PEPPERL+FUCHS

White Paper

"Requirements for fieldbus equipment installed in a Zone 2 and Division 2 hazardous area environment"

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1 Introduction

The use of Fieldbus in today's world of Process Automation is advancing rapidly. Already, there are simple standardized intrinsically safe concepts available for applications that require fieldbus instrumentation to be installed within Zone 1/0 or Division 1 hazardous areas. These concepts define the maximum allowed values for power, voltage, current, capacitance and inductance for a fieldbus segment under which the stored energy is not capable of causing an ignition of the specified gas. For power supplies, field devices and other components, for example terminators, these maximum values are well defined. The benefits give us a simplified assessment for the interconnection of fieldbus products to a segment and a wide range of compatible fieldbus products to choose from. FISCO and Entity models are the two concepts currently employed for intrinsically safe fieldbus in hazardous area installations.

For Zone 2/Division 2 hazardous locations, these types of simplified concepts do not yet exist. If the user wants to benefit from the same advantages he has with intrinsically safety, i.e. hot working, then the protection method of energy limitation or non-incendive field wiring has to be used. Due to the lack of a standard which defines the maximum safety values for fieldbus equipment, the user has to choose his products in a way that the combination fulfils the Zone 2/Division 2 requirements to form a system.

An investigation is being undertaken to extend the FISCO standard for use in Zone 2 locations. This approach was known for the last two years under the name "FNICO" mainly driven as proprietary solution from a supplier of fieldbus equipment. Due to the low achievable performance in fieldbus installations with this derivative of FISCO, the concept is not seen as a step into a standardized solution for Zone 2/Division 2.

This paper describes the requirements for non-incendive or energy limited fieldbus equipment, which is intended to be used in a Zone 2/Division 2 hazardous area. A special focus on the evaluation of the combination of fieldbus equipment, in different fieldbus topologies, is taken. It is assumed that the reader is familiar with the principles of intrinsic safety, and the international terminology used.

2 Standards

In the USA, the National Electrical Code (NEC), ANSI/NFPA 70 requires special precautions to be taken for equipment construction and installation, in order to minimize the risk of fire or explosion. Equipment used in hazardous areas can follow different protection concepts and must be certified by an authorized body such as FM (Factory Mutual Research Corp.) or UL (Underwriters Laboratories Inc.). Both bodies have released their own standards in which the requirements for construction and testing of equipment used in specified hazardous areas are defined. The following information related to Division 2 (non-incendive circuits) is based on the information taken from the FM standard 3611. The UL standards lead to similar requirements.

The international standard IEC 60079-15 describes the basic requirements for construction and testing Zone 2 (or type "n") equipment. Unfortunately, the requirements are inconsistent and partially contradictory to the requirements of the FM 3611 standard, and the theory of protection methods used in energy limited applications. The IEC 60079-15 does not specify the requirements for Zone 2 apparatus in a consistent way. However, European approval authorities such as TÜV and PTB apply the theory of energy limited protection in the correct manner as described in the following chapters.

In the meantime, an international working group from the International Electrotechnical Commission has been established to rework and restructure the sections related to Zone 2. Pepperl + Fuchs is contributing to this work.

The basic construction requirements for energy limited and non-incendive equipment are the same. One main difference is that non-incendive circuits (FM3611, chapter 7.1.2) require a safety factor of 1.1 (for either voltage or current limit). For an energy limited circuit, the maximum output parameters are determined in accordance with IEC 600079-11 (chapter 26.7.1), which is without any safety factor.

3 Definitions

Even if the protection methods for Zone 2 and Division 2 follow the same principles, the applied terminology is different. Below, the most important terms are explained, and where appropriate, the type of fieldbus equipment, which fits to the standard term, is mentioned.

A Zone 2 or Division 2 hazardous location is defined as a location in which the flammable material is only a hazard because of an abnormal occurrence, and as such, is very unlikely to happen or it occurs infrequently and only for a short time period.

Due to the low probability that a hazardous atmosphere may be present, energy limited and non-incendive circuits are only evaluated under normal operation conditions.

3.1 IEC-60079-15 related terms: (IEC-60079-15-2001, chapter 3)

3.1.1 "Energy limitation", (FM3611 equivalent term "non-incendive field wiring")

Concept applicable to circuits in which no spark or any thermal effect produced in the test condition prescribed in this standard is capable of causing ignition of a flammable gas or vapor.

3.1.2 "Non-sparking device", (FM3611 equivalent term "non-incendive equipment")

Device constructed to minimize the risk of occurrence of arcs or sparks capable of creating an ignition hazard during conditions of use. Normal use excludes the removal or insertion of components with the circuits energized.

3.1.3 "Associated energy limited apparatus", (FM3611 equivalent term "associated non-incendive field wiring apparatus")

Electrical apparatus, which contains both energy-limited and non-energy-limited circuits and is constructed so that the non-energy limited circuit cannot adversely affect the energy-limited circuits.

3.1.4 "Maximum output voltage, U_o", (FM3611 equivalent term "U_{oc}")

Maximum voltage (peak a.c. or d.c.) that can appear in normal operation, including open circuit conditions, at the connection facilities of an apparatus connected to an energy limited circuit.

3.1.5 "Maximum output current, I_o", (FM3611 equivalent term "I_{sc}")

Maximum current (peak a.c. or d.c.) that can be taken in normal operation, including short circuit at the terminals, at the connection facilities of an apparatus connected to an energy limited circuit.

3.1.6 "Maximum external capacitance, C_o", (FM3611 equivalent term "Ca")

Maximum capacitance in an energy limited circuit that can be connected to the connection facilities of the apparatus.

3.1.7 "Maximum external inductance, L_o", (FM3611 equivalent term "La")

Maximum inductance in an energy limited circuit that can be connected to the connection facilities of the apparatus.

3.1.8 "Maximum input voltage, U_i", (FM3611 equivalent term "Vmax")

Maximum voltage (peak a.c. or d.c.) that can be safely applied to the connection facilities of an energy-limited apparatus in normal operation.

3.1.9 "Maximum internal capacitance, C_i", (FM3611 equivalent term "Ci")

Total equivalent internal capacitance of the apparatus containing energy limited circuits which is considered as appearing across the connection facilities of the apparatus in normal operation.

3.1.10 "Maximum internal inductance, L_i" (FM3611 equivalent term "Li")

Total equivalent internal inductance of the apparatus containing energy limited circuits which is considered as appearing across the connection facilities of the apparatus in normal operation.

3.2 FMRC 3611 related terms: (FM 3611-1999, chapter 3)

3.2.1 "Non-incendive field wiring" (IEC 60079-15 equivalent term "energy limited circuit")

Wiring that enters or leaves an equipment enclosure and, under normal operating conditions of the equipment , is not capable, due to arcing or thermal effect, of igniting a specified flammable gas, vapor in air mixture, dust, fibers or flyings. Normal conditions include opening, shorting or grounding the field wiring.

3.2.2 "Non-incendive equipment" (IEC 60079-15 equivalent term "non sparking device")

Equipment having electrical/electronic circuitry that is incapable, under normal conditions, of causing ignition of a specified flammable gas-, vapor- or dust-air mixture of fibers or flying due to arcing or thermal means.

3.2.3 "Associated non-incendive field wiring apparatus" (IEC 60079-15 equivalent term "associated energy limited apparatus")

Apparatus which is either intended to be installed outside the hazardous (classified) location or is supplied by a non-incendive circuit which meets the requirements of this standard but which has connections to non-incendive field wiring circuits.

3.2.4 "Maximum output voltage, V_{OC}" (IEC 60079-15 equivalent term "U_0")

Maximum output voltage (peak a.c. or d.c.) in a circuit that can appear under open circuit conditions at the connection facilities of the apparatus under normal condition.

3.2.5 "Maximum output current, I_{SC}" (IEC 60079-15 equivalent term "I_0")

Maximum current (peak a.c. or d.c.) in a circuit that can be taken from the connection facilities of the apparatus.

3.2.6 "Maximum external capacitance, Ca" (IEC 60079-15 equivalent term "C_0")

Maximum capacitance in a circuit that can be connected to the connection facilities of the apparatus.

3.2.7 "Maximum external inductance, La" (IEC 60079-15 equivalent term "L_0")

Maximum value of inductance in a circuit that can be connected to the connection facilities of the apparatus.

3.2.8 "Maximum input voltage, V_{max}", (IEC 60079-15 equivalent term "Ui")

Maximum voltage (peak a.c. or d.c.) that can be applied to the connection facilities of the apparatus.

3.2.9 "Maximum internal capacitance, C_i" (IEC 60079-15 equivalent term "Ci")

Total equivalent internal capacitance of the apparatus which is considered as appearing across the connection facilities of the apparatus.

3.2.10 “Maximum internal inductance, L_i” (IEC 60079-15 equivalent term “Li”)

Total equivalent internal inductance of the apparatus which is considered as appearing across the connection facilities of the apparatus.

4 Zone 2/Division 2 use in Fieldbus

For fieldbus two major protection methods are used:

- Method 1: “Non arcing” for Zone 2 and “non-incendive” for Division 2.
- Method 2: “Energy limitation” for Zone 2 and “non-incendive field wiring” for Division 2.

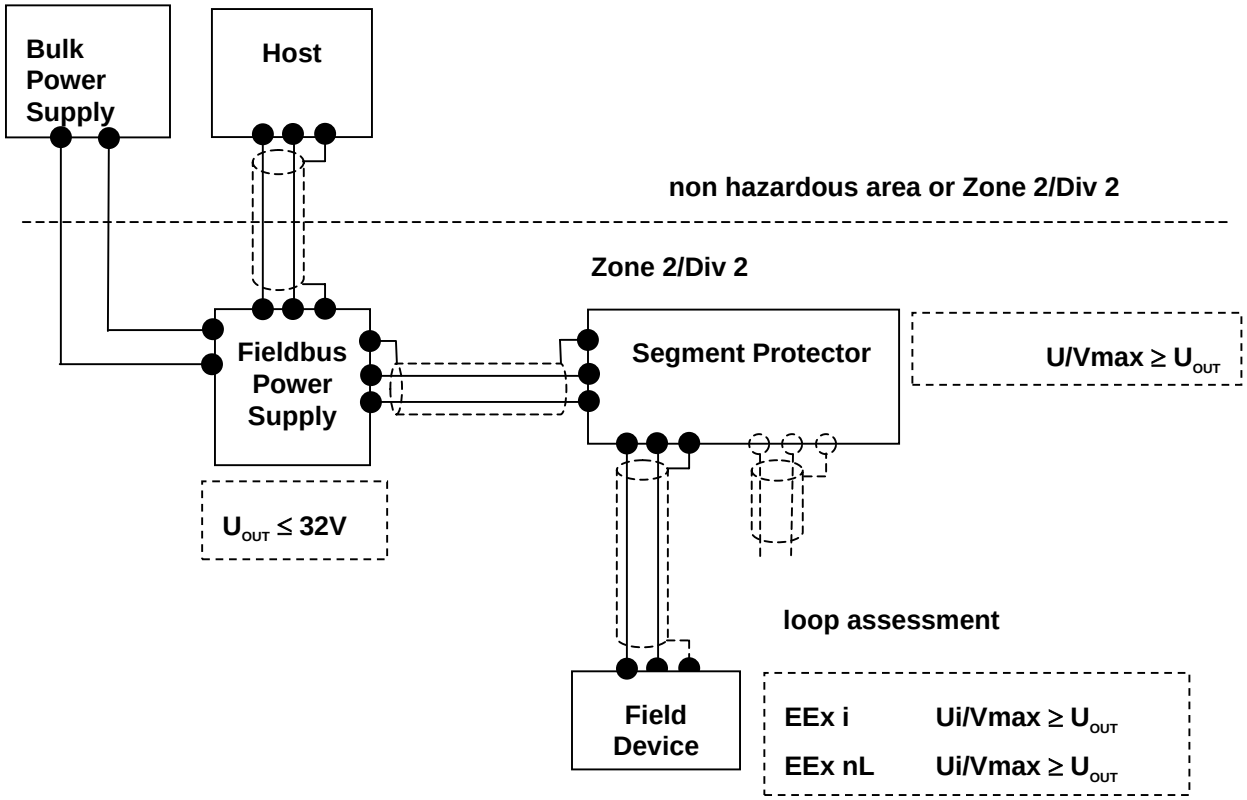
Due to the energy limitation protection, method 2 allows access to any part of the fieldbus wiring which is energized, whereas method 1 does not.

In conjunction with these protection methods, two different types of fieldbus topologies are commonly used, which depend on the customer’s requirements for live maintenance and the type of preferred fieldbus equipment. For the following examples it is assumed that, in addition to a fieldbus power supply, Segment Protectors are employed, which represent a wiring interface between the fieldbus trunk and the spurs to which the field devices are connected. Each spur output is individually short circuit protected (current limited) in a way that a short circuit at the spur will have no functional influence on the trunk and the adjacent spurs.

The equipment has either to be self certified by the manufacturer or certified by a certification authority following the IEC rules. For use in North America, a certificate is always required. The certification or declaration must include all the safety relevant values of the equipment.

4.1 Trunk and spurs, “non arcing” for Zone 2 and “non-incendive” for Division 2.

Fieldbus power on the trunk and spurs is not limited. Field devices and Segment Protectors are located in Zone 2/Div 2 and therefore need to be (self-)certified for non-arcing apparatus or non-incendive equipment. If the fieldbus power supplies are also located in hazardous area Zone 2/Div 2, the same requirements apply. Live maintenance at the trunk or spur level is not allowed without gas clearance. The evaluation of a non-arcing or non-incendive circuit is limited to the maximum voltage of the fieldbus power supply (U_{OUT}) which has to be less than or equal to the maximum input voltage (Uin/Vmax) of the Segment Protector and field devices (FM3611 chapter 7.1.5). Field devices and Segment Protectors following this requirement could be either (self-)certified for non-arcing apparatus/non-incendive equipment, energy limited/non-incendive field wiring apparatus or intrinsically safe apparatus according to Entity or FISCO.



4.2 Trunk “Non arcing” for Zone 2 and “non-incendive” for Division 2, spurs “energy limited” for Zone 2 and “non-incendive field wiring” for Division 2

The outputs of the Segment Protector are classified for energy limited EEx nL or non-incendive field wiring. The trunk is classified non arcing or non-incendive. Due to the unlimited trunk energy, live work at the trunk level is not permitted without gas clearance. However live connect or disconnect at the spur outputs of the Segment Protector and at the field devices is permitted.

The current limitation for the energy limited/non-incendive field wiring spurs is located within the Segment Protector, with the voltage limitation either in the Segment Protector or in the fieldbus power supply. In both cases the voltage limiting circuit has to be evaluated and approved. One common main requirement of the standards is that the components of the limiting circuit must be loaded only with 75 percent of their rated power (IEC 60079-14 chapter 21.8.1, FM3611 chapter 12.2.1).

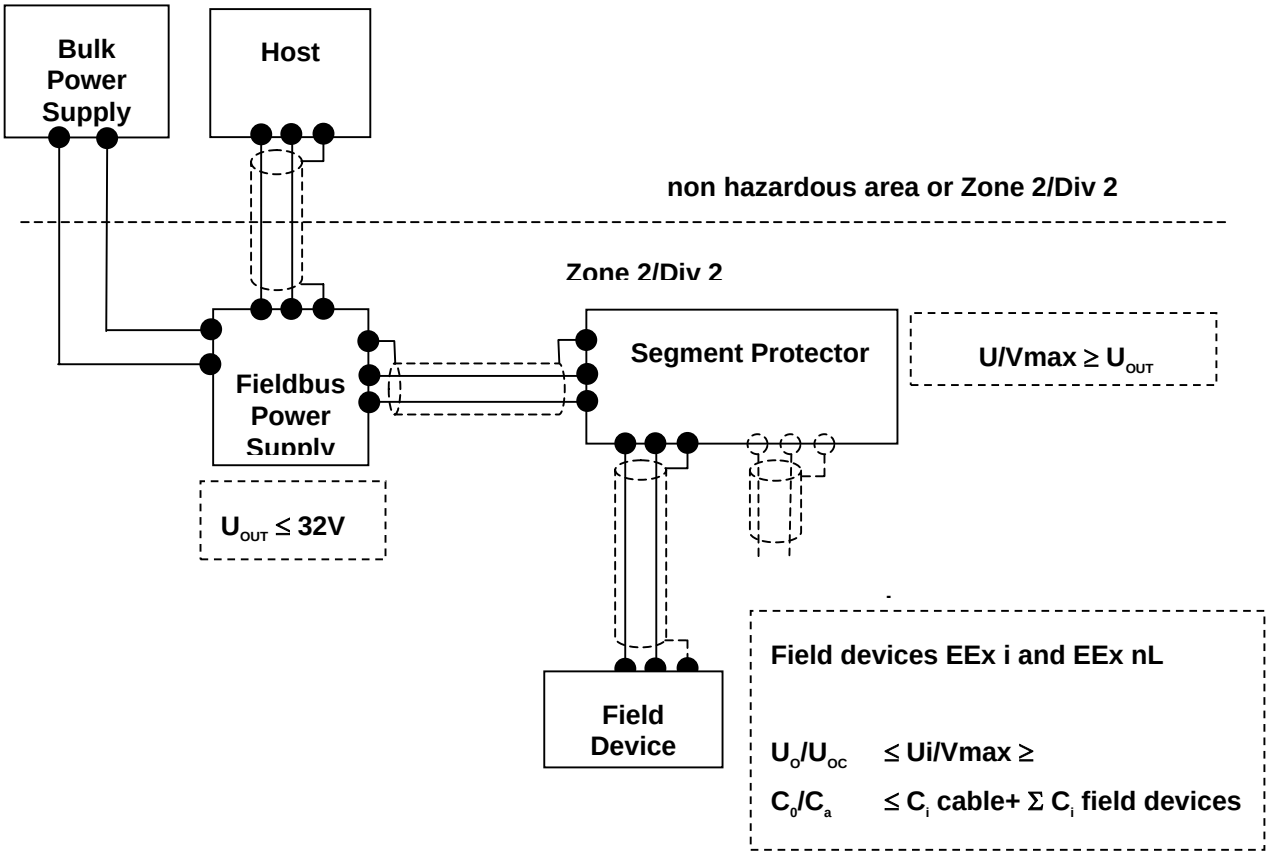
The Segment Protector must be identified with parameters that specify the maximum open circuit voltage (U_0/V_{OC},) the maximum short circuit current ($I_{0,}I_{SC}$) and the maximum allowed capacitance (C_0/C_a) and inductance ($L_{0/}$ L_a).

Passive equipment, such as field devices, not being able to feed energy into a energy limited/non-incendive circuit apart from the energy stored in internal capacitance and inductance, must be identified by the maximum voltage (U_i ,V_{max}), the maximum internal capacitance (C_i) and the maximum internal inductance(L_i). Field devices following this requirement could be either (self-)certified for energy limited/non-incendive field wiring apparatus or for intrinsically safe apparatus according to Entity or FISCO.

The examination of the interconnection of the equipment that follows the Entity concept is defined by the following rules:

V_O, U_{0C} Segment Protector/Power Supply	≤	U_i/V_{max} field device
C_0/C_a, Segment Protector	≤	C_i cable+ Σ C_i field devices
$L_{0/}$ L_a, Segment Protector	≤	L_i cable+ Σ L_i field devices

The short circuit current of the energy limited/non-incendive circuit has no relevance for the evaluation as only one power source is connected to a system. A field device is not considered to take more current than it is designed to take under normal operating conditions because the Zone 2/Division 2 standards do not assume any faults. For the same reason the output power (P_i) that must be considered for I.S. circuits has no relevance for the evaluation of Zone 2/Division 2 installations.



5 How to choose the fieldbus equipment for Zone 2/Division 2

5.1 Field Devices

For intrinsically safe applications, a wide range of existing field device are available. Most of them are certified for use within FISCO and Entity systems.

The maximum safety parameters for FISCO are defined in the IEC60079-27 standard and in the Foundation Fieldbus specification FF-816 FISCO “31,25 kbit/s Physical Layer Profile”.

For Entity, the maximum safety parameters are defined in the Foundation Fieldbus specification FF-816-1.4 “31,25 kbit/s Physical Layer Profile”.

	FISCO	Entity	
U_i/V_{max}	≥ 17,5 V	U_i/V_{max}	≥ 24 V
I_i	≥ 380 mA	I_i	≥ 250 mA
P_i	≥ 5,32 W	P_i	≥ 1,2 W
C_i	≤ 5 nF	C_i	≤ 5 nF
L_i	≤ 10 µH	L_i	≤ 20 µH

This kind of specification does not exist for equipment certified to be used in Zone 2/Divison 2. Each field device vendor defines his own internal specification for the maximum safety values. This sometimes leads to an incompatibility between the existing power supply solutions and available field devices.

One of the biggest advantages of Zone 2/Division 2, when considered against an intrinsically safe system, is the available high power. Customers wish to have a high segment voltage to get the flexibility to support long home run distances between the control room, where the power supply is installed, and the field.

Currently, the range of energy limited/non-incendive field equipment is limited, and customers are forced to use intrinsically safe certified field devices with a maximum voltage of Ui = 24 V (certified according the Entity concept). However an increasing number of instruments become available that provide a certification for Zone 2/Division 2.

Typical safety parameters of these instruments are :

U_i/V_{max} ≥ 32 V

C_i ≤ 5 nF

L_i ≤ 10 µH

Usually, general purpose or intrinsically safe instruments comply with these requirements. Therefore it should be easy for a device manufacturer to obtain an appropriate certificate.

5.2 Power Supply and Segment Protector

As discussed in the previous chapter, two methods exist to limit the voltage of an energy limited or non-incendive circuit. The safety defining limiting circuit may be either designed in the fieldbus power supply or in the Segment Protector. Typical Segment Protectors include a voltage limit protection of U_O/U_{OC} = 32 V. Again, this limits the use to field devices with a $U_i/V_{max} \geq 32$ V, either certified energy limited or non-incendive, which are currently available only in a small number. No further requirement for the fieldbus power supply exists.

The safety values for the spur outputs for such a Segment Protector are:

U_O/U_{OC} = 32 V

$I_{0/}\ I_{SC}$ = 45 mA

C_0/C_a = 120 nF

$L_{0/}\ L_a$ = 0,25 mH

In applications where, due choice reason, Entity certified field devices have to be used, the safety relevant voltage limitation is mostly located in the fieldbus power supply which has a maximum voltage of U_O/U_{OC} = 24 V. Consequentially, the voltage limitation of the fieldbus power supply has to be either self certified by the manufacturer or certified by a certification authority in accordance with IEC 60079-14 chapter 21.8.1, FM3611 chapter 12.2.1. The main requirement is that components of the limiting circuit must be loaded only with 75 percent of their rated power.

The safety values for the spur outputs at the Segment Protectors are:

U_O/U_{OC} = 24 V

$I_{0/}\ I_{SC}$ = 45 mA

C_0/C_a = 120 nF

$L_{0/}\ L_a$ = 0,25 mH

5.3 Fieldbus cable

Typical Type A fieldbus cables have a nominal value for capacitance and inductance of approximately C= 65 nF/km and L= 0,68 mH/km respectively. The energy limited/non-incendive field wiring rated spurs of a Segment Protector allow maximum values of C_0/C_a= 120 nF and $L_{0/}\ L_a$= 0,25 mH. The maximum values of the field device connected to a spur is C_i= 5 nF and L_i= 20 µH. Therefore, the maximum possible spur cable length using a fieldbus Type A cable would be ~ 370 meters. Never the less, the fieldbus standard limits the maximum allowed cable length to 120 meters at a spur.

6 Conclusion

For Zone 2 energy limited or Division 2 non-incendive field wiring applications, cost effective solutions are available using a ‘higher power trunk’ with non-arcing type protection for Zone 2, or non-incendive type protection for Division 2. No ‘hot working’ is permitted on this part of the fieldbus segment.

Using Segment Protectors in the field will result in higher segment availability, as a short on any of the spurs has no influence on the segment.

The spur outputs are energy limited for Zone 2 and non-incendive for Division 2. Hot work is permitted at the spur level if the field devices are certified as energy limited or non-incendive field wiring apparatus with the safety values U_i/V_{max}, C_i, L_i .

Currently, the field devices that are suitable for use in Zone 2 or Division 2 have different safety relevant maximum voltages, varying between 24 V and 32 V. Although no standard exists which defines the maximum voltage for a device, demands for field devices with a U_i/V_{max}= 32V will force manufacturers to design devices to meet the upper limits of 32 V rather than the lower limit of 24 V.

References

- Approval Standard FMRC 3611, “Non-incendive Electrical Equipment for Use in Class I and II, Division 2, and Class III Division 1 and 2, Hazardous (Classified) Locations”
- UL 1604, Electrical Equipment for use in Class I and Class II, Division 2 and Class III Hazardous (Classified) Locations.
- ISA-TR12.06.01-1999, “Electrical Equipment in a Class I, Division 2/Zone2 Hazardous Location
- ANSI/ISA S12.12, Electrical Equipment for Use in Class 1, Division 2 Hazardous (Classified) Location
- International Standard IEC 60079-15-2001, “Electrical apparatus for explosive gas atmospheres- Part 11: Intrinsic safety “i”.”
- International Standard IEC 60079-11-2001, “Electrical apparatus for explosive gas atmospheres- Part 15: Type of protection “n”.”
- International Standard IEC 60079-27-2005 FDIS , “Fieldbus intrinsically safe concept (FISCO)“.
- Foundation Fieldbus specification FF-816, “31,25 kbit/s Physical Layer Profile