Protecting Miners from Electrical Arcing Injury

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***Abstract* - Electrical arcing injuries are the most common form of electrical injury in mining. MSHA data show that 381 "non-contact electric arc burn" injuries occurred in the mining industry from 1996 - 2005. A more detailed study of data from 1990-2001 showed that five types of apparatus - circuit breakers, conductors, nonpowered hand tools, electrical meters and test leads, and connectors and plugs were involved in two-thirds of the lost workday injuries. Many of the protections from electrical arcing injury available to workers in other industries stem from the application of National Fire Protection Association Standard 70E - *Standard for Electrical Safety in the Workplace* (NFPA 70E). NFPA 70E is a generally accepted industry guideline document, but excludes underground mining from its scope. Many of its practices and procedures, however, can be applied in the mining workplace to supplement the existing electrical safety requirements of Title 30 Code of Federal Regulations. This paper describes how NFPA 70E can be applied to mining workplaces *after* an analysis of the mine power system electrical arcing hazards has been completed (and Hazard/Risk Categories determined) using the tables from NFPA 70E or the calculation method as described in IEEE 1584. NFPA 70E can then be used to determine the levels and types of personal protective equipment (PPE) needed to protect miners against burn injuries. Appropriate lockout and tagout (LOTO) procedures for use in the mining industry are also described. Suggestions for better selection of electrically-rated hand tools are included. Recommendations for electrical meter selection and use based on transient withstand capability are also discussed.**

***Index terms* – arc, electrical arcing, PPE, burns, electrical shock, flame resistant, FR clothing, mining**

I. Introduction [1, 2]

Electrical injuries resulting from arc flash hazards are the most common form of electrical injury in mining. Fig. 1 shows that "non-contact electric arc burns" (also referred to as arc burns or flash burns) (381 lost workday cases) were the leading source of electrical injury in nearly every major sector of the mining industry in a NIOSH examination of MSHA data covering 1996 - 2005. Injuries from electrical arcs are a serious problem in many other industries, too. IEEE Standard 1584 [3] gives detailed guidance for the engineering analysis of arc flash hazards using one-line diagrams and protective device settings for a specific installation. Standard NFPA 70E [5] addresses electrical hazards that are commonly encountered in the workplace, including arc flash hazards, and makes specific recommendations for protecting employees from these hazards. NFPA 70E gives detailed guidance for working on live equipment (although this practice is discouraged), lockout and tagout procedures, translating arc flash analysis data into "Hazard/Risk Categories", and recommending specific clothing solutions to protect workers against serious burns. NFPA 70E also provides Hazard/Risk Category tables for specific electrical tasks that employees can reference during job planning when an engineering analysis of the arc flash hazard is unavailable. Underground mines are explicitly excluded from coverage by NFPA 70E. Underground mines, surface mines, and their associated mills and plants are subject only to Title 30 - Code of Federal Regulations (30 CFR) [6]. Parts 56, 57, 75, and 77 contain mining electrical safety provisions. 30 CFR does not explicitly require anything beyond rudimentary PPE for workers exposed to electrical arcing hazards. As the following statistics show, arcing injuries are a serious hazard in the mining industry, too. Miners could benefit from reduced injury incidence and severity by applying certain provisions of NFPA 70E.

An earlier NIOSH study of 836 electrical accidents covering the period from 1990-2001 produced key findings about "non-contact electric arc burns"; these are summarized below:

- 55% of arc burn injuries occurred in bituminous coal, 21% in stone and 10% in sand and gravel
- 42% of arc burn injuries occurred underground, 26% in mills or preparation plants, and 22% in surface operations
- Electricians (39%), mechanics (20%), preparation plant workers (6%), and laborers (5%) were the most often injured workers
- In 52% of the cases involving injury to "mechanics/ repairman" the victim was performing "electrical maintenance/repair"
- Electrical work activities were involved in more than two-thirds of the cases:
  - installation (2%)
  - maintenance (5%)
  - troubleshooting and repair (42%)
  - unspecified electrical work (22%)
  - failed in normal operation (19%)
  - Other (10%)

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[2] The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

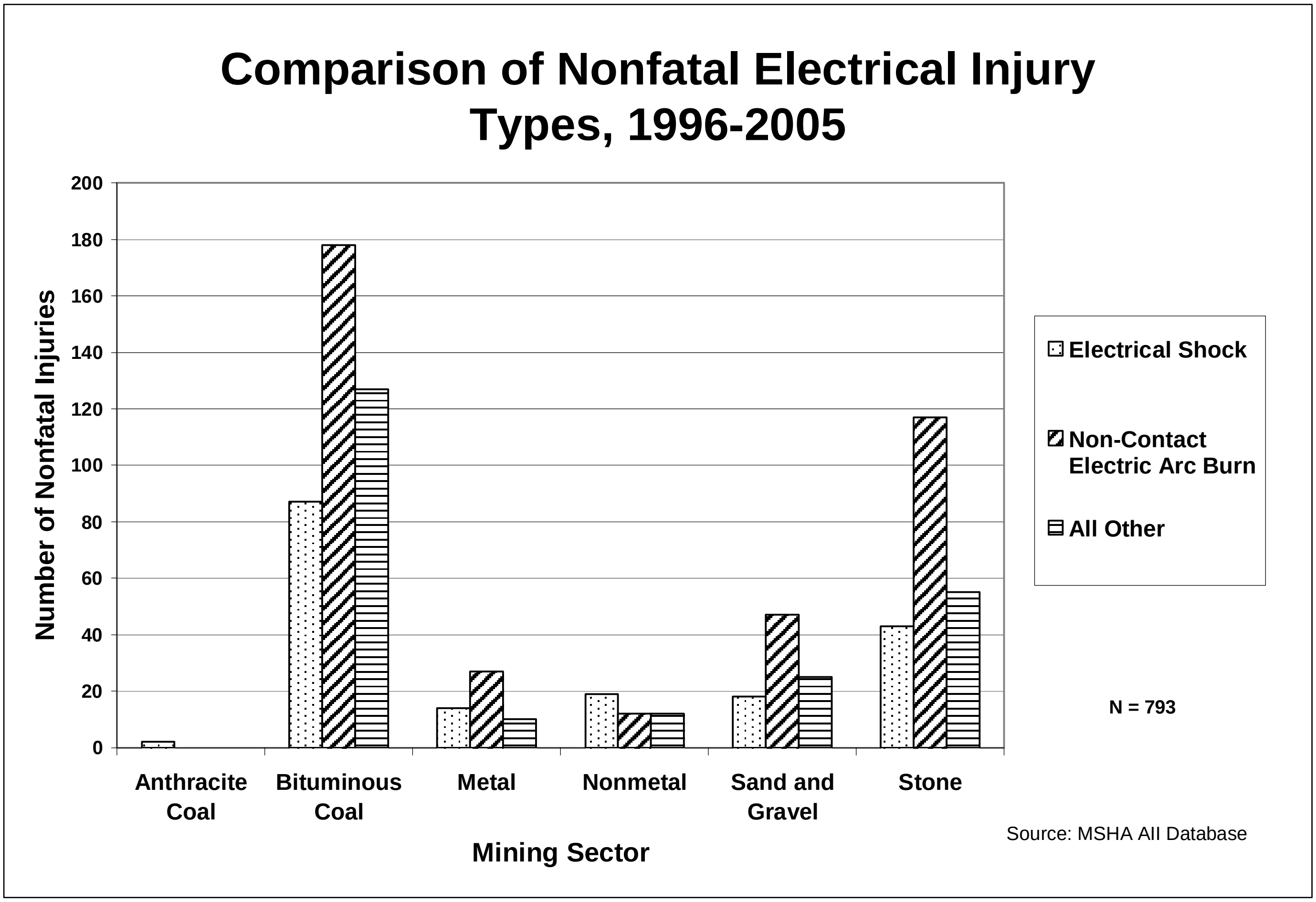

Figure 1. "Non-contact electric arc burns" outnumbered "electrical shock" injuries in every mining sector except Anthracite Coal and Nonmetal mining from 1996 to 2005.

- Two-thirds of lost work day accidents involved five electrical components:
  - circuit breakers (17%)
  - conductors (16%)
  - nonpowered hand tools (13%)
  - electrical meters and test leads (12%)
  - connectors and plugs (11%)

- 34% of the cases involved component failure:
  - 19% involved an electrical component that failed in routine operation

- Only 35% of cases (302 of 836 cases) reported voltage:
  - 84% (253 of 302 cases) occurred at less than 600 V
  - 2% occurred at 601-1000 V
  - 10% occurred at more than 1000 V

The remainder of this paper will discuss how miners can protect themselves from electrical injury and arc burn injury in particular. A measure of protection can be achieved by applying many of the concepts from NFPA 70E to the mining workplace. The information that follows assumes that the Hazard/Risk Category of the task has already been determined either from an engineering analysis of the mine power system or from an examination of Table 130.7(C)(9)(a) from NFPA 70 E.

II. Work Practices

A. Lockout and Tag Out (LOTO)

The preferred method of controlling electrical hazards is to establish what NFPA 70E calls an "electrically safe work condition" before commencing work.[3] This can be accomplished by properly locking out and tagging out the circuit. Many miners have been injured by contacting circuits that were not locked out or locked out improperly. NFPA

[3] NFPA 70E, Article 120.

Figure 2. A properly applied lock and tag. Note that the tag cannot be easily removed, contains the name of the person who applied it, and the date of the work.

70E devotes considerable attention to proper LOTO procedures. A "complex" LOTO procedure involves systems or workplaces where multiple energy sources feed equipment, multiple crews, locations, or employers are working on the system at the same time, different or unusual disconnecting means are required in a specific sequence, or the job will continue for more than one shift. A complex LOTO requires one qualified person to be in charge of the LOTO procedure and only that person will install or remove locks and tags.

The NFPA 70E LOTO procedure differs from the one described in 30 CFR Part 75.820. When a miner cannot remove their own lock (e.g., work extends beyond a single shift), MSHA allows another qualified person to remove a lock provided that the miner who installed it is told of the removal when they next report to work.

Fortunately, most mining LOTO procedures are "simple" LOTOs. This means that only one person works on a circuit, that circuit has only one energy source, and that the job will be completed within one shift. The steps in a simple LOTO are straightforward:

1. Wear appropriate PPE;
2. Deenergize the equipment;
3. Apply your lock to which *you* have the *only key*; keep the key in *your* pocket; apply your tag containing your name, the date, and warning others not to remove it;
4. Visually verify (if possible) that switch blades are disconnected [4];
5. Ensure that no "backfeeding" occurs from another circuit;
6. Release any stored energy;
7. Verify that the equipment cannot be restarted;
8. Test to ensure that the proper circuit is deenergized
    a. Using an appropriate meter on the correct setting, test the meter by measuring voltage on a known live circuit;
    b. Test the deenergized circuit for the presence of voltage between all conductors and between each conductor and ground;
    c. Retest for voltage on a known live circuit once again;
9. Ground circuit conductors, if induced voltages could be a problem;
10. Commence work;
11. Remove installed grounding conductors before reenergizing;
12. Wear appropriate PPE, then reenergize.

Fig. 2 is an example of a properly applied lock and tag.

B. Job Planning

NFPA 70E recognizes that some work must be performed live. Exceptions are generally allowed when a shutdown "introduces additional or increased hazards or is infeasible due to equipment design or operational limitations." [5] For example, an exception is allowed when a shutdown would interrupt ventilation to a hazardous area.

When work *must* be performed live, NFPA 70E suggests procedures beyond those described in 30 CFR[6] to protect miners against electric shock and arc flash injury. First, only qualified persons may perform live electrical work. Second, an "Energized Electrical Work Permit" should be obtained for the work.[7] The person requesting the live work must describe the job location, the work to be done, and justify in writing why the work cannot be deenergized or deferred until the next scheduled outage. In addition, the electrically qualified person doing the work is asked to: describe the job planning done for the task; explain what safety procedures will be employed; document the results of a shock hazard and arc flash hazard analysis; document the flash protection

[4] MSHA requires the use of visible disconnecting devices on low and medium voltage circuits (30 CFR 75.903) and on high voltage circuits (30 CFR 75.808).
[5] NFPA 70E -2004, Article 130.1.
[6] MSHA allows trouble shooting and testing tasks to be performed live when necessary (30 CFR 75.509).
[7] A sample Energized Electrical Work Permit is contained in Annex J of NFPA 70E.

boundary; describe the required PPE; explain how access to the work site will be restricted; document that a job briefing was conducted, and; concur that the work can be done safely. Management is required to review, approve, and sign each request.

A "Job Briefing and Planning Checklist" should be completed by those involved in the work. [8] This checklist prompts workers and supervisors to consider a number of important aspects of the job planning process such as identifying the hazards (voltage, "back-feeding" voltage sources, unusual work conditions, and protection boundaries), and to reexamine whether the task can be performed without the equipment energized. It reminds the workers about lockout and tag out procedures, proper voltage measurement verification of lockout and tag out, and considerations for emergency preparedness.

III. Personal Protective Clothing and Equipment

A. Establishing the Severity of the Electrical Arcing Hazard

The preferred method of establishing the severity of arcing hazards is through an engineering analysis of the power system using IEEE Standard 1584. Such an analysis will produce specific information regarding the available fault currents on the system. Using these available fault currents and a detailed knowledge of protective device clearing times, arc flash energies can be estimated in cal/cm^2 for specific points in the mine electrical system. NFPA 70E classifies electrical arcing hazards into Hazard/Risk Categories 0 through 4 using the level of incident arc energy predicted by the engineering analysis.

B. Flame Resistant Clothing

When a circuit cannot be deenergized to work on it, precautions must be taken against both electrical arcing and electrical shock injury. For arcing hazards, protections include flame resistant (FR) work clothing. Ordinary work clothing is usually made from 100% cotton, cotton-synthetic blends, or synthetic material alone. FR clothing is made from FR synthetic fabrics or FR cotton-synthetic blends. Some FR materials are inherently flame resistant while others are chemically treated. FR materials must meet the requirements of ASTM F-1506 [1], which defines their ability to self extinguish when controlled amounts of energy from an electrical arc is incident upon them. In addition, FR textile materials must resist the tendency of ordinary materials to "break open" during an electrical arc, exposing the wearer to further injury by having skin exposed directly to the electrical arc.

The ability of clothing or personal protective equipment (PPE) to withstand the energy from an electrical arc is called its Arc Thermal Performance Value [9] (ATPV) and is printed on FR clothing and PPE, usually on the label. Many users believe that FR garments sold as protection against arcing hazards will protect them from all injuries within the arc rating on the label. Such is *not* the case. The ATPV is the number of incident cal/cm^2 a FR garment can withstand while still offering its wearer a 50% chance of a sustaining no more than a second degree (curable) burn. Other PPE, such as face shields and full flash hoods are also characterized by their ATPV values and the meaning of the rating is the same.

Non-FR materials that melt when exposed to electrical arcing or flame, such as acetate, rayon, nylon, polyester, polypropylene, spandex, etc., should *never* be worn, even as under garments, to perform electrical tasks. Wearing non-FR garments made from these materials exposes the wearer to injury from both the initial electrical arc and from the continued melting and burning of the fabric directly on the wearer's skin.

Table 1 shows that as the energy available from an electrical arc hazard increases, the Hazard/Risk Category increases from 0 to 4. The need for FR clothing with higher ATPVs increases, as well. In addition, the need for other FR PPE (face shields, flash suit hoods, switching coats, full flash suits, etc.) increases as well. The need for FR clothing with higher ATPVs can be satisfied in several ways. First, clothing of heavier single layered FR fabric weights (in oz/yd^2) can be worn. Alternatively, multiple layers of FR clothing can be worn to achieve a higher ATPV. For example, donning FR coveralls over FR work clothing increases the overall ATPV of the clothing system. Simple addition of the ATPV values of individual layers of FR clothing gives a conservative estimate of the ATPV value of a clothing system. An accurate estimate of the ATPV for layered FR clothing may be available from the clothing manufacturer. For higher-level hazards, switching coats and multilayer flash suits can be worn to yield successively increasing ATPVs when worn over the basic FR pants and FR shirt.

C. Everyday Work Clothing for Mine Electrical Workers

Everyday wearable FR work clothing is available from several manufacturers in the form of pants or jeans and long sleeve shirts. Workers at risk for electrical arc exposure should wear only underwear that is 100% cotton. Never wear underwear containing synthetic materials.[10] Shirts must always be worn with the sleeves rolled down and neck

[8] A sample Job Briefing and Planning Checklist is contained in Annex I of NFPA 70E.

[9] ATPV is defined in ASTM F 1959-99.

[10] An incidental amount of elastic in the waistbands of non-melting underwear *is* allowed under NFPA 70E, Article 130.12 (c).

TABLE 1
HAZARD/RISK CATEGORIES AND THEIR ASSOCIATED ATPV AND CLOTHING REQUIREMENTS [11]

Hazard /Risk Category	Required Minimum Arc Rating (ATPV) (cal/cm^2)	Typical Protective Clothing Required
0	2*	Non-melting, flammable materials (i.e., untreated cotton wool, rayon, or silk, or blends of these materials) with a single fabric weight at least 4.5 oz/yd^2 (1 layer)
1	4	FR shirt and FR pants or FR coverall (1 layer)
2	8	Cotton underwear-conventional short-sleeved and brief/shorts plus FR shirt and FR pants (1 or 2 layers)
3	25	Cotton underwear plus FR shirt and FR pants plus FR coverall, or cotton underwear plus FR coverall (2 or 3 layers)
4	40	Cotton underwear plus FR shirt and FR pants plus multilayer flash suit
* See NFPA 70E-2004, Table 130.7 (C) (11) Protective Clothing Characteristics and Paragraph 130.7 (5)		

buttoned to provide the intended protection from electrical arcs. Shirts are available with ATPVs ranging from 4 to 8. The FR pants are available with ATPVs ranging from of 6 to 11. FR work jeans are available with ATPVs up to 20.

A typical work outfit consisting of a long sleeved shirt with an ATPV of 8 and work pants with an ATPV of 11 would provide everyday protections against electrical arcs up to Hazard/Risk Category 2. The addition of FR coveralls with an ATPV of 8 could be worn but the Hazard/Risk Category would remain at 2. Combined with appropriately rated face, eye, and hand protection this easily wearable outfit could protect a mine electrician against many common on-the-job electrical arcing hazards.

D. FR Clothing for Higher Hazard/Risk Categories

Hazard/Risk Category 3 (8-25 cal/cm^2) requires additional protective clothing to protect against burn injuries. Several clothing solutions are available. Two set of FR coveralls (each 11 cal/cm^2) worn over the everyday work outfit (8 cal/cm^2 shirt and 16 cal/cm^2 jeans) with an FR hood can increase the overall clothing system ATPV to cover arcing hazards in Hazard/Risk Category 3. Alternatively, a long sleeve undershirt (11cal/cm^2) plus the everyday work outfit plus one set of FR coveralls (11cal/cm^2) with an FR hood would also work. Hazard/Risk Category 4 requires the worker to wear cotton underwear, a FR shirt, FR pants, and a multilayer FR flash suit with FR hood.

TABLE 2
FREQUENCY OF BURN INJURY TO BODY PARTS EXPOSED TO ELECTRICAL ARCING.

Body Part	Frequency of Burn Injury
Right hand	67%
Right forearm	41%
Left hand	56%
Left forearm	34%
Face, neck, head	50%

E. Face and Eye Protection

When performing electrical maintenance and repair work, the hands, forearms, and face are usually positioned closest to the work. Consequently, these body parts often experience burn injury more often and, presumably more severely. One European guideline cites the frequency with which body parts sustained 1st, 2nd, or 3rd degree and higher injuries in electrical arcing accidents.[4] The results are shown in Table 2. It is a good practice to always wear safety glasses with side shields on the job. However, safety glasses do not protect the wearer from electrical arcing hazards. There are no arc-rated safety glasses on the market as of this writing. To protect workers from serious injury to the face, eyes, and neck areas NFPA 70E requires that employees wear nonconductive head and face protection when the danger of head injury exists from exposure to electric shock or electrical arcing hazards.[12] For Hazards/Risk Category 2, an arc-rated face shield with a minimum ATPV of 8 or more with wrap around guarding to protect not only the face, but also the forehead, ears, and neck, is required. (See Fig. 3) Alternatively, a flash suit hood with an ATPV of 8 or more could be worn. NFPA 70E also prohibits the use of face shields that are not arc-rated.[13] Wearing a face shield that is not arc-rated may present a greater danger of serious injury than not wearing a face shield. Face shields that are not arc-rated can melt and ignite during an electrical arcing event. The blast shockwave can then deform it back onto the wearer's face. It may continue to melt and burn on the wearer's face after the arc has been extinguished, causing injury even more severe than from the arc alone.

[11] Face, eye, hand, and other PPE are also required for complete protection. They were omitted here to clarify the discussion of clothing requirements. For other PPE requirements based on Hazard/Risk Category, see NFPA 70E Table 130.7(C)(10).

[12] NFPA 70E Article 130.7 (C)(3)
[13] NFPA 70E Article 130.7(C)(13)(b)

Figure 3. This worker is dressed for Hazard/Risk Category 2. He is wearing a hooded jacket and bib-overalls over FR work clothes, a combination face shield/hardhat over safety glasses, and voltage-rated gloves with leather protectors.

In addition, always wear ANSI-rated safety glasses or goggles under a face shield.

Three issues regarding face shields are problems for mine electricians. One is that the use of a face shield reduces transmitted light, making an underground workplace appear even darker. One possible solution is to use auxiliary lighting when working in electrical arc-prone situations underground. Newer face shield designs can now transmit about 70% of the available light to the wearer's eyes. Another problem is that available face shields/hard hat combinations do not accommodate the standard miner's cap lamp. Manufacturers of mine safety equipment should produce an arc-rated face shield/mine helmet combination to overcome this barrier. Finally, arc-rated face shields distort the wearer's perception of color to some extent. Newer designs have less color distortion, but still present problems for tasks requiring good color vision.

When an employee will be exposed to electrical arcing hazards determined to fall within Hazards/Risk Category 3, NFPA 70E requires employee head and face protection to be provided by a flash suit hood with an ATPV equal to or greater than the anticipated hazard.[14] When Hazards/Risk Category 4 hazards are present, a full flash suit and an

TABLE 3
VOLTAGE-RATED GLOVE DESIGNATIONS [15]

Class	Maximum Working Voltage (Vac)
00	500
0	1,000
1	7,500
2	17,000
3	26,500
4	36,000

appropriately rated flash hood, as described in Table 130.7(C)(10), are required.

F. Hand Protection

Table 2 shows that the hands are the most often injured body parts in an electrical accident. They are usually the body parts closest to an electrical arcing fault when it occurs. For protection from electrical arcing hazards alone, the minimum hand protection recommended is a pair of heavy-duty leather (more than 12 oz/yd^2) work gloves for arcing hazards up to Hazard/Risk Category 2. For Hazard/Risk Category 3 or 4, arc-rated gloves made from FR materials should be used.

When working where electrical shock hazards are present, voltage-rated gloves must be worn. As shown in Table 3, voltage-rated gloves are available from Class 00 (500 Vac) through Class 4 (36,000 Vac). A non-insulating inner liner can be worn next to the skin for moisture absorption and general comfort. Next, a rubber insulating glove covers the liner. Finally, a leather protector glove is worn over the rubber insulating glove to protect it from punctures, cuts, and abrasions in use. The rolled top of the rubber insulating gloves must extend up the forearm beyond the top of the leather protectors by at least 0.5-in for Class 00 or 0 gloves and by 1, 2, 3, and 4-in for Class 1, 2, 3, and 4 gloves, respectively. *Never* perform electrical work using the rubber gloves without the leather protectors. The rubber gloves alone are too susceptible to punctures and cuts. In addition, never wear the liners or the leather protectors alone without the rubber insulating gloves as protection from electrical shock.

The rubber insulating gloves must be inspected before each use by inflating them and looking and listening for air leaks from pinholes, cracks, etc. Glove inflators are available for this purpose or the inflation can be done manually. Leather protector gloves must also be inspected for imbedded wire strands, metal particles, or other material that could

[14] NFPA Table 130.7(C)(10)

[15] Excerpted from ASTM F 496-02a *Standard Specification for In Service Care of Insulating Gloves and Sleeves*, Table 1, p2, available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

Figure 4. Hand tools electrically rated for 1000Vac can significantly reduce the likelihood of starting an electrical arc if accidentally dropped into equipment.

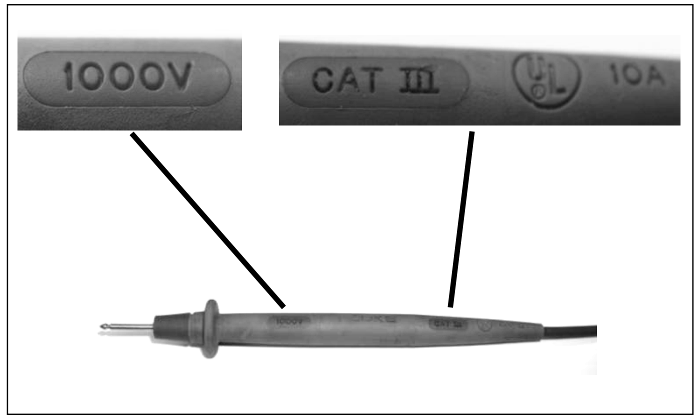

Figure 5. Test leads are marked with their CAT ratings. Make sure that the CAT rating of your test leads matches that of the multimeter you are using.

compromise their ability to protect the rubber insulating glove underneath.

IV. Other Equipment

A. Electrically-rated Tools

About one in eight electrical arcing accidents happened when non-powered hand tools such as screwdrivers, wrenches, pliers, etc., accidentally bridged two phase conductors or a single phase to ground while performing live work. Insulated hand tools are available that are ASTM rated [2] for 1000 working volts AC and have a minimum of metal exposed with which to bridge nearby conductors. They are impact resistant and flame resistant. At least one brand of tools has two layers of insulation; a yellow inner layer and an orange outer layer. If the yellow insulating layer becomes visible, the tool's insulation rating has been compromised and it should be discarded. Complete tool sets are available including open end and box wrenches, screwdrivers, pliers, cutters, and ratchet sets. (See Fig. 4) *Never use ordinary uninsulated hand tools for live work.*

B. Meters and Test Leads

About one in eight electrical arcing accidents happened while using a multimeter. One common type of accident involves taking measurements while using the wrong multimeter settings. For example, attempting to measure voltage with the test leads plugged into the current terminals can cause a low resistance fault across the source voltage. Newer multimeters beep to warn of this situation and are protected with a fuse that can clear a high-energy fault; older multimeters or inexpensive, non-professional multimeters may not be properly fuse protected and could seriously injure the user. *Never replace a blown multimeter fuse with anything other than an exact replacement fuse.* The improper use of a 600-1000V multimeter to measure voltages higher than 1000Vac is a common theme in mine electrical accidents. The voltage rating printed on the multimeter is the maximum voltage it can measure. Attempting to measure voltages beyond the multimeter and test lead ratings often leads to an explosion, with accompanying shock and burn hazards. Always double check to ensure that your multimeter and test leads are voltage-rated for the circuit you want to measure. [16, 17]

Multimeters are often used in mining to measure electrical parameters on motors, switchgear and 480-600V three-phase ac circuits near their connection to utility power. Newer multimeters for use at or below 1000V are transient rated. This transient rating defines Overvoltage Installation Categories I through IV, often abbreviated as CAT I, CAT IV, etc. A mine power distribution system can be divided into categories based on the likelihood of the presence of high-energy switching or lightning transients. A multimeter with a higher CAT number is needed when working on a section of the mine electrical system close to the utility connection, where higher-energy transients are more likely to occur. A higher CAT rating (e.g., CAT III, CAT IV) denotes a multimeter designed to be more resistant to high-energy transients. Multimeters used in mining applications should be CAT-rated for CAT III or IV. Test leads are also an important consideration in multimeter safety. In addition to using multimeters with the proper CAT ratings, it is important to use test leads with at least the CAT rating of the multimeter. The CAT rating is listed on the test lead. (See fig. 5) Most professional multimeters are supplied with test

[16] The interested reader should go to the Fluke Corporation website http://us.fluke.com/usen/apps/Safety/Default.htm for a more detailed discussion of multimeter Category ratings.

[17] Mention of specific products, services, or manufacturers does not imply endorsement of those products, services, or manufacturers by NIOSH, CDC, or the U.S. Government.

leads that match the CAT rating of the multimeter. In addition to their heavier insulation, these test leads have a minimum of exposed metal at the probe tips to prevent bridging conductors if the probe slips. In addition, a finger guard is used to prevent fingers from accidentally sliding onto the exposed metal of the probe tip. *Never* use uninsulated alligator clips to make measurements on live electrical connections.

Whenever possible, use straps or hangers to attach the multimeter to a nearby grounded metal surface. This leaves both hands free to manipulate test probes and to make measurements. It also gets the multimeter out of the user's hands in the event of a malfunction.

V. Summary

Although IEEE 1584 and NFPA 70E provide guidance in other industries, they have yet to find wide application in the mining industry. Many of the protections from electrical arcing afforded other workers could easily be used by miners, too. It is important to thoroughly examine decisions to work live and rigorously prepare for such work via a more formal live work permitting system. A thorough knowledge of LOTO is also important. By applying a series of steps from NFPA 70E, LOTOs can be performed quickly and safely. Supplementing the existing electrical safety provisions of 30 CFR with arc-rated FR clothing and face, eye, and hand protection could mitigate or prevent many of the electrical arcing injuries in the mining industry. After the Hazard/Risk Category is determined, either by calculation or by use of NFPA Table 130.7(C)(9)(a), appropriate clothing can be determined from Table 130.7(C)(11) and other PPE can be determined using Table 130.7(C)(10). Proper application of FR clothing and other arc-rated PPE is crucial to miner safety, especially for those who routinely work with electricity. In addition, the appropriate selection and use of tools and CAT-rated meters is also important to electrical safety.

References

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[5] NFPA Standard 70E-2004, *Standard for Electrical Safety in the Workplace*, available from NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471

[6] U.S. GPO, *Title 30-Code of Federal Regulations – 2006* (30 CFR) is available in print from the Government Printing Office at 888-293-6498 or in electronic format at www.gpoaccess.gov/nara .