Preventing Disasters Through Intrinsic Safety

The essentials behind an essential practice
Contents

Contents ......................................................................................................................... 1
Introduction .................................................................................................................. 1
PART ONE: Overview of Intrinsic Safety ................................................................. 2
  What is Intrinsic Safety? ....................................................................................... 2
  The Intrinsic Safety Protection Method ............................................................... 2
  Hazardous Area Classifications ....................................................................... 2
PART TWO: Intrinsic Safety Testing and Certification ............................................. 2
PART THREE: How to Approach Your Intrinsic Safety Project ......................... 4
  Defining the Classification .................................................................................. 4
  Limitations on Discharge, Current and Thermal Ignition Energy ................... 6
  Entity Parameters ............................................................................................... 6
  Entity Parameter Relationships of Intrinsically Safe Certified Devices ......... 7
  Separation Distances ......................................................................................... 8
  Enclosures ........................................................................................................... 8
  Tests ..................................................................................................................... 8
SUMMARY and Intertek’s Streamlined Process ..................................................... 9
About Intertek ........................................................................................................... 11
Contacts .................................................................................................................. 11

Introduction

This whitepaper discusses one of the most important safety subjects in every area where a simple spark can ignite a hazardous area or explosive atmosphere—intrinsic safety. It provides an overview of the subject and shows where and how hazardous situations can occur with devastating results. The paper then provides an overview of how hazardous locations are zoned or classified, the required testing and processes for certification, and how to approach an intrinsic safety project from design to specific parameters and tests. While this document provides extensive information on the complexities of intrinsic safety, it also outlines Intertek’s streamlined process to provide manufacturers with the highest quality intrinsic safety testing, standards and procedures in an efficient, accountable and expeditious manner.
PART ONE: Overview of Intrinsic Safety

What is Intrinsic Safety?
Intrinsic safety refers to the measures and materials put into place to prevent explosions in potentially hazardous areas by either electrical sparks or thermal energy. It does so by limiting both the electrical and thermal energy of the apparatus to levels too low to ignite an explosive environment of flammable gas, vapour, mist or dust. The intrinsic safety technique is accepted worldwide as the preferred method in preventing such explosions.

The Intrinsic Safety Protection Method
Numerous industries, such as chemical, oil and gas, pharmaceuticals, refineries and many manufacturers have potentially hazardous areas where a simple spark or thermal energy can trigger an explosion. Intrinsic safety systems limit electrical current, voltage and stored electrical energy to levels below the ignition point of the hazardous material. An “intrinsically safe circuit” is defined by IEC60079-11 as “circuit in which any spark or any thermal effect produced in the conditions specified in this standard, which include normal operation and specified fault conditions, is not capable of causing ignition of a given explosive atmosphere”. These requirements vary according to the nature of the volatile mixture, the device inside that environment and the circuitry. Intrinsically safe systems are designed to address faults in the product plus wiring faults. This means that multiple unrelated failures can occur and the system will still be safe.

Hazardous Area Classifications
North America primarily uses the Division classification system, but has also adopted the Zone system that is already in place in most other countries. Those using the Zone system accept the standards of the International Electrotechnical Commission (IEC) or European Committee for Electrotechnical Standardization (CENELEC).

PART TWO: Intrinsic Safety Testing and Certification
All equipment used in every designated hazardous area must meet specific requirements for certification. The equipment must carry a label that identifies the specific intrinsic safety rating with stringent certification requirements for each of the different prescribed levels. The equipment must also bear recognition from the Certification Body that certified it. For example, Intertek is an IECEx Certification Body and Test Laboratory, ATEX Notified Body, Nationally Recognised Test Laboratory (NRTL, in USA) and Certification Body under Standards Council of Canada (SCC). Be sure your testing laboratory has the correct accreditations for the markets you wish to enter.
Intrinsic safety certification embraces several zones. These, in turn, correspond to specific hazardous locations in which a given device is certified to operate. This classification is based on the probability of the occurrence of an explosion and the rating is stated on the final certified product. The table below shows some of these classifications.

<table>
<thead>
<tr>
<th>Hazard type</th>
<th>Explosive airborne mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I: Gases and/or vapours</td>
<td>Group I: Mines susceptible to firedamp</td>
</tr>
<tr>
<td>Class II: Dusts</td>
<td>Group II: Places other than mines susceptible to firedamp</td>
</tr>
<tr>
<td>Class III: Fibres or flyings</td>
<td>Group III: Surface and other locations susceptible to combustible dusts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Degree of hazard</th>
<th>Division 1: In normal operating conditions, hazardous material is likely to be present - continuously, periodically or intermittently.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 0: Hazardous air/gas mixture is present continuously or for long periods.</td>
<td></td>
</tr>
<tr>
<td>Zone 1: Hazardous air/gas mixture is likely to exist for short periods under normal operating conditions.</td>
<td></td>
</tr>
<tr>
<td>Zone 20: Combustible dust is present continuously or for long periods.</td>
<td></td>
</tr>
<tr>
<td>Zone 21: Combustible dust is likely to exist for short periods under normal operating conditions.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spark ignition</th>
<th>Hazardous atmospheres grouped by ignition capabilities. For example:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A: Acetylene</td>
<td>Group I: Methane</td>
</tr>
<tr>
<td>Group B: Hydrogen</td>
<td>Group II: Propane</td>
</tr>
<tr>
<td>Group C: Ethylene</td>
<td>Group IIA: Ethylene</td>
</tr>
<tr>
<td>Group D: Propane</td>
<td>Group IIC: Hydrogen, acetylene</td>
</tr>
<tr>
<td>Group E: Metal dust</td>
<td>Combustible dust groups:</td>
</tr>
<tr>
<td>Group F: Carbon dust</td>
<td>Group IIIA: Combustible flyings</td>
</tr>
<tr>
<td>Group G: Flour, starch, grain</td>
<td>Group IIIB: Non-conductive</td>
</tr>
<tr>
<td></td>
<td>Group IIIC: Conductive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hot surface ignition</th>
<th>Hazardous area apparatus classified by the maximum surface temperature produced under fault conditions at an ambient temperature of 40°C (or as otherwise specified).</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1: 450°C</td>
<td>T2: 300°C</td>
</tr>
<tr>
<td>T2A*:280°C</td>
<td>T2B*:260°C</td>
</tr>
<tr>
<td>T2C*:230°C</td>
<td>T2D*:215°C</td>
</tr>
<tr>
<td>T3: 200°C</td>
<td>T3:200°C</td>
</tr>
<tr>
<td>T3A*:180°C</td>
<td>T3B*:165°C</td>
</tr>
<tr>
<td>T3C*:160°C</td>
<td>T4: 135°C</td>
</tr>
<tr>
<td>T4A*:120°C</td>
<td>T5: 100°C</td>
</tr>
<tr>
<td>T6: 85°C</td>
<td>* Only applies to North America</td>
</tr>
</tbody>
</table>

An intrinsic safety rating doesn’t qualify the equipment for any hazardous area. Each intrinsically safe device can only be used in the specific hazardous location for which it is certified. Also, a device certified for intrinsic safety in the US isn’t necessarily certified for Europe and other countries, or vice versa. ATEX certification is the required approval rating for the European Union and IECEx certification is an international programme required by many international

www.intertek.com
markets. These certifications often still need additional requirements or national deviations.

Although the requirements may differ between global regions, intrinsic safety is the hazardous location protection method with standards that most easily translate across International, European and North American approval requirements. These are the most “harmonised” standards between markets and they provide a strong platform upon which international products can rely. However, understanding all the new nuances in selecting the right equipment is still an area of expertise unto itself and the crucial purchasing and implementation decisions can require a lot of time and strict attention to detail.

PART THREE: How to Approach Your Intrinsic Safety Project

When designing equipment using the intrinsic safety protection method, the rules of the “standard” must be applied. Consider the separation of the circuits, the temperature classification under normal and fault conditions, and the inability to cause ignition by sparking.

Defining the Classification

Defining the product classification for the desired market determines how certain sections of the standard are applied when the product’s design is evaluated.

For intrinsic safety, the Maximum Power method is applied to circuits in order to determine the conditions that need protection. The maximum energy that is transferred must be below the ignition curves and meet the de-rating criteria of the intrinsic safety standard under fault conditions. This step determines the protective components that need to be added to the design. The intrinsic safety standard applies faults to the design and the standard defines faults as follows:

- **Fault:** Any defect of any component, separation, insulation or connection between components, not defined as infallible by the standard, upon which intrinsic safety depends.

- **Countable Fault:** Fault which occurs in parts of electrical apparatus conforming to the constructional requirements of the standard.

- **Non-countable fault:** Fault which occurs in parts of electrical apparatus not conforming to the constructional requirements.

- **Infallible:** Considered not subject to certain fault modes as specified in the standard.
The circuit is reviewed under these fault definitions. In addition, the rules in the standard define how a component is considered infallible and faulted. In the case of EX ia intrinsic safety, the voltage applied to the circuit cannot be capable of causing ignition in any of the following conditions:

- In normal operation and with the application of those non-countable faults which give the most onerous condition.
- In normal operation and with the application of one countable fault plus those non-countable faults which give the most onerous condition.
- In normal operation and with the application of two countable faults plus those non-countable faults which give the most onerous condition.
- The non-countable faults may differ in each of the above cases.

Two separate intrinsic safety equivalent circuits must be analysed for compliance with the standard.

- For spark analysis and testing a 1.5 safety factor is applied to the power source. The calculation is based on using the open circuit voltage and short circuit current. If there is a fuse in the circuit it cannot be part of this analysis.
- For temperature analysis and testing a one-time safety factor is applied. The cold resistance (i.e. at the lower end ambient temperature) of the fuse can be counted in this case. Analysis must quantify the amount of power permitted in a circuit as heat. This heat must be limited for equipment used within the gas or dust environment. The product’s operating temperature limits must be known because testing is conducted at the upper ambient temperature.
- In addition to the safety factors, any current-limiting resistors must meet the infallible rules of the standard. The safety factor is applied to components that limit the energy in the circuit. Also, the components must be de-rated to two-thirds power/current/voltage, factoring in the component tolerances. If a fuse is in series with the current limiting resistor, it must be encapsulated and another safety factor of 1.7 times the current is applied to the circuit in addition to the 1.5 times safety factor.
- When analysing the equivalent circuit, the standard requires the circuit to be safe and incapable of igniting. Start with the power source and design the required protection. Then analyse all of the energy generating or storing components in the circuit, such as beepers, pumps, vibrating motors, inductors and capacitance. As a quick check, add up all of the capacitance and inductance in the circuit (including tolerance) and compare
it to the ignition tables in the standard. Components such as motors and piezoelectric beepers must be tested to ensure that the energy is limited to the value of the standard for the required ignition medium. Some tests require samples that are destroyed in order to determine the energy released. Think maximum inductance and maximum capacitance at minimum resistance, adding in tolerance when analysing these components. The result must be under ignition curves with the safety factor applied.

- The power source needs specific consideration especially if it is self contained e.g. battery or cell.

**Limitations on Discharge, Current and Thermal Ignition Energy**

Try to avoid the discharge of energy, or limit it. For capacitance and inductance, limit its value, make it ineffective or limit the discharge current. The total capacitance and inductance must be under the explosive atmospheres ignition level, and the component tolerance must be part of the analysis.

**Entity Parameters**

In intrinsic safety, design entity parameters are assigned at the terminals. These parameters are used to control the energy interfacing with a device in a hazardous location. They put limitations on the power, voltage, current, capacitance and inductance at the terminals of both devices that are to be connected. Also factored in is the capacitance and inductance of the cable which is dependant on cable type and length. A control drawing is created around these devices and parameters. The entity parameters are based on the value looking in through the connector with the fault conditions of the applied standard. The power source can be misunderstood with entity parameters. The power supplied to the hazardous areas device must be less than that device is capable of handling. In addition, when the device is located in a Class I, Division 1 or Zone 0 or Zone 1 area, it must use an intrinsically safe barrier to limit the energy.

Certified intrinsic safety barriers and isolators from suppliers are standardised around set groupings of entity parameters for the different zones and gas groups. It is important to select the intrinsic safety barrier/isolator first and then design the product around the intrinsic safety barrier/isolator entity parameters.
## Entity Parameter Relationships of Intrinsically Safe Certified Devices

<table>
<thead>
<tr>
<th>Intrinsically Safe Barrier (Non-hazardous location)</th>
<th>Cable</th>
<th>Intrinsically safe Instrument (Hazardous location)</th>
<th>Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uo = Maximum voltage that can appear at the output connection facilities of the barrier.</td>
<td>C cable = maximum capacitance of the interconnecting cable that can be connected to the intrinsically safe instrument without invalidating intrinsic safety. (If C cable is not known, use a value of 200 pF/m for conventional cable which comprises of two or three cores).</td>
<td>Ui = Maximum voltage that can be applied to the connection facilities of the intrinsically safe instrument without invalidating intrinsic safety.</td>
<td>Uo ≤ Ui</td>
</tr>
<tr>
<td>Io = Maximum current that can be taken from the output connection facilities of the barrier.</td>
<td>L cable = maximum inductance of the interconnecting cable that can be connected to the intrinsically safe instrument without invalidating intrinsic safety. (If L cable is not known, use a value of 1 µH/m for conventional cable which comprises of two or three cores).</td>
<td>Ii = Maximum current that can be applied to the connection facilities of the intrinsically safe instrument without invalidating intrinsic safety.</td>
<td>Io ≤ Ii</td>
</tr>
<tr>
<td>Po = Maximum electrical power that can be taken from the connection facilities of the barrier.</td>
<td>Po = Maximum electrical power that can be taken from the connection facilities of the barrier.</td>
<td>Pi = Maximum power that can be applied to the connection facilities of the intrinsically safe instrument without invalidating intrinsic safety.</td>
<td>Po ≤ Pi</td>
</tr>
<tr>
<td>Co = Maximum value of capacitance that can be connected to the output connection facilities of the barrier.</td>
<td>Ci = Maximum equivalent internal capacitance which is considered as appearing across the input connection facilities of the intrinsically safe instrument.</td>
<td>Co ≥ Ci + C Cable</td>
<td></td>
</tr>
<tr>
<td>Lo = Maximum value of inductance that can be connected to the output connection facilities of the barrier.</td>
<td>Li = Maximum equivalent internal inductance which is considered as appearing across the input connection facilities of the intrinsically safe instrument.</td>
<td>Lo ≥ Li + L cable</td>
<td></td>
</tr>
</tbody>
</table>

Intrinsic safety barrier located in a non-hazardous location is connected to an intrinsically safe instrument located in a hazardous location.
Separation Distances
The design’s protective circuitry must meet the minimum separation criteria in the standard to prevent arcing. The 1.5 safety factor must be applied to the fault voltage at the point of analysis of the circuit in the creeping and clearance table. There are options in the table for different separation, depending on whether or not the creepage and clearance measurements are through the air or under conformal coating, etc. Encapsulation is used to prevent sparking and to reduce temperatures. The standard requires a minimum thickness as an extra note beyond the values in the table.

Enclosures
Enclosure designs must be analysed and tested. Metal enclosures will be restricted on metal content. Plastic enclosures will need to be tested to prevent the build-up of electrostatic charges. Environmental and mechanical stress tests are done to ensure the durability of the product and its IP rating (which is dependant on the end application).

Tests
Intertek can help in the analysis, testing and design considerations for your product. We will need drawings and product samples to conduct the analysis. The following list highlights some of the actions to consider:

- Define all energy storage/discharge components.
- Spark ignition tests: To ensure the protection is adequate in your design.
- Battery test (hot temperature determination, surface temperature & leakage, plus voltage and current).
- Piezoelectric devices.
- Creepage and clearance.
- Partition impact test.
- Abnormal temperature test on components under fault conditions.
- Fuse resistance measurement at cold temperature.
- Thermal ignition test if needed to meet T-class on components.
- Plastic insulation resistance test.
- Thermal endurance and IP tests.
- Capacitive materials or discharge test.
- Encapsulation impact test.
- Encapsulation chemical resistance (external and internal conditions).
- Encapsulation breakdown.
- Light metals (aluminium, magnesium, titanium, and zirconium).
- Ambient and cold soak drop test.
- Intrinsic safety design review. (Marked up schematics and description of what was done to meet requirements.)
- Review compliance criteria for accessories associated with the product.
SUMMARY and Intertek’s Streamlined Process

While most realise the importance of proper intrinsic safety compliance and certification, many find the overall approval process slow, and they have difficulties getting their product to market quickly. Intertek has found that the problem is due greatly to a lack of communication and customer focus amongst some certification processes. We’ve created a testing and certification programme that saves time, money and keeps you in the loop to improve your own time-management.

- **Pre-design involvement.** If Intertek can be involved in your project during the design of the circuits, we can help assure you are immediately on track for more expedient approval. If you’ve already completed the circuitry, we’ll review it to help you understand the relevant standards and requirements before you approach the certification process. If your project involves areas where intrinsic safety standards are less established, we can recommend other requirements for your consideration.

- **Three-phase process with staged budgeting.** Rather than provide one budget for the entire project, Intertek breaks it down into a series of project phases:
  1. **Constructional Review.** A clause-by-clause analysis of the documentation and samples is conducted to get a fast set of answers as to the general state of compliance of the product. Often, this will find the major failure points that would normally have been found much later in a traditional certification process, thus saving on the total project time.
  2. **Testing/Assessment.** Again, you are in the loop, not waiting for the end of the project. We provide you with the complete draft reports in a timely manner and will be available to discuss your project as required, before finalisation.
  3. **Review and report.** This is the final push to get the reports that have been sent for consideration through a high-level technical review, followed by the legally necessary certification review.

- **Access to global markets.** If your product is destined for global markets, we can provide the required approvals for North America with our ETL mark, Europe with certification to the ATEX Directive and other international markets like Brazil, Russia, Korea, China, Australia and more with IECEx certification. Our breadth of experience and services can speed up the approval process and get your products to market quickly.

- **Benefits of Partnering with Intertek:**

  www.intertek.com
With the pricing structure broken down by phase, you control the budget throughout and we only charge you for the completed phase.

Phase-by-phase you know the project status. If modification is required, we can point out areas for your review and re-design.

If the product fails one of the phases, you’re informed immediately and can alter your plans as needed while keeping your associates and the system informed.

The project moves along in a systematic process that cuts delays and speeds up each phase.

The entire process is transparent and you constantly know where you stand at any given phase. You’re never left waiting for an undefined or delayed schedule.

You receive the most comprehensive reports, including the history of the project itself.
About Intertek

Intertek is a world leader in intrinsic safety testing and certification. We facilitate, speed up and simplify the process, while providing cost efficiencies and due diligence for quality and safety. As the industry leader, Intertek employs over 30,000 people at 1,000 locations in over 100 countries. We hold global accreditations, recognitions and agreements and our ability to overcome regulatory and supply chain hurdles is unrivalled.

Contacts

Technical
Peter D. Rawlinson BEng CEng MIET
Business Lead, Hazardous Locations
peter.rawlinson@intertek.com

Sales
Andrea Jones
Internal Sales Executive
andrea.jones2@intertek.com

Intertek, Deeside Lane, Chester, Flintshire, CH1 6DD, UK
Telephone: +44 (0)1244 882590

For more information on specific testing and certification information, please contact Intertek at +44 (0)1244 88259 , email hazloc@intertek.com or visit our website www.intertek.com

This publication is copyright Intertek and may not be reproduced or transmitted in any form in whole or in part without the prior written permission of Intertek. While due care has been taken during the preparation of this document, Intertek cannot be held responsible for the accuracy of the information herein or for any consequence arising from it. Clients are encouraged to seek Intertek’s current advice on their specific needs before acting upon any of the content.