Verification of intrinsic safety

C_0 and L_0 parameters for mixed circuits

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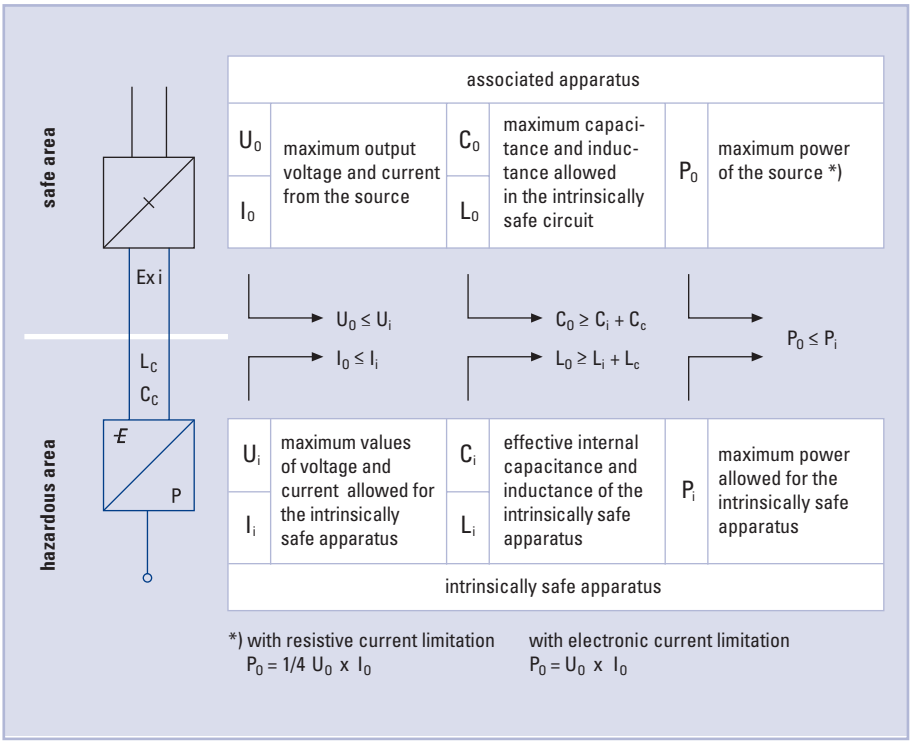

Figure 1: Criteria for the verification of a simple intrinsically safe circuit

The intrinsic safety of an electrical circuit is essentially dependent on the safe limitation of current and voltage, and consequently of the power supplied, so that in neither normal operation nor under specified fault conditions ignition capable sparks can be produced by making or breaking circuits, or when there is a short-circuit to earth.

To avoid spark ignition the energy stored in the circuit of course has to be limited. Even small amounts of additional energy can be sufficient to impair intrinsic safety.

Besides spark ignition also thermal ignition due to hot surfaces must be avoided. Therefore it has to be ensured, that the maximum current, voltage, and power available within the intrinsically safe circuit will not lead to unacceptably high surface temperatures at apparatus, components, and cables located in the hazardous area, in normal operation and under fault conditions.

For compliance with these criteria not only the individual device, but also the complete interconnection and interoperation of all apparatus in the intrinsically safe circuit, including the connecting cables, must be considered. The Standard for electrical installations EN 60079-14/IEC 60079-14 [1] consequently requires a verification of intrinsic safety for intrinsically safe circuits, which should ideally be carried out during planning and design, and includes the selection of apparatus, suitable for interconnection used.

For simple intrinsically safe circuits with only one source supplying current, voltage and power to the circuit, verification ➔

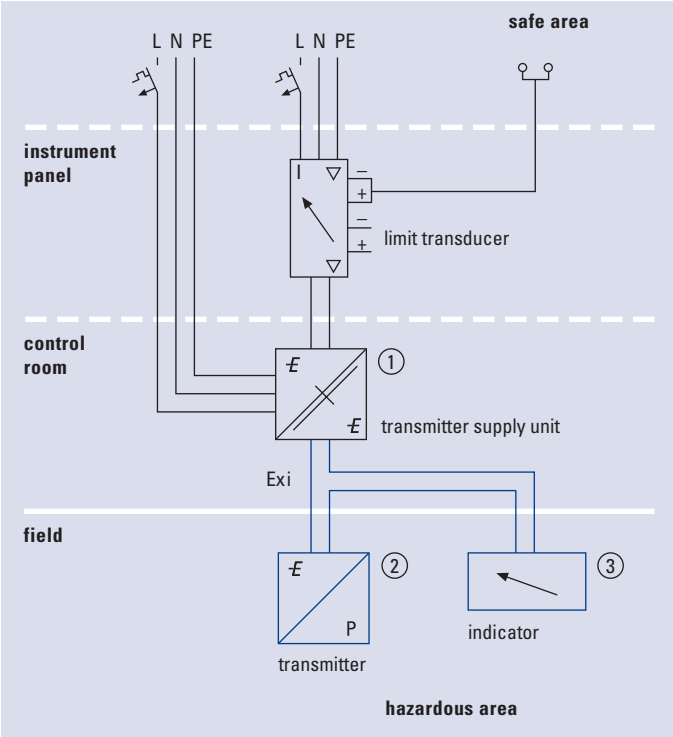

Figure 2a: Example of a simple intrinsically safe circuit (with one source)

Verification of intrinsic safety
for intrinsically safe circuits with one source

Loop diagram no. PIS 517

Associated apparatus (Source)

No.	Manufacturer/type	Test certificate	U_o [V]	I_o [mA]	P_o [mW]	L_o [mH]	C_o [nF]	Expl. group
1	Transmitter supply unit STAHL 9160/23-11-11	DMT 03 ATEX E010 X	27	88	576	2,3	90	IIC

Is reduction of C_o and L_o necessary for mixed circuit? [x] No [ ] Yes

Intrinsically safe apparatus

No.	Manufacturer/type	Test certificate	U_i [V]	I_i [mA]	P_i [mW]	L_i [mH]	C_i [nF]	
2	Pressure transmitter Rosemount 1151	BAS 99 ATEX 1294 X	30	125	670	0,02	34	*
3	Indicator Knick 830 X R	ZELM 00 ATEX 0025	60	150	700	0	0	*
Capacitance and inductance of cables (200 m)						0,2	40	
					Total:	0,22	74	

Protection level of intrinsically safe circuit: [ia ✓] [ib] [ic]

* **The circuit is a mixed circuit** with lumped L_i and lumped C_i

Figure 2b: Verification of intrinsic safety for the circuit in 2a

of intrinsic safety can easily be made by comparison of the safety values as shown in Figure 1.

C_o and L_o parameters for intrinsically safe circuits with lumped capacitances and inductances (mixed circuits)

Regarding the determination of the maximum allowable values of capacitance and inductance in an intrinsically safe circuit a national (German) foreword in the Standard for electrical installations DIN EN 60079-14 (VDE 0165-1): 1998-08 [2] already mentioned that, the maximum external inductances L_o and capacitances C_o marked on the associated apparatus are not intended for simultaneous use. Particularly when the intrinsically safe circuits are used in Zone 0 and the devices contain lumped inductances and capacitances, which are both directly effective to the circuit, PTB-Report PTB-W-39 [4] was recommended for the verification of intrinsic safety. The reference to Zone 0 – applications was even deleted from the national foreword to the next edition of the German version of DIN EN 60079-14 (VDE 0165-1): 2004-07 [3], thereby extending the requirement to all intrinsically safe circuits. For the assessment now reference was given to the PTB report PTB-ThEx-10 [5] or Annex C of system standard EN 60079-25 [6].

In intrinsically safe circuits containing both capacitances and inductances, spark ignition can in fact be demonstrated even at L and C values that are lower than the limits calculated using the reference curves of EN 50020 [7] or EN 60079-11 [8]. This effect is caused by the dynamic interaction of the energy stored in capacitance and inductance. In extreme cases this effect can lead to a definite reduction of the safety factor, making a separate evaluation necessary.

However, this effect is particularly noticeable when the intrinsically safe circuit includes lumped inductances and capacitances. Cable inductances and capacitances, on the other hand, are distributed along the entire length of the cable, and the conductor

resistance per unit length considerably dampens the dynamic interaction. Consequently no special measures are required for circuits that only contain cable inductances and capacitances, i. e. the limits derived from the reference curves can be fully utilised.

It is a different matter if the intrinsically safe circuit contains intrinsically safe apparatus, for which both internal capacitances C_i and internal inductances L_i are effective. They can become effective in the intrinsically safe circuit directly without limitation through a resistive element. In the case of such mixed circuits we must assume that the limit values of C_o and L_o need to be reduced.

Figure 2 shows an example of an intrinsically safe circuit with one associated apparatus (transmitter supply unit) and two intrinsically safe apparatus (transmitter and indicator), together with the relevant verification of intrinsic safety. The transmitter has both an internal capacitance C_i and an internal inductance L_i. So here we have a mixed circuit.

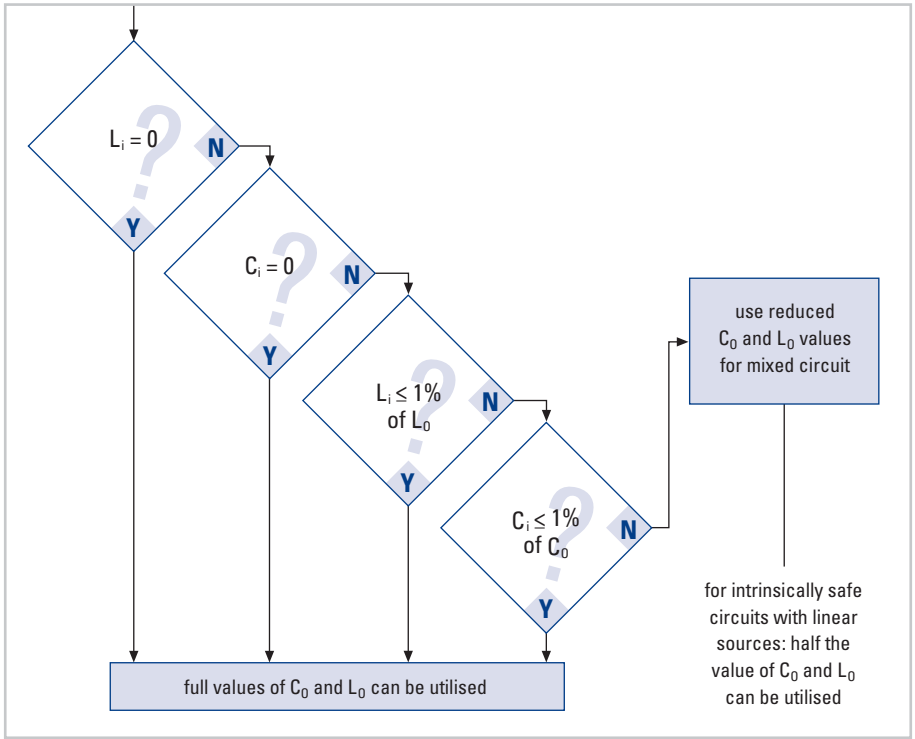

Figure 3: Assessment rules for the reduction of C_o and L_o values in the case of mixed circuits with linear sources in compliance with EN 60079-11: 01-2007

How can such a mixed circuit, which contains both lumped capacitances and inductances, be assessed for the verification of intrinsic safety?

The first and easiest option is to find out whether the manufacturer of the associated apparatus (source) has perhaps already specified the C_o and L_o values, which apply when lumped capacitances and inductances occur simultaneously. This has always been the case, for instance, with non-linear sources. Also for linear sources the type examination certificates or the operating instructions sometimes specify reduced C_o and L_o values, which can be used when the intrinsically safe circuit contains lumped capacitances and inductances simultaneously.

If this is not the case, then a second option is to consult the new apparatus standard EN 60079-11 [8] for the assessment. For intrinsically safe circuits with linear sources this standard has incorporated simplified rules to determine reduced C_o and L_o values for mixed circuits (see also Figure 3).

According to this

- the full values of C_o and L_o can be utilised in circuits that only contain cable capacitances or cable inductances;
- the full C_o and L_o values can also be used in circuits where either only up to 1 % of the C_o value is utilised by lumped capacitances C_i or only up to 1 % of the L_o value is utilised by lumped inductances L_i.
- If C_i and L_i are greater than this, half the value of C_o and L_o can be utilised.

The reduced C_o value does of course apply as a limit value for the total of all capacitances in the intrinsically safe circuit (i.e. the internal capacitances C_i of all devices plus the cable capacitance). The same applies to the L_o value. ➔

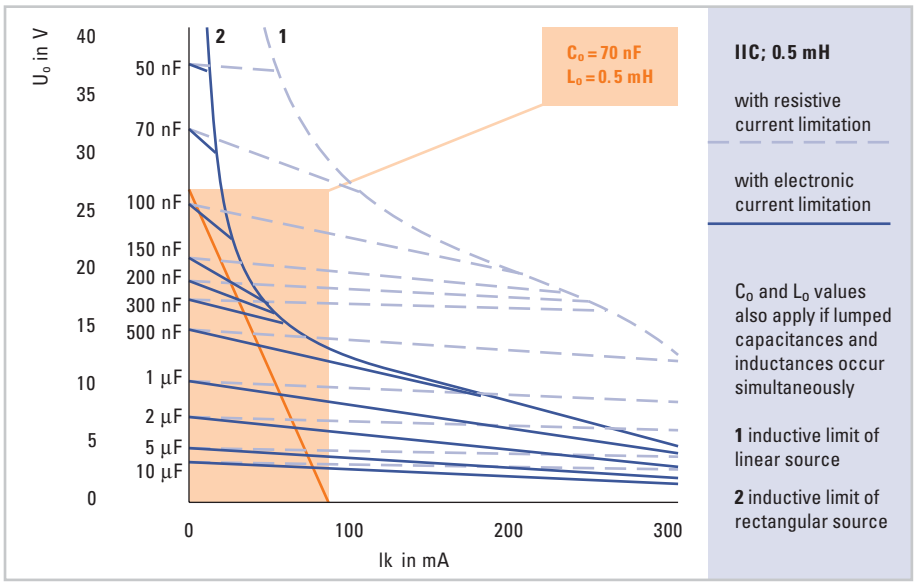

Figure 4: Determining C_o and L_o in a mixed circuit using the limit diagrams published in PTB report ThEx-10

In the example shown in Figure 2a the answer to the question $L_i < 1$ % of L_o ? would have to be yes, with the consequence that the full values of C_o and L_o can be utilised.

A third option for determining the permissible L_o and C_o values of mixed circuits would be to use PTB's ispark software or the limit diagrams shown in PTB report ThEx-10 [5], which were also incorporated in the system standard EN 60079-25 [6] as Annex C. This report describes a procedure for assessing interconnections involving several (linear or non-linear) sources. It contains a whole series of limit diagrams that differ in relation to the explosion group and the parameter L_o. The first step is to select a limit diagram that is suitable for a particular application. Into that diagram the output characteristic for the intrinsically safe circuit is to be plotted and then it has to be checked graphically whether the characteristic curve does not exceed the limit curve for rectangular sources at any point. Furthermore, the maximum safety value pair (U_o, I_o) shall not exceed the dashed limit curve for linear sources.

For the permissible capacitance limits C_o there are two sets of curves with dashed and continuous lines. With these curves it has to be checked, which continuous capacitance curve is not exceeded at any stage by the characteristic curve and additionally under which dashed capacitance curve the value pair U_o and I_o remains. The lower of the two established capacitance curves determines the maximum permissible capacitance in the intrinsically safe circuit that may occur simultaneously with the inductance specified for the selected limit diagram. The required safety factor of 1.5 has already been incorporated in the diagrams.

The C_o and L_o values determined using this method also apply if lumped inductances and capacitances occur simultaneously in the intrinsically safe circuit, i. e. the interaction of inductance and capacitance in a mixed circuit is taken into account.

The limit diagram for explosion group IIC and an inductance of L_o = 0.5 mH was selected for the example shown here. In this case the current-voltage characteristic for the linear source (transmitter supply unit) with the vertexes U_o = 27 V and I_o = 88 mA has been plotted on the diagram (Figure 4). These maximum values must be checked against the dashed limit curves that apply to linear sources. The rectangle spanned above the maximum values remains below the dashed curve with the parameter value of 70 nF. Here the combination of C_o = 70 nF and L_o = 0.5 mH could be determined as permissible for the mixed circuit, and consequently the combination can now be entered in the documentation for the verification of intrinsic safety.

It is evident that a considerable reduction had to be applied compared with the L_o and C_o values specified for the source. The relatively coarse grading available for the inductances in the limit diagrams is only responsible for a small part of this reduction.

A fourth option, theoretically, would be to conduct a test using the spark test apparatus, but this is normally not possible in practice, at least if the wiring system is extensive.

The appropriate requirements have now been incorporated in the new apparatus standard EN 60079-11 [8]. In terms of content they have also already been adopted in the draft of the new installation standard IEC 60079-14 [9]. However, the details still need to be finalised.

This does incur a certain amount of work for the user, as this check has not normally been carried out for existing installations in the past, at least for Zone 1 applications. However, it should be once again pointed out

that the permissible limit values do not need to be reduced if the C_o and/or L_o values are utilised for cable reactances only.

When planning new installations, preference should be given to equipment where the internal inductances L_i and capacitances C_i equal zero or at least have no effect on the intrinsically safe circuit.

In the case of existing installations (installed base) the question is how to deal with the existing verifications of intrinsic safety. Discussions on this subject are still continuing. In Germany they are being conducted by users within the NAMUR group, and their aim is to work out and publish a joint recommendation.

They might consider that the reference to a special assessment of mixed circuits in the national foreword to DIN EN 60079-14 (VDE 0165-1): 1998-08 [2] was still related in particular to zone 0 circuits. It was only made clear in the DIN EN 60079-14 (VDE 165-1): 2004-07 [3] edition that the reference was generally applicable to intrinsically safe circuits. Consequently, verifications of intrinsic safety for Zone 1 applications that were issued prior to the last-mentioned publication date can remain valid on the basis of a right of continuance.

However, with regards to circuits installed after this time, there will be no way of avoiding the need to check the verifications of intrinsic safety and amend them if necessary. In this context the more accurate determination of the actual cable capacitances and inductances, the reduction of possible cable lengths, and perhaps even a transfer to explosion group IIB could help to revalidate the verification of intrinsic safety, thereby allowing the circuits concerned to continue to operate.

References

[1] EN 60079-14: 2003-08 / IEC 60079-14: 2002-10: Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines)

[2] DIN EN 60079-14 (VDE 0165 -1): 1998-08 Elektrische Betriebsmittel für gasexplosionsgefährdete Bereiche Teil 14: Elektrische Anlagen in explosionsgefährdeten Bereichen (ausgenommen Grubenbaue) (Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines))

[3] DIN EN 60079-14 (VDE 0165 -1): 2004-07 Elektrische Betriebsmittel für gasexplosionsgefährdete Bereiche Teil 14: Elektrische Anlagen für gefährdete Bereiche (ausgenommen Grubenbaue)

[4] Göldner, H.-D., Johannsmeyer, U., Schebsdat, F., Storck, H.: Combination of non-linear and linear intrinsically safe circuits – PTB report PTB-W 39, 1989. Reprinted in Ex Magazine No.16 1990, page 11–21

[5] Johannsmeyer, U., Krämer, M.: Zusammenschaltung nichtlinearer und linearer eigensicherer Stromkreise (Interconnection of non-linear and linear intrinsically safe circuits) – PTB report PTB-ThEx-10, 1999 Wirtschaftsverlag NW, Bremerhaven ISBN 3-89701-440-8 The English version is published as Annex C of IEC 60079-25 Ed. 1 Electrical apparatus for explosive atmospheres, Part 25: Intrinsically safe systems

[6] EN 60079-25 : 2004-01 Electrical apparatus for explosive gas atmospheres – Part 25: Intrinsically safe systems

[7] EN 50020: 2002-06 Electrical apparatus for potentially explosive atmospheres – Intrinsic safety »i«

[8] EN 60079-11: 2007-01 / IEC 60079-11: 2006-07 Explosive atmospheres – Part 11: Equipment protection by intrinsic safety »i«

[9] IEC 60079-14 31J/120/CDV (Committee Draft for Voting) Explosive atmospheres – Part 14: Electrical Installations design, selection and erection