INTERCONNECTION OF MSHA EVALUATED MINE-WIDE MONITORING SYSTEMS AND MSHA APPROVED LONGWALL MINING SYSTEMS

BY
KEVIN L. HEDRICK
KENNETH A. SPROUL

MINE SAFETY AND HEALTH ADMINISTRATION
APPROVAL AND CERTIFICATION CENTER
DIVISION OF ELECTRICAL SAFETY

ABSTRACT

This paper presents requirements for the interconnection of MSHA evaluated mine-wide monitoring systems and MSHA approved longwall mining systems. Previously, Title 30, Code of Federal Regulations (30 CFR) has not been interpreted to allow such interconnection.

The past and present practices of monitoring longwall parameters are outlined, including methods of monitoring and identification of which parameters are monitored. The growing list of parameters that have potential significance and could be monitored are discussed. The technical (hardware) requirements and installation techniques to retain electrical safety in areas where permissibility is required, are presented. Finally, the administrative details of both 30 CFR Part 18 and the MSHA Mine-Wide Monitoring System Evaluation program are detailed, and installation practices for the safe interconnection of approved electrical equipment and monitoring systems are discussed.

INTRODUCTION

From the first use of longwall mining systems, various operational parameters have been observed and studied to learn how to use the systems more safely and efficiently. Originally such observation was simply visual monitoring of production techniques. As longwalls became mechanized and electrified, more parameters were available for monitoring and it became desirable to record the observations.

More sophisticated and permanent methods were developed to record and store data. Electronic instrumentation, such as strip chart recorders, developed for use in non-mining industries was adapted for use on longwall equipment to provide analog representations of various electrical characteristics, such as motor load current and input voltage. By connection to voltmeters and current transformers a graphic record was produced. Digital data recording eventually replaced analog signal monitoring. The manipulation of data obtained in the field was facilitated with digital recording and small hand-held recorders with high on-board storage were modified for mining applications.

As longwall equipment becomes more sophisticated, more and more parameters are available for monitoring. In addition to the motor load current and input voltage which are considered essential, other useful parameters include the status of protective components such as-overcurrent devices, ground monitors, ground fault devices, and overload protection are also being monitored.

Computers are being installed in increasing numbers on longwall equipment for monitoring and control. Shearers, roof and electrohydraulic control systems are examples of longwall components now being controlled by computers. Communication between computer-controlled components such as the shearer and the shield advance system is expected to be commonplace.
The data from these local computers could be combined with other data from the longwall section and transmitted to the surface.

Interpretation of this data could be used for component failure prediction or trend analysis, Not only does this increase the efficiency of the system, but creates a safer workplace by averting accidents caused by failures of the electrical equipment that is controlled by the computers. Additional parameters that may be potentially useful are hydraulic pressure, face alignment, hydraulic gear drives, and longwall production.

To optimize the use of the available data, communication between the local computers, transducers and other components and a centralized data collection/manipulation point is desirable. Installation of large mine-wide monitoring systems, using a central computer on the surface, is becoming more prevalent, making it logical for the longwall components to be interfaced with these mine-wide monitoring systems.

PERMISSIBILITY CONSIDERATIONS

The components that are being proposed for longwall monitoring include those located in areas where permissibility is required as well as areas not in or inby the last open crosscut. Therefore, measures must be taken to insure that, where necessary, the equipment will not cause an ignition of the mine environment. This can be accomplished by designing the equipment such that it will not cause an ignition (intrinsically safe) or housing equipment in an enclosure that will isolate an ignition from the mine environment (explosion-proof). These are methods that are recognized by 30 CFR Part 18 for reducing fire and explosion hazards.

Intrinsic Safety

Equipment that is intrinsically safe is incapable, under normal or reasonably established abnormal conditions, of releasing sufficient electrical or thermal energy to ignite a flammable mixture of methane, and air of the most easily ignitable composition. The composition of the mixture used when evaluating equipment for intrinsic safety under 30 CFR is 8.3% methane-in-air. Normal conditions consist of the normal operation of the equipment, including the effects of maximum supply voltage and extreme environmental conditions within equipment ratings. Other evaluation factors considered normal conditions are opening, shorting, and grounding of all conductors which are part of field wiring. Also, all adjustments and component tolerances are considered at their most unfavorable positions. Abnormal conditions include all probable component failures. This does not include those components which have been tested and found not subject to fault. The two worst case faults are applied during an MSHA intrinsic safety evaluation.

The electrical energy (spark) ignition sources considered are (1) discharge of a capacitive circuit, (2) interruption of an inductive circuit, (3) intermittent making and breaking of a resistive circuit, and (4) hot wire fusing.

Spark ignition depends on the amount of energy released in an arc, and in the case of (l), the energy stored in the capacitor is released when the circuit is closed. The amount of energy stored in a capacitive circuit is proportional to the applied voltage. The curve that describes the relationship between the amount of capacitance and the applied voltage at which the minimum ignition energy is produced is seen on Fig. 1. Similarly, the energy stored in an inductive component is released when the current flow through it is interrupted. This energy is proportional to the current flow, and the relationship between circuit inductance and ignition current is shown on Fig, 2. In resistive circuits (those where the effects of capacitance and inductance are negligible), the energy is proportional to both the current and the voltage. The relationship between voltage and current at which the minimum ignition energy is produced are graphically represented on Fig. 3. Resistive components must also be evaluated to make sure that the auto-ignition temperature of methane, 538° Celsius, is not to be exceeded under any condition.

Explosion-Proof Components

An explosion-proof enclosure is one which is designed and constructed to withstand an explosion of a specified gas or dust which may occur within it and to prevent the ignition of the specified gas or dust surrounding the machine by sparks, flashes, or explosions of the specified gas or dust which may occur within the enclosure.

The term "explosion-proof" is accepted as referring to the type of construction of enclosing cases for motors, controllers, and other electric equipment specially designed to prevent the propagation of explosions to the outside of the enclosures. The term is applied not only to equipment for mines, but also to equipment for the industries and services dealing with combustible gases and vapors other than methane.

It should be noted that the definition given for explosion-proof machine refers to "a specified gas or dust." Thus, it does not necessarily follow that an enclosure found to be explosion-proof in the presence of methane is also explosion-proof in the presence of gasoline vapors or hydrogen. To be certain that an enclosure is explosion-proof for a given gas or dust, it must be tested in explosive atmospheres containing that particular gas or dust, or a gas or dust more volatile. The gas that is considered when evaluating and testing enclosures to be used on approved longwall mining systems is methane.

Interconnection of Monitoring Systems and Longwalls

Mine-wide monitoring systems are evaluated for intrinsic safety per the requirements in MSHA Program Circular PC-4003. This program includes general requirements for the system and more specific requirements for certain components. The successful completion of the evaluation processes of the system and its components results in the issuance of a Mine-Wide Monitoring System Evaluation number, a Sensor Classification, or a Barrier Classification.

30 CFR Part 18, titled "Electric-Motor-Driven Mine Equipment and Accessories", is used to approve longwall mining systems. Section 18.4 of this Part states that "an approval will be issued only for a complete electrical machine or accessory. Also, "assemblies that include one or more non-explosion-proof components will not be considered for approval unless such component(s) contain intrinsically safe circuits or is constructed in accordance with paragraph (b), section 18.31." This section outlines the requirements for enclosures for potted components. Typical mine-wide monitoring systems include components that are neither explosion-proof nor intrinsically safe. These include the host computer, normally found at a surface installation, and underground data collection outstations.

In the past, on the basis of Sections 18.4, longwall mining systems interconnected to components such as these have not been granted approvals. However, 30 CFR has provisions to modify requirements for approved equipment so long as the degree of protection remains the same. The provisions are contained in Section 18.20(b), These types of components do not present a methane ignition hazard when installed in intake air and under certain conditions.

When evaluating a monitoring system, considering the provisions of Section 18.20(b), the components are separated into three general divisions: those in intake air or on the surface, those in intake air that interface with components taken into or used inby the last open crosscut, and those that are taken into or used inby the last open crosscut. The requirements for system evaluations are given in Appendix A. The more specific requirements in this appendix are designed to insure intrinsic safety in areas where intrinsic safety is necessary.

Circuitry which is taken into or used inby the last open crosscut must be intrinsically safe or housed in explosion-proof enclosures, per the system evaluation requirements. The typical system includes sensors that are taken into or used inby the last open crosscut and have been evaluated for intrinsic safety per the table found in Appendix B. The levels of energy storage in the sensor are compared with those found in the third and fourth columns on the table. The table values were derived by applying a safety factor to various points on the curves on Figures 1 and 2. Use of the table allows the sensor to be assigned a classification letter (dependent on the power supply and energy storage levels). Upon completion of the evaluation, an issue number is assigned,

The power supply to the classified sensor (and the signal return) must be protected by an intrinsic safety barrier. This is a device that limits the open circuit voltage and short circuit current to intrinsically safe levels. Shunt connected devices, such as zener diodes, are used to provide voltage limitation; and series connected devices, such as resistors and fuses, limit the short circuit current. The output characteristics of the barrier determine its classification letter, as shown in the first two columns of the table in Appendix B. These classes have been determined by applying a safety factor to various points on the curve in Figure 3.

As intrinsic safety barriers are normally tested with input voltages up to 250 volts rms, protection against higher input voltages must be provided, This is accomplished by an isolating network called a Power Circuit (P.C.) Barrier. This is a component that, with normal or fault input voltages up to its rating, limits the output voltage to 120 volts rms or less. This provides an additional margin of safety for the intrinsic safety barrier.
After the monitoring system and its components have been evaluated and found not to present an ignition hazard and the enclosures on the longwall have been certified explosion-proof, a procedure can be followed to insure that the interconnection of the monitoring system circuitry and circuitry inside longwall enclosures maintains electrical safety.

This procedure includes measures to insure that the energy levels in the cables interconnecting the longwall with the monitoring system are intrinsically safe in the presence of methane-air mixtures. This is accomplished by installing intrinsic safety barriers at both ends of the cable from the monitoring system to the longwall enclosure. Also, an appropriately rated P.C. barrier if needed must be installed in series with the intrinsic safety barrier, as per Fig. 4 to provide isolation from the high-voltage, non-intrinsically safe circuitry in the longwall enclosures and the intrinsically safe monitoring system circuitry. These barriers and associated MWMS circuitry must be physically protected from the rest of the longwall circuitry inside the explosion-proof enclosure by a grounded metallic shield to prevent accidental contact between the monitoring system wiring, and other wiring.

If there are no connections to the high-voltage circuitry, the monitoring system/longwall interface could be configured as shown on Fig. 5. 'This shows a P.C. barrier (P.C. bar) installed in the circuit to provide isolation from the power source (PWR) with a grounded metallic shield shown as a dotted line. If the power for the monitoring system is not derived from the longwall circuitry or the transducers do not require external power, no P.C. barrier is needed, Also shown are MSHA-classified sensors (S) connected to MSHA-classified barriers (L.BAR). The "circuits" shown could be any number of different components, as long as the connections to MSHA-classified barriers and sensors are as shown. The connection to the data transmission line must also be connected to an MSHA-classified barrier, with the classification matching that of a barrier on the opposite end of the data transmission line, located at a blue outstation. Other connection schemes are possible, provided that the methodology used when installing a longwall that is interconnected with a monitoring system is as in Appendix C. By following these rules, the intrinsic safety of the monitoring system is not compromised and the explosion-proof characteristics of the longwall enclosures are retained.

CONCLUSION

30 CFR Part 18.20(b) states "Since all possible designs, circuits, arrangements, or combinations of components and materials cannot be foreseen MSHA reserves the right to modify design, construction, and test requirement: to obtain the same degree of protection as provided by the tests described...." Following the procedures detailed herein, the same degree of protection is provided; therefore, the interconnection of MSHA evaluated mine-wide monitoring systems and MSHA approved longwall mining systems does not compromise safety and is consistent with present regulations.

The addition of monitoring capability, from the surface, of operating and environmental conditions in an underground mine has the potential for providing safer working conditions. Historical data can be accumulated which may provide the ability to predict problem areas and avoid them. The longwall/mine-wide monitoring interface allowing computer monitoring of a system may avert accidents.

B I B L I O G R A P H Y

MAGISON, E.C. Electrical Instruments in Hazardous Locations, 3rd ed. Pittsburgh: Instrument Society of America, 1978.

Gleim, E.J., James, R.S., and Brunot, H. B. "Explosion-proof Design and Wiring for Permissible Mining Equipment." Bureau of Mines Bulletin 541, 1955.

U.S. Code of Federal Regulations. Title 30-Mineral Resources; Chapter I-Mine Safety and Health Administration, Department of Labor; Subchapter A-P, Parts 0 to 199, July 1, 1987, 674 pp.

LIST OF ILLUSTRATIONS

APPENDIX A

MINE WIDE MONITORING SYSTEM

Drawing and Specification Requirements for use of Simplified Processing Procedures

Drawing(s) and specification(s) submitted for a Mine Wide Monitoring System should indicate that:

A. All interfaces to any data transmission line contain circuitry limiting the Data Transmission Line voltage to a maximum of 60 volts per conductor to ground.

B. All outstations are either blue or red in color and are located in intake air.

*Blue outstations may monitor sensors located in areas where equipment is required to be permissible.

*Red outstations are not connected to any circuits entering or located within areas where equipment is required to be permissible.

C. All blue outstations have MSHA power circuit (P.C.) classified input barriers installed in the data transmission line and that the barrier voltage classification is greater than or equal to the highest power circuit voltage being monitored.

D. All blue outstation inputs from power circuits or sensors requiring external power for operation have a MSHA classified power circuit (P.C.) barrier whose voltage classification is greater than or equal to the maximum voltage of the circuit monitored, or supplied to the barrier, or being supplied to the sensor for operation.

E. All outputs of power circuit (P.C.) barriers (inputs to blue outstations) are 120 volts/or less.

F. All sensors in areas where equipment is required to be permissible have a MSHA classification label. (The classification label shall designate an alphabetical classification for the sensor and the label shall be attached to the sensor or, when necessary for inspection purposes, in close proximity to the sensor, i.e. An oil level sensor label could be on the oil tank at the point of cable entry.)

G. Cables from MSHA classified sensors terminate in a MSHA classified barrier of the same classification. MSHA classified barriers, are located at a blue outstation(s).

H. Cables from MSHA classified barriers that terminate in explosion-proof enclosures located in areas where equipment is required to be permissible, comply with the following conditions:

(1). The modification of existing permissible electrical equipment and circuitry within the permissible electrical equipment shall be documented by the operator under an acceptable Field Modification Application.

(2). Cable termination (data transmission line from a blue outstation) within MSHA certified enclosures are to a barrier with a classification that matches the classification of the barriers at the blue outstation. A P.C. barrier with a voltage rating greater than or equal to the voltage input to the enclosure is required when power circuits are monitored or power is obtained from within the MSHA certified enclosure.

(3). All cables leaving an MSHA certified enclosure and terminating in a sensor must meet the following conditions:

A. The sensor has a classification label.

B. The cable is shielded and the shield grounded at the MSHA certified enclosure.

C. The sensor classification has the same letter classification as a barrier located within the MSHA certified enclosure and connected to each individual sensor cable. A barrier classification label shall be located on the exterior of the MSHA certified enclosure and in close proximity-to each and every barrier cable entrance.

D. Connections to the data transmission line shall be between the data transmission line classified barrier and the P.C. barrier when a P.C. barrier is required.

(4). Physical isolation is provided within an MSHA certified enclosure by means of an insulated or grounded metallic shield around all barriers and cables.

I. All sensors whose cable passes through an area where permissible equipment is required, have a MSHA classification label and interface with a blue outstation through a MSHA classified barrier of the same classification.

J. Barriers or barrier enclosures are attached to the blue outstation and are so labeled that barrier outputs identify the type of sensor to which the barrier cable is connected, i.e., CO sensor, CH4 Sensor, Anemometer,

K. All cables entering blue outstations from the P.C, barriers, and all cables connecting a classified barrier with a classified sensor, and all cables connecting the blue outstation with non-classified sensors are shielded with the shield connected to ground at the outstation.

L. Grounding techniques for outstations and barriers are employed using no less capacity than a No. 12AWG Wire.

M. All blue outstations shall contain a MSHA evaluation label with the conditions of use as specified by MSHA.

N. MWMS components and circuits (except under the conditions outlined in (O)) underground automatically deenergize upon loss of mine ventilation. Manual deenergization from a centralized surface control area is acceptable. Manual reenergization of each individual underground outstation is required.

O. Fire detection circuits that monitor conveyor belts or conveyor belt entries meet the conditions specified by 30 CFR, Part 75.1103, including the capability to monitor for 4 hours upon loss of mine power. Exception: circuits shall deenergize either manually or automatically upon loss of mine ventilation, unless the power supply and circuits have been accepted by MSHA as intrinsically safe. Such circuits must be manually reenergized at each individual underground outstation.

P. Detailed installation and maintenance instructions are supplied to all purchasers or users of these systems, installation inspection checklist(s) must be included.

Q. Restrictions of use and modification of the system are explained to purchasers or users of these systems.

APPENDIX B

TABLE 1

CLASS	VOLTS (Output)	CURRENT (Max)	CAPACITANCE (Max)	INDUCTANCE (Max)
A	5v	3A	5 mf	100 uh
B	5v	1A	5 mf	1 mh
C	10v	3A	60 uf	100 uh
D	10v	1A	60 uf	1mh
E	12v	3A	30 uf	100 uh
F	12v	1A	30 uf	1mh
G	15v	1.25A	15 uf	300 uh
H	20v	0.7A	7 uf	1 mh
I	20V/10V	0.7A/0.1A	1 uf	800 uh
J	25V	0.3A	3 uf	10 mh
K	30v	0.1A	1 uf	15 mh
L	18V	1.0A	10 uf	1mh

Z Sensor may be connected to any class barrier Non electrically operated switching devices or TC's & RTD's

APPENDIX C

Interconnection of MSHA Evaluated Mine-Wide Monitoring Systems and MSHA Approved Motor-Driven Electrical Equipment.'

Requests have been made to interface MSHA evaluated Mine Wide Monitoring Systems with MSHA approved mining equipment. 30 CFR, 18.4 indicates that approval will be issued only for a complete electrical machine. However, 30 CFR, 18.20(b) indicates that all possible designs, circuits, arrangements, or combinations of components could not have been foreseen at the time of writing and that modifications to the requirements could be made to obtain the same degree of protection.

The same degree of protection will be provided if the following requirements are met when interconnecting MSHA evaluated Mine Wide Monitoring Systems with MSHA approved electrical equipment:

A. On approval applications incorporating MSHA evaluated mine-wide monitoring systems, a one-line diagram shall show where the monitoring system cable is connected to the machine. The documentation shall include all pertinent cable information (no. of conductors, type, electrical rating, outside diameter, flame resistant hose conduit and method of strain relief). Notes indicating where the requirements of (B) below are met shall also be included.

B. Cables from MSHA classified barriers that-terminate in explosion-proof enclosures located in areas where equipment is required to be permissible, shall comply with the following conditions:

(1) The modification of existing permissible electrical equipment and circuitry within the permissible electrical equipment shall be documented by the operator under an acceptable Field Modification Application or by the approval holder via the Stamped Notification Acceptance Program.

(2) Cable termination (data transmission line from a blue outstation) within MSHA certified enclosures are to a barrier with a classification that matches the classification of the barrier at the blue outstation. A Power Circuit (P.C.) barrier with a voltage rating

greater than or equal to the voltage input to the enclosure is required when power circuits are monitored or power for external monitoring system components is obtained from within the MSHA certified enclosure.

(3) All cables leaving an MSHA certified enclosure and terminating in a sensor must meet the following conditions:

A. The sensor has a classification label.

B. The cable is shielded and the shield grounded at the MSHA certified enclosure.

C. The sensor classification has the same letter classification as the barrier located within the MSHA certified enclosure' and connected to each individual sensor cable. A barrier classification label shall be located on the exterior of the MSHA certified enclosure and in proximity to each and every barrier cable entrance; The size, material and method of attaching this label are subject to MSHA's concurrence. The method of affixing the label shall not impair any explosion-proof feature of the equipment.

D. Connections to the data transmission line shall be between the data transmission line classified barrier and the P.C. barrier when a P.C. barrier is required.

(4) Physical isolation is provided within an MSHA certified enclosure by means of an insulated or grounded metallic shield around all barriers and cables.

C. Control functions assumed by the monitoring system shall be capable of being overridden and operated manually at the machine.

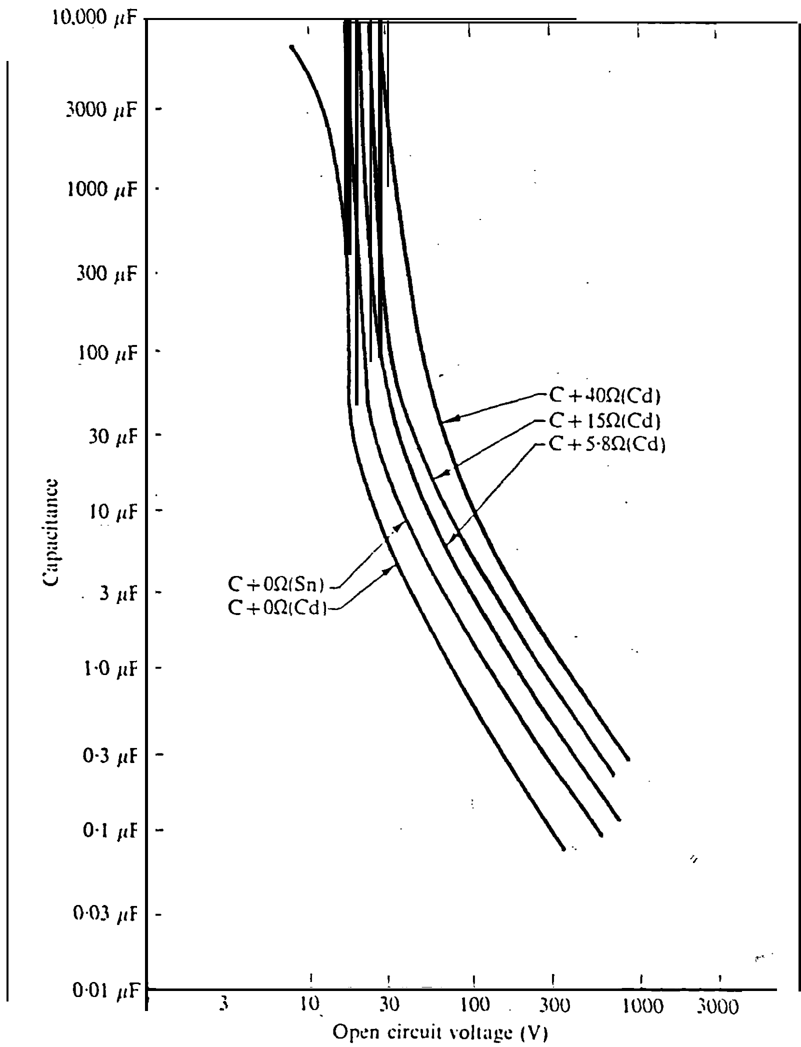

FIG. 1. Ignition characteristics, capacitive circuits, 8.3% methane-in-air.

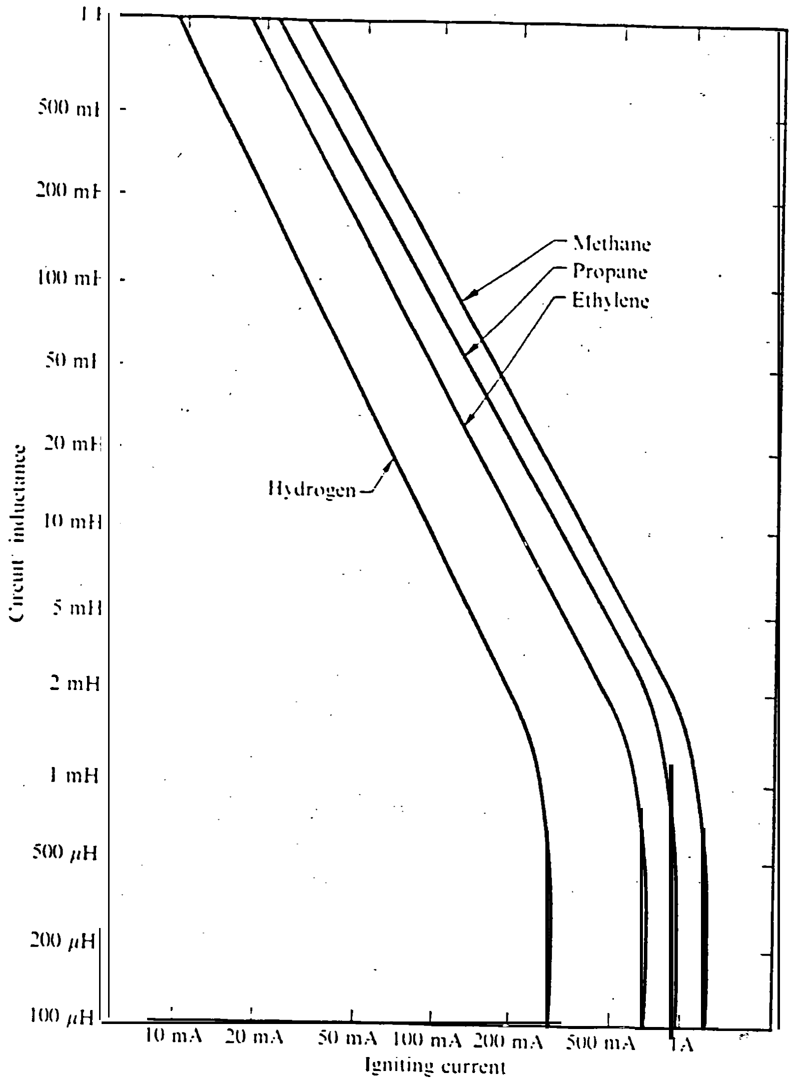

FIG. 2. Ignition characteristics, 24-V inductive circuits.

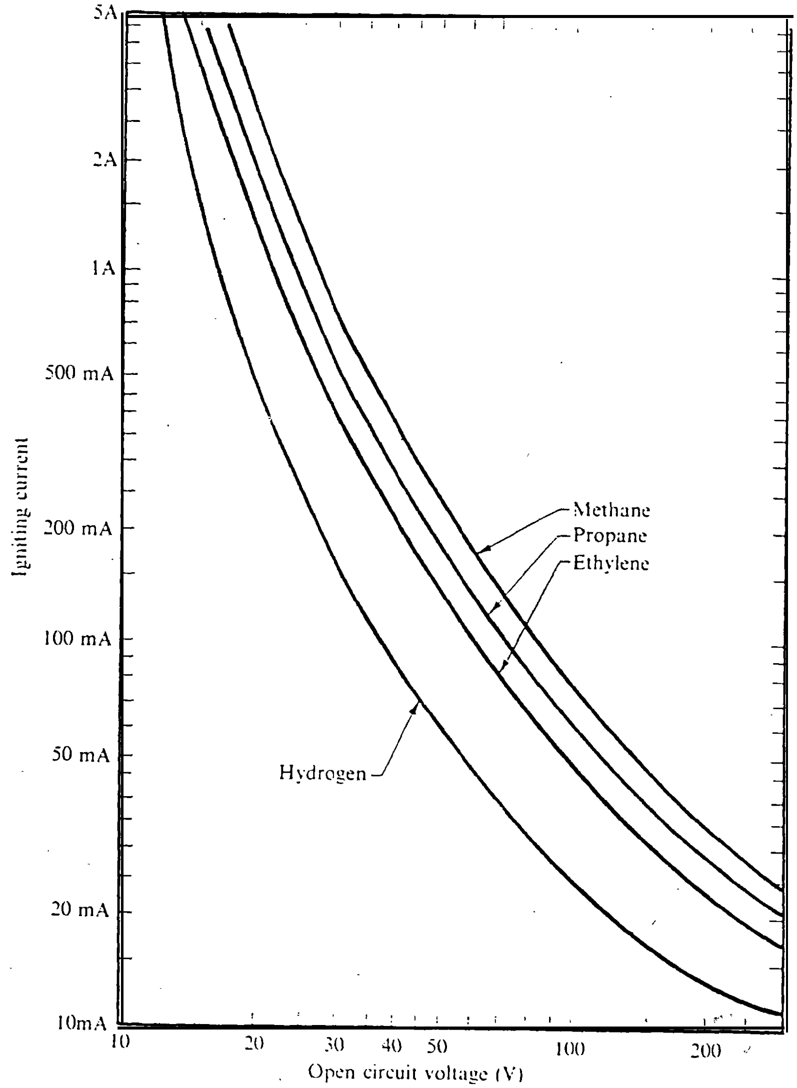

FIG. 3. Ignition characteristics, resistive circuits.

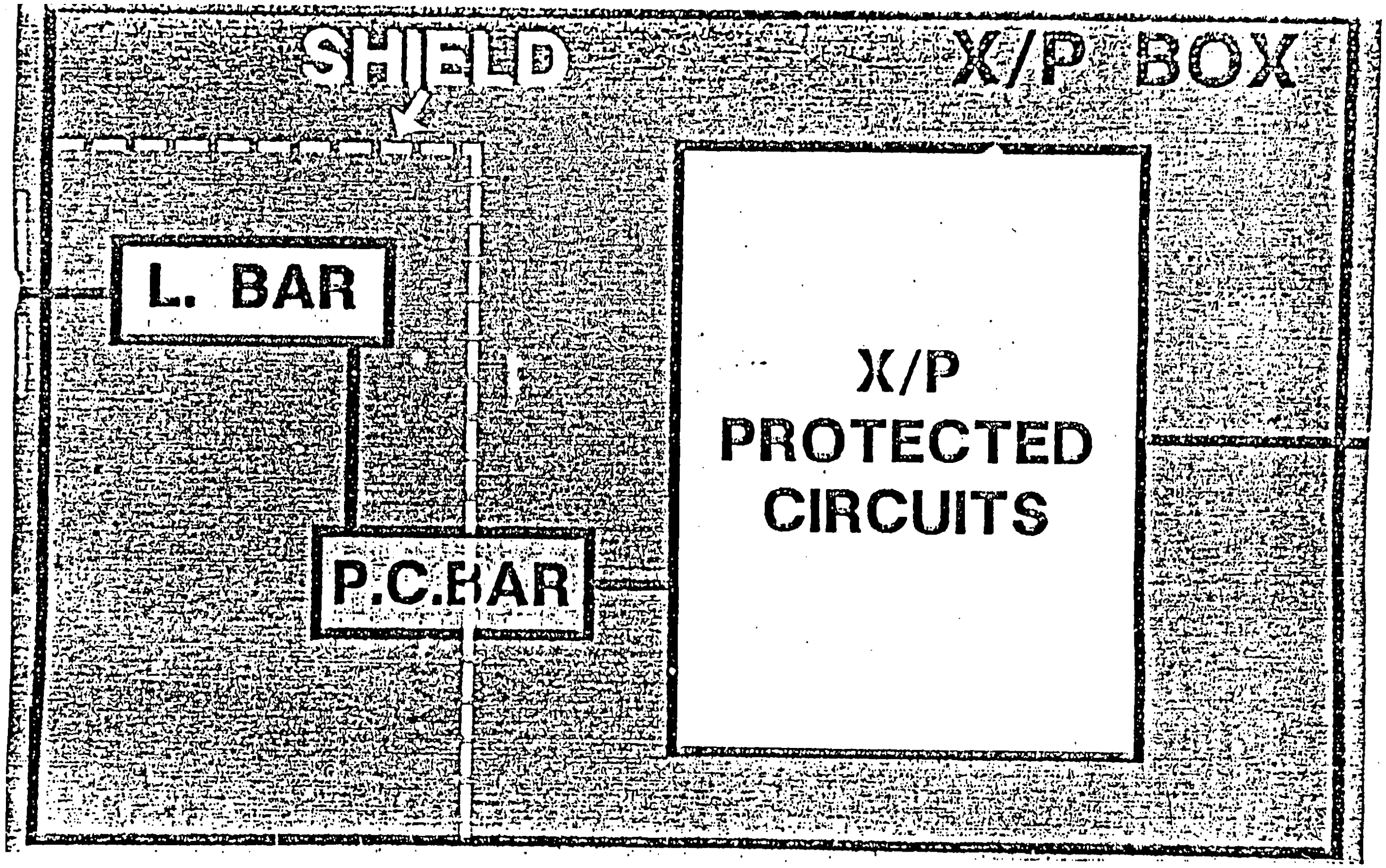

FIG. 4. Interconnection example no. 1.

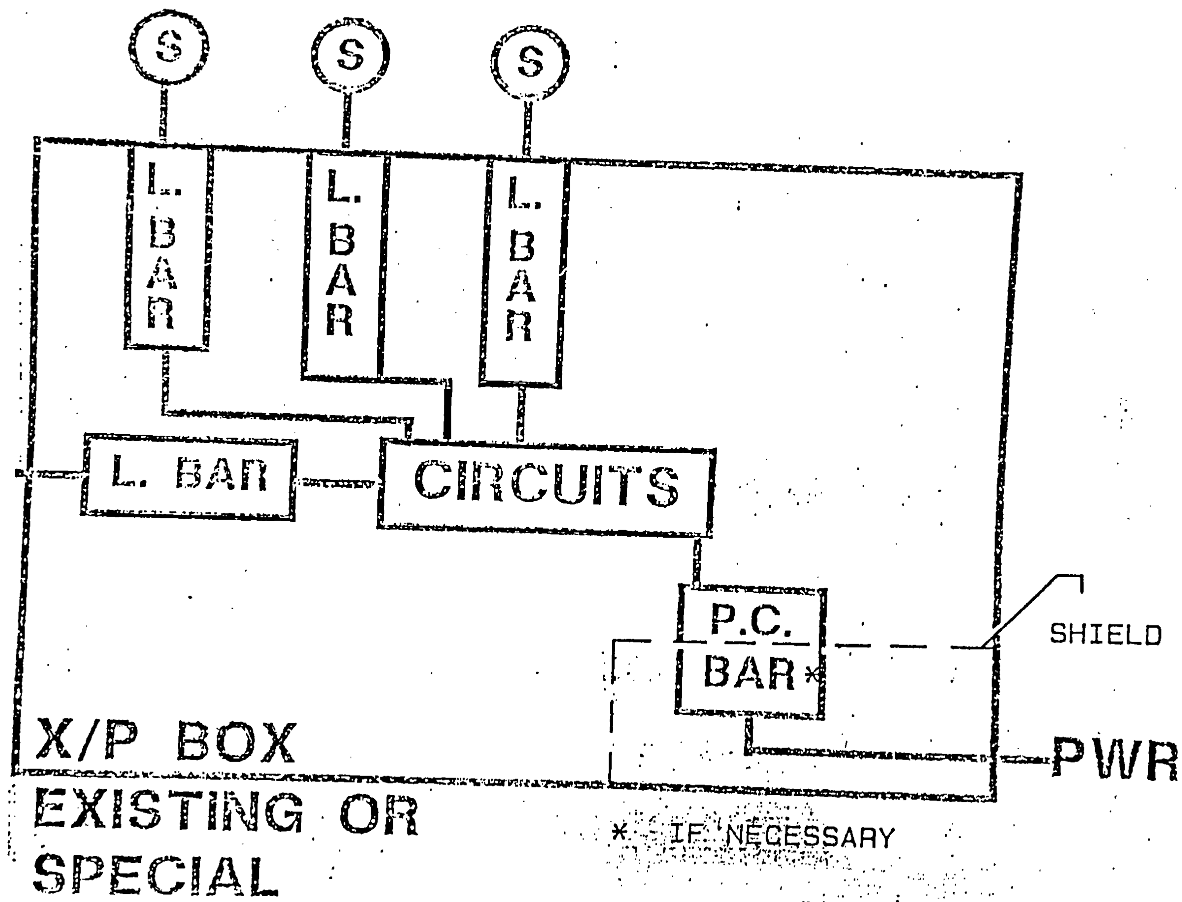

FIG. 5. Interconnection example no. 2.