Whitepaper

Specifying Temperature Sensors for Hazardous Areas

The manufacture of petroleum products, paint, and many chemicals can lead to the release of flammable gases. When these gases accumulate in enclosed areas, a single electrical spark can ignite a disastrous explosion.

Proper selection, installation, and maintenance of electrical devices will prevent such occurrences; but many specifiers experience confusion when designing for hazardous atmospheres. For example, what is the difference between explosionproof, intrinsically safe, and nonincendive equipment? How do you distinguish between the various types of hazardous (or classified) areas? Who decides whether an instrument can be safely installed in a particular area, and what is the basis of that decision?

This application aid will attempt to clarify these issues with respect to temperature sensors and transmitters.

Classification of Hazardous Areas

A hazardous area exists when the following three conditions are met:

1. Presence of flammable liquids, gases, vapors, combustible dust, or ignitable fibers or flyings in ignitable concentrations.
2. Sufficient source of air or oxygen to support combustion.
3. Source of ignition (e.g., electrical equipment, mechanical equipment capable of producing a spark, surface whose temperature exceeds the autoignition temperature of the flammable material).

Typical hazardous areas include petrochemical plants, spray finishing areas, aircraft hangars, grain elevators, flour and feed mills, spice, sugar, and cocoa processing plants, coal mines, textile mills, dry cleaning facilities, and plants that create sawdust or flyings, to name a few.

When constructing or modifying a potentially hazardous area, consult local authorities (e.g., Fire Marshal) for building and electrical requirements. Fire codes can differ between countries or, to a lesser extent, even from state to state.

Hazardous areas are classified using two basic parameters: first, the type of flammable material; second, the probability that a flammable material is present.

Division System

The Division system, used primarily in the United States under the auspices of the National Electrical Code (NEC), divides flammable materials into three classes: gases, dusts, and fibers. Gases and dusts are subdivided into groups with similar explosive potential. Table 1 lists some typical materials found in each category, in descending order of flammability.

Class I: Flammable gases and vapors	**Group A:** Acetylene
	Group B: Hydrogen, butadiene, ethylene oxide, propylene oxide
	Group C: Ethylene, coke oven gas, diethyl ether, dimethyl ether
	Group D: Propane, acetone, alcohols, ammonia, benzene, butane, ethane, ethyl acetate, gasoline, heptanes, hexanes, methane, octanes, pentanes, toluene
Class II: Combustible dusts	**Group E:** Metal dust
	Group F: Coal, coke dust

	Group G: Grain, plastic dust
Class III: Combustible flyings and fibers	Wood flyings, paper fibers, cotton fibers

Table 1: In addition to classifying types of hazardous materials, the area is defined by the probability that those materials are present (Table 2).

Division 1	Areas where hazardous materials may be present under normal operating conditions
Division 2	Areas where hazards arise only as the result of leaks, ventilation failure, or other unexpected breakdowns.

Table 2: Division 2 areas have a low probability of danger. Only a mishap such as a spill or equipment failure can create a hazard. As a rule of thumb, the probability of the presence of explosive materials must be less than 1% for an area to be assigned to Division 2. Even so, equipment that poses a constant threat of sparks still requires enclosures similar to those used in Division 1, and many installers use Division 1 equipment throughout Division 2 areas to be on the safe side.

Zone System

The International Electrotechnical Commission (IEC) has developed the Zone system, described in their specification IEC 60079. It is gaining acceptance worldwide with minor differences between countries. The United States recognizes the Zone system in Article 505 of the National Electrical Code (NEC), and uses the designation AEx. Canada has adopted IEC 60079, virtually as written, but generated their own specification E 79. In Europe, the designation is EEx, and it is defined under the CENELEC series of specifications EN50014-EN50039.

The Zone system groups above-ground gases into three groups, and adds a fourth group for underground methane. (In the U.S., underground methane is addressed by the Mine Safety and Health Administration – MSHA.)

Table 3 lists some typical materials found in each category, in descending order of flammability.

Group IIC	Acetylene, hydrogen
Group IIB	Ethylene, coke oven gas, diethyl ether, dimethyl ether, ethylene oxide

Group IIA	Propane, acetone, alcohols, ammonia, benzene, butane, ethane, ethyl acetate, gasoline, heptanes, hexanes, methane, octanes, pentanes, toluene
Group I	Methane (underground)

Table 3: IEC also classifies hazardous areas, based on the probability that hazardous materials are present. Division 1 is essentially divided into Zone 0 and Zone 1, with Zone 0 being areas where hazardous atmosphere is continuously present. Zone 1 is where the hazardous atmosphere is likely present. This allows some cost savings to the installer in many applications, because they only need maximum protection in the Zone 0 area, which is normally more confined than the Division 1 area.

Zone 0	Areas where flammable gas is continuously present, or present for long periods (typically over 1000 hours/year). (Zone 20 for combustible dusts.)
Zone 1	Areas where flammable gas may exist under normal operating conditions (typically 10-1000 hours/year). (Zone 21 for combustible dusts.)
Zone 2	Areas where flammable gas is not likely to occur, and if it does, exists for a short time (typically 1-10 hours/year). (Zone 22 for combustible dusts.)

Table 4

Methods of Protection

Prevention of explosions may incorporate any of three methods: containment (e.g., explosionproof, flameproof), energy limitation (e.g., intrinsically safe, nonincendive, increased safety), and isolation (e.g., purged, sealed). Some installations utilize a combination of these methods for added safety.

Acceptable protection methods for specific risk areas are listed in Table 5.

Containment

The principle of containment is not to prevent explosions, but to contain them inside enclosures from which they cannot propagate to surrounding atmospheres. In the Division system, these enclosures are called explosionproof; and in the Zone system, they are known as flameproof.

Figure 1 shows an explosionproof assembly consisting of an RTD or thermocouple probe, spring-loaded fitting, connection head, and transmitter. If the electrical circuits should produce a spark sufficiently powerful to ignite gases inside the head, the resulting flame has three possible escape paths: around the cover, between the probe and holder, or down the external conduit.

The cover threads are designed to block the first path. The spring-loaded holder has tight tolerances and an extended length to form a long and narrow spark gap between the probe and fitting. This prevents flame propagation down the second path. (The probe/holder assembly meets requirements similar to rotating shafts in explosionproof motors). The third potential escape route, external conduit, is the responsibility of the installer. NEC requires rigid conduit and placement of seals at regular intervals to act as flame stops.

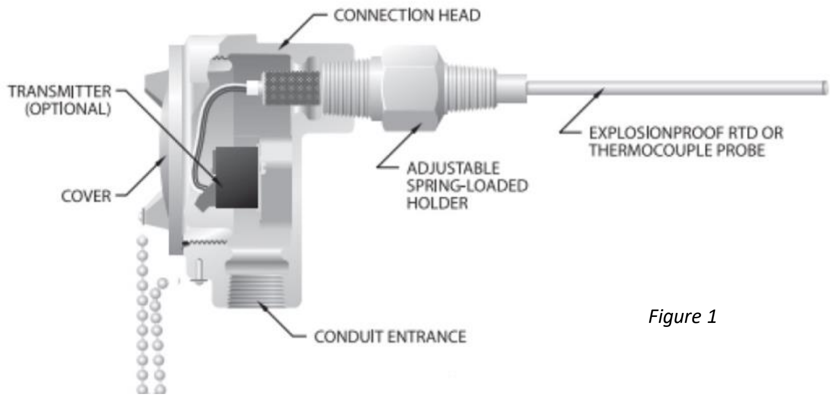

Figure 1

Isolation

Isolation is a technique that prevents potentially explosive atmospheres from coming in contact with potential ignition sources. An approach used for instrument cabinets or, in some cases, entire control rooms is to continually purge the enclosure with pressurized “safe” air and thus prevent the entry of flammable gases. Other methods of isolation include oil immersion, powder filling, and hermetic sealing.

Energy Limitation

For a spark to start an explosion it must have sufficient energy to ignite the gas. Many instruments such as RTD’s, thermocouples, and transmitters function at power levels below the threshold of danger. A signal loop terminating at these devices may be deemed “intrinsically safe” if it is incapable of ignition under four conditions: normal power levels, faults in the control room, faults in the signal line, and faults in the sensor or transmitter.

Intrinsically safe circuits meeting these conditions require no special housings. They offer an increasingly popular and often less costly alternative to explosionproof instrument enclosures.

Because most controlling and recording instruments operate on line power, shorts or opens in their circuitry might release hazardous voltages down signal lines to sensors. An intrinsically safe circuit therefore requires a Zener diode barrier in the signal line to limit the amount of energy entering the hazardous area. Several manufacturers offer barriers for use in thermocouple, RTD, or 4 to 20 mA lines. In the intrinsically safe installation shown in Figure 2, note that the barrier must be located in a safe area and not at the sensing site. There must be no entrance of flammable gases into the safe area.

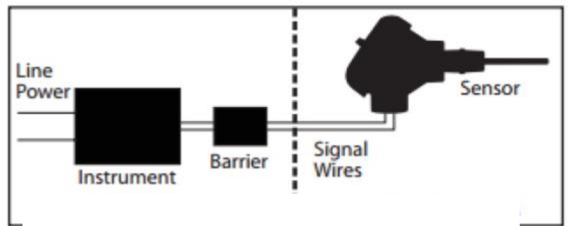

Figure 2

One must also consider the possibility of the transmitter storing energy and releasing it as a spark. The capacitance and inductance of the circuits are calculated assuming various line and instrument faults; if the potential stored energy is sufficiently low the transmitter is considered safe.

NEC (Division system)		CENELEC (Zone system)	
Hazardous area classification (Class I)	**Protection method**	**Hazardous area classification**	**Protection method**
Division 1	Explosionproof Intrinsically safe (2 fault) Purged/pressurized (Type X or Y)	Zone 0	Intrinsically safe (2 fault): “ia”
		Zone 1	Encapsulation: “m” Flameproof: “d” Increased safety: “e” Intrinsically safe (1 fault): “ib” Oil immersion: “o” Powder filling: “q” Purged/pressurized: “p”
Division 2	Hermetically sealed Nonincendive Non-sparking Oil immersion Purged/pressurized (Type Z) Sealed device	Zone 2	Hermetically sealed: “nC" Nonincendive: ”nC" Non-sparking: “nA” Restricted breathing: “nR” Sealed device: “nC”

Table 5

Finally, under both normal or abnormal operating conditions the sensor or transmitter must not produce surface temperatures capable of ignition.

Intrinsic safety certification might cover a matched set consisting of a transmitter and barrier (loop approval), or might cover the transmitter alone (entity approval). The installer must ensure that the entity parameters of the transmitter fall within the specified limits of the chosen barrier.

Nonincendive Devices

Devices classified as "nonincendive" are similar to intrinsically safe devices but do not require barriers to guard against fault conditions. The regulators reason that, in Division 2 (or Zone 2) areas, the probability of two simultaneous faults — a materials spill and an electric overload — is essentially zero.

Any purely passive device, such as an RTD or thermocouple, should be safe for Division 2 areas in normal operation. Most, but not all, transmitters are suitable.

The Zone system also recognizes "increased safety" equipment as an intermediate between intrinsically safe and nonincendive apparatus. This approach uses various constructional safeguards to avoid arcing or sparking components.

Temperature class/code		Maximum surface temperature
Zone system	**Division system**	
T1	T1	842°F (450°C)
T2	T2	572°F (300°C)
	T2A	536°F (280°C)
	T2B	500°F (260°C)
	T2C	446°F (230°C)
	T2D	419°F (215°C)
T3	T3	392°F (200°C)
	T3A	356°F (180°C)
	T3B	329°F (165°C)
	T3C	320°F (160°C)
T4	T4	275°F (135°C)
	T4A	248°F (120°C)
T5	T5	212°F (100°C)
T6	T6	185°F (85°C)

Electrical Apparatus Classification

The classification of an electrical apparatus essentially follows the same scheme as the hazardous area classification in which the apparatus can be used. The Division and Zone systems add a temperature class/code. The temperature class/code (Table 6) indicates the maximum surface temperature of the apparatus, under normal or fault conditions (such as overloads), at an ambient temperature of 104°F (40°C). It ensures that the apparatus will never exceed the ignition temperature of the hazardous material involved.

Equipment complying with ATEX Directive 94/9/EC has a slightly more complicated scheme. In addition to Zone system classification, ATEX requires some additional information. The first parameter under consideration is apparatus location.

Table 6

Group I equipment is used for underground mining operations, dealing primarily with firedamp and combustible dust. Group I equipment is further divided into two categories. Category M1 equipment is required to remain functional in an explosive atmosphere, while Category M2 equipment must be de-energized. Group II equipment — for non-mining applications — is subdivided into three categories. Category 1 equipment is suitable for Zone 0, Category 2 for Zone 1, and Category 3 for Zone 2.

As of July 1, 2003, compliance to ATEX Directive 94/9/EC is mandatory for selling in the European Community.

Ingress Protection

Another important consideration in the selection of electrical equipment is the potential for ingress of dusts, fibers, flyings, and fluids. This can contribute to the reliability of explosion protection.

The Zone system employs the IEC enclosure designation, where the letters "IP" are followed by two digits.

Ingress protection per IEC 60529			
First digit (solids)		**Second digit (liquids)**	
0	No protection	0	No protection
1	Objects > 50 mm	1	Vertically dripping water
2	Objects > 12 mm	2	75° to 90° dripping water
3	Objects > 2.5 mm	3	Sprayed water
4	Objects > 1 mm	4	Splashed water
5	Dust-protected	5	Water jets
6	Dust-tight	6	Heavy seas
		7	Effects of immersion
Table 7		8	Indefinite immersion

The first digit indicates protection against solids; the second digit against liquids (Table 7). The US has a system using the ANSI/NEMA 250 code that is similar but also contains tests for corrosion resistance (Table 8).

Standards and Certification

In theory, there are two types of entities to consider: Standards Agencies and Testing Laboratories.

Standards Agencies

Standards Agencies set the standards for safety equipment. Examples are NFPA (USA), ISA (USA), CSA (Canada), CENELEC (Europe), ATEX (Europe), and IEC (international).

Testing Laboratories

Testing Laboratories determine conformance to standards. Reciprocity between different authorities varies.

In practice, testing labs may publish their own standards for equipment design, especially in the U.S. where labs compete with each other as private-sector enterprises. Factory Mutual (FM) certification carries the most weight in the U.S. but has low recognition elsewhere. European labs are required to comply with ATEX Directive 94/9/EC.

Protective enclosure types per ANSI/NEMA 250	
1	Incidental personnel contact, falling dirt*
2	Same as 1 + dripping liquids and light splashing*
3	Incidental personnel contact, falling dirt; rain, sleet, snow, windblown dust, external ice formation
3R	Same as 3 without windblown dust protection
3S	Same as 3 + external mechanisms operable with ice formation
4	Incidental personnel contact, falling dirt; rain, sleet, snow, windblown dust, splashing water, hose-directed water, external ice formation
4X	Same as 4 + corrosion resistant
5	Incidental personnel contact, falling dirt, airborne dust, lint, fibers, and flyings, dripping liquids and light splashing*
6	Incidental personnel contact, falling dirt; rain, sleet, snow, windblown dust, splashing water, hose-directed water, occasional limited depth submersion, external ice formation
6P	Same as 6 + prolonged limited depth submersion
7	Class I, Div. 1, Groups A, B, C, or D*
8	Class I, Div. 1, Groups A, B, C, and D
9	Class II, Div. 1, Groups E, F, or G*
10	MSHA, 30 CFR, Part 18
12	Incidental personnel contact, falling dirt, circulating dust, lint, fibers, and flyings; dripping liquids and light splashing (without knockouts)*
12K	Same as 12 (with knockouts)*
13	Same as 12 + spray and seepage of water, oil, and noncorrosive coolants*

** indoor use only* *Table 8*

Country	Testing Authority
Austria	TÜV

Canada	CSA (Canadian Standards Association)
France	LCIE
Germany	PTB
Germany	TÜV
Netherlands	KEMA
Switzerland	SEV
United Kingdom	BASEEFA
United Kingdom	SIRA Test & Certification Ltd
United States	FM (Factory Mutual)
United States	UL (Underwriters Laboratories)

For Further Information

Installers should read NEC Articles 500-505 for U.S. installations, CEC Sections 18, 20 and E 79 for Canadian installations, and CENELEC Standards EN50014-50039, and EN60079 for European installations.

Acronyms

ANSI	American National Standards Institute
BASEEFA	British Approvals Service for Electrical Equipment in Flammable Atmospheres
CEC	Canadian Electric Code
CENELEC	European Electrotechnical Committee for Standardization
CSA	Canadian Standards Association
FM	Factory Mutual Research Corporation
IEC	International Electrotechnical Commission
INERIS	Institut National de l'Environnement Industriel et des Risques
I.S.	Intrinsically Safe
ISA	Instrument Society of America
KEMA	Keuring van Elektrotechnische Materialen
LCIE	Laboratoire Central des Industries Electriques
MSHA	Mine Safety and Health Administration
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association

PTB	Physikalisch-Technische Bundesanstalt
SEV	Swiss Electrotechnical Association
TÜV	Technischer Überwachungs Verein
TÜV/PS	Technische Überwachung Verein Product Services
UL	Underwriters Laboratories, Inc.

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