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INTRODUCTION TO INTRINSIC SAFETY

Intrinsic safety (I.S.) is a method of protection based upon limiting both electrical and thermal energy under normal and abnormal conditions that can flow in the hazardous area. This limited energy will never be enough to ignite the explosive atmosphere. Due to the limited amount of energy that can flow in this type of circuit, field devices like pressure transmitters, level sensors, proximity sensors, solenoids, and other I.S. rated field devices are the typical application used for I.S. installations. With an I.S. installation, there is no need of any special flameproof or pressurized enclosure design to be installed in the hazardous area because the method of protection relays on the limitation of energy and not on mechanical protection.

On an I.S. installation, it is imperative for a supply device to form an electrical loop by connecting to a field device (load) through the wires. Therefore, to create an I.S. loop, it is essential for an I.S. field device to be connected to an I.S. associated apparatus such as zener barriers or galvanic isolator barriers. It is important to perform energy calculations to confirm that an I.S. loop has been created.
1. BENEFITS OF I.S. SYSTEMS

When I.S. technology and installations are used, a hot swap of devices in their live condition is safe and allowed by the procedures. This means the hot work is possible and no plant down time is required to perform maintenance tasks during the operation.

The wiring and termination used in the I.S. loop do not need to carry their own hazardous area certification to ensure safety, as the safety of the loop relays on the I.S. barrier and I.S. field device. This means that general-purpose wiring is allowed in this type of I.S. loop, and these wires and connectors can be industrial in type.

2. I.S. LOOP COMPONENTS

In the next few sections, we will define each component in an I.S. loop and energy calculations accordingly.

A typical I.S. system consists of an associated apparatus, intrinsically safe electrical apparatus, and interconnecting wiring. When the system is properly installed, the incidence of spark-causing conditions such as electrical equipment failure, wrong wiring, overvoltage application to the circuit, or the grounding, shorting or open-circuitry of any lead(s) in the presence of a hazardous mixture shall not be of sufficient energy to cause ignition.

The standards relative to intrinsic safety include three types of apparatus:
- Associated apparatus
- Intrinsically safe electrical apparatus
- Simple apparatus

2.1 ASSOCIATED APPARATUS

An associated apparatus is a device that has I.S. circuits on one side and non-I.S. circuits on the other. These devices connect their I.S. circuit to the field device circuits. The associated apparatus limits the power to intrinsically safe energy levels allowing the device to be introduced into the hazardous location. Several associated apparatus options are available. R. STAHLE offers Remote I/O with built-in galvanic isolator barriers and Foundation Fieldbus with built-in galvanic isolator barriers, galvanic isolator barriers (also known as isolator barriers) and safety zener barriers (also known as zener barriers).

All associated apparatuses will have a set of values defined as entity parameters (safety values) and operational parameters (nominal values). Entity parameters shall be considered the highest amount of energy that the associated apparatus can pass to the hazardous area under normal and abnormal conditions. Operational parameters can be considered the amount of energy that has to be provided for power-up and operation of the electrical apparatus (field devices). An associated apparatus always requires a certification by the Authority Having Jurisdiction (AHJ).

2.2 INTRINSICALLY SAFE ELECTRICAL APPARATUS

Field devices being used in an I.S. application need to have a third-party certification that rates them as I.S. field devices. Such devices include transmitters, positioners, solenoid valves, among others. We still need to connect a simple apparatus to an associated apparatus to create an I.S loop. The field devices are designed and built as per I.S. circuit standards. These devices have to be submitted to a Nationally Recognized Test Lab (NRTL) and tested against the I.S. standard of that jurisdiction. Once the device passes the test, the NRTL will provide the paperwork identifying the specific manufacturer, model number, and wiring requirements. In North America, control drawings are part of the NRTL certification package and provide valuable information about installation and wiring conditions required to comply with the code.

Just like the associated apparatus, the I.S. field device will have a set of values defined as entity parameters (or safety data) and operational parameters. Entity parameters shall be considered the highest amount of energy that can be received in normal and abnormal conditions and will not cause a spark or heat release sufficient enough to react with the explosive atmosphere. Operational parameters can be considered the amount of energy required for the field device to power-up and work during normal operation.

2.3 SIMPLE APPARATUS

There are just a handful of field devices that can be used in an I.S. loop and do not need to be certified by a NRTL. The NEC® defines them as simple apparatus in section NEC® 504.2 as devices that cannot generate or store more than 1.5 V, 100 mA, 25 mW, and 20 µJ. Some examples include mechanical switches, RTDs, thermocouples, and load cells. It is necessary to confirm with the manufacturer of the device that such a device is considered a simple apparatus. Assumptions should not be made. Since these devices cannot contribute energy of sufficient magnitude to ignite a hazardous mixture under a fault condition, they can be connected to a certified I.S. circuit via an associated apparatus. The evaluation by a testing agency includes the connection of a simple apparatus to an I.S. circuit from an associated apparatus.
3. INTRINSIC SAFETY LOOP VERIFICATION

Associated apparatuses are evaluated to establish the maximum energy levels that can be discharged through their circuits under fault conditions. These faults include open or short circuits and grounding, and grounding of the intrinsically safe leads. The information is represented in the form of entity parameters (safety data) and consists of some combination of the following values:

- Open circuit voltage, \( V_{oc} (U_o) \) or \( V_i \)
- Power transfer, \( P_o \)
- Short circuit current, \( I_{sc} (I_o) \) or \( I_i \)
- Allowable external inductance, \( L_e (L_o) \)
- Allowable external capacitance, \( C_e (C_o) \)

Those products designed to be connected to an intrinsically safe circuit, such as transmitters, positioners, etc., are evaluated for the maximum voltage and current they can withstand before internal component failures begin, resulting in an excessive buildup of heat and subsequent ignition of the surrounding hazardous fuel-air mixture. They are also evaluated for the amount of internal energy-storing components (capacitance and inductance) that may be discharged under predefined fault conditions.

Under the entity concept, the intrinsically safe electrical apparatus will be assigned entity parameters that, when properly matched to those of an associated apparatus, will constitute an intrinsically safe system (I.S. loop). Such values include the following:

- Maximum voltage, \( V_{max} (U) \)
- Maximum current, \( I_{max} (I) \)
- Maximum power, \( P_{max} \)
- Total unprotected capacitance, \( C_i \)
- Total unprotected inductance, \( L_i \)

3.1 COMPARISON OF ENTITY PARAMETERS

An I.S. loop is created when the following rules are applied:

<table>
<thead>
<tr>
<th>I.S. Field Device</th>
<th>Cable</th>
<th>Associated Apparatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{max} (U) )</td>
<td>( \geq )</td>
<td>( V_{oc} (U_o) )</td>
</tr>
<tr>
<td>( I_{max} (I) )</td>
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<td>( I_{sc} (I_o) )</td>
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<tr>
<td>( P_o )</td>
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<td>( P )</td>
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<tr>
<td>( C_i )</td>
<td>( + C_{cable} \leq )</td>
<td>( C_e (C_o) )</td>
</tr>
<tr>
<td>( L_i )</td>
<td>( + L_{cable} \leq )</td>
<td>( L_e (L_o) )</td>
</tr>
</tbody>
</table>

Entity parameters can be found in the NRTL documentation of the associated apparatus as well as on the I.S. field device. Certain other considerations, such as certified temperature range or electrostatic additional protection methods, often need to be addressed. Given these special considerations, we always encourage reading the instruction manuals, reviewing the product certifications, and referring to the control drawings.

3.2 INTERCONNECTING WIRING

Interconnecting wiring can store energy that could, under normal or fault conditions, at some point react with an explosive atmosphere. Consequently, interconnecting wiring between the associated apparatus and I.S. field device (or simple apparatus) needs to be taken into consideration when an I.S. loop is built. If available, the actual capacitance and inductance values for the specific wires being used should be referenced. If these are not available, values of 60 pF/foot for capacitance per wire pair and 0.2 \( \mu \)H/foot for inductance are accepted and may be used for the cable length calculation.

4. INSTALLATION OF INTRINSICALLY SAFE SYSTEMS

With the correct associated apparatus (interface) selected, the installation phase may begin. In general, the requirements for the installation of intrinsically safe systems are more flexible than those of explosionproof or purged systems. The user should have good knowledge of the National Electrical Code with specific focus on Articles 504 and 505, which deal with intrinsically safe systems. Since there are differences in the equipment provided by different companies, R. STAHL recommends that the user reviews the installation requirements. This can vary among different locations based on local codes and enforcement. Another valuable source of information is the ANSI/ISA RP-12.6 document available through the ISA organization. The user should also refer to the control drawings supplied by the manufacturer of both the associated and the intrinsically safe apparatuses.

The associated apparatus itself is normally installed in the nonhazardous location using general-purpose enclosures or panels. However, if space is not available in the safe area or physical plant layout requires installation at the hazardous location, rated associated apparatus can be used and installed in hazardous areas, such as our INTRINSPAK and ISPac for Class I, Division 2 applications and IS1+ Remote I/O for Zone 1, Class I, Division 1 & 2.
The wiring between the associated apparatus and the intrinsically safe apparatus may be installed using any of the protection methods suitable for unclassified locations, with the exceptions noted below. For example, it is acceptable to use PLTC cable run in the open cable trays or raceways, along with general-purpose junction boxes.

1. Intrinsically safe wiring not run in raceways or cable trays shall be separated and secured from non I.S. wiring by at least 2 inches (50 mm). Exception: when Type MI or MC cables are used and properly grounded.

2. Intrinsically safe wiring shall never be placed in raceway or cable trays with nonintrinsically safe wiring unless they are separated by at least 2 inches (50 mm) using tie downs, grounded metal partitions, or approved insulating partition.

3. Intrinsically safe wiring in enclosures shall be separated by at least 2 inches (50 mm) and secured to prevent inadvertent contact. Wiring ducts may be used provided they maintain a 3/4 inch (19 mm) separation between intrinsically safe and nonintrinsically safe wiring.

4. Different intrinsically safe circuits shall be run in separate cables or separated by either a grounded shield or insulation with a minimum thickness of 0.01 inches (254 μm).

5. Intrinsically safe wiring shall be identified as such with labels placed no more than 25 feet (7.62 m) apart. Terminals shall be identified as well.

6. The color light blue is recognized internationally as identifying intrinsically safe wiring. It is recommended that cables, terminal blocks, raceways, cable ducts, and junction boxes entries be light blue in color.

7. Gastight seals shall be used where intrinsically safe wiring transitions hazardous location boundaries.

8. Intrinsically safe, associated apparatus, cable shields, enclosures, and raceways (metal) shall be grounded in accordance with the requirements of Section 250 of the NEC®.

9. Nonhazardous location electrical equipment must not contain a source voltage greater than 250 V unless sufficient means have been employed to prevent the shorting of a source voltage greater than 250 V onto the intrinsically safe terminals of the associated apparatus.

10. As all wiring contains stored energy (capacitance and inductance), all conductors must be considered when determining the length of intrinsically safe circuits. When available, the actual values of capacitance and inductance for the specific wire being used should be referenced. If these are not available, values of 60 pF/foot for capacitance per wire pair and 0.2 μH/foot for inductance are accepted and may be used.

11. To ensure correct operation of a zener barrier installation under fault conditions, the system must have an insulated, properly maintained, independent, low impedance I.S. ground connection. This is a connection from the barrier busbar to the star point (A) of the incoming power supply through which no supply system current flows.

12. The ground conductor of a zener barrier must be < 1 Ohm minimum 12 AWG (4 mm²) and connected using shakeproof terminals. It should also be secure, visible, clearly identified and accessible for routine inspections and maintenance. Additional information is available on ISA 12.6.

13. To prevent potential differences on a zener barrier and ensure correct operation under normal conditions, it is also advisable to connect the barrier busbar to the common / 0 V (B) of the equipment in the nonhazardous location.

14. In the hazardous location, all cables should be grounded at one point only, and we recommend that this be at the barrier busbar.

15. Where shielded cables are used, they must be bonded to ground and taped back. For installation options, please refer to the ISA 12.6 standard.
5. INTRINSIC SAFETY INTERFACE SELECTION

Once the instrumentation/field devices have been specified as intrinsically safe, the selection of an associated apparatus must be done accordingly. R. STAHL offers four technologies: zener barriers, isolator barriers, Remote I/O, and Foundation Fieldbus.

Zener barriers and isolator barriers use an approach known as point-to-point (or classic approach). Here, a loop starts at the DCS/PLC card and ends at the field device. Typically, each loop has a pair of wires and extends from the safe area to the hazardous location.

A Remote I/O uses an approach known as point-to-bus. Here, a DCS/PLC has a communication card (H1, Modbus TCP, Ethernet IP, etc.) and a digital bus runs from the safe area into the hazardous location where a Remote I/O station or field device coupler provides individual connections to the field devices. This approach has many advantages over point-to-point. The main four advantages are:
1. Minimizing the wiring
2. Minimizing the installed equipment hence faster commissioning and cost-efficient solutions
3. Providing diagnostic information of wiring and hardware
4. Reducing engineering work due to digital communication and the number of cables and terminations

5.1 ZENER BARRIERS

This is one of the first types of associated apparatus created. It is a passive device with essentially three safety components – a fuse, a resistor and zener diodes. These components have specific ratings and ensure that high amounts of energy cannot flow into the hazardous area.

Zener barriers are cost-effective solutions. They are also very compact devices and do not require an external source of power to work (loop powered). However, due to the fact that the devices are passive, they are more susceptible to outside factors like noise. Also, the built-in resistor creates a voltage drop that needs to be taken into consideration when selecting the right zener barrier for the application (operational parameters). Lastly, all zener barriers need to be grounded. This ground is a critical part of the I.S. protection and must be performed in accordance with the standards ISA 12.6, CEC and NEC® 504.5 Zener barriers are still popular for some applications that require the passive element approach such as load cells and some sensors that work with voltages lower than 24 V (12 V applications, for example) or AC voltage. They are also required for sensors that provide a frequency closer to 100 kHz.

R. STAHL family of zener barriers is known as INTRISPAK and is explained in Chapter 8 of this catalog.
5.2 ISOLATOR BARRIERS

These associated apparatus not only provide I.S. power into the field, but can also serve as signal conditioners. These are considered active devices and have several electronics on it to achieve the conditioning of the signal as well as the I.S. power. These devices are less susceptible to noise and do not require a dedicated ground connection. They do require an independent source of power, however.

Isolator barriers are slightly larger than zener barriers in size. However, nowadays it is easy to find dual channel isolator options, which reduce the real state footprint. External power is still required, but certain accessories have been developed to reduce the wiring requirements for this external power source. Lastly, selecting an isolator barrier is easier than a zener barrier, as these are designed specifically for classic applications, such as analog inputs, analog outputs, digital inputs, digital outputs and temperature measurements. There are other types of isolator barriers available for serial and Ethernet based bus communication.

The R. STAHL family of isolator barriers is known as ISpac. Refer to Chapter 7 for product information.

5.3 REMOTE I/O WITH BUILT-IN ISOLATOR BARRIERS

This type of associated apparatus not only provides an I.S. signal in the field, but can also be installed in hazardous location areas closer to field devices, even in Class I, Division 1 classified areas. When this concept is used, both wiring and energy loss will be significantly reduced. In addition, when the R. STAHL Remote I/O solution is used, no flameproof or purged enclosures are required. A Remote I/O station will have I/O cards with built-in isolator barriers and a gateway that digitalizes the information from the I/O cards and sends it via a communication bus (like Ethernet IP or Profinet DP) to a communication card on the PLC/DCS. Besides reducing wiring and minimizing the space in the safe area, the Remote I/O stations also provide preventive maintenance diagnostic information.

The selection of the I/O cards is very simple as the cards are designed specifically for classic applications, such as analog inputs, analog outputs, digital inputs, digital outputs and temperature inputs. Also, the cards are multichannel and multifunctional, which means the channels can be independently configured for inputs or outputs and in some cases even for digital or analog (restrictions may apply for combinations).

The R. STAHL family of Remote I/O is known as IS1+. Refer to Chapter 6 for product information.

5.4 FOUNDATION FIELDBUS WITH BUILT-IN ISOLATOR BARRIERS

This type of associated apparatus is required only when the DCS communication card is an FF H1 and the field devices are known to be FF certified as well as I.S. certified.

R. STAHL follows the high power trunk concept in which the intrinsic safety loop starts at the spur. The system consists of its own FF power supplies, as well as the couplers, which can be rated for hazardous locations such as Class I, Division 2 installations with or without I.S. outputs.

The R. STAHL family of Foundation Fieldbus is known as ISbus. Refer to Chapter 9 for product information.
6. ENERGY LIMITING METHODS OF PROTECTION FOR DIVISION 2

Under the protection technique concept known as energy release limitation, there are two approaches — intrinsic safety and nonincendive. The two approaches are similar in basic principle but have two major differences.

The first difference is that nonincendive circuits and devices are only evaluated under normal conditions so no faults need to be considered. Any equipment that meets the criteria for nonincendive can only be used in Class I, II or III, Division 2 locations. On the other hand, I.S. equipment can be used in Class I, II, III, Division 1 and 2 based on certification.

The second difference is that the connection to an associated apparatus and the entity parameter analysis is not required in all cases (refer always to the field device control drawing for confirmation). This depends on the way in which the field device is certified. A concept we will introduce in the next section constitutes the difference between nonincendive field wiring and nonincendive equipment.

An additional difference between intrinsic safety and nonincendive is that live maintenance is not permitted for nonincendive installations.

6.2 NONINCENDIVE FIELD WIRING (NIFW)

A concept called nonincendive field wiring methods (NIFW) also exists, that is different from nonincendive field devices. As with intrinsic safety, NIFW concept can be applied with a cable that is suitable for use in nonhazardous locations. The associated nonincendive field wiring apparatus and the nonincendive field wiring field device both have parameters associated with them which are shown on the control drawing and must be installed per the control drawing.

At this point, the entity concept for both intrinsic safety and nonincendive field wiring looks the same, but yet it is not. In both applications, a controller controls either the voltage or current or both values. For NIFW, the respective non-controlled value needs to be greater than or equal to that supplied by the associated nonincendive field wiring apparatus (see the above table). For example, when it is connected to a 4/20 mA transmitter, this unit controls the current, so the current parameter does not need to be evaluated. In these instances, the control drawing should be checked to find details of the connections permitted.

Disconnection in the classified area when energized is not acceptable.

6.1 NONINCENDIVE EQUIPMENT

For equipment to be listed as nonincendive it has to be assessed and tested under normal conditions by a third-party agency and certified as a nonincendive field device. The assessment and testing for thermal conditions is also conducted under normal conditions. Normal conditions include extremes of supply rating, ambient temperature rating and operator adjustments. Nonincendive devices are rated for Class I, II or III, Division 2.

If the field device has been approved as nonincendive equipment, it can be installed in a Class I, Division 2 area and be connected to a piece of equipment in the nonhazardous location that has no approvals using the cable types listed below and following the installation guidelines in the NEC® Article 501-4(b) 501.10.

- All wiring methods approved for Class I, Division 1, Zone 1
- Rigid metal conduit (RMC) and intermediate metal
- Enclosed gasket busways/wireways
- Type PLTC and Type PLTC-ER cable as per Article 725
- Type ITC and Type ITC-ER cable as per Article 727.4
- Type MC, MV, TC, or TC-ER cable
- Flexible connections such as flexible metal fittings are permitted for areas of limited space
- Liquid-tight flexible nonmetallic conduit and flexible cord (where permitted)
6.3 DIVISION 2 INTERFACE SELECTION

Once the instrumentation/field devices have been specified as nonincendive or Division 2 rated, a interface needs to be selected. R. STAHL offers one main technology for this. The wiring has been defined as NIFW so that nonhazardous-rated wiring can be used, an associated apparatus needs to be selected. R. STAHL also offers one main technology for this.

Remote I/O uses an approach known as point-to-bus. Here, a DCS/PLC has a communication card (Modbus TCP, Profibus, etc.) and a bus (a pair of wires) that go from the safe area into the hazardous location where a Remote I/O station provides individual connections to the field devices. This approach has many advantages over point-to-point. The main four advantages:

1. Minimizing the wiring
2. Minimizing the installed equipment hence faster commissioning and cost-efficient solutions
3. Providing diagnostic information of wiring and hardware
4. Reducing engineering work due to digital communication and the number of cables and terminations

The Remote I/O with the nonincendive associated apparatus can be installed in a hazardous location like Class I, II, Division 2 closer to the nonincendive field devices, which reduces the amount of wiring significantly. A Remote I/O station will have I/O cards for nonincendive field wiring and a gateway that merges the information from the I/O cards and sends it via a bus (such as Ethernet IP or, or Profibus DP) to a communication card on the PLC/DCS. Besides reducing wiring and minimizing the space in the safe area, Remote I/O stations also provide preventive diagnostics.

Selection of the I/O cards is simpler as the cards are multifunctional. This means the channels can be independently configured for inputs or outputs and in some cases even from digital to analog.

These solutions which can be installed in Class I, Division 2 could be interconnected to Class 1, Division 2 rated devices such as explosionproof, nonincendive, etc. by following the installation requirements of such instrumentation.

The R. STAHL family of Remote I/O is known as IS1+. Refer to Chapter 6 for product information.