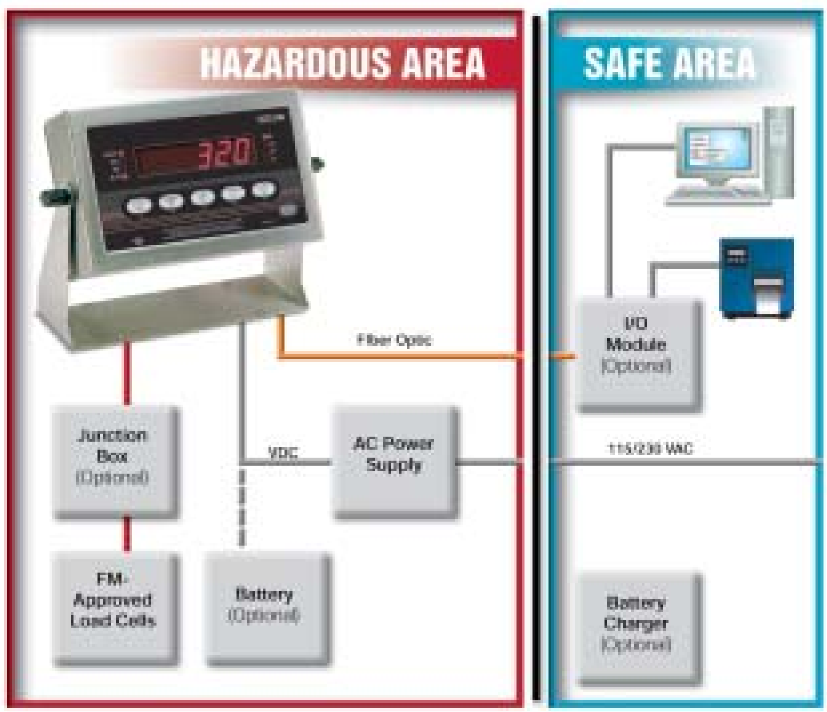
Explosive Environment Review

Version 3.0

A Comprehensive Guide to Electronic Weighing Equipment and Hazardous Environments



RICE LAKE WEIGHING SYSTEMS
Commitment Beyond Measurement™

ISO 9001 REGISTERED

PN 16985

Contents

1.0 Introduction

As we are all aware, electronic equipment is capable of generating and releasing electrical and thermal energy during both normal and abnormal operating conditions. If this energy is above the explosion causing level of the hazardous atmosphere, severe damage to equipment and personal injury can occur. For these reasons, weighing systems are oftentimes installed in “safe” environments that are costly, inconvenient and/or time consuming to use. By adhering to established standards, guidelines and recommended practices, a weighing system can be made safe to be utilized in hazardous environments.

Systems can be made explosion proof, intrinsically safe or purged and pressurized to render them safe to use in hazardous environments. This guide is not intended to take the place of the established standards, guidelines and practices, but to point them out to you and “guide” you on the path to safe hazardous environment weighing operations.

There is no substitute for experience. Installation of hazardous area equipment must be performed by certified electricians. The installation must be inspected and approved by an authority having jurisdiction over the hazardous area. The key to safe hazardous environment weighing operations is a concentrated team effort with close interaction between the scale professional, plant safety engineer and licensed electrician

Caution **Do not use these guidelines as your only references for scale installations. While performing maintenance refer to the manufacturer's manual for procedures that are peculiar to the equipment being serviced. It is important to be familiar with all standards, recommended practices and codes that apply to your installation.**

2.0 Standards

OBJECTIVE: *Familiarization with codes, standards and recommended practices.*

These standards, codes and recommended practices are national in scope. Local, state, county and city agencies may enforce codes which are more stringent. Often, local authorities see the need to offer more stringent protection as local conditions warrant. Since local officials are closer to their specific locale, they may be in a better position to determine if the national codes adequately protect equipment and lives for specific local conditions. Some of these documents have made provisions to allow some specific requirements to be waived by the authority having jurisdiction, or permit alternate methods where it is assured that equivalent objectives can be achieved by establishing and maintaining effective safety. The documents are not intended as a design specification nor as an instruction manual for untrained persons. They are intended for use by capable engineers, contractors and inspectors who are fully acquainted with the principles for which the standard is written. Local electricians and engineers should be familiar with the national and local regulations governing their installations.

The National Fire Protection Association (NFPA), Underwriters Laboratories (UL), Factory Mutual Global (FM) and the Instrument Society of America (ISA) publish guidelines for proper electrical installations. We will identify these publications that are applicable to hazardous environment equipment installations. (See Appendix "A" for organizational addresses.)

2.1 NFPA 70, "National Electrical Code (NEC) Handbook"

The NEC Handbook is a nationally accepted guide for the safe installation of electrical conductors and equipment. It is the basis for all electrical codes used in the United States. The "National Electrical Code Handbook" is periodically revised to reflect new information and/or available equipment. It is important to ensure your handbook is the current one. NFPA 70 contains an agenda for the meetings to compile the next handbook. You can use this to obtain an idea as to when the next NFPA 70 revision will occur, thus keeping your handbook up-to-date.

Articles 500 through 504 cover the requirements for electrical equipment and wiring for all voltages in locations where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust or ignitable fibers or flyings.

The address for the National Fire Protection Association is 1 Batterymarch Park, Quincy, MA 02269-9990.

2.2 NFPA 496, "Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Locations"

NFPA 496 governs purged enclosures for electrical equipment in Class I locations, and pressurized enclosures for electrical equipment in Class II locations.

2.3 NFPA 497M, "Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous (Classified) Locations"

NFPA 497M contains the properties of flammable liquids, gases and solids.

2.4 NFPA 325M "Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids"

NFPA 325M is a compilation of basic fire protection properties of various materials. The "General" section of 325M provides information such as definitions of fire hazard properties, extinguishing methods, health hazard ratings, flammability hazard ratings, and reactivity hazard rating. The "Properties" section includes flash point, ignition temperature, upper and lower flammable limits, specific gravity and boiling point.

2.5 ANSI/UL 913 “Standard for Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II and III, Division 1 Hazardous Locations”

ANSI/UL 913 provides requirements for the construction and testing of electrical apparatus or parts of such apparatus, in which circuits themselves are incapable of causing ignition in Class I, II, or III, Division 1 locations, in accordance with Article 500 of the NEC.

The address of Underwriters Laboratories is 333 Pfingsten Road, Northbrook, IL 60062.

2.6 ANSI/ISA RP 12.06.01 “Installation of Intrinsically Safe Instrument Systems for Hazardous (Classified) Locations”

ANSI/ISA RP 12.6 is a recommended practice (RP) prepared by the Instrument Society of America (ISA) to promote the uniform installation of intrinsically safe systems for hazardous (classified) locations. This RP should be used in conjunction with the NEC. It is not intended to include guidance for equipment design, testing, maintenance, repair nor apply to the use of portable equipment.

The address of the Instrument Society of America is 67 Alexander Drive, Research Triangle Park, NC 27709.

2.7 FM Global Standard 3610 “Approval Standard, Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II, and III, Division 1 Hazardous Locations”

This standard serves as the basis for Factory Mutual Approval of intrinsically safe apparatus and associated apparatus. It also provides requirements for the construction and testing of electrical apparatus of parts of such apparatus whose circuits are incapable of causing ignition in Division 1 hazardous locations as defined in Article 500 of the NEC.

The address of Factory Mutual Global is 1151 Boston-Providence Turnpike, Norwood, MA 02062.

2.8 FM Approval Standard 3615, “Approval Standard, Explosive Proof Electrical Equipment”

FM Approval Standard 3615 is used by Factory Mutual to evaluate and approve electrical equipment for use in hazardous (classified) locations. Areas evaluated are the product suitability, operation, performance, durability and reliability.

2.9 “Electrical Installations in Hazardous Locations”

“Electrical Installations in Hazardous Locations” is published by the National Fire Protection Association. It has not been processed in accordance with the NFPA Regulations Governing Committee Projects. The material in this publication should not be considered as the official position of the NFPA. The intent of the publication is to advise people who are unfamiliar with, or who occasionally become involved in, electrical installations in hazardous locations. It does not take the place of official documents about hazardous locations. It is a guide to steer you in the direction of official documents. The currency of these documents should be checked by obtaining a copy from the specific organization responsible for the document’s publication. This publication is a good general source of hazardous location information which gives excellent general information to steer you to the correct official document for your application.

REVIEW EXERCISE - PUBLICATIONS

1. Place the letter from the title next to its corresponding publication.

_____1. ANSI/UL 913

_____2. NFPA 496

_____3. NFPA 70

_____4. ANSI/ISA RP 12.06.01

_____5. NFPA 497M

A. “Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Location”

B. “Standard for Intrinsically Safe Apparatus and As-associated Apparatus for use in Class I, II and III, Division 1 Hazardous Locations”

C. “Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous (Classified) Locations”

D. “National Electrical Code Handbook”

E. “Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Locations”

See Appendix C for answers to Review Exercises.

3.0 Hazardous Locations

OBJECTIVE: *Define hazardous locations and categorize them as to their Class, Division and Group.*

To be adequately defined, hazardous locations must be categorized as to their Class, Division and Group. We will define the meaning of Class, Division and Group plus see what type of locations falls under each heading.

3.1 Class

Class defines the type of hazard present in the locations. Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

Class II locations are those that are hazardous because of the presence of combustible dust.

Class III locations are hazardous because of the presence of easily ignitable fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in the area, in quantities sufficient to produce ignitable mixtures.

3.2 Division

A Division defines the hazardous locations as to the conditions under which the hazard exists. A Division is a sub-category of a Class. Each Class is categorized into Division 1 and Division 2. Division 1 and Division 2 conditions vary for each class of material.

3.3 Group

A Group narrows the hazardous location down to the specific material or type of material present. Class I locations are categorized into Groups A, B, C and D where Group A materials provide more of an explosion hazard than Group B materials.

Class II locations are categorized into Groups E, F and G. Again, Group E environments are more explosive than Group G environments.

Class III locations are not grouped.

3.4 Categorization

The easiest way to illustrate the categorization of locations into Class, Division and Group is to study the charts in Figures 3-1, 3-2 and 3-3 on the following pages.

Hazardous (Classified) Locations

(In accordance with Article 500, National Electrical Code-1990)

CLASS I
FLAMMABLE GASES OR VAPORS

Division 1

1. Exists under normal conditions
2. May exist because of:
   - repair operations
   - maintenance operations
   - leakage
3. Released concentration because of
   - breakdown of equipment
   - breakdown of process
   - faulty operation of equipment
   - faulty operation of process which cause simulltaneous failure of electrical equipment

Division 2

1. Liquids and gases in closed containers or systems are:
   - handled
   - processed
   - used
2. Concentrations normally prevented by positive mechanical ventilation
3. Adjacent to Class I, Division 1 location

Group A: atmospheres containing acetylene

Group B: atmospheres containing hydrogen, fuel and combustible process gases containing more than 30 percent hydrogen by volume, or gases or vapors of equivalent hazard such as butadiene*, ethylene oxide**, Propylene oxide**, and acrolein**.

Group C: atmospheres such as cyclopropane, ethyl ether, ethylene, or gas or vapors of equivalent hazard.

Group D: atmospheres such as acetone ammonia***, benzene, benzol, butane, gasoline, ethanol, methanol, methane, hexane, naphtha, natural gas, propane, or gas or vapors of equivalent hazard.

Figure 3-1. NEC Class I

* Group D equipment may be used for this atmosphere if such equipment is isolated in accordance with NEC Section 501-5(a) by sealing all conduit 1/2-inch size or larger.

** Group C equipment may be used for this atmosphere if such equipment is isolated in accordance with NEC Section 501-5(a) by sealing all conduit 1/2-inch size or larger.

*** For classification of areas involving ammonia atmospheres, see ANSI/ASHRAE 15, “Safety Code for Mechanical Refrigeration” and ANSI/CGA G 2.1, “Safety Requirements for the Storage and Handling of Anhydrous Ammonia.”

CLASS II
Combustible Dusts

Division 1

1. In air under normal conditions
2. Ignitable mixture produced by:
    - mechanical failure of machinery
    - mechanical failure of equipment
    - abnormal operation of equipment and provide source of ignition from:
        - simultaneous failure of electrical equipment
        - simultaneous failure of operation of protection devices
        - other causes
3. Electrically conductive dusts may be present in hazardous quantities

Division 2

1. Not normally in the air
2. Accumulations normally insufficient to interfere with normal operation of electrical equipment or other apparatus
3. In air as a result of malfunctioning of:
    - handling & processing equipment
4. Accumulations sufficient to interfere with safe dissipation of heat from electrical equipment
5. Accumulations may be ignitable by abnormal operation or failure of electrical equipment

Group E: atmospheres containing combustible
- metal dusts regardless of resistivity
- other combustible dusts of similarly hazardous characteristics having resistivity of less than 100 ohm-centimeter

Group F: atmospheres containing
- carbon black, charcoal, coal or coke dusts which have more than 8 percent total volatile material
- these dusts sensitized so that they present an explosion hazard, and having resistivity greater than 100 ohm-centimeter or less than 100,000,000 ohm-centimeter

Group G: atmospheres containing combustible dusts having resistivity of 100,000,000 ohm-centimeter or greater

Figure 3-2. NEC Class II

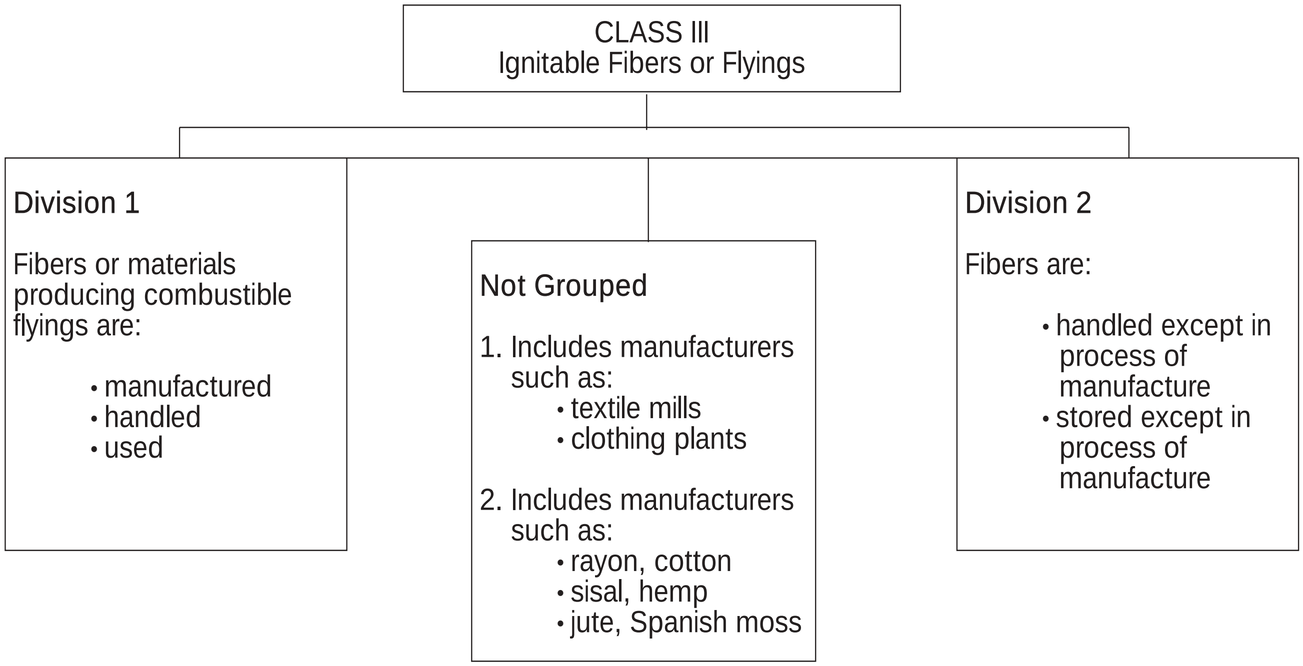


Figure 3-3. NEC Class III

Let's take an example of an atmosphere containing natural gas. Since we are dealing with a gas, we can determine from the charts that the correct class is Class I, Flammable gases or vapors. We will say that the natural gas may be present in our atmosphere because of leakage. Again, referring to our charts, we see that the possibility of a flammable gas being in the atmosphere because of leakage would place our location in Division 1. Now looking further into the chart, we see that natural gas is part of Group D. So to fully define our hazardous location we would say that it is a Class I, Division 1, Group D hazardous location.

Caution **Just because a particular material does not appear in the preceding charts does not necessarily mean it does not pose a hazard. Always consult the plant safety engineer, maintenance personnel or whomever the "authority having jurisdiction" is to determine the degree of hazard they need to assign to the location. It is essential that you become familiar with hazardous locations, but as the scale professional, do not put yourself in the position to make the final decision when categorizing hazardous atmospheres. That responsibility falls with the safety engineer, insurance underwriter or whoever is the authority having jurisdiction.**

For a complete list noting properties of flammable liquids, gases and solids, see NFPA 497M, "Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous (Classified) Locations."

3.5 Temperature

Prior to the 1971 National Electric Code, the auto ignition temperature (AIT) of a hazardous area was part of the group classification process. Because of low ignition temperatures of some materials, they were not able to be classified. This led to the removal of ignition temperature consideration when grouping hazardous areas. This does not mean that ignition temperatures can be ignored. In fact, they are taken into consideration as a separate, but just as important, identity from normal categorization of hazardous areas.

A system of marking equipment to identify the external surface temperature was initiated. Equipment can be used in locations where the ignition temperature is higher than the marked external surface temperature of the equipment. The system employs identification numbers to identify specific temperatures or temperature ranges. These numbers range from T1 through T6, where the maximum equipment surface temperature allowed for the hazardous location is highest for T1 identified equipment and lowest for T6 equipment. Sub-identification are provided for identification numbers T2, T3 and T4. The following chart provides the identification numbers and their maximum temperature ratings.

External Surface Temperature Identification Numbers

Maximum Temperature		Identification Number
°C	°F	
450	842	T1
300	572	T2
280	536	T2A
260	500	T2B
230	446	T2C
215	419	T2D
200	392	T3
180	356	T3A
165	329	T3B
160	320	T3C
135	275	T4
120	248	T4A
100	212	T5
85	185	T6

Table 3-1. External Surface Temperature ID Numbers

NFPA 497M provides information on ignition temperatures for Class I and Class II materials. Equipment that has the ignition temperature marked on it has been tested and the operating temperature is known.

REVIEW EXERCISE - HAZARDOUS LOCATIONS

I. Classify each environment below according to Class, Division and Group.

1. Location where fibers that produce combustible flyings are handled.

2. A location containing gasoline which is processed in a closed system.

3. A location where ethylene oxide gas may exist during maintenance operations.

4. A location where coal dust is sensitized to present an explosion hazard and having a resistivity of 1000 ohm-centimeter during normal conditions.

5. A location where combustible dusts having a resistivity of 100,000,000 ohm-centimeter are in the air as a result of infrequent malfunctioning of handling equipment.

6. A location where ethylene gas is released because of faulty equipment operation.

7. A location adjacent to a Class I, Division 1 location where manufactured gas containing 33% hydrogen by volume is present.

See Appendix C for answers to Review Exercises

5.0 Specifying Hazardous Environment Equipment

OBJECTIVES: *Identify who is responsible for determining the hazardous location classification. Calculate system output signal sensitivity including barrier voltage drops.*

5.1 Classification Determination

As previously discussed, each hazardous environment must be categorized as to its Class, Division and Group. Each of these three parts must be defined in order to completely describe the hazardous location. Class III locations are not categorized into groups. Class and Division adequately describe a Class III location. NFPA 497M "Manual for Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous (Classified) Locations" contains information on specific flammable gases, flammable and combustible liquids and combustible dusts. The relevant combustion properties of these gases, liquids and dusts have been identified sufficiently to allow their classification into groups established by the NEC. NFPA 497M assists the engineer in the selection of special electrical equipment for hazardous areas. NFPA 497M is not an all inclusive list. It does contain definitions of flammable and combustible liquids to aid the engineer in determining if a hazard may be present.

Caution **The authority having jurisdiction over the area is the final authority when categorizing a hazardous location. Under no circumstances should a scale professional define a hazardous area classification.**

5.2 Hazardous Area Classification Liability

Specifying, installing and servicing equipment designed for hazardous locations involves coordination between the manufacturer, distributor, installer, servicing agency and the authority having jurisdiction over the hazardous area. Attention to detail is a must! Rice Lake Weighing Systems has developed a Hazardous Area Classification form which will help you specify your hazardous area application. This form is a record of the Class, Division and Group of the hazardous location for which the system is to be specified. The signature of the individual who classified the location also must be on the form in case questions arise about the hazardous location and the system. The end user's company name is also required so we all have a record of where our hazardous location designed equipment is located. After you have completely annotated this form, retain a completed copy for your records. Any distributor that is interested in quoting and selling our line of explosive environment equipment must first attend one of our Explosive Environment Product Reviews.

RICE LAKE WEIGHING SYSTEMS

Commitment Beyond Measurement™

Hazardous Area Classification

For assistance in selecting hazardous Area Control Equipment for your application requirements, please complete this form and submit, along with a description of the application to:

Rice Lake Weighing Systems
Attn: Hazardous Environment Dept.
230 W. Coleman Street
Rice Lake, WI 54868
Telephone: 715-234-9171
Fax: 715-234-6967

RLWS File #:____________________________ Date:_____________________________	For RLWS Office Use Only
Sales Order #:___________________________ Checked By:_______________________	
Equipment PN(s) & Serial #(s)____	
Factory Mutual Not Applicable_______________ (Inernational Orders Only)__________	

RLWS CUSTOMER INFORMATION:

RLWS Customer Name: ______________________________ Customer Number:_____________

Address:_____________________________ City:________________ State: _____ Zip:____________

Telephone: (_____)_________________________ Fax:(_____) ________________________________

Contact Name:____

(Print Name) (Signature) (Date)

Authorized Signature:____

(Print Name) (Signature) (Date)

End User Information:

End User Company Name: ____

Address:_____________________________ City:________________ State: _____ Zip:____________

Telephone: (_____)_________________________ Fax:(_____) ________________________________

Contact Name:____________________________________ Title:______________________________

(Print Name)

Authorized Signature:____

(Print Name) (Signature) (Date)

(The following information is to be defined and completed by the END USER'S Plant Safety Engineer or other authorized party)

Hazardous Area Classification: Class:____________, Division:____________ , Group:____________

Specific Hazard/Material (please print):____

Defining Indivudual:____
(Pirnt Name) (Signature) (Date)

Defining Authority (Title):____

PLEASE USE THIS PAGE AS A MASTER, MAKE PHOTOCOPIES TO FILL OUT AND RETURN

Please retain a copy of this completed form for you records

5.3 Calculate System Load Cell Output Sensitivity (µV/Grad)

When specifying equipment, it is important that the load cell output not be smaller than the indicator can accept. Output sensitivity is expressed in microvolts/graduation (µV/grad). Some indicators can accept a signal as small as .8 µV/grad. This means it takes an input signal of at least .8 µV to change the display one graduation. Anything less (more sensitive) than .8 µV will cause erratic and inaccurate indicator operation.

When calculating load cell output sensitivity with intrinsic safety barriers involved, we must also take the voltage drop introduced by the barriers into consideration. The barriers decrease the excitation voltage available to the load cells to an acceptable hazardous location level. By decreasing the excitation voltage, the load cell output signal is also decreased. Therefore, it is imperative to factor in barrier voltage drops during the stages of specifying an intrinsically safe weighing system. You wouldn't want to install a system to find out there isn't sufficient signal available to drive the indicator.

Before we look at a particular scale application, let's look at the barrier system and see how the barrier decreases the available load cell excitation voltage. Refer to the barrier system used in Figures 5-1 and Tables 5-1 & 5-2. You will notice with 10 volts applied to one 350Ω load cell through the barrier system only 8.5 volts of excitation voltage reaches the load cell. Less excitation means less output signal strength.

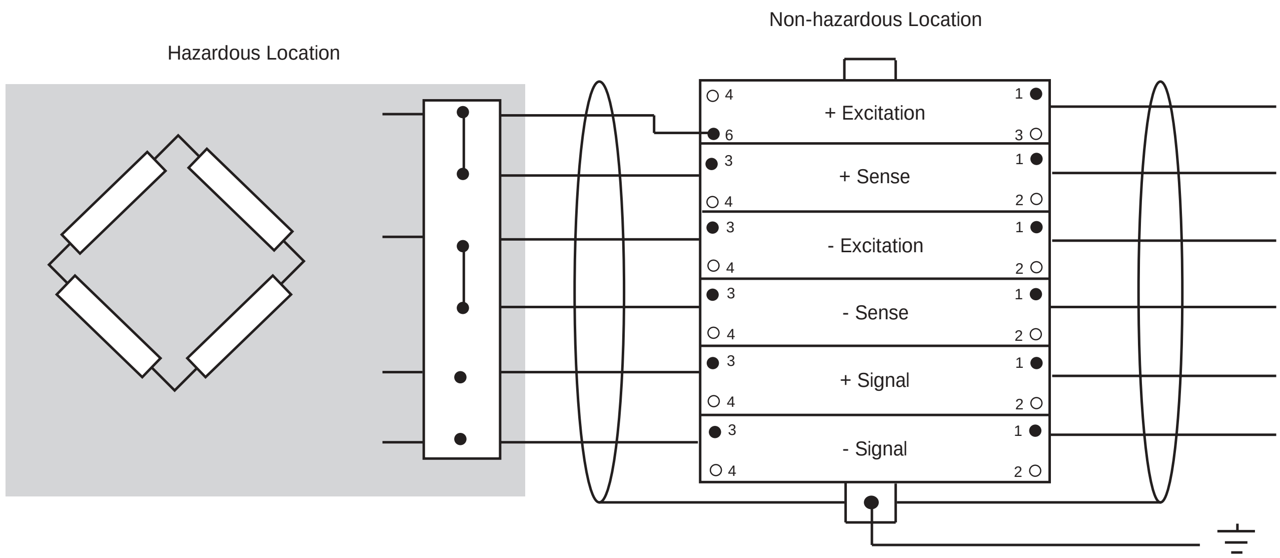


Figure 5-1. Barrier System

Conductor	Intrinsic Safety Barrier Model Number	Input Voltage V (rated)	Input Voltage V (max)	Fuse Rating [mA]	Internal Resistance [Ω]	Maximum Allowed Excitation Voltage
+ Excitation	9001/02-093-390/00	6	7.7	160	30.5	±7.7 VDC
+ Sense	9001/02-093-030-00	6	7.7	160	335	
- Excitation	9001/02-093-390-00	6	7.7	160	30.5	
- Sense	9001/02-093-030-00	6	7.7	160	335	
+ Signal	9001/02-093-030-00	6	7.7	160	335	
- Signal	9001/02-093-030-00	6	7.7	160	335	

Table 5-1. Barrier System

Operational Data			**Safety Data**				
Number of Strain Gauges in Parallel	Excitation Voltage at Strain Gauge 350Ω	Excitation Voltage at Strain Gauge 700Ω	Hazardous Location Class I, II, III Div. 1 & 2	Open Circuit Voltage [Voc]	Short Circuit Current [Isc]	Maximum Allowed Capacitance [Ca µF]	Maximum Allowed Inductance [La mH]
1	8.50 V	9.20 V	Groups C - G	20.99 V	487 mA	0.885 µF	0.049 mH
2	7.42 V	8.50 V					
3	6.55 V	7.93 V					
4	5.89 V	7.42 V					

Table 5-2. Barrier System

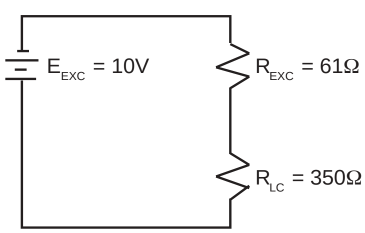


Figure 5-2. Equivalent Circuit of the Excitation Circuit

Figure 5-2 is an equivalent circuit of the excitation circuit of our barrier system shown in Fig. 5-1. The 10 volt battery is the excitation voltage applied to the system. R_{EXC} is the internal resistance of the +Excitation barrier (30.5Ω) and the -Excitation barrier (30.5Ω). This gives us a total excitation barrier resistance of 61Ω. R_{LC} is the load cell resistance. The total circuit resistance is 411Ω (61Ω + 350Ω). Using Ohm's Law, we can figure total circuit current (I_T) and use the current to figure the voltage drops across the barrier (E_{EXC}) and the load cell (E_{LC}).

$I_T = E_T \div R_T$

$= 10V \div 411\Omega$

$= .0243$ amps or 24.3 mA (milliamps)

$E_{LC} = R_{LC}\ (I_T)$ $\quad$ $E_{EXC} = R_{LC}\ (I_T)$

$= 350\Omega\ (.0243A)$ $\quad$ $= 61\Omega\ (.0243A)$

$= 8.50$ volts $\quad$ $= 1.48$ volts

The two voltage drops should add up to 10 volts. (There may be a few hundredths of a volt difference because of where we choose to round-off our calculations). For our purposes, we will use 8.50 volts of excitation voltage that the load cell actually sees.

Let's look at an application using three 350Ω load cells.

Figure 5-3 is an equivalent circuit of the excitation circuit. R_{EXC} is the internal resistance of the excitation barrier. The R_{LC} values are the load cell resistances. The first thing to look at is the total load cell resistance (R_{LCT}) that is seen by the 10 volt excitation voltage.

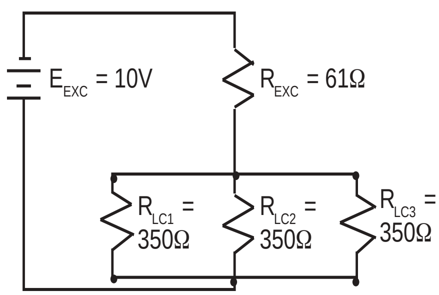


Figure 5-3. Equivalent Circuit of the Excitation Circuit

Since our load cell values are equal and are in parallel with each other, we can divide the value of one resistor by the total number of resistors and find the value of R_{LCT}.

$R_{LCT} = R_{LC1}$ or R_{LC2} or $R_{LC3} \div 3$

$= 350\Omega \div 3$

$= 117\Omega$

Figure 5-4 is the excitation circuit that is seen by the excitation voltage. Just as we did in the one load cell example, in Fig 5-5, we can use Ohm's Law to calculate the voltage drop across the load cells.

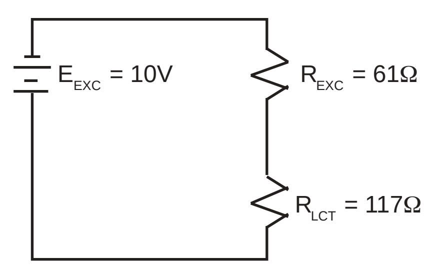


Figure 5-4. Excitation Circuit

$I_T = E_T \div R_T$

$= 10V \div 178\Omega$

$= .056A$ or 56mA

$E_{LCT} = R_{LCT}\ (I_T)$ $\quad$ $E_{EXC} = R_{EXC}\ (I_T)$

$= 117\Omega\ (.056A)$ $\quad$ $= 61\Omega\ (.056A)$

$= 6.55V$ $\quad$ $= 3.42V$

Again, depending on how you round off your calculations, the values of voltage drops across the load cells and the excitation barriers should equal the total excitation voltage.

Also, notice that the more load cells you place in parallel, the lower the excitation voltage across the load cell. Looking back at Table 5-2, you can see that by placing 4-350Ω load cells in parallel causes a 50% decrease in load cell excitation. You can also see that by using 700Ω load cells, the excitation voltage decrease across the load cells is not as much.

5.3.1 Hazardous Area Application

We will discuss a weighing application utilizing a hopper scale and three 350Ω load cells. Our indicator has a sensitivity of 1 µV/grad. The excitation voltage is bipolar, that is the negative excitation voltage is -7.5VDC as referenced to ground. The positive excitation voltage is +7.5VDC as referenced to ground. This yields a potential difference of 15 volts between the positive and negative excitation terminals. The safety barriers used for this application have an internal resistance of 335Ω each or 670Ω for the total excitation circuit barrier resistance.

Other system parameters are as follows:

Dead Load—300 lbs	Excitation Voltage—15VDC
Live Load—6000 lbs	Load Cell Full Scale Output—3.0 mV/V
Scale Capacity = 6000 lbs x 1 lb	

The total system load will equal the dead load plus the live load or in our case, 6300 lbs. The 6300 lbs is shared by all three load cells or 2100 lbs each. The next larger load cell capacity available is 2500 lbs. So we will select 3 2500-lb load cells for our applications, giving us a total system capacity of 7500 lbs.

To determine what percentage of load cell output is used for the live load, we divide the live load by the total load cell capacity, or:

$$\frac{\text{Live Load}}{\text{Cell Capacity}} = \frac{6000 \text{ lbs}}{7500 \text{ lbs}} = 80\%$$

Normally, to determine the millivolt output of our load cells, we would multiply the excitation voltage (15VDC) by the load cell full scale output (3.0mV/V) and come up with a load cell output at full load. In this case, without figuring in the barrier voltage drop, the load cells would see an excitation voltage of 45mV at full scale. However, with our barrier application, we must figure in the barrier voltage drop.

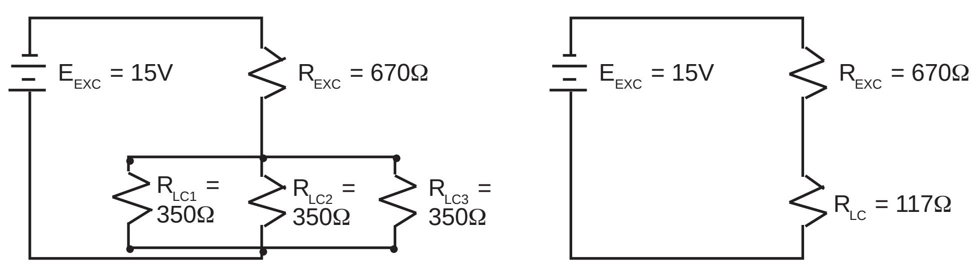


Figure 5-5. 3 - 350Ω Load Cell & Barrier Resistance Combination

Figure 5-5 represents our 3 load cells and barrier resistance combination. As previously stated, our barrier internal resistance is 670Ω. From the example in Fig. 5-5, we know the total resistance of 3-350Ω parallel load cells is 117Ω. (Fig. 5-5)

Using Ohm's Law:

$I_T = E_T \div R_T$	$E_{LCT} = R_{LC}(I_T)$	$E_{EXC} = R_{EXC}(I_T)$
$= 15V \div 787\Omega$	$= 117\Omega\,(.019A)$	$= 670\Omega\,(.019A)$
$= .019A$ or 19mA	$= 2.22$ volts	$= 12.73$ V

You can see the high resistance excitation barrier has dropped 12.73 volts leaving only 2.22 volts excitation for our load cells. Instead of 45mV output at full load, the load cells only put out 2.22V (3mV/V) or 6.66mV.

As previously calculated, the 6000 lbs live load only represents 80% of our scale capacity. So, at 6000 lbs, the load cell is only using 80% of its full scale output or in our case, 6.66mV (.8) = 5.33mV.

To figure the µV/grad sensitivity of our load cell outputs, we divide the mV output caused by our live load (5.33mV) by the resolution desired (6000 graduations).

Sensitivity =5.33mV ÷ 6000 grads

=.89 µV/grad

Remember, the sensitivity of our indicator is 1 µV/grad. As you can see, our indicator is not sensitive enough to accurately measure our load.

Now let's look at the same example except we will use 700Ω load cells in place of the 350Ω load cells. All other parameters will stay the same.

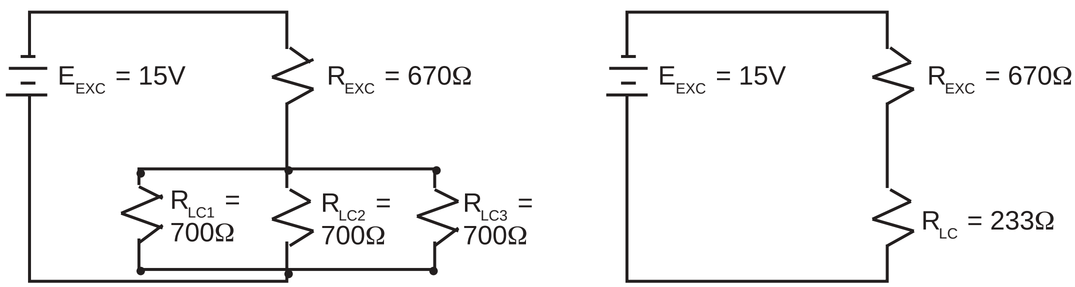


Figure 5-6. Load Cell & Barrier Resistance Combination

Figure 5-6 represents our load cell/barrier resistances. Three 700Ω load cells in parallel equals 233Ω total equivalent load cells resistance (700Ω/3 = 233Ω). Refer back to Ohm's Law to calculate total current, barrier and load cells voltage drops (Fig. 5-6)

$I_T = E_T \div R_T$

$= 15V \div 903\Omega$

$= .0166$ amps or 16.6mA

$E_{LC} = R_{LC} (I_T)$

$= 233\Omega\ (.0166A)$

$= 3.87$ volt

$E_{EXC} = R_{EXC} (I_T)$

$= 670\Omega\ (.0166A)$

$= 11.12$ volts

You can see that the 700Ω load cells have more excitation voltage available than the 350Ω load cells. With the 3mV/v full scale output, our load cell output at full load is 11.61mV.

Again, going back to our original system configuration, the 6000 lbs live load represents only 80% of our total load cell capacity. At full scale, our load cell is outputting 11.61mV (.8) or 9.29mV.

Again, calculating the sensitivity:

Sensitivity = 9.29mV ÷ 6000 grads

= 1.55 µV/grad

Our indicator is sensitive enough (1 µV/grad) to measure this signal.

REVIEW EXERCISE-SPECIFYING EQUIPMENT

1. Who is responsible for classifying hazardous environments?

2. Determine the system output sensitivity for the following scale:

Dead load:	50 lbs	Load Cell Size:	1000 lbs/350Ω
Live Load:	500 lbs	F.S.O.:	3mV/V
Scale Cap.:	500 lbs x .05 lbs	Excitation Voltage:	10V
+Excitation Barrier Resistance:	40Ω	-Excitation Barrier Resistance:	65Ω

3. Determine the system output sensitivity for the following system:

Dead load:	1000 lbs	Load Cell Size:	4000 lbs/700Ω
Live Load:	6000 lbs	F.S.O.:	3mV/V
Scale Cap.:	6000 lbs x 1 lb	Excitation Voltage:	15VDC
+Excitation Barrier Resistance:	50Ω	-Excitation Barrier Resistance:	75Ω

See Appendix c for answers to Review Exercises.

5.4 Communication Interface

Communication data interface techniques for hazardous environments are handled like other wiring schemes for the Class, Division and Group where the equipment is located. Any communications equipment that does not have Factory Mutual Approval cannot be used inside the hazardous location. The use of intrinsically safe barriers to reduce data transmission energy levels eliminates the necessity to employ explosion proof protection techniques. Generally, each single conductor used for communications purposes will have a single barrier terminal associated with it. A separate terminal is used for the ground connection. The ground lead must be connected to true earth ground and have a resistance no greater than one ohm. The barriers must be able to handle the signal current and voltage levels. RS-232C voltage levels are normally in the ±12 volt range but may be as high as ±15 volts. As with all intrinsically safe wiring, communications wiring must be provided with a means to prevent transmission of gases and/or vapors. For sealing cables and raceways containing intrinsically safe circuits, ordinary conduit fittings for sealing can be used. Non-explosion proof seals are appropriate.

6.0 Installation

OBJECTIVE: *Identify correct installation procedures for explosion proof, intrinsically safe, and dust ignition proof systems.*

6.1 Correct Procedures and Responsibilities

When installing weighing systems in hazardous locations, the scale professional, certified electrician and authority having jurisdiction over the area must work together as a team. The more each one of these individuals knows about the others' responsibilities, the smoother the installation will proceed. If you have questions about your area of responsibility, be sure to ask the questions and have it answered thoroughly before you proceed any further in the installation process. Also, if you have questions about the other parties' responsibilities and techniques, bring those questions up to them. By double checking and being sure of your and others' responsibilities, a safe, efficient system can be installed. Correct installation procedures are found in the National Electrical Code Handbook and ANSI/ISA RP 12.06.01 "Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations."

6.2 Explosion Proof Systems

The design of an explosion proof system does not contain the explosion, but it does control it. Because there are paths between the inside of the enclosure and the hazardous area, certain installation techniques must be employed to retain the enclosures explosion proof integrity.

6.2.1 Wiring Methods

NOTE: See Class I and Class II wiring charts in Appendix D.

Class I, Division 1

Protection of energized conductors is just as important as the protection of other energized parts. The most common wiring method is the use of rigid metal conduit, either steel, aluminum or bronze. Also, threaded steel intermediate metal conduit is used. These conditions must be met:

- A minimum of 5 fully engaged threads made wrench tight to provide adequate conduit system joints
- Enclosure connections shall always be threaded
- Knockouts with lock nut and bushing connections are not acceptable
- Explosion proof flexible connections and fittings are allowed if approved for Class I locations
- All boxes and fittings are to be marked with their hazardous location class and group for which they are designed. Threaded couplings provided as part of the conduit need not be marked.
- Conduit bends and threaded nipples made from conduit are permitted.

Class I, Division 2

The following wiring methods are permitted:

- All acceptable Class I, Division 1 methods
- Enclosed and gasketed busways and wireways
- Flexible metal fittings and conduit
- Liquid tight flexible metal conduit
- Extra hard service flexible cord
- Non-hazardous locations outlets and junction boxes, conduit and cable fittings.

If flexible conduit or liquid tight flexible metal conduit is used, the conduit should not be used as the equipment grounding path. The circuit should contain an equipment grounding conductor or there should be a bonding conductor around the conduit. The bonding conductor should not be wrapped around the raceway as this will cause greater inductance in the circuit.

6.2.2 Seals

Seals are made for either horizontal or vertical installation. A vertical seal is **not** to be used in a horizontal application and vice versa.

Class I, Division 1

Seals are required to complete the explosion proof enclosures. Rigid metal conduits are considered explosion proof enclosures. Flammable gases can be transmitted from one location to another simply by pressure differentials at the ends of horizontal conduit runs as a result of air movement outside the conduit. However, gases and vapors can move through non-hazardous runs without any pressure differential. Seals are used to minimize this passage of gases, vapors and/or flames from one portion of the electrical installation to another through the conduit system.

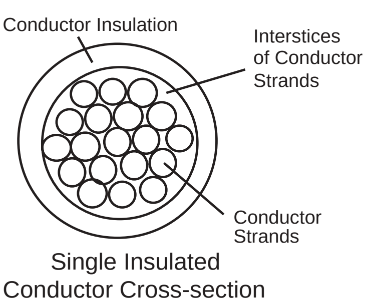
Seals are required:

- In each conduit run leaving the Division 1 location whether the conduit run is entering a Division 2 or non-hazardous location
- Within 18" of explosion proof enclosures housing parts that are ignition sources under normal operating condition, such as switches, circuit breakers and/or high temperature parts.
- Within 18" of each enclosure for conduits larger than 1 1/2".

Sealing of conduits, regardless of size, will permit use of more readily available and lower cost explosion proof equipment than would be required if all conduits were sealed in accordance with minimum requirements of the NEC.

Class II, Division 2

The requirements for seals in Division 2 locations are somewhat more complex than Division 1 locations because more cable wiring types are permitted. Consideration must therefore be given to cable in conduit and cable not in conduit.



When conductors in a conduit are sealed, the sealing compound is poured around the conductor insulation. Spaces between each strand of a stranded conductor (called interstices, see Figure 6-1) are not sealed by a conduit seal. In large conductors (larger the #2 AWG), strand interstices may permit passage of gas and even weak explosions. In critical situations, these small passages of gas should be taken into consideration. The strands can be sealed by using compression-type connectors and tape between the end of the connector and the end of the conductor insulation.

Figure 6-1. Single Insulated Conductor Cross-section

Multiconductor cables can be considered similar to insulated conductors in a conduit. There may be space between the individual insulated cable conductors and the outer jacket. This space is called the cable core (see Figure 6-2). Some cable cores contain fillers which act as gas blockers (see Figure 6-2). If a cable is constructed so it blocks gases or is installed so the core of the cable is equivalent to a conduit seal, the cable is considered a gas-blocking cable. Some cables are specifically designed and listed as gas-blocking cables.

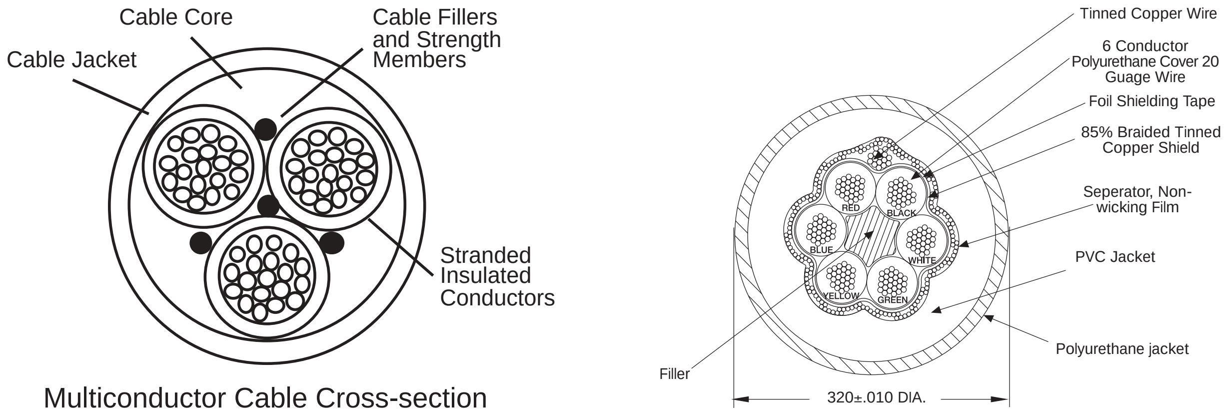


Figure 6-2. Cable Types

If your cable is in conduit, use Division 1 sealing procedures. Sealing procedures for cables not in conduit vary, depending on the cable type.

For cables with gas/vapor tight continuous sheathes, a seal is not required at the boundary of the Division 2 and non-hazardous location if the cable is sealed at the enclosure (see Figure 6-3). The enclosure seal may be a Division 2 approved cable sealing fitting or a combination conduit nipple and seal.

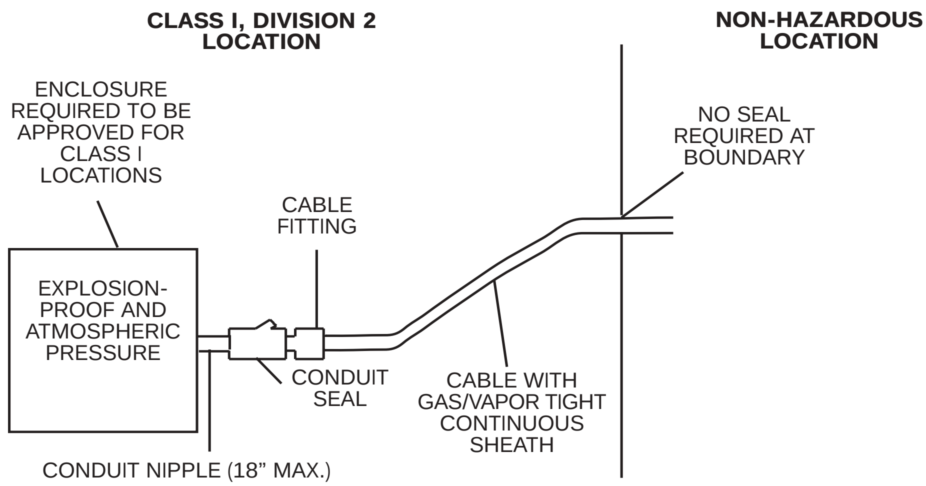


Figure 6-3. Seal Not Required

If the cable does not have a gas/vapor tight continuous sheath, a seal is required at the boundary of the Division 2 and non-hazardous location. A seal is also required at the enclosure (see Figure 6-4). If any cable enters the explosion proof enclosure and is not in conduit, its jacket must be removed and the individual insulated cable conductors must be sealed.

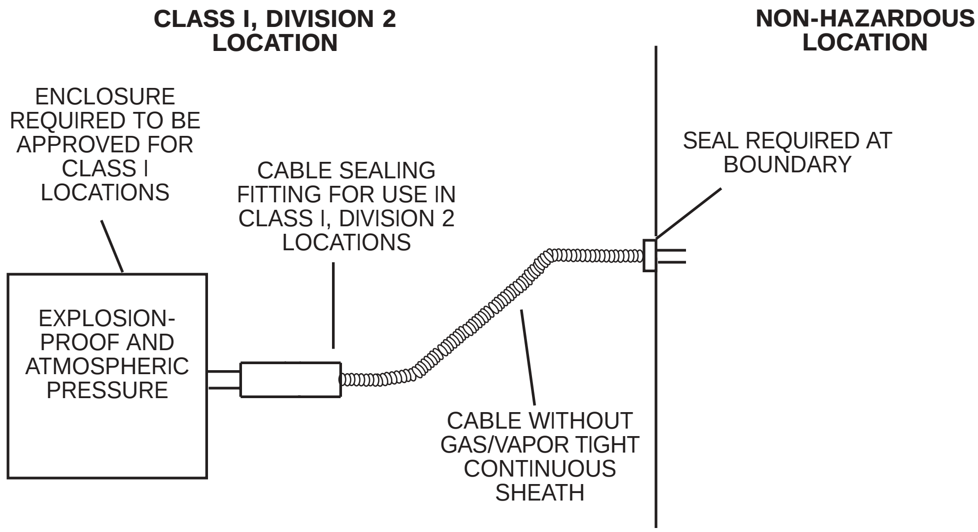


Figure 6-4. Seal Required

Special Precautions

The mounting and installation of explosion proof equipment is different from that of a standard unit. The explosion proof enclosure is substantially heavier than the standard enclosure. The mounting structure must be capable of supporting this weight.

All joint surfaces should be protected so they are not scratched or damaged. If equipment is to be painted after installation, care should be taken to ensure that the paint does not get on joint surfaces.

Bolts and nuts should be drawn up tightly. If a torque is specified by the manufacturer, that torque should be used. (35-45 ft./lbs for Rice Lake Weighing Systems enclosures.) Bolts left out or not tightened can reduce or destroy the explosion proof enclosure effectiveness. Conduit should be tightened wrench tight. Threaded covers, plugs, etc. must be securely tool tightened. Hand tightening is not adequate.

Care should be taken to determine that various components of the explosion proof system are compatible with each other. Conduit fittings for sealing are tested based on the use of specified materials. Only these sealing materials should be used. A sealing compound made by Manufacturer A should not be used with a sealing fitting made by Manufacturer B. Although it may appear to be the identical compound, sealing compounds have additives often unique to the particular manufacturer that cause the compound to expand during the drying process. This expansion could result in large mechanical forces on the fitting itself and could crack or otherwise damage the fitting if it is not designed for that particular compound. Too little expansion can reduce the seal effectiveness.

Some enclosures use high strength bolts. Substitution of an equivalent size bolt of a different strength can reduce enclosure effectiveness.

6.2.3 Intrinsically Safe Systems

Intrinsically safe equipment and wiring must not be capable of releasing sufficient electrical or thermal energy under normal or abnormal conditions, to cause ignition of a specific flammable or combustible atmospheric mixture in its most easily ignitable concentration.

Wiring Methods

Article 504 of the NEC covers the installation of intrinsically safe apparatus and wiring in Class I, II and III locations. Also, refer to ANSI/ISA RP 12.06.01. Intrinsically safe apparatus, associated apparatus and other equipment will be installed in accordance with the control drawing(s) provided by the manufacturer of the intrinsically safe or associated apparatus.

Conductors and cables of intrinsically safe circuits not in raceways or cable trays must be separated by at least 2" and secured from conductors and cables of any non-intrinsically safe circuits. Two inches should also be maintained between intrinsically safe conductors and non-intrinsically safe conductors when placed in any raceway or cable tray unless these circuits are separated by a grounded metal partition or an approved insulating partition. It is also permissible to place intrinsically safe conductors in raceways or cable trays with non-intrinsically safe conductors where either group of conductors are in grounded metal-sheathed or metal clad cables where sheathing or cladding is capable of carrying fault current to ground. Different intrinsically safe circuits shall be in separate cables or will be separated from each other by placing conductors of each circuit within a grounded metal shield or by ensuring each conductor has insulation with a minimum of 0.01".

Conductors of intrinsically safe circuits within enclosures shall be separated by at least 2" from non-intrinsically safe circuits. All conductors will be secured so that any conductor that might come loose from a terminal cannot come in contact with another terminal. The use of separate wiring compartments for the intrinsically safe and non-intrinsically safe terminals is the preferred method of complying with this requirement. Physical barriers such as grounded metal partitions or approved insulating partitions can be used to help ensure the required wire separation.

Remember, wiring has inductance and capacitance associated with it. Inductive and capacitive elements store energy. Consult the manufacturer’s specifications as to the maximum cable length permitted for your specific installation.

Identification

Intrinsically safe circuits must be identified at terminal and junction locations to prevent unintentional interference with the circuits during testing and servicing. Raceways, cable trays and open wiring for intrinsically safe wiring must be identified with permanently fixed labels with the wording “Intrinsically Safe.” The labels will be located so they are visible, after installation, and placed so they may be readily traced through the entire length of the installation. Spacing between labels will not be more than 25 ft. Color coding may be used to identify intrinsically safe circuits if the color used is light blue and no other conductors are colored blue.

Barrier Locations

Intrinsic safety barriers are usually installed and grounded in non-hazardous locations. They should be located as close as possible to the hazardous location to prevent the connection of high energy circuitry onto the intrinsically safe side of the safety barrier. There are some applications where it is necessary to install the barriers in a hazardous location. If this is the case, then the barriers must be in a suitable enclosure, such as a purged or explosion proof enclosure.

Barrier Grounding

To ensure the voltage limiting section of the barrier is working properly, the barriers must be properly grounded. The grounding path resistance from the farthest barrier to the designated ground electrode must not exceed 1Ω. The barrier ground conductor must be capable of carrying the maximum fault current (#8 AWG is recommended). In any case, the ground conductor cannot be any smaller than #12 AWG. Shake proof terminals must be used to connect the ground conductor to the barrier ground bus. All ground path connections will be secure, permanent, visible and accessible. The safety of the entire installation is ensured by proper grounding. The total ground assembly must be maintained and routinely inspected.

6.3 Class II. Division 1

6.3.1 Dust Ignition Proofing

Since the wiring methods in Class II, Division 1 environments need not be designed to withstand the pressures of explosions, the requirements are not as stringent as they are in Class I, Division 1 hazardous locations.

Wiring Method

Fittings and boxes in which taps, joints or terminal connections are made and are used in locations where dusts of a combustible electrically conductive nature are used are required to be approved for Class II locations, which means they must be dust ignition proof or pressurized. However, if the boss or fitting does not include taps, joints or terminal connections, the fittings and boxes are not required to be dust ignition proof or pressurized. However, these boxes must be provided with threaded bosses for connection to threaded conduit or cable terminations, and to have close-fitting covers with no openings through which dust might enter or through which sparks or burning material might escape.

Seals

Seals in Class II, Division 1 locations must prevent dust from entering an otherwise dust-tight enclosure. There are several acceptable methods to prevent dust from entering a dust ignition proof enclosure from one that is not dust ignition proof. A permanent and effective seal may be placed in the raceway. A horizontal raceway not less than 10 feet long or a vertical raceway not less than 5 feet long and extending downward from the dust ignition proof enclosure may be used. These 5 feet and 10 feet raceways are considered being long enough to permit any dust which enters the raceway to settle out of the air before it reaches the dust ignition proof enclosure.

Special Precautions

Precautions for dust ignition proof equipment are essentially the same as for explosion proof equipment. The joints and gaskets should be protected during installation. All bolts and nuts must be properly torqued and threaded conduit systems made wrench tight. Grounding and bonding is just as important in Class II locations as it is in Class I locations. Faults within the equipment must be cleared quickly to maintain the dust ignition proof properties of the enclosure and prevent excessive surface temperatures that could ignite a dust layer.

6.3.2 Intrinsically Safe Systems

Intrinsically safe has exactly the same meaning in Class II locations as it does in Class I locations. Because the ignition temperatures of dusts are generally below the ignition temperatures of gases and vapors, intrinsically safe equipment in Class II locations is limited to surface temperatures on exposed parts of 200°C (392°F) for Groups E and F locations and 160°C (329°F) for Group G locations. An exception is made where tests show that higher temperatures on small parts will not result in ignition or charring of the appropriate test dusts.

6.4 Class III Locations

Equipment suitable for Class II, Division 2 locations is acceptable for use in Class III locations. Wiring methods are required to be rigid metal conduit, rigid non-metallic conduit, intermediate metal conduit, electrical metallic tubing, dust-tight wireways or type MI, MC or SNM cable. Boxes and fittings are required to be dust-tight where flexible connections are necessary.

Always consult the National Electrical Code Handbook and ANSI/ISA RP 12.06.01 when installing equipment in hazardous locations. Make sure your copies of these publications are current. A certified electrician must make all electrical installations. These installations must be certified “safe” by the authority having jurisdiction over the hazardous location before the installations are put into operation.

Also, the scale professional should ensure all wires are connected as they should be. For example, load cells are connected to the correct excitation, sense and signal terminals and all communication lines are correctly connected to provide RS232, BCD or 20 mA current loop data transmission.

6.5 Initial Calibration

After the certified electrician has properly installed the weighing system to your specifications and the authority having jurisdiction over the area has certified the systems safe for operation, then the scale professional may proceed with the initial calibration.

6.5.1 Explosion Proof/Dust Ignition Proof Equipment

To perform calibration on equipment in explosion proof/dust ignition proof equipment, the enclosure must be opened. Before opening the enclosure, make sure the hazardous area has been made “safe.” That is, the explosive atmosphere is not present in the area. Have the authority having jurisdiction over the area declare the area safe before opening any enclosures. After the area is declared safe, proceed with calibration as you would for a normal scale installation using equipment instruction manuals. After the calibration is completed, secure the enclosure by torquing the bolts/fasteners to the appropriate manufacturer recommended torque values. Failure to properly torque the enclosure could compromise the system’s explosion proof/dust ignition proof integrity. Before applying power to the system, contact the authority having jurisdiction so he/she can certify the system safe for use.

6.5.2 Intrinsically Safe Systems

Because intrinsically safe systems do not emit enough energy to ignite the hazardous location, they may be calibrated in a hazardous atmosphere. Some preliminary adjustments may need to be made when setting up intrinsically safe equipment. You should be electrically grounded while making these internal adjustments to prevent static discharge and damage to components. The equipment should be in contact with the same ground. Since you will be grounded, it is imperative that you do not come into contact with electrical power as you may be severely injured. A common way to ground yourself is through a conductive wrist strap connected to ground through a 1 MΩ resistor. This constitutes a “soft” ground to prevent lethal currents from passing through your body in case you contact live circuits.

Before performing any calibration, make sure the authority having jurisdiction over the area has given you the go-ahead. Also, have the authority having jurisdiction over the area inspect the system after you have set up and calibrated the system

REVIEW EXERCISE - INSTALLATION

1. In which publications can correct hazardous area installation procedures be found?

2. What are the purposes of seals in Class I, Division 1 locations?

3. What is the minimum separation distance between conductors and cables of intrinsically safe circuits not in raceways or cable trays?

4. Explain why and how intrinsically safe circuits should be identified.

5. What is the maximum resistance for a barrier ground connection? What is the smallest wire that can be used as a barrier ground conductor?

6. What is the torque specifications for Rice Lake Weighing Systems explosion proof enclosures?

7. Explain how gas or vapors can be transmitted through cables?

8. What is the purpose of seals in Class II, Division 1 locations?

9. What must be done before opening an explosion proof enclosure in a hazardous environment?

See Appendix C for answers to Review Exercises.

7.0 Service

7.1 Explosion Proof Systems

When servicing explosion proof systems, be sure the authority having jurisdiction over the area has declared the area safe before opening any enclosures in the area. All bolts and nuts should be in place and drawn tight and torqued to manufacturer's specifications. Many hazardous areas are corrosive areas. Check for signs of corrosion. Replace corroded enclosures if necessary. Joint surfaces are susceptible to corrosion. Check and clean these surfaces. Visually check all threaded joints for corrosion. Visually check all ground connections for tightness. All enclosures should be checked to make sure they are complete. Make sure covers and plugs are not missing.

Some explosion proof enclosures have a lens assembly that screws into place. This assembly must be handled carefully. After taking the lens assembly off of the enclosure, place it in a protected area so the threads are not damaged nor the lens scratched. The threads must be clean. Remember, threads on an explosion proof enclosure are critical as they serve to cool escaping exploded gases.

⚠ Caution **Scratches on the lens weakens the lens' ability to contain the amount of the explosion it is designed to contain. An explosion could shatter a scratched lens causing serious fire and potential loss of life. Inspect the lens during periodic inspections.**

7.2 Dust Ignition Proof

Dust ignition proof equipment is inspected much like explosion proof equipment. If a dust ignition proof enclosure is opened at any time, all dust that enters the enclosure should be carefully cleaned out before re-closing the enclosure.

7.3 Intrinsically Safe Systems

7.3.1 Maintenance

The condition of each safety barrier should be checked at least once each year. These periodic inspections should ensure that no accumulation of dust, corrosion, film or moisture is present on barrier terminals, ground terminals and conductors or the ground sink. Connections should be checked and tightened if vibration has caused them to loosen. No stray wire strands are allowed, as they may short out terminals. A test of the ground system resistance should be made to ensure maintenance of less than the 1Ω specification. Under no circumstances should a test instrument or lead of any kind contact intrinsically safe terminals or wiring. Check to see if all safety components of the system are intact, including both diodes in a diode barrier. Check to see that the separation between the intrinsically safe and non-intrinsically safe circuits, both in hazardous and non-hazardous areas is still being maintained and there are no changes from the original system design. Remember, barriers are by design made unrepairable. Repair of all intrinsically safe instruments can be made only at the factory or a Factory Mutual approved service center. Some barriers are equipped with keyed fuse assemblies The fuse is replaceable but is keyed so it fits in only the size of barrier that it is intended. This eliminates the possibility of a wrong size fuse being installed into the barrier.

7.3.2 Barrier Replacement

The following are guidelines for barrier replacement. Do not use these guidelines as your only reference for replacement. Replacement should be accomplished in accordance with the manufacturer's specifications. Maintenance on any equipment associated with hazardous locations must be accomplished per manufacturer's directions. Be sure to have the manufacturer(s) manuals with you and use them at all times, even if you have accomplished the tasks many times.

1. Disconnect the wiring from the barrier's non-hazardous terminals prior to disconnecting the wires from the intrinsically safe terminals.

2. Cover bare wire ends with tape or other insulating material, especially those conductors that are towards the hazardous location.

3. Disconnect the barrier from ground. In most cases, this step will also remove the safety barrier from the mounting hardware.

4. Reverse this procedure to mount the new barrier.

Anytime any hazardous area system is serviced and recalibrated, have the system re-inspected and rendered "safe" by the authority having jurisdiction over the area prior to reapplying power to and/or operating the system.

REVIEW EXERCISE - SERVICE

1. Name three things to check when servicing explosion proof systems.

2. Name four guidelines to use when replacing intrinsic safety barriers.

3. Who should repair intrinsically safe equipment?

See Appendix C for answers to Review Exercises.

Appendix A

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9990
1-800-344-3555

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

Underwriters Laboratories, Inc.
Publications Stock
333 Pfingsten Road
Northbrook, IL 60062
708-272-8800 (Ext. 2612 or Ext. 2622)

Instrument Society of America
67 Alexander Drive
Research Triangle Park, NC 27709
919-549-8411

Appendix B

GLOSSARY

AIT

Auto Ignition Temperature.

ANSI

American National Standards Institute.

API

American Petroleum Institute.

Approved

Acceptable to the authority having jurisdiction.

Associated Apparatus

Apparatus in which the circuits are not necessarily intrinsically safe themselves, but may affect the energy in the intrinsically safe circuits and are relied upon to maintain intrinsic safety. An associated apparatus has identified intrinsically safe connections for intrinsically safe apparatus and also may have connections for non-intrinsically safe apparatus.

Authority Having Jurisdiction

Where public safety is primary, the "Authority having Jurisdiction" may be a federal, state, local or other regional institution, department or individual. Some examples are a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector or other having statutory authority. For insurance purposes, an insurance inspection department rating bureau or other insurance company representative may be the "Authority having Jurisdiction."

Auto Ignition Temperature (AIT)

The minimum temperature required for a substance to initiate or cause self-sustained combustion independently of the heating or heated equipment. Also referred to as ignition temperature.

BASEEFA

British Approvals Service for Electrical Equipment in Flammable Atmospheres.

BSI

British Standards Institute.

CSA

Canadian Standards Association

Catalytic Reaction

A relatively fast, self-sustaining, energetic, sometime luminous, sometimes audible reaction that occurs as a result of the catalytic action of any substance on the sample or its decomposition products, in a mixture with oxygen.

CENELEC

European Electrotechnical Committee for Standardization

Class I Location

A location in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

Control Drawing

A drawing or document provided by the manufacturer of the intrinsically safe or associated apparatus that details the allowed interconnections between the intrinsically safe and associated apparatus.

DIP

Dust ignition proof.

Dust Ignition Proof

Equipment so enclosed to exclude ignitable amounts of dust or amounts that might affect performance or rating and that where installed and protected in accordance with the NEC will not permit arcs, sparks, or heat otherwise generated or liberated inside the enclosure to cause ignition of exterior accumulations or atmospheric suspensions of a specified dust on or in the vicinity of the enclosure.

Dust-Tight

Equipment so constructed that dust will not enter the enclosing case under specified test conditions.

Entity Approval

Each piece of intrinsically safe equipment is evaluated separately and assigned a set of safety parameters. Entity approved equipment can be used with other entity approved equipment. “Entity” is an American word. In Europe they use the word “Parametric” in lieu of “Entity”.

Explosion Proof Apparatus

An apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor which may occur within it. It must also prevent the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes or explosion of the gas or vapor within. It must operate at external temperatures so that a surrounding flammable atmosphere will not be ignited by it.

Flash Point

The flash point of a liquid is the minimum temperature at which the liquid gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid or within the test vessel used.

FM

Factory Mutual Global

Fuse-Protected Shunt Diode Barrier

A network designed to limit current and voltage that consists of a series fuse, voltage-limiting shunt diodes, and a current limiting resistor or other current-limiting resistor or other current-limiting components. The fuse is intended to protect the diodes from open-circuiting when high fault current flows.

Hazardous (Classified) Location

A location where fire or explosion hazards may exist due to the presence of flammable gases or vapors, flammable liquids, combustible dust or easily ignitable fibers or flyings.

Hot-Flame Ignition

A rapid, self-sustaining, sometimes audible gas-phase reaction of the sample or its decomposition products with an oxidant. A readily visible yellow or blue flame usually accompanies the reaction. Also called the Auto Ignition Temperature.

IEC

International Electrotechnical Commission

ISA

Instrument Society of America

Parametric Approval

Each piece of intrinsically safe equipment is evaluated separately and assigned a set of safety parameters. Parametrically approved equipment can be used with other parametrically approved equipment. “Parametric” is a European word. In North America we use the word “Entity” in lieu of “Parametric”.

Pressurization

The process of supplying an enclosure with clean air or an inert gas with or without continuous flow at sufficient pressure to prevent the entrance of combustible dust.

Protective Component

A component or assembly which is so unlikely to become defective in a manner that will lower the intrinsic safety of the circuit that it may be considered not subject to fault when analysis or tests for intrinsic safety are made.

Purging

The process of supplying an enclosure with clean air or an inert gas at sufficient flow and positive pressure to reduce to an acceptable safe level the concentration of any flammable gases or vapors initially present, and to maintain this safe level by positive pressure with or without continuous flow.

Resistivity

The electrical resistance offered by a unit cube of material to the flow of direct current between opposite faces of the cube. It is measured in ohm-centimeter.

SAMA

Scientific Apparatus Makers Association

Simple Apparatus

An apparatus that does not generate or store more than 1.2 Volts, 100 milliamps, 20 microjoules, 25 milliwatts. A simple apparatus does not need to be approved for use with intrinsically safe circuits. However it does need to be connected to an intrinsic safe barrier to prevent a fault from being introduced into the intrinsically safe area. Example are switches, thermocouples, light emitting diodes, and resistance temperature devices (RTD's).

SIT

Spontaneous Ignition Temperature

SMRE

Safety in Mines Research Establishment

System Approval

A method used by approval, certifying, or listing agencies in which intrinsically safe equipment including barriers, are approved as a system and cannot be used in combination with any other item or device for intrinsically safe applications.

UEL (UFL)

Upper Explosive Limit (Upper Flammable Limit). A mixture above the UEL (UFL) is too rich to burn.

UL

Underwriters' Laboratories, Inc.

Vapor Density

The ratio of the weight of a volume of pure vapor or gas (no air present) to an equal volume of dry air at the same temperature and pressure. A vapor density of less than 1 indicates that the substance is lighter than air and will tend to rise in a relatively calm atmosphere. A vapor density greater than 1 indicates that the substance is heavier than air and may travel along grade level for a considerable distance to a source of ignition and flash back, assuming the gas or vapor is flammable.

Appendix C

REVIEW EXERCISE

Publications

(From page 4)

1. Place the letter from the title next to its corresponding publication.

B___ 1. ANSI/UL 913

E___ 2 NFPA 496

D___ 3. NFPA 70

A___ 4. ANSI/ISA RP 12.06.01

C___ 5. NFPA 497M

A. "Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Location"

B. "Standard for Intrinsically Safe Apparatus and As-associated Apparatus for use in Class I, II and III, Division 1 Hazardous Locations"

C. "Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous (Classified) Locations"

D. "National Electrical Code Handbook"

E. "Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Locations"

REVIEW EXERCISE

Hazardous Locations

(From page 10)

I. Classify each environment below according to Class, Division and Group.

1. Location where fibers that produce combustible flyings are handled.

   Class III, Division 1

2. A location containing gasoline which is processed in a closed system.

   Class I, Division 2, Group D

3. A location where ethylene oxide gas may exist during maintenance operations.

   Class I, Division 1, Group D

4. A location where coal dust is sensitized to present an explosion hazard and having a resistivity of 1000 ohm-centimeter during normal conditions.

   Class II, Division 1, Group F

5. A location where combustible dusts having a resistivity of 100,000,000 ohm-centimeter are in the air as a result of infrequent malfunctioning of handling equipment.

   Class II, Division 2, Group G

6. A location where ethylene gas is released because of faulty equipment operation.

   Class I, Division 1, Group C

7. A location adjacent to a Class I, Division 1 location where manufactured gas containing 33% hydrogen by volume is present.

   Class I, Division 2, Group B

REVIEW EXERCISE

Explosion Proof Systems

(From page 16)

1. Explain how the explosion proof enclosure flange and thread design prevent hazardous area explosions.

Flanges are machined so there is a slope formed. The opening is larger at the outside of the flange than at the inside. Exploded gases gradually escape through the sloped flange opening, causing the gas to cool before it reaches the outside environment.

The threads are long as compared to their width. The gas cools as it travels through the threads to the outside environment.

REVIEW EXERCISE

Intrinsic Safety

(From page 29)

1. What is the purpose of intrinsically safe circuitry?

To limit electrical and thermal energy to a level below that required t o ignite a specific hazardous atmospheric mixture.

2. For the following statements, circle "T" if the statement is true and circle "F" if the statement is false.

T / F Intrinsically safe circuits always operate below minimum ignition energy levels.
TRUE

T / F Intrinsic safety design is applied to Class I, II, and III, Division 1 hazardous locations.
TRUE

T / F The length of cable connected to intrinsically safe circuits has no bearing on its energy producing effects.
FALSE

T / F If circuit power requirements are above the minimum ignition levels of the hazardous location, engineering means other than intrinsic safety need to be employed.
TRUE

T / F Intrinsic safety systems designed for Class II hazardous locations are suitable for use in Class I hazardous locations of the same group.
FALSE

REVIEW EXERCISE

Purged Systems

(From page 32)

1. What is the purpose of purged systems as they pertain to hazardous environments?

Purged enclosures are designed to keep the hazardous environment out of the instrument enclosure by maintaining a slightly positive pressure inside the enclosure.

REVIEW EXERCISE

Enclosure Ratings

(From page 36)

I. Place the letter of the description in Column B next to its corresponding enclosure "Type" in Column A.

C___ 1. Type 8

A___ 2. Type 7

D___ 3. Type 9

B___ 4. Type 4

A. Use in Class I, Groups A, B, C & D, indoor use only.

B. Use in indoor and/or outdoor applications. Excludes water under test conditions. Non-hazardous design.

C. Use in Class I, Groups A, B, C & D, indoor and/or outdoor applications.

D. Use in Class II, Groups E, F or G, indoor use only.

II. Describe when non-hazardous designed enclosures may be used in hazardous locations.

Enclosures rated for non-hazardous locations which have met the requirements for the dust test described in section 6.5 of NEMA Standard No. 250 may be used in Class III, Division 2, Group G and Class III, Division 1, and 2 locations.

REVIEW EXERCISE

Specifying Hazardous Environment Equipment

(From page 49)

1. Who is responsible for classifying hazardous environments?

   The authority having jurisdiction over the area, e.g., Plant Safety Engineer, Insurance Underwriter, Fire Safety Inspector.

2. Determine the system output sensitivity for the following scale:

Dead load:	50 lbs	Load Cell Size:	1000 lbs/350Ω
Live Load:	500 lbs	F.S.O.:	3mV/V
Scale Cap.:	500 lbs x .05 lbs	Excitation Voltage:	10V
+Excitation Barrier Resistance:	40Ω	-Excitation Barrier Resistance:	65Ω

1.15 µV/grad

3. Determine the system output sensitivity for the following system:

Dead load:	1000 lbs	Load Cell Size:	4000 lbs/700Ω
Live Load:	6000 lbs	F.S.O.:	3mV/V
Scale Cap.:	6000 lbs x 1 lb	Excitation Voltage:	15VDC
+Excitation Barrier Resistance:	50Ω	-Excitation Barrier Resistance:	75Ω

2.4 µV/grad

REVIEW EXERCISE

Installation

(FRom page 58)

1. In which publications can correct hazardous area installation procedures be found?

   National Electrical Code Handbook and ANSI/ISARP 12.6

2. What are the purposes of seals in Class I, Division 1 locations?

   Seals complete the explosion proof enclosures. Seals are used to minimize the passage of gases, vapors, and/or flames from one portion of the electrical installation to another, through the conduit system.

3. What is the minimum separation distance between conductors and cables of intrinsically safe circuits not in raceways or cable trays?

   2 inches

4. Explain why and how intrinsically safe circuits should be identified.

   Intrinsically safe circuits must be identified at terminal and junction locations to prevent unintentional interference with the circuits during testing and servicing. Spacing between labels will not be more than 25 feet.

5. What is the maximum resistance for a barrier ground connection? What is the smallest wire that can be used as a barrier ground conductor?

   The maximum resistance is 1 ohm. The smallest wire size is #12 AWG.

6. What is the torque specifications for Rice Lake Weighing Systems explosion proof enclosures?

The torque specification is 35 – 45 ft-lbs.

7. Explain how gas or vapors can be transmitted through cables?

   Gas or vapors may be transmitted through the conductor interstices or through the space between the cables called the cable core.

8. What is the purpose of seals in Class II, Division 1 locations?

   Seals in Class II, Division 1 locations must prevent dust from entering an otherwise dust tight enclosure.

9. What must be done before opening an explosion proof enclosure in a hazardous environment?

   The hazardous are has to be made “safe”. The explosive environment cannot be present in the area and the authority having jurisdiction over the area must declare the area safe prior to the enclosure being opened.

REVIEW EXERCISE

Service

(From page 61)

1. Name three things to check when servicing explosion proof systems.

    1. All bolts and nuts are in place and torqued
    2. Check for corrosion
    3. Check that all parts are in place and tight

2. Name four guidelines to use when replacing intrinsic safety barriers.
    1. disconnect non-hazardous wiring prior to disconnecting hazardous wiring
    2. Cover bare wire ends with insulating material
    3. Disconnect the barrier from the ground
    4. reverse this procedure step-by-step when installing the barrier

3. Who should repair intrinsically safe equipment?

    The factory or Factory Mutual Approved service center are the only agencies that should repair intrinsically safe equipment.

Appendix D

WIRING IN CLASS I LOCATIONS [a,b]

WIRING SYSTEM	DIVISION 1		DIVISION 2	
	IS	NIS	IS	NIS
Threaded rigid metal conduit	A	A	A	A
Threaded steel intermediate metal conduit	A	A	A	A
Flexible metal explosion proof fitting	A	A [c]	A	A
Type MI cable	A	A [d]	A	A
Type PLTC, MC, SNM, and TC cable	A	NA	A	A
Flexible metal conduit	A	NA	A	A [c,e]
Liquid-tight, flexible metal conduit	A	NA	A	A [c,e]
Electrical metallic tubing (steel)	A	NA	A	NA
Flexible cord	A	Note 3 [f]	A	A [cf] Note 3 or 4
Any other wiring method suitable for nonhazardous locations	A	NA	A	NA

Table 7-1. Wiring, Class I

[a] Abbreviations: IS = Intrinsically safe, NIS = Not Intrinsically Safe,
A = Acceptable, NA = Not Acceptable, NEC = National Electrical Code

[b] See the NEC for a description and use of wiring systems.

[c] Acceptable only where flexibility needed.

[d] Acceptable only with termination fittings approved for Class I Division 1 locations of the proper groups.

[e] Special bonding/grounding methods for hazardous (classified) locations are required.

[f] Extra-hard-usage type with grounded conductor only acceptable.

NOTES:

1. Acceptable if entire conduit system and all enclosures are purged and pressurized using type X purging. Acceptable if entire conduit system and all enclosures are purged and pressurized using type Y purging, and there are no ignition-capable parts (arcing, sparking or high temperature) under normal operating conditions.
2. Acceptable if circuit, under normal operating conditions, cannot release sufficient energy to ignite hazardous atmospheric mixture when any conductor is opened, shorted to ground, or shorted to any other conductor in the same cable or raceway.
3. Acceptable on approved portable equipment where provisions made for cord replacement per NEC.
4. Acceptable on process control instruments to facilitate replacements per NEC.

WIRING IN CLASS II LOCATIONS [a,b]

WIRING SYSTEM	DIVISION 1 IS	DIVISION 1 NIS	DIVISION 2 IS	DIVISION 2 NIS
Threaded rigid metal conduit	A	A	A	A
Threaded steel intermediate metal conduit	A	A	A	A
Flexible metal explosion proof fitting	A	A[c]	A	A[c]
Type MI cable	A[d]	A[e]	A	A
Type MC and SNM cable	A[d]	NA	A	A
Type PLTC and TC cable	A[d]	NA	A	A
Flexible metal conduit	A[d]	NA	A	NA
Liquid-tight, flexible metal conduit	A[d]	A[c,d,g]	A	A[c,d,g]
Flexible cord	A[d]	A[c,d,h]	A	A[c,d,h]
Dust-tight wireways and raceways	A	NA	A	A
Any other wiring method suitable for non-hazardous locations	A[d]	NA	A	NA
Electrical metallic tubing	A[d]	NA	A	A

Table 7-2. Wiring, Class II

[a] Abbreviations: IS = Intrinsically safe, NIS = Not Intrinsically Safe,
A = Acceptable, NA = Not Acceptable, NEC = National Electrical Code

[b] See the NEC for a description and use of wiring systems.

[c] Acceptable only where flexibility needed.

[d] Acceptable only with dust-tight seals at both ends when electrically conductive dusts will be present.

[e] Acceptable only with termination fittings approved for Class II, Division 1 locations of the proper groups.

[f] Acceptable in ventilated channel-type cable trays in a single layer with a space not less than the larger cable diameter between adjacent cables.

[g] Special bonding/grounding methods for hazardous (classified) locations are required.

[h] Extra-hard-usage type with grounded conductor only acceptable.

Appendix E

CABLE TYPES

AC - Armored Cable

Type AC cable is a flexible metallic enclosure with circuit conductors installed at the time of manufacturing. The maker of AC cable must be marked along its total length. AC cable is used for branch circuits and feeders. It must have a bonding strip that touches the outer flexible metal covering for its full length. AC type cable is to be secured at intervals not to exceed 4-1/2 feet and within 12 inches of a box or fitting. The 12 inches may be extended to 24 inches at terminals where there is a necessity for flexibility. The bends radius is taken from the inner edge of the bend and shall be not less than five times the diameter of the cable. Approved fittings to prevent abrasion of the conductors and their insulation shall be used. An approved insulating bushing is required to be inserted at the end between the conductors and the outer metallic covering. The connection to the fitting box must be designed that the insulated bushing will be visible for inspection without removing the fitting.

ACL - Lead Covered Armored Cable

The conductors are covered with lead. Used when armored cable is exposed to weather, continuous moisture, exposed to oil, for underground raceways, embedded in masonry or concrete or in filling buildings under construction and elsewhere where conditions may cause the insulation to deteriorate. ACL is not permitted for direct burial in the earth. An insulated bushing, as required for AC cable, is not required for ACL cable.

FCC - Flat Conductor Cable

FCC contains flat conductors made only of copper. Three or more flat copper conductors which are placed edge to edge and entirely enclosed with an assembly of insulation make up FCC cable. They are permitted to be used with individual branch circuits for general purpose and appliance branch circuits. FCC can be used on floors that are of sound construction and smooth. If metal surface raceways are used on walls FCC can be used. FCC cable will NOT be installed outdoors where they will be in wet locations, wherever subject to corrosive vapors, hazardous locations, residences, hospitals or schools.

IGS - Integrated Gas Spacer Cable

IGS is to be under pressure from an inert gas. It may be used underground, as well as for service entrance conductors as well as feeder or branch circuit conductors. IGS shall not be used in direct contact with the building when exposed. The insulation is composed of dry kraft paper tapes, which shall be pressurized by sulfur hexafluoride gas. Both the paper and gas shall be approved for electrical use. The pressure of the gas between the taped conductors and the outer nonmetallic conduit shall be 20 pounds per square inch gage (psig).

MI - Mineral Insulation

The cable consists of solid copper conductors insulated from each other and enclosed in a gas-tight, seamless copper sheath by tightly packed magnesium oxide powder. The cable materials are highly inorganic and will out last any system using usual types of insulation. MI cables are highly resistant to heat, cold, liquids, and corrosion. Because there are no voids in the cable it is suitable for use in hazardous locations Class I, II, and III without the need to seal against the passage of gases, vapors or flames. It is relatively small in diameter and readily usable in crowded areas. The copper sheath is corrosive resistant, but where corrosive condition is harmful a plastic outer jacket can be factory installed.

Because the magnesium oxide is highly absorbent it is necessary to seal the ends whenever the cable is cut so moisture in the air is not absorbed by the insulation. A sealing compound must be placed at the end of the mineral insulation and the bare conductors must be provided with insulating sleeving, Type MI seals have a compression ring and fittings similar to those used on copper tubing. In addition there is a neoprene sleeve which slips into these fittings and is sealed with an epoxy resin, after which a neoprene bushing with holes for the conductors and the sleeves is inserted. Sealing must be done immediately after stripping or heating the cable to prevent the entrance of any moisture. The cable must be supported every 6 feet and bends must have a radius of at least five times the cable, diameter. Single conductor MI cable must be used when entering metal boxes to prevent induced currents from heating the cable.

MC - Metal Clad

There are three forms of MC cable.

1.Spiral armor formed of steel or aluminum strip. This type appears to be the same as AC cable but there are differences. A separate insulated (green) equipment grounding conductor is required because it does not have the bonding strip that AC (armored cable) does.

2. Smooth seamless metal jacket (usually aluminum) The bending radius for cables not more than 3/4 inch in diameter shall be a minimum of 10 times the diameter of the cable. For MC cable of more than 1-1/2 inches in diameter, the bending radius shall be a minimum of 12 times the diameter of the cable. For MC cable more than 1-1/2 inches in diameter the bending radius shall be a minimum of 15 times the diameter of the cable.

3. Corrugated seamless metal jacket. The bending radius shall not be less than seven times the diameter of the cable, measured for the radius from inside the coil.

Insulating bushings are not required but connectors must be specifically listed for use with MC cable. The connector throat is intended to hold the conductors away from the cut end of the armor. MC cable cannot be fished. MC is permitted for use as service entrance, in hazardous locations and in places of assembly. MC cable can be used for wet locations if the sheath is impervious to moisture or where the contained conductors are approved for use in wet locations.

MC cable can not be used where corrosive conditions exist. Some of the corrosive conditions are; direct burial in earth, causing electrolysis of the metal sheath or cinder fills which will consume the metal sheath rapidly. Some of the corrosive chemicals that deteriorate MC cable are hydrochloric acid, chlorine vapor, strong chlorides, and caustic alkalies. If the metal sheath is made of a material that resists corrosion caused by corrosive vapors it may be used per direction of the inspection authority.

MC cable must be supported every 6 feet.

MV - Medium Voltage

MV cable may be multiconductor or single conductor that is a solid dielectric cable. MV cable may be used for up to 35,000 volts, nominal, for power systems. It may also be used in wet or dry locations in raceways or cable trays. It may not be used when exposed to direct sunlight unless specifically identified for that purpose. Copper, aluminum or copper-clad aluminum conductors are permitted.

NM - Nonmetallic Sheathed Cable

NM is an assembly of two or more conductors having an outer sheath of moisture-resistant, flame-resistant, nonmetallic material. This cable is commonly called Romex. NM may have an uninsulated conductor or green insulated conductor for equipment grounding purposes in addition to the current-carrying conductors. NM cable is used mostly in residential areas.

There must be a distinctive marking on the exterior of the cable for its entire length that specifies the cable type and the name of the manufacturing company.

NM cable must not be used as service entrance, in commercial garages, theaters and assembly halls, motion picture studios, storage battery rooms, hoistways, hazardous locations, or embedded in poured cement, concrete, aggregate, fill, or plaster, or adobe. It may not be used where exposed to corrosive vapors or fumes.

NMC - Nonmetallic Sheathed Cable

Non metallic sheathed cable has an overall covering that is not only flame-retardant and moisture resistant but also fungus retardant and corrosion-resistant.

NM cable must not be used as service entrance, in commercial garages, theaters and assembly halls, motion picture studios, storage battery rooms, hoistways, hazardous locations, or embedded in poured cement, concrete or aggregate.

SNM - Shielded Nonmetallic Sheathed

SNM is permitted where the operating temperature of the cable is maintained at or below the temperature marked on the cable, in cable trays and raceways such as conduit and in specified hazardous locations. Its bends shall have a radius from the inner surface of the bend of not less than five times the diameter of the cable. Only fittings that are identified for use with SNM cable for connecting it to enclosures are to be used. The outer jacket is water-, oil-, flame-, corrosion-, fungus-, and sunlight-resistant.

SE - Service Entrance Cable

SE cable may be a single conductor or a multi conductor assembly. It is usually supplied with an outer covering but may be supplied without the covering. The covering must be flame-retardant and moisture-resistant. The neutral may be bare or covered. It may have a grounding conductor for the purpose of grounding equipment. When SE cable consists of two or more insulated conductors they are permitted to have a bare conductor wrapped around the insulated conductors and it will serve as a neutral conductor. SE cables are permitted to be used for branch circuits and feeders on interior wiring where all of the circuit conductors are rubber-covered or thermoplastic type.

TC - Power and Control Tray Cable

TC cable is made in copper, aluminum and copper-clad aluminum.The outer sheath is flame retardant and nonmetallic. If used in wet location it must be resistant to moisture and corrosive agents. TC cable is used where lighting and power, control and signal, and communication circuits may be used in cable trays and raceways outdoors, when supported by messenger wire. In some cases it may be used in hazardous areas. TC cable cannot be mounted on cleats or brackets in an attempt to use it as open wiring. It must be listed for exposure to direct sunlight if used in such a location. Direct burial is nor permitted unless it is specifically listed for that use.

UF - Underground Feeder

UF is used for underground branch circuits and feeders. It is not to be confused with USE which is direct burial cable for services. The outer covering is flame-retardant, moisture-resistant, fungus-resistant, and corrosive-resistant.

UF is NOT to be used as service entrance cable, in theaters, commercial garages, motion picture studios, storage battery rooms, nor hazardous locations. It is not to be embedded in poured concrete or aggregate. It is not to be used in sunlight, unless specifically listed for such use.

USE - Underground Service Entrance Cable

USE is a direct burial cable recognized for use underground.Its insulation shall be moisture-resistant but not flame retardant.