# INTERNATIONAL ELECTROTECHNICAL COMMISSION SCHEME FOR CERTIFICATION TO STANDARDS RELATING TO EQUIPMENT FOR USE IN EXPLOSIVE ATMOSPHERES (IECEx SCHEME)

## Title: Guidance document for the Assessment of I.S systems and equipment

**IECEx Operational Document**

The IECEx Technical Committee, ExTAG, identified the need for a guidance document for use by ExTLs and ExCBs when conducting assessments of apparatus and systems utilising the Intrinsically Safe (IS) technique of explosion protection.

During 2005 ExTAG, through ExTAG Working Group 8, worked to compile a set of Assessment and Reporting Guidelines, now presented as Operational Document OD/021/V1. During the preparation of this document, ExTAG consulted with SC31G - the Subcommittee and Maintenance Team responsible for IEC 60079-11.

This Operational Document applies to all ExTLs and ExCBs operating within the IECEx Scheme.

It is expected that this Operational Document will be expanded to include further guidance. Any comments or suggestions concerning the use of this Operational Document should be directed to the ExTAG Secretariat as follows:

ExTAG Secretariat
C/o Ms Christine Kane
E-mail:christine.kane@iecex.com

Document History

| Date | Summary |
|---|---|
| 2006 01 | Original Issue (Version 1) |
| 2006 05 | Version 2 Amended clauses 4.2, 5.2 & 7.2 |

| Address: | Contact Details: |
|---|---|
| Standards Australia Building<br>IECEx Secretariat<br>286 Sussex Street<br>Sydney NSW 2000<br>Australia | Tel: +61 2 8206 6940<br>Fax: +61 2 8206 6272<br>E-mail: chris.agius@iecex.com<br>http://www.iecex.com |

# ExTAG Working Group 8 – Assessment of IS equipment and Systems

## 1. Purpose and Scope

The purpose of this document is to provide a consistence of approach in the understanding, assessment and reporting of equipment and systems to IEC60079-11: between the IECEx test houses.

As the Intrinsically Safe Standard is undergoing some significant changes, and it is not unreasonable to expect these changes to be prolonged, the intention of this document is to recommend a common approach in documenting all relevant information in the existing ExTR.

## 2 Use of this Document

This document is divided into various Sections to address the areas that impact on an Intrinsic Safety assessment with each Section further divided into the following:

x.1 Overview
x.2 Possible Methods of Assessment
x.3 Information for reporting in ExTRs

## 3 Resistance limited Power Supplies – Ignition Evaluations

### 3.1 Overview

The ignition capabilities of all power supplies under fault conditions must meet the requirements of IEC 60079.11. Non-linear power supplies cannot be assessed from the reference curves.

### 3.2 Possible Methods of Assessment

Calculations, taking into account the most onerous values of component tolerances can be used to determine the maximum voltages, current and power values. For resistive limited power supplies the reference curves or tables can then be used to ensure that the voltage and current have the appropriate factor of safety.

For Non-linear power supplies spark testing will need to be carried out to confirm that the voltage current combination has a suitable factor of safety.

Notes:

1) Any internal power source such as a battery or fuel cell that can combine with the supplies under fault conditions must be taken into consideration.

### 3.3 Information for reporting in ExTRs

The ExTR should clearly identify which components are critical to safety and have been used in the evaluation to determine the maximum voltages/currents and power. The maximum spark voltage, the maximum voltage for thermal evaluation, the maximum short circuit current and the maximum output power should also be stated in the ExTR. Suggestions include the use of a table or an equivalent circuit diagram included in the report.

As a guide to determine which component there are critical, document IECEx Operational Document No OD017/ should be refereed to.

## 4 Capacitive Evaluations

### 4.1 Overview

The ignition capabilities of all capacitive circuits under fault conditions must meet the requirements of IEC 60079.11. Group II resistor protected capacitors cannot be assessed from the reference curves.

The reporting of the evaluations/tests in ExTRs may need to clearly specify what equivalent circuit was evaluated.

### 4.2 Possible Methods of Assessment

The simplest method of carrying out the capacitive assessment is to sum all the capacitance within the apparatus together, including the maximum tolerance of the capacitors.

This approach can be justified by using the segregation clause of the Standard where segregation distances less than one third of the relevant value quoted in the segregation table can be considered as conducting without fault count. Where a track passes beneath a component, the segregation distance cannot be guaranteed. The segregation distance must be assumed to be less than one third the minimum required by the Standard and therefore, short circuited between component and track.

The advantage of this approach is that segregation distances and fault analyses applied to the printed wiring board can be reduced to a minimum, thus allowing changes to the board without the costly process of reassessing the segregation distances. However, this approach can be very restrictive in the amount of capacitance permitted.

A common solution to this capacitance problem is to use adequately rated and segregated current limiting resistors to suppress the discharge from high value capacitors. These resistor protected capacitor networks can then be removed from the cumulative sum of unprotected capacitors. The printed wiring board will have to meet the requirements of the Standard for segregation distances in these resistor protected capacitor nodes, but the segregation distances of the remaining circuits may not require checking.

Another common solution to excessive capacitance is to reduce the voltage that the capacitors can become charged to. An infallible voltage clamp can achieve this. It should be noted that all the capacitors in the circuit could charge to the lower voltages.

A combination of current limiting resistors suppressing the discharge from capacitors and infallible voltage clamps can also be used.

To ensure that the combinations of unprotected capacitance, resistors protected capacitance and capacitance clamped at lower voltage have a factor of safety not less than 1.5, it may be necessary to test the circuit using the spark test apparatus. The factor of safety is achieved as provided in Clause 10.4.2 of IEC 60079.11:1999 (or Clause 10.1.4.2 of FDIS 60079.11 5th Edition).

Figure 1 below shows sample equivalent circuits ready for spark testing. In this case, V1 > V2. The diode D is used to prevent capacitors C4, C5 and C6 from charging to the higher voltage of V1. (The voltage drop across the diode D shall be eliminated by increasing the voltage V2 i.e. V2 + the forward volts drop across the series diode).

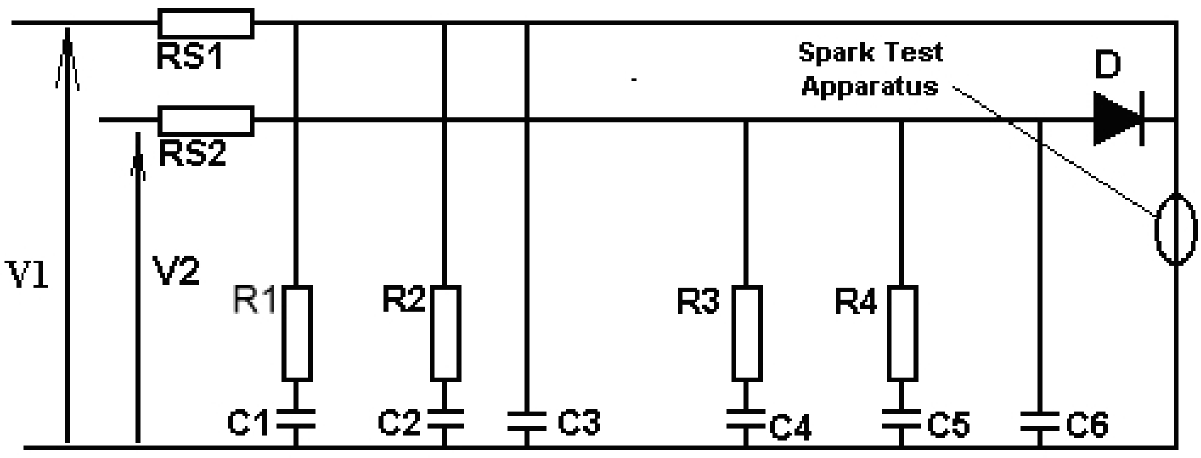


Fig 1

**Piezo electric devices**
The voltage generated by an impact on a piezo electric crystal needs to be considered in the ExTR and compared again the acceptable energy level for the group. To calculate this the maximum capacitance of the piezo device needs to be determined from either the piezo manufacturers datasheet or from impact tests or from capacitance measurement and the output voltage is measured during impact on the housing containing the piezo-electric crystal.

This can be calculated from: $\mathbf{E = 0.5.C.V^2}$
Where **E** = energy in Joules.
**C and V** = maximum internal capacitance of crystal and maximum voltage generated within the crystal determined from impact test.

### 4.3 Information for reporting in ExTRs

The ExTR should clearly identify which capacitors have been assumed to combine in parallel and identify which capacitors are protected by series current limiting resistors and which capacitors are considered infallibly clamped to a lower voltage. Suggestions include the use of a table or an equivalent circuit diagram included in the report.

When considering the voltage available on the external pins of an integrated circuit that includes voltage converters (for example for voltage increase or voltage inversion), the internal voltages need not be considered, provided that the enhanced voltage is not present at any external pin and no external components like capacitors or inductors are used for the conversion e.g. EEPROMS. If the enhanced voltage is available at any external pin, then the enhanced voltage shall be assumed to be present on all external pins of the integrated circuit;

The ExTR should quote maximum values of energy generated from the piezo crystal when subjected to impact energy not less than that specified by the Standard.

## 5 Inductive Assessment

### 5.1 Overview

The ignition capabilities of all inductive circuits under fault conditions must meet the requirements of IEC 60079.11.

The reporting of the evaluations/tests in ExTRs may need to clearly specify what equivalent circuit was evaluated.

### 5.2 Possible Methods of Assessment

The simplest method of carrying out the inductive assessment is to sum all the inductors within the apparatus together (in series) including the maximum tolerance of the inductors.

This approach can be justified by using the segregation clause of the standard where segregation distances less than one third of the relevant value quoted in the segregation table can be considered as conducting. Where a track passes beneath a component, the segregation distance can not be guaranteed. The segregation distances are to be assumed to be less than one third the minimum required by the Standard and therefore, conducting.

This approach has the advantage to the designer of the circuit that segregation distances and fault analysis do not have to be applied to the printed wiring board, thus allowing changes to the board without the costly process of reassessing the segregation distances. However, this approach can be very restrictive in the amount of inductance permitted.

A common solution to this inductive problem is to use the minimum internal resistance of the inductor and the maximum voltage across the inductor to limit the current through the inductor, to an intrinsically safe value. The minimum resistance of the inductor is to be specified in the client's documentation and is treated as infallible when counting faults. The minimum resistance shall be at the lowest ambient temperature that the apparatus may be situated.

Another common solution to this inductive problem is to use adequately rated and segregated current limiting resistors to limit the current that can flow through high value inductors. These resistor protected inductor networks may then be removed from the cumulative sum of unprotected inductors. The printed wiring board will have to meet the requirements of the Standard for segregation distances for these resistor-protected inductor nodes, but the segregation distances of the remaining circuits may not require checking.

A further common solution is to reduce the current that can flow through the inductor by reducing the voltage across the inductor. An infallible voltage clamp can achieve this.

An infallible voltage clamp for category "ia" consists of either three branches of shunt connected adequately rated zener diodes or duplicated zener diodes mounted on 2 mm wide (minimum) copper interconnecting track. Care should also be taken to ensure that under fault conditions these infallible voltage clamps could not be by-passed due to poor segregation.

A combination of current limiting resistors and infallible voltage clamps can also be used to limit the current through the inductor.

A further method of limiting the discharge from an inductor is to encapsulate two shunt connected diodes across the inductor. These components must be rated at two thirds their manufacturers rating the minimum peak inverse voltage shall be found. Suitable bridge connected diodes or zener diodes are acceptable as shunt components. The depth of the encapsulant must not be less than 1 mm. Where shunt zener diodes are fitted, circuit assessments should take into consideration the additional voltage due to the zeners would need to be considered,

When testing a coil with the spark test apparatus account shall be taken of the increased current in the coil caused by the reduction in its resistance at low temperatures. (Typically -20 $^{o}$C.)

When the safety of the inductor is determined from tests using the spark test apparatus full constructional details of the inductor, including details of the core (size and material) if any, will need to be specified in the clients drawings.

### 5.3 Information for reporting in ExTRs

The ExTR should clearly identify which inductors have been assumed to combine in series/ parallel and identify which inductors are protected by series current limiting resistors (including the minimum resistance and maximum current used in the calculations) and which inductors are considered infallibly protected by shunt diodes and encapsulation. Suggestions include the use of a table or an equivalent circuit diagram included in the report.

## 6. Combination of resistive, capacitive and inductive ignitions

### 6.1 Overview

The energy stored in inductors and capacitors can combine with the energy from the power supply.

### 6.2 Possible Methods of Assessment

Reference to ignition curves published in the Standards, only if no significant values of inductors and capacitors are present in combination.

Calculations based on energy stored in inductors and capacitors.
Spark test results with gas having the factor of safety of approximately 1.5.

### 6.3 Information for reporting in ExTRs

The ExTR must demonstrate how the evaluation/testing was conducted.

## 7 Thermal Assessment

### 7.1 Overview

The surface temperature of components shall not exceed that specified by the Standards for the appropriate temperature classification.

### 7.2 Possible Methods of Assessment

The mounting arrangements of components significantly affect the temperature characteristics of them.

The simplest method of carrying out the thermal assessment is to assume that all components used within the apparatus can be faulted to optimum load. The maximum surface temperature of the component with the worst case temperature characteristic will then be considered. The maximum surface temperature of components can then be assessed.

This approach saves time and money, as the Testing Engineer does not have to carry out time consuming fault analysis.

**Encapsulation**
Encapsulation is used in Intrinsic Safety typically for gas exclusion for components, and the requirements for the encapsulant are provided in Clause 6.6 of FDIS 60079.11 5$^{th}$ Edition. Damage to the encapsulation due to the high temperatures in the encapsulated component under fault is an area that requires careful observation.

**Capacitors**
Electrolyte and tantalum capacitors can dissipate heat where the fault conditions allow the polarity across the capacitors to be reversed, This may need to be taken into account.

**Coils**
For temperature rise purposes a coil is assumed to fail to any value between its maximum resistance and short circuit.

**Notes;**

- If it is considered that the coil may open circuit due to the power dissipation, testing shall be carried out at a level that will not cause the coil to open circuit. The temperature rise shall then be calculated to the matched power ($T \alpha P$) or input current level ($T \alpha I^2$).

- It also should be noted that the temperature of a winding derived from using the change of resistance method will be an average temperature of the winding and may not reflect the true maximum surface temperature of the winding. Also any series component such as thermal cut out device will affect the accuracy of the reading. (Simple fusing devices should not introduce significant errors but semiconductor and resetting thermal devices will change resistance as they heat up – an alternative method should be determined for these types. Some types allow direct contact to the windings and thermal device through taps on the transformer, this allows the test current to pass through both the thermal device and winding but allows for the resistance measurement of the winding only).

**Wiring**
The Temperature Classification of internal wiring shall be determined from IEC 60079-11.

**Printed Wiring Board Tracks**
The Temperature Classification of printed circuit board track work shall be determined from IEC 60079-11.

### 7.3 Information for reporting in ExTRs

The ExTR should clearly identify which components do not meet the requirements of the small component clause and justification/test results given to show how these components meet the requirements of the Standard. Suggestions include the use of a table or an equivalent circuit diagram included in the report.

The ExTR shall record the maximum temperature rise of the specified cell(s) under prolonged short circuit conditions and record if any leakage of electrolyte was observed. According to the decision sheet ExTAG/42/CD.

The ExTR shall record the maximum surface temperature of any coil or inductor when dissipating the most onerous power that can be dissipated in to the device and state how the power was determined.

The ExTR shall record the most onerous power/current that can be dissipated in to the wiring and state how the power was determined.

## 8 Segregation Assessment/Tests

### 8.1 Overview

**Notes;**

- Where a track passes beneath a component, the segregation distance can not be guaranteed, the segregation distance must be assumed to be less than one third the minimum required by the Standard and therefore, conducting.
- Components mounted on printed wiring boards which may be susceptible to movement, this must be considered when measuring the segregation distances. This can be achieved by applying gentle pressure to the components.

Measurement of segregation has become a major issue. In the past, large segregation distances were incorporated into IS circuits. Measurement using a digital vernier was an acceptable method. Designs are now more complex and smaller, with PCB layouts being prepared using computer aided drafting and design resulting in much smaller distances and tolerances and uncertainties. The accuracy of measurements by test stations using traditional methods should be scrutinized. The use of a reliable CAD system is essential for the manufacturers and test stations in assessing segregation distances in inner layers, the accuracy of the manufacturing process can then be assessed by comparing the software results against the actual results from a physical sample on the outer layers.

### 8.2 Possible Methods of Assessment

Measurements on actual samples.

### 8.3 Information for reporting in ExTRs

The ExTR shall record the worst case dimensions at the appropriate voltage of the areas under review and have records available to show where segregation was considered.

## 9 Safety Components

### 9.1 Overview

Safety components have their rating affected by temperature. Consideration must be taken in to account.

### 9.2 Possible Methods of Assessment

Component manufacturers' datasheets.
Temperature rise tests to determine the rating of components when dissipating the maximum appropriate power.

### 9.3 Information for reporting in ExTRs

**Transformers**

Transformers used as infallible transformers must meet the segregation requirements of the Standard as well as the appropriate type test as required by the Standard.

The ExTR shall record the following;

1. The worst case segregation measurements between windings and windings to core.
2. The maximum temperature of the transformer during the test and the suitability of the insulation material.
3. The maximum current through the transformer winding and how this was determined.

**Resistors**

- Resistors have their ratings affected by the temperature of the component. The manufacturer's datasheet must be reviewed to determine the actual minimum rating of the component.

- A safety resistor that is used solely to protect the discharge from a capacitor can be rated on W = $CV^2$ Where V is the maximum voltage the capacitor can become charged to and C is the maximum capacitance including tolerance.

The ExTR shall record the following;

1. Identify the component, its value and its rating. The table in the ExTR will satisfy this purpose.
2. Assessment records should be available to detail exactly how the rating of the safety components was calculated.

**Semiconductors**
**Notes:**

- The rating of semiconductors is particularly sensitive to thermal and mounting effects and careful examination of the manufacturer's data sheet will be required to determine the actual rating.
- Where a semiconductor package contains multiple elements mounted on the same chip, such as bridge rectifier diodes, the whole package may be considered to fault with a single fault count, even if all elements are used within 2/3rds the manufacturer rating. Where it can be proved from the manufacturers data sheet that the package contains separate elements each element can be considered as a separate fault, subject to being not operated above two thirds their manufacturers rating.
- When calculating the power that may be dissipated in to zener diodes it may be necessary to consider both upper and lower tolerances in order to derive the appropriate rating.

The ExTR shall record the following;

1. Identify the component, its value and its rating. The table in the ExTR will satisfy this purpose.
2. Test records should be available to detail exactly how the rating of the safety components was calculated.

Detailed testing or analysis of components and assemblies of components to determine the parameters, for example voltage and current, to which the safety factors are applied shall not be performed since the factors of safety obviate the need for detailed testing or analysis. For example a Zener diode stated by its manufacturer to be 10 V + 10 % shall be taken to be 11 V maximum without the need to take into account effects such as voltage elevation due to rise in temperature.

However, when determining the power rating or junction temperature, account should be taken of mounting conditions and ambient temperature, as indicated earlier in this clause.

**Relays**
Relays used as infallible components must meet the segregation requirements of the Standard.

Where relay contacts of associated apparatus are used to connect non-IS circuits, the maximum voltage can be limited by *Um*, but the maximum current (<5A) and power (<100VA) are not necessarily known and becomes an installation issue. The relay contact specifications could however be stated in the ExTR as a condition as they are required to be observed during installation.

The ExTR shall record the following;

1. The worst case segregation measurements between coil winding and contacts.
2. The maximum temperature of the relay coil during the test.
3. The maximum current through the relay winding and how this was determined.
4. The maximum voltage and current the contacts are subjected to and their manufacturers rating.

**Opto Couplers**
The ExTR shall record the following;

1. The worst case segregation measurements between transmitter and receiver if applicable.

2. The maximum parameters that the transmitter and receiver may be exposed to how these values were determined.

**FUSES AND FILAMENT LAMPS**

Associated apparatus fuses to have a minimum breaking capacity of 1500 A or have a suitable series resistor to limit the prospective short circuit current to below the breaking capacity of the fuse. The operating voltage of the fuse to be not greater than the manufacturers specification.

Hazardous area fuses and filament lamps are to be encapsulated to either a minimum depth of 1 mm. The breaking capacity and working voltage of the fuse will have to be within the manufacturer specification.

It should be noted that the standard does not require a minimum breaking capacity of 1500A for all fuses. This breaking capacity is considered acceptable for mains connection in accordance with IEC 60079-11 Clause 7.3. For example, battery operated circuits would not need a breaking capacity of 1500A

Alternatively hazardous area fuses may be unencapsulated provided that current does not flow through fuse in the hazardous areas, under fault conditions, such as in the case of a series diode protected battery charging circuit for use only in the safe area.

Alternatively a fuse is acceptable if it can be proved that the maximum fault current that could flow through the fuse and diameter of the fusing elements meets the requirements of the temperature classification of wiring as published in IEC 60079.11.