Evaluation of the Technical Basis for Specific Provisions of the ANSI/ISA Intrinsic Safety Standards – Report 2, Fuse Factor Ratings and Other Issues

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The Offices of Mine Safety and Health Research (OMSHR) prepared a report that provides a detailed comparison of the requirements of the Mines Safety and Health Administration (MSHA) intrinsic safety standard ACRI2001 and the recognized consensus intrinsic safety standard ANSI/ISA 60079-11. The comparison identified several points of difference. One of the more significant ones is what factor to apply to fuses to establish the test current for the protected downstream safety related components both for thermal effects and maintaining functionality. This report addresses that issue as well as several other less critical ones.

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11/4/2014

CDC-NIOSH-OMSHR REPORT 2

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Introduction:

The Offices of Mine Safety and Health Research (OMSHR) prepared a report that provides a detailed comparison of the requirements of the Mines Safety and Health Administration (MSHA) standard ACRI2001, Criteria for the Evaluation and Test of Intrinsically Safe Apparatus and Associated Apparatus and the recognized consensus standard ANSI/ISA 60079-11, Explosive Atmospheres – Part 11: Equipment Protection by Intrinsic Safety "i" (5th Edition). The object of the report was to identify those items that are or may be more conservative in the MSHA standard in order to initiate a meaningful discussion to try to resolve these differences to the point that MSHA could accept the ANSI/ISA standard as a replacement for the currently used ACRI2001 standard. Early discussions between personnel from the National Institute for Occupational Safety and Health (NIOSH) and MSHA identified two items of particular concern to MSHA that address temperature rating relaxations for small components (Item 17 in the report) and what factor is appropriate to be applied to fuses used as overcurrent protection for downstream component(s) to establish the test current used for thermal analysis and the ratings of the downstream components (Item 6 in the report). MSHA expressed a willingness to consider this action if the issues of concern could be resolved by providing scientific evidence that supported the differences of the two specifically identified issues.

Accordingly, NIOSH issued contract 254-2014-M-59190 requesting that the two identified items be thoroughly researched to determine their origin(s) and any scientific evidence that support the criteria as given in the ANSI/ISA standard(s). In addition, comments on the remaining issues (Items 1 through 5 and 7 through 11) was invited to the extent that it could be provided without the depth of research expected for the two main issues. The information contained in this report is in response to the "Statement of Work for Professional Services" in the contract and is organized in two reports. The first report addresses the temperature relaxation for small components issue while the second report addresses the factor applied to fuse ratings to establish test currents for downstream components as well as the remaining items identified as less significant issues by MSHA.

Summary of Results:

The information discovered for the fuse factor issue is interesting in that although several attempts were made to use a scientific approach to establish the factor for setting the test current value beyond the fuse, failure of these efforts resulted in an arbitrary decision made to set a common factor. The decision was ultimately based on common practice used in industry for similar devices and the desire to keep it simple.

For the remaining issues, the information provided is based on the knowledge and experience of the writer enhanced by information from expert colleagues and some specific data that that was somewhat readily available.

It is also worth noting that the overall issue of whether the ACRI2001 standard is more conservative than the ANSI/ISA can be viewed in two ways: at the macro level or at the micro level. At the macro level the most significant difference between the two standards is the safety factor applied to voltage and current levels in the intrinsic safety analysis and/or tests. The MSHA standard applies a safety factor of the square root of 1.5 on voltage or current which is a 1.5 factor on energy while the ANSI/ISA standard uses a factor of 1.5 on voltage or current which is a 2.25 factor on energy. It is the opinion of the writer that this one point alone makes the MSHA standard less conservative than the ANSI/ISA standard despite the differences at the micro level as identified in the OMSHR report.

Item 6. *For determining current levels to be used to evaluate circuit components, based on protective fuse ratings, ACRI2001 and ANSI/ISA standards use criteria that are similar, but cannot be compared directly.*

As stated in the Item 6 description above, although the factors used in the two standards are similar, they cannot be compared directly. The factor in the MSHA standard is variable normally 2 times the fuse rating but can be higher but usually not more than 3 times depending how the manufacturer presents its information on their data sheet. Some manufacturers provide a rating for the fuse to open at two minutes and that factor would be used (usually 200%), but if a two minute specification is not provided, then the next time less than 2 minutes where data is presented would be used. The ANSI/ISA standard uses the factor developed for the CENELEC standard in Europe later adopted by the IEC which is 1.7 times the fuse rating. This data establishes that for this point, the MSHA standard is more conservative than the ANSI/ISA standard.

The search for the background that led to the ANSI/ISA 1.7 factor had interesting results. An inquiry was first made to an English colleague who was active in the development of the intrinsic safety concept in the 1970's and 1980's. His recollection that factors on fuses and circuit breakers had been used for similar purposes in England prior to intrinsic safety and that fuses being considered ”coarse excess current protection” used a factor of 1.6 while circuit breakers considered as “close excess current protection” used a factor of 1.3 and appeared in the British wiring regulations. He further thought that the 1.7 factor came from somewhere in Europe.

Based on that input an inquiry was made to a German colleague as to the origin of the 1.7 factor in Europe. He responded that it was in place prior to his involvement (1975) but thought it was based on time/current characteristics of fuses used in the UK and Germany. Since there was nothing obviously available that was more definitive, he suggested I contact Chris Towle in the UK, also a colleague of the writer, who may have further information on this issue.

Mr. Towle did indeed have additional information. He stated that the 1.7 factor was introduced in the early 1960’s as a pragmatic solution to solve the problem of rating the diodes in zener barrier devices. At the time, engineers were struggling with trying to compare the transient time of fuses with the pulse rating of the diodes. All efforts to reconcile this failed. After several unsuccessful attempts, a fuse expert from ERA (Electrical Research Association) and the principal electrical inspector (a gentleman named Arnaud) were asked to propose a single factor that could be universally used representing the point where the fuse might carry such current for a long enough period to be considered steady. These gentlemen proposed the 1.7 figure which was accepted by BSI and subsequently found its way into the CENELEC intrinsic safety standard, and finally, the IEC standard. The 1.7 figure was debated and the discussions brought out that 1.7 had been used elsewhere. The prior use was beyond Mr. Towle’s recollection. It has been satisfactorily used since the early 1960’s and none of the experts around the world challenged it when it was proposed for the CENELEC or IEC standards.

Despite the lack of scientific evidence and the similarity of the two approaches to establishing the fuse factor, the ANSI/ISA approach was certainly pragmatic. The general acceptance of the IEC criteria worldwide including some of the most conservative organizations in the world, it would seem that the practice is a reasonable one. With the issues surrounding small component ignition discussed in Report 1and the relative difficulty of generating thermal ignition, and with the allowable temperature for methane possibly moving to 950C based on the data in report 1, it makes the fuse factor somewhat moot as an issue. The effect on the probability of ignition would be nil by accepting the ANSI/ISA practice for the factor applied to fuse current ratings.

Item 2. *ACRI2001 prohibits using alternate test gas mixtures to introduce a safety in spark testing, but ANSI/ISA standards allow using alternative test gas mixtures.*

I discussed this issue with Mr. Tim Adam of FM who acknowledged that use of enhanced gas mixtures to achieve safety factors is not uncommon practice especially with the electronic design approaches used today and the emergence of semiconductor voltage and current limiting. The latter makes it quite difficulty if not impossible to achieve safety factors using the traditional means. Perhaps MSHA has not faced this problem yet with the type of equipment presented to them for evaluation and test. For more "traditional" designs, using the normal safety factor approach is obviously chosen, and is still the method of choice. If MSHA does get a design to evaluate and test than can apply necessary safety factors only by adjusting the gas mixture, it is unclear what they would do. This can be resolved by adopting the ANSI/ISA approach even if the ANSI/ISA standard is not adopted. The mixtures provided in the ANSI/ISA standard to achieve the safety factor have been in place for a very long time and have proven to be equivalent.

Item 3. *ACRI2001 has spark testing criteria that are more conservative than ANSI/ISA spark testing criteria, with respect to the number of test apparatus revolutions required.*

The ignition test apparatus now universally used was developed by the Physikalisch-Technische Bundensanstalt (PTB) the German authority on metrology and physical safety. It was developed in the 50's and 60's and introduced to be the international standard circa 1970. The IEC Intrinsic Safety Committee, SC31G, adopted the apparatus in the 1970's. IEC standard 79-3, Testing of Intrinsically Safe Apparatus, was first issued in 1963 that included an Appendix describing the British 'break-flash' apparatus as a means to perform ignition testing. It was later revised and ultimately adopted the PTB designed test apparatus because of its attributes that accommodated testing for most electrical circuit configurations. PTB had performed literally years of testing with this apparatus including ignition curve data as well as the details of the practical operation of the apparatus. The number of revolutions to use for ignition testing is at best an arbitrary figure, but PTB suggested the current numbers used based on their extensive experience using the apparatus. In running the calibration circuit to establish that the mixture and contacts were properly set, ignition usually occurred within 0 – 20 revolutions. When testing a real circuit, their experience over time led them to a number of 400 revolutions, 200 in each polarity or ten times the usual number of revolutions of the calibration run in each direction. This was considered a reasonable number of revolutions as compared to the ideal calibration set-up and the sensitivity it displayed. The German proposal at the IEC level was readily accepted by all countries participating in SC 31G at that time as most had already adopted it independently anyway. I expect the German data may still be in their archives somewhere, but all individuals involved with its development have long since retired and are deceased. Inquiries could be made to see if the data could be made available, but It is not clear what value it would be since the number revolutions selected was arbitrary and most likely related to probability of ignition based on the calibration data. I do not view this as an issue and am confident that it would make no difference in the test result or the safety of the equipment.

I would recommend that MSHA consider revising this section of their standard to agree with the IEC standard unless the ANSI/ISA standard is ultimately adopted.

Item 4. *ACRI2001 requires (under certain conditions) a more conservative maximum interrupt current and maximum voltage rating for fuses, than do ANSI/ISA standards.*

The ACR2001 standard specifies that when the fuse is used as a “protective” component, meaning the resistance of the fuse is being used as part of the current limiting to achieve an intrinsically safe current level, the fuse shall not be exposed to values greater than 2/3 of the manufacturer’s specified maximum voltage and interrupting current ratings.

The ANSI/ISA 60079-11 standard specifies that when the fuse… is used as a “protective” component, again for the resistance of the element, it is considered as an infallible resistor. A rational interpretation could be that such a fuse must meet the same criteria. This includes not exceeding 2/3 of the manufacturer’s maximum ratings for current, voltage, and power as stated in Clause 7.1 of the standard. Fuses have a voltage rating, a current rating for fuse opening, and a current rating at which it will safely clear (breaking capacity or interrupting rating), but no power rating. The standard also states in Clause 7.1 that fuses shall be rated based on the normal operating voltage and current of the circuit. Further, in Clause 8.5, Current-limiting resistors, it states that “Cold resistance (at the minimum ambient temperature) of fuses… may be considered as infallible current limiting resistors where they are used within their normal operating conditions…. In the absence of available information, this may be taken as the minimum resistance at the minimum ambient temperature when measured as required in 10.4.” This latter statement might lead one to conclude that fuses can be used anywhere in their normal specified range including up to the rated voltage of the fuse.

At present, UL and FM are interpreting the above to mean that the fuse may be used up to its manufacturers’ maximum voltage rating with no limits on the operation regarding the breaking capacity since it will be operating at a current below its normal fuse opening rating. It is clear that MSHA chose a more conservative approach by imposing the 2/3 rating not only to the voltage, but also to the interrupting current rating under normal or fault conditions.

How significant is this difference? Typical fuse manufacturer voltage ratings vary from 24 V up to 600 V and interrupting current ratings range from 35 A to 50,000 A. For intrinsically safe circuits with their usual relatively low current, voltage, and power limits, fuses rated at 600 V and 50,000 A are meaningless, while fuses rated at 24 V and 35 A may have significance as the 2/3 values would be 16 V and 24 A respectively. The 16 V certainly is in the operating range of many intrinsically safe circuits, e.g. those powered from a 24 V source, common in numerous instrumentation installations. The 24 A figure would be a difficult one to achieve except, perhaps, in a transitory spike. But such a spike would necessarily be of extremely short duration in a limited power source. Any such spike lasting less than 5 microseconds or so will not cause ignition which is why zener diodes or “crow bar” circuits can be successfully used for voltage limiting in intrinsically safe circuit designs such as in barriers. With regard to safety, there is no significant difference when practically viewed. The real issue is the viability of the resistance and to have a failure mode that leads only to an open circuit. Could there be a set of conditions where the voltage could be high enough to drive current through an open fuse or that there was enough current continuously present to cause a breakdown across the fuse? Certainly not with portable, battery operated equipment, and extremely unlikely in an approved design where any such fuse would be properly rated and controlled by construction details.

The application of fuses as current limiters has limited use and usually for battery operated equipment where it is important to be able to claim resistance where you can in order to not use up more battery power than required and save it for its intended function. As such, derating the voltage and interrupting current in this circumstance seems unnecessary. I expect that MSHA should be in position ton accept this difference as non-consequential when safety is considered.

Item 5. *ACRI2001 requires a more conservative interpretation of ignition curves used to evaluate circuits, than do ANSI/ISA standards (ignition curves are used in lieu of spark testing); specifically, ACRI2001 requires spark testing if circuit values fall between 90% and 100% of curve values.*

The ACRI2001 approach for using the curves to evaluate the possibility of ignition by an electrical circuit is a bit more conservative than the ANSI/ISA standard’s approach, but not significantly so. It is not usual for an evaluating engineer to use the curves in many instances as a means to establish a gross sense of a given circuit passing or failing due to high capacitance or inductance levels but due to the complexity of many circuits, an ignition test is run. The usual exception to this is when the IS circuit voltage and/or current levels are so low relative to the appropriate curve values, it is clear that ignition is not possible. What is important to understand is why the other standards writers of the world allowed the evaluation method to be acceptable up to the curve values. The reason was simple. The curves were developed over thousands of tests and at many locations around the world using the standardized ignition test apparatus. The conditions of these tests were to use the ideal gas mixture for each gas, with benign laboratory conditions, using a test apparatus with ideal contact materials not commonly found in circuits all of which would be extremely difficult , if not impossible, to be found in the real world where flammable materials might be present. Also, when testing a circuit, the voltage or current is raised by some factor above the levels that the circuit can produce. In other words, the conditions used to develop the curves and the procedures used to apply such curves are extremely conservative relative to real world conditions. When the ACRI2001 standard was written the author group either didn't quite understand how conservative the curves and evaluation process are, or just wanted to add a little bit more comfort level in the standard. I do know that at the time the intrinsic safety standards were being written in the U.S. (in the late 60's and 70's), the (at the time) Bureau of Mines always held a more conservative point of view "because it was a mine". Perhaps, this thought process stuck and still manifests itself in the current version. The bottom line is that the difference is insignificant and falls in the area of "engineering judgment" in the overall scheme of things. It certainly does not present a safety issue no matter what approach is used. At other laboratories, it has always been the evaluating engineers call whether to test or not. When it was questioned on any of my projects, I always encouraged the evaluating engineer to run the ignition test to remove all doubt. MSHA also has this option even accepting the ANSI/ISA approach.

Item 7. *ACRI2001 spark test apparatus calibration procedures are more conservative than those in ANSI/ISA standards; specifically, ACRI2001 allows fewer revolutions to achieve ignition, and specifies a resistive circuit calibration not called for by ANSI/ISA.*

I would consider this item a non-issue. By all measures, the difference between 400 and 440 revolutions is within the tolerance normally applied, and the SME is correct that if an ignition is to occur, it will occur within a relatively few revolutions such as 15 or fewer. The issue of using a resistive circuit for calibration is also irrelevant because no matter what is used to calibrate the apparatus, the critical issue is to assure that the machine is producing the correct fuel to air ratio which either approach will accomplish if the ignition occurs at the prescribed calibration current. MSHA should be able to accept this difference.

Item 8. *ACRI2001 creepage and clearance distances are more conservative than those specified by ANSI/ISA 60079-11 Annex F.*

This difference is understandable since the IEC 60079-11 standard having Annex F was published a few years after ACRI2001 was published. Annex F appeared in the IEC edition published in 2006 (ISA Edition 5). Since the ACRI2001 was, I presume, issued in 2001, the Annex F information has not even been considered by MSHA. For info, the purpose of the addition of Annex F is to recognize application of IEC standards aimed at cleanliness of electronic equipment by keeping contaminates away from the electronic parts. It is well documented that surface breakdown in a clean assembly will not occur even at reduced spacing. It is also well known that most surface contaminates increase surface conductivity which normal spacing requirements have taken into account. From a safety point of view there are already relaxations in the spacing requirements along surfaces when the electronic assemblies are protected from contaminates such as by board coatings or encapsulation, so accepting this relaxation by assuring cleanliness should not be an issue. MSHA should be able accept this difference based on the already existing relaxations for the same circumstances.

Item 9. *ACRI2001 provisions to prevent potentially hazardous plug/receptacle interchangeability are more restrictive than corresponding ANSI/ISA standard requirements.*

The interchangeability of plugs and receptacles is another one of those issues when equipment designers scratch their heads in wonder because they are good designers they wouldn't use interchangeable plugs and receptacles in any design because of functionality problems related to putting the wrong plug in the wrong receptacle. The requirement does not pose a problem because they just wouldn't do such a thing. It was surprising that one of the SME's indicated they see it often. In all my years reviewing thousands of products, I have never seen it. However, it is in the standards, and always has been I might add, as needing to be said rather than leaving it open as not all designers are good ones.

The differences between the ACRI and ANSI/ISA standards exist but are not very significant since the obvious solution is to not have interchangeable plugs and receptacles in the product. I believe the ACRI statement allowing such only if interchange does not affect intrinsic safety is the more elegant approach. The ANSI/ISA standard covers more alternatives including allowing the use of interchangeable ones if they are distinguishably marked such as by color coding or obvious marking. There is something to be said for color code marking as most home entertainment TV and sound system use interchangeable plugs and receptacles that are color coded intended for connection by anyone and presumably works quite well. In the case of intrinsically safe equipment, the person inserting the plugs would be one skilled in the art and such that the likelihood of making a mis-connection is highly unlikely especially if it is clearly marked on the plugs and receptacles.

In view of all of the above I would submit that the two standards fundamentally agree, and the deviation is not very significant such they provide an equivalent level of safety.

Item 10. *ACR2001 has specific criteria for the use of optical isolators, but ANSI/ISA standards have no provisions specifically for optical isolators.*

A conclusion is easy to reach in this case if the latest ANSI/ISA document is adopted as it would be far more restrictive than the requirements in the ACRI document.

When I reviewed the ACRI document my thoughts were that it went further than was necessary. I totally agree with the SME representatives who stated they would apply the requirements already in the standard, i.e. meeting the spacing requirements and passing the dielectric strength test. The writers of the early U.S. standards for intrinsic safety intended it to be that way and strongly believed that the requirements provided adequate evidence that there would be no breakdown from emitter to receiver. I expect the ACRI authors were influenced by the detailed requirements for another isolating device, a transformer. However, the construction approach is so different, optical isolators should be treated differently. The transformers are relying on the integrity of insulation which demands testing to prove the integrity of the design while the optical isolator relies solely on separation distance which is good enough for all other IS to non-IS circuit separation situations.

Those who authored the latest requirements in the ANSI/ISA requirements for optical isolators have a very active imagination of dire things that might happen. It adds significant cost to the certification process without changing the result an iota. Such devices have been applied successfully under the simple rules for over fifty years without incident so it is unclear why it was decided that the new criteria were necessary.

(Note: I expect this section will get significantly edited , but I couldn't help it as it is a waste of resources to have to deal with what has emerged. For what it is worth, the ACRI approach is much more practicable.)

Item 11. *ACRI2001 has more explicit restrictive requirements for the use of lithium batteries, than do ANSI/ISA standards.*

In reviewing both ANSI/ISA standards and the ACRI standard there is only one significant issue remaining if the latest ANSI/ISA standard is applied. This involves replacement of lithium batteries and who can do it. Not only does the ACRI standard not allow anyone but authorized persons to change the batteries, it requires use of special construction to prevent casual replacement such as encapsulation or using some sort of special fasteners or the like. The ANSI/ISA standard allows users of the equipment to replace the batteries, but requires the use of warnings to advise such person to follow all instructions in so doing. This type of thing is always a knotty problem because it is so easy for users to ignore the "you can't do this" admonition even when precautions as described in the ACRI document are in place. If the batteries need to be replaced in a given situation, whoever is involved in the process will do so. If it is as a result of trouble shooting, it will likely be a technician qualified to perform such maintenance. In either event it would certainly be helpful to have instructions as required in the ANSI/ISA standard available at the batteries to increase the likelihood that the proper battery will be used. Having special retention means on the batteries required in the ACRI standard enhances the possibility of doing collateral damage to the device in trying to remove the old batteries if done by a non-qualified person. Whichever direction is taken, it is a subjective judgement, and I could argue the case on either side.

My recommendation would be to accept the ANSI/ISA approach as being simpler and that it at least specifies the proper part to be used at its location enhancing the probability that the correct part will be used which is the most important point. I believe one achieves the same level of safety no matter which approach is used.

BIBLIOGRAPHY

Some of the material contained here-in is based on email discussions with colleagues from England , USA, and Germany. These are included as enclosures with this report.