Evaluation of the Technical Basis for Specific Provisions of the ANSI/ISA Intrinsic Safety Standards, Report 1, Small Component Temperature Ratings

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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 most significant ones is the relaxation of maximum allowed temperatures for small components. This report addresses that specific issue presenting scientific data that led to these relaxations in the ANSI/ISA standard for both above ground equipment and equipment used in coal mines.

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CDC-NIOSH-OMSHR REPORT 1

Evaluation of the Technical Basis for Specific Provisions of the ANSI/ISA Intrinsic Safety Standards – Small Component Temperature Ratings

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 and the remaining items identified as less significant issues by MSHA.

Report 1: Small Component Temperature Ratings

Summary of Results:

There were some successes in contacting individual experts from Europe who were either directly involved with the process or were able to provide reports that give significant scientific evidence for the small component temperature relaxation issue. Scientific data was available in several books and documents that justify allowing higher temperatures than would be allowed for a T4 rating (135C max. at 40 C ambient) for small components while maintaining the same level of safety.

Item 17. *ACRI2001 and ISA/ANSI have similar provisions addressing small component thermal ignition, but some differences exist.*

The thermal ignition issues in MSHA standard ACRI2001 are stated quite succinctly. It provides a requirement related to methane and one for coal dust. The former allows any component to have a surface temperature up to 530C in a methane atmosphere but must be tested to demonstrate that thermal ignition does not occur if the surface temperature exceeds 530C. The latter allows component temperatures up to 150C where coal dust can accumulate on components or the enclosure surfaces but must be tested if the surface temperature exceeds 150C to demonstrate that ignition does not occur. This standard does not have a small component temperature rating relaxation such as given in the ANSI/ISA 60079-11 standard.

The ANSI/ISA standard has an approach that is a bit more complicated because it is addressing all classified flammable materials with regard to thermal ignition rather than just methane and coal dust as is the case with the MSHA standard. The relaxation for temperature limits on small components in the ANSI/ISA standard is based on a considerable amount of test work in several countries over several decades.

Organizations that performed small component thermal ignition tests include the Electrical Research Association (ERA), Safety in Mines Research Establishment (SMRE), and Sira Certification Services in the UK; Physikalisch-Technische Bundensanstalt (PTB) in Germany, Centre d'Études et Recherches des Charbonnages de France (CERCHAR) in France; the Department of Energy, Mines, and Resources in Canada; and the Bureau of Mines in the USA. Much of the work from all of these organizations is compiled and summarized in E. C. Magison's book, Electrical

Equipment in Hazardous Locations, 4th Edition[1], Chapter 9, "Ignition of Gases and Vapors by Electrical Means", pp. 324 – 335. Magison's book provides specific data from the German work by D. Markworth and F. Schebsdat[2] at PTB who tested a variety of component sizes in a uniformly heated glass tube of both 1 liter and 2.5 liters volume using diethyl ether at either a 10% mixture, or injecting liquid into the chamber and allowing it to pass through a continuum of concentrations. A sample of the data for four components is summarized in Table 9-16, page 333 which shows ignition temperatures from 243C to 315C for components having areas from 113 mm^2 (transistor) to 474 mm^2 (resistor). For these tests the chamber was maintained in a 20C ambient. A copy of the Markworth/Schebsdat report identified as PTB-W-25 was obtained from PTB and is available in English. These data correlated very closely with the work at ERA and CERCHAR. Most of the meaningful data were developed using the classified material having the lowest autoignition temperature (AIT), diethyl ether, at 160C.

Based on these tests, it was easy to conclude that small components as defined in the standard could be allowed a higher surface temperature than the AIT of diethyl ether. Accordingly, the British Committee of the European Committee for Electrotechnical Standardization (CENELEC) submitted a proposal[3, 4] to the CENELEC intrinsic safety committee to allow a T4 temperature classification for small components. CENELEC adopted the proposal after which it was proposed to the IEC as an amendment to the IEC 60079-11 intrinsic safety standard that was subsequently adopted. All of these changes were primarily aimed at Group 2 (above ground) equipment since the gas of interest for Group 1 (below ground) equipment was methane which was already rated in the most lenient temperature class, T1 (450C).

In the mid 1990's, manufacturers of equipment used in UK mines were interested in having a similar relaxation for Group 1 equipment. Mr. Peter Walsh of Sira Safety Services in England performed a literature search for ignition data on methane gas. He found what he was looking for in the Lewis and von Elbe[5] book, "Combustion, Flames and Explosions of Gases, Third Edition". The data is found in Part II: Flame Propagation, Chapter V: Combustion Waves in Laminar Flow, Section 14: Ignition by Other Sources. He performed an analysis of this section and determined that a relaxation for small components would be appropriate for methane based on the data he found in Figures 186 and 189 and the associated text. Figure 186 shows critical energies as the function of the critical heating period for several wire diameters. In the plots for 11% methane-air mixture, the curves were incomplete because ignition of the nichrome wire could not be obtained due to the longer heating periods and fineness of the wires. Figure 186 also shows that the critical energies for ignition of the methane-air mixture are higher than the fusing energies in air meaning that the wires fused before ignition occurred and the arc generated was the ignition source except as noted for long heating times and very fine wires. This section also described further tests performed on a horizontally mounted nickel bar 4 inches long x ½ inch wide x 0.04 inch thick (approx. 25.8 cm^2) that resulted in ignition above 1000C over a broad range of methane-air mixtures. This is shown in the lower curve of Fig. 189. This specific data was generated in tests by Stout and Jones[6] (1949).

Based on this data, a proposal[7] was prepared by Mr. Walsh to add data to the temperature relaxation clause for Group I equipment where firedamp is present, but where dust is excluded from the parts that could achieve those elevated temperatures such as within a dust-tight enclosure. A safety factor of 50C was applied to 1000C resulting in the 950C proposal. The original proposal asked for the relaxation to apply to components having surface areas up to 10 cm^2. This proposal was accepted in part changing the surface area from up to 10 cm^2 to $\leq$ 20 mm^2 thus making the relaxation significantly more conservative than the data suggested was quite safe. The power limitation for surface areas > 20 mm^2 was calculated by subtracting the normalized ambient temperature (40C) from the allowed temperature of 450C and dividing by the accepted thermal resistance of components at 125 K/W resulting in the adopted 3.3 W.

The 125 K/W component thermal resistance figure was developed by Widginton and Goodwin[4] based on tests they ran on several components normally found in electronic circuits. All components had a lower thermal resistance than 125 K/W with the exception of one diode that had a slightly higher thermal resistance. A component with this thermal resistance will reach 200C (the temperature limit set for components with surface areas between 20 mm^2 and 1000 mm^2) when dissipating 1.3 W.

As a point of interest and more scientific data, additional data on hot wire ignition was found in Bulletin 680, “Investigation of Fire and Explosion Accidents in the Chemical, Mining, and Fuel-Related Industries – A Manual” prepared by Joseph M. Kuchta and published by the United States Department of the Interior, Bureau of Mines, 1985. In this bulletin Table 16 on page 37 reports ignition of methane by a heated 0.1 cm diameter nichrome wire at 1220C and in a 1 cm diameter heated air jet at 1040C. Note that the heated wire exceeds the melting point of copper (1083C). Figure 49 on the same page illustrates that as the surface area decreases the ignition temperature rises significantly for the several flammable materials tested.

Since the comparative study of the ACRI2001 and ANSI/ISA 60079-11 standards, the ISA committee revised ANSI/ISA 60079-11 which has been processed and released as the 6^{th} edition. In reviewing this document, there were several changes but the most significant one was the reinstatement of all aspects of Group I and Group III equipment including all related portions of ANSI/ISA 60079-0, General Requirements. ISA also released an update to ANSI/ISA 60079-0 (sixth edition) to undo the editing that negated all requirements related to Group I. The latest version of the ANSI/ISA IS standard specifies maximum surface temperatures for the general case and then maximum surface temperature for small components for methane (there are no relaxations for coal dust). The general case allows surface temperatures up to 150C for coal dust and 450C for gases (methane). The temperature limit for coal dust is the same in both documents before testing is required but the temperature limit for gases is more conservative in the ANSI/ISA standard than the MSHA standard. The former requires testing when the surface temperature exceeds 450C as opposed to the latter requiring such testing when the temperature exceeds 530C.

The evidence presented above demonstrates that the relaxation of the temperature limits for small components is safe practice with a significant margin of safety and the effect on the probability of ignition comparing the ACRI2001 standard to the ANSI/ISA standard is negligible.

CDC-NIOSH-OMSHR REPORT

Evaluation of the Technical Basis for Specific Provisions of the ANSI/ISA Intrinsic Safety Standards

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7. Walsh, P., "Proposed Amendment to IEC 60079-11 Maximum Surface Temperature and Ignition Temperature 'Small Components' Group I Intrinsically Safe Equipment", 1996

Note: Items 1, 2, and 5 above are not attached being books or a major document. The remainder or excerpts from them is included as attachments to this report.