Intrinsically Safe Systems: Equivalency of International Standards Compared to U.S. Mining Approval Criteria

William Calder, David P. Snyder, and John F. Burr

Abstract—**This paper provides a suitability determination of international standards for evaluating electrical and electronic systems and line powered apparatus as an alternative to the Mine Safety and Health Administration (MSHA) criteria for two-fault intrinsic safety approval. The primary issue is to demonstrate that international equipment evaluation standards will provide at least the same level of protection for miners as the MSHA requirements. The secondary issue is to identify additional benefits that may be derived from the use of the "entity concept" in the approval process, such as potential cost savings, and an easier and quicker path for the introduction of new technology.**

Index Terms—**Coal mining, explosion protection, flammability, hazardous areas, health and safety, intrinsic safety (IS), standards, permissible.**

Nomenclature

Apparatus	Collection of components, such as electrical circuits in an enclosure, used synonymously with equipment and device.
Component	Part of an apparatus, such as a resistor, relay, etc.
System	Assembly of interconnected electrical apparatus, devices, or equipment.

I. Introduction

"EXPLOSION PROTECTION" for electrical and electronic equipment refers to techniques and controls used to minimize the ignition potential of equipment that may operate in an explosive environment. U.S. regulations limit the use of electrical and electronic equipment in potentially gassy or dusty mine atmospheres to equipment that Mine Safety and Health Administration (MSHA) approves as "permissible." U.S. mining explosion protection regulations generally recognize two approaches for eliminating the ignition potential and establishing equipment permissibility. The first is an explosion containment approach such as an explosion-proof enclosure. The second is an energy-limiting approach that limits the system energy to less than 0.3 mj under normal operating conditions and up to two simultaneous faults. The probability of the presence of methane or coal dust often determines international mining explosion protection requirements with explosion protection methods corresponding to different probability levels. [1]

U.S. mining laws [2] prohibit MSHA from accepting alternative explosion protection methods and standards unless they determine that these alternative approaches provide an equivalent level of protection for miners. A recently completed National Institutes of Occupational Safety and Health (NIOSH) funded study, "An Evaluation of the Relative Safety of U.S. Mining Explosion-Protected Equipment Approval Requirements versus Those of International Standards" [3], determined that two-fault intrinsic safety (IS) international standards provide equivalent protection for miners as the MSHA criteria relative to self-contained battery operated electrical and electronic equipment. That study focused on self-contained battery operated equipment for simplicity. This paper extends the two-fault IS equipment alternative evaluations by considering line powered, nonself-contained systems.

MSHA published the "Criteria for the Evaluation and Test of Intrinsically Safe Apparatus and Associated Apparatus" [4], also known as ACRI 2001. This document contains the criteria that MSHA uses to evaluate electrical apparatus or parts of an apparatus for IS as required in Title 30 of the Code of Federal Regulations. The ACRI 2001 criteria use many older U.S. design and testing standards, whereas other industries in the U.S. and internationally (including coal mining operations outside the U.S.) accept newer consensus-based international standards for equipment evaluation and certification. The U.S. version of these international standards is ANSI/ISA 60079-11, (12.02.01)–2014, Explosive Atmospheres Part 11 – Equipment Protection by Intrinsic Safety "I" [5] drafted in the early 2000's. Members of the responsible standards committee periodically update these standards through established ANSI consensus procedures. The prior referenced study [3] contended that the level of integrity of the update process was at least equivalent to

Manuscript received July 14, 2017; revised January 17, 2018; accepted January 19, 2018. Date of publication February 8, 2018; date of current version May 18, 2018. Paper 2017-MIC-0601.R1, presented at the 2017 IEEE Industry Applications Society Annual Meeting, Cincinnati, OH, USA, Oct. 1–5, and approved for publication in the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS by the Mining Committee of the IEEE Industry Applications Society. This work was supported by the National Institutes of Occupational Safety and Health, Office of Mine Safety and Health Research, under a contract. *(Corresponding author: William Calder.)*

W. Calder was with the U.S. National Committee for the International Electrotechnical Commission, New York, NY 10036 USA. He resides in The Villages, FL 32162 USA (e-mail: calderent@aol.com).

D. P. Snyder and J. F. Burr are with the National Institutes of Occupational Safety and Health Mining, Pittsburgh, PA 15236 USA (e-mail: fwx4@cdc.gov; xdq9@cdc.gov).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TIA.2018.2804322

the MSHA process, a conclusion which applies equally to this paper; we will not restate those arguments herein.

The purpose of this paper is to highlight the specific differences between U.S. and international standards for nonportable electrical/electronic equipment, explain how these differences are either nonconsequential or equivalent, and accordingly assert that the ANSI/ISA standards are a safe alternative to ACRI2001.

II. Technical Approach and Findings

A. Differences in the Requirements

A NIOSH two-fault IS study completed in 2015 [6] compared the MSHA approval criteria and the international standard but considered only one category of equipment (portable electronic equipment). This paper expands that previous study to all equipment including nonself-contained battery operated equipment, mine powered "associated" equipment supplying IS devices, IS barriers supplying IS devices, and system approaches including the entity concept allowed in the ANSI/ISA standards [7].

The most significant of those additional considerations is the entity concept.

B. IS Systems and the Entity Concept

Most equipment, other than stand-alone battery operated devices, consist of two or more interconnected devices that form a system that may be line voltage supplied. MSHA evaluates the interconnected devices as a system for approval. This means that any change in or substitution of any of the interconnected devices requires a new evaluation to determine permissibility of the system.

The early U.S. nonmining standards of the 1960's used the same approval structure for systems. Maintaining approval for such systems was difficult considering ongoing refinements, improvements, and newer technology integration to replace obsolete system devices or components. U.S. IS experts addressed the issue and developed a solution that now has international acceptance. The solution was introduced as the "entity concept" which had the advantages of increasing manufacturer flexibility and reducing future workload by allowing the evaluation of devices without restricting their use to a particular system. After "approval" of the individual devices that could comprise a system, changes affecting the system become less burdensome as the evaluation targets the altered device and not the overall system. The "new" system is still valid as long as the devices meet the criteria for interconnecting them.

The entity concept treats each device independently within a system with a testing authority performing a normal two-fault IS evaluation on each device. This approach is more conservative than MSHA's current practice of evaluating each combination of devices as a single apparatus and then applying a two-fault evaluation to that system. For example, MSHA would perform a two-fault IS evaluation on a system made up of two devices as shown in Fig. 1.

Up to two simultaneous faults are introduced anywhere in the system while remaining within the IS energy limits. (*X* indicates faults).

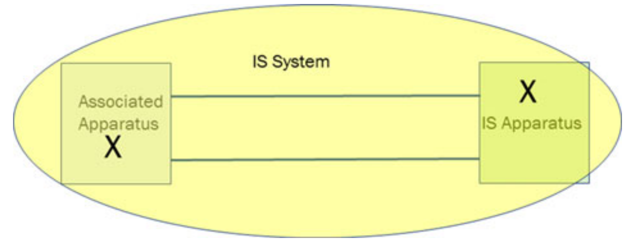

Fig. 1. IS testing under complete systems approach (MSHA).

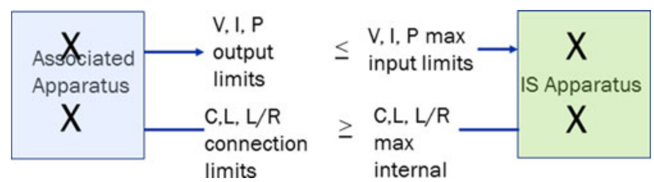

Fig. 2. IS testing under the entity concept.

However, a testing authority would evaluate four faults for the same system under the entity concept since they will evaluate two faults for each incorporated device, as shown in Fig. 2.

Interconnection limits (entity parameter ratings) are established by introducing two simultaneous faults in each apparatus (*X* indicates faults) anywhere in the apparatus while remaining within IS energy limits.

Manufacturers categorize equipment as an IS apparatus or an associated apparatus. An IS apparatus contains only IS circuits. An associated apparatus contains IS and non-IS circuits and provides IS energy to a connected device installed in a hazardous location. Mine operators install associated apparatus in low ignition risk locations unless they provide additional protection to mitigate ignition risk. The most common example of associated apparatus are the "IS barrier" family of devices that limit current, voltage, and total energy delivered to a sensor or any other actuator instrument located in a higher ignition risk area. IS devices include but are not limited to sensing or measuring devices for pressure, temperature, flow, switch positions, and load cells.

A testing authority assigns an associated apparatus several "entity parameters" for its output terminals based on their evaluation. These entity parameters include the maximum output terminal voltage ($V_{\rm oc}$ or U_o) that the apparatus can supply, the maximum short-circuit current ($I_{\rm sc}$ or I_o) at the output terminals, the maximum capacitance (C_a or C_o) that the apparatus can connect to, the maximum inductance (L_a or L_o) that the apparatus can connect to, and in some cases the maximum output power (P_o) from the device and/or the L/R ratio (L_o/R_o) of the wiring between the output terminals and the IS device.

Likewise, a testing authority assigns an IS apparatus several "entity parameters" for its connection terminals based on their evaluation. These entity parameters include the maximum voltage ($V_{\max}$ or U_i) that may be applied to the apparatus, the maximum current ($I_{\max}$ or I_i) that may be applied to the apparatus, the total unprotected capacitance (C_i) of the device, the total unprotected inductance (L_i) of the device, the maximum

TABLE I
ENTITY PARAMETER REQUIREMENTS FOR IS INTERCONNECTION

Associated Apparatus	Condition to Satisfy	IS Apparatus
V_{oc} or U_o	$\leq$	V_{max} or U_i
I_{sc} or I_o	$\leq$	I_{max} or I_i
P_o	$\leq$	P_i
C_a or C_o	$\geq$	C_i
L_a or L_o	$\geq$	L_i
L_a/R_a or L_o/R_o	$\geq$	L_i/R_i

power (P_i) that the apparatus can receive, and the maximum internal inductance to resistance (L_i/R_i) ratio, as appropriate. These devices may be installed in any location consistent with their hazard rating.

Associated apparatus and IS apparatus manufacturers must either mark the apparatus with appropriate entity parameters or provide this information in the accompanying installation literature. The manufacturer supplied literature for each device must have an approved control drawing that defines device parameters and provides any other pertinent information to assure a proper IS installation. ISA 60079-25, (12.02.05) Explosive Atmospheres – Part 25: Intrinsically Safe Electrical Systems [8], prescribes the control drawing content requirements as well as other installation criteria.

Qualified personnel can determine the IS compatibility of interconnected apparatus by comparing the entity parameters. Table I shows the criteria needed for connecting an associated apparatus with an IS apparatus.

The IS barrier (associated apparatus) manufacturing community have developed a large assortment of barrier devices to work with a variety of IS sensing and measurement equipment. The allowable capacitance and inductance connected to an associated apparatus must include the sum of the unprotected capacitance and inductance of the IS apparatus and the interconnected wiring; this information must be on the control drawing. Cable manufacturers routinely provide cable values for capacitance and inductance as part of the cable specifications; however, using the standard maximum values found in typical wiring of 60 pF/ft capacitance and 0.2 μH/ft inductance is acceptable if the actual cable specifications are lacking. ANSI/ISA 12.06.01-2003, Wiring Practices for Hazardous (Classified) Locations [9], recommends these standard maximum values as being equal to or greater than the values found in such cables.

ANSI/ISA standards do not provide qualifications concerning persons that design systems of interconnected apparatus; however, these persons should understand the safety issues and know how to select and properly interconnect these devices. They need this knowledge and understanding even for simple, straightforward, and easy to evaluate systems such as two-terminal, two-device systems. Table I implies simplicity in interconnecting these devices, and in most cases it is simple. However, there are circumstances that require more in-depth technical analyses to assure that device combinations satisfy control drawing criteria, such as multiterminal devices handling several circuits or interconnecting more than two pieces of associated apparatuses. ISA Technical Report ISA-TR12.2-1995 [7] contains additional information and ISA 60079-25, Explosive Atmospheres – Part 25: Intrinsically Safe Electrical Systems [8] provides comprehensive guidance for more complex systems.

C. Evaluation of Devices When the Entity Concept is Used

Testing authorities evaluate and test IS devices under the entity concept in the same way as any other device. They apply the same fault criteria, perform safety component evaluations, analyze thermal effects, and consider energy storage elements such as capacitors and inductors. The manufacturer typically provides the maximum voltage, current, and applied power ratings. The testing laboratory evaluation determines the total unprotected capacitance and inductance internal to the device. The testing laboratory simulates the power source for any required testing using the manufacturer provided maximum voltage, current, and power parameters.

The physical difference between an IS device and one evaluated as part of a specific system is usually the label markings, such as the entity parameters and control drawing references. The entity parameters define the operating conditions that make the device IS, notwithstanding the device design and construction criteria.

A testing authority performing an entity concept evaluation on an associated apparatus, such as an IS barrier device or a power supply device, would not consider any interconnected IS devices as part of the evaluation. Determining the associated apparatus maximum output parameters is part of the evaluation. The testing laboratory would determine the maximum open-circuit voltage and maximum short-circuit current at the device output terminals. This maximum open-circuit voltage determines the maximum capacitance that the associated apparatus can connect to, either from the capacitance curves or the capacitance table. Similarly, the short-circuit current determines the maximum inductance that the associated apparatus can connected to, either from the inductance curves or the inductance table.

The physical difference between this power source device and one evaluated as part of a specific system is usually the label markings, such as the entity parameters and control drawing references.

Some product designs will be identical whether evaluated using the entity concept or MSHA's singular system concept; however, equipment manufacturers using the entity concept will have to evaluate a higher fault count considering testing for each device used in the system. In some cases, the application of the added faults requires some adjustment to the design. The entity concept can lead to an increased factor of safety for the system considering the increased fault testing.

In contrast to the entity approach, systems-based acceptance is problematic for equipment manufacturers and mine operators who may need to quickly replace a device or a component within a device that is no longer available. Re-evaluating the entire system can create significant delays and unnecessary negative impacts on the manufacturer and mine operators. The approach can become increasingly unwieldy in today's environment where electronic components may become obsolete and therefore require multiple certifications in a relatively short time on each system variation.

D. Installation Criteria and Control Drawings

The most recognized and generally mandated source for installing electrical apparatus in hazardous locations in the U.S. is the National Fire Protection Association (NFPA) published National Electrical Code [10] (NEC), NFPA 70. Chapter 5 of the NEC addresses special occupancies which include hazardous location installations. Article 504, "Intrinsically Safe Systems," addresses installation criteria for all types of IS systems and specifically references ANSI/ISA RP 12.06.01-2003 [9], "Wiring Methods for Hazardous (Classified) Locations Instrumentation – Part 1: Intrinsic Safety" for additional details regarding installation of IS systems. Article 504 also mandates that "intrinsically safe apparatus, associated apparatus, and other equipment shall be installed in accordance with the control drawing(s)" and that the control drawing number be marked on the apparatus. The "control drawing" definition in Article 500.2 of the NEC is identical to that found in ANSI/ISA RP12.06.01-2003.

The last edition of the ANSI/ISA RP 12.06.01 – 2003 document addressed the requirements given in NEC Article 504 and expanded the criteria to provide additional detail and examples in order to answer most questions that might arise during installation.

Control drawing details date back to the early development of the entity concept. It was originally a requirement of the testing laboratories that test and certify devices as part of a system. ISA developed Technical Report ISA-TR12.2, "Intrinsically Safe System Assessment Using the Entity Concept," last published in 1995, to supplement equipment selection criteria for the entity concept. This guide helps equipment manufacturers to prepare sufficient control drawing details and documentation to support the IS rating. This guide also helps system designers, users, and installers to maintain the IS rating when interconnecting independently certified devices.

The NEC expanded the requirement for control drawings to cover any system, even when they are not using the entity concept. The ISA subsequently published ANSI/ISA 12.02.02-2014 [11], "Recommendations for the Preparation, Content, and Organization of Intrinsic Safety Control Drawings" to address control document content needed to support the NEC-required control drawings. The original Technical Report ISA – TR12.2 and ANSI/ISA RP 12.06.01-2003 [9] was the basis for much of the information. The control drawing and documentation is a requirement for all IS systems.

The internationally accepted standards and associated guides cover most IS system features and provide useful tools for all IS applications, including the mining industry. The ANSI/ISA tools presented in the IS standard, related standards, and associated documents provide a significant degree of flexibility for interconnecting a variety of intrinsically safe and associated equipment. Manufacturers and users alike can use these tools not only without compromising safety, but in many cases enhancing safety. Moreover, the entity concept provides an expedited path for introducing product innovation and change without having to submit complete systems for re-evaluation, as long as the modified component satisfies the entity parameters of the interconnected components in the apparatus.

E. Other Differences

The NIOSH comparison study [6] identified 68 sections within the MSHA ACRI 2001 document that applied to other than self-contained battery operated equipment. Further review condensed these 68 sections into nine technical categories [1]. Seven of the nine do not diminish miner safety because the IEC standards are clearly equivalent to or more conservative than the MSHA criteria. The two remaining categories show that the MSHA criteria are slightly more conservative; however, these items have no measureable diminutive effect on miner safety.

One of the two differences where the MSHA criteria are slightly more conservative involves the maximum voltage applied for normal operating conditions. The MSHA document requires a 20% increase to the nominal voltage supplied to a device while the IEC standard requires the nominal voltage plus any stated tolerance. The MSHA maximum voltage regulation is slightly more conservative because the normal IEC tolerance is 10%. However, MSHA uses a 1.5 safety factor on energy while the IEC standard uses a 2.25 factor. This difference in safety factors offset and minimalizes the effect of the slightly higher MSHA maximum voltage. [3]

The other difference where the MSHA criteria are slightly more conservative involves one of the methods of separating IS circuits and non-IS circuits when both are present within a relay. MSHA and IEC both require the same power-dependent separation distance between the IS and non-IS parts of the circuit for a circuit up to 250 V rms, 5 A, or 100 VA, with some exceptions for clean environments discussed later in this section. Also, MSHA and IEC both require metal or insulated barriers that meet common test criterion between the IS and non-IS parts of the circuit for circuits above 250 V rms, 10 A, or 500 VA. Moreover, these IEC barriers are equivalent to or thicker than the MSHA barriers. The noted difference is that IEC allows the manufacturer to double the separation distances in lieu of the barrier when the circuits are above 250 V rms, 5 A, or 100 VA (but below the 250 V rms, 10 A or 500 VA limit) which MSHA does not offer; MSHA requires the use of barriers at these levels. IEC asserts that this practice is safe, manufacturers rarely use this exception, and the impact on safety is negligible.

The IEC standard also allows reduced spacing distance when applying the principles of the IEC 60664-1 [12] standard addressing insulation coordination and degrees of pollution (cleanliness). Both documents considered dirty environments (such as coal dust in a mine) in establishing the normally applied separation distances and therefore meet pollution degree 3 in IEC 60664-1 and the criteria for the use of barriers still apply. However, Appendix F of that document allows for reduced spacing distances if the manufacturer can maintain a pollution degree 2 environment (such as an environmentally controlled room). In this case, the device marking must indicate that it is only for pollution degree 2 environments or use within an IP54 enclosure per IEC 60529 [13]. The MSHA standard is more conservative because it does not recognize the cleanliness factor and associated reduced spacing distances. But again, this difference is minor relative to safety when considering the overall concept.

MSHA also requires a dielectric test applied to the relay that is four times the nominal working voltage (Un) or 2500 V, whichever is higher, as part of the design verification. The IEC standard does not specify such a test for the relay but does specify a lower level dielectric test of 2U plus 1000 V or 1500 V, whichever is greater, for the entire device, of which the relay is a component. While a dielectric test of this nature may be useful for discovering manufacturing workmanship defects, it has minimal value for the design validation. The MSHA test criteria are a little more conservative by requiring the more stringent design test, but the impact on the level of protection is negligible, since the MSHA criteria considered herein is for approval of the design, not the manufacturing process.

Both MSHA and IEC requirements will adequately separate IS and non-IS parts of a relay and the probabilities that two or more internal circuits could short together are similarly very low using either approach.

III. Conclusion

U.S. mining law requires the demonstration of equivalent safety for any new standard that is proposed for use in coal mines. This paper considers the relative level of protection afforded the miner by the use of the ANSI/ISA 60079 two-fault IS standard as an alternative to MSHA ACRI2001 when such electrical equipment is installed in mines. It is the authors' considered opinion that the use of such equipment not only would provide at least an equivalent level of safety as that provided by equipment approved to MSHA criteria, but also provide other potential benefits. Applying the entity concept for the evaluation of two or more interconnected devices in an IS system would likely increase miner safety because the number of assumed device faults would increase.

The mining industry would also benefit from the more efficient entity concept process when introducing modifications and new technology to enhance product function. The broadened base of available equipment components could enable the modification of equipment improvements as well as lower costs. The lowered costs may be possible because manufacturers would not have to have more than one design to satisfy the differences in criteria between the ANSI/ISA standard and MSHA ACRI2001, and could produce a single product saving the cost of an additional, low volume product line. Finally, currently developing technology could potentially be introduced to the coal mining industry much sooner assuming that such equipment was submitted for and received approval against the ANSI/ISA standard. An example of this is the in the field of sensors where a variety of sensors along with their associated equipment have been developed or are under development for mining applications [14].

Acknowledgment

The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the NIOSH. Mention of any company or product does not constitute endorsement by NIOSH.

References

[1] NIOSH, "Electrical equipment explosion protection research," Nat. Inst. Occupational Safety Health, Pittsburgh, PA, USA, Nov. 2016. [Online]. Available: https://www.cdc.gov/niosh/mining/content/electrical/explosionprotectionresearch.html

[2] *Federal Mine Safety and Health Act of 1977, Public Law 91-173, SEC.101(a)(9)*, Public Law 91-173.

[3] W. Calder, D. P. Snyder, and J. F. Burr, "An evaluation of the relative safety of U.S. mining explosion-protected equipment approval requirements versus those of international standards," *Trans. Society Mining, Metallurgy, Exploration*, vol. 392, no. 1, pp. 43–50, 2017.

[4] U.S. Department of Labor, MSHA, "Criteria for the evaluation and test of intrinsically safe apparatus and associated apparatus," MSHA ACRI2001, Nov. 2008. [Online]. Available: www.msha.gov/techsupp/acc/application/acri2001.pdf

[5] *Explosive Atmospheres–Part 11: Equipment Protection by Intrinsic Safety "i"*, ANSI/ISA Standard 60079-11, 2006.

[6] G. Homce, J. Waynert, M. Yenchek, and R. J. Matetic, "A comparison of U. S. mining industry criteria for intrinsically safe apparatus to similar IEC-based standards," Office Mine Safety Health Res. Nat. Inst. Occupational Safety Health, Pittsburgh, PA, USA, 2015. [Online]. Available: https://www.cdc.gov/niosh/mining/content/comparisonofminingcriteria.html.

[7] *Intrinsically Safe System Assessment Using the Entity Concept*, ISA-TR 12.5-1995.

[8] *Explosive Atmospheres – Part 25: Intrinsically Safe Electrical Systems*, ANSI/ISA Standard 60079-25 (12.02.05), 2011.

[9] *Wiring Methods for Hazardous (Classified) Locations Instrumentation – Part 1: Intrinsic Safety*, ANSI/ISA Standard 12.06.01-2003.

[10] *National Electrical Code*, NFPA Standard 70, 2017.

[11] *Recommendations for the Preparation, Content, and Organization of Intrinsic Safety Control Drawings*, ANSI/ISA Standard 12.02.02-2014.

[12] *Insulation Coordination for Equipment Within Low Voltage Systems – Part 1: Principles, Requirements and Tests*, IEC Standard 60664-1, 2007.

[13] *Degrees of Protection Provided by Enclosures (IP Codes) Consolidated Edition*, IEC Standard 60529, 1989.

[14] M. E. Kiziroglou, D. E. Boyle, E. M. Yeatman, and J. J. Cilliers, "Opportunities for sensing systems in mining," *IEEE Trans. Ind. Informat.*, vol. 13, no. 1, pp. 278–286, Feb. 2017.

[15] W. Calder, D. P. Snyder, and J. F. Burr, "An alternative international-standards-based approach for the evaluation of intrinsically safe systems in U.S. mines," in *Proc. IEEE Ind. Appl. Soc. Annu. Meeting*, Cincinnati, OH, USA, Oct. 2017, pp. 1–9.

William Calder received the B.S. degree in electrical engineering from Worcester Polytechnic Institute, Worcester, MA, USA, in 1961, and the M.S. degree in engineering management from Northeastern University, Boston, MA, in 1968.

He is an independent Technical Consultant and has enjoyed a distinguished career in the electrical safety field having specialized in designing electrical equipment for use in classified (hazardous) areas and the development of the standards used to evaluate such equipment. His work experience includes a lengthy career at a leading process control instrumentation manufacturer where he rose to Director of Product Safety and later served as an Assistant Vice-President in charge of all electrical engineering operations at a well-known product testing laboratory.

Mr. Calder is a Professional Engineer. He was involved with the development of the intrinsic safety standards, participating and playing a leadership role in both the U.S. and international committees for intrinsic safety through the Instrument Society of America (now known as the International Society for Automation) and as a member of the U.S. National Committee for the International Electrotechnical Commission that developed the intrinsic safety standards.

David P. Snyder received the B.S. degree in mining engineering from Penn State University, State College, PA, USA, in 1981, and the M.S. degree in electrical engineering from George Washington University, Washington, DC, in 1990.

Earlier in his career, he worked as an Engineer at Bethlehem Mines. He is a Principal Engineer with the National Institutes of Occupational Safety and Health (NIOSH) Office of Mine Safety and Health Research (OMSHR), Pittsburgh, PA, responsible for mine safety and health technologies research and development, and previously led the communications and tracking research under the MINER Act for OMSHR. Before NIOSH, he held positions in technology research and integration including founder of a public Wi-Fi company, Vice-President of a cable and telephone company, and CTO of a large international corporation.

Mr. Snyder is a licensed Professional Engineer.

John F Burr received the B.S.E.E. degree from the University of Pittsburgh, Pittsburgh, PA, USA, in 1969.

He is a Senior Engineer with the National Institutes of Occupational Safety and Health Office of Mine Safety and Health Research (OMSHR), Pittsburgh, responsible for mine safety and health technologies research and development, he leads the external contracting program for both new technology and capacity building contracts. He previously spent 42 years with the Consol Energy Mining Group, where many of his projects were equipment safety driven. These projects included the specification and design of high-voltage longwall systems, safety testing of all new and modified elevator and hoist installations, and the implementation of the required MINER Act tracking and communication systems.