Type RWS 002

-20 °C ≤ Ta ≤ +60 °C

INERIS 02 A 2345

Serial No. 060128

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FISCO Field device

Ex ia IIC T4

- - - - - - - - - - - - - - - -

Ex ia IIC T6

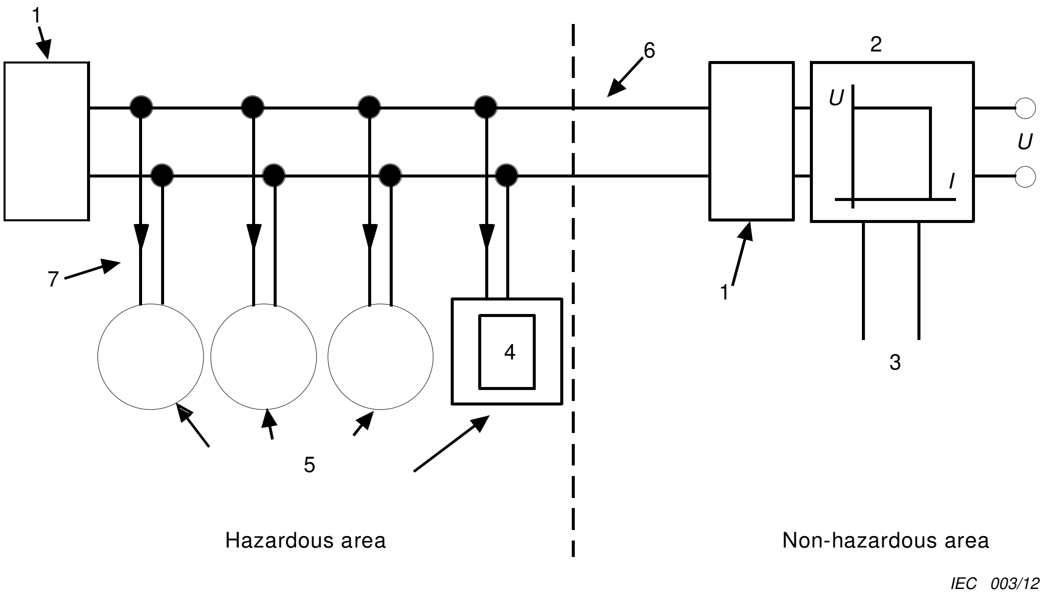
U_i: 28 V

C_i: 3 nF

I_i: 200 mA

L_i: 10 µH

P_i: 1,2 W



Key

1 Terminator

2 Power supply

3 Data

4 Hand held terminal

5 Field devices

6 Trunk

7 Spur

Figure G.1 – Typical system

Annex H
(informative)

Ignition testing of semiconductor limiting power supply circuits

H.1 Overview

Power supplies are an essential item in any electrical circuit. Where the power is supplied to intrinsically safe circuits located in hazardous areas, the output of the power supply should be intrinsically safe.

NOTE 1 For the purposes of this annex, the term ‘power supply’ is a generic term. It may be dedicated equipment that provides intrinsically safe power, and it also may be a current regulator or a voltage enhancement circuit within equipment.

NOTE 2 This annex refers only to the intrinsically safe output of the power supply.

The earliest intrinsically safe power supplies consisted of an infallible transformer, rectifier, smoothing capacitor, followed by a current limiting resistor to limit the maximum output current. The output voltage was the voltage on the smoothing capacitor under no load conditions, or the voltage across the shunt connected Zener diodes that limit the maximum output voltage.

The curves and tables in Annex A are based on the voltages, currents, capacitances and inductances tested on the spark test apparatus using such simple power supply circuits, with no ignitions permitted for 400 revolutions of the spark test apparatus using 4 tungsten wires with cadmium disk. Mathematically, assuming that 1 600 sparks have occurred, it means that the probability of ignition (based on number of ignitions obtained) on an opening or closing of the output connections of the power supply is less than $6{,}25 \times 10^{-04}$. Actually, due to the bouncing of the tungsten wire on the cadmium disk, and due to the slots on the cadmium disk, the number of sparks is much higher. Therefore, the actual probability of ignition is lower.

Based on empirical data, it has been seen that a plot of logarithmic of probability of ignition versus the logarithmic of current in the circuit shows a linear relationship (see Figure H.1). Based on the requirements of this standard, power supplies (for “ia” and “ib”) are considered in compliance with the standard only if they are spark tested using 1,5 times the current that they would normally provide, with the test gas being that specified for the particular group.

Based on the relationship of probability and current described above, such a power supply would have, at normal current, a probability of ignition lesser than $1{,}16 \times 10^{-06}$.

In summary, only such power supplies are considered satisfactory that provide a probability of ignition on an opening or closing of the output connections of the power supply at normal current and voltage of less than $1{,}16 \times 10^{-06}$.

Later developments in the design of power supplies introduced complex circuits that provide intrinsic safety not only by the limitation of current, voltage, inductance and capacitance, but also by the use of artificial limitation of discharge duration or limitation of voltage changing at switch contacts. Conventional tests using the spark test apparatus became unsatisfactory due to several reasons:

- it is not easily possible to increase the current or voltage in the power supply to provide the necessary 1,5 safety factor, as the circuits in most cases cannot be easily altered,
- the supply cannot deliver the increased current or voltage due to limitations in the rating of its components,
- changes made to the power supply to provide an increase in the current or voltage alters its timing circuits and hence changes its circuit performance

In such cases, it was generally considered satisfactory to provide the safety factor by increasing the sensitivity of the test gas mixture, using the mixtures specified as ‘safety factor 1,5’. The intention was that the power supply would be tested with the increased safety factor of the test gas mixture to show that no ignition took place in the 400 revolutions of the spark test apparatus, hence proving that the ignition probability was less than $6,25 \times 10^{-04}$. It was hence assumed that under normal conditions, the ignition probability would be less than $1,16 \times 10^{-06}$.

However, it has been found that in some cases, that although the power supply has been tested for the ignition probability of less than $6,25 \times 10^{-04}$ with the gas mixture of safety factor 1,5, it did not provide the ignition probability of $1,16 \times 10^{-06}$ at normal conditions because the power supply did not follow the linear relationship of logarithmic of ignition probability with logarithmic of current. This has caused concern, and such power supplies are not considered as providing an ‘acceptably low probability of ignition’ at normal current.

This annex provides the test methods for testing such complex power supplies; a test gas mixture with increased sensitivity is used to achieve the safety factor (see 10.1.3.2).

It requires testing using a test gas with safety factor of 1,5, and ensuring that no ignition takes place in 400 revolutions. This test is done to ensure that the normative requirements of this Standard, as specified in 10.1.4, are followed.

It then requires further tests to ensure that the circuit exhibits a relationship between probability of ignition and safety factor of the test gas to ensure that at normal current and unity safety factor gas, the acceptably low ignition of $1,16 \times 10^{-06}$ is achieved. This is done by testing the power supply with gas mixtures with safety factors of SFx = 1,5, SFy = 2,0, SFz = 2,5. The plot of probability of ignition and safety factor on a log-log scale is taken. It is tested that either no ignition has taken place at these safety factors, or if ignitions have taken place, the slope of the semiconductor limited power supply is greater than that for simple circuits. Also, that the slope of the semiconductor limited supply continues to increase as the safety factor is reduced, hence ensuring that at normal current and unity safety factor, the ignition probability is less than that for a simple circuit, that is, less than $1,16 \times 10^{-06}$.

This annex is suitable for semiconductor current or voltage limited power supplies that limit or shut the current when the current or voltage limit is exceeded, but recover sufficiently rapidly between the successive strikes or opening of the wire and disc of the spark test apparatus so that they regain normal operation before the next strike or opening of the wire. This annex is not suitable for supplies that switch off for extended periods when the current or voltage is exceeded. In such cases, Annex E may be applicable.

H.2 Test

The power supply should be tested using the spark test apparatus for the following cases:

- 400 revolutions using test gas mixture providing a safety factor of 1,5, with no ignitions observed; and
- further tests as provided in Table H.1, to ensure that the probability of ignition at unity safety factor would be acceptable and lower than that for a simple circuit.

Some of the gas mixtures suitable for the above tests, and the corresponding calibrating currents using the standard 24V 95 mH calibrating circuit are provided in Table H.2.

Reference to DUT in the test sequence of Table H.1 refers to device under test. It is the power source within the equipment, with faults applied as per the level of protection, and the voltage and current set at the maximum values within the tolerances of the circuit components. Safety factors are not applied to the current or voltage, because these are applied to the test gases.

Where the test sequence described in Table H.1 requires the use of a simple circuit, it will be made up of a laboratory power supply with a voltage set at the Uo of the DUT, and short circuit current limited to Io of the DUT by use of a series low-inductance current limiting resistor.

Table H.3 is an example of a circuit that passes the test sequence of Table H.1. The plot of this circuit is provided in Figure H.1, labelled 'Pr – Table H.3 – PASS'. When the plot of this circuit is compared with the plot for a simple circuit, labelled 'Pr – Simple Circuit', it shows that while there are more ignitions when the safety factor is higher, at 1,67 and 2,5, but as the safety factor is reduced, the probability reduces faster than for a simple circuit, and therefore has an acceptably low figure as the safety factor would drop to unity.

Table H.4 is an example of a circuit that does not pass the test sequence of Table H.1. The plot of this circuit is provided in Figure H.1, labelled 'Pr – Table H.4 – FAIL'. When the plot of this circuit is compared with the plot for a simple circuit, labelled 'Pr – Simple Circuit', it shows that while there are less ignitions when the safety factor is higher, at 1,67 and 2,5, but as the safety factor is reduced, the probability does not reduce faster than for a simple circuit, and therefore it does not slope to an acceptably low figure as the safety factor would drop to unity.

Table H.1 – Sequence of tests

Step #	Description	Column 'x'	Column 'y'	Column 'z'
1	Target safety factor	1,5	1,67 to 2,0	2,0 to 2,5
2	Determination of target calibration current for 24 V 95 mH calibration circuit	$\frac{(calibration\_current\_provided\_in\_Table7)}{(Target\_Safety\_Factor)}$	$\frac{(calibration\_current\_provided\_in\_Table7)}{(Target\_Safety\_Factor)}$	$\frac{(calibration\_current\_provided\_in\_Table7)}{(Target\_Safety\_Factor)}$
3	Test gas used	Use Table H.2 if useful	Use Table H.2 if useful	Use Table H.2 if useful
4	Calibration current achieved	Measure using 24V 95mH calibration circuit	Measure using 24V 95mH calibration circuit	Measure using 24V 95mH calibration circuit
5	Safety factor achieved (should be within range specified in Step 1)	$SFx = \frac{(Calibration\_current\_provided\_in\_Table7)}{(Calibration\_Current\_Achieved)}$	$SFy = \frac{(Calibration\_current\_provided\_in\_Table7)}{(Calibration\_Current\_Achieved)}$	$SFz = \frac{(Calibration\_current\_provided\_in\_Table7)}{(Calibration\_Current\_Achieved)}$
6	Number of revolutions for DUT (Device Under Test)	4000	400	40
7	Number of sparks assumed for above number of revolutions	16 000	1 600	160
8	DUT tested for number of revolutions at Step 6 and number of ignitions obtained	Nx	Ny	Nz
9	Probability based on number of ignitions per spark obtained	$Px = \frac{Nx}{16000}$	$Py = \frac{Ny}{1600}$	$Pz = \frac{Nz}{160}$
10	Possible compliance result	If either Px = 0, or Py = 0, or Pz = 0, the DUT has passed. If all are not 0, then continue to Step 11		
11	Simple circuit (made up of laboratory power supply and current limiting resistor) tested as provided in Step 8 above, and number of ignitions obtained	Na	Nb	Nc
12	Probability based on number of ignitions per spark obtained for the simple circuit	$Pa = \frac{Na}{16000}$	$Pb = \frac{Nb}{1600}$	$Pc = \frac{Nc}{160}$
13	Compliance calculation	The DUT has passed if the following conditions are met: (log Px) ≤ (log Pa), or $Px \le Pa$		

Step #	Description	Column 'x'	Column 'y'	Column 'z'
		(log Py – log Px) ≥ (log Pb – log Pa), or $\frac{Py}{Px} \geq \frac{Pb}{Pa}$ $\frac{(\log Py - \log Px)}{(\log SFy - \log SFx)} \geq \frac{(\log Pz - \log Py)}{(\log SFz - \log SFy)}$, or $\left(\frac{Py}{Px}\right)^{\log\frac{SFz}{SFy}} \geq \left(\frac{Pz}{Py}\right)^{\log\frac{SFy}{SFx}}$		

Table H.2 – Safety factor provided by several explosive test mixtures that may be used for the tests in Table H.1

	Compositions of explosive test mixtures, % by volume in the air	Current in the calibration circuit, mA	Safety factor for group and subgroup of electrical equipment			
			I	IIA	IIB	IIC
	(8,3 ± 0,3) % methane	110-111	1			
	(5,25 ± 0,25)% propane	100-101	1,089-1,11	1		
	(52 ± 0,5) % hydrogen	73-74	1,49-1,52	1,35-1,38		
	(48 ± 0,5) % hydrogen	66-67	1,64-1,68	1,49-1,53		
	(7,8 ± 0,5) % ethylene	65-66	1,67-1,7	1,52-1,55	1	
	(38 ± 0,5) % hydrogen	43-44	2,5-2,58	2,27-2,35	1,47-1,53	
	(21 ± 2) % hydrogen	30-30,5	3,6-3,7	3,27-3,36	2,13-2,2	1
	(60 ± 0,5)% hydrogen/ (40 ± 0,5)% oxygen	20-21	5,23-5,55	4,76-5,05	3,09-3,3	1,42-1,53
	(70 ± 0,5)% hydrogen/ (30 ± 0,5)% oxygen under the pressure of 0,22 MPa	15-15,3	-	-	-	1,96-2,03

Table H.3 – Example of a Group I circuit with characteristics described by Curve II of Figure H.1 – This passes the test sequence of Table H.1

Step #	Description	Column 'x'	Column 'y'	Column 'z'
1	Target safety factor	1,5	1,67 to 2,0	2,0 to 2,5
2	Determination of target calibration current for 24 V 95 mH calibration circuit	$\frac{110\_mA}{(1.5)}$ = 73 mA	$\frac{110\_mA}{(1.67\_to\_2.0)}$ = 66 to 55 mA	$\frac{110\_mA}{(2.0\_to\_2.5)}$ = 55 to 44 mA
3	Test gas used	52 % H_2: 48 % air	48 % H_2: 52 % air	38 % H_2: 62 % air
4	Calibration current achieved	73 mA	66 mA	44 mA
5	Safety factor achieved (should be within range specified in Step 1)	$SFx = \frac{(110\_mA)}{(73\_mA)}$ = 1,5 Okay Log *SFx* = 0,17609	$SFy = \frac{(110\_mA)}{(66\_mA)}$ = 1,67 Okay Log *SFy* = 0,22272	$SFz = \frac{(110\_mA)}{(44\_mA)}$ = 2,5 Okay Log *SFz* = 0,39794
6	Number of revolutions for DUT (Device under test)	4 000	400	40
7	Number of sparks assumed for above number of revolutions	16 000	1 600	160
8	DUT tested for number of revolutions at Step 6 and number of ignitions obtained	*Nx* = 1 ignition	*Ny* = 9 ignition	*Nz* = 80 ignition
9	Probability based on number of ignitions per spark obtained	$Px = \frac{1}{16000} = 6,25 \times 10^{-5}$ Log *Px* = -4,20412	$Py = \frac{9}{1600} = 5,6 \times 10^{-3}$ Log *Py* = -2,25181	$Pz = \frac{80}{160} = 5,0 \times 10^{-1}$ Log *Pz* = -0,30103
10	Possible compliance result	$Px \neq 0$, $Py \neq 0$, $Pz \neq 0$, therefore continue to Step 11		
11	Simple circuit (made up of laboratory power supply and current limiting resistor) tested as provided in Step 8 above, and number of ignitions obtained	*Na* = 10 ignitions	*Nb* = 3 ignitions	*Nc* = 32 ignitions
12	Probability based on number of ignitions per spark obtained for the Simple circuit	$Pa = \frac{10}{16000} = 6,25 \times 10^{-4}$ Log *Pa* = -3,20412	$Pb = \frac{3}{1600} = 1,88 \times 10^{-3}$ Log *Pb* = -2,72584	$Pc = \frac{32}{160} = 2,0 \times 10^{-1}$ Log *Pc* = -0,69897
13	Compliance calculation	The DUT has passed because: (log *Px*) ≤ (log *Pa*)? Yes, because -4,20412 < -3,20412		

Step #	Description	Column 'x'	Column 'y'	Column 'z'
		(log *Py* – log *Px*) ≥ (log *Pb* – log *Pa*)? Yes, because (-2,25181 + 4,20412 = +1,95231) > (-2,72584 + 3,20412 = +0,47828) $\frac{(\log Py - \log Px)}{(\log SFy - \log SFx)} \geq \frac{(\log Pz - \log Py)}{(\log SFz - \log SFy)}$? Yes, because $\left\{ \frac{(-2{,}25181 + 4{,}20412)}{(0{,}22272 - 0{,}17609)} = 41{,}868 \right\} \geq \left\{ \frac{(-0{,}30103 + 2{,}25181)}{(0{,}39794 - 0{,}22272)} = 11{,}1333 \right\}$		

Table H.4 – Example of a Group I circuit with characteristics described by Curve III of Figure H.1 – This does not pass the test sequence of Table H.1

Step #	Description	Column 'x'	Column 'y'	Column 'z'
1	Target_safety_factor	1,5	1,67 to 2,0	2,0 to 2,5
2	Determination of target calibration current for 24 V 95 mH calibration circuit	$\frac{110\_mA}{(1,5)}$ = 73 mA	$\frac{110\_mA}{(1,67\_to\_2,0)}$ = 66 to 55 mA	$\frac{110\_mA}{(2,0\_to\_2,5)}$ = 55 to 44 mA
3	Test_gas_used	52 % H_2: 48 % air	48 % H_2: 52 % air	38 % H_2: 62 % air
4	Calibration_current_achieved	73 *mA*	66 *mA*	44 *mA*
5	Safety factor achieved (should be within range specified in Step 1)	$SFx = \frac{(110\_mA)}{(73\_mA)}$ = 1,5 Okay Log *SFx* = 0,17609	$SFy = \frac{(110\_mA)}{(66\_mA)}$ = 1,67 Okay Log *SFy* = 0,22272	$SFz = \frac{(110\_mA)}{(44\_mA)}$ = 2,5 Okay Log *SFz* = 0,39794
6	Number of revolutions for DUT (Device under test)	4 000	400	40
7	Number of sparks assumed for above number of revolutions	16 000	1 600	160
8	DUT tested for number of revolutions at Step 6 and number of ignitions obtained	*Nx* = 6 ignition	*Ny* = 1 ignition	*Nz* = 1 ignition
9	Probability based on number of ignitions per spark obtained	$Px = \frac{(6)}{16000} = 3,75 \times 10^{-4}$ Log *Px* = -3,42597	$Py = \frac{1}{1600} = 6,25 \times 10^{-4}$ Log *Py* = -3,20412	$Pz = \frac{1}{160} = 6,25 \times 10^{-3}$ Log *Pz* = -2,20412
10	Possible compliance result	$Px \neq 0$, $Py \neq 0$, $Pz \neq 0$, therefore continue to Step 11		
11	Simple circuit (made up of laboratory power supply and current limiting resistor) tested as provided in Step 8 above, and number of ignitions obtained	*Na* = 10 ignitions	*Nb* = 3 ignitions	*Nc* = 32 ignitions
12	Probability based on number of ignitions per spark obtained for the simple circuit	$Pa = \frac{10}{16000} = 6,25 \times 10^{-4}$ Log *Pa* = -3,20412	$Pb = \frac{3}{1600} = 1,88 \times 10^{-3}$ Log *Pb* = -2,72584	$Pc = \frac{32}{160} = 2,0 \times 10^{-1}$ Log *Pc* = -0,69897
13	Compliance calculation	The DUT has not passed because: (log *Px*) ≤ (log *Py*)? Yes, because -3,42597< -3,20412		