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National Standards and Code Compliance for Electrical Equipment and Instruments Installed in Hazardous Locations for the Cone Penetrometer

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Abstract:

This document describes the cone penetrometer electrical instruments and how it complies with national standards.

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NATIONAL STANDARDS AND CODE COMPLIANCE FOR ELECTRICAL EQUIPMENT AND INSTRUMENTS INSTALLED IN HAZARDOUS LOCATIONS FOR THE CONE PENETROMETER

by

J.H. BUSSELL

March 13, 1996

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1.0 SYSTEM OVERVIEW

The cone penetrometer is designed to measure the material properties of waste tank contents at the Hanford Site. The penetrometer system consists of a skid-mounted assembly, a penetrometer assembly (composed of a guide tube and a push rod), an active neutron moisture measurement probe, decontamination unit, and a support trailer containing a diesel-engine-driven hydraulic pump and a generator. The skid-mounted assembly is about 8 feet wide by 23 feet long and 15 feet high. Its nominal weight is about 40,000 pounds with the provisions to add up to 54,500 pounds of additional ballast.

The thickness requirement for explosion-proof housings is found in Table 6.1 of UL-1203, under the column labeled "Sheet Steel." The guide tubes come in two different sizes for 4-inch and 12-inch risers. The guide tube sections are 24.375 inches long with outside diameters of 3.5 and 6.0 inches. Guide tube sections are joined together with Acme threads. The push rod sections are 39.4 inches long; the push rod outside diameter is 1.75 inches. Tapered threads are used to join the push rod sections together. The screw threads on the push rod satisfy the five-threads-of-engagement requirement for tapered threads found in paragraph 7.28 (Group B gases) in UL-1208.

An O-ring or similar type seal will be present on the outside of the push rod to prevent the in-leakage of waste into the push rod. Figures 1 and 2 show the cone penetrometer and its skid installed in a waste tank. The instrumentation in the tip of the push rod is illustrated in Figure 3 and Table 1. The probe tip assembly will only be used once.

The use of the cone penetrometer system can be described as follows: The skid is lifted off its transporter (flatbed truck, etc.) with a crane and set over the riser. Leveling jacks are then lowered and the skid is leveled. The skid is bonded and grounded to the riser where the penetrometer guide tube and push rod will be inserted into the tank. Electric power cables and hydraulic lines are connected between the skid and the generator and hydraulic support trailer. Then the blind flange is removed from the riser and the adapter (if required) and washer assembly are attached to the riser. The instrumentation cable for the instrumentation in the penetrometer tip is threaded through the guide tubes and push rods. The guide tube with the push rod inside is then lowered through the adapter assembly until the guide tube is embedded about 6 inches into a "hard" waste layer. Then the push rod is pushed into the waste under force (up to 70,000 pounds) until the push rod is about 12 to 20 inches above the tank bottom. As the push rod pushes through the waste, required measurements are obtained from the instrumentation in the tip. After the required measurements are complete, the cable to the tip instrumentation is removed. Then, the active neutron moisture probe is lowered down the inside of the push rod.

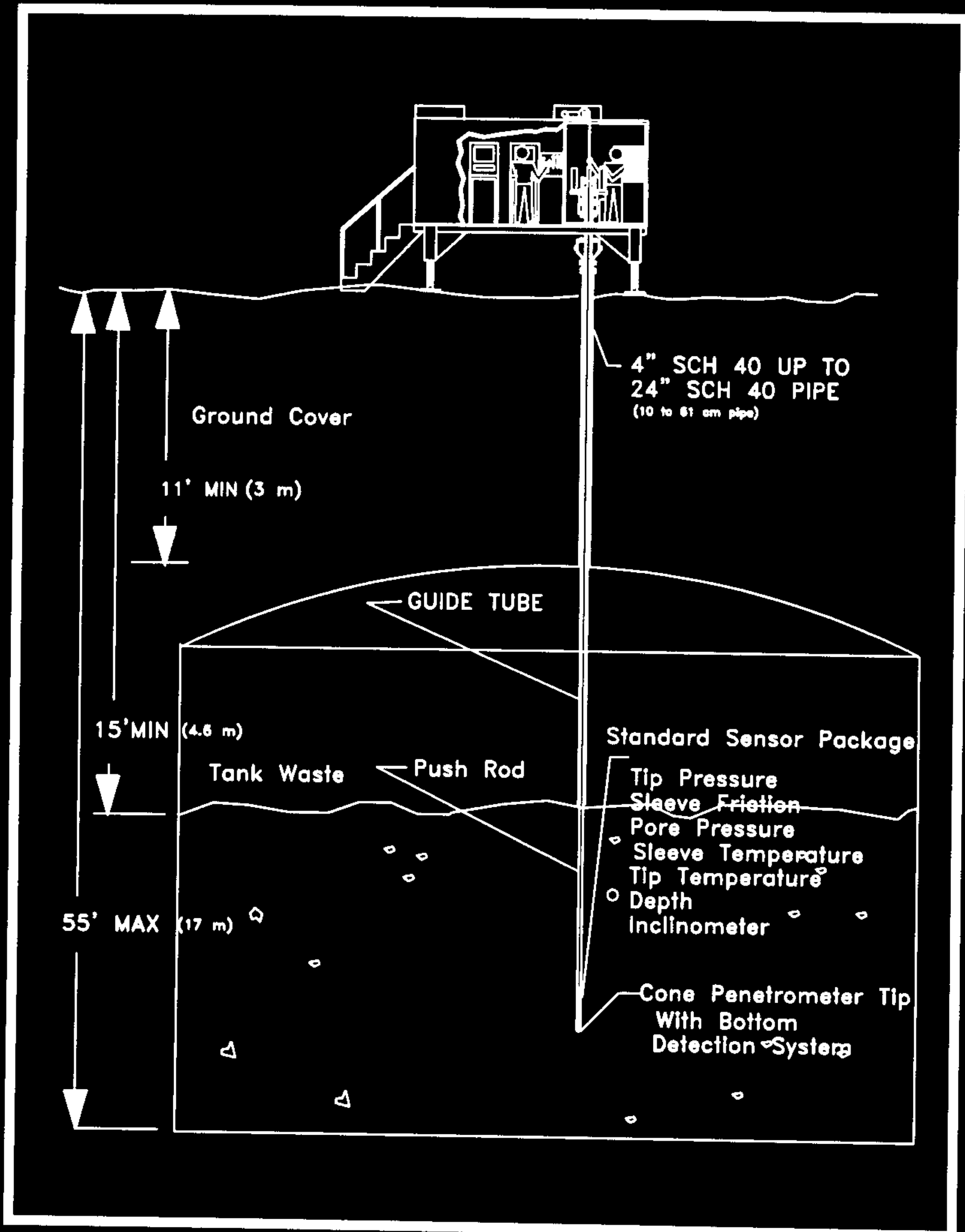

Figure 1. Cone Penetrometer

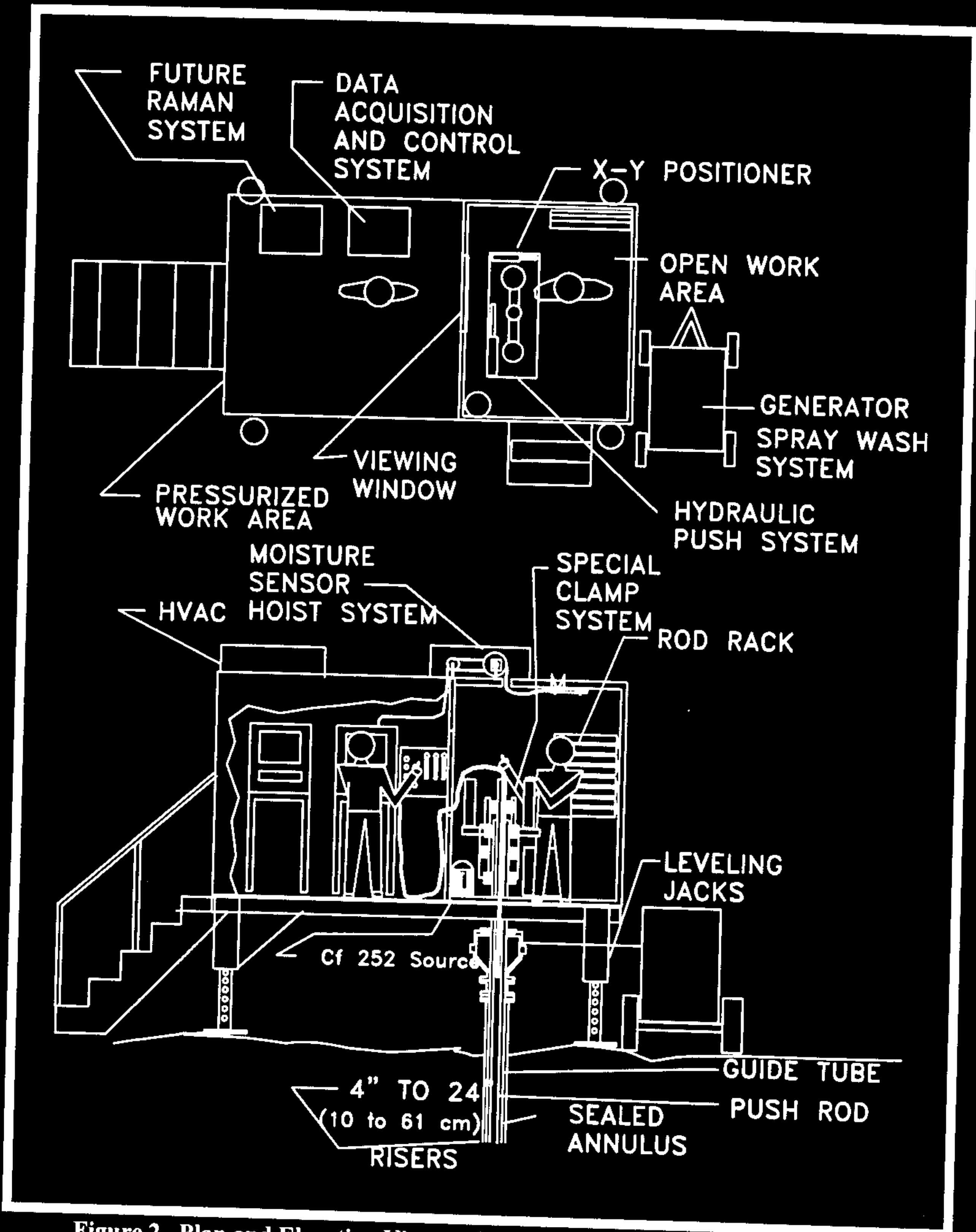

Figure 2. Plan and Elevation View of Cone Penetrometer Deployment System

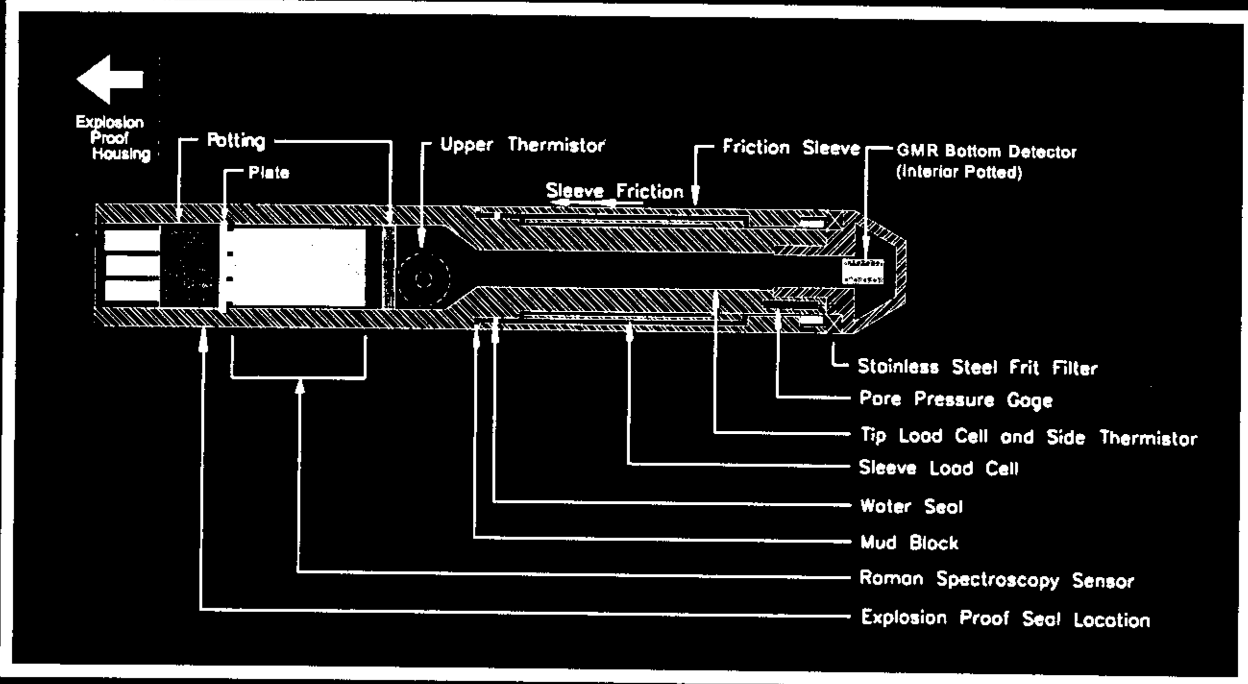

Figure 3. Cone Penetrometer Probe Instruments

Table 1. Penetrometer Tip Instrumentation

Measurement	Instrument
Tip Stress	Load Cell using foil strain gages Manufacturer: MicroMeasurements (LEA-06-02UT-350)
Sleeve Stress	Load Cell using foil strain gage Manufacturer: MicroMeasurements (LEA-06-02UT-350)
Pore Pressure Transducer	Strain Gage Bridge Pressure Transducer Manufacturer: Kulite Corp. XT-140-200
Tip Temperature	Thermistor: 10,000 ohms at 20° C Manufacturer: NTC
Side Temperature	Thermistor: 10,000 ohms at 20° C Manufacturer: NTC
Inclinometer	Two Axis Electrolytic Potentiometer Sensor, Manufacturer: Spectron Systems Technology
Bottom Detector	Redundant Giant Magnetoresistive Bridge Manufacturer: ARA, & Nonvolatile Electronics, Inc.

Table 1. Penetrometer Tip Instrumentation

Measurement	Instrument
Chemical Analysis	Raman Spectroscopy Manufacturer: Lawrence Livermore National Laboratory
Moisture Measurement	Active Neutron Dual Detector Manufacturer: SAIC

2.0 HAZARDOUS LOCATION CLASSIFICATION

In response to a recent event where a core drilling casing filled with hydrogen gas to a concentration above the lower flammability limit, site management has prescribed that the interior of waste tanks to be Class I, Division 2, Group B for non-intrusive operations and has classified the interior of waste to be Class I, Division 1, Group B for intrusive operations. A recent study by Pacific Northwest National Laboratory found a correlation between tank level changes and barometric pressure [Whitney, PNL]. This report concludes that gases trapped in the waste may be released during an intrusive operation. Since the use of the cone penetrometer is an intrusive operation, the instrumentation will be designed to be meet the criteria of Class I, Division 1, Group B. The head space or vapor space the tanks have measurable quantities of nitrous oxide, ammonia, hydrogen, methane, and non-paraffinic hydrocarbons (kerosene-like or naphtha-like hydrocarbons). The group classification and autoignition temperatures, per NFPA 497M, for these gases are shown below in Table 2. Autoignition temperature is the temperature at which a gas, vapor, or dust will ignite spontaneously without any other source of ignition.

Table 2. NFPA Group Classification for Common Flammable Gases Found in Waste Tanks

Gas	NFPA Group	Autoignition Temperature
Ammonia	D	928° F
Hydrogen	B	968° F
Methane	D	999° F
Naphtha (NPH)	D	550° F
Source: NFPA 497M		

2.1 AREA CLASSIFICATION OF PENETROMETER TIP

From the discussion above, the inside of the tank below the liquid waste level is classified as Class I, Division 1, Group B. The tip instrumentation will be deployed into a Class I, Division 1, Group B location.

2.2 AREA CLASSIFICATION OF INTERIOR OF PUSH ROD

The interior of the push rod is a non-classified location. The push rod is an explosion proof housing which will contain any explosions within the push rod. The estimated internal volume of the push rod is 613 cubic inches, based on a 65-foot long cone penetrometer. The Raman spectroscopy sensor is located at the bottom of the push rod assembly between the adaptor and cone penetrometer tip. A sapphire window is located in the side of the Raman spectroscopy sensor housing. The window is brazed to the 420 stainless steel Raman housing with Indalloy #3 (90% Indium - 10% Silver). The requirements for the cone penetrometer will be developed in the section below.

3.0 DESIGN REQUIREMENTS AND EQUIPMENT DESCRIPTION

3.1 GENERAL

Electrical equipment and devices to be used in a classified hazardous location must be approved for that service by a nationally recognized testing laboratory, e.g. Underwriters Laboratory, Factory Mutual, etc (only explosion-proof and intrinsically safe equipment). One must not only consider the specific device, but also must consider any and all associated equipment. Associated equipment is any other equipment or device connected to, or otherwise coupled to, the same wiring. Specific apparatus and wiring requirements vary with the Class I and Division 1 or 2 classification for the location specified in the National Electrical Code (NEC) Articles 500, 501, and 504.

In the NEC, there are two distinct areas in classified locations, Division 1 and Division 2. Division 1 implies that there is possibility of flammable concentrations above the lower flammability limit (LFL) during normal conditions. This does not mean flammable gas concentrations exceeding the LFL are present. In a probability of explosion analysis (see Magison) the percentage of time when flammable concentration of gases are present is set at 10% for Division 2 classified locations. Division 2 implies that flammable gas concentrations above the LFL are present only in abnormal conditions. In the probability of explosion analysis previously cited, 0.01% of the time there is a flammable gas concentration above the LFL in Division 2 classified locations. The same risk analysis establishes that in non-classified locations, 1×10^{-11}% of the time there are flammable gas concentrations above the LFL. While the NEC does not explicitly recognize the Division 0, the Division 0 locations always have flammable concentration of gases. An example of a Division 0 classified locations is the hydrogen reactor column in an oil refinery. The above information is provided to give a qualitative meaning between the differences of Division 1 and Division 2 classified locations and the reason for more stringent requirements in Division 1 classified locations as compared to Division 2 classified locations.

The NEC provides for three alternative methods to prevent fire or explosions from electrical equipment operating in a classified hazardous locations. These methods are (simplified interpretations):

- Intrinsically safe apparatus: The electrical equipment/device does not store and can not provide sufficient energy to ignite a flammable mixture and is approved for the flammable vapor group (A to D) and for area classification (Class I, Division 1 or Division 2). Figure 4 shows a simple fault tree illustrating the number of faults required for an intrinsically safe apparatus to ignite a flammable mixture. This figure is provided for illustrative purposes and is not meant to convey or represent an accident probability.

- Purging and pressurizing of electrical enclosures: Reducing either the fuel or the oxidizer, or both, to a noncombustible level and providing power cutoff switches to the equipment if purge and pressurization control for explosion/fire prevention cannot be maintained. Three different purging methods are recognized by the NEC, Types X, Y, and Z, and their respective requirements are described in NFPA 496.

- Explosion proof enclosures and wiring methods: Housing the electrical device within a qualified enclosure which will contain possible explosions due to arcing or other possible ignition sources within the enclosure is also acceptable. The enclosure will prevent ignition sources within the enclosure from igniting combustible gas mixtures that may present outside of the enclosure. The requirements for explosion proof housing are described in UL-1203.

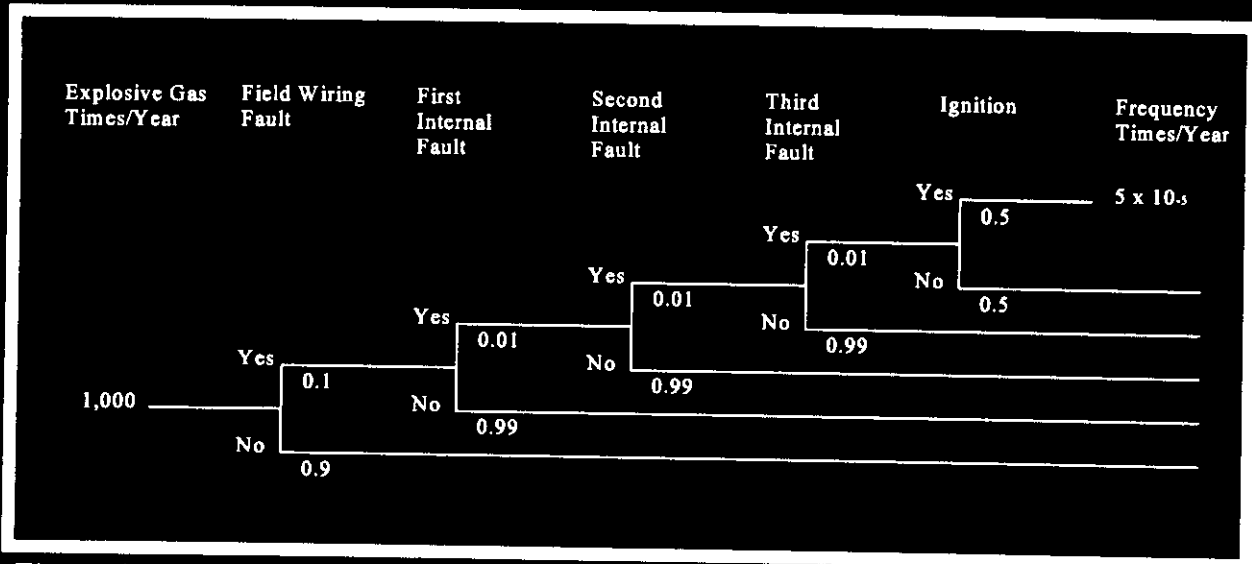

Figure 4. Simple Fault Tree Illustrating Faults Required for Intrinsically Safe Apparatus to Ignite Flammable Vapor [Bossert, 1994]

3.2 CONE PENETROMETER AND BOTTOM SENSING DETECTOR HOUSINGS

The probe is, as shown in Figure 3, is constructed from 4340 alloy steel. The probe tip or housing, containing the bottom sensing detector, is hardened and heat treated.

3.3 TIP AND SLEEVE STRESS LOAD CELLS

The sleeve and tip stress load cells are located in the tip. In order to enhance sensitivity, MicroMeasurements foil strain gages will be used to provide greater sensitivity over a broader stress range. Strain gages are considered a simple apparatus per ANSI/ISA RP12.6. All that is needed to make the strain gage elements and associated wiring comply are appropriately selected intrinsic safety barriers (ISB). Standard wiring methods can be used in non-classified locations because the circuit is intrinsically safe. The insulation thickness on wiring must be at least 0.010 inches. If connectors are used, then configuration of the design must not permit incorrect connection of the connectors. This design approach applies to configuration of connector pins. The design must also preclude shorts between separate circuits. This means multiple intrinsically safe circuits in a cable must have insulation, rated for 500 VAC, between the conductors. This requirement is not applicable if it can be shown that a shorting fault between intrinsically safe circuits results in available short circuit less than the 50% of the ignition value for the circuit situation. The ignition value is obtained from ignition curves found in Factory Mutual Class 3610 or Underwriters Laboratory Document 913.

Since the load cells are a simple apparatus, their heat generation is negligible. The heat generated by these sensors should not increase significantly above the ambient temperature.

Passive zener intrinsic safety barriers (Stahl*Model Numbers: 9002/10-187-270-00, 9002/10-187-020-00, and 9002/10-093-040-00) have been selected for this application. A single set of Stahl intrinsic safety barriers (Stahl: 9002/10-187-270-00 and 9002/10-187-020-00) are used to provide excitation voltage to the pore pressure gage, sleeve load cell, tip load cell, and the two GMR magnetic field sensors (tank bottom sensor elements). The last intrinsic safety barrier (Stahl: 9002/10-093-040-00) is used to provide the required isolation between the classified location side of the intrinsic safety barrier and the non-classified location. Figure 5 shows the connection diagram for these intrinsic safety barriers and Tables 3, 4, and 5 show the entity safety parameters for the respective barriers.

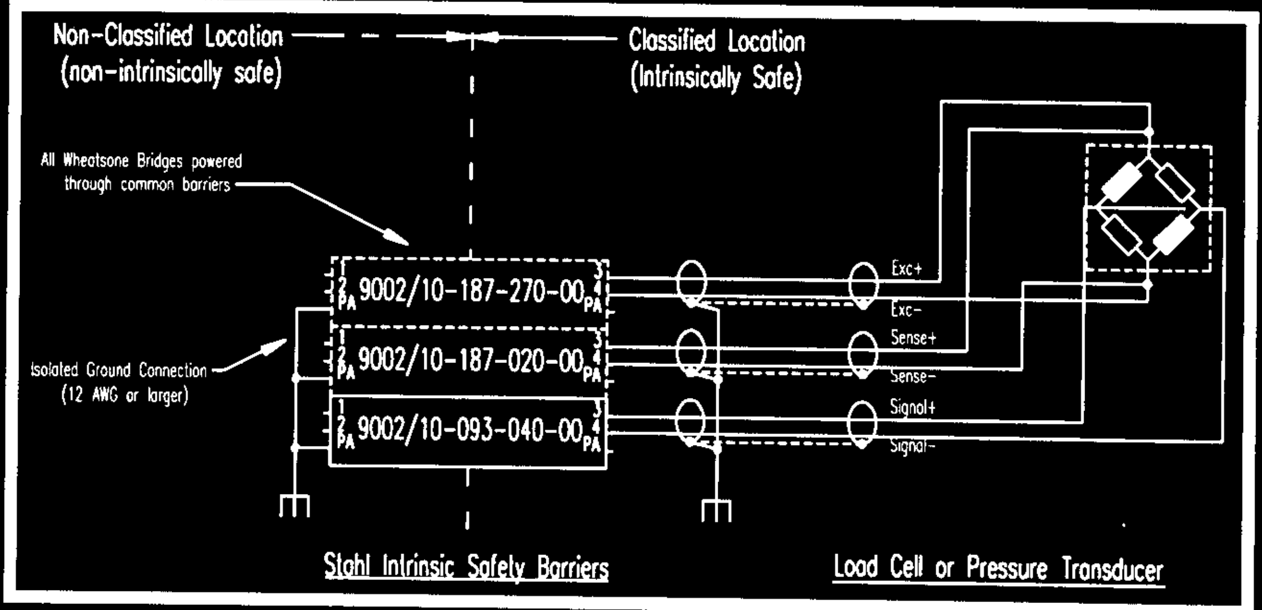

Figure 5. Load Cell and Pore Pressure Transducer ISB Connection Diagram

*Stahl is a trademark of R. Stahl, Inc., Woburn, MA

Table 3. Intrinsic Safety Barrier Entity Safety Parameters for Load Cells and Pore Pressure Transducer Stahl 9002/10-187-270-00

Parameter	Channel[1]	
	I	II
V_{oc} : Maximum Open Circuit Voltage from IS Barrier (V)	9.3	9.3
V_{max} : Intrinsically Safe Apparatus Maximum Allowed Voltage (V)		
I_{sc} : Maximum Short Circuit from IS Barrier (mA)	251.8	251.8
I_{max} : Intrinsically Safe Apparatus Maximum Allowed Current (mA)		
C_a : IS Barrier Maximum Allowed Circuit Capacitance (μF)	4.3	4.3
C_{total} : Circuit Total Capacitance (μF)	0.009	0.009
C_{cable} : Cable Capacitance (150 ft x 60 pF/ft) (μF)	0.009	0.009
C_i : Intrinsically Safe Apparatus Capacitance (μF)		
L_a : IS Barrier Maximum Allowed Circuit Inductance (mH)	0.27	0.27
L_{total} : Circuit Total Inductance (mH)	0.003	0.003
L_c : Cable Inductance (150 ft x 0.2 μH/ft) (mH)	0.003	0.003
L_i : Intrinsically Safe Apparatus Inductance (mH)		

Notes:

1. The intrinsic safety barrier is dual channel passive barrier. One channel is terminals 1 to 3 and the other channel is terminals 2 to 4.
2. Inductance and capacitance per foot are assumed to be 60 pF/ft and 0.2 μH/ft.

Table 4. Intrinsic Safety Barrier Entity Safety Parameters for Load Cells and Pore Pressure Transducer Stahl 9002/10-187-020-00

Parameter	Channel[1]	
	I	II
V_{oc} : Maximum Open Circuit Voltage from IS Barrier (V)	9.3	9.3
V_{max} : Intrinsically Safe Apparatus Maximum Allowed Voltage (V)		
I_{sc} : Maximum Short Circuit from IS Barrier (mA)	19.8	19.8
I_{max} : Intrinsically Safe Apparatus Maximum Allowed Current (mA)		
C_a : IS Barrier Maximum Allowed Circuit Capacitance (μF)	4.3	4.3
C_{total} : Circuit Total Capacitance (μF)	0.009	0.009
C_{cable} : Cable Capacitance (150 ft x 60 pF/ft) (μF)	0.009	0.009
C_i : Intrinsically Safe Apparatus Capacitance (μF)		
L_a : IS Barrier Maximum Allowed Circuit Inductance (mH)	83.4	83.4
L_{total} : Circuit Total Inductance (mH)		
L_c : Cable Inductance (150 ft x 0.2 μH/ft) (mH)		
L_i : Intrinsically Safe Apparatus Inductance (mH)		

Notes:
1. The intrinsic safety barrier is dual channel passive barrier. One channel is terminals 1 to 3 and the other channel is terminals 2 to 4.
2. Inductance and capacitance per foot are assumed to be 60 pF/ft and 0.2 μH/ft.

Table 5. Intrinsic Safety Barrier Entity Safety Parameters for Load Cells and Pore Pressure Transducer Stahl 9002/22-093- 040-00

Parameter	Channel[1]	
	I	II
V_{oc} : Maximum Open Circuit Voltage from IS Barrier (V)	9.6	9.6
V_{max} : Intrinsically Safe Apparatus Maximum Allowed Voltage (V)		
I_{sc} : Maximum Short Circuit from IS Barrier (mA)	20.4	20.4
I_{max} : Intrinsically Safe Apparatus Maximum Allowed Current (mA)		
C_a : IS Barrier Maximum Allowed Circuit Capacitance (μF)	3.8	3.8
C_{total} : Circuit Total Capacitance (μF)	0.009	0.009
C_{cable} : Cable Capacitance (150 ft x 60 pF/ft) (μF)	0.009	0.009
C_i : Intrinsically Safe Apparatus Capacitance (μF)		
L_a : IS Barrier Maximum Allowed Circuit Inductance (mH)	78.7	78.7
L_{total} : Circuit Total Inductance (mH)	0.003	0.003
L_c : Cable Inductance (150 ft x 0.2 μH/ft) (mH)	0.003	0.003
L_i : Intrinsically Safe Apparatus Inductance (mH)		

Notes:
1. Inductance and capacitance per foot are assumed to be 60 pF/ft and 0.2 μH/ft.

3.4 SIDE AND TIP TEMPERATURE SENSORS

The tip temperature sensor is located in the tip of probe and is bonded to the tip stress load cell strain gages. The side temperature sensor is bonded to a stainless steel button which is then bonded to a Kevlar*button which is screwed into the side of the mandrel. Temperature sensors are thermistors with 10,000 ohms at 20° C. Like the load cells, the thermocouples are considered a simple apparatus per the definition found in ANSI/ISA RP12.6. All that is needed to make the temperature sensor intrinsically safe is an appropriately selected intrinsic safety barrier.

A Stahl model 9002/22-032-300-11 has been selected as the intrinsic safety barrier for this application. Figure 6 shows the connection diagram for two thermistors. Table 6 shows the entity approval safety parameters and the verification the thermistors are within the entity approval safety limits.

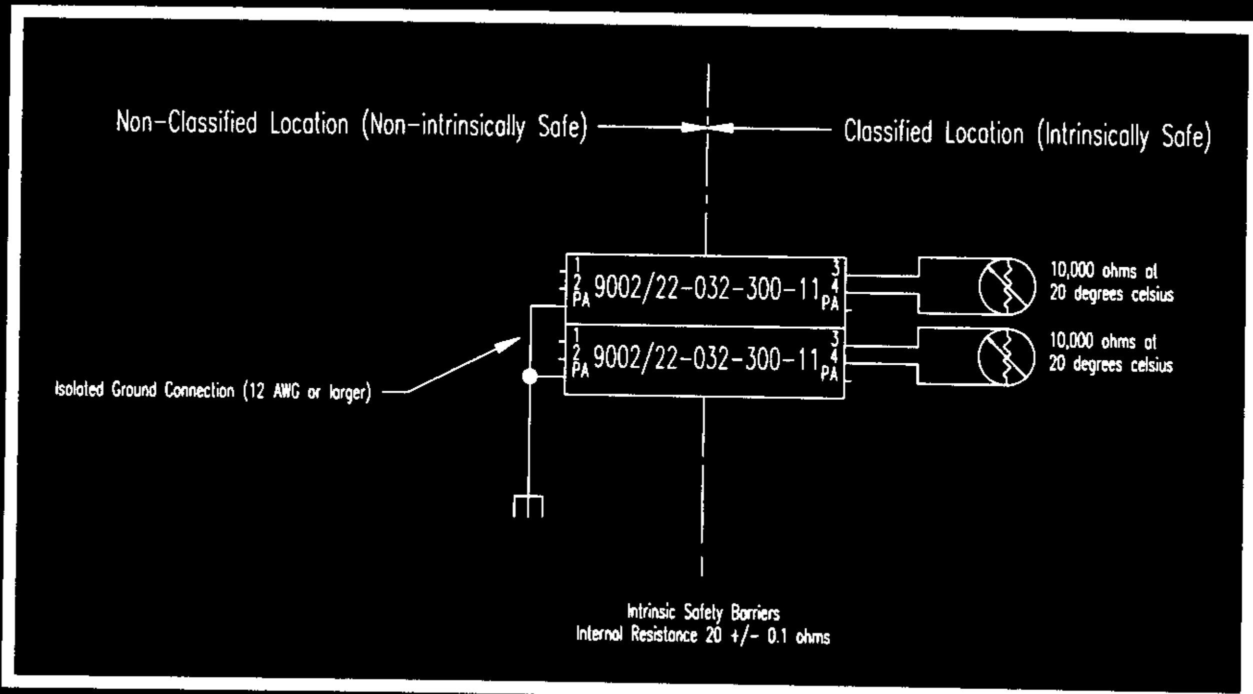

Figure 6. Thermistor Intrinsically Safe Circuit Connection Diagram

*Kevlar is a trademark of E.I. du Pont de Nemours and Company, Wilmington, DE.

Table 6. Intrinsic Safety Barrier Entity Parameters for Side and Tip Thermistors Stahl 9002/22-032-300-11

Parameter	Channel[1]	
	I	II
V_{oc} : Maximum Open Circuit Voltage from IS Barrier (V)	1.64	1.64
V_{max} : Intrinsically Safe Apparatus Maximum Allowed Voltage (V)		
I_{sc} : Maximum Short Circuit from IS Barrier (mA)	127.4	127.4
I_{max} : Intrinsically Safe Apparatus Maximum Allowed Current (mA)		
C_a : IS Barrier Maximum Allowed Circuit Capacitance (μF)	1800	1800
C_{total} : Circuit Total Capacitance (μF)	0.009	0.009
C_{cable} : Cable Capacitance (150 ft x 60 pF/ft) (μF)	0.009	0.009
C_i : Intrinsically Safe Apparatus Capacitance (μF)		
L_a : IS Barrier Maximum Allowed Circuit Inductance (mH)	8.7	8.7
L_{total} : Circuit Total Inductance (mH)	0.003	0.003
L_c : Cable Inductance (150 ft x 0.2 μH/ft) (mH)	0.003	0.003
L_i : Intrinsically Safe Apparatus Inductance (mH)		

Notes:
1. The intrinsic safety barrier is dual channel passive barrier. One channel is terminals 1 to 3 and the other channel is terminals 2 to 4.
2. Inductance and capacitance per foot are assumed to be 60 pF/ft and 0.2 μH/ft.

3.5 INCLINOMETER SENSOR

The inclinometer is a dual axis electrolytic tilt sensor. The sensor is a 0.5 inch diameter by 0.625 inch tall cylindrical glass envelope filled with a proprietary electrolytic fluid. Four electrodes are located 90 degrees apart around the circumference and one sensor is located in the center of the sensor. The sensor has an estimated capacitance of 1 nanofarad between any of the pins and an impedance of about 7000 ohms. Since the fluid in the sensor is an electrolyte, the excitation voltage must not contain an average DC value, otherwise the electrolyte will dissociate and may cause the sensor to eventually fail. Since this sensor does not store or generate any energy and the energy stored in the capacitance between the electrodes is less 0.3 microjoules (based on energy stored in capacitance between electrodes), the inclinometer can be considered to be a simple apparatus per the definition in ANSI/ISA RP12.6. Temperature compensation shall be accomplished by using two thermistors in the package.

The inclinometer is excited with a 10 volt peak-to-peak square wave applied between electrodes at opposite sides of the sensor. One set of electrodes is excited with a 1.1 kiloHertz square wave and a 2.2 kiloHertz square wave. A cable connects the tilt sensor to the electronics package located in the skid mounted assembly. Three signal pairs will be required for the inclinometer. The cable must be selected such that requirements of NEC 504-20(a)(3)(b) are satisfied: 0.01 inch insulation or a grounded metal shield between conductors of intrinsically safe circuits. The voltage measured at the center electrode, a complex addition of the two square waves of the input square waves, is processed by the electronics package located in the skid mounted assembly. Passive zener diode intrinsic safety barriers will be used for this application. These barriers will require a ground connection to earth, e.g. the riser where the penetrometer is being inserted into the tank. The barriers selected for this application have been successfully used to transmit pulses from a classified location to a non-classified location. Additional padding resistance will be necessary in the excitation leads to ensure that line resistance in excitation leads are equal to eliminate the possibility of an average DC voltage being applied to the sensor. Table 7 shows the entity approval safety parameters and the verification the inclinometer is within the entity safety limits. Temperature compensation for the inclinometer will be done based on the temperature measurements from the two thermistors located at the probe.

Table 7. Intrinsic Safety Barrier Entity Parameters for Inclinometer Passive Barriers Stahl 9002/77-150-00

Parameter	Channel[1]	
	I	II
V_{oc} : Maximum Open Circuit Voltage from IS Barrier (V)	14.5	14.5
V_{max} : Intrinsically Safe Apparatus Maximum Allowed Voltage (V)		
I_{sc} : Maximum Short Circuit from IS Barrier (mA)	138	138
I_{max} : Intrinsically Safe Apparatus Maximum Allowed Current (mA)		
C_a : IS Barrier Maximum Allowed Circuit Capacitance (μF)	0.25	0.25
C_{total} : Circuit Total Capacitance (μF)	0.009	0.009
C_{cable} : Cable Capacitance (150 ft x 60 pF/ft) (μF)	0.009	0.009
C_i : Intrinsically Safe Apparatus Capacitance (μF)		
L_a : IS Barrier Maximum Allowed Circuit Inductance (mH)	1.4	1.4
L_{total} : Circuit Total Inductance (mH)	0.003	0.003
L_c : Cable Inductance (150 ft x 0.2 μH/ft) (mH)	0.003	0.003
L_i : Intrinsically Safe Apparatus Inductance (mH)		

Notes:
1. The intrinsic safety barrier is dual channel passive barrier. One channel is terminals 1 to 3 and the other channel is terminals 2 to 4.
2. Inductance and capacitance per foot are assumed to be 60 pF/ft and 0.2 μH/ft.

3.6 PORE PRESSURE TRANSDUCER

The pore pressure transducer measures the pressure of the tank waste (0 to 500 psig). The transducer is isolated from the tank waste with a high viscosity silicone oil and stainless steel sintered frit filter. The pore pressure transducer is a Kulite* Products, XT-140-200 semiconductor transducer. The pressure transducer consists of a 1000 ohm strain gage bridge. Strain gages are considered a simple apparatus per ANSI/ISA RP12.6. All that is needed to make the strain gage elements and associated wiring is appropriately selected intrinsic safety barriers (ISB). Standard wiring methods used in non-classified locations can be used because the circuit is intrinsically safe. The insulation thickness on wiring must be at least 0.010 inches. If connectors are used, then configuration of the design must not permit incorrect connection of the connectors. This design approach applies to configuration of connector pins. The design must also preclude shorts between separate circuits. This means multiple intrinsically safe circuits in a cable must have insulation, rated for 500 VAC, between the conductors. This requirement is not applicable if it can be shown that a shorting fault between intrinsically safe circuits results in available short circuit less than the 50% of the ignition value for the circuit situation. The ignition value is obtained from ignition curves found in Factory Mutual Class 3610 or Underwriters Laboratory Document 913.

Since the load cells are a simple apparatus, their heat generation is negligible. The temperature of sensors will never rise must above the ambient temperature.

The same intrinsic safety barriers described for the tip load cell are also used for this application. Figure 5 shows the connection diagram for the case when remote sensing leads are used. Tables 3, 4, and 5 show the entity approval safety parameters and the verification the pore pressure transducer is within the entity safety limits. This barrier can also be used with local sensing if desired. The output of the barrier provides a 4 to 20 mA output for 0 to 100% input signal.

3.7 BOTTOM DETECTOR

The bottom detector consists of a coil which is excited by two Giant Magnetoresistive Ratio (GMR) magnetic field sensors and the application of a 100 Hertz 3.25 mA peak-to-peak current. This sensor is used to sense the bottom of the tank. Figure 7 and 8 show an electrical diagram and the mechanical layout of the bottom detector. The coil's dimensions are: 0.5 inches in diameter, 0.188 inches thick, and 1 inch tall. The coil has 1600 turns of 34 AWG copper wire around a steel core containing the two GMR sensors. The air core inductance value of the coil is 7 to 10 millihenries. The GMR sensor is a NVSB series sensor manufactured by Nonvolatile Electronics, Inc. The sensor senses the increase in magnetic flux in the iron core, located in the center of the coil, as the bottom detector approaches the steel tank bottom. The operating principles and a detailed description of this sensor can be found in [Bratton, 1995].

*Kulite is the trademark of Kulite Tungsten Corp., Leonia, NJ.

Figure 7 shows the intrinsically safe circuit connection diagram for the bottom detector. Two types of intrinsically circuits are used. One is to provide the coil drive current and the other type is for the GMR sensors. The same transformer isolated barrier used for the load cell and pore pressure transducers will be used for the two GMR sensors. Because of the coil's 100 Hz excitation frequency, a passive zener diode intrinsic safety barrier is used to provide power. This intrinsic safety barrier requires grounding to earth. The interface to the cable from the coil must present less than 2.87 mH of inductance and present less than 0.131 μF of capacitance. Figure 9 shows the isolation network between the coil and cable. The isolation network will be rated for open circuit voltage and the short circuit current of the intrinsic safety barrier. The coil will have redundant back-biased diodes to dissipate the inductor's stored energy when the current is removed from the inductor. These redundant diodes will be an integral part of the coil winding and potted within the coil assembly. The isolation network does not have to be part of the coil.

The GMR sensor's fault probability is reduced by the use of encapsulation and coated magnet wire. The interior of the GMR sensor is potted. This encapsulation provides an additional barrier between flammable vapors and the possible ignition source (coil) and decreases the possible volume for gas accumulation in the bottom detector. Encapsulation is an accepted ignition prevention method for Class I, Division 2, Group B locations; this application is classified as Class I, Division 1, Group B. Magnet wire with heavy film insulating coating is used for the GMR sensor. Use of the coating decreases the probability of internal faults, in the coil or the two GMR sensors, such as condensation, turn-to-turn faults, or open circuits. The combination of encapsulation and the coated magnet wire significantly decreases the probability of faults.

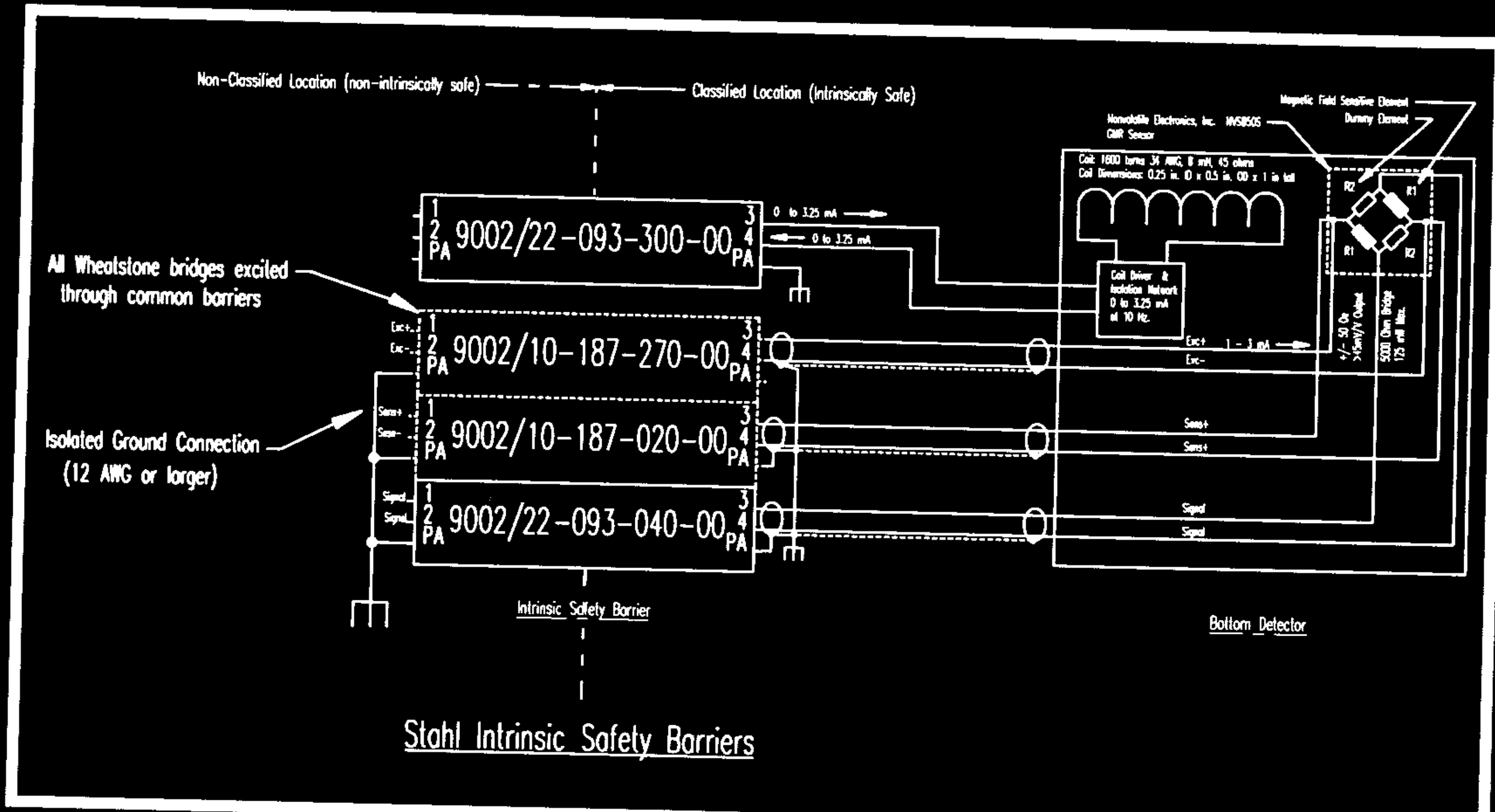

Figure 7. Bottom Detector Intrinsic Safety Circuit Connection Diagram (only one GMR sensor is shown).

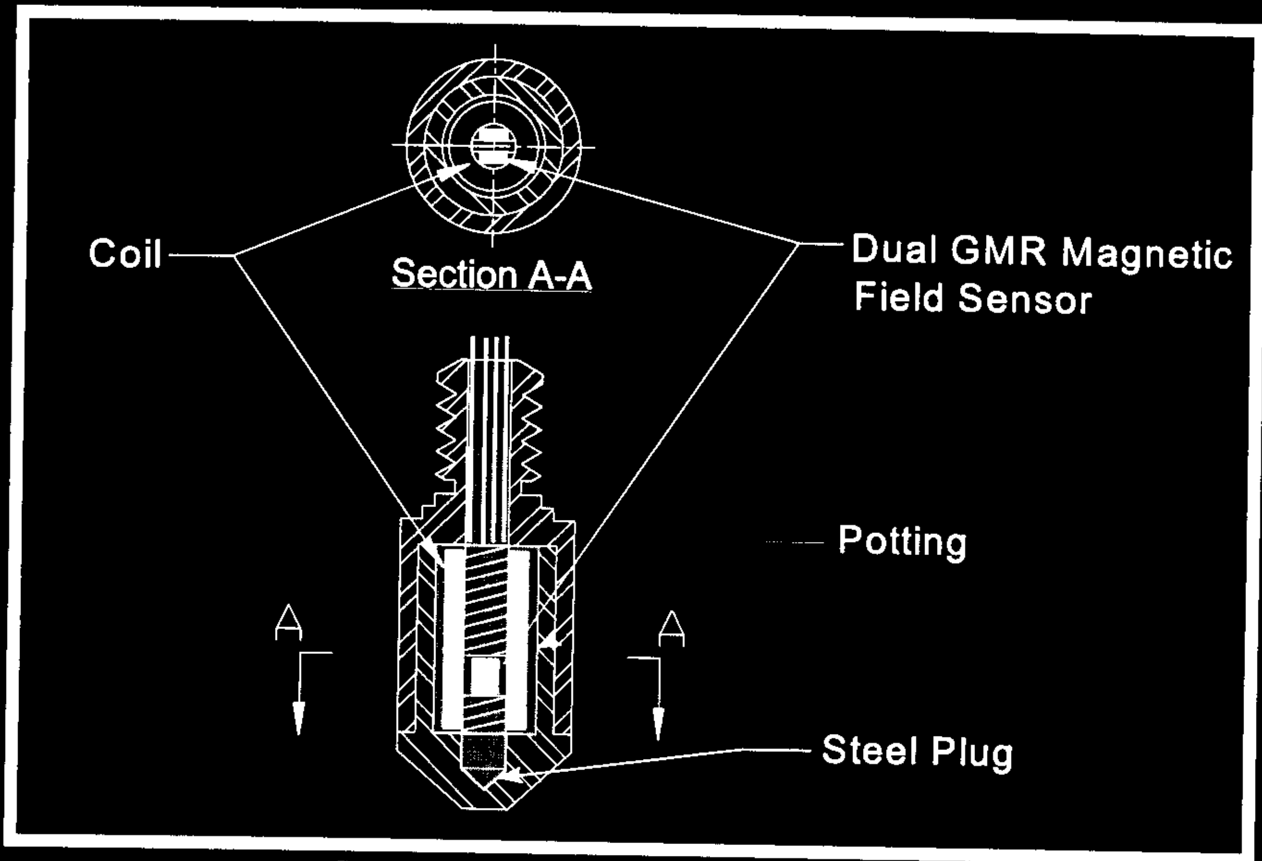

Figure 8. Bottom Detector Sensor Housing

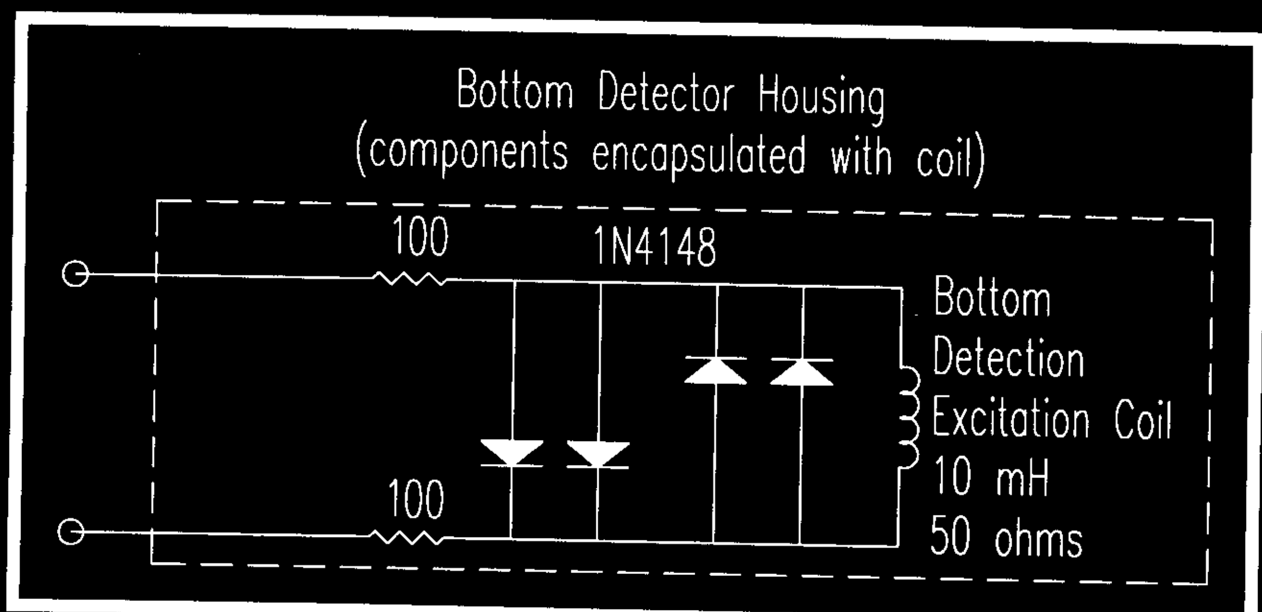

Figure 9. Bottom Detector Isolation Network for Bottom Detector Excitation Coil

3.8 CHEMICAL ANALYSIS (RAMAN) SENSOR

A Raman spectroscopy sensor system is used in the cone penetrometer. The Raman sensor is located at the bottom of the cone penetrometer push rod, between the adaptor and cone penetrometer tip. The Raman sensor housing uses a sapphire (a form of Al_2O_3) window between the fiber optic sensors and the waste. Figure 10 shows a diagram of the Raman spectroscopy system. The cone penetrometer rod is an explosion-proof housing. The Raman sensor is intrinsically safe and does not require an explosion-proof housing.

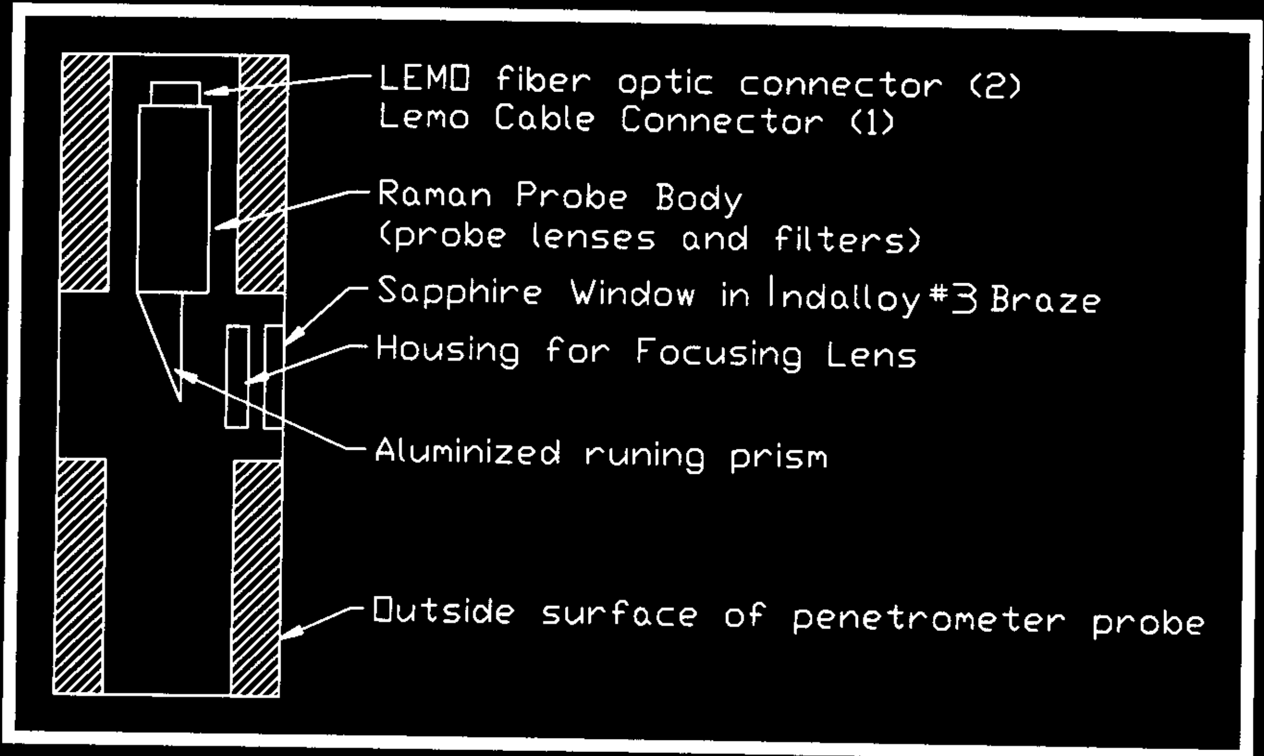

Figure 10. Raman Spectroscopy System

3.9 OTHER PROBE TIP REQUIREMENTS

The top of the cone penetrometer probe must be sealed to withstand the pressure wave of the flame front during an explosion inside the push rod. Typically, the pressure of the flame front is five times the explosion pressure in a spherical chamber. The explosion pressure of hydrogen in a four liter spherical chamber is about 102 psi, with a seven millisecond rise time [Magison, 1978]. Detailed calculation or testing is required to verify the peak explosion pressure. The push rod is very long; pressure piling may increase the peak explosion pressure beyond five times the spherical geometry explosion pressure. The value of the peak pressure will dictate requirements for the seal between the probe and the push rod.

Although it is not required, another method to reduce the probability of ignition of hydrogen in the probe tip is to fill the void space with glass beads (0.02 to 0.04 inch diameter). The principle of ignition prevention is to limit the volume of flammable gases in the probe tip and to limit the propagation of the flame front, if ignition takes place. This principle is also used in cartridge power fuses to cool and to extinguish the electric arc.

3.10 INTERIOR PUSH ROD AND GUIDE TUBE

The interior of the push rod meets the requirements defined in UL-1203. However, as discussed in the previous section, detailed calculations are needed to determine the peak pressure of the pressure wave that results from the ignition of flammable gases in the push rod. The structural strength of the push rod and the threaded joints must be reviewed on the basis of the calculated peak explosion pressure. The threaded seals are not gas tight and will allow gas leakage into the interior of the push rod and guide tube. Combustion gases are cooled sufficiently in the thread joints to prevent the combustion gases from igniting flammable gases outside the explosion proof housing. Figures 11 and 12 show the guide tube and the push rod.

Additional rubber seals (e.g. o-rings) may used outside the threaded area of the guide tube and push rod provided the seals do not decrease the effectiveness of joints (reference: UL-1203, Paragraph 7.7). In general, sealants may not be used on threaded joints unless they are qualified for used by explosion tests (reference: UL-1203, Section 13, Paragraph 7.2 and 15.20.

Table 8. Summary of Explosion Proof Enclosure Design Requirements per UL-1203

Section/Para.	Requirement
Table 4.1	Nema Type 7 enclosure
5	Material: Iron, steel, copper, cast brass, bronze, aluminum There are limitations on use copper and aluminum. [see section 11.16 for portable equipment which calls for bronze or brass]
6, Table 6.1	Minimum Thickness: 0.093 inches for malleable iron 0.125 inches for cast iron 0.067 inches for sheet steel
7.28	Joining Threads: (coarser than 20 threads/inch) Non tapered 8 fully engaged threads Class 1 fit 7 fully engaged threads Class 2 fit 6 fully engaged threads Class 3 fit Tapered (use pipe threads although not specified) 5 full engaged threads
11.16	Portable equipment: Material specified for portable equipment is brass, bronze, or aluminum The basis for this to prevent sparking from striking (if this is an issue).
11.1 to 11.3	Conduit Threads: If a conduit fitting is used as part of the cable seal, e.g. close nipple, then the enclosure must be threaded for the proper size with 5 full threads of engagement. Provisions must also be made for a conduit stop or provide space for an insulating bushing.
11.24 -11.28	Packing Gland for cable seal
16	Hydrostatic Pressure Testing The explosion pressure for hydrogen is 102 PSI. Use a safety factor of 5. Apply 510 PSI water and verify that case does not rupture or distort. Test applied for 1 minute.

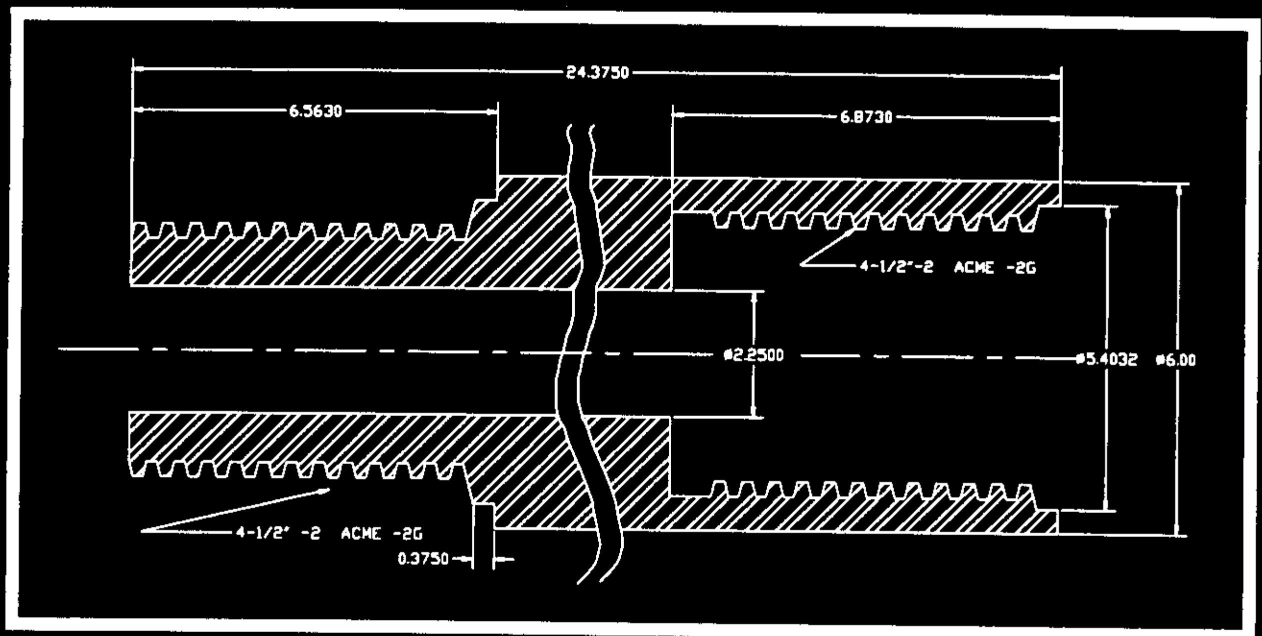

Figure 11. Guide Tube Dimensions

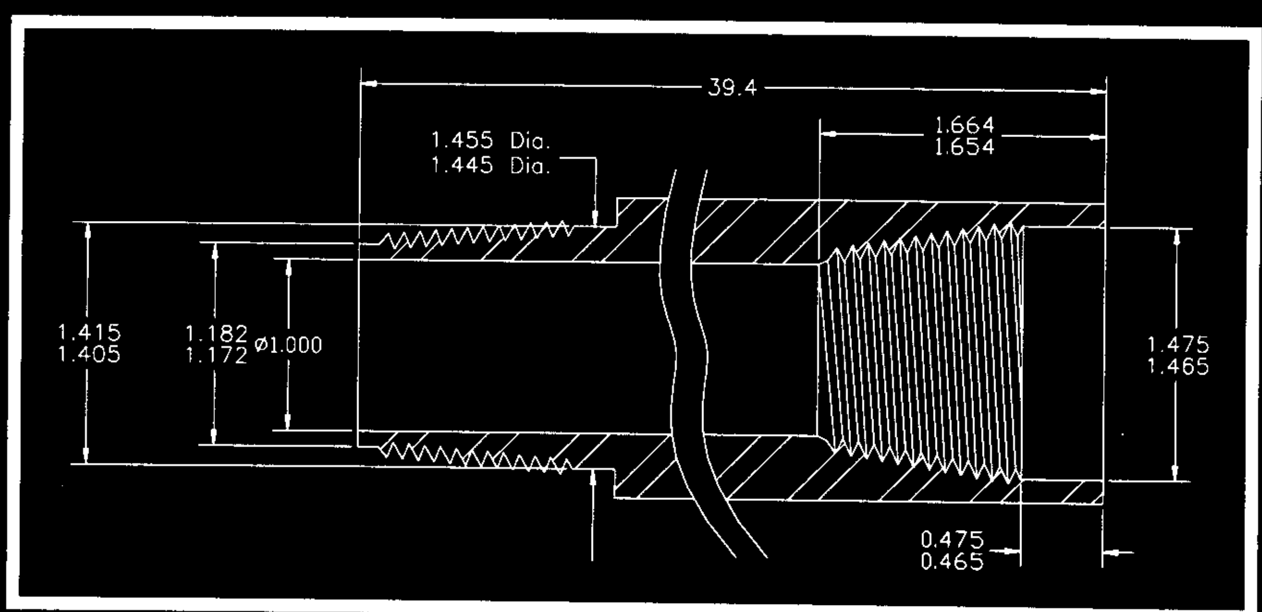

Figure 12. Push Rod Dimensions

3.11 ACTIVE NEUTRON MOISTURE PROBE

The active neutron probe contains two boron-10 lined neutron detector tubes. These detector tubes are polarized with approximately +700 VDC. The probe also contains two solid state temperature sensors. A special cable, incorporating a Kevlar strength member, is used to connect the probe to the nuclear counting system electronics, located on the skid mounted assembly. Two coaxial cables are provided for connecting the counting tubes to their respective preamplifiers, which are located on the skid mounted assembly. These two coaxial cables also provide the +700 VDC polarizing voltage to the detectors. The cable has a semiconductive jacket; this means that it will dissipate static charge as it is lowered into the push rod. This probe is not designed for use in a hazardous location; it may be used in an explosion proof enclosure (push rod). The active neutron moisture probe is shown in Figure 13 and the complete system is shown in Figure 14. Figure 15 shows the operating principles for the active neutron moisture probe.

3.12 REQUIRED PRECAUTION FOR USE OF ACTIVE NEUTRON MOISTURE PROBE

To prevent an explosion from occurring inside of the push rod, the active neutron moisture probe must not be used until it is known that the concentration of flammable gases in the push rod is less than 25% of the lower flammability limits. This action will preclude personnel injury from the hazard described above. This action can be implemented by measuring the flammable gas concentration in the push rod prior to using the active neutron moisture probe.

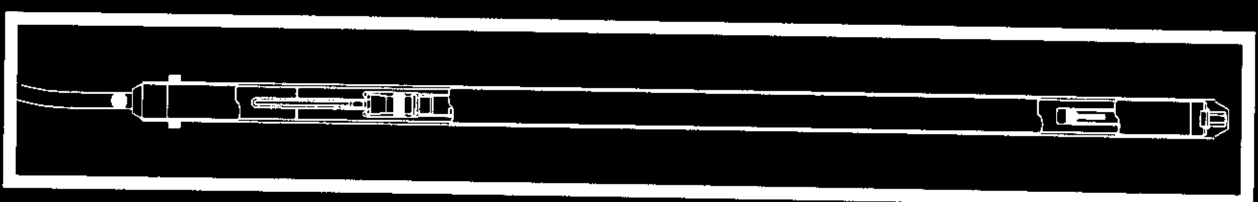

Figure 13. Active Neutron Probe

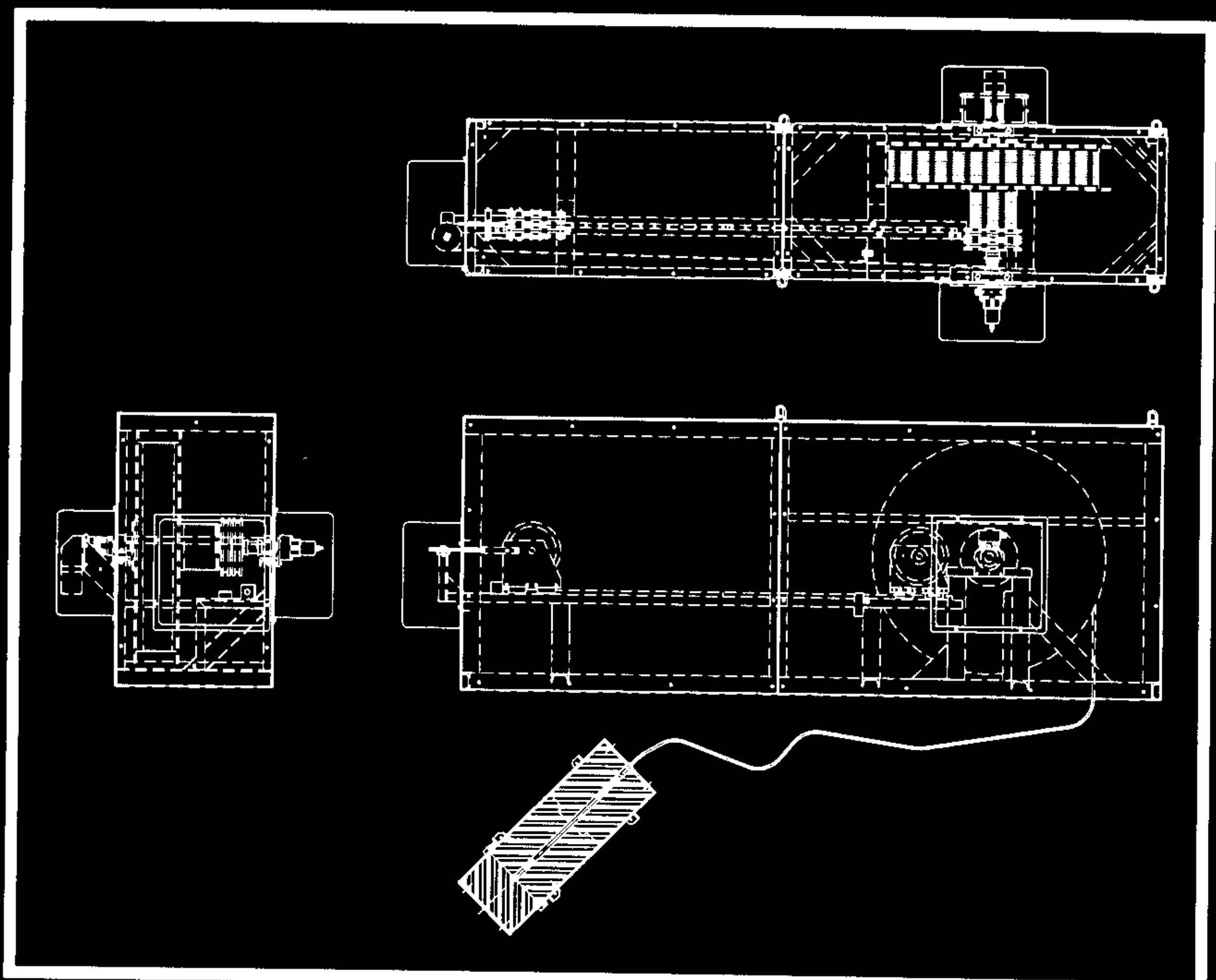

Figure 14. Active Neutron Moisture Measurement System

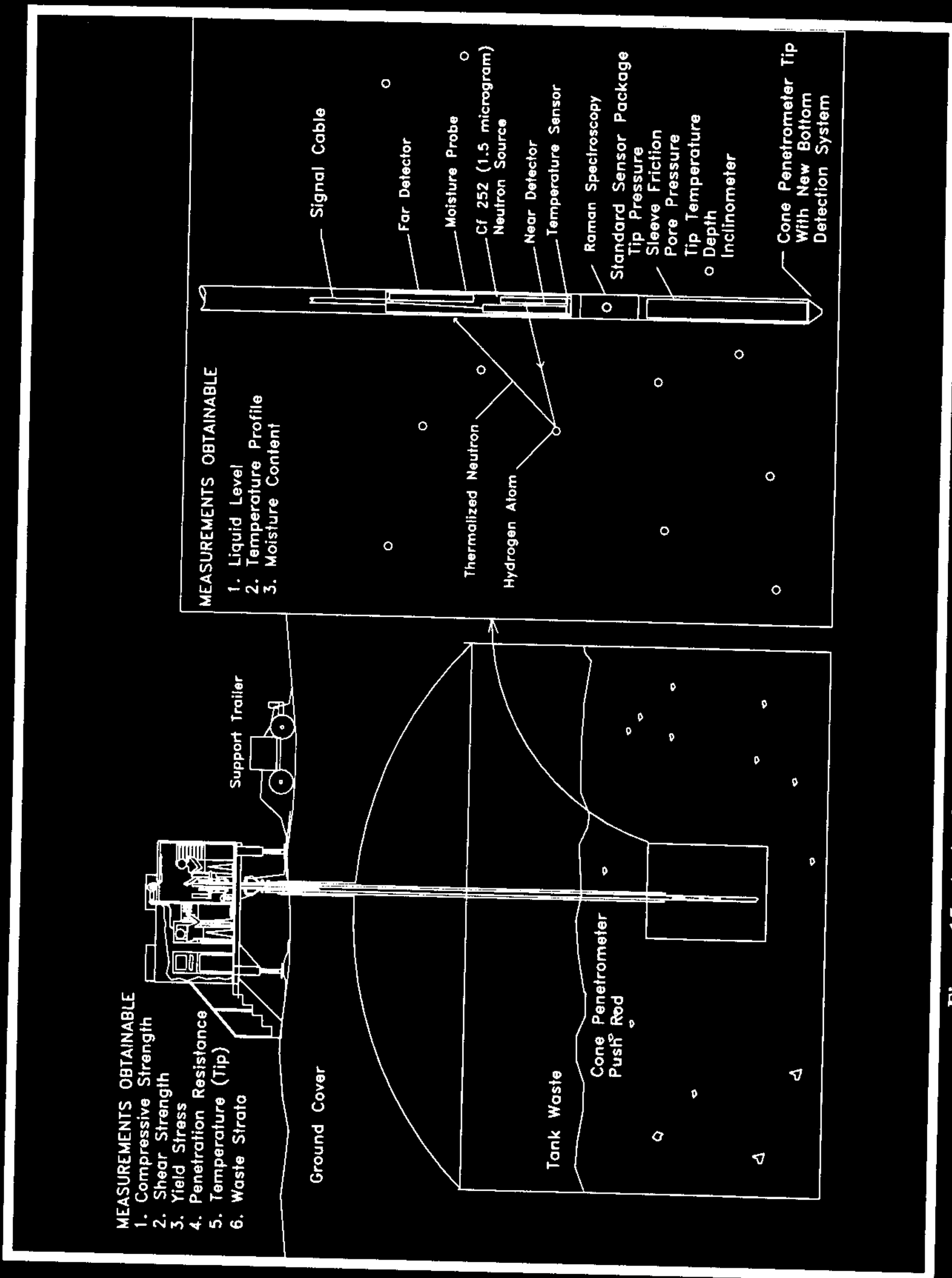

Figure 15. Active Neutron Moisture Probe Principles of Operation

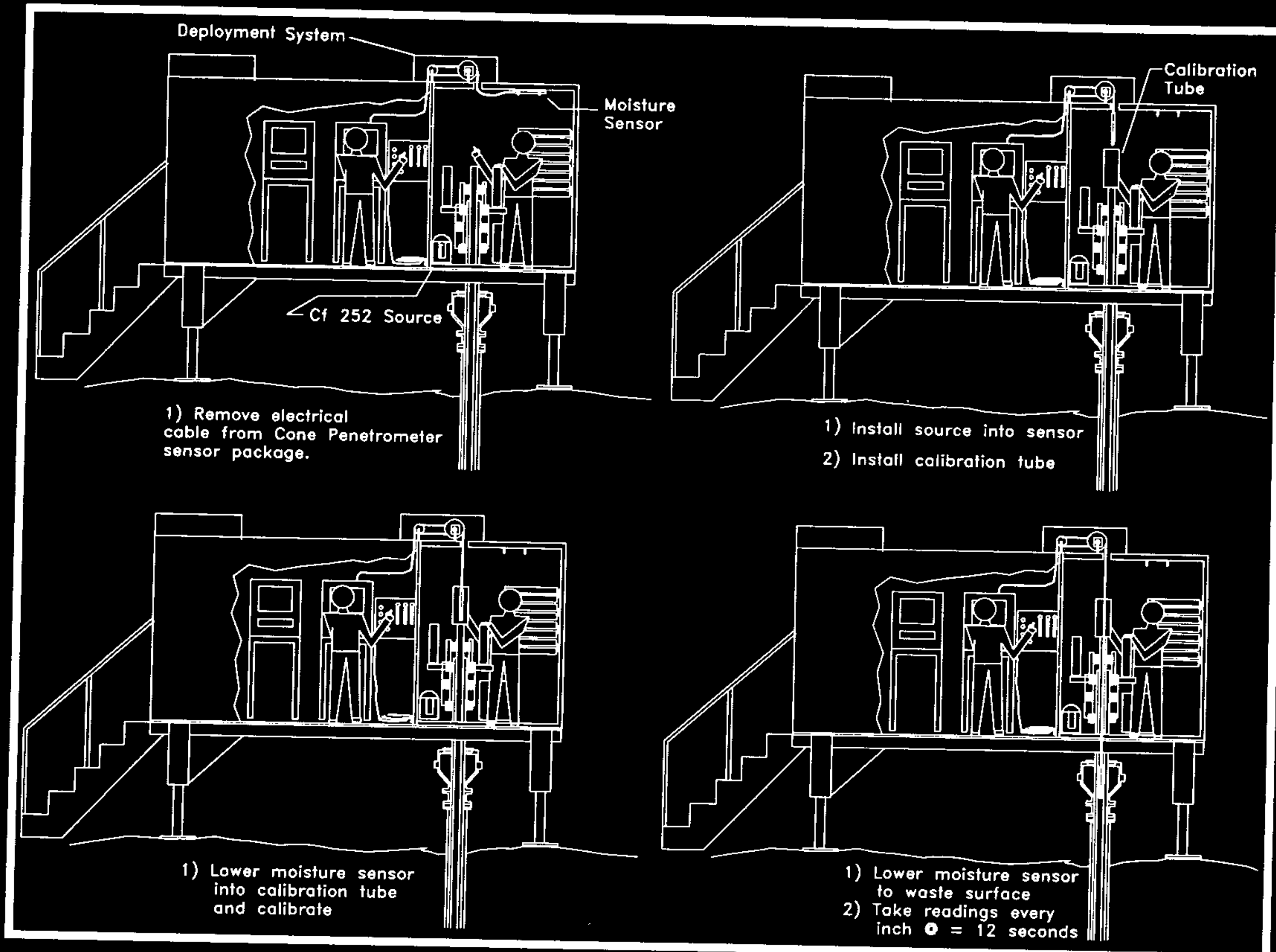

Figure 16. Active Neutron Moisture Probe Operation Sequence

3.13 WIRING PRACTICES

Wiring practices found in ISA RP12.6 should be followed in the installation of intrinsically safe wiring. In general, intrinsically safe wiring must be separated by 2 inches (5.0 centimeters) from non-intrinsically safe wiring. A grounded metal partition can also be used to separate intrinsically safe wiring from non-intrinsically safe wiring. Intrinsically safe enclosures must be identified on their covers as containing intrinsically safe wiring and circuits. Connectors used in intrinsically safe circuits should be selected such that different mating connectors are not interchangeable. Pin spacing in these connectors must preclude inadvertent interconnections between two intrinsically safe circuits. Associated instrumentation, or the instrumentation connected on the non-intrinsically safe side of the intrinsic safety barrier, must be powered from a 120 VAC power supply.

4.0 CONCLUSIONS

Electrical equipment and devices to be used for tank waste intrusive activities are designed to meet the requirements for a Class I, Division 1, Group B environment. The method chosen to design the cone penetrometer, to prevent fire or explosion from electrical equipment operating in this classified hazardous location, was intrinsically safe apparatus and explosion proof enclosures and wiring methods. All the requirements have been met for this environment except for the effectiveness of the seal between the probe and push rod. In order to determine the effectiveness of the seal, testing or analysis of interface at 510 psi at the interface is recommended.

5.0 REFERENCES

ANSI/ISA RP12.6, *Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations*, Instrument Society of America, 1987

ANSI/UL-913-1988, *Standards for Intrinsically Safe Apparatus and Associated Apparatus for Use In Class I, II and III, Division 1 Hazardous (Classified) Locations*, 1988

NFPA 70-1993, *National Electrical Code* (NEC), National Fire Protection Association, 1993, Article 500, Hazardous (Classified) Locations.

NFPA 497M, *Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations*, National Fire Protection Association, 1987.

Bossert, John A., "Hazardous Locations Guide for Design, Testing, Construction, and Installation of Equipment in Explosive Atmospheres", 1995, Canadian Standards Association.

Bratton, W. L., "Development of Bottom Detecting Unit for Hanford Tank Farm CPT Work", Applied Research Associates (ARA) Report No. 5968-3, September 15, 1995

Magison, Ernest C., "Electrical Instruments in Hazardous Locations," 3rd Edition, Instrument Society of America.

Whitney, P.D. , "Screening the Hydrogen Tanks for Trapped Gas", WTSFG95.13, Pacific Northwest Laboratory, Richland, WA, April, 1995.