

Installation and Maintenance of Intrinsically Safe
Field Wiring in Gassy Mines

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Abstract - Advances in mining technology, utilizing increased automation with state-of-the-art electronics, have resulted in increased use of intrinsically safe circuits on electric face equipment. The importance of proper installation and maintenance of intrinsically safe field wiring in gassy mines utilizing multiple intrinsically safe systems is not adequately recognized. Current published standards and codes of practice do not provide adequate guidance on the installation and maintenance of intrinsically safe field cables and wires.

This paper discusses the potential hazards associated with the improper installation and maintenance of multiple intrinsically safe cables. United States and other countries' standards, codes of practice, and current field practice pertaining to installation and maintenance of intrinsically safe field wiring are reviewed. The paper concludes with a detailed recommended practice with explanatory commentary for the safe installation and maintenance of intrinsically safe field wiring.

I. INTRODUCTION

As a result of advances in mining technology utilizing increased automation and state-of-the-art electronics, intrinsically safe circuits are being used to greater extent on electric face equipment in underground mining. It is not uncommon to have separate intrinsically safe cables routed on longwall face equipment for control, methane monitoring, communication, illumination, and machine diagnostics. Because of the increased applications for intrinsically safe circuits, an area of concern has arisen relative to proper installation and maintenance of intrinsically safe field cables and wires.

Intrinsic safety is a type of protection for electrical apparatus designed to operate in an environment in which explosive concentrations of combustible materials, such as methane gas and coal dust, are potentially present. Intrinsically safe circuits limit, by design, the available electrical and thermal energy to levels that are below the minimum necessary to ignite the flammable atmosphere under certain prescribed fault conditions and applied test safety factors.

Because the electrical energy in an intrinsically safe circuit is incapable of igniting an explosive concentration of methane and coal dust, there has been a tendency to disregard the possibility of any hazard arising from the improper installation and maintenance of intrinsically safe

field cables and wires. This is an erroneous and potentially dangerous practice.

Intrinsic safety is dependent on both equipment design, and installation and maintenance. Apparatus designed to meet standards for intrinsic safety incorporates several factors of safety which will ensure the safety of the circuit under normal operating conditions as well as reasonably established abnormal conditions. Safety is determined through testing and analysis which include the application of test safety factors, worst case fault analysis, and the consideration as a normal condition that field wiring conductors may be open-circuited, be connected together or to ground, or both. This field wiring fault consideration is only applied to the apparatus or system under evaluation. Field wiring faults between separate apparatus or systems are not evaluated unless they are electrically interconnected.

Improper installation and maintenance of intrinsically safe field wiring can compromise the safety of equipment complying with the design standards for intrinsic safety. An intrinsically safe circuit may be compromised by improper cable routing, mechanical damage or accidental contact with a non-intrinsically safe conductor; such as, a power conductor or a machine frame having an induced voltage due to eddy currents, leakage, or ground loops.

An area of increased concern is the contact between separate intrinsically safe circuits from different apparatus or systems due to the exposure of bare conductors as the result of mechanical damage to cable insulative jackets. The additive energy from the contact of two separate intrinsically safe circuits, each of which is individually intrinsically safe, may not be intrinsically safe. The contact might occur through ground or direct short circuit contact between cables.

Consideration of contact between separate intrinsically safe circuits is most important when the intrinsically safe cables are installed on mobile equipment or equipment with articulating appendages. Of particular concern are hydraulic roof supports, cutting booms, and other equipment which cause flexing of cables, relative motion between cables, or introduce the possibility of cable pinching or abrasion.

In recognition of the lack of complete published guidelines for the safe installation and maintenance of intrinsically safe field wiring in underground mines, current standards and codes of practice, current mining equipment manufacturer practice, and current field practice relative to

this topic were examined. This information was used to develop a detailed recommended practice, along with an explanatory commentary for the safe installation and maintenance of intrinsically safe field wiring.

II. LITERATURE SEARCH

A literature search was conducted for United States and other countries' approval standards and codes of practice involving intrinsically safe systems looking specifically for guidance in the installation and maintenance of intrinsically safe cables and wires.

A. United States' Standards and Codes of Practice

The National Electrical Code ANSI/NFPA 70-1987, National Fire Protection Association, is a widely used standard for safe electrical installation, but it does not provide adequate guidance for the installation of intrinsically safe systems. The only statement applicable to installation states, "Wiring of intrinsically safe circuits shall be physically separated from wiring of all other circuits that are not intrinsically safe. Weans shall be provided to prevent the passage of gases and vapors."

National Fire Protection Association NFPA 493-1978, Underwriter Laboratories UL 913-1979, and Factory Mutual Research Class Number 3610-1979 are basically similar approval standards for intrinsically safe apparatus and associated apparatus for use in Class I, II, and III Division 1, Hazardous Locations. They give constructional requirements for intrinsically safe apparatus and systems, but no guidance for the installation and maintenance of such systems.

Instrument Society of America, ANSI/ISA-RP 12.6 - 1987, Recommended Practice. Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations, provides useful guidance for installation practices for intrinsically safe cables and wires for instrumentation applications in the process control industry, but is not specifically intended to address the mining industry application. This practice addresses and provides significant input for defining segregation requirements for intrinsically safe and non-intrinsically safe wiring, identification requirements, and multiple intrinsically safe cable routing considerations. However, it does not address maintenance considerations.

Although the RP-12.6 practice provided input for consideration in developing the MSHA recommended practice, the differences between the fixed, protected, and well segregated wiring environment in the process control industry have to be considered in contrast to the mobile, comparatively unprotected, hostile mining environment where segregation of wiring is difficult because of the relative movement of various machine components and their interconnecting cables.

Title 30, Mineral Resources, Code of Federal Regulations (30 CFR) contains Parts that set forth the requirements for MSHA approval, certification and acceptance of various types of equipment intended for use in the United States' mining

industry. The various applicable Parts basically specify construction, design, and performance requirements for various types of equipment, some of them intrinsically safe.

Part 18, 30 CFR, contains the requirements for electric motor-driven equipment and accessories. Section 18.36, 30 CFR, addresses cables between machine components and sets forth requirements for the flame-resistant properties and mechanical protection of intrinsically safe cables. Section 18.68, 30 CFR, Tests for Intrinsic Safety, addresses the consideration of intermingling of intrinsically safe and non-intrinsically safe circuits, but it does not define what constitutes intermingling. This section also addresses the consideration of induced voltages in intrinsically safe circuits through insufficient isolation from non-intrinsically safe circuits.

MSHA Policy Memorandum No. 85-38-TSF, Subject: "Title 30, Code of Federal Regulations (30 CFR), Part 18, Paragraph 18.68(c)(3) - Concerning Separation of Intrinsically-Safe Conductors from Nonintrinsically-Safe Conductors," defines what constitutes intermingling of intrinsically safe and non-intrinsically safe wiring and provides the basis for the development of the MSHA recommended practice in this area.

B. Other Countries' Standards and Codes of Practice

The search was limited to those published by the International Electrotechnical Commission (IEC), European Committee for Electrotechnical Standardization (CENELEC), and British Standards Institution (BSI). The standards published by these organizations probably comprise the most complete collection available involving electrical apparatus used in explosive atmospheres.

IEC 79-11 (1976) Part 11: Construction and Test of Intrinsically Safe and Associated Apparatus (currently being revised), CENELEC EN50014 and equivalent BSI BS5501 Part 1, Electrical Apparatus for Potentially Explosive Atmospheres and CENELEC EN50020 and equivalent BSI BS5501 Part 7, Intrinsic Safety 'i', are current standards for the construction and design of intrinsically safe apparatus, but provide little information for the installation and maintenance of such apparatus.

CENELEC EN50039 and equivalent standard BSI BS5501 Part 9, Electrical Apparatus for Potentially Explosive Atmospheres, contain useful guidance on the interconnecting wiring of an intrinsically safe electrical system. These standards address fault analysis considerations, insulation, and shielding requirements for multiconductor cables containing more than one intrinsically safe circuit. Information from these standards was used in the formulation of the MSHA recommended practice.

BSI BS5345, Code of Practice for the Selection, Installation, and Maintenance of Electrical Apparatus for Use in Potentially Explosive Atmospheres (Other Than Mining Applications or Explosive Processing and Manufacture) is a comprehensive code of practice for installation and maintenance of intrinsically safe apparatus for the process control industry; but it is not intended to address the mining industry. Part 1 addresses basic requirements for all parts of the code and Part 4 addresses

installation and maintenance requirements for electrical apparatus with Type of Protection 'i', Intrinsically Safe Electrical Apparatus and Systems.

BS 5345 addresses the following areas of interest regarding interconnecting cables: minimum conductor sizes, insulation, mechanical protection, shielding, armoring, intermingling, induction, multiconductor cables and maintenance. This standard provided useful information for the development of the MSHA recommended practice.

BSI BS6704, Code of Practice for Selection, Installation and Maintenance of Intrinsically Safe Electrical Equipment in Coal Mines, offers guidance on the selection, installation and maintenance of intrinsically safe electrical equipment and is the only code of practice found that specifically applies to the mining industry. As such, it was studied carefully and provided useful input for the formulation of the MSHA recommended practice. BS6704 addresses the following areas of interest regarding interconnecting cables: minimum cable sizes, insulation, mechanical protection, shielding, armoring, intermingling, induction, multiconductor cables and maintenance.

C. Current OEM and Field Practice

Visits were made to mine sites to obtain information on original equipment manufacturer (OEM) and mine operator practices related to the installation, repair and maintenance of intrinsically safe field cables and wires in coal mines. The following is a summary of current field practice in each of the areas of concern addressed in the MSHA recommended practice.

It is customary in current field practice for the sizing of conductors, insulation thickness and voltage breakdowns, to meet the recommended practice. Consideration of the rugged mine environment places a limit on the minimum size of conductors used which helps prevent the use of undersized conductors. Since conventional wiring designed for non-intrinsically safe circuits is usually used for intrinsically safe circuits, it generally meets the size and insulation recommendations with no special consideration given to its selection.

It is typical for intrinsically safe multiconductor cables to utilize an insulative outer jacket with at least a 0.25 mm thickness, thereby meeting recommended practice. An exception noted is the use of twisted pair insulated conductors without an outer jacket for mine pager phone line interconnections not part of a machine design.

It is common in current field practice to find cables without MSHA flame-resistant acceptance used for intrinsically safe cables in applications not involving wiring between machine components. Flame-resistant properties are not required in these applications. For cables between machine components, it is customary to use cables with MSHA accepted flame-resistant properties or to enclose the cables in MSHA accepted flame-resistant hose conduit as required in 30 CFR Part 18. Some intrinsically safe cables between electro-hydraulic shield control boxes on longwall support control systems bearing a foreign country flame resistance

certification have been accepted as equivalently safe in lieu of MSHA testing.

Current MSHA policy is to require the Part 18 MSHA tested flame resistance properties for the intrinsically safe cabling between the longwall shield control boxes, or the use of flame-resistant hose conduit. Alternatively for intrinsically safe cables containing conductor sizes smaller than AWG No. 14, cables passing the MSHA flame test for fiber optic cables are acceptable.

A means for easy identification of intrinsically safe field wiring is not typically addressed in current field practice. However, bright blue insulation for intrinsically safe cables is used on some systems designed in other countries where such identification is required. When questioned, mine personnel usually were uncertain, when a large number of cables were present, as to which cables were intrinsically safe and which were non-intrinsically safe. In many cases, the cables had to be traced back to their source to identify them. Current field practice does not generally meet the recommended practice.

It is common practice in the field to not run intrinsically safe circuits from different intrinsically safe systems or multiple intrinsically safe circuits from a common apparatus or system in the same multiconductor cable which is in accordance with the recommended practice. In a few instances, where allowed by the MSHA acceptance drawings, multiple intrinsically safe circuits from a common apparatus or system were run in the same multiconductor cable. In these cases, the intrinsic safety evaluation had determined that combinations of cable faults between the circuits created no problem or else required each conductor to be enclosed in a grounded shield.

Review of current field practice did not find intrinsically safe cables and wires positioned too close to intense magnetic fields, power conductors, or heavy current carrying single conductors that would allow induction of unsafe energy levels into the intrinsically safe circuits. This is in accordance with the recommended practice. Although positioning is a necessary consideration when routing cables and wires, induction into interconnecting cables at a level which could lead to a significant reduction in safety is unlikely in most practical situations. It is probable that the intrinsically safe circuits would malfunction at induction levels below those presenting a hazard. The malfunction would reveal the problem and result in rerouting of the cables or other corrective action.

Current field practices in the areas of mechanical protection and prevention of undue movement of intrinsically safe cables and wires need to be improved to bring them into accordance with the recommended practice. Although adequate protection and securing of cables is provided in many installations, there are others where powered intrinsically safe cables were found to be unconnected and dangling. Occasionally, damaged intrinsically safe cables were found with bare copper conductors accessible for contact with other circuits. One installation, where exposed conductors were present on different intrinsically safe cables from separate intrinsically safe circuits, was thought to be the possible cause of a

methane ignition due to the possible contact of two cables.

The means of mechanical protection typically employed are by position, hose conduit, and wiring trays. Armoring is only rarely used for protection.

The field survey did not attempt to establish by direct comparison with drawings the degree to which the recommended practice is being followed in regard to the selection and installation of intrinsically safe cables and wires in accordance with the MSHA acceptance drawings and conditions. The survey did establish that there is not a complete understanding by personnel in the field that cable length, capacitance per foot and inductance per foot may be determining factors in the intrinsic safety of an electrical system. These factors are not usually considered in maintenance; it is not generally understood that the substitution of a cable having apparently similar physical characteristics could have different distributed electrical parameters which could create a spark ignition hazard. When OEM cable-connector assemblies are used for replacement, the potential problem with cable parameters is minimized.

The only time the cable parameters are likely to be checked against the approval drawings is during the MSHA approval inspection of the machine. Even then, it is unlikely that all parameters are checked because of the lack of information on the parameters on the particular cable used. The intrinsic safety drawings call out the required electrical parameters, when necessary, but not the manufacturer and type number for the cable. To ensure conformance to the recommended practice, more consideration needs to be given to these cable parameters than is currently given.

It is usual in current field practice for intrinsically safe cables to be routed together in the same bundle or wiring tray. Hose conduit is typically used to prevent mechanical damage and armoring is occasionally used as in the recommended practice. However, some instances were found where mechanical damage was likely, cable insulation integrity was not maintained, and no additional means of mechanical protection was provided.

Review of current field practice found that the recommended practice and MSHA Policy Memorandum No.85-38-TSF are not being followed fully in regard to intermingling of intrinsically safe and non-intrinsically safe cables and wires. Intrinsically safe circuits are not being included in the same cable or conduit with non-intrinsically safe circuits. However, in some instances, intrinsically safe cables are being bundled together with non-intrinsically safe cables without the use of hose conduit or a 50 mm spacing being maintained. Routing of intrinsically safe cables and non-intrinsically safe cables in the same wiring tray without a non-combustible physical barrier between them was also observed. Many times, the installation of cables allowed sufficient slack to permit intrinsically safe cables to contact non-intrinsically safe cables. This essential and fundamental means for maintaining an intrinsically safe system; i.e., separation of intrinsically safe cables from non-intrinsically safe cables, is an

area where significant effort needs to be applied to bring field practice in accordance with the recommended practice.

A survey of current field practice in regard to maintenance and repair of intrinsically safe field cables and wires showed a general lack of appreciation of the importance of the following points addressed by the recommended practice: (1) The importance of the timely repair or replacement of wires and cables with damaged insulation was not fully appreciated by field personnel. The prevailing attitude is that since the circuits are all intrinsically safe it does not matter if exposed conductors from different cables touch one another. (2) The same attitude is prevalent with regard to energized cables left unconnected and the need to ensure protection from mechanical damage. (3) Maintenance personnel also lack an appreciation for the shock hazard that some intrinsically safe circuits can present. Although most intrinsically safe circuits are low voltage and present no shock hazard, maintenance personnel should not become complacent to the shock hazard that some circuits can present. (4) The potential spark ignition hazard of connecting a test instrument across different intrinsically safe circuits simultaneously is not fully appreciated by field maintenance personnel.

It is customary in current field practice to only take MSHA approved test instruments into hazardous areas.

In order to ensure the safety of intrinsically safe systems used in the mining environment, there has to be an increased awareness that replacement cables and interconnections of intrinsically safe apparatus and systems must be in accordance with applicable MSHA acceptance drawings and conditions.

III. RECOMMENDED PRACTICE

INSTALLATION AND MAINTENANCE OF INTRINSICALLY SAFE FIELD WIRING IN GASSY MINES

A. Installation of Intrinsically Safe Field Cables and Wires

1.1 Copper conductors shall be used and sized such that their maximum surface temperature shall not exceed 150°C when carrying the maximum current that could flow in the circuit under fault conditions. Table I lists the maximum current versus conductor size to ensure meeting this requirement.

Table I
Maximum Current/Cross Sectional
Area Relationship

| Max. Current (amps) | Cross Sectional Area (mm ²) | Equivalent AWG No. |
|---------------------|---|--------------------|
| 1.0 | 0.017 | 34 |
| 1.65 | 0.03 | 32 |
| 3.3 | 0.09 | 27 |
| 5.0 | 0.19 | 24 |
| 6.6 | 0.28 | 22 |
| 8.3 | 0.44 | 20 |

The cross sectional area for stranded conductors is the total cross sectional area of all the strands of the conductor.

1.2 Conductors shall be covered with an insulation thickness of 0.25 mm, minimum.

1.2.1 The insulation shall be capable of withstanding an rms AC test voltage of twice the nominal voltage of the intrinsically safe circuit with a minimum of 500 V.

1.3 Multiconductor cables shall contain all conductors within an insulative outer jacket having a minimum thickness of 0.25 mm.

1.4 Cables between machine components shall have flame-resistant properties and NRA acceptance markings indicating they meet the flame resistance test requirements of Title 30, Code of Federal Regulations, Section 18.64 (30 CFR 18.64), or be enclosed within flame-resistant hose conduit having a minimum wall thickness of 3/16 inch and MSHA acceptance markings indicating it meets the flame test requirements of 30 CFR 18.65.

1.4.1 Cables and wires containing intrinsically safe circuits where conductor size is smaller than AWG No. 14 shall be accepted as meeting MSHA flame-resistant requirements if they pass the MSHA flame test for fiber optic cables, MSHA Program Policy Letter No. 88-II-1.

1.5 Cables and wires containing intrinsically safe circuits shall be so identified. The use of a bright blue color on the outer jacket is the preferred method for identification. Alternative methods of identification are the use of a bright blue band around the cable or wire, 0.5 inch minimum width, at intervals not exceeding 3 feet, or the marking "IS" impressed or durably printed on the cable jacket at intervals not exceeding 3 feet. The means of identification shall be visible after installation.

1.6 Intrinsically safe circuits from different intrinsically safe systems shall not be run in the same multiconductor cable. Multiple intrinsically safe circuits from a single intrinsically safe system or apparatus shall not be run in the same multiconductor cable unless allowed in the MSHA acceptance drawings for that system or apparatus. When allowed, each intrinsically safe circuit will be required to be shielded with the shields connected to ground at one end unless combinations of cable faults have been found to not create a safety hazard.

1.7 Cables and wires containing intrinsically safe circuits shall not be positioned close to intense magnetic fields, power distribution lines, heavy current carrying single conductor cables or wires, or high voltage uninsulated conductors to avoid electro-magnetic induction effects that might allow the energy level of intrinsically safe circuits to become capable of producing an ignition. When physical separation is not possible, attention should be given to twisting or shielding of the intrinsically safe conductors.

1.8 Intrinsically safe cables and wires between machine components shall be clamped in place to prevent undue movement, protected from mechanical damage, isolated from hydraulic lines and protected from abrasion by removing all sharp edges which they might contact.

1.8.1 Protection from mechanical damage may be by Position, flame-resistant hose conduit,

armoring, metal tubing, or troughs and trays. The armoring of armored cables shall be grounded at both ends of the cables.

1.8.2 Intrinsically safe machine remote control cables are not required to be protected by conduit.

1.9 Since the intrinsic safety of apparatus and systems may be dependent on cable length; distributed capacitance, inductance and resistance; or inductance to resistance ratio (L/R), cables and wires containing intrinsically safe circuits must be selected and installed in accordance with the MSHA acceptance drawings and conditions in regard to these parameters.

1.10 Intrinsically safe cables and wires interconnecting intrinsically safe apparatus, associated apparatus, or systems may be intermingled and routed together in the same bundle, conduit, or wiring tray when the likelihood of mechanical damage is low and the insulation integrity of all cables and wiring is assured through regular maintenance.

1.10.1 Where the likelihood of mechanical damage cannot be ignored, some form of additional mechanical protection shall be provided for each cable or wire, such as the use of flame-resistant hose conduit or armoring.

1.11 Cables and wires containing intrinsically safe circuits shall not be intermingled with cables and wires containing non-intrinsically safe circuits.

1.11.1 Intrinsically safe circuits and non-intrinsically safe circuits should not be included within the same cable.

1.11.2 Intrinsically safe wires and cables shall not be included in the same bundle as non-intrinsically safe wires and cables.

1.11.3 Intrinsically safe wires and cables shall not be included within the same conduit with non-intrinsically safe wires and cables.

1.11.4 Intrinsically safe wires and cables shall be positively separated from non-intrinsically safe wires and cables by at least 50 mm spacing with the wiring separately tied down. Where machine design precludes maintaining a 50 mm spacing, intrinsically safe wires and cables may be routed together with non-intrinsically safe wires and cables if each are enclosed in MSHA accepted flame-resistant hose conduit having a minimum wall thickness of 3/16 inch.

1.11.5 The installation of wires and cables shall preclude excessive slack that might permit intrinsically safe wires and cables to contact non-intrinsically safe wires and cables.

1.11.6 -Intrinsically safe wires and cables shall not be included within the same wiring tray with non-intrinsically safe wires and cables unless separated by a non-combustible physical barrier.

8. Maintenance of Intrinsically Safe Field Cables and Wires

2.1 All intrinsically safe cables and wires shall be periodically examined by qualified personnel to ensure that no damage, change, or deterioration has occurred that may degrade intrinsic safety. Replacement or repair is to be accomplished in a timely fashion.

2.1.1 Each cable and wire shall be examined

to ensure its outer insulation or insulating jacket is intact with no exposed conductors, burns, cracks, or splits.

2.1.2 An examination shall be made that each cable is adequately supported and unstressed.

2.1.3 An examination shall be made that segregation is maintained between all intrinsically safe and non-intrinsically safe cables and wires and that all cables and wires are installed according to the recommended installation practice.

2.1.4 An examination shall be made that all replacement cables and wires are in accordance with the recommended installation practice and the applicable requirements of the MSHA acceptance drawings and conditions included in the equipment manufacturer's installation instructions.

2.1.5 An examination shall be made that the interconnection of all intrinsically safe apparatus and systems is in accordance with the applicable requirements of the MSHA acceptance drawings and conditions included in the equipment manufacturer's installation instructions, and that no connectors or connections have been interchanged.

2.1.6 When necessary for maintenance, cables shall be disconnected from intrinsically safe equipment in such a way that live terminals or conductors are not left exposed. Cables shall not be left unconnected and repairs shall be made in a timely fashion.

2.2 Since some intrinsically safe circuits operate at voltage and current levels sufficient to constitute a shock hazard, the same safe precautions against shock hazard shall be observed when installing or servicing intrinsically safe circuits as are observed with non-intrinsically safe circuits.

2.3 When troubleshooting tests are conducted on intrinsically safe cables, wires and connectors, installed in hazardous locations, only MSHA approved test instruments shall be used. The instruments shall be used in accordance with all MSHA approval conditions.

2.3.1 Before a test instrument is taken into a hazardous area, it shall be checked to ensure that it is working properly and is not physically damaged.

2.3.2 When troubleshooting multiconductor cables containing energized multiple intrinsically safe circuits or separate cables carrying energized intrinsically safe circuits, the test instrument shall not be connected simultaneously to separate energized intrinsically safe circuits. Connection shall be restricted to one circuit at a time.

C. Commentary on the Recommended Practice

The Agreement Matrix Table II, illustrates how the recommended practice agrees with other standards, practices, and regulations that were found to provide relevant information during the literature search. The following comments are numbered to correspond with the applicable section of the recommended practice and provide a summary rationale for that section.

1.1 - It is important to ensure an adequate conductor size to prevent the conductors from becoming coal dust thermal ignition sources under maximum fault current conditions. The hot surface ignition temperature for coal dust is 150°C.

1.2 - An insulation thickness of 0.25 mm, minimum, is chosen because it ensures a 1 mm clearance distance between conductors of cables from separate intrinsically safe apparatus or systems because each cable is to also utilize a 0.25 mm, minimum, insulative outer jacket. The 1 mm clearance is consistent with the minimum clearance distance requirements for internal circuitry of electrical apparatus for the spacing to be considered not subject to fault for intrinsically safe circuits less than 60 volts.

Other standards require either a 0.2 mm, 0.25 mm, or a 0.3 mm, minimum, thickness.

1.2.1 - The voltage withstand requirement is important to ensure breakdown of the insulation does not occur and compromise intrinsic safety. The 500 V minimum is accepted in all standards and is typically met by conventional wiring.

1.3 - The insulative outer jacket is important for mechanical protection and to define the cable parameters. The 0.25 mm minimum thickness is chosen to ensure the 1 mm total clearance distance between conductors as explained in the preceding Section 1.2.

1.4 - Flame resistance is a regulatory requirement of 30 CFR. Although intrinsically safe cables are not likely to become thermal ignition sources, the requirement is in consideration of minimizing combustible material on face equipment that could become ignited by other thermal sources.

1.4.1 - The MSHA flame test for fiber optic and electrical signaling cables, Program Policy Letter No. 88-11-1, was developed for cables containing conductor sizes smaller than AWC No. 14 in consideration of the limited energy levels of cables containing intrinsically safe communication and signaling circuits.

1.5 - As a result of the increasing number of intrinsically safe cables in the mining environment, it is becoming increasingly difficult to identify these cables in order to ensure adequate mechanical protection and separation from non-intrinsically safe cables. The use of the bright blue color allows instant identification of intrinsically safe cables and allows more effective implementation of the recommended practice.

1.6 - Although the standards researched allow multiple intrinsically safe circuits to be run in the same multiconductor cable under certain conditions; i.e., with use of special insulation, shielding, armoring or mechanical protection, it is judged in the best interest of safety for the U.S. mining industry, that this practice not be left uncontrolled as a field wiring decision. However, this practice will be allowed when shielding is utilized and evaluated or approved by MSHA on multiple intrinsically safe circuits from a single system or apparatus. This practice is not allowed for intrinsically safe circuits from different intrinsically safe systems [1] since the combination of systems utilized in mines is not evaluated for intrinsic safety by MSHA if the systems are not interconnected.

1.7 - Although unlikely in most practical situations, significant induction could occur if cables are positioned parallel to and close to power distribution lines or heavy current carrying single conductor cables, or very intense magnetic fields. Accordingly, care should be taken in the

Table II - Agreement Matrix
MSHA Recommended Practice Versus Other Standards

* Indicates Basic Agreement
() Refer to Footnotes for Comments
{ } Indicate: Applicable Section of Standard
N/A Indicate: Not Addressed in Standard

| Recommended Practice | Not addressed elsewhere | MSHA Policy | 30 CFR | ANSI/ISA-RP12.6 - 198 | BSI BS5345:Part | SI S6704 | BSI BS5501:Part 9 | CEN/IEC EN50039 |
|--|-------------------------|---------------|---------------------|-----------------------|----------------------|--------------|-------------------|-----------------|
| 1.1 Minimum Conductor Size | | N/A | N/A | N/A | * (15.1.1) | * 0.3.1 | N/A | N/A |
| 1.2 Insulation Thickness | | N/A | N/A | * (1) (4.1.4) | * (2) (15.1.2) | * (3) 0.3.2 | * (3) (5.2.1) | * (3) (5.2.1) |
| 1.2.1 Insulation Withstand | | N/A | N/A | N/A | * (4) (15.1.2) | * 0.3.2 | * (5.2.1) | * (5.2.1) |
| 1.3 Multiconductor Cable Outer Jacket | | N/A | N/A | N/A | * (5) (15.1.3) | N/A | N/A | N/A |
| 1.4 Flame Resistance | | N/A | * (10.64) | N/A | N/A | N/A | N/A | N/A |
| 1.4.1 Flame Resistance Smaller than MFG No. 14 | | * (16) | N/A | N/A | N/A | N/A | N/A | N/A |
| 1.5 Cable Markings | | N/A | * (6) (10.64(c)) | * (4.1.7) | N/A | N/A | N/A | N/A |
| 1.6 Multiple Circuits in Common Cable | X | N/A | N/A | {4.1.6} | {15.1.7} | 0.3.3 | 5.3 | {5.3} |
| 1.7 Induction | | N/A | * (10.64(d)) | * (14.4.1) | * (15.1.6) | * 0.4.4 | N/A | N/A |
| 1.8, 1.8.1, 1.8.2 Damage Protection | | N/A | * (8) (10.34(b)(c)) | N/A | * (9) (25.4) | * (10) 0.4.3 | N/A | N/A |
| 1.9 Cable Parameters | | | * (10.64(a)) | * (4.3.4) | * (19.14) | * 0.3.2 | * 5.1.1 | * (5.1.1) |
| 1.10, 1.10.1 Intermin- gling I.S. Cables | X | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 1.11 Intermin- gling Non-I.S. Cables | | * (95-30-TSP) | * (10.64(c)(3)) | * (4.4.1) | N/A | N/A | N/A | N/A |
| 1.11.1 Intermin- gling Same Cable | | * (95-30-TSP) | J/J | * (4.4.1.1) | * (15.1.7) | * 0.4.1 | * 5.1.2 | * (5.1.2) |
| 1.11.2 Intermin- gling Same Bundle | | * (95-30-TSP) | N/A | * (4.4.1.1) | {(11) (15.1.5)} | * (12) 0.4.2 | N/A | N/A |
| 1.11.3 Intermin- gling Same Conduit | | * (95-30-TSP) | N/A | * (4.4.1.1) | {(11) (15.1.5)} | * (12) 0.4.2 | N/A | N/A |
| 1.11.4 Intermin- gling Spacing | | N/A | J/J | * (4.4.1.1) | N/A | N/A | N/A | N/A |
| 1.11.5 Intermin- gling Excessive Slack | | * (95-30-TSP) | J/J | N/A | N/A | N/A | N/A | N/A |
| 1.11.6 Intermin- gling Physical Barrier | | * (95-30-TSP) | N/A | * (4.4.1.1) | {(11) (15.5.1)} | * (12) 0.4.2 | N/A | N/A |
| 2.1, 2.2, 2.3 Cable Maintenance | | N/A | {(13) (95.543)} | N/A | * (15) (20,21,23,25) | * (14) § 3.4 | N/A | N/A |

- (1) 0.25 mm for multiple intrinsically safe circuits in the same multiconductor cable.
- (2) 0.5 mm minimum thickness required.
- (3) 0.2 mm for multiple intrinsically safe circuits in the same multiconductor cable.
- (4) Address a 500 V minimum only.
- (5) Does not address minimum thickness.
- (6) Does not discuss method of marking.
- (7) Does not detail the means of alternate marking.
- (8) Does not address armoring.
- (9) Addressed by Part 1 of BS 5345.
- (10) Does not address methods for mechanical protection.
- (11) Intermin- gling allowed if armoring is used or risk of mechanical damage is slight.
- (12) Intermin- gling allowed if armoring is used.
- (13) Part 7: states the general requirement for maintaining permissibility of face equipment, but does not address the particular points of the recommended practice.
- (14) Does not address the cable maintenance requirements of 2.1.1, 1.2, 1.3, 1.5, or 2.2.
- (15) Also addressed in Section 35 of Part 1 of BS 5345. Shock hazard not addressed.
- (16) MSHA flame test for fiber optic cables, Program Policy Letter No. 88-11-1.

routing of intrinsically safe cables. It is probable that an intrinsically safe circuit would malfunction at induction levels below those presenting a hazard.

1.8, 1.8.1, 1.8.2 - This is a regulatory requirement of 30 CFR. The use of armoring as a means of mechanical protection, not addressed in 30 CFR, is addressed in some of the other researched standards.

1.9 - All standards researched recognize the importance of the cumulative energy-storing effect of distributed cable inductance and capacitance on intrinsic safety and the need for the selection and installation of cables in accordance with the approval acceptance drawings and conditions in regard to these parameters.

1.10, 1.10.1 - Although the researched standards do not specifically address this point, intermingling of intrinsically safe cables and wires is implicitly allowed by all of the standards. Because of the harsh mine environment, the requirement for additional mechanical protection, where mechanical damage is likely, has been added to the recommended practice in recognition of the potential hazards of bare conductors of separate intrinsically safe circuits contacting one another

1.11, 1.11.1 through 1.11.6 - The general recommendation prohibiting intermingling of intrinsically safe and non-intrinsically safe wiring in 1.11 is a regulatory requirement in 30 CFR. MSHA Policy 85-38-TSP further defines intermingling and is listed in the recommended practice as Sections 1.11.1, 1.11.2, 1.11.3, 1.11.5, and 1.11.6. This policy does not define the spacing requirements of Section 1.11.4. The 50 mm spacing requirement, which is consistent with the ARSI/ISA RP 12.6 - 1987 practice was added to define a minimum spacing distance. The policy implies separation is adequate to prevent intermingling but does not specify a minimum spacing. Section 1.11.4 specifies the minimum spacing requirement when a physical barrier is not used for separation. Section 1.11.4 also addresses the use of hose conduit in lieu of the 50 mm spacing in machine applications where design and practicality prevent maintaining the 50 mm spacing.

The standards researched show general support for all sections of the recommended practice relating to intermingling except for Section 1.11.5 which is only found in MSHA Policy 85-38-TSP. This section, pertaining to excessive slack that might allow intrinsically safe wires and cables to contact non-intrinsically safe wires and cables, was judged to be necessary in the mining environment because of the mobile nature of mining machinery and the use of movable components and appendages that may require the use of extra slack in cable installation. That slack, though necessary in certain instances, must not be excessive to the point of allowing intrinsically safe and non-intrinsically safe cables to touch and possibly compromise intrinsic safety.

2.1, 2.1.1 through 2.1.6 - These sections, addressing periodic inspection and maintenance of intrinsically safe wires and cables, are recommendations to ensure that Part 75.503, 30 CFR, is followed. Part 75.503 requires the operator of a coal mine to maintain all electric face equipment in permissible condition. Part 75.512-2 requires

that examination be made at least weekly and that permissible equipment be examined to see that it is in permissible condition. Part 75.512 requires all electrical equipment to be properly maintained to assure safe operating conditions.

Although the considerations of Section 2.1.6 are not specifically addressed by Part 75, 30 CFR, this section is included because of the spark ignition hazard that can occur if different intrinsically safe circuits contact one another due to cables left disconnected with exposed conductors or terminals when repairs are awaited or in progress.

2.2 - Although most intrinsically safe circuits are low voltage, less than 30 V, and these levels are not considered a shock hazard, some intrinsically safe circuits operate at higher voltage levels and at current levels that could pose a human shock hazard.

2.3, 2.3.1 - These sections are based on the requirement of Part 75.500, 30 CFR, that all equipment used at face areas of gassy mines be permissible, and Part 75.503 requiring such equipment to be maintained in permissible condition.

2.3.2 - This section is a caution against the accidental or deliberate simultaneous connection of a test instrument to separate live intrinsically safe circuits because of the possible spark ignition hazard that could result from the additive energies of the two circuits.

IV. CONCLUSIONS

Although the installation and maintenance of intrinsically safe field wiring has not proven to be a safety concern as reflected in injury and equipment loss statistics, there is concern for present and future safety as the applications of intrinsically safe circuits continue to grow. Review of current field practice in the installation and maintenance of intrinsically safe field wiring indicates a need for improvement. Review of current standards and practice finds no single publication providing complete guidelines for the underground mining industry.

The recommended practice is seen as the first step in providing to the mining industry a collection of guidelines for the safe installation and maintenance of intrinsically safe field wiring. The concerns addressed in the practice are those currently recognized by United States and other countries: regulatory agencies, standards, and codes of practice.

Since the recommended practice consists of recommendations, it does not carry the enforcement impact of policy, rules and regulations. The recommended practice is not intended to negate any policy, rule or regulation in effect. Possible outcomes of the recommended practice include an increased awareness of the relevant concerns, voluntary adoption of the practice, discussion, and the ultimate development of a regulatory standard.

[1] An intrinsically safe system consists of two or more items of electrical apparatus and interconnecting wiring in which those parts of the system which may be used in hazardous locations are intrinsically safe circuits.

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