

Voltage	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
V	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
28,0	0,272	0,083	1,65	0,650	6,60	2,15	9,35	3,76

Zone 0, 1 (Ex ia or ib) requires 1.5 safety factor
Zone 2 (Ex ic) does not require safety factor
IIC Zone 0, 1 - 83nF Zone 2 – 272nF
IIB Zone 0, 1 – 650nF Zone 2 – 1.65uF
IIA Zone 0,1 - 2.15uF Zone 2 – 6.6uF
Remember L/R if Lo > Li + Lc fails!

Figure 8. Co values

Remember Figure 4: Ex ia loop with a Co=83nF; Cc=63nF; typical cable capacitance of 95nF/km = maximum cable of 660m.

If the loop was Ex ic, the Co=272nF, so Cc=252nF would theoretically allow 2.5kms of cable. i.e. no longer a limiting factor.

If the Gas Group were IIB, the Co=650nF which aso eliminates capacitance as a limiting factor.

Conclusion:
Flameproof (Ex d) offers hazardous area protection for zone 1 and 2 and offers protection for higher voltage (110Vac, 220Vac) applications and requires mechanical planning & preparation. For 24V systems, Intrinsic Safety offers a simple & flexible solution for zone 0, 1 & 2. Intrinsic Safety is the only protection that considers faults of the field wiring and offers live working without the need for a gas clearance certificate. It does require some design and planning to ensure that the system loop analysis is acceptable.
For installations requiring long cable runs, classifying the area as zone 2 (if possible) offers significant benefit. Alternatively, if there is an option for IIB (or IIA) classification, this is another way of allowing longer cables lengths.

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