Installing a Type AV Positioner in a Hazardous Location

Introduction

This product application guide provides guidance on using a Type AV positioner in a location which is made hazardous by the presence of ignitible concentrations of gases, dusts or fibers. All guidance provided for the Type AV2 positioner also applies to the Type ITOP11 converter.

The terminology used throughout this product application guide has been simplified for ease of understanding. However, many terms have very specific meanings to testing laboratories and inspectors. Specific details are available from the standards listed in the ***Applicable Standards*** section.

Equipment Marking

Electrical equipment used in a hazardous location must be marked as suitable for the hazardous location by both class and group. A positioner without such a marking may not be used in a hazardous location since it may have differences in the electronics that would invalidate the protection.

Environmental Conditions

The ignitability and explosion severity of flammable materials is dependent upon the oxygen concentration, prepressurizing and temperature. Electrical equipment evaluated for use in hazardous locations are generally tested only for the following conditions:

Ambient Temp.	O_2 Concentration	Ambient Pressure
-25° to 40°C (-13° to 105°F)	21% maximum	12.5 to 15.7 psi (86 to 108 kPa)

It is generally felt that temperatures between 40° and 60°C do not affect the test results for most gases as long as the T Code (temperature code) is adjusted for the higher temperature. The T Code is based upon a 40°C ambient temperature.

Area Classification

Area classification is by class, division and group in North America. The European system of zone and group classification is further detailed in the ***Comparison of European versus North American Area Classification*** section.

Class – Hazardous locations are divided into three classes:

Class I for gases.
Class II for dusts.
Class III for fibers.

Division – Each class is further divided into two divisions:

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 ventilated pumps and valves.

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

Group – The flammable materials are divided into groups to help describe the nature of the material.

Gases are divided into four groups:

Group A for acetylene.
Group B for hydrogen and similar gases.
Group C for ethylene and similar gases.
Group D for propane and similar gases.

Dusts are divided into three groups:

Group E for metal dusts.
Group F for carbonaceous dusts.
Group G for chemical and agricultural dusts.

Fibers are not further divided and have no group designations.

The classification for a specific material is found in ANSI/NFPA 497M. Guidelines for area classification are found in standards such as ANSI/NFPA 497A for gases and ANSI/NFPA 497B and ANSI/ISA S12.10 for dusts.

Temperature Codes (T Codes)

Flammable atmospheres can be ignited not only by electrical arcs but also by hot surfaces. Fortunately, most gases and dusts ignite at temperatures considerably above what would be acceptable operating temperatures for electronic equipment.

The National Electrical Code uses a system of identification numbers which will be referred to as ***T Codes***. These codes represent the hottest component for intrinsically safe and nonincendive equipment which would ignite the flammable gas.

The T Codes most likely to be marked on a Type AV positioner are the following:

T Code	°F	°C
T3C	320	160
T4	275	135
T4A	248	120
T5	212	100
T6	185	85

The positioner must not be used with a gas which has a lower ignition temperature than the temperature corresponding to the T Code for that protection technique. The ignition temperatures for various gases can be found in ANSI/NFPA 497M.

Division 1 Protection Techniques

Type AV positioners have been designed for use in intrinsically safe loops to allow their use in ***normally*** flammable atmospheres.

Intrinsically Safe Loops

Intrinsic safety relies on the fact that even if the gas penetrates the enclosure, it will not be ignited by the electrical equipment because the energy available is limited. The energy required for ignition is greatly dependent upon the material, e.g. 17 μJoules for hydrogen and 200 μJoules for propane. Because the energy is limited, this protection can only be used for low-energy circuits such as 4 to 20 mA loops.

Intrinsic safety analysis assumes that the field wiring may short together, open circuit, or short to ground. Since the analysis assumes this will happen, it is thus permitted to use any wiring technique. On the other hand, it requires that all power sources must be energy limited. This is usually accomplished by a product called an intrinsic safety barrier. These intrinsic safety barriers limit both the open circuit voltage and the short circuit current that can enter the hazardous location. Intrinsic safety analysis further assumes that faults can occur within the control equipment so that any wire not connected to ground could become a ***power source***. Therefore, an intrinsic safety barrier is required on each wire unless it is connected to ground.

The nature of shunt diode intrinsic safety barriers requires that they introduce series resistance into the loop. Therefore, a performance review is required to verify that the full 20 milliamps can flow with the added series resistance.

The energy limitation and tests done with shorted and grounded field wiring allows for limited

maintenance to be done while the circuit is energized. The maintenance must not result in shorting of separate intrinsically safe circuits. This is a special concern when one positioner has multiple intrinsically safe circuits. This occurs for example, when the 4 to 20 mA position transmitter is used in the Types AV2, AV3 and AV4 positioners.

Also, maintenance of the positioner must not introduce additional capacitance or inductance into the intrinsically safe loop. Test equipment such as meters should be verified as acceptable before using on energized circuits.

Refer to the ***Intrinsically Safe Loop Installations*** section for specific installation guidelines.

Division 2 Protection Techniques

Although the intrinsically safe loop protection is also suitable for Division 2 hazardous locations, it requires that it be implemented as rigorously as if in a Division 1 hazardous location. There is another protection technique that is suitable only for Division 2. This is referred to as nonincendive equipment in the United States.

Nonincendive Equipment

The flammable atmosphere will only be present in a Division 2 hazardous location infrequently and for a short time. Therefore, if the electrical equipment is not normally an ignition source, it can be shown that the possibility of the flammable atmosphere existing simultaneously with a fault in the electrical equipment is very unlikely. The electrical equipment is evaluated to verify that there are no normal ignition sources such as arcing contacts or hot surfaces. Arcing contacts could be from motor brushes, relay contacts, switches actuated by moving parts or accessible to the operator, etc.

The advantage of the nonincendive rating is that the installation does not require intrinsic safety barriers. Typical wiring used is power limited tray cable (PLTC), a designation assigned by Underwriters Laboratories.

Refer to the ***Nonincendive Equipment Installations*** section for specific installation guidelines.

Intrinsically Safe Loop Installations

WARNING

Intrinsic safety is dependent upon the components used in the positioner. Any substitution of components may impair the intrinsic safety.

AVERTISSEMENT

La securite intrinseque depend des composantes utilisees dans l'positioneur. Toute substitution de composante pourrait nuire a cette securite intrinseque.

Selecting intrinsic safety barriers is a two step process. The barrier must be suitable based upon intrinsic safety parameters and must also be acceptable from a performance standpoint.

Suitable Barrier Intrinsic Safety Parameters

The first step requires determining which intrinsic safety barriers are acceptable using the limits imposed by the intrinsic safety analysis. These limits are specified on drawing B222611 and in Table 1.

Table 1. Intrinsic Safety Barrier Limits (Drawing B222611)

Sheet No.	Description
2.0	FM approved I.S. system loops (4-20 mA position transmitter)
2.2	FM approved I.S. system loops (Type AV2 I/P circuit)
3.0	FM approved I.S. entity parameters (4-20 mA position transmitter)
4.0	CSA certified I.S. parameters
4.1	CSA certified I.S. loop diagrams

Only barriers which conform to the specified limits on these drawings may be used.

Pulse Input Positioner (Type AV4)

The servo portion of the Type AV4 positioner requires a +24 volt (nominal) connection to terminal 3. To cause movement of the positioner, either terminal 4 or terminal 5 is connected to the power supply common. This requires that the servo portion be connected to three intrinsic safety barrier channels. This restricts the barrier choice to ***diode*** returns for terminals 4 and 5.

Potentiometric Option

The potentiometric option uses a 2000 ohm conductive plastic element. 600 ohm barriers must be selected so that when the outputs are shorted together, the available current is not ignition capable. The third lead of the potentiometer must be grounded.

Basic Criteria for Determining Performance

The second step is a determination of the effect on performance when using these intrinsically safe barriers. There are five circuits that will be described for the performance valuation:

- 4-20 mA I/P Positioner (Type AV2) and 4-20 mA I/P Converter (Type ITOP11).
- 4-20 mA I/P Positioner (Type AV3).
- Pulse Input Positioner (Type AV4).
- Potentiometric option.
- 4-20 mA position transmitter option.

NOTE: The 4-20 mA position transmitter is always included with the Type AV4 positioner.

Suitable performance is determined by analyzing the total resistance (or total voltage drop) of the loop. This loop includes not only the AV resistance (or minimum operating voltage), but also the intrinsic safety barrier resistance and the cable resistance.

Table 2 provides a tabulation of cable resistance and voltage drop at 20 mA for various wire sizes and distances between the positioner and the intrinsic safety barrier.

Table 2. Cable Voltage Drop as a Function of Distance and Wire AWG

AWG	Ω/ 500 ft.	500 ft. (V)	1000 ft. (V)	2000 ft. (V)	3000 ft. (V)	4000 ft. (V)	5000 ft. (V)
24	25	0.5	1.0	2.0	3.0	4.0	5.0
22	17	0.4	0.7	1.4	2.1	2.7	3.4
20	11	0.3	0.5	0.9	1.4	1.8	2.2
18	6.5	0.2	0.3	0.6	0.8	1.1	1.3
16	4.6	0.1	0.2	0.4	0.6	0.8	1.0

Table 3 provides the maximum load resistance for some typical Network 90®/INFI 90® modules and Command Series® controllers.

Table 3. Maximum Load Resistance for Various Bailey Units

Equipment	I/O Voltage (V)	Maximum Load (Ω)	Minimum Output (Ω)
IMASO01	21.6	750	12
IMCIS02	21.6	600	40
CLC03/04	21.6	700	140
CBC01	21.6	700	260
CPC01	24 nom	750	37

Table 4 provides a list of typical barriers suitable for use with the Type AV positioners. The series resistance (R_{e-e}) of the various barriers is tabulated. The voltage drop across the barrier ($V_{barrier}$) at 20 mA is also tabulated. For those barriers with a diode drop, the equivalent resistance of the diode drop may be obtained by multiplying the voltage identified as $V_{barrier}$ by 50, e.g. for $V_{barrier}$ = 1.3 volts, the equivalent resistance is 65 ohms.

4 - 20 mA I/P Positioner (Type AV2) 4 - 20 mA I/P Converter (Type ITOP11)

The Type AV2 positioner is driven by a module or controller providing a 4-20 mA analog output. The module or controller will have a specified maximum load. Table 5 tabulates the maximum cable resistance permitted when using selected intrinsic safety barriers with various Bailey modules and controllers.

those that have a series resistance of less than 200 ohms. Recommended barriers and the minimum power supply voltage are shown in Table 7.

Potentiometric Option

The feedback potentiometer must be connected with one terminal grounded and the other two leads each connected to a 600 ohm, 28 volt barrier. The barrier resistance added in series with the wiper contact (terminal 4) generally will not affect the accuracy for most analog inputs with one meg-ohm input impedances. However, the barrier resistance in series with the 2000 ohm potentiometer may affect accuracy. The user will need to evaluate his control equipment to determine how zero and span will be adjusted and maintained.

4 - 20 mA Position Transmitter Option

Suitable performance is determined by calculating the voltage drop on the loop at 20 milliamps. There are several factors that go into determining the voltage drop. They include the voltage required by the position transmitter, the voltage required by the control equipment, the voltage drop on the barriers and the voltage drop on the cables.

The total loop voltage drop must not exceed the minimum value of the power supply (V_{ps}). V_{ps} must be determined based on worst case ambient temperature, load and mains input. For a Network 90 system, V_{ps} = 21.6 volts, and for an INFI 90 modular power system, V_{ps} = 25.0 volts.

The minimum voltage (V_{xmtr}) required by the position transmitter option is 14 volts.

Performance Using Isolating Intrinsic Safety Barriers

The manufacturer of the isolating barrier specifies the maximum load voltage (V_{load}). Examples of various I.S. barriers and the maximum load voltage rating are provided in Table 4. Calculate the voltage drop allowed for the cables by subtracting the position transmitter voltage (V_{xmtr}) from the maximum load voltage. Table 2 can then be used to select the minimum wire gauge (AWG) required to not exceed this voltage. Table 8 tabulates the allowed cable voltage drop for selected barriers and power supply voltage (V_{ps}).

Table 6. Maximum Cable Resistance for I/P Positioner (Type AV3 - 370 Ω Maximum)

Vendor	Supply Barrier	Return Barrier	Groups	Re-e (Ω)	IMCIS02 600 Ω (Ω)	CBC/CLC 700 Ω (Ω)	IMASO01 750 Ω (Ω)	CPC01 750 Ω (Ω)
Stahl	9001/01-280-100-00	9001/01-086-150-00	A-D	374	—	—	6	6
Stahl	8903/31-315-050-70	9001/01-086-150-00	A-D	251	—	79	129	129
Stahl	8903/31-284-050-70	9001/01-086-150-00	A-D	251	—	79	129	129
Stahl	8903/31-284-050-70	9001/03-273-000-00	A-D	305	—	25	75	75
Stahl	8903/31-315-050-70	9001/03-273-000-00	A-D	305	—	25	75	75
MTL	728	none	A-D	340	—	—	—	40
MTL	304	same	A-D	—	380	380	380	380

Table 7. Minimum Power Supply Voltage (Not Including Cable Voltage Drop) for Various I.S. Barriers Used with the Type AV4 Positioner

Vendor	Supply Barrier	Diode Return Barriers	Groups	$V_{barrier}$ (V) @ 32 mA	Minimum Voltage
Stahl	9001/01-280-165-00	9001/03-273-000-00	C,D	9.5	25.5
Stahl	8903/31-315-050-70	9001/03-273-000-00	A-D	9.1	25.1
Stahl	8903/31-284-050-70	9001/03-273-000-00	A-D	9.1	25.1
Crouse-Hinds	SB19140M2420	SB59440M0786	C,D	7.0	23.0

NOTE: This table does not include the cable voltage drop, nor does it include the voltage drop at the control system, which would occur when using open collector contacts.

Table 4. Intrinsic Safety Barrier Performance Parameters

Vendor	Supply Barrier	Isolating Load	Shunt Diode		V_{op}	Return Barrier	Re-e (Ω)	V_d	$V_{barrier}$	Groups
			R_{e-e} (Ω)	Vbarrier						
Stahl	9001/01-280-165-00	—	195	3.9	26.0	9001/01-086-150-00	71	—	1.4	C,D
Stahl	9001/01-280-100-00	—	303	6.1	26.0	9001/01-086-150-00	71	—	1.4	A-D
Stahl	8903/31-315-050-70	—	180	3.6	28.0	9001/01-086-150-00	71	—	1.4	A-D
Stahl	8903/31-284-050-70	—	180	3.6	26.0	9001/01-086-150-00	71	—	1.4	A-D
Stahl	9001/51-280-110-00	15 V	—	—	35.0	same	—	—	—	A-D
Stahl	9001/01-280-100-00	—	303	6.1	26.0	9001/03-273-000-00	—	—	2.5	A-D
Stahl	8903/31-284-050-70	—	180	3.6	26.0	9001/03-273-000-00	—	—	2.5	A-D
Stahl	8903/31-315-050-70	—	180	3.6	28.0	9001/03-273-000-00	—	—	2.5	A-D
MTL	702	Vsply-5	—	—	35.0	same	—	—	—	A-D
MTL	787s+	—	340	6.8	25.5	same	20	0.9	1.3	A-D
MTL	728	—	340	6.8	25.5	710	85	—	1.7	A-D
MTL	788R	—	340	6.8	25.5	same	n/a	—	0.0	A-D
MTL	3042	750 Ω	—	—	35.0	same	—	—	—	A-D
MTL	3046	15 V	—	—	35.0	same	—	—	—	A-D
ELCON	MB4/4/28+ 28+	—	168	3.4	25.5	same	63	—	1.3	C,D
ELCON	MB4/4/15R+ 15R+	—	328	6.6	25.5	same	n/a	—	0.0	A-D
ELCON	1026	15.5 V	—	—	28.0	same	n/a	—	—	A-D
Crouse-Hinds	SB59440M1787	—	340	6.8	25.5	same	20	0.9	1.3	A-D
Crouse-Hinds	SB49430M2427	—	273	5.5	25.0	same	13	0.7	1.0	A-D
Crouse-Hinds	SB59240M0778	—	665	13.3	25.5	identical channel	665	—	13.3	A-D
Crouse-Hinds	SB19140M2420	—	142	4.6	25.5	—	—	—	—	C,D
Crouse-Hinds	SB59440M0786	—	—	2.4	25.5	identical channel	30	1.5	2.4	A-D

Table 5. Maximum Cable Resistance for I/P Positioner (Type AV2 or Type ITOP11 - 245 Ω Maximum)

Vendor	Supply Barrier	Return Barrier	Groups	Re-e (Ω)	IMCIS02 600 Ω (Ω)	CBC/CLC 700 Ω (Ω)	IMASO01 750 Ω (Ω)	CPC01 750 Ω (Ω)
Stahl	9001/01-280-100-00	9001/01-086-150-00	A-D	374	—	81	131	131
Stahl	8903/31-315-050-70	9001/01-086-150-00	A-D	251	104	204	254	254
Stahl	8903/31-284-050-70	9001/01-086-150-00	A-D	251	104	204	254	254
Stahl	9001/01-280-100-00	9001/03-273-000-00	A-D	428	—	27	77	77
Stahl	8903/31-284-050-70	9001/03-273-000-00	A-D	305	50	150	200	200
Stahl	8903/31-315-050-70	9001/03-273-000-00	A-D	305	50	150	200	200
MTL	787s+	same	A-D	405	—	50	100	100
MTL	728	none	A-D	340	—	115	—	165
MTL	304	same	A-D	—	505	505	505	505
Crouse-Hinds	SB59440M1787	same	A-D	405	—	50	100	100

4 - 20 mA Input Positioner (Type AV3)

The Type AV3 positioner functions similarly to the Type AV2 positioner, but has the feature of holding the last position upon loss of signal. The Type AV3 resistance is higher than the Type AV2, with a maximum value of 370 ohms. Table 6 tabulates the maximum cable resistance permitted when using selected intrinsic safety barriers with the modules and controllers shown in Table 3.

Pulse Input Positioner (Type AV4)

Proper operation requires 32 mA at a minimum voltage of 16. This restricts the barrier selection to

Table 8. Maximum Cable Voltage for 4-20 mA Position Transmitter Option (14 V Lift-Off)

Vendor	Supply Barrier	Return Barrier	Groups	$V_{barrier}$ (V) @ 20 mA	Power Supply (V_{ps})	
					21.6 (V)	25.0 (V)
Stahl	9001/01-280-165-00	9001/01-086-150-00	C,D	5.3	—	0.7
Stahl	8903/31-315-050-70	9001/01-086-150-00	A-D	5.0	—	1.0
Stahl	8903/31-284-050-70	9001/01-086-150-00	A-D	5.0	—	1.0
Stahl	9001/51-280-110-00	same	A-D	n/a	1.0	1.0
MTL	702	same	A-D	n/a	2.6	6.0
MTL	3046	same	A-D	n/a	1.0	1.0
ELCON	MB4/4/28+ 28+	same	C,D	4.7	—	1.3
ELCON	1026	same	A-D	n/a	1.5	1.5

Performance Using Shunt Diode Intrinsic Safety Barriers

Most analog input control equipment use a 250 ohm resistor which results in a five volt drop at the control equipment (V_{ce}).

The voltage drop on the barrier ($V_{barrier}$) is equal to the end-to-end resistance multiplied by 0.02. In some cases, the barrier will have both a resistance and an internal diode voltage drop specified. This occurs for barriers that use blocking diodes on the return path. In this case, the resistance should be multiplied by 0.02 to obtain the voltage drop across the resistance. This value is then added to the diode voltage drop to obtain the barrier voltage drop ($V_{barrier}$). Some examples of barrier voltage drops are provided in Table 4.

Frequently, there is an intrinsic safety barrier both on the power supply wire and on the return wire leading to the control equipment. The voltage drop must be calculated for each wire and summed. Alternatively, a barrier can be selected that has an internal resistor that converts the 4 to 20 mA signal to a one to five volt signal. The barrier resistance for the return leg is then no longer part of the analysis nor is the voltage drop on the cable between the barrier and the control equipment part of the current loop.

The manufacturer of the barrier will also specify a maximum operating voltage (V_{op}) that can be applied to the barrier without risk of blowing the internal fuse on the barrier. In some cases, the manufacturer may provide one voltage which allows for shorts on the transmitter wiring and a second higher voltage which assumes that only 20 milliamps will flow in the field wiring. If it is possible that shorts can occur during installation or maintenance, then the lower voltage should be used for the analysis. The maximum value of the power supply voltage must not exceed V_{op} under any conditions of load, ambient temperature and mains input.

The allowed cable voltage drop is then the difference between the minimum value of the power supply (V_{ps}) and the sum of the position transmitter voltage, the barrier(s) voltage drop, and the control equipment voltage drop.

$$V_{cable} < V_{ps} - (V_{xmtr} + V_{ce} + V_{barrier})$$

The allowed cable voltage drop must also include the cable between the barrier and the control equipment if that is still part of the 4 to 20 mA loop. Table 8 tabulates the allowed cable voltage drop for selected barriers and power supply voltage.

NOTE: The above assumes that there is no additional resistance in the loop between the power supply barrier and the power supply. Some control equipment provides a series resistor for protection in case of inadvertent shorts in the field wiring. Since the intrinsic safety barrier performs this same function, any other resistance between the power supply and the intrinsic safety barrier must be removed. This is usually done by wiring the power supply directly to the intrinsic safety barrier.

Installation Requirements

Any intrinsically safe installation must be done in accordance with barrier manufacturer's instructions. ISA RP12.6 ***Installation of Intrinsically Safe Systems in Hazardous (Classified)***

Locations also provides detailed recommendations for installing equipment and wiring in intrinsically safe loops. The essential parts of a proper installation are:

1. Mounting barriers and field equipment only in flammable atmosphere for which they are specified.

2. Segregating intrinsically safe wiring to prevent contact with other circuits.

3. Grounding shunt diode intrinsic safety barriers.

4. Verifying the control equipment connected to the intrinsic safety barriers does not contain voltages above 250 VAC unless suitably certified to limit the voltage to barriers.

5. Maintaining separation of different intrinsically safe circuits. This occurs in a Type AV4 positioner which has an input and an output circuit, or in the Types AV2 and AV3 positioners when the transmitter option is used.

Nonincendive Equipment Installations

WARNING

Substitution of components may impair suitability for use in a hazardous location. Disconnecting/reconnecting wiring or repairing the positioner is not considered normal operation. These operations should only be done if power has been removed from all wiring or if the flammable atmosphere is known not to be present.

AVERTISSEMENT

La substitution de composants peut rendre l'emetteur inadequat a l'utilisation dans un environement dangereux. Le debranchement ou le rebranchement des fils ainsi que la reparation du transmetteur n'entrent pas dans les procedures normales. Si l'atmosphere est inflamable, on ne doit effectuer les etapes ci-dessus que si l'alimentation a ete interrompue.

The nonincendive rating is based upon normal operation which does not include maintenance.

The circuits connected to a Type AV positioner or Type ITOP11 converter are normally assumed to be at ignition capable levels. Therefore, this wiring must be suitable for use in Class I, Division 2, hazardous locations. The National Electric Code requires the use of rigid metal conduit or nonmetallic cable (Types MV, PLTC, SNM and PC) or metallic cable (Types MI and MC). The Canadian Electrical Code requires nonmetallic cable certified as HL or metal conduit. PLTC cable is rated 300 volts and can be obtained in wire sizes 22 AWG to 16 AWG at various temperature ratings. PLTC cable is the recommended wiring for positioners installed in the United States.

Nonincendive Field Circuits

If it is desired to use ordinary location wiring for the circuit or if it is desired to service individual positioners while they are powered, then each power source must be voltage and current limited such that opening, shorting or grounding of the circuit will not cause an ignition capable arc. In addition, operating on live circuits should only be done if there is not a shock hazard. For dry locations, the voltage should be less than 42 VDC or 30 VAC.

The intrinsic safety and nonincendive documents listed in the ***Applicable Standards*** section provide ignition curves as guidelines for limiting voltage and current. In general, there are three criteria:

1. For a given open circuit voltage, adequate series resistance must be provided at the power source to limit the short circuit current.

2. For a given open circuit voltage, the capacitance of the positioner plus cable must not exceed a specific value.

3. For a given short circuit current, the inductance of the positioner plus cable must not exceed a specific value.

Example of Nonincendive Levels

Table 9 shows the series resistance required to make the circuit nonincendive for the various groups based upon a 26.4 volt open circuit voltage. The inductance is based upon using a 150 ohm resistor in series with the power supply to limit the short circuit current to 176 milliamps. If the short circuit current is higher because a lower value series resistor is used, then the allowed inductance will decrease. Table 3 tabulates the minimum output resistance for selected analog output controllers and modules. In most cases, additional series resistance is required to make the circuit nonincendive. Particular attention must be given to not exceeding the allowed inductance, since many I/P converters have inductance.

Table 9. Nonincendive Series Resistance (V_{oc} = 26.4 V)

Group	Allowed Current (mA)	Series Resistance (Ω)	Allowed Inductance @ 176 mA (mH)	Allowed Capacitance (μF)
A or B	185	142	2	0.5
C	468	56	9	1.5
D	612	43	18	4.0

Any wiring type may be used for nonincendive field circuits per the exception in the NEC article 501-4 (b) and CEC article 18-066 (2). A nonincendive circuit may be installed and tested while powered. Care must be taken to insure that only one circuit is worked on at a time. Shorting of separate circuits is not part of the evaluation and could result in ignition capable arcs.

Comparison of European versus North American Area Classification

The European system is similar to the North American system, but has enough differences to make it very difficult to adopt directly. The European system:

- Does not have classes since their system has only been developed for gases and not for dusts.
- Uses the term zone in place of the term division.
- Subdivided the North American Division 1 into a Zone 0 and a Zone 1.
- Has gas groups that go alphabetically opposite to the North American groups.

Table 10. Zones

Europe	USA/Canada	Description
Zone 0	Division 1	Flammable atmosphere exists frequently
Zone 1	Division 1	Flammable atmosphere exists normally
Zone 2	Division 2	Flammable atmosphere exists abnormally

Table 11. Groups

Europe	USA/Canada	Description
I	none	Coal mines
IIA	Group D	Propane, gasoline, etc.
IIB	Group C	Ethylene
IIC	Group B	Hydrogen
IIC	Group A	Acetylene

Table 12. Protection Techniques

Europe	USA/Canada	Description	Zone
Ex d	Explosionproof	Flameproof	1, 2
Ex ia	Intrinsic safety	Intrinsic safety (2 fault)	0, 1, 2
Ex ib	Intrinsic safety	Intrinsic safety (1 fault)	1, 2
Ex n	Nonincendive	Nonsparking	2

Applicable Standards

The following standards are available for designing and installing circuits and equipment used in hazardous locations.

Table 13. Fundamental Information

Document	Title
ANSI/ISA S12.1	Definitions and Fundamental Information Pertaining to Electrical Instruments in Hazardous Locations
ANSI/NFPA 70	National Electrical Code
CSA C22.1	Canadian Electrical Code

Table 14. Area and Material Classification

Document	Title
ANSI/NFPA 497A	Classification of Class I Hazardous Locations
ANSI/NFPA 497B	Classification of Class II Hazardous Locations
ANSI/NFPA 497M	Classification of Gases, Vapors, and Dusts
ANSI/ISA S12.10	Classification of Class II Hazardous Locations

Table 15. Intrinsically Safe Loops

Document	Title
ANSI/ISA RP12.6-1988	Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations
ANSI/UL 913	Intrinsically Safe Apparatus and Associated Apparatus
CSA C22.2 No. 157-M1987	Intrinsically Safe and Nonincendive Equipment
FM Class Number 3610	Intrinsically Safe Apparatus and Associated Apparatus

Table 16. Nonincendive Equipment

Document	Title
ANSI/ISA S12.12-1984	Electrical Equipment for use in Class I, Division 2 Hazardous (Classified) Locations
CSA C22.2 No. 213-M1987	Nonincendive Electrical Equipment for use in Class I, Division 2 Hazardous Locations

Table 16. Nonincendive Equipment (continued)

Document	Title
FM Class Number 3611 (1986)	Electrical Equipment for use in Class I, Class II Division 2; Class III, Division 1 and 2 Hazardous Locations
UL 1604 (1982)	Electrical Equipment for use in Hazardous Locations

To obtain these standards, contact:

Canadian Standards Association
178 Rexdale Boulevard
Rexdale (Toronto), Ontario Canada M9W 1R3
416-747-4044

Factory Mutual Research
1151 Boston-Providence Turnpike
Norwood, MA 02062
617-762-4300

Instrument Society of America
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, NC 27709
919-549-8411

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
800-344-3555

Underwriters Laboratories
333 Pfingsten Road
Northbrook, IL 60062
708-272-8800 - Ext. 3542

Glossary

Class - A hazardous location designator used to differentiate between gases, dusts or fibers.

CSA - The Canadian Standards Association. A test lab in Canada.

Division - A hazardous location designator used to differentiate between whether the flammable atmosphere occurs normally or only as a result of a fault.

Dust-Ignitionproof Enclosure - A protection technique in which a tightly sealed enclosure is used to prevent entry of dusts within an enclosure containing electrical equipment.

Explosionproof Enclosure - A protection technique by which hot internal gases resulting from ignition of a flammable gas by the electrical equipment are prevented from exiting the enclosure and igniting flammable gases external to the equipment.

FM - Factory Mutual Research Corporation. A NRTL which tests electrical equipment used in hazardous locations.

Group - A hazardous location designator used to subdivide gases or dusts depending upon their ignition characteristics or other effect on electrical equipment.

Hazardous Location - An area where a flammable material may create a fire or explosion hazard. The National Electrical Code has defined hazardous locations specifically to limit the type of equipment used in these areas. The National Electrical Code uses the phrase ***Hazardous (Classified) Locations*** to distinguish from other hazards such as high voltage.

Hot Work Permit - A work permit that allows specific work to be done upon specific equipment during a specific time period. This permits the use of test equipment or procedures that could ignite a flammable atmosphere based upon analysis done to verify that the flammable atmosphere is not present during the specific time period. This is further explained in NFPA 30, Clause 5710.

Intrinsically Safe Loops - A protection technique by which energy into the hazardous location is limited to levels that will not ignite the flammable material under normal and specified fault conditions.

Isolating Intrinsic Safety Barrier - An intrinsic safety barrier that limits the energy into the hazardous location by a galvanic isolating device such as a transformer or optical coupler.

Nonincendive Equipment - A protection technique suitable only for Division 2 hazardous locations. The electrical equipment is not normally an ignition source for the flammable material.

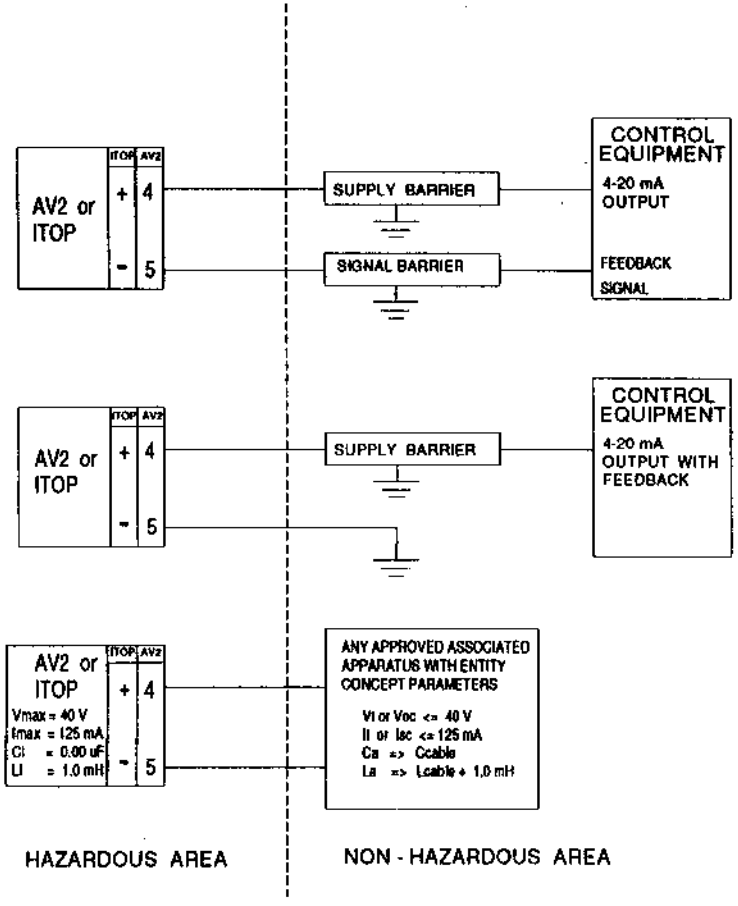
NRTL - A nationally recognized test lab in the United States. These labs are authorized to provide third party certification that equipment complies with required standards.

PLTC - A nonmetallic cable type that is a permitted wiring technique in Division 2 hazardous locations.

Shunt Diode Intrinsic Safety Barrier - An intrinsic safety barrier that relies on zener diodes to limit the voltage entering the hazardous location.

T Code - A temperature identification number which represents the hottest surface on an electrical product that could ignite the flammable material.

UL - Underwriters Laboratory. A NRTL which tests electrical equipment used in hazardous locations.



NOTES ON AV2 POSITIONER AND ITOP CONVERTER

1. SEE SHEETS 3.4 AND 3.5 IF AV2 USED WITH OPTIONAL FEEDBACK CIRCUIT.

NOTES ON BARRIERS

1. MAY BE IN A DIVISION 2 LOCATION IF SO APPROVED.
2. OUTPUT CURRENT MUST BE LIMITED BY A RESISTOR SUCH THAT THE OUTPUT VOLTAGE-CURRENT PLOT IS A STRAIGHT LINE DRAWN BETWEEN OPEN CIRCUIT VOLTAGE AND SHORT CIRCUIT CURRENT.
3. MUST BE INSTALLED IN ACCORDANCE WITH GUIDELINES PROVIDED BY THE MANUFACTURER. BARRIERS MAY NOT BE CONNECTED IN PARALLEL UNLESS ALLOWED BY THE MANUFACTURER'S APPROVAL.
4. CABLE CAPACITANCE PLUS INTRINSICALLY SAFE EQUIPMENT CAPACITANCE MUST BE LESS THAN THE MARKED CAPACITANCE (Ca) SHOWN ON ANY BARRIER USED. CABLE INDUCTANCE MUST BE LIMITED TO:

	GP A,B	GP C	GP D
WHEN USING GP ABCDEFG PARAMETERS:	0.17 mH	1.3 mH	2.4 mH
WHEN USING GP CDEFG PARAMETERS:	.....	0.5 mH	1.4 mH

5. THE BARRIERS SHOWN IN THE TABLE BELOW ARE FM APPROVED AS A SYSTEM.

Class I, II, III Haz Loc Group	VENDOR	SUPPLY BARRIER	SIGNAL BARRIER
A,B,C,D,E,F,G	MTL	728	
A,B,C,D,E,F,G	MTL	787S	
A,B,C,D,E,F,G	MTL	3042	
A,B,C,D,E,F,G	STAHL	9001/01-280-100-00	9001/03-273-000-00
A,B,C,D,E,F,G	STAHL	9001/01-280-100-00	9001/01-086-150-00
A,B,C,D,E,F,G	STAHL	8903/31-284-050-70	9001/03-273-000-00
A,B,C,D,E,F,G	STAHL	8903/31-284-050-70	9001/01-086-150-00
A,B,C,D,E,F,G	STAHL	8903/31-315-050-70	9001/03-273-000-00
A,B,C,D,E,F,G	STAHL	8903/31-315-050-70	9001/01-086-150-00
A,B,C,D,E,F,G	CROUSE-HINDS	SB59440M1787	

6. INTRINSIC SAFETY BARRIERS MUST BE FMRC APPROVED IN THE CONFIGURATION SHOWN. MULTIPLE SAFETY BARRIER CONFIGURATIONS OR DUAL-CHANNEL BARRIERS WILL HAVE A Vt AND AN It SPECIFIED. CABLE CAPACITANCE/INDUCTANCE IS BASED ON THE Ca & La.

NOTES ON CONTROL EQUIPMENT

1. MAINS POWER MUST NOT EXCEED 250 VOLTS WITH RESPECT TO EARTH.

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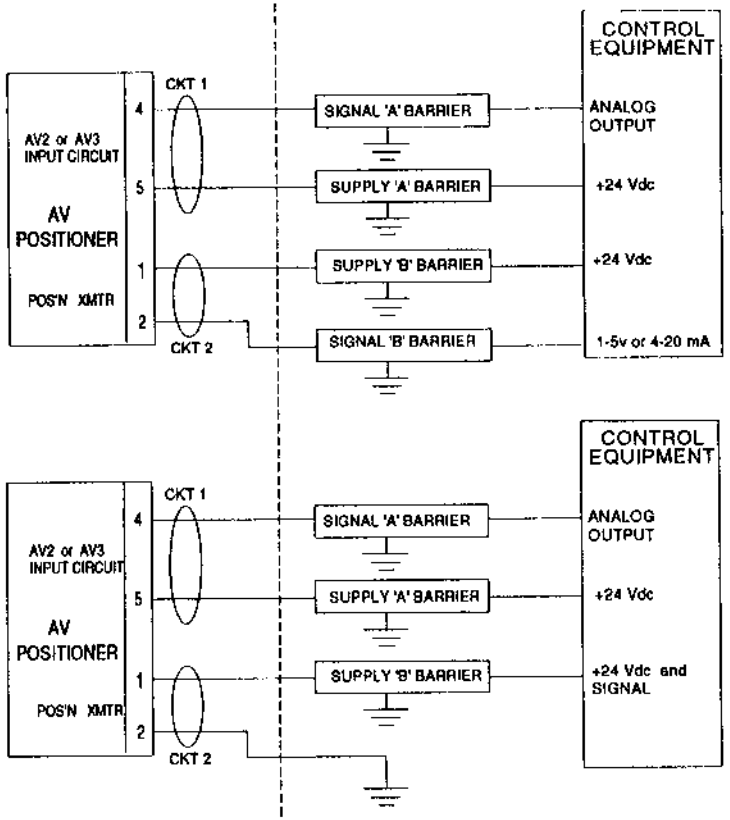
Sheet 2.2



NOTES ON AV2 AND AV3 POSITIONERS

1. CIRCUIT 1 AND CIRCUIT 2 MUST BE IN SEPARATE CABLES OR IN ONE CABLE THAT HAS SUITABLE INSULATION. REFER TO RECOMMENDED PRACTICE ANSI/ISA-RP12.6 FOR INSTALLING INTRINSICALLY SAFE LOOPS.

NOTES ON BARRIERS

1. MAY BE IN A DIVISION 2 LOCATION IF SO APPROVED.
2. OUTPUT CURRENT MUST BE LIMITED BY A RESISTOR SUCH THAT THE OUTPUT VOLTAGE-CURRENT PLOT IS A STRAIGHT LINE DRAWN BETWEEN OPEN CIRCUIT VOLTAGE AND SHORT CIRCUIT CURRENT.
3. MUST BE INSTALLED IN ACCORDANCE WITH GUIDELINES PROVIDED BY THE MANUFACTURER. BARRIERS MAY NOT BE CONNECTED IN PARALLEL UNLESS ALLOWED BY THE MANUFACTURER'S APPROVAL.
4. CABLE CAPACITANCE PLUS INTRINSICALLY SAFE EQUIPMENT CAPACITANCE MUST BE LESS THAN THE MARKED CAPACITANCE (Ca) SHOWN ON ANY BARRIER USED. THE SAME APPLIES FOR INDUCTANCE.
5. SELECTED BARRIERS MUST HAVE Voc NOT EXCEEDING Vmax AND Isc NOT EXCEEDING Imax AS SHOWN FOR EACH TYPE OF BARRIER IN THE TABLE BELOW. ALL BARRIERS MUST BE OF THE SAME POLARITY.

	4-20 mA POS'N XMTR BARRIERS				AV2 POSITIONER	AV3 POSITIONER
Class I, II, III	SUPPLY 'B' BARRIER		SIGNAL 'B' BARRIER		SUPPLY 'A' BARRIER & SIGNAL 'A' BARRIER	SUPPLY 'A' BARRIER & SIGNAL 'A' BARRIER
Haz Loc Group	Vmax	Imax	Vmax	Imax		
A,B,C,D,E,F,G	40 V	150 mA	13 V	332 mA	SEE SHEET 2.2 FOR LIST OF FM APPROVED BARRIERS FOR THE 4-20 mA INPUT.	SEE SHEET 3.1 FOR LIST OF FM APPROVED BARRIERS FOR THE 4-20 mA INPUT.
C,D,E,F,G	35 V	250 mA	13 V	332 mA		

6. SELECTED BARRIERS FOR CIRCUIT 2 WITH Vt/It RATINGS MUST HAVE Vt NOT EXCEEDING 40 Vdc AND It NOT EXCEEDING 332 mA.
7. THE SUM OF THE BARRIER POWER RATINGS FOR THE 4-20 mA POS'N XMTR MUST NOT EXCEED 1.3 W. THE POWER RATING FOR EACH BARRIER CAN BE CALCULATED AS (Voc * Isc)/4.

NOTES ON CONTROL EQUIPMENT

1. MAINS POWER MUST NOT EXCEED 250 VOLTS WITH RESPECT TO EARTH.

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FACTORY MUTUAL APPROVED ENTITY PARAMETERS

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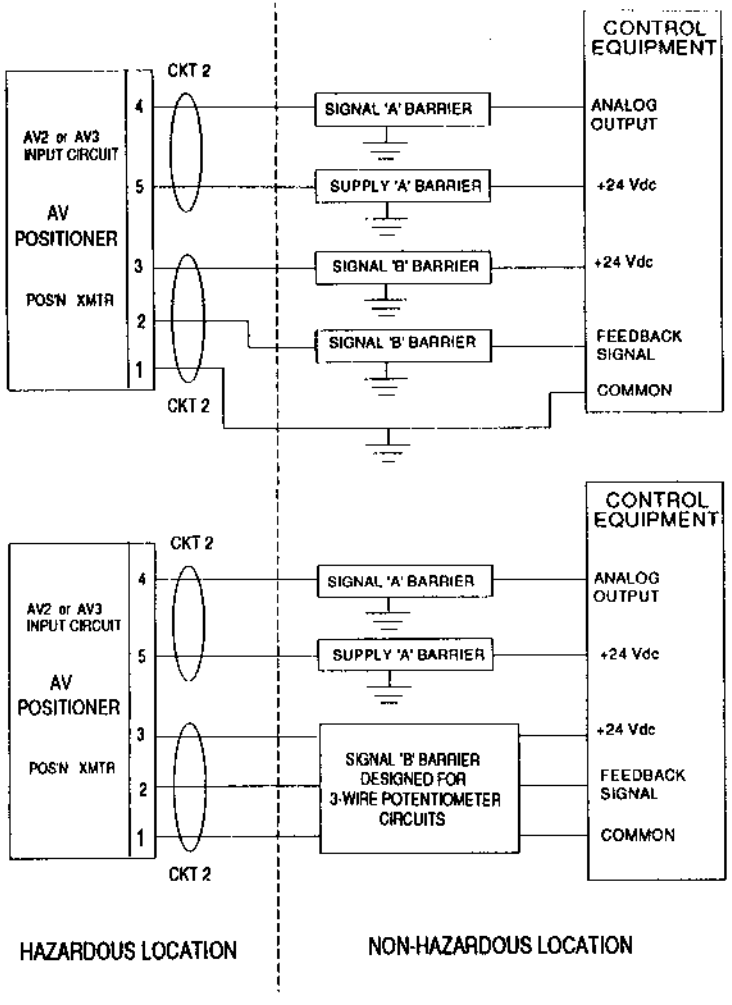

1. CIRCUIT 1 AND CIRCUIT 2 MUST BE IN SEPARATE CABLES OR IN ONE CABLE THAT HAS SUITABLE INSULATION. REFER TO RECOMMENDED PRACTICE ANSI/ISA-RP12.6 FOR INSTALLING INTRINSICALLY SAFE LOOPS.

NOTES ON BARRIERS

1. MAY BE IN A DIVISION 2 LOCATION IF SO APPROVED.
2. OUTPUT CURRENT MUST BE LIMITED BY A RESISTOR SUCH THAT THE OUTPUT VOLTAGE-CURRENT PLOT IS A STRAIGHT LINE DRAWN BETWEEN OPEN CIRCUIT VOLTAGE AND SHORT CIRCUIT CURRENT.
3. MUST BE INSTALLED IN ACCORDANCE WITH GUIDELINES PROVIDED BY THE MANUFACTURER. BARRIERS MAY NOT BE CONNECTED IN PARALLEL UNLESS ALLOWED BY THE MANUFACTURER'S APPROVAL.
4. CABLE CAPACITANCE PLUS INTRINSICALLY SAFE EQUIPMENT CAPACITANCE MUST BE LESS THAN THE MARKED CAPACITANCE (Ca) SHOWN ON ANY BARRIER USED. THE SAME APPLIES FOR INDUCTANCE.
5. SELECTED BARRIERS MUST HAVE Voc NOT EXCEEDING Vmax AND Isc NOT EXCEEDING Imax AS SHOWN FOR EACH TYPE OF BARRIER IN THE TABLE BELOW. ALL BARRIERS MUST BE OF THE SAME POLARITY.

	POTENTIOMETRIC OPTION		AV2 POSITIONER	AV3 POSITIONER
Class I, II, III Haz Loc Group	SIGNAL 'B' BARRIER Vmax	Imax	SUPPLY 'A' BARRIER & SIGNAL 'A' BARRIER	SUPPLY 'A' BARRIER & SIGNAL 'A' BARRIER
A,B,C,D,E,F,G	30 V	50 mA	SEE SHEET 2.2 FOR LIST OF FM APPROVED BARRIERS FOR THE 4-20 mA INPUT.	SEE SHEET 3.1 FOR LIST OF FM APPROVED BARRIERS FOR THE 4-20 mA INPUT.
C,D,E,F,G	30 V	50 mA		

6. SELECTED BARRIERS WITH Vt/It RATINGS MUST HAVE Vt NOT EXCEEDING 40 Vdc AND It NOT EXCEEDING 332 mA.

NOTES ON CONTROL EQUIPMENT

1. MAINS POWER MUST NOT EXCEED 250 VOLTS WITH RESPECT TO EARTH.

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FACTORY MUTUAL APPROVED ENTITY PARAMETERS

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FIGURE 1

FIGURE 4

FIGURE 5

DIVISION 1 POTENTIALLY FLAMMABLE ATMOSPHERE

BARRIERS MAY BE LOCATED IN A DIVISION 2 HAZARDOUS LOCATION IF SUITABLY CERTIFIED BY CSA.

NON-FLAMMABLE ATMOSPHERE

PARAMETERS CERTIFIED BY THE CANADIAN STANDARDS ASSOCIATION

BAILEY FIELD EQUIP.	HAZARDOUS LOCATIONS I II III	FIG.	BARRIER PARAMETER FOR GROUPS A, B, C, D, E, F, G MAX VOLTS/ MIN OHMS													BARRIER PARAMETER FOR GROUPS C, D, E, F, G MAX VOLTS/ MIN OHMS						
			10V	12V	20V	20.8V	22V	25V	28V	29.5V	30V	32V				10V	12V	27V	28V	30V	33V
AP73	ABCD no	4		40			150	200	270			400							120	150	200
AP83	ABCD no	1 & 5		40			150	200	270			400					40		120	150	200
AP93	ABCD no	4		40			150	200	270	305		400					40		120	150	200
AV(xmtr)	ABCD no	8 *		40			150	200	270	305		400					40		120	150	200
AV (pot)	ABCD no	6 *							600												
AV2	ABCD no	7		40			150	200	270	305		400					40		120	150	200
AV3	ABCD no	4		40			150	200	270			400					40		120	150	200
AV4	ABCD no	1 & 5		40			150	200	270			400					40		120	150	200
BCN	ABCD EFG yes	1		40			150	200	270	305		400					40		120	150	200
EQ10	ABCD EFG yes	1	40						240		250					40				120	150
EQN	ABCD EFG yes	1		40			150	200	270	305		400					40		120	150	200
ITOP	ABCD no	4		40			150	200	270	305		400					40		120	150	200
PTS	ABCD EFG yes	1		40			150	200	270	305		400					40		120	150	200
RQ	ABCD FG yes	1	40		100				240		300					40		120		150	
TBN580	ABCD EFG yes	1		40			150	200	270	305		400					40		120	150	200

TABULATION SHOWS ALLOWED COMINATION OF BARRIER VOLTAGE AND RESISTANCE RATINGS.

FOR ANY COMBINATION, THE SELECTED BARRIER MUST NOT HAVE A VOLTAGE RATING EXCEEDING THE TABULATED VALUE NOR HAVE A RESISTANCE RATING (IN OHMS) LESS THAN THE TABULATED VALUE.

SIGNAL BARRIERS MUST BE DIODE RETURN TYPE OR NOT EXCEED 12 VOLT RATING.

* AV(xmtr) AND AV(pot) ARE OPTIONS PERMITTED WITH AV1, AV2, AND AV3 POSITIONERS. THE AV4 ALWAYS INCLUDES THE AV(xmtr). THE WIRES FOR THE AV(xmtr) OR AV(pot) MUST BE SEPARATED FROM THE POSITIONER INPUT WIRES BY A GROUNDED SHIELD.

INSTALLATION TO BE IN ACCORDANCE WITH THE CANADIAN ELECTRICAL CODE (CEC) PART 1 UNLESS OTHERWISE SPECIFIED.

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CANADIAN STANDARDS ASSOCIATION CERTIFIED I.S. ENTITY LOOPS

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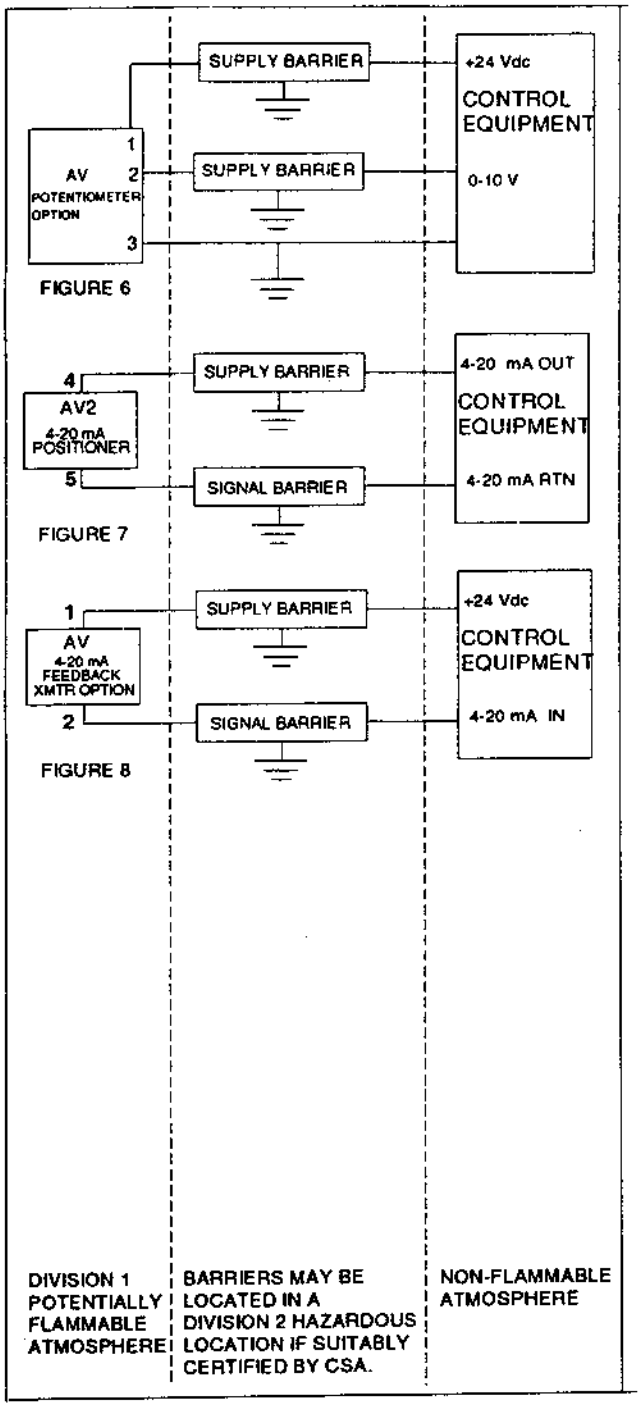
SUPPLY BARRIER
+24 Vdc
CONTROL EQUIPMENT
AV
POTENTIOMETER OPTION
1
2
3
SUPPLY BARRIER
0-10 V
FIGURE 6
SUPPLY BARRIER
4-20 mA OUT
4
AV2
4-20 mA POSITIONER
5
SIGNAL BARRIER
CONTROL EQUIPMENT
4-20 mA RTN
FIGURE 7
SUPPLY BARRIER
+24 Vdc
1
AV
4-20 mA FEEDBACK XMTR OPTION
2
SIGNAL BARRIER
CONTROL EQUIPMENT
4-20 mA IN
FIGURE 8
DIVISION 1 POTENTIALLY FLAMMABLE ATMOSPHERE
BARRIERS MAY BE LOCATED IN A DIVISION 2 HAZARDOUS LOCATION IF SUITABLY CERTIFIED BY CSA.
NON-FLAMMABLE ATMOSPHERE
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CANADIAN STANDARDS ASSOCIATION
CERTIFIED I.S. ENTITY LOOPS
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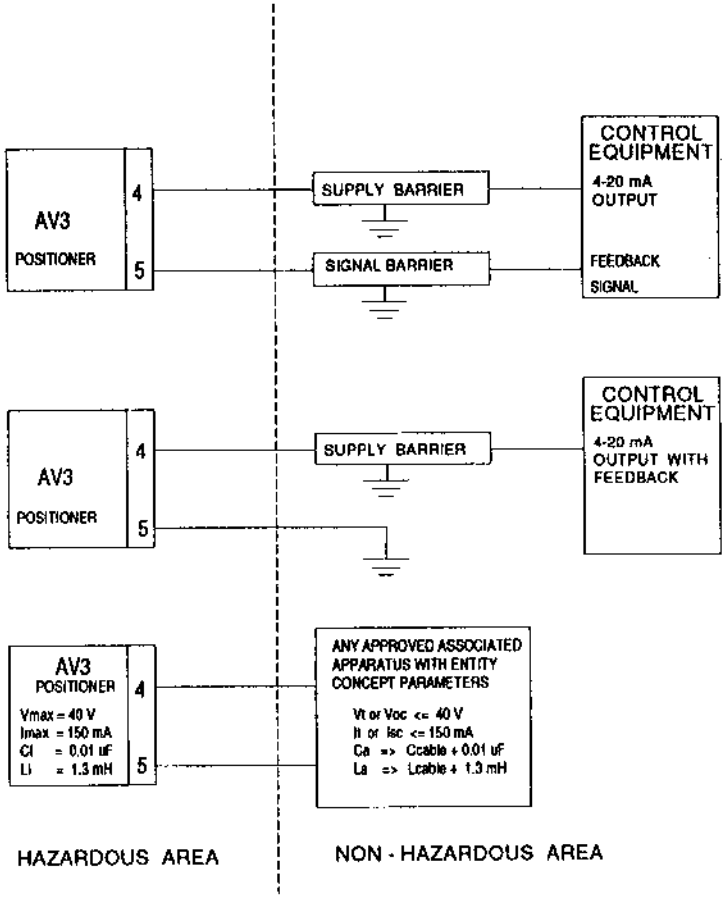
Sheet 4.1



NOTES ON AV3 POSITIONER

1. SEE SHEET S 3.4 AND 3.5 IF USED WITH OPTIONAL FEEDBACK CIRCUIT.

NOTES ON BARRIERS

1. MAY BE IN A DIVISION 2 LOCATION IF SO APPROVED.
2. OUTPUT CURRENT MUST BE LIMITED BY A RESISTOR SUCH THAT THE OUTPUT VOLTAGE-CURRENT PLOT IS A STRAIGHT LINE DRAWN BETWEEN OPEN CIRCUIT VOLTAGE AND SHORT CIRCUIT CURRENT.
3. MUST BE INSTALLED IN ACCORDANCE WITH GUIDELINES PROVIDED BY THE MANUFACTURER. BARRIERS MAY NOT BE CONNECTED IN PARALLEL UNLESS ALLOWED BY THE MANUFACTURER'S APPROVAL.
4. CABLE CAPACITANCE PLUS INTRINSICALLY SAFE EQUIPMENT CAPACITANCE MUST BE LESS THAN THE MARKED CAPACITANCE (Ca) SHOWN ON ANY BARRIER USED. CABLE INDUCTANCE MUST BE LIMITED TO:

	GP A,B	GP C	GP D
WHEN USING GP ABCDEFG PARAMETERS:	0.17 mH	1.3 mH	2.4 mH
WHEN USING GP . CDEFG PARAMETERS:	----------	0.5 mH	1.4 mH

5. SELECTED BARRIERS MUST HAVE Voc NOT EXCEEDING Vmax AND Isc NOT EXCEEDING Imax AS SHOWN FOR EACH TYPE OF BARRIER IN THE TABLE BELOW. ALL BARRIERS MUST BE OF THE SAME POLARITY.

Class I, II, III	'SUPPLY BARRIER'		'SIGNAL BARRIER'	
Haz Loc Group	Vmax	Imax	Vmax	Imax
A,B,C,D,E,F,G	40 V	150 mA	13 V	200 mA
C,D,E,F,G	35 V	250 mA	13 V	200 mA

6. INTRINSIC SAFETY BARRIERS MUST BE FMRC APPROVED IN THE CONFIGURATION SHOWN. MULTIPLE SAFETY BARRIER CONFIGURATIONS OR DUAL-CHANNEL BARRIERS WILL HAVE A Vt AND AN It SPECIFIED. CABLE CAPACITANCE/INDUCTANCE IS BASED ON THE Ca & La.

NOTES ON CONTROL EQUIPMENT

1. MAINS POWER MUST NOT EXCEED 250 VOLTS WITH RESPECT TO EARTH.

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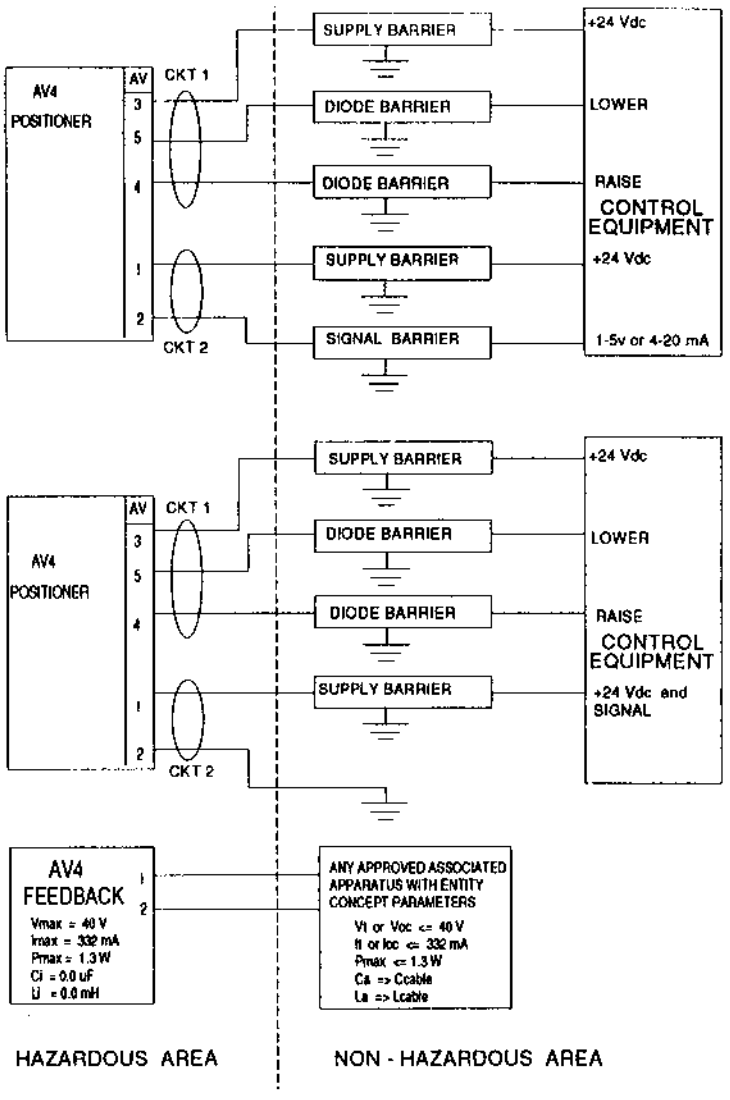

NOTES ON AV4 POSITIONER

1. CIRCUIT 1 AND CIRCUIT 2 MUST BE IN SEPARATE CABLES OR IN ONE CABLE THAT HAS SUITABLE INSULATION. REFER TO RECOMMENDED PRACTICE ANSI/ISA-RP12.6 FOR INSTALLING INTRINSICALLY SAFE LOOPS.

NOTES ON BARRIERS

1. MAY BE IN A DIVISION 2 LOCATION IF SO APPROVED.
2. OUTPUT CURRENT MUST BE LIMITED BY A RESISTOR SUCH THAT THE OUTPUT VOLTAGE-CURRENT PLOT IS A STRAIGHT LINE DRAWN BETWEEN OPEN CIRCUIT VOLTAGE AND SHORT CIRCUIT CURRENT.
3. MUST BE INSTALLED IN ACCORDANCE WITH GUIDELINES PROVIDED BY THE MANUFACTURER. BARRIERS MAY NOT BE CONNECTED IN PARALLEL UNLESS ALLOWED BY THE MANUFACTURER'S APPROVAL.
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5. SELECTED BARRIERS MUST HAVE Voc NOT EXCEEDING Vmax AND Isc NOT EXCEEDING Imax AS SHOWN FOR EACH TYPE OF BARRIER IN THE TABLE BELOW. ALL BARRIERS MUST BE OF THE SAME POLARITY.

Class I, II, III	'SUPPLY BARRIER'		'SIGNAL BARRIER'		'DIODE BARRIER'	
Haz Loc Group	Vmax	Imax	Vmax	Imax	Vmax	Imax
A,B,C,D,E,F,G	40 V	150 mA	13 V	350 mA	40 V	0 mA
C,D,E,F,G	35 V	250 mA	13 V	350 mA	35 V	0 mA

NOTES ON CONTROL EQUIPMENT

1. MAINS POWER MUST NOT EXCEED 250 VOLTS WITH RESPECT TO EARTH.

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