Preventing Disasters Through Intrinsic Safety
The essentials behind an essential practice.
INTRODUCTION

This whitepaper discusses one of the most important safety subjects in every area where a simple spark can ignite a combustible environment – intrinsic safety. It provides an overview of the subject and shows where and how hazardous locations and situations can occur with devastating results. The paper then provides, in detail, how hazardous locations are classified, the required testing and processes for safety certifications, 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 companies 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 environments 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, vapors 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, energy groups, 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 the National Electric Code (NEC) as, “A circuit in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in the air under prescribed conditions.” (NEC 504.2) 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 two independent faults in the product plus a wiring fault. This means that two different and unrelated failures can occur and the system will still be safe.

As an “intrinsically safe” apparatus, the product is safe by its own inherent design and needs no additional external help. Installation does not require metal-clad cables, conduits or special devices. Maintenance can be efficiently conducted while the circuit is being powered and the plant remains functioning.
### Hazardous Area Classifications

Hazardous locations are categorized by:
- **Class**: The type of hazard present
- **Division/Zone**: The potential for a fire or explosion to exist
- **Group**: The specific type of medium present in the hazard

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

<table>
<thead>
<tr>
<th>Hazard type</th>
<th>Explosive airborne mixtures</th>
<th>Explosive airborne mixtures with flammable vapors and/or gases</th>
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<tbody>
<tr>
<td><strong>Class I</strong>:</td>
<td>Gases and/or vapors</td>
<td>Group I: Mines with methane potential</td>
</tr>
<tr>
<td><strong>Class II</strong>:</td>
<td>Dusts</td>
<td>Group II: Places other than mines susceptible to methane</td>
</tr>
<tr>
<td><strong>Class III</strong>:</td>
<td>Fibers or flyings</td>
<td>Group III: Surface and other locations susceptible to combustible dusts.</td>
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<tr>
<th>Degree of hazard</th>
<th>Division 1:</th>
<th>Zone Classifications</th>
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<tr>
<td><strong>Division 1</strong>:</td>
<td>In normal operating conditions, hazardous material is likely to be present - continuously, periodically or intermittently.</td>
<td><strong>Zone 0</strong>: Hazardous air/gas mixture is present continuously or for long periods. <strong>Zone 1</strong>: Hazardous air/gas mixture is likely to exist for short periods under normal operating conditions. <strong>Zone 20</strong>: Combustible dust is present continuously or for long periods. <strong>Zone 21</strong>: Combustible dust is likely to exist for short periods under normal operating conditions.</td>
</tr>
<tr>
<td><strong>Division 2</strong>:</td>
<td>Hazardous material is not likely to be present during normal operation - only under fault conditions and only for a short period.</td>
<td><strong>Zone 2</strong>: Hazardous air/gas mixture is not likely to occur under normal operating conditions or, if so, only for a short period. <strong>Zone 22</strong>: Combustible dust is not likely to occur under normal operating conditions or, if so, only for a short period.</td>
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</tbody>
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<tr>
<th>Spark ignition</th>
<th>Hazardous atmospheres grouped by ignition capabilities. For example:</th>
<th>Explosive gas groups:</th>
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<tr>
<td><strong>Group A</strong>:</td>
<td>Acetylene</td>
<td><strong>Group I</strong>: Methane</td>
</tr>
<tr>
<td><strong>Group B</strong>:</td>
<td>Hydrogen</td>
<td><strong>Group II</strong>: Propane</td>
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<tr>
<td><strong>Group C</strong>:</td>
<td>Ethylene</td>
<td><strong>Group IIIB</strong>: Ethylene</td>
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<tr>
<td><strong>Group D</strong>:</td>
<td>Propane</td>
<td><strong>Group IIIC</strong>: Hydrogen, acetylene</td>
</tr>
<tr>
<td><strong>Group E</strong>:</td>
<td>Metal dust</td>
<td>Combustible dust groups: <strong>Group IIIA</strong>: Combustible flyings</td>
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<tr>
<td><strong>Group F</strong>:</td>
<td>Carbon dust</td>
<td><strong>Group IIIB</strong>: Non-conductive</td>
</tr>
<tr>
<td><strong>Group G</strong>:</td>
<td>Flour, starch, grain</td>
<td><strong>Group IIIC</strong>: Conductive</td>
</tr>
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<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>
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<tbody>
<tr>
<td><strong>T1</strong>: 450°C</td>
<td><strong>T2</strong>: 300°C</td>
</tr>
<tr>
<td><strong>T2A</strong>: 280°C</td>
<td><strong>T2B</strong>: 260°C</td>
</tr>
<tr>
<td><strong>T2C</strong>: 230°C</td>
<td><strong>T2D</strong>: 215°C</td>
</tr>
<tr>
<td><strong>T3</strong>: 200°C</td>
<td><strong>T4</strong>: 160°C</td>
</tr>
<tr>
<td><strong>T4A</strong>: 120°C</td>
<td><strong>T5</strong>: 100°C</td>
</tr>
<tr>
<td><strong>T6</strong>: 85°C</td>
<td></td>
</tr>
<tr>
<td><strong>T3A</strong>: 180°C</td>
<td><strong>T3B</strong>: 165°C</td>
</tr>
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</table>

* Only applies to North America
PART TWO: Intrinsic Safety Testing and Certification

All equipment used in every designated hazardous environment 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 accredited agency that tested it. For example, Intertek is an authorized Nationally Recognized Test Laboratory (NRTL) in the US, a Standards Council of Canada (SCC) accredited agency in Canada, an IECEx Certification Body and Test Laboratory (CBTL) in North America and Europe and a Notified Body for the ATEX directive in Europe. Be sure your testing laboratory has the correct accreditations for the markets you wish to enter.

Intrinsic safety approval certifications embrace several classes, groups and divisions. 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.

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 program required by some international markets. These certifications often still need additional requirements or country deviations.

Although the requirements may differ between global regions, intrinsic safety is the hazardous location protection method with standards that most easily transition across North American, European and International approval requirements. These are the most “harmonious” standards between markets and they provide a strong platform upon which international products can rely. However, understanding all the ins and outs 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 Theorem 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 the top-level of 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 analyzed 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 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, the current-limiting resistor 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, 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 analyzing 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 analyze all of the energy-generating 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 gas group. 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 analyzing these components. The result must be under ignition curves with the safety factor applied.
Understand Your Battery Requirements

Batteries in an intrinsically safe design must meet the standard’s construction criteria or they will require significant modification. The spacing criteria must be met, batteries cannot leak electrolyte, and a pressure requirement must be met so that released gases cannot build pressure and ignite.

Vendors’ safety circuit and fuse links are not allowed due to de-rating and spacing violations must be removed for certification testing. Batteries are tested to determine the worst case temperature for fault conditions and all further testing is conducted at that temperature. The battery is tested for open circuit voltage and short circuit current, and for maximum abnormal temperature and electrolyte leakage under short circuit conditions. Under certain conditions, spark tests are needed for batteries. Some batteries, such as lithium models, must also be certified by standards such as UL 1642 / UL 2054 or they cannot be considered.

Any component or construction not complying with the standards is assumed to fail to open or short conditions. As far as the standard is concerned, a semiconductor is a diode, zener diode, FET, Transistor, or simple PN junction device. It does not include integrated circuits because what is inside the integrated circuit is an unknown. Integrated circuits are assumed to fault to any state between their pins and this is not considered as a countable fault.

Redundancy is also key to this protection concept. For example, two zener diodes are required that are de-rated to two-thirds power to aid in making a circuit infallible. If transient conditions exist, three zener diodes are required for compliance. Intertek can assist you in this analysis and perform the standard’s required testing.

Limitations on Discharge, Current and Thermal Ignition Energy

Try to avoid the discharge of energy, keep it as low as possible, 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 gases’ ignition level, and the component tolerance must be part of the analysis.

Entity Parameters

In intrinsic safety, design entity parameters are assigned at the ports. 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 ports of both devices that are to be connected. Also factored in is the capacitance and inductance of the cable which multiplies every meter. 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 area’s 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 and Zone 1 area, it must use an intrinsically safe barrier to limit the energy.

Certified intrinsic safety barriers from suppliers are standardized around set groupings of entity parameters for the different divisions and gas groups. It is important to select the intrinsic safety barrier first and then design the product around the intrinsic safety barrier’s entity parameters. It is also important in working with systems such as 4 – 20 mA loops to monitor the total resistance of the current loop, ensuring the sum of all system products in the loop plus cable resistance doesn’t exceed the maximum allowed. The port’s spacing criteria is based on assuming a voltage of 250 VDC.
Intrinsically Safe Barrier | Instrument | Optional Alarm
--- | --- | ---
Voc (Uo) ≤ Vm (Ui) | Vm (Ui) ≤ Vm (Ui) | The maximum allowed entity parameters are marked on each certified device.
Isc (Io) ≤ Im (Li) | Im (Li) ≤ Im (Li)
Ca (Co) ≥ Ci | Ci + C Cable ≥ Ci
La (Lo) ≥ Li | Li + L Cable ≥ Li

**Intrinsic Safety Barrier to Instrument**
- Ca includes intrinsic safety barrier Ci + C cable.
- La includes intrinsic safety barrier Li + L cable.
- Voc = maximum open circuit voltage at intrinsic safety barrier terminals.
- Isc = maximum short circuit at intrinsic safety barrier terminals.
- Ca = maximum inductance allowed connected to intrinsic safety barrier terminals.
- La = maximum inductance allowed connected to intrinsic safety barrier terminals.

**Instrument Option**
- Vm = maximum voltage that may be connected to terminals of the gas detector or option. Operational voltages are required to be lower than this parameter.
- Im = maximum current that may be connected to terminals of the gas detector or option. Operational currents are required to be lower than this parameter.
- Ci = internal capacitance of gas detector or option at the specified terminals.
- Li = internal inductance of gas detector or option at the specified terminals.

**Port to Option**
- If cable capacitance (C cable) is unknown, use 60 pF/foot in calculations.
- If cable inductance (L cable) is unknown, use 0.20 uH/foot in calculations.
- Other parameters that sometimes appear are: Po and Pi (Po ≤ Pi); La/Ra and LiRi (La/Ra ≥ LiRi).

Intrinsic safety barrier located in ordinary location is providing power or charging a certified gas detector located in Class I, Division 1. The gas detector is supplying power to a certified option located in the same hazardous location.

**Spacings**
The design’s protective circuitry must meet the minimum spacing 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 spacing table. There are options in the table for different spacings, 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 analyzed and tested. Metal enclosures will be restricted on metal content. Plastic enclosures will need to be tested to prevent the build-up of trapped changes. Environmental and mechanical stress tests are done to ensure the durability of the product and its ingress protection rating.

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

- Define all energy storage/release components.
- Spark ignition tests: To ensure the protection is adequate in your design.
- Battery test (UL1642 & UL 2054.): Cell qualification (hot temperature determination, surface temperature & leakage, plus voltage and current).
- Piezoelectric devices.
- Motor qualification test. Determine Lmax and Rmin.
- Creepage and clearance. Possible short placed across trace.
- 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-code on components.
- Plastic insulation resistance test (1GOhm.)
- Ingress protection and thermal endurance tests.
- Capacitive materials or discharge test.
- Encapsulation impact test.
- Encapsulation chemical resistance (external and internal conditions).
- Encapsulation breakdown.
- Light metals (aluminum, magnesium, titanium, and zirconium).
- Ambient and cold soak drop test.
- Label gas vapour test.
- Antenna intrinsic safety coupling.
- Internal charger transient test. (Only if charger resides inside of the instrument.)
- 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.

The NFPA 497 Standard (National Fire Protection Association) or API 500 (American Petroleum Institute) provides guidelines on assessing the extent of a potential hazard. According to their adaptation by other areas, gas zones guidelines are provided in the current edition of IEC 60079-10. For hazardous dusts, the guiding standard is IEC 61421-10.
SUMMARY and Intertek’s Streamlined Process

While most realize 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 program 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.

- **Five-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. **Documentation Review.** Improper documentation can hold up the evaluation process as you wait for the evaluation, then restart the process with required revisions. Prior to submission, Intertek reviews your documentation and quickly makes any adjustments. We request all documents two weeks prior to the project and our reviewing process is done in a timely manner with the average project requiring four hours of review time.
  2. **Analysis.** Intertek does a thorough circuit analysis and spark ignition test on batteries and the circuit, bundled together. Nearly 85% of submissions fail. Often, you might be left hanging with traditional programs, unaware of the delay and its cause. However, Intertek keeps you advised throughout the process, so you know where you stand and can plan accordingly.
  3. **Construction review.** Next, we review the physical product itself. You receive a thorough outline of the specific testing we conduct and how we conduct the test.
  4. **Testing.** Again, you are in the loop, not waiting for the end of the project. We provide you with the complete test reports in a timely manner and will be available to discuss your project as required.
  5. **Review and report.** You receive a thorough report, written by an engineer. It also goes through a complete internal review to assure every possible aspect is covered.

- **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**
  - 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 unrivaled.

To discuss your company’s intrinsic safety or other hazardous locations testing and certification needs, contact us today:

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