

## CHAPTER 4 METHODS OF PROTECTION

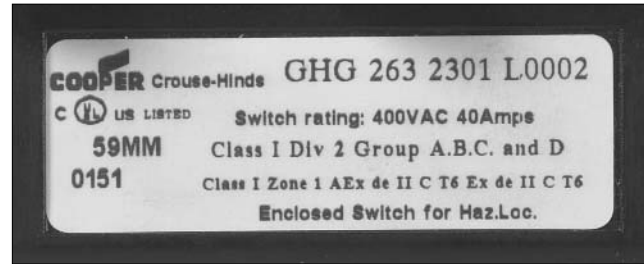
*An explosion-protected device will not create an internal, or transmit an external ignition source, either by spark, or hot surfaces.*

### 4.0 PRINCIPLES OF EXPLOSIONPROOF PROTECTION

The definition of Explosion Protection is electrical apparatus designed with specific safety measures to prevent ignition of a surrounding gas or vapor during normal operation. An explosion-protected device will not create an internal, or transmit an external ignition source, either by spark, or hot surfaces. It is therefore Ex Protected to a recognized International or National Standard and certified by a recognized test authority (UL, CSA, FM).

The U.S. recognizes the “AEx” and Canada recognizes the “Ex” marking for products installed in Hazardous Locations. The

term EEx can sometimes cause confusion compared to the symbol Ex. The term EEx means that the apparatus is Explosion Protected (Ex) to a CENELEC European Standard demonstrated by the additional “E”.



Zone-rated equipment will have the AEx mark for the US market and Ex mark for the Canadian and IEC markets.

A list of the Ex Protection concepts for electrical apparatus is given in the CENELEC and IEC Standards for electrical apparatus construction and test requirements. Table 4.1 shows where these protection techniques can be used.

**Table 4.1 - Types of Protection**

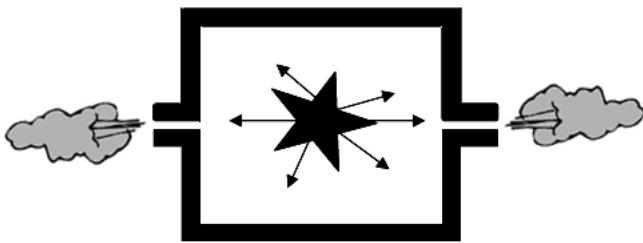
<u>Method of Protection</u>	<u>Symbol</u>	<u>Protection Principle</u>	<u>Zone</u>	<u>Standards</u>	
				<u>CENELEC</u>	<u>IEC</u>
Flameproof	d	Withstand and contain the explosion & prevent transmission of explosion to surrounding external atmosphere.	1	EN 50 018	60079-1
Increased Safety	e	No arcs, sparks, or hot surfaces.	1	EN 50 019	60079-7
Intrinsic Safety	ia	Removes <i>ignition</i> from explosion triangle through prevention of high fault current & voltage.	0	EN 50 020	60079-11
	ib		1	EN 50 020	60079-11
Pressurization	p	Removes <i>fuel</i> from explosion triangle by passing protective gas through enclosure.	1	EN 50 016	60079-2
Non-Sparking	nA	No arcs, sparks, or hot surfaces.	2	EN 50 021	60079-15
	nC		2	EN 50 021	60079-15
	nR		2	EN 50 021	60079-15
Powder Filled	q	Electrical components are covered with a filling medium, preventing presence of explosive gas-air mixtures.	1	EN 50 017	60079-5
Oil Immersion	o	Electrical parts are immersed in oil, preventing exposure of arc or spark to explosive atmosphere.	1	EN 50 015	60079-6
Encapsulation	m	Component parts which could ignite an explosive atmosphere are enclosed in resin compound.	1	EN 50 028	----
Special Protection	s	Special protective techniques not covered by standards	1	National	----
			2		

## 4.1 FLAMEPROOF TYPE 'd' PROTECTION DESIGN CONCEPTS

*The IEC standards permit routine tests which allow Ex-d enclosures to be individually tested at 1.5 times the maximum pressures. Explosionproof enclosures are tested to 4 times the maximum pressures.*

### 4.1.1 FLAMEPROOF TYPE "d" PROTECTION

Ex-d is a type of Ex Protection in which the parts that can ignite an explosive gas air mixture are placed in an enclosure which can withstand the pressure developed during an internal explosion, and which prevents transmission of the explosion to the surrounding external atmosphere.



*Flameproof enclosures contain the explosion and allow gases to cool as they escape across the joints.*

*Field drilling of flameproof, Ex-d enclosures is not allowed. To maintain the certification, flameproof enclosures can only be modified by the manufacturer.*

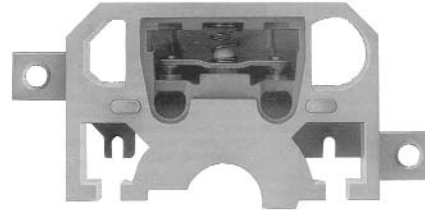
### 4.1.2 FLAMEPROOF VS. EXPLOSIONPROOF—WHAT IS THE DIFFERENCE?

Flameproof enclosures may differ from explosionproof enclosures in their design. The major difference is that explosionproof enclosures are constructed to withstand 4 times the explosive pressure of the gases. With flameproof enclosures, manufacturers can construct the enclosure to meet only 1.5 times the explosive pressure if each enclosure is tested to this pressure before leaving the factory, referred to as a routine test. Otherwise, construction to 4 times the explosive pressure is required. Most flameproof enclosures are individually tested at 1.5 times the explosive pressure while most explosionproof enclosures withstand 4 times the explosive pressures.

In North America standards for explosionproof equipment are quite similar to flameproof. Explosionproof equipment has been evolving from large, cast explosionproof enclosures which require conduit seals to small, much lighter factory sealed equipment or components containing arcing contacts.

This evolution of products has made many explosionproof and flameproof products very similar. For example, factory sealed, explosionproof switches are made of non-metallic materials.

These devices pass the explosionproof tests because the internal volume containing the contacts and the gas-air mixture is very small so the explosive force is limited. The hot gases, which are minimized, escape through more elaborate labyrinth or cylindrical joints. These switches are now widely used in control stations and panels where the current levels are typically less than 16 amps.



*The Ex-d non-metallic switch has a small internal volume.*

Other innovative enclosure techniques use sintered bronze plates as flame paths in non-metallic enclosures to make larger switches up to 100 amps explosionproof.



*Larger amperage switches such as the non-metallic 100 amp RSWP use sintered bronze plates as the explosionproof joint.*

### 4.1.3 FLAMEPROOF APPLICATIONS

Flameproof protection is often used for motors and switchgear. Since very little heat is generated in switchgear, the surface temperature of the enclosure is only slightly higher than the surrounding atmosphere. In most cases the switchgear satisfies the temperature classes T5 and T6.

Motors dissipate more heat. In order not to exceed the permissible limiting temperature, it may be necessary to lower the rated output of a flameproof motor as compared to a standard motor. Examples of components requiring flameproof protection:

- Motors with slip rings and commutators
- Three-phased squirrel cage motors
- Switchgear with opening and closing contacts such as motor protection switches, circuit breakers and air break contactors
- Fuses
- Transformers
- Lighting fixtures
- Communication equipment measuring instruments

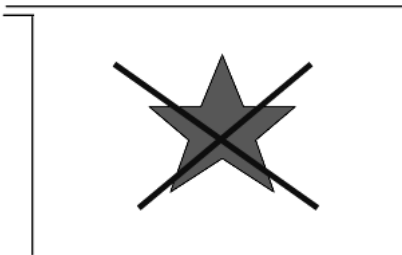
*Refer to Chapter 7 Installation of Explosionproof and Flameproof Enclosures for more details.*

**4.2 INCREASED SAFETY TYPE “e”  
PROTECTION DESIGN CONCEPTS**

*The increased safety concept is only suitable for nonsparking apparatus and is commonly used in Zone 1 designated hazardous areas.*

**4.2.1 INCREASED SAFETY TYPE “e”  
PROTECTION**

The definition of Type “e” Protection is where increased measures are taken to prevent the possibility of excessive heat, arcs, or sparks occurring on internal or external parts of the apparatus in normal operation. The increased safety concept can be used for electrical equipment such as terminal boxes, lighting, transformers, instruments, and motors.



*Ex-e prevents the possibility of excessive heat, arcs or sparks from occurring on internal or external parts of the apparatus in normal operation.*

**4.2.2 ENCLOSURES**

General requirements for enclosures are: ingress protection to at least IP 54 (See section 5.3) and additional tests for non-metallic parts including thermal endurance, resistance to solvents, ultraviolet light, surface conductivity and mechanical impact resistance to either 4 or 7 joules depending on the use of the enclosure. The increased safety concept is only suitable for nonsparking apparatus and is commonly used in Zone 1 hazardous areas.



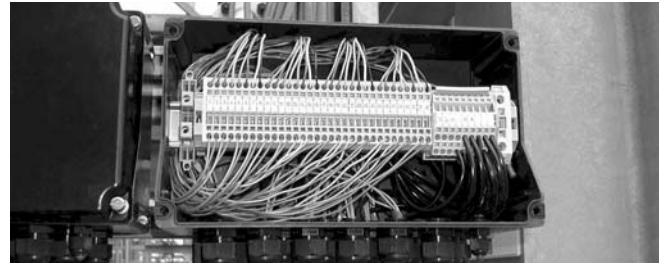
*Cooper Crouse-Hinds manufactures non-metallic and stainless steel Ex-e enclosures.*

**4.2.3 TERMINALS**

General requirements for terminals are:

- They must be designed so the conductor can be easily inserted and clamped. Contact pressure must be maintained without reducing the cross sectional area of the conductor and a positive locking device must prevent conductors from working loose by vibration.

- Specified creepage distances as detailed in EN 50-019 and IEC 60079-7 for the grade of insulation material (CTI) and subsequent maximum voltage rating.
- Temperature limitation,
- Current de-rating of the terminals (and conductors)



*Rail mounted Ex-e terminal assembly terminal boxes in the Cooper Crouse-Hinds GHG74 Terminal box.*

**4.3 INTRINSIC SAFETY TYPE “ia”  
PROTECTION DESIGN CONCEPTS**

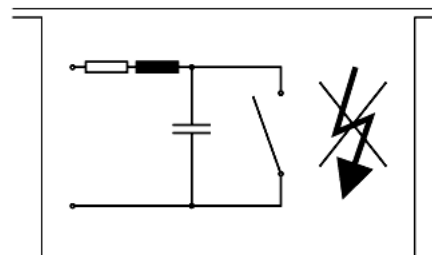
*Intrinsic Safety is normally applied to sensing or control circuits which are 24 VDC/AC or less. Intrinsic safety offers savings and benefits to OEMs that sell to the global markets since it is more widely accepted and used in Europe.*

**4.3.1 INTRINSIC SAFETY TYPE “ia, ib”  
PROTECTION**

Whereas the other protective techniques use mechanical means to prevent ignition from electrical faults, intrinsic safety, Ex-ia is an electrical protective measure. This protective technique removes ignition from the explosion triangle. Intrinsic Safety, used in both Zones 0 & 1 and Division 1, prevents high fault currents and voltage from occurring in control circuits. Intrinsic Safety cannot be applied to *power circuits*.

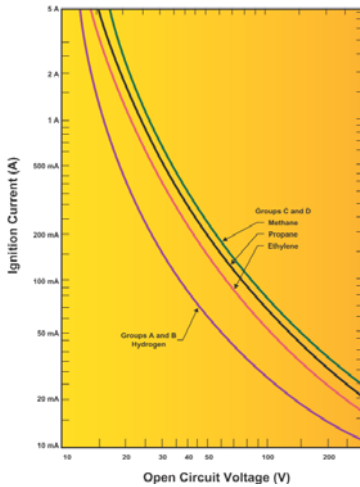
**4.3.2 EX-ia LIMITS THE ENERGY**

Voltage and current limitations are determined by ignition curves, as seen in Fig. 4.2. A circuit with a combination of 30 V and 150 mA would fall on the ignition level of some gases. This combination of voltage and current could create a spark with enough energy to ignite the mixture of gases and oxygen. Intrinsically safe applications always stay below these curves, using a safety factor of 1.5, where the operating level of energy is about 1 watt or less. There also are capacitance and inductance curves which must be examined in intrinsically safe circuits.



*Ex-ia prevents excess voltage and current from creating sparks with enough energy to ignite gases.*

Figure 4.  
Ignition Curves – Resistance.



Resistance curves where (in theory) the combination of voltage and current will have enough energy to ignite volatile gases. Ex-ia ensures that the energy in the circuit is always below these curves.

All intrinsically safe circuits have three components, the field device (sensor or instrument), the energy-limiting device, also known as the barrier, and the field wiring. There are 3 components to a barrier that limit current and voltage: a resistor, at least two zener diodes and a fuse. The resistor limits the current to a specific value known as the short circuit current,  $I_{sc}$ . The zener diodes limit the voltage to a value referred to as the open circuit voltage,  $V_{oc}$ . The fuse will open when the diode conducts. This interrupts the circuit, which prevents the diode from burning and prevents excess voltage from reaching the Hazardous Location. There are always at least two zener diodes in parallel in each intrinsically safe barrier. If one diode should fail, the other will operate, providing complete protection.



Cooper Crouse-Hinds offers grounded and isolated intrinsically safe barriers in addition to intrinsically safe I/O. See Chapter 9 for complete details.

There are 2 categories of intrinsically safe protection. Ex-ia is used in Zones 0, 1 and 2 while Ex-ib can only be used in Zones 1 & 2. Ex-ia barriers offer added redundancy (zener diodes) for voltage protection. Virtually all intrinsically safe barriers are classified as Ex-ia.

### 4.3.3 Ex-ia APPLICATIONS

Intrinsic Safety can only be used on instrumentation, control and sensing circuits where the voltage is typically 24 VDC and less than 100 mA. Instruments and sensors in the hazardous area are classified as either simple or complex devices. Simple apparatus is defined in paragraph 3.12 of the ANSI/ISA-RP 12.6-1987 as a device which will neither generate nor store more than 1.2 volts, 0.1 amps, 25 mW or 20  $\mu$ J. Examples are simple contacts,

thermocouples, RTDs, LEDs, noninductive potentiometers and resistors. These simple devices do not need to be approved as intrinsically safe. If they are connected to an approved “barrier,” the circuit is considered intrinsically safe.

A complex device can create or store levels of energy that exceed those listed above. Typical examples are transmitters, transducers, solenoid valves and relays. These devices need to be approved as being intrinsically safe.

For complete details visit [www.isbarriers.com](http://www.isbarriers.com).

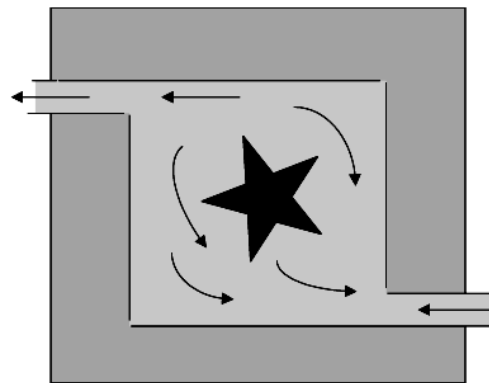
### 4.4 PRESSURIZED TYPE “p” PROTECTION DESIGN CONCEPTS

Ex-p protection is similar to purging. It guards against the ingress of the external atmosphere into an enclosure or room by maintaining a positive pressure above that of the external atmosphere.

#### 4.4.1 PRESSURIZED TYPE “p” PROTECTION

Pressurization, which is similar to purging, removes fuel from the explosion triangle by passing a quantity of protective gas through the enclosure. This ensures that any potentially explosive mixture that may be present inside the system is expelled, and the mixture reduced to a concentration well below the lower flammable limit. It guards against the ingress of the external atmosphere into an enclosure or room by maintaining a positive pressure above that of the external atmosphere, e.g., normally by an overpressure of 0.5 mbar (50 Pa or 0.007 psi).

Normally air is the protective gas used provided that the oxygen content is not more than 21%. Alternatively, an inert gas such as nitrogen may be used.



Ex-p pressurization by continuous dilution of air removes fuel from the enclosure.

Pressurization is used to overcome installation problems in hazardous areas where other explosive protected techniques would be difficult or too expensive. This technique became popular with the installation of programmable logic computers and computer monitors in Hazardous Locations. The only feasible method of protection was Ex-p.

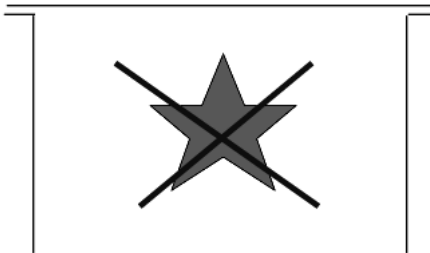
There are few limitations on the types of electrical components that can be protected by the pressurized concept. Some typical applications for pressurization include analyzer rooms, offshore oil platform accommodations, large (high voltage) rotating machines and instrument panels. To prevent the ingress of flammable materials, the pressurized gas must be carefully controlled, requiring accurate pressure control systems for both pressure and flow measurement. If the pressure fails or, the purge cycle has not been completed, the pressurized enclosure must be "volt free," meaning power is disconnected to the enclosure. Although the basic principles of pressurization are simple, the practical aspects are usually considerably more complex.

#### 4.5 NON-SPARKING TYPE "n" PROTECTION DESIGN CONCEPTS

*Present thinking within the IEC is that certification will not be required for Zone 2 equipment as it is for Zones 0 and 1.*

##### 4.5.1 NONSPARKING TYPE "n" PROTECTION

For Zone 2 applications there is an option different from Zone 1 referred to as a type of protection "n," sometimes called "Ex-n" or *nonsparking*. Type "n" apparatus is standard industrial equipment which in normal operation will not produce arcs, sparks or surface temperatures high enough to cause ignition. The apparatus has an IP rating called *Ingress Protection* which is similar to NEMA enclosure ratings such as NEMA 4, hoesight. A nonincendive component is limited in use to the particular circuit for which it has been shown to be non-ignition capable. Unlike intrinsic safety, there is no restriction on the energy levels.



*Ex-n prevents or limits electrical apparatus sparking in Zone 2.*

##### 4.5.2 Ex-n APPLICATIONS

*Refer to Appendix 6 for more details on non-sparking.*

For particular types of equipment such as motors and receptacles detailed requirements are applied:

- Motors must have secure rotor bars and fans, ventilation screens, adequate clearances and tight terminal boxes.
- Plugs and receptacles must be of the locking type, designed so incorrect connection is not possible, and labeled, "Do Not Disconnect When Energized."
- Luminaries may be incandescent, fluorescent, or other high intensity discharge lamp except for low-pressure sodium, but must be marked with the lamp rating and information relevant to the temperature class. Lamps must be enclosed, nonsparking, and meet other safety requirements.

Type "n" is very similar to nonincendive that has been used by North American manufacturers for many years, but only recently has the IEC begun to develop guidelines on how to apply this technique. IEC 60079-15 defines requirements for this equipment. Present thinking within the IEC is that certification will not be required for Zone 2 equipment as it is for Zones 0 and 1. While this will be a cost savings for everyone, it remains to be seen whether the users will accept self-certifications.

Contained within the Type "n" guidelines are the following definitions of hazardous area protection.

**Enclosed-break devices**—These devices are applied when energy is limited. They have small internal volume, use resilient gasket seals, and are subject to ignition testing similar to a Westerberg test, i.e. the device is put in a box and both the device and the box are filled with a flammable mixture. The device is operated with maximum rated voltage and current and if no damage or external ignition occurs, the device passes the test.

**Nonincendive components**—Energy is limited and external ignition may not occur.

**Hermetically sealed devices**—Reliability requirements are applied to fusion seals.

**Sealed devices**—Requirements cover construction and resilient gasket seals.

**Energy limited apparatus and circuits**—This is similar to North American nonincendive, except that the device and circuits need not be tested with ground faults or short circuits.

#### 4.6 POWDER FILLED TYPE "q" PROTECTION DESIGN CONCEPTS

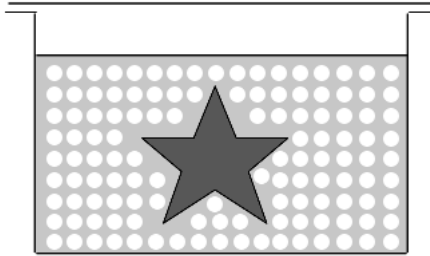
*Powder filled, Ex-q, protection method is generally only used for small transformers, capacitors and on electrical components that have no moving parts.*

##### 4.6.1 POWDER FILLED TYPE "q" PROTECTION

Powder filling originated in France as a concept in 1954, but it was not generally recognized as an Ex Protection concept until the publication of IEC Standard 60079-5 in 1967.

This protection method is typically only used for small transformers, capacitors and on electrical components that have no moving parts. The protection consists of a sealed enclosure (normally with a vent) containing quartz sand (the origin of the "q" description), powder or glass beads.

The enclosed electrical components are covered and surrounded by the filling medium. This ensures that under normal use no arc can be created which is able to ignite the explosive mixture inside the enclosure and the surrounding hazardous area.



*Ex-q surrounds electrical apparatus in sand.*

#### 4.6.2 Ex-q APPLICATIONS

This protection concept is normally suitable up to and including Group IIC gases and the T6 temperature classification, in Zone 1 or 2 hazardous area locations.

The enclosure construction requirements are a pressure test of 0.5 bar (1 bar = 14.5 psi) over-pressure for 1 minute and, if not protected by another enclosure, a minimum Ingress Protection of IP 54, the same requirement for Ex-e enclosures. If the q-component is protected by another enclosure (e.g. a capacitor in the type of protection “q” built into a light enclosure) then no specific requirements for the type of IP protection is required.

When the enclosure is filled with the “q” medium (quartz sand, powder or glass beads) there must be no voids in the enclosure.

The maximum distance from live parts of electrical components to earth fitted inside the metal enclosure or metal screen is specified and, depending on the applied voltage, can vary from 10 mm at 250 volts to 50 mm at 6,600 volts. If the enclosure is permanently factory sealed and the voltage does not exceed 500 volts, the minimum distance between live parts or live parts to earth can be reduced by 5 mm.

If there are “flying leads” from the apparatus, they must be connected to Ex-e certified terminals.



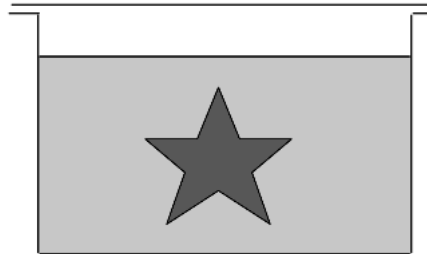
*The Ex-q concept was originally used for the electronic ballast in the SpecOne eLLK fluorescent luminaires. (The ballast was redesigned in 1992 to the Ex-d design.) If these devices fail, they are replaced “like for like” from the original manufacturer as a certified spare part. The user cannot repair them..*

### 4.7 OIL IMMERSION TYPE “o” PROTECTION DESIGN CONCEPTS

*There are very few examples of Ex-o certified products installed in hazardous areas even though the standards permit its use in Zones 1 and 2.*

#### 4.7.1 OIL IMMERSION TYPE “o” PROTECTION

The Oil Immersion Ex-o concept has historically been used for heavy duty switchgear, motor starters and transformers. The standard for design and testing of Ex-o type electrical apparatus is IEC 60079-6.



*Ex-o immerses electrical apparatus in oil to prevent arcs or sparks from igniting volatile gases.*

The basic principle as shown above is to immerse the electrical parts in mineral oil, which will prevent any exposure of the arcing or sparking to the an explosive atmosphere. It will also quench arcs and limit the temperature rise on electrical parts.

Standards for oil immersion protection, Ex-o, require that all parts capable of producing arcs or sparks must be immersed in the oil at a depth not be than 25 mm. A method to check the oil level must be provided, e.g., by a sight glass or by some other reliable method.

Some mineral oils used in switchgear apparatus produce acetylene and hydrogen gas when arcing occurs. Because of the risk of fire or an explosion with oil immersion, this application for apparatus in hazardous areas has been generally restricted. In the Petro-Chemical industries there are very few examples of Ex-o certified products installed in hazardous areas even though the standards permit its use in Zones 1 and 2.

## 4.8 ENCAPSULATION TYPE “m” PROTECTION DESIGN CONCEPTS

*Encapsulation is finding increased usage for printed circuit boards that are assembled in small rail-mounted housings similar to terminals.*

### 4.8.1 ENCAPSULATION TYPE “m” PROTECTION

Encapsulation is a type of protection whereby parts that are capable of igniting an explosive atmosphere, by either sparking or heating, are enclosed in a compound in such a way that the explosive atmosphere cannot be ignited under operating or installation conditions. The selected compound must be in line with the requirements given in IEC 60079-18 and may be any thermosetting, thermoplastic, epoxy, resin (cold curing) or elastomeric material with or without fillers and/or additives, in their solid state. The temperature range must satisfy the requirements of an appropriate standard for this type of protection. (Thermal stability at maximum operating temperature.)



*Ex-m encloses all ignitable component parts in resin, preventing contact with explosive gases.*

When considering the safety aspects of Ex-m encapsulation, the design must account for:

- Resistors, capacitors, optoisolators, diodes etc., must not operate at more than 2/3 of their rated voltage.
- The temperature rise of components and wiring must be limited.
- Voids and air pockets other than those for relays or other devices must be avoided.
- The effect of a component's short-circuit during fault conditions.

The Ex-m encapsulation protects electronic circuit relays, timers, lamp test devices and components in Zones 1 or 2 hazardous areas. Encapsulation is finding increased usage for printed circuit boards that are assembled in small rail-mounted housings similar to terminals.

*For questions or comments, please contact the author at [paul.babiarz@crouse-hinds.com](mailto:paul.babiarz@crouse-hinds.com)*