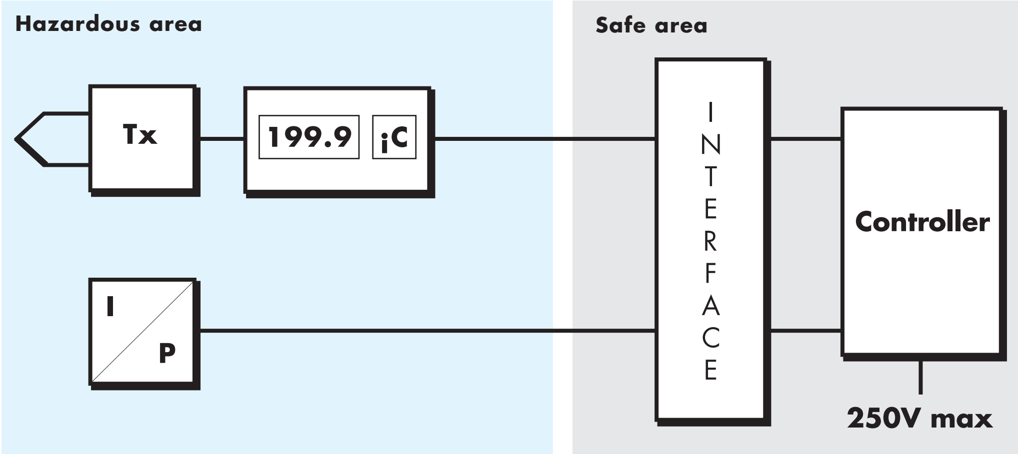
principles and practice

INTRINSIC SAFETY



Hazardous areas. In the many industrial processes where flammable materials are handled, any leak or spillage may give rise to an explosive atmosphere. To protect both plant and personnel, precautions must be taken to ensure that this atmosphere cannot be ignited. The areas at risk are known as hazardous areas and the materials that are commonly involved include crude oil and its derivatives, alcohols, natural and synthetic process gases, metal dusts, carbon dust, flour, starch, grain, fibres and flyings.

Explosion protection. To enable electrical equipment to be used safely in such environments, eight different 'explosion protection' techniques have been developed over the years. National, or in some cases international, standards and codes of practice govern each technique and define in detail how the equipment should be designed and applied. National certifying ('approvals') authorities ensure design compliance and national inspectorates (insurance companies) have the right to vet each installation. The different techniques lend themselves to different applications, and for instrumentation used in measurement and control the simplest and lowest cost technique is intrinsic safety.

Intrinsic safety (IS) is based on the principle of restricting the electrical energy available in hazardous-area circuits such that any sparks or hot surfaces that may occur as a result of electrical faults are too weak to cause ignition. The useful power is about 1W, which is sufficient for most modern instrumentation. IS is therefore inherently safe as evidenced by the fact that it is the only technique that is universally accepted for Zone 0 (high risk) hazardous areas. It is also safe for personnel since the voltages are low and it allows field equipment to be maintained and calibrated 'live' without the need to obtain a gas-free certificate. Finally, IS equipment is light in weight and can be interconnected by ordinary instrument cabling.

The basic principles of IS are very simple. All flammable materials are grouped according to the spark energy needed to ignite them. All IS equipment is designed and certified as being safe for a particular group of gases. In practice most IS systems are safe with all the gases normally encountered, while a few employ more power in particular environments. As with all other explosion protection techniques, equipment located in a hazardous area must also be classified according to the maximum surface temperature that it can produce, and the user must check that this is safe for the gases used in his process.
Finally, hazardous areas are classified according to the probability that an explosive atmosphere is present, and this dictates whether or not a particular explosion protection technique may be used.

Practical installations can be considered in three parts as shown in the above diagram. A certified IS interface passes signals to and from the process, but limits the voltage and current that can reach the hazardous area under fault conditions. Usually the interface is made up of a number of discrete devices such as shunt-diode safety barriers or isolators, manufactured by specialist companies such as MTL and widely certified. Then, in the safe ('non-hazardous') area ordinary non-IS controllers, computers and other equipment can be used and modified or exchanged without having to worry about explosion dangers.

In the hazardous area, 'simple' devices that do not generate or store significant electrical energy also can be used without certification: they include thermocouples, resistive sensors, LEDs and switches. 'Energy-storing' equipment, on the other hand, must be suitably designed to prevent this energy escaping and be certified and labelled. There are now many certified transmitters, indicators, current-to-pressure (I/P) converters and other IS instruments.

Since the interconnecting cables may store energy in their capacitance or inductance and release it suddenly in the event of a fault, the certificate for any interface defines the maximum permitted 'cable parameters'. MTL interfaces are designed to tolerate long cables and in practice, although the user needs to check, there is very seldom any problem.

Certification in the past was applied to IS systems as a whole, including the safe-area equipment. This was inflexible and restrictive, eliminating choice and making it difficult to change any item. But now all certifying authorities have adopted a modular approach, known in the USA as the 'entity concept', which allows the user to assemble safe systems on his own, using equipment from any manufacturer, provided that it is electrically compatible.
IS standards today are steadily converging all over the world under the umbrella of the International Electrotechnical Commission Standard IEC 60079 11:1999, which virtually all countries now accept in principle. In particular all countries in Western Europe are members of the European Committee for Electrotechnical Standardisation (CENELEC) and give CENELEC standards national status. However, there are still some differences in approach between the major blocs, and the USA and Canada still use their own terminology. The principles and terminology for 'IEC' countries and for the USA and Canada are summarised overleaf. MTL products are certified (approved) for all the countries in which they are likely to be used.

INTRINSIC SAFETY PRINCIPLES FOR IEC

Intrinsic safety (IS)

Technique that achieves safety by limiting the electrical-spark energy (and surface temperature) that can arise in hazardous areas to levels that are insufficient to ignite an explosive atmosphere.

Categories

Ex ia: explosion protection maintained with up to two component or other faults.
IS apparatus may be located in, and associated apparatus may be connected into Zone 0, 1 and 2 hazardous areas (Germany prefers galvanic isolation for Zone 0.)

(EN 50284 states small additional requirements for apparatus mounted in Zone 0.)

Ex ib: explosion protection maintained with up to one component or other fault.
IS apparatus may be located in, and associated apparatus may be connected into Zone 1 and 2 hazardous areas.

Area classification

Zone 0: explosive gas-air mixture continuously present, or present for long periods.

Zone 1: explosive gas-air mixture is likely to occur in normal operation.

Zone 2: explosive gas-air mixture not likely to occur and, if it occurs, it will exist only for a short time.

CENELEC

Zone 20: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.

Zone 21: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.

Zone 22: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Gas and dust classification

Flammable gases, vapours and mists are classified according to the spark energy required to ignite the most easily-ignitable mixture with air. Apparatus is grouped according to the gases that it may be used with.

Surface industries

Group IIC: acetylene
Group IIC: hydrogen
Group IIB: ethylene
Group IIA: propane

↑ more easily ignited

Dusts under active consideration

Mining industry
Group I: methane (firedamp)

Temperature classification

Hazardous-area apparatus is classified according to the maximum surface temperature produced under fault conditions at an ambient temperature of 40°C, or as otherwise specified.

T1	T2	T3	T4	T5	T6
450°C	300°C	200°C	135°C	100°C	85°C

Gas characteristics

Details of the classification (C) and the ignition temperatures (T) of commonly used gases and vapours are contained in:

IEC 60079-20 most comprehensive list (CT)

Approval

National certifying authorities issue certificates for approved equipment, defining how it may be used.

Standards

All countries in Western Europe work to CENELEC standards EN 50020 (apparatus) and EN 50039 (systems). EC member countries issue Certificates of Conformity to these standards and accept products and systems certified by other members. Other countries either work to their own standards based on IEC 60079-11 (eg Australia, Brazil, Japan, USSR) or accept products and systems certified to European and/or North American standards.

Note: Some IEC standards have been adopted as CENELEC standards e.g. IEC 60079-14: 2002 is also BS EN 60079-14: 2003

Codes of practice

IEC 60079-14
VDE 0165

INTRINSIC SAFETY PRINCIPLES FOR USA & CANADA

Intrinsic safety (IS)	Technique that achieves safety by limiting the electrical-spark energy (and surface temperature) that can arise in hazardous areas to levels that are insufficient to ignite an explosive atmosphere.
Categories	**One category:** safety maintained with up to two component or other faults. IS apparatus may be located in, and associated apparatus may be connected into Division 1 and 2 hazardous locations. When IEC zone classification is used as indicated below, then methods of protection permitted by IEC standards may also be used.
Area classification	**Division 1:** hazardous concentrations of flammable gases or vapours – or combustible dusts in suspension – continuously, intermittently or periodically present under normal operating conditions. **Division 2:** volatile flammable liquids or flammable gases present, but normally confined within closed containers or systems from which they can escape only under abnormal operating or fault conditions. Combustible dusts not normally in suspension nor likely to be thrown into suspension. In the USA, the use of IEC zone classification is permitted as an alternative. In Canada, new plants use the IEC code.
Gas and dust classification	Flammable gases, vapours and mists and ignitable dusts fibres and flyings are classified according to the spark energy required to ignite the most easily-ignitable mixture with air. Surface industries **Class I, Group A:** acetylene **Class I, Group B:** hydrogen **Class I, Group C:** ethylene **Class I, Group D:** propane ↑ more easily ignited **Class II, Group E:** metal dust **Class II, Group F:** carbon dust **Class II, Group G:** flour, starch, grain **Class III:** fibres and flyings *Mining industry* **Unclassified:** methane (firedamp)
Temperature classification	Hazardous-area apparatus is classified according to the maximum surface temperature produced under fault conditions at an ambient temperature of 40°C, or as otherwise specified. **T1** 450°C; **T2** 300°C; **T3** 200°C; **T4** 135°C; **T5** 100°C; **T6** 85°C
Gas characteristics	Details of the classification (C) and the ignition temperatures (T) of commonly used gases and vapours are contained in: NFPA 325M (C) NFPA 497M (includes dusts) (CT) CSA C22.1 (CT)
Approval	FM (USA) and CSA (Canada) issue certificates for approved equipment, defining how it may be used. FM and UL (USA) and CSA (Canada) issue reports and publish listings of approved equipment, defining how it may be used.
Standards	FM and UL work to their own standards; FM 3610 and UL913 are based on ANSI/UL913. Canada works to CSA C22.2, No.157.
Codes of practice	ANSI/ISA RP 12.6 NFPA 70 National Electrical Code 1999 Articles 500 to 505

ATEX directives. There are two new approach directives which will determine the acceptability and use of electrical apparatus in hazardous atmospheres within the European Economic Area for the forseeable future.

The 100a directive lists essential safety requirements for all types of apparatus in both gas and dust atmospheres. It categorises apparatus according to a fault count as indicated in the table for surface industry gas atmospheres and requires some additional marking. Until June 30th 2003, the 100a directive is an optional directive becoming mandatory after that date.

The 137 directive covers the installation requirements for apparatus in hazardous areas.

Fundamentally it requires a risk analysis approach usually using the conventional area classification technique but taking some other factors into consideration. It will become mandatory on the same date as the 100a directive.

Intrinsic safety is a system concept involving safe- and hazardous-area equipment, usually communicating through a separate IS interface. The rules governing how these instruments and devices may be interconnected and installed are similar (though not identical) in all countries and are outlined below. IEC terminology is used for simplicity throughout but the notes apply also to the USA and Canada.

In the safe area. Electrical 'apparatus' connected to the safe-area terminals of a certified IS interface device need not be certified provided only that:

a) It is not powered from and does not contain any source of potential exceeding the value specified on the certificate (250V rms or dc with respect to earth for all MTL equipment).
b) A double-wound transformer or other isolating device prevents multiple earthing of the neutral lead if the equipment is mains powered. The isolation may be provided in the safe-area apparatus or in the interface.

The IS interface ('associated apparatus')

Since the IS interface protects the hazardous-area installation, all interface devices must be certified and properly installed.
a) They must be certified as suitable for connection into the relevant zone and gas group.
b) They must be suitably protected against the ingress of foreign bodies. All MTL interface devices are protected to at least IP20 for use in clean, controlled environments.
c) If installed in a hazardous area, they must be protected by an appropriate enclosure, eg, flameproof or pressurised for Zone 1.
d) They must be used within the limits of ambient temperature for which they are designed and certified.
e) Shunt-diode barriers must be suitably earthed to the equipotential bonding system for the plant via an insulated and identified conductor having not more than 1W resistance. Duplicate conductors are recommended for reliability and to facilitate routine testing. In the UK they are usually connected to the neutral point of the electrical supply, in Germany to the potential-equalising conductor for the plant, in the USA and Canada to a designated ground electrode, connected to the power system ground.
f) Except in rare circumstances, isolating barriers do not require an IS earth except for bonding of screens.
g) A key to the system documentation for the protected circuits should be provided at the interface.

Simple apparatus

a) 'Simple apparatus' such as thermocouples, resistive sensors, LEDs and switches may be employed in a hazardous area without certification provided that it does not generate or store more than 1.5V, 100mA and 25mW. The USA uses a voltage restriction of 1.2V.
b) The surface temperature of simple apparatus under normal or fault conditions must not exceed the ignition temperature of the gas, subject to the following very valuable exception.
c) Because the ability of hot surfaces to cause ignition depends on their size, simple apparatus having a surface area of not less than 20mm^2 will be classified T4 when the matched output power of the interface device does not exceed:

1.3W into 40°C ambient
1.2W into 60°C ambient
1.0W into 80°C ambient

The 1.3W/40°C element of this European dispensation is now becoming accepted in the USA and Canada. All MTL isolating interface devices and the great majority of MTL shunt-diode barriers allow a T4 classification for simple apparatus. Switches and junction boxes dissipate no power and are normally classified T6.

Intrinsically safe apparatus

a) All 'energy-storing' apparatus employed in a hazardous area must be designed to prevent the energy causing an ignition and be certified as intrinsically safe for installation in the relevant zone, gas group and gas ignition temperature.
b) It must be used within the ambient temperature limits for which it is designed and certified.

The entity concept. All countries now accept and operate a modular approach whereby users can assemble their own simple IS systems without reference to any certifying authority. Europe for many years has worked on the basis that 'simple systems' do not require individual certification, provided that the parameters of the constituent items make it 'unambiguously clear' that the system is IS.
More recently the USA has defined the 'entity concept', whereby combinations of apparatus are considered safe provided that the maximum output voltage and current of the interface device do not exceed the maximum permitted input voltage and current for each item of hazardous-area apparatus.

This modular approach provides great flexibility for the majority of applications.

Certain complex systems, such as those using non-linear supplies, require special consideration.

Hazardous-area circuits

a) IEC 60079-14 requires that all hazardous-area circuits protected by shunt-diode safety barriers must be capable of withstanding a test voltage of 500V rms to earth. Cable conductors must be insulated to a thickness of at least 0.2mm. This is to reduce the probability of sparks due to earth faults when there are differences in earth potential.
b) Isolating barriers permit single earthing of a circuit. The cables must still be insulated to prevent multiple earths.
c) In all countries, multicore cables may be used provided that they contain only IS circuits and that these circuits are not interconnected unless specifically permitted. Circuits are regarded as separate if each conductor is insulated to a thickness of at least 0.2mm (IEC) or 0.25mm (USA & Canada) and the cable is protected against damage. Any overall screen must be insulated and earthed at one point only, and there is a further requirement that no circuit shall have a peak voltage exceeding 60V. The maximum 'cable parameters' specified in the certificate for the interface device must not be exceeded by the cable together with any residual capacitance and inductance of the hazardous-area equipment (usually negligible).
d) Ordinary (safe-area) instrumentation cables may be used, and in practice the cable parameter limitation seldom creates a problem. If the electrical parameters of the cable are unknown it can be assumed that the capacitance, inductance and L/R ratio will not exceed 200pF/m, 1µH/m and 30µH/W respectively.
e) IS circuits must be suitably identified.
f) Surge suppression devices may be introduced if adequately documented.

ATEX categories for surface industry (II) gas atmospheres (G)

ATEX category	No. of faults for failure	Zone of use	Acceptable IS category
II 1 G	3	0, 1, 2	ia + additional II 1G
			requirements
II 2 G	2	1, 2	ia or ib
II 3 G	1	2	ia or ib