Selecting Field Equipment
For Use In Flammable Atmospheres

Introduction

The Chemical Process Industry (CPI) has numerous areas which are potentially explosive or flammable because of gases or dusts in the air. Careful attention must be exercised in the selection and installation of electrical equipment used in these areas to ensure that hot or arcing components do not ignite the gases or dusts. This Technical Guide provides specific guidelines for using Bailey control systems and Positioners in these areas.

Hazardous Locations

Areas in which a flammable (explosive) atmosphere may occur are defined as "Hazardous (Classified) Locations" by the National Electrical Code (NFPA 70). The flammable atmosphere results from the presence of ignitable concentrations of gas, dust, or fibers in the air. Area classification is by Class, Division, and Group in North America. (The European system of Zone and Group classification is further detailed in Appendix B.)

Class

Hazardous Locations are subdivided into three classes:
- Class I for gases
- Class II for dusts
- Class III for fibers

Division

Each Class is further subdivided into either Division 1 or Division 2.

Division 1 hazardous locations are areas where the flammable atmosphere occurs during normal operation. Examples of Division 1 areas would be around paint spraying operations or where flammable liquids or vapors could escape from open tanks, indoor vents, indoor hose couplings, and inadequately vented indoor pumps and valves.

Division 2 hazardous locations are areas where the flammable atmosphere occurs because of an infrequent failure. Typical failures may be leakage from pump and valve packings, leakage from sealed containers, or failure of purging or ventilating systems.

Group

The flammable materials are divided into groups to help describe the nature of the material and the ease of ignition. The ease of ignitability is primarily based upon how small the gap must be between flanges on an explosion-proof enclosure. Any gases or dusts escaping from the enclosure must be cool as they pass out through the enclosure flanges to ensure they will not ignite the external flammable atmosphere. Gases which either require a "large" amount of energy to ignite or which have "weak" explosion permit the use of large flange gaps. Gases in Groups A and B ignite at low energy levels with a strong explosion. Thus, they require an enclosure with very small gaps. Groups C and D allow progressively larger gaps.
Division 1  Applications

Bay ey transmitters have been des gn ed and cert ified with two different protect on methods to a low the r use in "nor mally" flammable atmospheres These methods are explos on proof enclosure and ntrnscally safe instal at on

The AP Positioners have only been certified for intrinsically safe instal at on

Explosion Proof

Explos on proof certification assumes that the gas will penetrate the enclosure and w  be gnted by the internal electrca circuit The re quirement s to prevent the inerna explosion from propagat ng to the outs de of the enclosure and gnitng the externa fmmab e atmosphere If the atmosphere contains a dust, then this design is referred to as dust gnitionproof Primary design guidelines are

1 Insure that enclosure wi l withstand an interna exploson (this usually necessttes thick, heavy metal),

2 Insure that hot gases are adequately cooled before they reach the outside of the enclosure (this requires wide flanges and several thread engagement of covers and conduit),

3 Mark the unit to show which flammable atmospheres are permitted

When a transmitter is ut ized as explosionproof a l w r ng must be n r gid conduit that is properly sealed (sea ng is done by pouring a specia compound into the conduit) This type of nstallaton is t me consum ng, costly, and d ficul to modify once assemb ed The covers must always be kept fu ly on the transm t ters

Intrinsic Safety

Intr ns c safety certification assumes that even f the dust or gas penetrates the field equip ment s enclosure, it w l not be ignited because the energy available in the feld equipment s ess than the energy required to gnite the atmosphere The energy required is gre at y dependant upon the mater nal and vanes from 17 m cro Joules for hydrogen and 200 micro-Joules for propane to 60,000 micro Joules for coa dust Aga n, the equipment must be marked to ind cate which fmmab e atmosphere is suitab e

Intrnsic safety certif cat on allows the use of ord nary ocation w r ng n p ace of ng d conduc t Th s makes the circt us much eas er to nsta nd mod fy However since w r ng s not protected by conduc t t is assum ed that the wires cou d short, open or ground Therefore, the energy must not only be limited nterna to the feld equip ment, but must also be limited in the feld w r ng The norma method of doing this is to place an ntnns c Safety Barr er in a location externa to the flammable atmosphere Ths barr er mt s the vottage and the current which can f ow in the wr ng and in the feld equip ment

Intrnsic Safety Bar res can be ether act ve or passive A typical pass ve barr res conta ns four essent al components as shown below

![Diagram of Intrinsically Safe Barrier]

CR1 and CR2 are redundant diodes which prevent the voltage from exceeding a specified value Typical va ues run from 1 volt for thermocouples to 30 volts for the 24 V dc 4-20 mA transm t ters and positioners F1 is a fuse that protects the diodes from open c rcu t fa ure R1 s a series res stor to prevent the current from exceed ng a specified value The value of th s res stor can range from 10 to over 400 ohms The va u depends upon the voltage eve of the diodes and the group c as fication of the fmmable atmosphere Ths add tona res stance can exceed the drive capabilit es of the contro system

Active barriers have been des gn ed to overcome this problem of the add tona res stance These barriers draw current from the power supply to amp fy or repeat the 4 20 ma s gna l These barriers still use diodes to lmit the voltage but use solid state dev ces np ace of the res stor s to n t the current

The selection of an appropriate ntnns c Safety Bar res cannot be arbitrary The barrier must be evaluated to insure both ntrnsic safety and proper performance

1 The ntrnsic safety eva uation must ver fy that the energy limiting features of the Barrier for vottage and current are not compromised by the energy storage components (capacitors and nductors) n the feld equip ment
2 The performance evaluation must verify that the total loop resistance is low enough to allow the maximum current to flow. This is normally 20 mA.

Third party verification to ensure that various barrier/field equipment combinations are intrinsically safe can be done using either system evaluation or entity evaluation.

Intrinsic Safety System Evaluation

System evaluation involves testing a specific field instrument with a specific barrier. Fault conditions are introduced into both units and tests are run to determine if ignition of a test gas will occur. Under system evaluation, the laboratory certification is maintained only if the customer uses the field instrument with the specific barrier tested by the laboratory.

Bailey Positioners and Transmitters have Factory Mutual system approval with specific barriers manufactured by Bailey, Leeds & Northrup, Foxboro, Taylor and Westinghouse. These specific barriers are designated by the prefix “s” in Tables 1 thru 5.

Intrinsic Safety Entity Evaluation

Entity evaluation involves testing the barriers and field equipment independently. Each unit is assigned a voltage and current rating (FM) or a voltage and resistance rating (CSA). The customer can select any combination of certified field equipment and certified barrier providing the barrier parameters do not exceed those allowed by the field equipment parameters. This concept is relatively new and is further explained in Appendix A.

Intrinsic Safety Installation

Intrinsically safe loops are normally wired with routine wire methods, not rigid conduit. Therefore, they are considerably easier to modify. Although the same explosionproof enclosure is used on the transmitters, the cover and conduit openings do not have to be kept tight (fully sealed or screwed down) unless there are dusts present (Class II and Class III hazardous locations). The additional expense for the barrier can be a major consideration in these installations.

Miscellaneous Field Equipment

Other equipment which is frequently used in a flammable atmosphere include thermocouples, RTDs, switches, solenoids, amps, analog meters and digital displays. The selection of barriers for these units is discussed in Appendix Guide 999-14.

Division 2 — Applications

Bailey Transmitters have been designed and certified with three different protection methods to allow use in locations which become flammable "by a failure." Both the explosionproof enclosures and the intrinsically safe installations are allowable. Each must be implemented with the same strictness as if a Division 1 hazardous location. The third method is as nonincendive. The Positioners and many of the 7000 line products have also been designed and certified as nonincendive.

Nonincendive

Nonincendive certification assumes that the flammable gas, dust, or fumes will only be in the environment as a result of an infrequent failure. The field equipment is evaluated to ensure that during normal operation, it does not release enough energy in the form of sparks or hot components to cause ignition of the flammable atmosphere. It is extremely unlikely that a failure would occur which would cause a flammable atmosphere to exist at the same time that a fault in the equipment would occur which would be capable of igniting the flammable atmosphere. The evaluation to verify a nonincendive rating consists of analyzing all arcing parts and all thermally hot parts. Arcing parts include relays, switches, motors, thermostats, potentiometers, connectors, fuseholders, and lampholders. The analysis must show that either arcing cannot occur in normal operation or that the arcing is energy limited to a level below the ignition energy of the flammable atmosphere.

The advantage of the nonincendive rating is that the installation does not require intrinsically safety barriers nor must the wiring be placed in rigid conduit.Typically, wiring is Power Limited Tray Cable (PLTC), a designation assigned by Underwriters Laboratories. The usual nonincendive rating obtained for Bailey field equipment is for Class I, Division 2 groups C and D.

References

This summary about hazardous locations is intended to help put the various terms in an overall context. The terms have not been rigorously defined. For more exact definitions and specific code, standard and certification requirements refer to the following:

ANSI/UL 913 1988 "Intrinsically Safe Apparatus"

ANSI/SA S12.12 1984 "Electrical Equipment for Use in Division 2 Locations"
Appendix A

Bailey Field Equipment Under Entity Evaluation

The entity evaluation provides a method for specifying independent barrier parameters and independent field equipment parameters. The barrier parameters are normally determined by testing under fault conditions. The field equipment parameters are usually specified by the manufacturer. These field equipment parameters are then used by the testing laboratories to ensure that the equipment will not ignite the flammable atmosphere when operated at these parameters. The tests also include induced faults. During these faults, the components in the equipment may be subject to voltages and currents several times the normal levels.

Once the field equipment is certified to the specified parameters, the customer can select any certified barrier that does not exceed these parameters and use the combination without any further evaluation by the testing laboratory.

EXAMPLE

The Bailey BC Transmitter is rated $V_{\text{max}} = 40$ V dc and $I_{\text{max}} = 332$ mA under the Factory Mutual entity method. This would allow the use of any FM entity approved barrier with a $V_{\text{oc}}$ of 40 V dc or ess and an $I_{\text{sc}}$ rating of 332 mA or ess.

EXAMPLE

The Bailey BC Transmitter is rated by CSA to be suitable for any certified barrier that does not exceed 30 V dc by itself. It has a series resistance of at least 250 ohms. CSA has also certified the BC for barriers with less resistance if the voltages are approximately lower such as 40 ohms minimum if the voltage does not exceed 10 volts.

The primary advantage of entity certification is that the user is given flexibility in the initial selection of the barriers and field equipment and then maintains the flexibility of replacing field equipment with newer or better units.

Bailey field equipment has been designed and certified to be used with the broadest range of barriers.

CSA Entity Listing

The entity parameters assigned by CSA are the maximum voltage and minimum resistance that the associated barrier may have. The parameters selected for the field equipment are usually based on actual barrier parameters. This is in contrast to the FM system discussed after. As a consequence, several sets of parameters must be selected to cover the range of available barrier ratings. The sets of Maximum Voltage/Minimum Resistance ratings usually selected are 32V/400 ohms, 28V/270 ohms, 22V/150 ohms, and 10V/40 ohms for Groups A thru G flammable atmospheres. The resistance can be lower if Group A and B gases are of no concern. The sets of ratings for Group C thru G flammable atmospheres are 33V/200 ohms, 28V/120 ohms, and 10V/40 ohms. Table 8 shows the sets of barrier parameters certified for the various Bailey products. Different parameter sets were predetermined due to different barriers being available when the submittals were made. The barriers compatible with Bailey field equipment from an intrinsic safety evaluation are shown in Table 7.

$V_{\text{max}}$ is the maximum allowed supply voltage which may be applied to the barrier. Voltages above the tabulated value may cause permanent damage. $R_{\text{res}}$ is the end to end resistance of the barrier. Ths is the maximum possible resistance that the barrier adds to the loop. Both $V_{\text{max}}$ and $R_{\text{res}}$ are used to verify the performance of the barrier/field equipment combination.

FM Entity Listing

The entity parameters assigned by FM are the maximum voltage ($V_{\text{max}}$) and the maximum current ($I_{\text{max}}$) that the field equipment can safely receive. Barriers are assigned an open circuit voltage ($V_{\text{oc}}$) and a short circuit current ($I_{\text{sc}}$). Barriers which have a $V_{\text{oc}}$ exceeding the $V_{\text{max}}$ rating or an $I_{\text{sc}}$ exceeding the $I_{\text{max}}$ rating may not be used. Since the lower voltage barriers have higher current outputs, the ratings assigned to the field equipment are not representative of an actual barrier. The parameters selected for Bailey Transmitters and Acoustic monitors are 40 $V_{\text{max}}$ and 332 $I_{\text{max}}$. The barriers compatible with Bailey field equipment from an intrinsic safety evaluation are shown in Table 6.

Performance Evaluation of Barrier/Field Equipment

The barriers which are acceptable under the FM and CSA entity requirements must now be evaluated to ensure that the added resistive resistance added to the loops is not excessive.

Active barriers minimize the problem and often provide more output capability than the back-up system. Examples of active barriers are MTL's 322 and
2441 for transmitters and MTL's 2442 for positioners. In addition, some barriers are suited more for systems other than Bailey's Foxboro, Honeywell and Taylor systems provide either grounded returns or lower feedback voltages to ensure that their barriers can be used with typical transmitters and positioners. Intrinsically safe loops with these barriers are shown in Figures 1, 4, 7, and 9.

Barriers used in transmitter loops often provide a 250 ohm resistor internal to the barrier. This converts the 4-20 mA signal to a 1-5 V dc signal and maintains the series resistance of the return barrier from the 4 20 mA loop. These barriers are shown in Figures 3 and 5. Minimizing the series resistance of the return barrier can also be accomplished by mounting a 250 ohm resistor to the return barrier as shown in Figure 6.

The power supply is often critical in intrinsically safe loops. If the voltage is too high, it will destroy the barrier by 'bowing' the nonreparable internal fuse. Yet, if the voltage is too low, the 20 mA current cannot be achieved. Normally, a 24 V, +1 V supply is sufficient for Group A/B flammable atmospheres only if active barriers are used. Passive barriers will usually require a 25 or 26 volt power supply. The regulation/stability of the supply should be ± 0.1 volts.

Bailey controllers in the NETWORK 90® and 7000 systems utilize a 250 ohm reference resistor in the return leg. This requires that the lower barrier be a minimum of 5 volts. A grounded return leg may not be used. In order to minimize the resistance in the return barrier, a low voltage barrier or a barrier with diode returns is used.

Tables 1 thru 5 show the matching requirements for functional performance. The primary specification is the allowed cable resistance. Each 1 ohm of a lowed cable resistance is equivalent to 200 feet of 14 AWG wire, 125 feet of 16 AWG wire, or 30 feet of 22 AWG wire. The use of the optional EMICO 35 W T meter is equivalent to 15 ohms of cable resistance.

Table 1 is for transmitters used with Bailey systems. Cable resistance is dependent upon the supply voltage.

Table 2 is for transmitters used with non-Bailey systems. Cable resistance is not always dependent upon the power supply voltage.

Table 3 is for AP7 Positioners used with Bailey systems. Cable resistance is dependent upon the system drive capability which is 750 ohms for 7000, 600 ohms for standard NETWORK 90 systems, and 850 ohms for NETWORK 90 systems with 26 volt power supplies.

Table 4 is for AP7 Positioners used with non-Bailey systems. Cable resistance is again dependent upon the system drive capability.

Table 5 is for AP8 Positioner (servo portion only). There is no maximum loop resistance specification. The total loop resistance does affect the drive current. The drive current generally affects the speed of operation. Therefore, the tabulated specification is the drive current and not the allowed cable resistance. The cable resistance is assumed to be 10 ohms. The AP8 feedback portion is a 4-20 mA position on transmitter. Barrier section is done from Table 1 and 2.

**Definition of Terms Used In Figures and Tables**

<table>
<thead>
<tr>
<th>Rc</th>
<th>Resistance of all cables and wiring in the 4-20 mA loop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rd</td>
<td>Maximum total loop resistance active barrier can drive</td>
</tr>
<tr>
<td>Rp</td>
<td>Maximum internal resistance of Bailey Positioner</td>
</tr>
<tr>
<td>Rf</td>
<td>Maximum added resistance by return barrier</td>
</tr>
<tr>
<td>Rs</td>
<td>Maximum added resistance by supply barrier</td>
</tr>
<tr>
<td>Vmax</td>
<td>Maximum allowable voltage to the barrier</td>
</tr>
<tr>
<td>Vout</td>
<td>Minimum output voltage from active barrier to drive loop</td>
</tr>
<tr>
<td>Vpe</td>
<td>Voltage of system power supply (nominal 24 V dc)</td>
</tr>
</tbody>
</table>

**Appendix B**

**European System For Classifying Explosive Atmospheres**

The European classification system for hazardous locations is substantially different from the North American system. It contains the Zone 0 concept which...
the flammable atmosphere is assumed to be present on virtually a continuous basis. This would occur in the area space above the tank containing a flammable liquid. The European system has not effectively treated explosive dusts or fibers at this time although work is in process.

The following table compares the classification for various gases:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Group</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>Group A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene</td>
<td>Group B</td>
<td>Group H</td>
<td>Group I</td>
<td></td>
</tr>
<tr>
<td>Propane</td>
<td>Group D</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Markings used to designate the various protective methods are as follows:

<table>
<thead>
<tr>
<th>Marking</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex A</td>
<td>Intrinsic safety (Zone 1)</td>
</tr>
<tr>
<td>Ex B</td>
<td>Intrinsic safety (Zone 2)</td>
</tr>
<tr>
<td>Ex C</td>
<td>Flameproof (same as North American Explosionproof)</td>
</tr>
<tr>
<td>Ex D</td>
<td>Dust-proof</td>
</tr>
</tbody>
</table>

**TABLE 1 Transmitter Intrinsic Safety Loops CI**

(Compatible with Bailey NETWORK 90® and 7000 systems)

**KEY**
- eA-G (entry certified Groups A thru G)
- eC-G (entry certified Groups C thru G)
- eD (entry certified Group D only)
- eG (system certified Groups A thru G)
- sC-G (system certified Groups C thru G)
- sA-D (system certified Groups A thru D)
### TABLE 2 — Transmitter Intrinsc Safety Loops  
(Compatible with non-Balley systems)

<table>
<thead>
<tr>
<th>KEY</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>eA-G</td>
<td>Entity certified Groups A thru G</td>
</tr>
<tr>
<td>eC-G</td>
<td>Entity certified Groups C thru G</td>
</tr>
<tr>
<td>sA-G</td>
<td>System certified Groups A thru G</td>
</tr>
<tr>
<td>sC-G</td>
<td>System certified Groups C thru G</td>
</tr>
</tbody>
</table>

### TABLE 3 — Positioner Intrinsc Safety Loops  
(Compatible with Bailey NETWORK 90® and 7000 systems)

- AP63 POS T ONER (132 ohms)
- AP73 POS T ONER (350 ohms)
TABLE 4 — Positioner Intrinsic Safety Loops
(Compatible with non-Bailey systems)

AP73 POS T ONER (350 ohms)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>1 mA</td>
</tr>
<tr>
<td>Min.</td>
<td>20 mA</td>
</tr>
<tr>
<td>Resistance</td>
<td>50 ohms</td>
</tr>
</tbody>
</table>

KEY:
- eA-G (entity cert. fed Groups A thru G)
- eC-G (entity cert. fed Groups C thru G)
- sA-G (system cert. fed Groups A thru G)
- sC-G (system cert. fed Groups C thru G)

TABLE 5 — Positioner Intrinsic Safety Loops
(Compatible with Bailey NETWORK 90® and 7000 systems)

AP83 POSITIONER (650 ohms)

Servo portion only [4-20 mA Transmitter for feedback needs separate barriers]

The resistance Rp of the AP83 Positioner is dependent upon the dp switch setting.

- The minimum resistance of 650 ohms is obtained by using four switches.
- The speed of operation is greatly dependent upon the series resistance and the operating temperature.
- At 25 degrees C, the approximate time for 0 to 100% travel as follows:
  - 5 seconds @ 34 mA drive current
  - 15 seconds @ 17 mA drive current
  - 25 seconds @ 13 mA drive current
  - 50 seconds @ 10 mA drive current

Fault analysis of the Return Barr are must assume their outputs are shorted together through the ow resist ance of the motor coil resistors (45 ohms), therefore, they must be higher resistance than normal or conta n blocking diodes.

Suitable barriers are limited to the following:

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# 15 volts is subtracted for the voltage drop across the solenoid state contacts in the NETWORK 90 digital outputs
FIGURE 1 — Transmitter with Single Barrier and Grounded Return

FIGURE 2 — Transmitter with Return Barrier and 4 to 20 mA Signal to Controls
FIGURE 3  Transmitter with Dual Channel Barrier and 1-5 V Signal to Controls

FIGURE 4 — Transmitter with Active Barrier
FIGURE 5 — Transmitter with Return Barrier and 1-5 V Signal to Controls

FIGURE 6 — Transmitter with Return Barrier and External Resistor for Converting 4 to 20 mA Signal to 1-5 Volt
FIGURE 7  Positioner with Single Barrier and Grounded Return

FIGURE 8  Positioner with Return Barrier for Bailey-type Controls
FIGURE 9  Position with Active Barrier

FIGURE 10 — AP8 Positioner (Servo) with three Barriers