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DEPARTMENT OF LABOR

Occupational Safety and Health Administration

29 CFR Parts 1910 and 1926

[Docket No. OSHA-S215-2006-0063]

RIN 1218-AB67

Electric Power Generation, Transmission, and Distribution; Electrical Protective Equipment

AGENCY: Occupational Safety and Health Administration (OSHA), Labor.

ACTION: Final rule.

SUMMARY: OSHA last issued rules for the construction of transmission and distribution installations in 1972. Those provisions are now out of date and inconsistent with the more recently promulgated general industry standard covering the operation and maintenance of electric power generation, transmission, and distribution lines and equipment. OSHA is revising the construction standard to make it more consistent with the general industry standard and is making some revisions to both the construction and general industry requirements. The final rules for general industry and construction include new or revised provisions on host employers and contractors, training, job briefings, fall protection, insulation and working position of employees working on or near live parts, minimum approach distances, protection from electric arcs, deenergizing transmission and distribution lines and equipment, protective grounding, operating mechanical equipment near overhead power lines, and working in manholes and vaults.

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Protection from flames and electric arcs.

Paragraph (g) of the final rule addresses protective clothing and other personal protective equipment worn by employees exposed to hazards posed by flames and electric arcs. OSHA revised the title of paragraph (g) in the final rule to "Protection from flames and electric arcs" to reflect more accurately that this paragraph addresses forms of protection other than protective clothing. (For the same reason, OSHA included language in final paragraph (g)(5) to be clear that that provision requires both protective clothing and other protective equipment.) In the 1994 rulemaking on §1910.269, OSHA determined that electric power generation, transmission, and distribution workers face a significant risk of injury from burns due to electric arcs (59 FR 4388). In that rulemaking, OSHA also concluded that certain fabrics increase the extent of injuries to employees caught in an electric arc or otherwise exposed to flames (59 FR 4389). Therefore, the Agency adopted two rules: (1) existing §1910.269(l)(6)(ii), which requires that employers train employees exposed to flames and electric arcs in the hazards related to the clothing that they wear, and (2) existing §1910.269(l)(6)(iii), which requires employers to ensure that employees exposed to flames or electric arcs do not wear clothing that, when exposed to flames or arcs, could increase the extent of injuries sustained by the workers. A note following existing §1910.269(l)(6)(iii) indicates the types of clothing fabrics that the §1910.269 rulemaking record demonstrated were hazardous when worn by employees exposed to electric arcs, namely, acetate, nylon, polyester, and rayon. The note explains that the standard prohibits the use of clothing made from these types of fabric unless the employer can demonstrate that the fabric was treated to withstand any relevant conditions or the employee wears it in a manner that eliminates the hazard.

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Need for protection from electric arcs and hazard assessment. Even after existing §1910.269(l)(6) became effective,[275] employees continue to sustain burn injuries when working on energized lines and equipment. In the preamble to the 2005 Subpart V proposal, OSHA noted that, from January 1, 1990, to October 30, 1994, there were 46 accidents investigated by Federal OSHA or State-plan occupational safety and health agencies involving burns addressed later by §1910.269(l)(6)(iii) (70 FR 34866). These 46 accidents resulted in 71 total injuries (*id.*). Averaged over this period, there were 9.5 accidents and 14.7 injuries per year. Also in the preamble to the 2005 proposal, OSHA noted that, from November 1, 1994 (when §1910.269(l)(6)(iii) became effective), to December 31, 1998, there were 17 relevant accidents resulting in 26 injuries (*id.*). Averaged over this period, there were 4.0 accidents and 6.2 injuries per year. Thus, while the clothing rule in §1910.269 appeared to reduce the number of relevant accidents and injuries by more than 50 percent, OSHA believed that the remaining risk of burn injury was still serious and significant when it published the proposal in 2005.

OSHA based its belief that the risk of burn injury was serious and significant on two assumptions. First, the accidents identified in the 2005 preamble represented only a small fraction of the accidents that occurred during this period because employers must report to the Agency only accidents involving a fatality or three or more hospitalized injuries (29 CFR 1904.39(a)). In this regard, OSHA generally does not investigate accidents that are not reported by employers (see OSHA directives CPL 02-00-150 and

[275]The original *Federal Register* notice promulgating §1910.269 set an effective date for §1910.269(l)(6) of May 31, 1994 (59 FR 4320). However, OSHA subsequently stayed the enforcement of §1910.269(l)(6)(iii) until November 1, 1994 (59 FR 33658; June 30, 1994).

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CPL 02-00-094). Therefore, OSHA does not investigate, or have documentation of, most injury-producing accidents, even serious ones, so data on these accidents are not included in the information that OSHA reviewed. Second, the reported burn injuries identified in the 2005 preamble were extremely serious and costly. Eighty-four percent of the burn injuries were fatalities or required hospitalization (70 FR 34866). Eighty-seven percent of the accidents for which the report lists the severity of the injury involved third-degree burns (*id*.). Such burns are extremely painful and costly, typically requiring skin grafts and leaving permanent scars.

Dr. Mary Capelli-Schellpfeffer testified as OSHA's expert witness on the subject of protecting workers from the hazards posed by electric arcs. Dr. Capelli-Schellpfeffer received her medical degree from the University of Florida in 1982. She also holds a master's degree in public administration. Following her postgraduate medical training and several years in private practice, Dr. Capelli-Schellpfeffer served as the medical director of Wisconsin Energy Company, which included an electric utility and a nuclear power generating plant. She joined the University of Chicago, Department of Surgery Faculty, in 1993, where she served as the director of the hyperbaric unit of the University of Chicago Burn Center. Since 1999, she has worked as a consultant, researcher, and teacher, and has treated employees in outpatient clinical settings. She is licensed as a physician in Wisconsin, Illinois, and Maryland, and she is board certified by the American College of Preventive Medicine. Dr. Capelli-Schellpfeffer is also a member of the American College of Occupational and Environmental Medicine and a fellow of IEEE (Tr. 175 – 177).

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In her prepared testimony for the 2006 public hearing, Dr. Capelli-Schellpfeffer described the physical properties of an electric arc and possible injury following exposure to an arc as follows:

> [A]n electric arc exposure in a 480 V installation with 22.6 kA available current is … captured on video from a high voltage test laboratory.… In the … test, data results showed peak monitored temperature exceeded 225 degrees C in 10 ms at the mannequin's hand, and at the mannequin's neck at 120 ms. Cooling of the hand to 70 degrees C required more than 2500 ms.
>
> The injuries that accompany high temperature exposures at the body surface are commonly referred to as skin burns. High temperature exposures that occur volumetrically, or that distribute ***within*** the body's tissues, are also called burns. The term ***burn*** generally refers to a physico-chemical change in the human tissue.
>
> For example, most people are familiar with the appearance of a superficial sunburn, and how painful this can be. As the skin's appearance changes more severely, the burn trauma is more profound, and can affect other organ systems. When skin changes are irreversible and irreparable, the trauma is severe.
>
> Other organs beside the skin can be burned. The mechanism or way organ injury unfolds in response to temperature is again sensitive to the temperature peak, duration, and biophysical processes.
>
> Additionally, the form of energy which creates the temperature rise can influence the injury, once more because of biophysical processes. For example, temperature change in the eye and recognition of the resulting injury from conductive heat exposure (like a piece of molten metal on the cornea) will be different than the injury from a radiation exposure (like UV light).
>
> The latent heat of melting subsequent to an electric arc can also serve as an ignition hazard for clothing. This means that along with the hazard from an arc's heat burning the skin, there is additional possibility of severe harm from the arc burning up clothing which lies against the skin. Burning clothing against the skin creates damage to the skin through conductive heating for the extended time which might be necessary to extinguish the clothing and start cooling.
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> * * *
>
> [T]est results illustrated the high degree of variability in electric arc faults and led to excerpts of video images into time-lapsed photographs. The test results also provided exposure data. Finally, the stop action frames of video recordings permitted visualization of the dynamic changes in the tests involving the mannequin worker.

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> Of particular note in the stop action frames of video recordings is the explosive speed and "blast" character of electric arcs. These images allow for the viewing of a destructive plasma ball, flames, and waves of air, smoke, and other gases.
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> The heating from the sub-second thermal expansion of air and vaporization by sublimation of metallic conductors leads to pressure waves, referred to as the "thermo acoustic effect" of an electric arc.
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> * * *
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> [A picture] illustrates the extent of injury that can follow an electric arc exposure. Eyes, ears, face, skin, limbs, and organs are affected. Basic bodily function, including the ability to breath[e], eat, urinate, and sleep are completely changed. For this patient, initial medical treatment cost more than $650,000, including five surgeries; $250,000 for reconstructive surgeries for five subsequent admissions; and $250,000 for [5] years of rehabilitation including over 100 physician visits and numerous therapy sessions. These costs represent only direct medical expenditures, without inclusion of indirect employer and family costs …. [Ex. 0373; emphasis included in original]

Dr. Capelli-Schellpfeffer's testimony reveals the power and injury-producing effects of electric arcs. She also highlights the potential extent and costs of these injuries.

OSHA's existing clothing requirement in §1910.269 does not require employers to protect employees from electric arcs through the use of flame-resistant (FR) clothing. It simply requires that an employee's clothing do no greater harm. Because the remaining risk to power workers from electric arcs is serious, the Agency proposed to revise the standard to require the use of flame-resistant clothing, under certain circumstances, to protect employees from severe burns. As OSHA noted in the preamble to the proposal (70 FR 34866), the electric power industry is beginning to recognize this need, as evidenced by the many employers that provide flame-resistant clothing to employees (see, for example, Ex. 0080), in ASTM standards that provide for arc ratings of protective

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clothing[276] (see, for example, Exs. 0061, 0065, 0131, 0326), and by the adoption of protective-clothing requirements in the 2007 NESC[277] (Ex. 0533). The National Fire Protection Association also recognizes the need to protect employees working on energized equipment from the hazards posed by electric arcs (see, for example, Ex. 0134).

When OSHA promulgated §1910.269, there were no standards for clothing to protect employees from the thermal hazards resulting from electric arcs. Since then, ASTM adopted such standards (see, for example, Exs. 0061, 0065, 0131, 0326). These standards ensure that clothing does not ignite and that it is rated to provide protection against a specific level of heat energy. Manufacturers label apparel meeting the ASTM standards with the amount of heat energy that the clothing can absorb under laboratory test conditions without letting through sufficient heat to cause a second-degree burn.[278] Such clothing currently is widely available in ratings from about 4 cal/cm^2 to over 50 cal/cm^2 (Tr. 412). In general, the higher the rating, the heavier the clothing; however, lighter fabrics now provide a level of protection equivalent to heavier fabrics used in the past (Tr. 440).

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[276]ASTM also has standards for other arc-protective equipment, including ASTM F2178-08, *Standard Test Method for Determining the Arc Rating and Standard Specification for Face Protective Products*.

[277]The 2012 NESC also contains protective-clothing requirements.

[278]OSHA explains the arc rating for clothing in the summary and explanation for final paragraph (g)(5), under the heading *Selecting arc-rated protective clothing and other protective equipment*, later in this section of the preamble.

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Some rulemaking participants generally supported OSHA's proposal to require the use of FR clothing[279] in certain circumstances. (See, for example, Exs. 0155, 0230, 0235, 0241, 0505; Tr. 895 – 897.) IBEW, ESCI, and the Independent Electrical Contractors, among others, supported FR clothing requirements (Exs. 0155, 0230, 0241, 0505; Tr. 895 – 897). ORC voiced general support for the proposal's approach to arc-flash protection, commenting:

> ORC generally supports the proposed requirements to protect employees from the thermal hazards of electric arcs. Assessing the potential for employee exposure to hazards from flames or electric arcs is appropriate for employees working with or near energized equipment and where their work clothing could be ignited directly by molten metals or electric arcs or by flammable materials ignited by an electric arc. Prohibiting the wearing of clothing that could melt or ignite and requiring the wearing of flame-resistant and appropriate arc-rated clothing based on the extent of the hazards present are also appropriate. [Ex. 0235]

Many electric utility representatives generally opposed the proposed requirements for protection from electric arcs. (See, for example, Exs. 0177, 0183, 0202, 0220, 0227, 0233, 0238, 0401; Tr. 371 – 374, 1093 – 1104, 1184 – 1185.) Some of these rulemaking participants suggested that the requirements in existing §1910.269 were sufficiently protective and that there was insufficient evidence of a need to adopt more protective requirements. (See, for example, Exs. 0177, 0181, 0227.) For instance, Consumers Energy stated that, in its experience, existing §1910.269(1)(6)(iii) "has been largely

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[279]The final rule requires arc-rated clothing (which also is flame-resistant) in some circumstances and FR clothing in others. When the distinction is unimportant, as when discussing general comments on the need for protective clothing, OSHA uses the term "FR clothing," even though the final rule may require that clothing also be arc rated. For a detailed explanation of the difference between FR clothing and arc-rated clothing, see the summary and explanation for final paragraph (g)(5), under the heading *Selecting arc-rated protective clothing and other protective equipment*, later in this section of the preamble.

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effective" (Ex. 0177). Some commenters argued that the accidents that occurred were the result of employees violating safety-related work rules. (See, for example, Exs. 0152, 0238.) For instance, Mr. Frank Owen Brockman with Farmers Rural Electric Cooperative Corporation commented: "Most people are … injured not by arcs and their heat, but by not following the simple, most basic rules" (Ex. 0401).

OSHA acknowledges that the adoption of existing §1910.269 in 1994 led to a reduction in the number (and potentially the severity) of burn and other injuries incurred by power line workers exposed to electric arcs. However, the Agency concludes that existing §1910.269 has not been sufficiently protective in preventing these injuries.

As noted earlier, the 6.2 injuries per year that OSHA identified as being caused by electric arcs represent only a small fraction of such injuries experienced by electric power generation, transmission, and distribution workers. Moreover, the vast majority of the injuries OSHA identified are extremely serious, such as the accident described in Dr. Capelli-Schellpfeffer's testimony.

OSHA's final regulatory analysis estimates that there are 444 serious injuries occurring each year during work addressed by the final rule. This estimate was derived by multiplying the 25 serious injuries actually reported annually over the period examined by a specified correction factor to account for undercounting. (See Section VI, Final Economic Analysis and Regulatory Flexibility Analysis, later in the preamble to the final rule.) Multiplying the 6.2 reported serious arc-related injuries by the ratio of 444 estimated injuries to 25 reported injuries yields an estimate of 110 serious arc-related injuries still occurring each year. As noted earlier, the vast majority of these injuries involve third-degree burns.

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Existing §1910.269 requires extensive training in electrical safety-related work practices, and evidence in the record indicates that workers covered by this final rule receive extensive training in these practices and are highly qualified to perform electric power generation, transmission, and distribution work. Mr. Albert Smoak with Southwestern Electric Power Company stated, "We have a very extensive apprentice program. And so we spend lots of money doing that. Our apprentices are very well trained" (Tr. 1229). Mr. William Mattiford of Henkels & McCoy testified, "Employees are trained either by Henkels and McCoy or other construction companies or have undergone extensive training in a certified apprenticeship program" (Tr. 1318 – 1319). Similar statements appear elsewhere in the rulemaking record. (See, for example, Tr. 1238 – 1239.) As the data show, however, serious arc-related incidents continue to occur during work covered by this final rule. Even Mr. Brockman recognized that "in the majority of [accidents], the fatality involved [a] worker who had been appropriately trained for the exposure" (Tr. 1278).

It would be contrary to the purposes of the OSH Act for the Agency to set standards based on an expectation that there will be perfect compliance with work-rule requirements. To be effective, such work-rule provisions rely, in part, on employee compliance with employer work practices. Because there will always be occasional instances of noncompliance with work rules, OSHA standards incorporate secondary protective measures. Moreover, arcs can occur as a result of circumstances that work rules cannot control. For example, electric arcs can result from accidents, such as an

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employee's dropping a tool onto energized parts (Ex. 0004[280]). According to Dr. Capelli-Schellpfeffer, other causes of electric arcs on electric utility systems include transient overvoltage disturbances (such as lightning, switching surges, arcing ground fault in ungrounded systems), mechanical breaking, cracking, loosening, abrading or deforming of static or structural parts, and shorting by animals (Ex. 0373). These types of electric arcs generally do not result from poor work practices. Exhibit 0004 describes 100 accidents involving electric arcs. More than 10 percent of those accidents involved equipment failure or internal faults.[281] Dr. Capelli-Schellpfeffer testified about one of the reasons for this type of event:

> There is more available power in the electric system, and the higher availables put more stress, electromechanical stress, on the infrastructure, at the same time that the infrastructure that we have installed is mature. It is aging. And so there is a transition in the experience of the power systems from fairly low levels of available power and a relatively young infrastructure from the time of the 1950s and '60s, to where we are today at the beginning of the 21st century where the availables are orders of magnitude higher, and the infrastructure is far more mature. [Tr. 205 – 206]

IBEW explained:

> Arcs can occur for reasons totally independent of the conduct of employees or the utilities or contractors. Thus, arcs can result from the presence of rodents, changes in mechanical properties, environmental conditions or the amount of stress that increasing amounts of available power are putting on the aging infrastructure. [Tr.] 205, 207. Arc events are complicated and variable, and no one strategy for preventing or protecting against them will be "maximally protective." Moreover, whatever the reason for an arc flash, the fact is that they occur in the electrical transmission and distribution industry, and there are measures that can be taken to

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[280]See, for example, the accident described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=201841061.

[281]See the 12 accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=201340395&id=170749873&id=170632699&id=170762769&id=14343594&id=170238109&id=170891899&id=170358428&id=170888259&id=170727697&id=14241863&id=170193353.

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> minimize the hazard they pose to employees. As Dr. Capelli-Schellpfeffer noted, employee protection requires a "multifactorial approach," [Tr.] 210, which includes the use of FR clothing so that if all else fails, employees will remain protected. [Ex. 0505]

The Agency, thus, continues to believe that further reductions in the number and severity of arc-flash-related injuries will result from adopting requirements that provide protection from electric arcs in a way that supplements the existing requirements in §1910.269 designed to prevent electric arcs and the ignition of clothing when arcs do occur. OSHA concludes that, under existing §1910.269 and subpart V, the risks associated with electric arcs warrant additional protection for employees.

The Agency does agree with APPA, however, that protective clothing "is not a comprehensive solution to eliminating fire related injuries in [the electric utility] industry" (Ex. 0504). Paragraph (g) of the final rule protects employees in case an electric arc occurs in spite of other provisions in the final rule designed to prevent them from happening in the first place.

The National Association of Manufacturers (NAM) recommended that, even if the Agency found that there is a significant risk of arc-flash burns for activities covered by this final rule, it should state clearly that no findings indicate whether there is significant risk for activities outside the scope of the final rule (Ex. 0222). The association maintained that §§1910.132 and 1926.95 do not presently require arc-flash hazard assessments or arc-rated clothing and that there is no justification for citations under those standards or the general duty clause. NAM also recommended that the Agency instruct its enforcement personnel not to issue such citations.

The risk findings OSHA makes in this preamble regarding hazards posed by electric arcs address only the types of work covered by this final rule. However, some

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existing general industry and construction standards already address these hazards. For example, §1910.335(a)(2)(ii) requires the use of protective shields, barriers, or insulating materials "to protect each employee from shock, burns, or other electrically related injuries while that employee is working . . . *where dangerous electric heating or arcing might occur*" (emphasis added). Furthermore, §1926.95(a) requires personal protective equipment "wherever it is necessary by reason of hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation, or physical contact." Also, the generally applicable PPE provisions for both general industry and construction—§§1910.132(a) and 1926.95(a)—specifically mention "protective clothing" as one form of required protection. The Agency described its enforcement policy relating to the protection of employees from electric-arc hazards in certain situations not covered by this final rule in several letters of interpretation. (See, for example, the November 14, 2006, letter to Ms. Joanne Linhard and the February 29, 2008, letter to Mr. Brian Dolin.[282])

Several commenters argued against the proposed requirements for arc-protective clothing on the grounds that it is expensive and uncomfortable. (See, for example, Exs. 0158, 0183, 0202, 0229, 0233, 0239.) For instance, NRECA commented:

> Data so far suggest that arc protective clothing is expensive and is uncomfortable to wear, especially in hot and humid climates. Of course, the discomfort in wearing arc protective clothing is largely because it must act as a heat shield and, therefore, it is inherently bulky. [Ex. 0233]

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[282] The Dolin letter is available at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=25973.

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OSHA finds that the costs associated with the requirements of paragraph (g) of the final rule are commensurate with the benefits resulting from those requirements. (For a detailed response to this issue, see the discussion of comments on balance of risk and costs in employing protective equipment to prevent arc-related burns in Section VI, Final Economic Analysis and Regulatory Flexibility Analysis, later in the preamble to the final rule.)

As explained later in this section of the preamble, OSHA determined that the PPE required by paragraph (g) of the final rule is not likely to be unduly uncomfortable for employees to wear. In any event, the Agency does not believe that discomfort alone would justify deleting §1926.960(g) from the final rule. Complaints that PPE is uncomfortable have been common throughout the Agency's history. For example, employees have complained that hard hats and eye protection are too uncomfortable to wear. (See, for example, *I.T.O. Corp. of New England v. OSHRC*, 540 F.2d 543, 546 (1st Cir. 1976), noting "employee complaints that the [hard] hats created minor inconveniences e.g., because they were too heavy, too light, too hot, or too cold"; and *Lewis County Dairy Corp.*, 2006 WL 3247249, at *10 (03-1533, 2006) (ALJ), noting that "[the plant manager] knew that employees did not always wear eye protection and that it was difficult to get them to do so as they found it uncomfortable.") In this rulemaking, the tree trimming industry complained that employees find body harnesses uncomfortable. (See, for example, Exs. 0174, 0200, 0219.) Although OSHA generally advises employers to take the comfort of protective equipment into consideration when selecting appropriate protective items for their employees, the Agency concludes that the potential for complaints about comfort does not outweigh the strong evidence that there is

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a safety need for employees covered by this final rule to use PPE when exposed to electric-arc hazards.

Paragraph (g)(1) of the final rule, which is being adopted without substantive change from the proposal, requires the employer to assess the workplace to identify employees exposed to hazards from flames or electric arcs.[283] This provision ensures that the employer evaluates employee exposure to flames and electric arcs so that employees who face such exposures receive the required protection. Because final §1926.960 applies to work performed on or near exposed, energized parts of electric circuits, employers do not need to conduct assessments under paragraph (g)(1) for employees who do not perform such work. However, until the employer ensures the complete deenergization of a line or part of an electric circuit following the procedures required by final §1926.961, including any required testing and grounding, the line or part must be considered and treated as energized as required by final §1926.960(b)(2). Also, final paragraphs (g)(2) through (g)(5) protect employees only from the thermal hazards posed by flames and electric arcs. Therefore, if the hazard assessment required by paragraph (g)(1) shows employee exposure to other hazards, then other standards, such as §§1910.132(a) and 1926.95(a), may require the employer to provide PPE for those hazards. (See the discussion under the heading *Protecting employees from flying debris from electric arcs*, later in this section of the preamble.)

[283]Under paragraph (g)(1), employers need not identify employees by name. The required identification can also be occupation based, task based, or location based provided that each employee exposed to hazards from flames or from electric arcs receives the protection that paragraph (g) requires.

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Final paragraph (g)(1) requires the employer to assess the workplace to identify employees "exposed to hazards from flames or from electric arcs." A few commenters requested that OSHA define this phrase in the final rule (Exs. 0170, 0222, 0237). These commenters argued that simply operating electric equipment, such as a disconnect switch in an electrical box, does not pose a significant risk of injury from an electric arc. For example, the American Forest & Paper Association stated these concerns as follows:

> [W]e are concerned that the language of proposed Sections 1910.269(l)(11) and 1926.960(g) could have unintended consequences if interpreted to apply to employees not exposed to a significant risk…
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> * * *
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> [W]e do not believe the individual who opens or closes the electrical disconnect on an enclosed electrical box or panel with the cover on/closed would be **exposed** to a significant risk of harm from arc flash hazards, but that is not clear from the proposed regulatory text or the preamble. A contrary interpretation would involve a huge increase in the cost of both the proposed standards and their potential extension outside the Electric Power Sector. [Ex. 0237; emphasis in original; footnote omitted.]

If the employer properly installs and maintains enclosed equipment and if there is no evidence of impending failure, the risk that an electric arc will occur is low enough that the Agency would not deem there to be exposure to electric-arc hazards.[284] For the purposes of final paragraph (g), OSHA will consider an employee "exposed" to electric-arc hazards whenever there is a reasonable likelihood that an electric arc will occur in the employee's work area. The Agency considers there to be a reasonable likelihood that an

[284]There is still a low risk that the equipment will fail (with or without an employee operating it); however, that risk is low enough that no arc-flash protection is necessary. This risk is equivalent to the risk encountered by employees every day when they turn on the lights.

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electric arc will occur whenever the probability of such an event is higher than it is for the normal operation of enclosed equipment.[285]

In contrast, whenever the risk that an arc will occur is higher than the risk of such an occurrence posed by the normal operation of enclosed equipment, the Agency considers electric-arc hazards to be present. For example, operating equipment that is not enclosed (for example, racking in a circuit breaker) poses such a risk (Ex. 0004[286]). Conductive objects can fall onto exposed live parts and cause an arc. Evidence that the equipment may be defective, for example, arcing noises or unusual behavior or heating, indicates that there is employee exposure to the hazards of electric arcs (*id.*[287]). Also, working near energized parts exposes employees to electric-arc hazards whenever the employee or another conductive object can contact those energized parts and other parts at a different potential (*id.*[288]). (See the definition of "exposed" and the summary and explanation for final §1926.960(b)(3), earlier in this section of the preamble.)

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[285]Basically, OSHA considers there to be a reasonable likelihood that an electric arc will occur when an employee operates enclosed electric equipment in a manner that is not in accordance with the manufacturer's recommendations (that is, normal operation) or when an employee operates enclosed electric equipment that the employer has not maintained properly.

[286]See, for example, the three accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=14328736&id=200962322&id=170197156.

[287]See, for example, the two accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=170762769&id=170204622.

[288]See, for example, the three accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=170054258&id=170614002&id=170611057.

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With respect to the American Forest & Paper Association's comment about opening and closing disconnects in an enclosed electrical box, evidence in the record indicates that equipment enclosures do not always provide adequate protection against electrical faults (Ex. 0373). A paper by Jones *et al*.[289] described the results of one arcing-fault test as follows: "the fault blew the door open and progressed up the vertical bus, completely destroying the vertical section of the [motor control center]" (*id*.). A paper by Land[290] described problems the Navy had in 1979 with arcing faults in switchboards: "These arcs could completely destroy a switchboard within a matter of seconds" (*id*.). Although these events may be uncommon, OSHA believes that it is appropriate for the standard to require the employer to assess the hazards posed by different operations and distinguish conditions that expose employees to electric-arc hazards from conditions that do not. For example, employers may consider a properly maintained switch as posing no electric-arc hazards when an employee is opening it under normal conditions. On the other hand, if there is evidence that the switch may be faulty or if the employee is opening the switch to troubleshoot the circuit, OSHA would expect the employer to assume that the switch does pose electric-arc hazards. Evidence that a switch may be faulty can include the presence of arcing or unusual noise from the switch, abnormally high temperatures around the switch, and safety bulletins from the switch manufacturer

[289]Jones, R. A., Liggett, D. P., Capelli-Schellpfeffer, M., Macalady, T., Saunders, L. F., Downey, R. E., McClung, L. B., Smith, A., Jamil, S., Saporita, V. J., "Staged Tests Increase Awareness of Arc-Flash Hazards in Electrical Equipment," *IEEE Transactions on Industry Applications Society*, 36(2): 659 – 667, March – April 2000.

[290]Land III, H. B., "The Behavior of Arcing Faults in Low Voltage Switchboards," 2005 IEEE ESTS, Philadelphia, pp. 133 – 140, 2005.

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indicating that the device might fail under certain operating conditions. Thus, OSHA concludes that it is not always safe to operate an enclosed switch and, therefore, is not generally exempting such activities from the hazard-assessment requirement in final paragraph (g)(1) or any of the other provisions in final paragraph (g).

OSHA does not believe that applying paragraph (g)(1) of the final rule in this manner will impose substantial extra costs on employers. The Agency anticipates that, in the vast majority of cases, the employer will determine that employees operating enclosed switches will have no exposure to hazards from electric arcs. On the basis of the foregoing discussion, it should be clear that the only occasions that an employee performing a switching operation would have exposure to electric-arc hazards under paragraph (g)(1), and, thus, be required to use arc-rated protection, would be if: a switch or other disconnect may be faulty (which should be rare); an employee operates a switch outside its rating[291] (which also should be rare), or an employee is performing troubleshooting or repair on the switch or a circuit controlled by the switch. In the latter case, the employee will be exposed to those same hazards during the troubleshooting or repair activities, when appropriate arc-flash protection would be required anyway. For the rare cases in which the employer has reason to believe that the switch might fail and expose an employee to an electric-arc hazard, the protection afforded by arc-flash protection would be necessary. However, the need to outfit the employee in arc-flash protection in such cases will serve as an incentive to effect repair of the switch and remove the hazard.

[291]Operating a switch or other disconnect outside its rating is prohibited by §1926.960(k) of the final rule.

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Some commenters argued that some utilities perform work with live-line tools, which limits employee exposure to hazards posed by electric arcs and makes FR clothing unnecessary. (See, for example, Exs. 0125, 0171, 0179, 0188, 0226.) NECA also argued that 40-cal/cm^2 arc-flash suits with hoods would reduce manual dexterity to the point that they would interfere with the employee's ability to use live-line tools (Ex. 0171).

OSHA agrees that work with live-line tools exposes employees to a lower incident-energy level than work directly on energized parts with rubber insulating gloves because employees working with live-line tools are normally farther from an electric arc than employees using gloves. (The tables in Appendix E use a method of estimating heat energy that assumes that employees using live-line tools will be substantially further away from the arc than employees using rubber insulating gloves.) All of the incident-energy calculation methods (described later in this section of the preamble) result in energy estimates that are approximately inversely proportional to the square of the distance. This proportion means that, when the employee is twice as far from the electric arc, he or she has exposure to no more than a quarter of the energy. OSHA does not believe that there are many, if any, working conditions that would expose an employee using a live-line tool to an incident energy of 40-cal/cm^2. NECA's example using clothing appropriate for such high exposure contradicts its claim that employees using live-line tools face reduced exposures.

As discussed later in this section of the preamble, final paragraph (g)(4)(iv) requires FR clothing when the estimated incident-energy levels are more than 2.0 cal/cm^2. If live-line tool work practices limit incident-energy levels to that value or less, then paragraph (g)(4) may not require flame-resistant clothing. However, clothing can

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ignite even at low incident-energy levels. For example, an arc can ignite insulating fluid in transformers and other equipment, which could ultimately ignite clothing (Ex. 0004[292]). Current passing through grounding conductors can melt those conductors and ignite clothing (*id*.[293]). Hot debris from faulted equipment can spew out and ignite clothing (Exs. 0342, 0373). Final paragraph (g)(4), as described more fully later in this section of the preamble, requires flame-resistant clothing in those scenarios. OSHA is not exempting live-line tool work from the hazard assessment or other requirements in paragraph (g) of the final rule. Employers must account for the possibility of clothing ignition from sources other than incident heat energy in the hazard assessment required by paragraph (g)(1) of the final rule.

The American Forest & Paper Association commented that the proposed definition of "exposed" in §1926.968 does not seem applicable to the use of the word "exposed" in proposed §1926.960(g) because the definition refers to a conductor or part rather than a person (Ex. 0237).

OSHA agrees that the definition in final §1926.968 relates only to parts of electric circuits; it does not address employee exposure to hazards other than exposure to live parts.[294] To clarify the application of the definition of "exposed" in §1926.968 of the final

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[292]See the seven accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200671253&id=201340395&id=170762769&id=170632699&id=14504773&id=14343594&id=837815.

[293]See the accident described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=596304.

[294]Several provisions in subpart V in addition to final §1926.960(g) refer to employee exposure.

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rule, OSHA is adding the parenthetical phrase "(as applied to energized parts)" to the defined term "exposed."

Estimating incident heat energy.[295] Once an employer determines the employees exposed to hazards from flames or electric arcs, the next step in protecting these employees is to determine the extent of the hazard. Paragraph (g)(2) of the final rule, which OSHA revised from the proposal as described later in this section of the preamble, requires the employer to make a reasonable estimate of the incident heat energy to which each employee exposed to electric-arc hazards would be exposed. Under final paragraph (g)(5), employers must use this estimate to select appropriate PPE.

As noted in the preamble to the proposal, OSHA is aware of various methods of calculating values of available heat energy from an electric circuit (70 FR 34866 – 34867). Table 10, later in this section of the preamble, lists methods that were available when OSHA proposed paragraph (g)(2). Each method requires the input of various parameters, such as fault current, the expected length of the electric arc, the distance from the arc to the employee, and the clearing time for the fault (that is, the time the circuit protective devices take to open the circuit and clear the fault). Some of these parameters, such as the fault current and the clearing time, are known quantities for a given system. Other parameters, such as the length of the arc and the distance between the arc and the employee, vary depending on what happens to initiate the electric arc and are estimated parameters. It should be noted that NFPA 70E-2004 Annex D contains three different methods of estimating incident heat energy: (1) a method based on a paper by Lee

[295]This preamble uses the term "incident energy" as a synonym for "incident heat energy."

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entitled "The Other Electrical Hazard: Electric Arc Blast Burns,"[296] also known as the "Lee equation"; (2) a method based on the Doughty, Neal, and Floyd paper, which Table 10 lists separately; and (3) the IEEE 1584 method, which Table 10 also lists separately.[297] The following discussion refers to the method based on the Lee equation as the NFPA 70E Annex D method.[298]

Table 10—Methods of Calculating Incident Heat Energy from an Electric Arc

1. *Standard for Electrical Safety Requirements for Employee Workplaces*, NFPA 70E-2004, Annex D, "Sample Calculation of Flash Protection Boundary."
2. Doughty, T. E., Neal, T. E., and Floyd II, H. L., "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600 V Power Distribution Systems," *Record of Conference Papers IEEE IAS 45th Annual Petroleum and Chemical Industry Conference*, September 28 – 30, 1998.
3. *Guide for Performing Arc Flash Hazard Calculations*, IEEE Std 1584-2002.
4. Heat Flux Calculator, a free software program created by Alan Privette (widely available on the Internet).
5. ARCPRO, a commercially available software program developed by Kinectrics, Toronto, ON, CA.

[296]Lee, R. H., "The Other Electrical Hazard: Electric Arc Blast Burns, " *IEEE Transactions on Industry Applications*, 1A-18(3):246 – 251, May/June 1982 (Ex. 0433).

[297]NFPA 70E-2012, Annex D, contains the same three methods plus an additional method for calculating incident heat energy for dc systems. Although OSHA has not evaluated this new method, employers may use it to calculate incident heat energy if it reasonably predicts the incident energy for the system involved.

[298]NFPA 70E-2012, Annex D, also contains the Lee equation. Consequently, OSHA's conclusions regarding the NFPA 70E-2004 Annex D method also apply to NFPA 70E-2012, and Appendix E to final Subpart V references NFPA 70E-2012. Unless otherwise noted, the preamble references to the content of NFPA 70E-2004, Annex D, apply equally to NFPA 70E-2012.

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Employee arc exposures. One of the following three separate types of electric arcs typically serves as the basis for the methods used to estimate incident energy: single-phase arc in open air, three-phase arc in open air, and three-phase arc in an enclosure (arc in a box) (Exs. 0425, 0430, 0433, 0463, 0468, 0469). A single-phase arc occurs when electric current arcs from a circuit part for one phase to ground or to a circuit part for another phase. A three-phase arc involves arcing between all three phases of a three-phase circuit. A single-phase arc can escalate into a three-phase arc as the air around the arc ionizes and becomes more conductive (Ex. 0425). Both kinds of arcs can occur in open air or inside an enclosure. The incident-energy levels vary between the types of arcs, with energy levels progressively increasing from single-phase arcs in open air, to three-phase arcs in open air, to three-phase arcs in a box (Exs. 0425, 0430, 0468). OSHA finds that, for an estimate of heat energy to be reasonable, it must account for the type of exposure the employee likely will encounter.

Varying results using different calculation methods. Many rulemaking participants objected to the proposed requirement that employers make a reasonable estimate of the incident heat energy associated with an employee's exposure to an electric-arc hazard. (See, for example, Exs. 0152, 0173, 0178, 0201, 0209, 0227, 0233, 0501; Tr. 374 – 376, 547 – 548, 1094 – 1098, 1100 – 1102.) Some of these rulemaking participants focused on purported problems with methods of calculating incident heat energy. (See, for example, Exs. 0152, 0173, 0201, 0209, 0227, 0233, 0501; Tr. 547, 1094 – 1098, 1100 – 1102.) These commenters maintained that the results of calculations from the different methods varied widely or are subject to manipulation that would make the calculation methods unreliable or unscientific (*id.*). For example, Ms. Kathy Wilmer,

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testifying on behalf of EEI, spoke to the wide variations she found in calculating incident heat energy using the methods listed in the proposed rule:

> OSHA does not endorse any of the methods listed in the table. OSHA further acknowledges that the method of calculation can affect the results inasmuch as each method yields somewhat different values using the same input parameters.
>
> * * *
>
> [F]our methods, including two tables and two formulas, were compared for the conditions of 15,000 volts, 5,000 amps, and 34.5 cycles. The heat energies determined were, No. 1, from Appendix F, Table 8,[299] of the proposal, 5 calories per square centimeter; No. 2, from the HeatFlux Calculator, 2.9 calories per square centimeter; No. 3, from NFPA 70E, Table 130.7(c)(9)(a),[300] 40 calories per square centimeter, as it is listed as risk category 4[301] for work on energized parts in the other equipment over 1,000-fold category; No. 4, from NFPA 70E, Annex D, D7, formula, 153 calories per square centimeter.
>
> In summary, the results were 2.9, 5, 40, and 153 calories per square centimeter for the same conditions: 15,000 volts, 5,000 amps, 34.5 cycles. Again, this example illustrates serious concerns about the reliability of methods offered to determine heat energy on transmission and distribution systems. [Tr. 1096, 1101 – 1102]

OSHA applied the same methods Ms. Wilmer described in this comment and arrived at values similar to the values provided in her testimony, as shown in Table 11.

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[299]Table 8 in proposed Appendix F listed estimates of incident energy for different parts of an electrical system operating at 4 to 46 kilovolts. OSHA based these estimates on the ARCPRO method.

[300]NFPA 70E-2004 Table 130.7(C)(9)(a) is a method for selecting PPE based on hazard/risk categories. Proposed Appendix F did not list NFPA 70E-2004, Table 130.7(C)(9)(a), as an acceptable method of estimating incident-energy level.

[301]NFPA 70E-2004, Table 130.7(C)(11) lists the following hazard-risk categories (HRC) with the corresponding minimum required arc ratings: 0 – none, 1 – 4 cal/cm^2, 2 – 8 cal/cm^2, 3 – 25 cal/cm^2, 4 – 40 cal/cm^2.

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Table 11—Sample Incident-Energy Calculations Using Different Methods

Method	Incident Energy (cal/cm^2)
Heat flux calculator	3.0 (results must be rounded up to ensure that the protective equipment rating equals or exceeds this value)
Table 8 from proposed Appendix F	5.0
NFPA 70E-2004, Annex D, section D.7	152
NFPA 70E-2004, Table 130.7(C)(9)(a)	Not applicable. Table 130.7(C)(9)(a) lists a Hazard-Risk Category of 2 (8 cal/cm^2) for insulated cable examination in open areas, which is an exposure comparable to that of a single-phase arc in open air represented by the Heat Flux calculator and Table 8 from proposed Appendix F. Table 130.7(C)(9)(a) lists a Hazard-Risk Category of 4 (40 cal/cm^2) for work on energized parts, which is an exposure comparable to the three-phase arc in an enclosure represented by the method in NFPA 70E-2004, Annex D, section D.7. However, as explained later in this section of the preamble, Table 130.7(C)(9)(a) combines a risk assessment with incident-energy calculation and does not represent incident energy alone.

A closer look at these results shows that the two software programs, heat flux calculator and ARCPRO (upon which OSHA based Table 8 of proposed Appendix F), produce similar results: 3.0 cal/cm^2 for the heat flux calculator and 5.0 cal/cm^2 for ARCPRO. Because the arc rating for the lightest weight arc-rated clothing ranges from

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4.0 to 5.0 cal/cm^2, both programs would lead generally to the use of the same minimum level of protection for the system parameters at issue.[302]

The heat flux calculator and ARCPRO both calculate incident energy produced by single-phase arcs in air, which is clear in the ARCPRO documentation (Ex. 0468). Also, the preamble to the proposal clearly stated that the results from the heat flux calculator require adjustment for application to exposures involving three-phase arcs or arcs in enclosures (70 FR 34867), and other evidence in the record indicates that the calculator is designed for application to single-phase arc exposures (Exs. 0430, 0463).

The incident-energy estimate resulting from application of the formula in NFPA 70E-2004, Annex D, is significantly higher than the results obtained using either of the software programs. There are two reasons for this difference. First, the formula that appears in section D.7 of NFPA 70E, Annex D, is designed to calculate the incident energy produced by a three-phase arc in open air. The corresponding single-phase exposure, based on an ARCPRO conversion factor (multiplying single-phase values by 2.2 to convert them to three-phase values or, conversely, dividing three-phase values by 2.2 to convert them to single-phase values), would be 70 cal/cm^2 (Ex. 0468). Second, although NFPA 70E states that the formula in section D.7 of Annex D can be used to predict the incident energy produced by arcs on systems operating at more than 600 volts, it also explicitly warns about doing so, noting:

> The following example is conservative at voltage levels above 600 volts. Experience suggests that the example is conservative at voltage levels above 600

[302]As explained later in this section of the preamble, Table 6 and Table 7 in Appendix E in the final rule set a minimum level of 4.0 cal/cm^2, which is the minimum level of arc-rated clothing currently available.

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volts and becomes more conservative as the voltage increases. [Ex. 0134; annex section D.1[303]]

Consequently, it is not surprising that the incident-energy estimate calculated using Annex D of NFPA 70E-2004 for a scenario involving a single-phase arc on a 15-kilovolt system[304] is substantially higher than the values derived using the two software programs.

Ms. Wilmer also mentioned Table 130.7(C)(9)(a) of NFPA 70E-2004. The closest hazard-risk category from Table 130.7(C)(9)(a) is 2 (requiring clothing rated at 8 cal/cm^2), which is for the task of "[i]nsulated cable examination in open air" (Ex. 0134). The other tasks in the category entitled "Other Equipment 1 kV and Above" appear to represent exposures from arcs in enclosures, and all of those tasks, including the one for cable examination, represent three-phase exposures. Moreover, OSHA examined this table more closely and found that it does not represent incident-energy calculations alone. The hazard-risk categories listed in NFPA 70E-2004, Table 130.7(C)(9)(a),[305] include a risk component, as well as an incident-energy component, as can be seen from the entries for the various tasks on 600-volt class motor control centers. The hazard-risk categories for this equipment vary from 1 to 3 (which require clothing rated from 4 to 25 cal/cm^2)

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[303]NFPA 70E-2012, Annex D, contains the same equation in Section D.6. Similar language warning about conservative results from using the Lee paper for voltages over 600 volts appears in Table D.1, Limitation of Calculation Methods.

[304]Although Ms. Wilmer did not state that her scenario involved a single-phase exposure, her use of Table 8 in proposed Appendix F, the use of which is limited to such exposures, implies that the scenario is for a single-phase arc.

[305]NFPA 70E-2012 contains an equivalent table in Table 130.7(C)(15)(a). As noted earlier, NFPA 70E-2004, Table 130.7(C)(11) lists the minimum arc rating for each hazard-risk category. NFPA 70E-2012 lists minimum arc ratings for each hazard-risk category in Table 130.7(C)(16). OSHA's conclusions regarding NFPA 70E-2004 Table 130.7(C)(9)(a) apply equally to NFPA 70E-2012 Table 130.7(C)(15)(a).

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depending on the task, even though, according to the notes to the table, the system parameters are the same for all the tasks; thus, the calculated incident energy for all the tasks for this equipment should be the same. While not clear from NFPA 70E-2004, it appears that the NFPA 70E Committee chose to reduce the amount of protection for a task based on the likelihood that an electric arc would occur.[306] The level of protection needed for a particular incident heat energy is the same regardless of the probability that an electric arc will occur. In other words, whether there is a 5-percent risk or a 10-percent risk is not relevant to whether the employee's PPE is adequate. As will be explained later in this section of the preamble, OSHA based the determination of the level of PPE required under the final rule solely on incident heat energy. OSHA's final rule separates the determination of risk (that is, whether an employee is exposed to hazards posed by electric arcs), as required by final paragraph (g)(1), from the calculation of incident energy, as required by final paragraph (g)(2). Therefore, the Agency concludes that NFPA 70E-2004, Table 130.7(C)(9)(a), is not a reasonable method of estimating incident energy under final paragraph (g)(2) and, therefore, is not referencing that table in Appendix E in the final rule.

In the following discussion, the Agency evaluates the various methods listed in Table 10 across three distinct voltage categories (600 volts and less, 601 to 1,000 volts, and more than 1,000 volts), and for each type of electric arc (single-phase arc in open air, three-phase arc in open air, and three-phase arc in an enclosure).

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[306]Earlier editions of NFPA 70E, such as the 2000 edition, and NFPA documentation on the adoption of the task table show that the hazard/risk category is reduced by 1 if the probability of an arc is low and reduced by 2 if the probability is very low.

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Voltages of 600 volts and less. As can be seen from the tasks listed in Table 130.7(C)(9)(a), much of the work addressed by NFPA 70E-2004 involves voltages of 600 volts or less (Ex. 0134). This category represents the dominant voltage class for utilization equipment installed in buildings, including electric power generation stations. It also includes service-class equipment, such as meters, installed on distribution circuits. There is wide experience using the incident-energy calculation methods included in Annex D of NFPA 70E-2004 and in IEEE Std 1584a-2004,[307] and there is evidence that some electric utilities use these methods successfully (Exs. 0216 (showing TVA's use of IEEE Std 1584 to calculate incident-energy levels), 0444 ("INPO (Institute for Nuclear Power Operations) was and is a huge factor in driving the use of NFPA 70E as a

[307]IEEE adopted two amendments after it published IEEE Std 1584-2002: IEEE Std 1584a-2004 (Amendment 1 to IEEE Std 1584-2002), and IEEE Std 1584b-2011 (Amendment 2: Changes to Clause 4 of IEEE Std 1584-2002). (Ex. 0425 contains both the IEEE Std 1584-2002 standard and the 1584a-2004 amendment.) This preamble refers to specific versions of IEEE Std 1584 as follows:

IEEE Std 1584-2002:	the base IEEE Std 1584 standard
IEEE Std 1584a-2004:	IEEE Std 1584-2002 as amended by IEEE Std 1584a-2004
IEEE Std 1584b-2011:	IEEE Std 1584-2002 as amended by IEEE Std 1584a-2004 and IEEE Std 1584b-2011.

IEEE Std 1584a-2004 and IEEE Std 1584b-2011 use the same basic methodology to calculate incident-energy levels as IEEE Std 1584-2002. In this section of the preamble, OSHA analyzed IEEE Std 1584a-2004 (Ex. 0425) to determine whether employers can use that standard to make reasonable estimates of incident energy. The Agency also examined the latest version of IEEE Std 1584 and found that, because the calculation method did not change from IEEE Std 1584a-2004 to IEEE Std 1584b-2011, OSHA's conclusions regarding IEEE Std 1584a-2004 also apply to IEEE Std 1584b-2011, and Appendix E to final Subpart V references IEEE Std 1584b-2011. Unless otherwise noted, the preamble references to the content of IEEE Std 1584a-2004 apply equally to IEEE Std 1584b-2011.

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recognized 'best practice' for electrical safety programs in the nuclear power industry")). A national consensus standard recognizes these methods (NFPA 70E),[308] and there is considerable test data validating them (Exs. 0425 ("[the IEEE 1584 committee] has overseen a significant amount of testing and has developed new models of incident energy" and "[IEEE Std 1584a-2004 provides calculations based on] new, empirically derived models based on statistical analysis and curve fitting of the overall test data available"), 0430 (this paper, which the IEEE 1584 committee referenced, reported on the results of 25 tests that supplemented "previously completed extensive arc testing").)

OSHA concludes that the methods of calculating incident heat energy in NFPA 70E-2004, Annex D, and IEEE Std 1584a-2004 are reasonable at voltages of 600 volts and less for the exposures these methods address, as explained more fully later in this section of the preamble. No evidence in the record persuades OSHA otherwise. A paper by Stokes and Sweeting entitled "Electric Arcing Burn Hazards" criticized both the NFPA 70E Annex D and IEEE 1584 methods (Ex. 0452).[309] That paper notes that the NFPA and IEEE methods use a predominantly radiant model of incident heat energy from an electric arc, in which 90 percent of the heat is radiant heat and in which the entire exposure will be outside the electric arc plasma. The Stokes and Sweeting paper disagrees that radiant heat is the predominant hazard and shows that orienting the test electrodes in a horizontal configuration can result in the transference of a greater degree

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[308]As previously mentioned, NFPA 70E-2004, Annex D, recognizes IEEE Std 1584-2002 as a valid method of calculating incident heat energy (Ex. 0134).

[309]Stokes, A. D., Sweeting, D. K., "Electric Arcing Burn Hazards," IEEE Transactions on Industry Applications. Vol.. 42. No. 1, January/February 2006, pp. 134 – 141.

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of convective heat and that the amount of heat within the electric arc plasma[310] is more than three times higher than predicted by the NFPA and IEEE models. The Stokes and Sweeting paper also noted that the Lee paper, which is the basis of the NFPA method, predicts a smaller plasma diameter than the plasma diameter found during testing. The Stokes and Sweeting paper explained:

> As an example, for a three-phase arcing exposure of 5000 V and 20000 A, the Lee prediction forecasts a plasma diameter of 170 mm [7 inches].… The authors' test results for this condition, for an arc duration of 0.5 s, show a brilliant plasma cloud some 3000 mm [118 inches] long and around 1500 mm [59 inches] tall in the plane of the camera. [*Id*.]

OSHA recognizes that exposures within the plasma field of an electric arc will produce heat that is several times the incident energy predicted by any of the methods used to calculate heat energy recognized by the final rule. However, the Agency believes that the predominant exposure for employees covered by this final rule will be outside the plasma field. Although, in the Stokes and Sweeting paper, the plasma field extended beyond the distance provided for in the NFPA and IEEE methods, the paper did not indicate how to estimate the field's reach. Furthermore, all of the calculation methods require an estimate of the distance from the electric arc to the employee. The IEEE 1584 method uses 455 to 610 millimeters (18 to 24 inches) for low-voltage (600 volts and less) equipment such as switchboards, panelboards, and motor control centers. As explained later in this section of the preamble, those distances are reasonable estimates of the distance from the employee to the arc. In addition, the testing supporting the IEEE 1584 method, which is representative of typical exposures, confirms the incident-energy results

[310]Plasma is the high-temperature ionized gas cloud that results from the electric arc.

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derived using that method (Ex. 0425). There is no evidence in the record that indicates that employees will typically be closer than these distances for this type of work or will be in the plasma field at these working distances. Therefore, OSHA concludes that, in general, the incident-energy calculation methods in NFPA 70E-2004, Annex D, and IEEE Std 1584a-2004 reasonably represent employee exposure for voltages of 600 volts and less.

The IEEE 1584 method accounts for differences between single-phase and three-phase arcs and between arcs in open air and arcs in an enclosure (*id*. ("The arc-flash hazard calculations included in this guide will enable quick and comprehensive solutions for arcs in single- or three-phase electrical systems either of which may be in open air or in a box, regardless of the low or medium voltage available")). In addition, as noted earlier, this method is based on extensive testing, and a consensus standard recognizes this method. Therefore, OSHA concludes that this method reasonably represents employee exposures for single-phase and multiphase arcs in enclosures and open air.

Proposed Appendix F also listed a paper by Doughty, Neal, and Floyd as a method of estimating incident energy from an electric arc. (See Table 10 earlier in this section of the preamble.) This paper describes the results of tests performed on a 600-volt power system with a 36.25-kiloampere prospective fault current and contains algorithms to estimate incident energy at a specified distance from an arc as a function of the available bolted-fault current on a 600-volt system (Ex. 0430). The tests included three-phase arcs in enclosures and in open air (*id*.). Because this paper was peer reviewed and the methods it uses are based on testing electric arcs, OSHA finds that the method in this

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paper reliably estimates incident energy for the 600-volt systems it represents.[311] The Agency also finds that it reasonably represents incident energy for systems of lower voltages and for single-phase systems because the power produced by these systems should be comparable to, and not exceed, the power from a three-phase 600-volt system with an equivalent supply. The Doughty, Neal, and Floyd method will produce conservative results for lower-voltage and single-phase systems. On the other hand, this method does not estimate incident energy for systems of higher voltages. Therefore, OSHA finds that it is not reasonable to use this method to estimate incident energy for systems of voltages of more than 600 volts.

The Doughty, Neal, Floyd paper compared the results of its authors' testing with other methods of estimating incident-energy levels, including the NFPA Annex D method, the heat flux calculator, and a commercial software program (apparently ARCPRO), which OSHA listed in the proposal (*id*.). The paper compared the incident energy it found for three-phase electric arcs with the incident energy calculated by the Lee equation used in NFPA 70E, Annex D, by examining the distance required to achieve an incident-energy level of 1.2 cal/cm^2. This distance is the "curable burn distance," which is the distance at which an employee will begin to sustain a second-degree, or curable, burn. The paper explained the results of this comparison as follows:

> The Lee "curable burn" distances coincide almost exactly with the second-degree burn distances for the open three-phase arc. The second-degree burn distances for

[311]The equations given in this paper are for an arc lasting 6 cycles. An employer using the Doughty, Neal, and Floyd method will need to adjust the results to account for any clearing times different from 6 cycles by multiplying the incident energy calculated using these equations by the ratio of the actual clearing time to 6 cycles.

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the arc in the cubic box, however, are significantly higher. The difference is more pronounced at higher bolted fault levels. [*id*.]

Figure 8 depicts these functions.

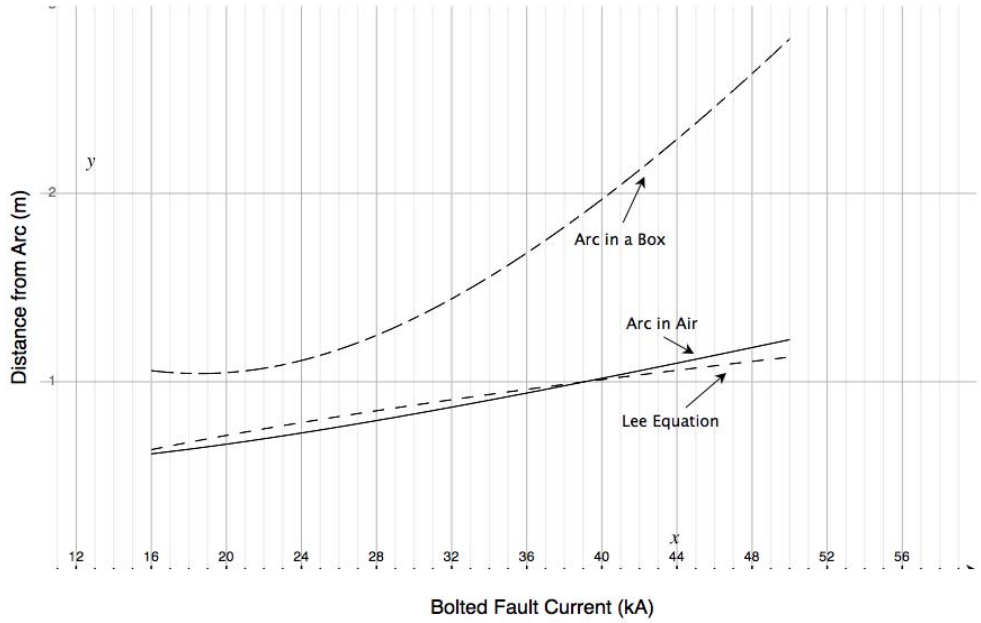


Figure 8--Curable Burn Distance

Based on this analysis, the Agency finds that the Lee equation from NFPA 70E-2004, Annex D, is a reasonable method of estimating the incident energy of a three-phase electric arc in open air for systems of 600 volts or less. However, because the Lee equation significantly underestimates incident energy from three-phase arcs in an enclosure, OSHA finds that this is not a reasonable method to estimate incident energy from such exposures. The Agency also finds that the NFPA 70E-2004, Annex D, method reasonably represents incident energy for single-phase systems because the power produced by these systems should be comparable to, and not exceed, the power from a three-phase system with an equivalent supply. Thus, this method will produce conservative results for single-phase systems.

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The Doughty, Neal, and Floyd paper also compared the results of its authors' testing with the heat flux calculator and "a commercially available computer program" (*id.*).[312] The paper found that:

- The three-phase test values of maximum incident energy for open arcs were 2.5 to 3.0 times the amounts calculated for single-phase arcs in air by the two programs; and
- The three-phase test values of maximum incident energy for arcs in a box were 5.2 to 12.2 times the amounts calculated for single-phase arcs in air by the two programs (*id.*).

This comparison clearly shows that neither program reasonably estimates incident heat energy from three-phase electric arcs or electric arcs in an enclosure. Although there are conversion factors recommended for these programs, these conversion factors do not account for the wide variation between the incident energies the programs calculate and the actual incident energy found during testing. Thus, OSHA finds that the heat flux calculator and ARCPRO do not reasonably estimate incident heat energy for three-phase arcs or arcs in a box for systems of 600 volts or less.

On systems of 600 volts or less, the phase conductors are typically relatively close together, approximately 30 millimeters (1.25 inches), as noted in the Doughty, Neal, and Floyd paper (*id.*). When an arc occurs between one phase and ground, or between two phases, the surrounding air becomes ionized (and, thus, conductive), and it can relatively

[312] Although the paper did not identify the "commercially available computer program" by name, OSHA closely examined the results from ARCPRO and compared them with the commercial software program incident-energy estimates reported by the paper and found them to be equivalent.

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easily escalate to a three-phase arc (Ex. 0425). In addition, as seen from NFPA 70E-2004, Table 130.7(C)(9)(a), most of the exposures at this voltage level, with the exception of work on service drops, involve equipment in enclosures (Ex. 0134).[313] Consequently, OSHA concludes that it normally would be unreasonable to estimate incident-energy levels for systems of 600 volts using methods based on single-phase open air arcs. However, the employer may use such methods when it can demonstrate that there is only one phase present or that the spacing of the phases is sufficient to prevent the formation of a three-phase arc. The incident energy results from the electric-arc model used by ARCPRO "have shown good agreement with measured values from a series of tests covering the following ranges of parameters: currents from 3.5 kA to 21.5 kA, arc durations from 4 cycles to 30 cycles, arc lengths from 1 inches to 12 inches, and distances of 8 inches to 24 inches from the arc" (Ex. 0469). The ARCPRO documentation does not indicate the voltage range verified by the test results; however, the model used by this program uses voltage only to ensure that an arc can be sustained over the distance between electrodes. Consequently, OSHA finds that this program can reasonably estimate incident energy from a single-phase arc in open air for systems of 600 volts or less, and the employer may use the program as long as the employer can demonstrate that there is only one phase present or that the spacing of the phases is sufficient to prevent the formation of a three-phase arc.

[313]OSHA acknowledges that NFPA 70E exempts work on electric power generation, transmission, and distribution installations. However, the electric equipment installed in generating plants is of the same type as that covered by NFPA 70E (Ex. 0077), and OSHA concludes that the tasks performed on this equipment would be of a similar nature.

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For reasons explained later in this section of the preamble, OSHA finds that the heat flux calculator is not a reasonable method for estimating incident energy for any type of exposures, irrespective of voltage.

Table 12 summarizes OSHA's findings regarding the reasonableness of using the various methods of estimating incident heat energy for exposures involving single-phase and three-phase arcs in open air and in an enclosure for voltages of 600 volts and less.

Voltages of 601 volts to 15 kilovolts. Work at voltages from 601 volts to 15 kilovolts is common to both electric power distribution work and to work in industrial and electric utility substations and plants. Industrial installations use equipment similar to that used by electric utilities (see, for example, 59 FR 4333 – 4334). Therefore, any method that is appropriate for use with industrial systems operating at these voltages should be appropriate for use with electric power generation and distribution installations.

Again, there is wide experience using the incident-energy methods included in Annex D of NFPA 70E-2004 and in IEEE Std 1584, and there is evidence that some electric utilities use these methods successfully (Exs. 0216, 0444). A national consensus standard (NFPA 70E) recognizes these methods, and there is considerable test data validating them (Exs. 0425, 0430). OSHA, therefore, finds that the IEEE 1584 method reasonably estimates incident-energy levels for systems operating at voltages of 601 volts to 15 kilovolts for exposures involving single-phase and three-phase arcs in open air or in enclosures. As explained previously in the discussion of Ms. Wilmer's comments, the method in NFPA 70E, Annex D (the Lee method), is conservative at more than 600 volts. In addition, this method estimates incident-energy levels for three-phase arcs and, thus, is even more conservative for exposures involving single-phase arcs. Because the NFPA

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70E Annex D method is conservative, OSHA finds that it reasonably estimates incident-energy levels for systems operating at voltages of 601 volts to 15 kilovolts, that is, it will provide employees with adequate protection.[314] However, clothing appropriate for the levels of incident energy calculated by the NFPA 70E Annex D method will be heavier and bulkier, as well as more expensive, than clothing appropriate for incident energy calculated using other acceptable methods. (See, for example, Ex. 0213, "[The NFPA 70E Annex D method] could be used to calculate incident energies for transmission system voltages, but [it] will produce very conservative (high heat energy) results. This will result in employees wearing unnecessarily heavy arc flash protection when working on lines.") Consequently, the Agency anticipates that employers will only use this method to estimate incident-energy levels at voltages of 601 volts to 15 kilovolts when it would result in the use of clothing with a relatively low arc rating.

The method in the Doughty, Neal, and Floyd paper described earlier in this section of the preamble is based on testing performed exclusively with an electrode spacing of 32 millimeters (1.25 inches) at 600 volts (Ex. 0430). There is no evidence in the record that suggests that this method is suitable at higher voltages, at which electrode gaps likely are significantly longer. Therefore, OSHA finds that this method does not reasonably estimate incident-energy levels for systems operating at voltages above 600 volts.

[314]For reasons already explained, the NFPA 70E Annex D method is not reasonable for estimating incident energy exposures from three-phase arcs in an enclosure.

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The Agency closely examined the two software calculation methods, ARCPRO and the heat flux calculator, over the voltage range 601 volts to 15 kilovolts. OSHA performed this examination in part by looking at the estimates of heat flux for different system parameters. Heat flux is a measure of the flow of heat energy per unit area per second. The incident energy from an electric arc can be computed by multiplying the heat flux, which has the units cal/cm^2-sec, by the number of seconds the arc lasts (that is, the clearing time or the amount of time the devices protecting a circuit take to open the circuit). The clearing time for circuit protective devices typically is given in cycles, which then is converted to seconds by dividing the number of cycles by the number of cycles per second, usually 60. The two software programs, ARCPRO and the heat flux calculator, can be used to calculate the heat flux at a given distance from an electric arc with varying parameters (for example, arc length, system voltage, and current). Figure 9 compares the heat flux calculated by these two programs at 380 millimeters (15 inches) from an arc with an electrode spacing of 51 millimeters (2 inches).[315] Note that, although 15 kilovolts is the voltage input to these programs, the incident energy calculated by both programs would be the same at 601 volts. The two programs only use the voltage to verify that an arc can be sustained across the given electrode gap. Figure 9 shows that the heat flux calculator produces results that can be more than 50 percent less than the results produced by ARCPRO.

After calculating the incident heat energy using ARCPRO or the heat flux calculator, an employer can select arc-rated protective equipment. NFPA 70E-2004

[315]In preparing Figure 9, OSHA used the values from Table 6 in Appendix E for the distance to the arc and the electrode spacing corresponding to 15 kilovolts.

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contains a widely used, five-level system for selecting protective clothing based on different incident-energy levels (Ex. 0134). Figure 10 shows the protective-clothing arc rating, based on the NFPA 70E levels, that employers would select based on the heat-flux results shown in Figure 9 for each software program using clearing times of 6, 12, and 36 cycles. The figures clearly show that incident-energy calculations from the heat flux calculator can be more than 50 percent lower than the calculations from ARCPRO. This difference generally increases with increasing fault current.

The documentation for ARCPRO describes the formulas for calculating energy and heat estimates and the basis for that program's formulas, as follows:

> The ARCPRO computer program is based on a state-of-the-art electrical arc model …. Temperature-dependent gas properties, the electrode materials and configuration are taken into account in the model.…
>
> Energy and heat values computed by ARCPRO have been verified by comparison with measured results from high current laboratory tests involving controlled vertical arcs in air. ARCPRO results have shown good agreement with measured values from a series of tests covering the following ranges of parameters: currents from 3.5 kA to 21.5 kA, arc durations from 4 cycles to 30 cycles, arc lengths from 1 inches to 12 inches, and distances of 8 inches to 24 inches from the arc. [Ex. 0469]

Ontario Hydro Technologies (now known as Kinectrics), the same company that performs high-voltage and high-current electrical testing, including arc testing, developed this program for numerous purposes. (See, for example, Exs. 0469, 0501; Tr. 283.[316]) Consequently, OSHA concludes that the incident-energy values calculated by this program relate reasonably to the heat energy faced by employees facing exposures involving single-phase electric arcs in open air. (As explained previously, ARCPRO's conversion factors for exposures involving three-phase arcs and arcs in enclosures do not

[316]See also http://www.kinectrics.com/en/serviceline/ElectricalTesting.html.

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reasonably estimate employee exposures and would result in significant underprotection for workers.) The Agency believes that this program is highly accurate over the range of input parameters for which testing validated the results, that is, single-phase arcs in open air only. Therefore, OSHA finds that ARCPRO reasonably estimates incident-energy levels for single-phase arcs in open air for systems operating at 601 volts to 15 kilovolts.

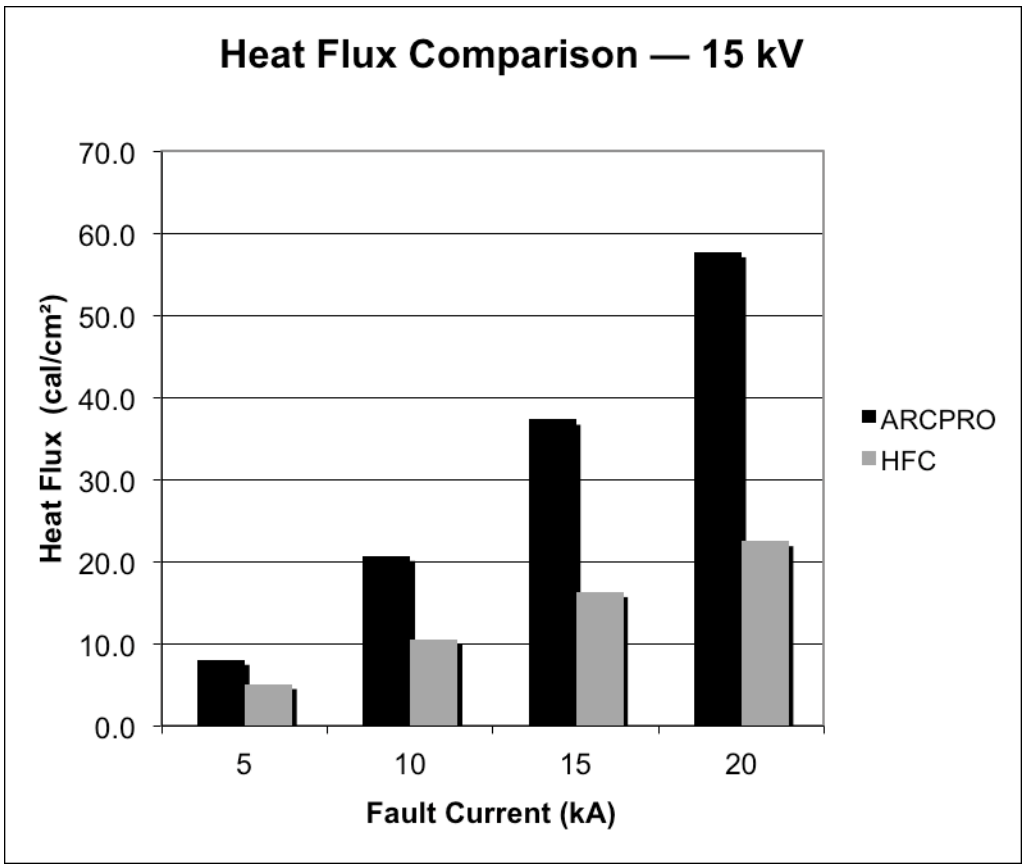
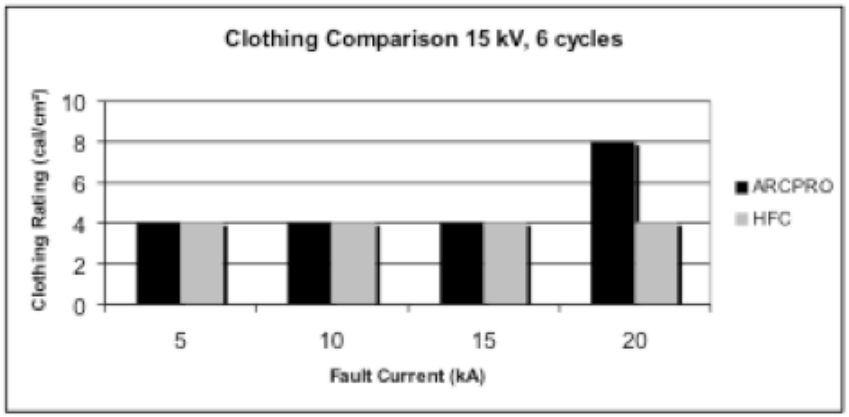
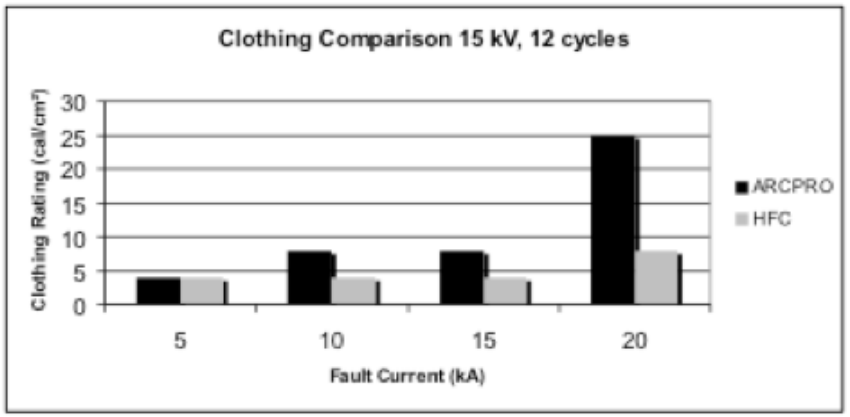


Figure 9—Heat Flux Comparison—ARCPRO and Heat Flux Calculator (HFC)

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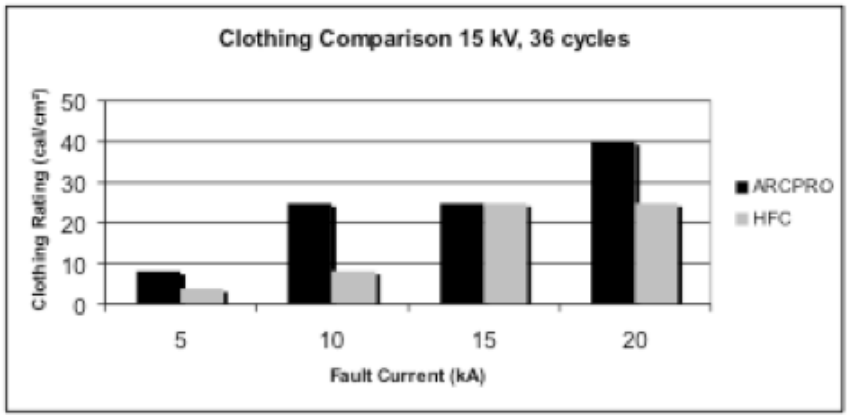


Figure 1—Comparison of Clothing Level Selection Based on ARCPRO and Heat Flux Calculator (HFC)

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On the other hand, there is little documentation supporting use of the heat flux calculator beyond the documentation provided by the NASCO Electric Arc Hazard Support Page, which describes the program (Ex. 0467).[317] OSHA is aware that some employers, electric utilities and others, use this program to estimate incident-energy levels and select appropriate PPE (Ex. 0430). However, there is little information in the record on which to judge the heat flux calculator on its own merits or the results it produces. In fact, TVA commented that it is "not aware of any test verification of the results derived from the Heat Flux Calculator" (Ex. 0213). Because the heat flux calculator provides incident-energy levels that are substantially below the levels resulting from the testing that supports ARCPRO and because there is no other means of validating the incident energy results from this program, OSHA cannot find that the heat flux calculator reasonably estimates incident heat energy levels for any exposures covered by this final rule.

Table 12 summarizes OSHA's findings regarding the reasonableness of using the various methods of estimating incident heat energy for exposures involving single-phase and three-phase arcs in open air and in an enclosure for voltages of 601 volts to 15 kilovolts.

OSHA expects employers to determine the type of exposure employees will face. If the energized parts are not in an enclosure, the employer may use a method appropriate for single-phase arcs in open air as long as the employer can demonstrate that there is

[317]The updated online version of this page contains a link to download the free program (http://www.nascoinc.com/quick_links/heatflux.htm). The program is also available on other Internet Websites.

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only one phase present or if the spacings of the phases is sufficient to prevent the formation of a three-phase arc. Otherwise, employers must use a method suitable for three-phase arcs in open air or in an enclosure, as appropriate.

Voltages of more than 15 kilovolts. Systems that operate at more than 15 kilovolts generally are electric power distribution or transmission systems covered by existing §1910.269 and subpart V. Although some industrial plants operate systems at these voltages, these existing OSHA standards typically cover systems operating at more than 15 kilovolts regardless of whether an electric utility or an industrial operation operates the system. (See, for example, the preamble to the 1994 final rule adopting existing §1910.269 (59 FR 4333 – 4335).)

IEEE Std 1584a-2004 describes the limits of its application as follows:

> This model is designed for systems having:
>
> - Voltages in the range of 208 V – 15 000 V, three-phase.
>
> * * *
>
> Use of this model is recommended for applications within the parameters stated in this subclause. [Ex. 0425]

Systems operating at voltages above 15 kilovolts are, thus, outside the recommended range of applications for the IEEE standard. Consequently, OSHA finds that the IEEE 1584 method does not reasonably estimate incident-energy levels for systems operating at voltages of more than 15 kilovolts.

As noted earlier, the NFPA 70E Annex D method gives conservative results for voltages over 600 volts. For example, as explained in the discussion of Ms. Wilmer's comment earlier in this section of the preamble, that method produces an incident heat energy level of 152 cal/cm^2 for an exposure involving a three-phase arc in open air for a

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system of 15 kilovolts with a fault current of 5,000 amperes, a clearing time of 34.5 cycles, and a distance from the employee to the arc of 381 millimeters (15 inches). In addition, the NFPA 70E Annex D method produces an incident-energy level of 1254 cal/cm^2 for an exposure involving a three-phase arc in open air for a system of 800 kilovolts with a fault current of 20,000 amperes, a clearing time of 54.5 cycles, and a distance from the employee to the arc of 2,200 meters (86.6 inches).[318] These values are too high to be meaningful, particularly at the higher end of the voltage range. Employers using the NFPA 70E Annex D method to select arc-rated clothing would outfit employees in clothing that exposes employees to severe heat-stress hazards even though the incident energy is not high enough to warrant such protection. Thus, OSHA finds that it is not reasonable to use this method to estimate incident energy for systems of voltages of more than 15 kilovolts. However, in some cases, employees may be far enough away from any potential arc that even the NFPA 70E Annex D method does not result in an estimated incident energy that is sufficient to ignite flammable clothing (2.0 cal/cm^2 or less, as explained later in this section of the preamble). Because that method is conservative, employers may use it to determine that employee exposure to estimated incident-heat energy is not more than 2.0 cal/cm^2 and, thus, that employees need not wear FR clothing under final paragraph (g)(4)(iv).

[318]Table 9 in proposed Appendix F listed incident heat energies for various voltage ranges of more than 46 kilovolts and fault currents. These are the values for the distance to the arc and the electrode spacing used in that table for 765 to 800 kilovolts. The corresponding table in the final rule (Table 7 of Appendix E) has been revised, as explained later in this section of the preamble, but those parameters are the same for that voltage range.

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For reasons explained previously, OSHA finds the Doughty, Neal, and Floyd method does not reasonably estimate incident energy for systems at voltages of more than 600 volts.

OSHA compared incident-energy values evaluated by the heat flux calculator to the values computed by ARCPRO at voltages higher than 15 kilovolts using parameters from Table 8 and Table 9 of proposed Appendix F. The results of this comparison were similar to the results of the comparison using voltages of 601 volts to 15 kilovolts described earlier. The incident energies computed by the heat flux calculator were substantially lower than the results computed by ARCPRO using the same parameters for systems of more than 15 kilovolts. In addition, as noted earlier, there is no information in the record validating the incident-energy results obtained using the heat flux calculator. Therefore, OSHA concludes that the heat flux calculator does not reasonably estimate incident energy from systems of more than 15 kilovolts.

As noted earlier, verification of the ARCPRO incident-energy calculation model occurred by testing a wide range of input parameters (Ex. 0469). This model is mostly independent of voltage (in other words, the results do not vary with voltage); the program only checks that the voltage will sustain an arc across the electrode gap (*id*.). The program accepts parameters outside the range verified by testing,[319] and there is no evidence in the record to indicate that results using parameters outside that range would be invalid (*id*.). As noted earlier, this program calculates incident energy from a single-

[319]"ARCPRO results have shown good agreement with measured values from a series of tests covering the following ranges of parameters: currents from 3.5 kA to 21.5 kA, arc durations from 4 cycles to 30 cycles, arc lengths from 1 [inch] to 12 inches, and distances of 8 inches to 24 inches from the arc" (Ex. 0469).

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phase arc in open air. OSHA concludes that this program accurately calculates incident heat energy from such arcs. Therefore, the Agency finds that ARCPRO reasonably estimates incident energy from single-phase arcs in open air on systems of more than 15 kilovolts.

As mentioned previously, the incident energy calculated by ARCPRO was significantly less than the actual heat energy found when testing 600-volt, three-phase arcs in open air and in an enclosure (Ex. 0430). Regardless of voltage, three-phase arcs consume more power and, therefore, produce more energy, and three-phase arcs in an enclosure produce even more heat energy because the heat energy radiating away from the worker reflects back towards the worker and because all of the convective heat energy is directed toward the worker (Exs. 0430, 0433).[320] Therefore, OSHA concludes that using unmodified ARCPRO results would significantly underestimate the amount of incident heat energy from these exposures. ARCPRO provides multiplication factors for adjusting the results to estimate incident energy from three-phase arcs in open air and in enclosures.[321] However, the Agency found that those adjustments were not reasonable for

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[320]Convection occurs in fluids (liquids and gases) through the mixing of hot and cold fluid regions driven by pressure, gravity, or mechanical agitation. This is the type of heating that occurs as a pot of water is heated to boiling on a stove. Thermal radiation occurs when radiation (such as infrared radiation) is emitted from an object and is absorbed by another object. This is the type of heating provided by the sun.

[321]Here are the conversion factors listed in ARCPRO's help system:

Energy for:	Multiply by:
1-phase in a box	1.5
3-phase	1.2 to 2.2
3-phase in a box	3.7 to 6.5

(Ex. 0468).

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systems up to 15 kilovolts. In those cases, there are alternative calculation methods, identified in Table 12, that more accurately estimate incident energy for those exposures. In contrast, there is no reasonable alternative for voltages of more than 15 kilovolts. Therefore, because ARCPRO is the best available technology for estimating incident energy for three-phase arcs in open air and in an enclosure for systems operating at more than 15 kilovolts, OSHA will treat this program as reasonably estimating incident energy for these exposures provided the employer adjusts the results using the conversion factors in the instructions included with the program.

Mr. Tommy Lucas with TVA maintained that there are no nationally recognized methods of reasonably estimating incident energy over 60 kilovolts (Ex. 0213).

As noted previously, however, OSHA evaluated the ARCPRO computer-software method and found that it provides a reasonable estimate of incident energy for voltages above 15 kilovolts, including voltages of more than 60 kilovolts.

Table 12 summarizes OSHA's findings regarding the reasonableness of using the various methods of estimating incident heat energy for exposures involving single-phase and three-phase arcs in open air and in an enclosure for voltages higher than 15 kilovolts.

Underground exposures, internal transformer faults, and other potentially high exposures. Consolidated Edison Company of New York (Con Edison), commented that the methodologies included in the proposal would not be useful for exposures faced by its employees, explaining:

> Con Edison has spent millions of dollars to recreate real life fault situations on our system at a high power testing laboratory. In these recreation scenarios we deliberately caused cable faults both in open air and in manholes and had mannequins wired with heat sensors to measure the incident energies our employees could potentially be exposed to. Based on the experience gained through thousands of these faults, both open air and in manholes, we realized that

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> none of the methodologies OSHA now proposes would be useful in conducting an analysis to arrive at a protective scheme for our employees. [Ex. 0157]

Although Con Edison did not provide the results of its tests, Dr. Mary Capelli-Schellpfeffer submitted a presentation that Con Edison prepared describing the company's tests (Ex. 0371). This presentation did not include any quantitative comparisons with OSHA's proposed methods of estimating incident energy. However, it did indicate that Con Edison was able to select appropriate protective garments that "have proven to be effective in the protection of [its employees]" (*id.*).

The company's tests included tests of faulted transformers and cable faults in manholes, and OSHA acknowledges that it is possible for the incident energy for these exposures to exceed results obtained using the IEEE 1584 method, which addresses exposures involving three-phase arcs in both open air and enclosures.[322] If a transformer experiences an internal fault, the transformer oil can ignite, and the burning oil will contribute additional heat energy not accounted for by that method (Ex. 0004[323]). For underground exposures in manholes and vaults, it is possible not only for the wall of the enclosure close to the arc to reflect the heat energy, but for the far walls to do so as well. The IEEE 1584 method accounts for the former but not the latter reflections (Ex. 0425).

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[322]Because Con Edison did not provide the parameters involved in its tests, OSHA cannot determine for certain what the exposure was. However, the Agency assumes that the manhole and cable testing was performed with three-phase voltages between 601 volts and 15 kilovolts. From Table 12, the IEEE 1584 method is the only method that provides a reasonable estimate for three-phase arcs in an enclosure, which is the exposure most common in manholes; and the IEEE 1584 and NFPA 70E Annex D methods are the only methods that provide a reasonable estimate for three-phase arcs in open air, which is the exposure associated with three-phase cables.

[323]See, for example, the two accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=170632699&id=14343594.

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Because the IEEE 1584 method, if the voltage is 15 kilovolts or less, and ARCPRO, if the voltage exceeds 15 kilovolts, are the best available methods for estimating incident energy for three-phase arcs in open air or in enclosures, OSHA will treat those two methods as reasonably estimating incident energy for the exposures cited by Con Edison. However, these estimates may not fully protect employees from electric-arc exposures resulting from internal faults in transformers or similar equipment or from arcs in underground manholes or vaults. Despite this shortcoming, the Agency believes that using these methods to estimate incident energy and to select appropriate protective equipment in accordance with the other provisions of final paragraph (g) will better protect employees than if employers permitted employees to work without arc-rated protective equipment. (See, also, the summary and explanation of paragraph (g)(5), later in this section of the preamble.)

Manipulation of results. Some rulemaking participants maintained that employers could manipulate the estimate of incident energy by selecting an inappropriate calculation method or by varying the parameters, such as arc length or distance from the arc, to achieve desired results. (See, for example, Exs. 0156, 0161, 0183.) Others commented more generally that the results of incident-energy calculations will vary depending on the parameters selected. (See, for example, Exs. 0163, 0173, 0181.) For instance, Mr. Alan Blackmon with Blue Ridge Electric Cooperative commented:

> Estimates of maximum amounts of heat energy to which an employee would be exposed require making so many subjective assumptions as to render the calculations useless. OSHA therefore should drop this requirement. There is no value in an estimation that so easily can be manipulated through choosing of, for example, duration of arc and distance from arc to employee. [Ex. 0183]

The parameters used by the calculation methods discussed earlier include: the fault current (usually the maximum available fault current), the system voltage, the arc

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length, the arc duration, and the distance from the arc to the employee.[324] The system fixes most of these parameters. Each system has a fixed system voltage, fault current, and fault clearing time.[325] The system voltage is a known "quantity." IEEE Std 1584a-2004, Section 4.4, explains the calculation of the maximum fault current based on known characteristics about the circuit involved (Ex. 0425). IEEE Std 1584a-2004 describes how to determine the corresponding fault-clearing time by checking the maximum fault current against the time characteristics provided by the protective device manufacturer as follows:

> An arc-flash hazard analysis should be performed in association with or as a continuation of the short-circuit study and protective-device coordination study. The process and methodology of calculating short-circuit currents and performing protective-device coordination is covered in IEEE Std 141-1993 (IEEE *Red Book*™) and IEEE Std 242-2001 (IEEE *Buff Book*™), respectively. Results of the short-circuit study are used to determine the fault current momentary duty, interrupting rating, and short-circuit (withstand) rating of electrical equipment. Results of the protective-device coordination study are used to determine the time required for electrical circuit protective devices to isolate overload or short-circuit conditions. Results of both short-circuit and protective-device coordination studies provide information needed to perform an arc-flash hazard analysis. [*id*.[326]]

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[324]IEEE Std 1584a-2004 also expects the user to select the overcurrent device protecting the circuit (Ex. 0425). However, that method makes certain assumptions about some of the other parameters, in particular, arc duration, that avoid the need to enter those parameters. The consensus standard also provides a generic case in which all of the typical parameters are input. IEEE Std 1584b-2011 provides additional guidance on selecting arc-duration times for different types of overcurrent protective devices (that is, fuses, integral-trip circuit breakers, and relay-operated circuit breakers) for the generic case.

[325]The arc will last until the protective device opens the circuit. Thus, the fault clearing time equals the duration of the arc.

[326]IEEE Std 1584b-2011 revises this paragraph and separates it into five paragraphs. The revisions are editorial, except for updated references to relevant IEEE standards, including the substitution of IEEE Std 551™-2006 (IEEE *Violet Book*™) for IEEE Std 141-1993 (IEEE *Red Book*™), and additional language explaining that (*Continued*)

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Engineers typically perform system coordination studies during the design of the system and again periodically and after any significant change to the system (Tr. 1030 – 1031). If no initial or periodic studies take place, the system owner risks having a fault on one part of the system cause an outage over an extended portion of the system instead of having the fault confined to the affected circuit. (See, for example, 269-Exs. 8-15, 8-16, 8-17, 8-20, 8-21, 8-22.) As required by existing §1910.269(n)(4)(i), employers must ensure that a similar engineering analysis is performed to determine the appropriate ampacity for protective grounding equipment; this provision specifies that protective grounding equipment must be "capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault." As noted by Mr. James Tomaseski of IBEW: "For … employees to install personal protective grounds on a circuit, they need to establish what level of … fault currents are available, and that will decide what size grounds they will install" (Tr. 960). Consequently, OSHA concludes that employers are likely to have information that the Agency can verify about the system voltage, fault current, and clearing times. OSHA will deem any manipulation of these parameters for purposes of estimating heat energy under final paragraph (g)(2) to result in an unreasonable estimate of incident energy in violation of the standard.

Table 8 in proposed Appendix F presented estimates of available energy for different parts of an electrical system operating at 4 to 46 kilovolts. Table 9 of proposed Appendix F presented similar estimates for systems operating at voltages of 46.1 to 800 kilovolts. These tables were for open-air, phase-to-ground (that is, single-phase) electric-

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"electrical system analysis software may be used to simplify the calculations for complex distribution systems …" and explaining the limitations and advantages of such software.

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arc exposures typical for overhead systems operating at these voltages. Table 8 and Table 9 of proposed Appendix F provided information on what OSHA would consider as reasonable estimates of arc length and the distance from the arc to the employee, as described later in this section of the preamble. OSHA revised these tables as described later in this section of the preamble and included them in the final rule as Table 6 and Table 7 of Appendix E. OSHA will consider it reasonable for an employer to use the Table 6 and Table 7 estimates of arc length and the distance from the arc to the employee—for single-phase arcs in open air—for purposes of the calculations required by final paragraph (g)(2). IEEE Std 1584a-2004 also provides guidance on these parameters (Ex. 0425).

Reasonable estimates of the arc gap (arc length). As noted earlier, the exposures covered by Table 6 and Table 7 of Appendix E of final subpart V, that is single-phase arcs in open air, typically occur during overhead line work. In this case, the arc will almost always occur when an energized conductor approaches too close to ground. Thus, employers can determine the arc gap, or arc length, for these exposures by the dielectric strength of air and the voltage on the line (Exs. 0041, 0533).[327] The dielectric strength of air is approximately 10 kilovolts for every 25 millimeters (1 inch) (Ex. 0041), with a

[327]Table 6 of Appendix E of final subpart V uses a more conservative arc gap that equals the electrical component of the minimum approach distance rather than a value corresponding to the dielectric strength of air for the system voltage. (See the summary and explanation for final §1926.960(c)(1), earlier in this section of the preamble, and Appendix B to final Subpart V for additional information on determining the electrical component of the minimum approach distance based on the maximum transient overvoltage for a system and determining the dielectric strength of air for the maximum phase-to-ground system voltage.) OSHA used the electrical component of the MAD to create Table 6 in final Appendix E for consistency with the approach used in similar tables in the 2007 NESC (Ex. 0533) and the 2012 NESC.

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minimum arc gap of 51 millimeters (1 inch). For example, at 50 kilovolts, the arc gap would be $50 \div 10 \times 25$, or 125 millimeters (5 inches). Although OSHA is providing this guidance in the final rule, as discussed later in this section of the preamble, employers may use other estimates of the arc gap for single-phase arcs in open air if the estimates reasonably resemble the actual exposures faced by employees.

For three-phase arcs in open air and in enclosures, the IEEE 1584 method provides guidance (Ex. 0425). That method does not require the user to input an arc gap (*id*.). Instead, it incorporates the arc gap into its calculations based on the class of equipment involved. The user selects the type of equipment involved (for example, 600-volt switchgear). It then uses the appropriate bus or conductor spacings in that equipment as the arc gap in the calculation of incident energy. For a three-phase arc to occur, current must arc between all of the phases. Such arcs typically occur when a conductive object drops across the phases or when there is an internal fault in the equipment; therefore, OSHA concludes that it is reasonable to use the bus or conductor spacing as the arc gap. Notably, neither the NFPA 70E Annex D nor the Doughty, Neal, and Floyd method require users to input an arc gap.

Reasonable estimates of the distance from the employee to the arc. All of the acceptable methods of estimating incident energy require the user to input the distance from the arc to the employee. This approach requires some judgment by the employer. However, the hazard assessment required by final paragraph (g)(1) will provide information that the employer can use to assess where arcs are reasonably likely to occur in relation to the employee. To determine employee exposure to hazards from electric arcs as required by final paragraph (g)(1), the employer must determine where an

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employee is reasonably likely to be when an arc occurs (in addition to whether there is a reasonable likelihood that an arc could occur in the first place).

In Appendix E to final subpart V, OSHA provides guidance on distance assumptions it will consider reasonable for estimating incident energy for exposures involving single-phase arcs in open air. As noted earlier, work on overhead power lines typically exposes employees to single-phase arcs in open air. Employees performing this type of work handle conductors; and these conductors can contact a grounded object, or a grounded conductor (such as a guy or grounding jumper) can contact a phase conductor (Ex. 0004[328]).

As noted under the summary and explanation for final paragraph (c)(1), earlier in this section of the preamble, much of the work performed on energized parts operating at 46 kilovolts and less is done by employees using rubber insulating gloves.[329] Working in a comfortable position with elbows bent, an employee would be approximately 380 millimeters (15 inches) from the energized conductor on which he or she is working,

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[328]See, for example, the six accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=170805238&id=200021004&id=170070981&id=201791803&id=14291868&id=170178370.

[329]Work is not performed on energized parts in the 46.1- to 72.5-kilovolt range using rubber insulating gloves. The maximum voltage rating for rubber insulating gloves is 36 kilovolts. (See Table E-4 to final §1926.97.) The phase-to-ground voltage on a 72.5-kilovolt circuit is 41.8 kilovolts, which is above the maximum use voltage for rubber gloves. Minimum approach distances are set for the 46.1- to 72.5-kilovolt range based on the rubber insulating glove work technique because rubber insulating glove work is performed close to energized parts in this voltage range. For the purposes of estimating incident-energy levels, the Agency believes that the most likely electric arc will generally involve live parts the employee will be handling, which will be energized at 46 kilovolts or less.

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measured from the employee's chest.[330] Thus, OSHA used a distance of 380 millimeters (15 inches) to calculate the incident-energy values in Table 8 in proposed Appendix F (Table 6 in final Appendix E) and will deem that a reasonable estimate for employers to use when performing incident-energy calculations for single-phase open-air exposures on voltages of 46 kilovolts and less. Employers may use other distances if those distances reasonably resemble the actual exposures faced by employees.

TVA maintained that the 380-millimeter (15-inch) distance assumption for these exposures was too small, commenting:

> OSHA states that an employee's chest will be about 380 millimeters (15 in.) from an energized conductor during rubber glove work on that conductor. A review of anthropometric estimates ("Anthropometry, Ergonomics, and the Design of Work" by S. Pheasant) for British adults (19 to 65 years old) shows that the elbow to finger tip length for the 5th percentile is 440 mm (17.3 inches) for men and 400 mm (15.75 inches) for women. After adding a distance of 51 mm (2 inches) for the arms to move toward the front of the body and into a working position, the distance from the chest to the potential arc point will be 451 mm (17.76 inches) for women and 491 mm (19.33 inches) for men. Based [on] this data, the default distance from the worker to the arc point should be 451 mm (17.76 inches) or about 18 inches. The 15-inch distance proposed by [OSHA] will increase the calculated arc flash incident energy, which means that employees will have to wear heavier protection within the area of the arc flash boundary. This heavier protection is not warranted based on anthropometric data. IEEE 1584 states that a typical distance is 455 mm (17.91 inches) to the arc for cable work and low voltage panelboards and motor control centers. It is recommended that the final rule adopt 457 mm (18 inches) as the default distance to the arcing point. [Ex. 0213]

OSHA does not dispute the anthropometric data described by TVA. However, the Agency does not agree with TVA's application of this data to rubber glove work. An employee working in a comfortable position on a conductor will have his or her upper

[330]Rubber insulating gloves with leather protectors and rubber insulating sleeves normally cover the employee's arms. This equipment provides protection against incident heat energy (Exs. 0373, 0466; Tr. 434).

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and lower arms at an angle of about 60 degrees (269-Ex. 8-5). This position forms an equilateral triangle with the sides produced by the upper arm, the lower arm, and the distance between the employee's chest and the conductor. Therefore, the distance from the energized part to the worker's chest is the same as the distance between the energized part and the worker's elbow. Although the 95th percentile distance between the elbow and the fingertip may be 440 millimeters (17.3 inches), the conductor will be closer than that distance because it will originate at the crotch between the thumb and the palm rather than at the fingertip (*id.*). Subtracting 60 millimeters (2.4 inches) from the length of the lower arm, which is a conservative approximation of the distance between the middle fingertip and the crotch between the thumb and the palm, yields a distance of 380 millimeters (15 inches). This is the approximate distance between an employee using rubber gloves on an energized conductor and the live part, which also is the same distance as the estimated distance TVA was challenging.[331] OSHA does not dispute the IEEE Std 1584 distance mentioned by TVA; however, the IEEE distances are for cables and enclosed equipment, not for open conductors in air (which involve the use of rubber insulating gloves). The Agency concludes that the distance from the arc to the employee should be different for these exposures, as explained later. Consequently, OSHA concludes that 380 millimeters (15 inches) is a reasonable distance to assume between the employee and the arc for work by employees using rubber gloves involving exposures to single-phase arcs of up to 46 kilovolts in open air.

[331]OSHA's approach is identical to the approach taken by the 2007 NESC in Table 410-1 (Ex. 0533). (The 2012 NESC retains this approach in Table 410-2.)

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At voltages higher than 46 kilovolts, employees must use live-line tools or the live-line barehand technique to handle energized parts.[332] For this work, OSHA considers it reasonable to calculate incident-energy exposures for single-phase open-air arcs using a distance from the employee to the arc that is equal to the applicable minimum approach distance minus twice the arc length. In this case, the employee would be at the minimum approach distance from the energized part,[333] where OSHA assumes the arc occurs, and subtracting twice the arc length from that distance accounts for movement of the arc[334] and for small errors in judging and maintaining the minimum approach distance. There is no evidence on the record that this distance is unreasonable, and the Agency received no adverse comments on that assumption. Therefore, OSHA concludes that, for exposures involving single-phase arcs in open air when employees perform work using live-line tools, a reasonable estimate of the distance from the arc to the employee is the minimum approach distance minus twice the arc length.

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[332]Although the rest of this discussion relates to work performed using live-line tools, an employer can use the same technique to reasonably estimate the distance from the employee to the electric arc when the employee is performing live-line barehand work. An employee performing live-line barehand work is at the potential of the conductor and is maintaining the applicable minimum approach distance from ground. From the worker's perspective, the dangerous potential is ground, not the conductor to which he or she is bonded. In that case, the employer can reasonably assume that the arc, if one occurs, will be close to objects at ground potential as, for example, if an energized conductor drops onto a grounded tower leg, or at the potential of other phase conductors as, for example, if a phase conductor drops on another phase conductor below.

[333]The design of the live-line tool keeps the employee at a distance from the energized part equal to, or greater than, the applicable minimum approach distance.

[334]When the arc initiates, the worker is likely to react by pulling the live-line tool away from the energized part and toward himself or herself. This action would pull the arc toward the worker. If the worker reacts in the opposite direction, then he or she would get closer to the arc.

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Table 9 in proposed Appendix F only covered work on systems operating at more than 46 kilovolts. The Agency recognizes that some employers require their employees to use live-line tools on voltages of 46.0 kilovolts and less. (See, for example, Exs. 0125, 0127, 0159.) Therefore, the Agency is extending Table 7 in final Appendix E to cover these lower voltages as well. Table 7 applies whenever employees use live-line tools, irrespective of voltage, because OSHA based the table on the work method, not on the voltage. OSHA also revised the titles of Table 6 and Table 7 in final Appendix E to indicate that they are applicable to work using rubber insulating gloves and live-line tools, respectively, rather than work on systems based on voltage as proposed.

One mechanism for reducing estimated incident energy is to move the employee farther away from the electric arc. One way to accomplish this objective is to use live-line tool work methods with a larger minimum approach distance than the minimum distance required by paragraph (c)(1) of final §1926.960. OSHA encourages employers to use such methods to reduce incident-energy levels. If an employer requires an employee to maintain a minimum approach distance greater than the minimum distance required by paragraph (c)(1), OSHA would deem it reasonable for the employer to use an estimate of the distance from the employee to the arc that reflects the employer-imposed minimum approach distance rather than the minimum approach distance required by the standard.

Work that exposes employees to three-phase arcs in open air, or single-phase or three-phase arcs in enclosures, typically involves the employee working at a greater distance from energized parts than is the case when an employee is working on a single phase conductor of an overhead line. For example, employees typically perform work on energized equipment using insulating tools or test equipment on the energized parts or by

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operating the equipment or removing covers. In the first two cases, that is, using insulated tools or test equipment on energized parts, the employee will be working with arms extended. In the latter two cases, that is, operating the equipment or removing covers, employees would be working with their hands near the outside of equipment. OSHA believes that, in all four cases, it is reasonable to assume that the employee is working at a greater distance from the energized parts than an employee working with rubber insulating gloves on energized overhead line conductors. IEEE Std 1584a-2004 uses distances based, at least in part, on the dimensions of the equipment enclosure (Ex. 0425). Because IEEE designed that standard to address a wide range of equipment, OSHA believes that the IEEE approach is broadly applicable to work on energized equipment. The IEEE approach is explained in Section 4.8 of that standard as follows:

> Arc-flash protection is always based on the incident energy level on the person's face and body at the working distance, not the incident energy on the hands or arms. The degree of injury in a burn depends on the percentage of a person's skin that is burned. The head and body are a large percentage of total skin surface area and injury to these areas is much more life threatening than burns on the extremities. Typical working distances are shown in [the following table:]

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Classes of equipment	Typical working distance[a] (mm) [inches]
15 kV switchgear	910 [36]
5 kV switchgear	910 [36]
Low-voltage switchgear	610 [24]
Low-voltage MCCs[335] and panelboards	455 [18]
Cable	455 [18]
***	

[a] Typical working distance is the sum of the distance between the worker standing in front of the equipment, and from the front of the equipment to the potential arc source inside the equipment. [*id.*[336]]

IEEE Std 1584a-2004 – *IEEE Guide for Performing Arc-Flash Hazard Calculations—Amendment 1* – Reprinted with permission from IEEE – Copyright 2004, by IEEE. (Table revised from original).

There is no evidence on the record that the distances in IEEE Std 1584a-2004 for three-phase arcs in open air or single-phase or three-phase arcs in enclosures are unreasonable. Therefore, OSHA concludes that the distances in IEEE Std 1584a-2004 described earlier are reasonable estimates for the distance from the employee to the electric arc for three-phase arcs in open air, and single-phase and three-phase arcs in enclosures, for voltages up to 15 kilovolts. Above that voltage, employers must consider equipment enclosure size and the working distance to the employee in selecting a

[335]Motor control center.

[336]IEEE Std 1584b-2011 makes editorial changes to the quoted paragraph and adds a column with English units to the table. The metric distances in the table remain unchanged.

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distance from the employee to the arc. The Agency will consider a distance reasonable when the employer bases it on equipment size and working distance.

Summary and discussion of general issues related to incident-energy calculation methods. Table 12, Table 13, and Table 14 in this preamble summarize OSHA's findings related to methods employers can use to estimate incident heat energy as required by final paragraph (g)(2). OSHA included these tables in Appendix E to Subpart V in the final rule to enable employers to readily select incident-energy calculation methods and input parameters that OSHA will consider reasonable and acceptable for compliance with paragraph (g)(2) of final §1926.960.

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Table 12—Selecting a Reasonable Incident-Energy Calculation Method[1]

Incident-Energy Calculation Method	600 V and Less[2]			601 V to 15 kV[2]			More than 15 kV		
	1Φ	3Φa	3Φb	1Φ	3Φa	3Φb	1Φ	3Φa	3Φb
NFPA 70E-2004 Annex D (Lee equation)[3]	Y-C	Y	N	Y-C	Y-C	N	N[4]	N[4]	N[4]
Doughty, Neal, and Floyd	Y-C	Y	Y	N	N	N	N	N	N
IEEE Std 1584a-2004[5]	Y	Y	Y	Y	Y	Y	N	N	N
ARCPRO	Y	N	N	Y	N	N	Y	Y[6]	Y[6]

Key:

- 1Φ: Single-phase arc in open air
- 3Φa: Three-phase arc in open air
- 3Φb: Three-phase arc in an enclosure (box)
- Y: Acceptable; produces a reasonable estimate of incident heat energy from this type of electric arc
- N: Not acceptable; does not produce a reasonable estimate of incident heat energy from this type of electric arc
- Y-C: Acceptable; produces a reasonable, but conservative, estimate of incident heat energy from this type of electric arc.

Notes:

[1]Although OSHA will consider these methods reasonable for enforcement purposes when employers use the methods in accordance with this table, employers should be aware that the listed methods do not necessarily result in estimates that will provide full protection from internal faults in transformers and similar equipment or from arcs in underground manholes or vaults.

[2]At these voltages, the arc is presumed to be three-phase unless the employer can demonstrate that only one phase is present or that the spacing of the phases is sufficient to prevent a multiphase arc from occurring.

[3]The entries for NFPA 70E-2004 Annex D (Lee equation) apply equally to NFPA 70E-2012, and the comparable table in Appendix E refers to NFPA 70E-2012 Annex D (Lee equation).

[4]Although OSHA will consider this method acceptable for purposes of assessing whether incident energy exceeds 2.0 cal/cm^2, the results at voltages of more than 15 kilovolts are extremely conservative and unrealistic.

[5]The entries for IEEE Std 1584a-2004 apply equally to IEEE 1584b-2011, and the comparable table in Appendix E refers to IEEE Std 1584 with this latest amendment.

[6]OSHA will deem the results of this method reasonable when the employer adjusts them using the conversion factors for three-phase arcs in open air or in an enclosure, as indicated in the program's instructions.

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Table 13—Selecting a Reasonable Arc Gap

Class of Equipment	Single-Phase Arc mm (inches)	Three-Phase Arc mm[1] (inches)
Cable	NA[2]	13 (0.5)
Low voltage MCCs and panelboards	NA	25 (1.0)
Low-voltage switchgear	NA	32 (1.25)
5-kV switchgear	NA	104 (4.0)
15-kV switchgear	NA	152 (6.0)
Single conductors in air, 15 kV and less	51 (2.0)[3]	Phase conductor spacing
Single conductor in air, more than 15 kV	Voltage in kV times 2.54 (0.1), but no less than 51 mm (2 inches)[3]	Phase conductor spacing

[1]Source: IEEE Std 1584a-2004.

[2]"NA" = not applicable.

[3]Table 6 of Appendix E of final Subpart V uses a more conservative arc gap that equals the electrical component of the minimum approach distance rather than a value corresponding to the dielectric strength of air for the system voltage, which forms the basis for the values in this table.

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Table 14—Selecting a Reasonable Distance from the Employee to the Arc

Class of Equipment	Single-Phase Arc mm (inches)	Three-Phase Arc mm (inches)
Cable	NA*	455 (18)
Low voltage MCCs and panelboards	NA	455 (18)
Low-voltage switchgear	NA	610 (24)
5-kV switchgear	NA	910 (36)
15-kV switchgear	NA	910 (36)
Single conductors in air (up to 46 kilovolts), work with rubber insulating gloves	380 (15)	NA
Single conductors in air, work with live-line tools and live-line barehand work	$MAD - (2 \times kV \times 2.54)$ ($MAD - (2 \times kV / 10)$)†	NA

*"NA" = not applicable.

†The terms in this equation are:

MAD = The applicable minimum approach distance, and

kV = The system voltage in kilovolts.

With the guidance provided here and in Appendix E to final subpart V, OSHA believes that employers will be able to reasonably estimate incident-energy levels as required by final paragraph (g)(2). The Agency expects that, upon inspection, it will be able to detect any manipulation of input parameters designed to undermine the purpose and requirements of this final rule.

In enforcing paragraph (g)(2) of the final rule, the Agency will accept as reasonable any estimates made following the guidance in the preamble and in Appendix

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E. Employers may depart from this guidance as long as the methods and variables used to calculate incident heat energy relate reasonably to the electric-arc exposures actually faced by employees. Duke Energy pointed out that "standard writing committees … are continuing to address the electric-arc hazards, specifically NFPA 70E, IEEE Std 1584-2002, and technical papers written by the IEEE/ESMOL[337] committee" (Ex. 0201). These efforts may result in additional sources of information for employers to use in estimating incident heat energy for purposes of final paragraph (g)(2).

Several rulemaking participants noted that IEEE and NFPA are undertaking a joint research effort to address issues related to methods of calculating incident heat energy from electric arcs. (See, for example, Exs. 0177, 0201, 0227; Tr. 1095, 1128 – 1129.) These rulemaking participants recommended that OSHA delay the rulemaking pending the results of this research. For example, Ms. Kathy Wilmer, testifying on behalf of EEI, stated:

> In 2005, IEEE and NFPA sponsored a joint task force whose charge was to develop a research and test plan intended to address technical issues, including those raised by the calculation methods. It will be several years, however, before the results of the IEEE/NFPA Research and Test Plan Committee are available to employers. [Tr. 1095]

EEI recommended that "OSHA wait for NFPA and IEEE to answer some of [the] questions" related to the calculation methods (Tr. 1129).

As noted by Ms. Wilmer, the results of any research conducted as a result of the IEEE-NFPA joint effort may be years away. Today, the final results of this research are not available. OSHA concludes that there is sufficient information in the rulemaking

[337]Electrical Safety and Maintenance of Lines.

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record to determine that existing calculation methods can reasonably estimate incident heat energy from electric arcs. Therefore, the Agency does not believe that it is necessary to wait for IEEE and NFPA to complete the research. In the future, this research may result in additional sources of information for employers estimating incident heat energy for the purposes of final paragraph (g)(2).

Note 2 to paragraph (g)(2), which is being adopted without substantive change from the proposal, explains that paragraph (g)(2) does not require the employer to estimate the heat-energy exposure for every job task performed by each employee. The note indicates that the employer may make broad estimates that cover multiple system areas provided that: (1) the employer uses reasonable assumptions about the energy-exposure distribution throughout the system, and (2) the estimates represent the maximum exposure for those areas.

Proposed Appendix F explained that the employer could use the maximum fault current and clearing time to cover several system areas at once.

NIOSH expressed concern that, following this guidance, an employer could estimate incident energy based on the maximum available fault current, even though a higher incident-energy level is possible with a lower fault current (Ex. 0130). NIOSH explained:

> [Proposed Note 2 to paragraph (g)(2) and proposed Appendix F] suggest that the point in a power system that has the highest available fault current will also have the maximum heat energy hazard in the event of an arcing-fault. [T]he heat energy released during an arcing-fault is a function of both current and duration (clearing time). The maximum heat energy hazard may be at a point in the system where available fault current is less than the system maximum and may consequently have a longer clearing time. This longer clearing time is due to the inverse-time characteristic of many circuit protection components such as fuses and relays (the higher the fault current, the more quickly the circuit protection components will clear the fault). [*Id*.]

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NIOSH recommended "providing a more detailed explanation of the interdependence of current and clearing time with respect to arcing-fault hazards," and indicated that "NFPA 70E-2004 provides an example of such an explanation" (*id.*).

OSHA recognizes that fault current lower than the maximum available fault current can produce a higher incident energy. The maximum fault current, also known as the bolted-fault current, occurs when the fault has no impedance,[338] as if the two conductors were bolted together. The current in an electric arc is never as high as the maximum available fault current because the arc itself has some impedance, and this lowers the fault current. All of the incident-energy calculation methods, except ARCPRO, account for this reduction (Exs. 0134, 0425, 0430, 0469).

As NIOSH notes, when the current is less than the maximum available fault current, the protective devices for the circuit may take longer to clear the fault, resulting in longer clearing times. IEEE Std 1584a-2004 accounts for this difference in clearing times and for variations in arc current with arc voltage in the formulas it uses to calculate incident energy (Ex. 0425). The other methods use the clearing time corresponding to the fault current used to calculate the incident energy.

However, the fault current and the clearing times used to calculate incident energy in these calculations are only approximations of the values that might occur in an actual fault. Like the distance from the employee to the arc and, in some cases, the arc length, the fault current and clearing time in an actual fault likely will be different from the fault current and clearing time used to calculate incident energy. The final rule requires that

[338]Impedance is the effective resistance of an electric circuit to alternating current. It includes the combined effects of ohmic resistance and reactance.

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the employer's estimate of incident energy be reasonable, not that it be a precise estimate of the maximum possible incident energy. Lower fault current may produce a higher incident energy, but so would exposures with the employee closer to the arc. Other variations, such as short clearing times (which can occur if the arc self-extinguishes) or longer distances between the employee and the arc, could lead to lower incident energy. Considering the evidence in the record as a whole, the Agency believes that using maximum fault current in estimating incident energy will produce reasonable estimates of the exposures faced by employees.

Mr. John Vocke with Pacific Gas and Electric Company stated that his company conducted testing to verify the values in Table 8 and Table 9 in proposed Appendix F (Ex. 0185). He maintained that the incident-energy values provided in those tables may be inaccurate.

As noted earlier, the Agency concluded that the ARCPRO method, on which OSHA based the incident-energy values in proposed Table 8 and Table 9, reasonably estimates incident energy from single-phase arcs in open air on systems of more than 600 volts. Mr. Vocke did not provide the parameters used in, or the results of, Pacific Gas and Electric Company's testing. For example, it is not clear from Mr. Vocke's comment whether the testing was with single-phase arcs in open air. If not, then the Agency would expect their results to differ from the values in proposed Table 8 and Table 9.

As described earlier, OSHA based Table 8 and Table 9 in proposed Appendix F on calculations using ARCPRO and designed those tables to cover a wide range of exposures faced by employees performing overhead line work. TVA noted that these

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tables had little application and expressed concern that employers would misuse the tables, commenting:

> We believe the use of tables, e.g., … proposed Tables 8 & 9, have limited application for estimating heat energy for electrical circuits common to the electric utility industry. The footnotes to these tables instruct users to use other methods if the circuit assumptions in the tables are not applicable to the circuit being analyzed. Our concern is that many companies will not understand the limitations of these tables or choose to ignore the instruction to use other methods. Either of these actions could result in under estimating the arc flash hazard.
>
> * * *
>
> [W]e do not agree with the "table" method approach. We believe that for many exposures in generating and transmission facilities OSHA's proposed Tables 8 and 9 will not be useful to employers for selecting arc flash protection. The tables are misleading because in reality there are too many circuits with parameters that do not meet the table use criteria. OSHA states in [proposed Appendix F] that employers will need to use other methods in situations not addressed by Table 8 or Table 9. We believe that an accepted method should be used to calculate arc flash incident energies and recommend that the final rule not include tables like proposed Table 8 and Table 9 for selecting arc flash protection. [Ex. 0213]

OSHA believes that Table 8 and Table 9 from proposed Appendix F (Table 6 and Table 7 in final Appendix E, which OSHA revised as described elsewhere in this section of the preamble) serve as relatively simple ways for employers to estimate incident energy. The SBREFA Panel Report specifically recommended that OSHA consider including such tables in the standard (Ex. 0019). The National Electrical Safety Code committee adopted provisions on protection from electric arcs that included tables similar to the ones in the proposal (Ex. 0480). Mr. James Tomaseski of IBEW supported the proposed tables and stated that the values in those tables represent "common exposures out on distribution lines" (Tr. 939 – 940). Mr. Brian Erga with ESCI also supported proposed Table 8 and Table 9, testifying:

> ESCI fully supports the table 8 and table 9 in the appendix of this proposal as a way of providing a method of choosing some FR clothing for workers or small companies.

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> It will allow a company to figure out, take their fault current, their clearing time, go into a table, and find … some clothing that might be appropriate, buy that for them, and feel … assured that they were doing what they could do and … what OSHA would require. [Tr. 1246 – 1247]

The Agency concludes that Table 8 and Table 9 in proposed Appendix F will assist employers in complying with the requirement in final paragraph (g)(2) to estimate incident heat energy and that the tables reasonably represent exposures in electric distribution systems, as noted by Mr. Tomaseski, if not transmission systems.[339] (See, also, Mr. Erga's testimony at Tr. 1247: "I passed table 8 and table 9 around to my customers. All of them feel it looks very good and looks very straightforward for them to follow. And they feel pretty comfortable that they would be willing to get into an FR program using [those] table[s] ….") Consequently, OSHA is including the tables in final Appendix E, with revisions as described elsewhere in this section of the preamble. OSHA agrees with TVA that it is important for employers to heed the notes to these tables, which limit their application to rubber insulating glove work (Table 6) and live-line tool work (Table 7) involving exposure to single-phase arcs in open air. OSHA further agrees that these tables are of little, if any, use in electric power generating plants, where most of the exposures come from three-phase arcs. Nevertheless, the Agency believes that many employers, especially small ones, will find these tables useful.

[339]Although there is nothing in the record that states explicitly that Table 9 represents actual exposures for employees working on transmission systems, the existence of similar tables in the 2007 NESC (Ex. 0533) and the 2012 NESC strongly suggests that Table 9 does reasonably represent transmission exposures. (Table 8 of proposed Appendix F covers only distribution voltages.)

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Mr. Tom Chappell of Southern Company suggested that the final rule not require incident-energy estimates for voltages of 600 volts and less, arguing that these systems do not pose the same risk as higher voltage systems:

> This proposed language would require that the employer make estimates of the maximum available heat energy to which employees are exposed to at 600 volts and below as well as those above 600 volts. We do not believe this to be reasonable. Even OSHA recognizes that the risks of exposures at 600 volts and below do not carry the same risk as those above 600 volts since the proposed regulations do not require flame resistant clothing at voltages 600 volts and below. Additionally, Note 2 suggests making broad estimates that cover multiple system areas, and further gives an example of how that may be done for distribution circuits. Both of these suggest that the OSHA's intent was not to cover systems operating at 600 volts or less where such broad estimates are meaningless and not possible. We recommend that estimates of heat energy not be required for systems operating at 600 volts and below and that engineering controls and work practices be used for these systems so that contact is avoided. This recommendation would be consistent with NESC proposed language. [Ex. 0212]

Mr. Chappell misunderstood the rationale behind OSHA's final rule. First, Note 2 to proposed paragraph (g)(2), which OSHA is adopting without substantive change, contained an example, clearly identified as such, of how to estimate incident heat energy over a wide area. There are other possible circuits that might be suitable for wide estimates. In addition, the note only addresses circuits that are far-ranging, such as transmission and distribution circuits. Circuits that operate at 600 volts and less are found normally as services or as feeder or branch circuits inside electric power generation plants. (See, for example, 269-Exs. 8-5, 8-17, 8-20, 8-21, 8-22.) These circuits do not normally extend for miles; each of them usually serves a single facility. Second, OSHA does not agree that 600-volt systems produce lower amounts of incident energy or pose a lower risk of burn injury to employees than higher voltage systems. The rationale behind the requirement in final §1926.960(g)(4)(i) that employees exposed to contact with circuit parts operating at more than 600 volts wear flame-resistant clothing relates to the reduced

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likelihood that contact with a circuit part energized at lower voltages would produce an electric arc through, and ignite, the clothing. As noted under the summary and explanation for final paragraph (g)(4)(i), many commenters noted that systems operating at 600 volts and less are capable of producing extremely high levels of incident energy, sometimes even higher than systems operating at higher voltages. For example, Mr. Paul Hamer stated, "Many systems and equipment operating at 600 volts and below have severe arc-flash hazards …" (Ex. 0166). In addition, TVA noted:

> The magnitude of the heat energy in 480 V arc flash accidents is greater [than at voltages higher than 600 volts] because of the following: 1. The single phase fault typically propagates to three phase fault. 2. The clearing times in generating plants are typically longer. 3. The arc flash energy is typically forced into one direction (arc in a box). [Ex. 0213]

Therefore, while there may not be an ignition hazard from contact at the lower voltages, burn hazards at these voltages may still be serious and require arc-rated protective equipment.

For these reasons, OSHA is not adopting Mr. Chappell's recommendation. The Agency believes that it is just as important to estimate incident-energy levels for systems operating at 600 volts and less as it is for systems of higher voltages. Without an estimate of incident energy, an employer would not be able to select appropriate arc-rated protective equipment for employees exposed to these voltages in accordance with final §1926.960(g)(5).

Some rulemaking participants maintained that incident-heat-energy exposures change over time. (See, for example, Exs. 0126, 0163; Tr. 404 – 405.) For instance, Ms. Susan O'Connor with Siemens Power Generation commented that "if new equipment is added or the available fault current to the plant from the utility changes, the entire

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calculations change. The arc faults become a moving target" (Ex. 0163). Noting that fault current can change hourly, Mr. James Shill with ElectriCities of North Carolina testified:

> [I]n one of my first assignments in the power company I was in charge of coordinating the equipment, and fault currents change hourly. [I]t depends on where your source of energy comes from. [Tr. 404]

The final rule does not require employers to estimate incident-energy levels on a moment-by-moment basis. As indicated by Note 2 to paragraph (g)(2), the final rule permits employers to make broad estimates of incident-energy exposure, provided those estimates represent the reasonably expected maximum exposures. There would be no need to perform additional calculations when changes to the system would lower incident energy. In addition, as long as the protective clothing and other protective equipment selected by the employer will protect against the incident energy, including any increase caused by changes to the system, the final rule does not require the employer to reconduct the incident-energy estimates required by paragraph (g)(2).

The Agency believes that employers will select arc-rated protective equipment, not on the basis of estimates for individual circuits, but on the basis of what levels will provide protection for broad areas of the employers' systems. For instance, an employer could select a base clothing outfit rated at 8 cal/cm^2. This clothing would be acceptable as long as the estimated energy levels are less than that value. Accordingly, OSHA believes that an employer can take measures to minimize the number of times it must perform additional calculations. For example, an employer using Table 6 or Table 7 in final Appendix E, can select an incident-energy estimate for a maximum number of cycles at a given level of fault current on a particular circuit. As long as any change to the circuit does not increase the fault current or clearing time beyond the fault current and clearing time used in selecting a value from the table, the employer would not have to make

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additional estimates. The employer then would know that as long as relay settings (which affect clearing time) and transformer kilovolt-ampere ratings (which affect maximum fault current) stay below the values on which the employer bases the selection of incident-energy level, then employees would remain safe, and the employer would remain in compliance. Thus, the employer could avoid having to reestimate incident-energy levels simply by limiting the types of changes that could be made to a circuit or by selecting protective clothing and other protective equipment that accommodates any changes that will be made. As Mr. Donald Hartley of IBEW testified: "[If] you don't find that [the fault current and clearing times] are substantially different [then] you may not have to change what it is you were doing" (Tr. 1031 – 1032). On the other hand, it is possible that employers that do not adequately plan changes to their systems will need to reestimate incident heat energy for some of their circuits.

OSHA does not expect employers to account for unanticipated changes to their systems in estimating incident-energy levels. As Mr. Shill noted, it is possible that an unanticipated system change could increase incident energy. For example, an unidentified faulty relay could substantially increase the clearing time and, thus, an employee's potential incident-energy exposure. However, final paragraph (g)(2) does not require employers to anticipate such events. The estimates required by this paragraph are for normal operating conditions.

For these reasons, OSHA concludes that concerns that employers would need to constantly update their incident-energy estimates are largely baseless. To the extent that employers must update these estimates, the Agency's regulatory analysis fully accounts

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for periodic updates. (See Section VI, Final Economic Analysis and Regulatory Flexibility Analysis, later in the preamble.)

Some commenters maintained that employers would need to hire consultants to perform the incident-energy calculations required by final paragraph (g)(2). (See, for example, Exs. 0163, 0178; Tr. 375 – 376, 563.) Mr. James Shill of ElectriCities of North Carolina testified: "Even if professional engineers know the method to use in calculating maximum available heat energy, small electric utilities often do not have such qualified personnel on staff. Instead, small utility businesses will be faced with hiring outside consultants to perform this work for each job at each workplace, and for each employee" (Tr. 375 – 376).

OSHA agrees with these commenters that small employers may need to hire consultants to perform or assist in the preparation of incident-energy calculations. Even some larger utilities hire consultants to help perform incident-energy calculations (Tr. 1197). The Agency understands that estimating incident heat energy demands some electrical engineering expertise. OSHA believes that most employers that work on electric power generation, transmission, and distribution systems have such engineering expertise available. As noted by some witnesses, these estimates require much of the same knowledge and skill as other assessments needed to operate, maintain, and work on electric power generation, transmission, and distribution systems (Tr. 1030 – 1032). In any event, OSHA's estimate of the costs associated with complying with paragraph (g)(2) in the final rule accounts for the possibility that, in some instances, consultants will perform the required estimates. (See Section VI, Final Economic Analysis and Regulatory Flexibility Analysis, later in this preamble.)

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Some rulemaking participants suggested that contractors would have difficulty estimating incident energy or would not be able to perform the estimates at all. (See, for example, Exs. 0162, 0169, 0234, 0501; Tr. 1326 – 1327, 1335 – 1336.) For instance, Quanta Services noted that utility operators frequently do not know the maximum fault current on their systems, making it "difficult [for contractors] to determine the maximum fault current" (Ex. 0234). The Davis H. Elliot Construction Company suggested that utilities might provide worst-case estimates to their contractors because of potential liability concerns (Exs. 0156, 0206, 0231).

OSHA understands that contractors may face challenges in estimating incident heat energy as required by paragraph (g)(2) in the final rule. The requirements in final §1926.950(c)(1), which specifies that host employers provide information about their systems to contract employers, should ensure that contractors have the information they need to estimate incident energy. Paragraph (c)(1)(iii) of final §1926.950 specifically requires host employers to provide information to enable contract employers to perform the assessments required by the final rule. This would include information contractors need to estimate incident heat energy as required in final §1926.960(g)(2).[340] In any case in which the host employer does not provide the contractor with necessary information and, therefore, violates this final rule, contractors can use other (albeit less certain) means of estimating the system parameters needed to perform incident-energy calculations.

[340]In the economic analysis, OSHA assumes that costs related to estimating incident energy will be borne only by host employers. The Agency anticipates that, for economic reasons, host employers will provide the results of their estimates to contract employers even though the final rule does not require them to do so. See Section VI, Final Economic Analysis and Regulatory Flexibility Analysis, later in the preamble.

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Contractors can estimate fault currents through the ratings of the transformers supplying the circuit[341] and clearing times from the type of overcurrent devices protecting the circuit[342] (Ex. 0425; 269-Ex. 8-15). The Agency assumes that, when utilities are not providing this information, contractors already are using these methods when determining the size of grounds necessary under existing §1910.269(n)(4)(i) ("Protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.") There is no evidence in the record that utilities are currently providing unduly conservative estimates of fault current or clearing times to contractors for the purposes of existing §1910.269(n)(4)(i), and it seems unlikely that they would provide different estimates after this final rule becomes effective. Consequently, the Agency concludes that the concerns specific to contractors are baseless.

Several commenters suggested that proposed paragraph (g)(2) was too vague. (See, for example, Exs. 0126, 0152, 0227; Tr. 1095 – 1097.) For instance, Ms. Jean Thrasher with Community Electric Cooperative commented: "With undefined terms in the equation and no firm guidelines from OSHA the employer has the potential to be cited even though they performed a good faith appraisal but the inspector disagreed with the values chosen" (Ex. 0152).

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[341]For example, a contractor can estimate the fault current on the secondary side of a transformer on a radial system by calculating the fault current at the transformer, which is equal to the transformer rating divided by the product of the per-unit impedance and the voltage (Ex. 0134).

[342]IEEE Std 1584a-2004 gives the clearing times for a wide range of circuit protective devices (Ex. 0425). Contractors also can try to obtain clearing times from a number of other sources, including the manufacturer.

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OSHA made it clear in this preamble and in Appendix E to final Subpart V that the employer is free to choose any method for estimating incident energy that results in a reasonable estimate of incident heat energy to which the employee would be exposed. Appendix E provides guidance on how to estimate incident heat energy and information on approaches that OSHA will recognize as reasonable for performing these estimates. In the final rule, OSHA revised Note 1 to paragraph (g)(2) to further clarify what constitutes compliance with that paragraph. The revised note provides that: (1) OSHA will deem employers that follow the guidance in Appendix E to be in compliance with paragraph (g)(2), and (2) employers can choose another method of estimating incident heat energy if the chosen method reasonably predicts the incident energy to which the employee would be exposed. (Note 1 in the proposal simply referred to the appendix for guidance.) Employers can rely on the guidance in this preamble and final Appendix E to select methods and input parameters accepted by OSHA for compliance with final paragraph (g)(2). Accordingly, the Agency concludes that paragraph (g)(2) in the final rule is not unenforceably vague.

Proposed paragraph (g)(2) would have required employers to make "a reasonable estimate of the maximum available heat energy to which the employee would be exposed." OSHA concludes that this language might not accurately convey the purpose of the proposed rule and, therefore, could confuse the regulated community. For example, as should be clear from the foregoing explanation of what OSHA will consider a "reasonable estimate," the Agency believes that it is reasonable to estimate incident-energy exposures based on the location where an employee is reasonably expected to be working when an arc occurs. However, as explained earlier, the maximum heat energy

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will occur within the arc plasma, and the Agency concludes that it is not necessary to estimate heat energy assuming that the employee is close enough to the arc to be within the plasma field. In addition, as explained previously, the choice of methods and other input parameters also can affect the calculated incident energy. To clarify that the Agency is expecting a reasonable estimate, and not an estimate of the maximum heat energy, OSHA replaced the phrase "a reasonable estimate of the maximum available heat energy" in paragraph (g)(2) in the proposed rule with "a reasonable estimate of the incident heat energy" in the corresponding provision in the final rule. The Agency believes that the final rule more accurately reflects the purpose of this provision and will clarify some of the confusion related to the requirement to estimate incident-energy levels.

NIOSH stated that arc warning labels would be valuable for new or upgraded installations (Ex. 0130). NIOSH explained its position as follows:

> Arc warning labels that explain the voltage, available fault current, Arc Hazard Category, the ATPV of the required protective clothing, and the approach distances would be a valuable addition to all new or upgraded installations. Such information, as calculated by the systems' designers, would then be readily available to the workers who need to maintain such systems. Many commercial power systems analysis packages can automatically generate these labels as part of the systems design and analysis procedure. Having labels on new equipment would eliminate the need for the employer to estimate arc hazards by providing calculated engineering data. [*id*.]

OSHA decided against requiring arc-hazard warning labels such as those recommended by NIOSH. OSHA believes that the employer can effectively provide information on arc hazards and the required protective measures in other ways. Employers must train their employees in the recognition of electrical hazards, including hazards from electric arcs, and the proper use of PPE, including FR and arc-rated clothing, as required by final §1926.950(b)(2)(v) and (b)(2)(iv), respectively. The employer can use several methods other than labels to ensure that employees wear

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appropriately rated protective equipment, including requiring a minimum level of protection that will cover most exposures and including the arc rating on work orders. OSHA believes that these other measures are likely to be more effective than warning labels since they inform the employee of the appropriate rating before the employee arrives at the jobsite. If the employer relies on labels, employees may arrive at the jobsite without properly rated protective equipment. In addition, OSHA does not believe that providing labels on transmission and distribution installations is feasible or effective. It is not possible to label the entire length of a transmission or distribution line, and installing labels at switching points would not prove effective or useful to employees whose work is remote from those switching points. Therefore, OSHA is not adopting the requirement for arc-hazard warning labels recommended by NIOSH.

Prohibited clothing. Paragraph (g)(3), which is being adopted with only minor changes from the proposal, requires the employer to ensure that employees exposed to hazards from flames or electric arcs do not wear clothing that could either melt onto their skin or ignite and continue to burn when exposed to flames or the heat energy estimated under final paragraph (g)(2). This rule is equivalent to existing §1910.269(l)(6)(iii), although OSHA revised the language to explicitly prohibit clothing that could melt onto an employee's skin or ignite and continue to burn.[343] Final paragraph (g)(3) ensures that

[343]The existing rule prohibits clothing that could increase the extent of injuries to an employee. The Agency interprets this rule as prohibiting clothing that could melt or that could ignite and continue to burn in the presence of an electric arc faced by an employee. (See, for example, Memorandum to the Field dated August 10, 1995, from James W. Stanley, "Guidelines for the Enforcement of the Apparel Standard, 29 CFR 1910.269(l)(6), of the Electric Power Generation, Transmission, and Distribution Standard." This memorandum is available at
(*Continued*)

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employees exposed to electric arcs do not wear clothing presenting the most severe burn hazards.

A note following this provision lists fabrics, including acetate, nylon, polyester, and rayon, that the final rule specifically prohibits unless the employer demonstrates that the clothing is treated or worn in such a manner as to eliminate the hazard. In the proposed rule, this note was the same as the note following existing §1910.269(l)(6)(iii). In the preamble to the proposal, OSHA requested comments on whether it should add any other fabrics posing similar hazards to the note.

Many commenters recommended adding polypropylene to the list of prohibited fabrics. (See, for example, Exs. 0148, 0183, 0233, 0239; Tr. 563 – 564.) Mr. Mark Zavislan, representing NRECA, testified:

> Polypropylene is a synthetic fabric under heat conditions. It melts. It's terrible. I have not witnessed it in an arc type of exposure, but I was an EMT for several years, and one of the worst injuries I have ever seen, vehicle accident involving a fire, an individual wearing long underwear made out of this material, and it was pretty ugly.
>
> So I think, if you are looking at the heat exposures from an arc, you've got the potential for the same type of damage. [Tr. 564]

OSHA finds that this evidence indicates that polypropylene can melt. Although Mr. Zavislan's testimony did not indicate that this fabric is likely to melt in an arc exposure, it does indicate that, if polypropylene is exposed to sufficient heat, it will melt. In this regard, OSHA believes that the heat generated by an arc flash is at least as severe as the heat generated by an vehicle fire. Consequently, OSHA is adding polypropylene to

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http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=21878.)

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the list of prohibited fabrics contained in the note following paragraph (g)(3) in the final rule.

Two commenters suggested adding acrylic fibers to the list in the note, although they did not provide any evidence that this fabric melts or ignites and continues to burn when exposed to electric arcs (Exs. 0148, 0213). While OSHA decided against adding acrylic fibers to the list of prohibited fabrics contained in the note, the Agency observes that the note's list of the types of fabric prohibited by final §1926.960(g)(3) is not exhaustive. Employers must ensure that employees do not wear clothing made from an acrylic fiber if such clothing could melt onto the skin or ignite and continue to burn when exposed to the heat energy estimated under final paragraph (g)(2), regardless of whether the note lists the fabric. One of the two commenters that advocated adding acrylic fibers to the note was ASTM. ASTM has extensive experience with testing materials. The Agency suspects that acrylic fibers will melt onto the skin or easily ignite and continue to burn in the presence of an electric arc, although it did not arrive at this conclusion in this rulemaking.

Two commenters recommended removing rayon from the list of prohibited fabrics contained in the proposed note (Exs. 0166, 0228, 0235). These commenters pointed out that rayon is a cellulose-based synthetic fiber that burns but does not melt.

OSHA included rayon as one of the prohibited fabrics on the basis of evidence in the record for the 1994 §1910.269 rulemaking (59 FR 4389; 59 FR 33658 – 33659, 33661). In that rulemaking, the Agency described the evidence and rationale for prohibiting certain fabrics as follows:

> The IBEW introduced a videotape, produced by the Duke Power Company, demonstrating the effects of different types of clothing upon exposure to electric

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> arcs (Ex. 12-12). This tape provides clear evidence of the hazards of wearing clothing made from certain untreated synthetic fabrics, such as polyester, acetate, nylon, and rayon.
>
> * * *
>
> Therefore, for exposed employees, … final §1910.269 adopts a requirement that these employees be trained in the hazards related to the clothing that they wear [and prohibits] apparel that could increase the extent of injuries received by a worker who is exposed to an electric arc. OSHA has also included a note … to indicate the types of clothing fabrics that the record demonstrates are hazardous to wear by employees exposed to electric arcs.
>
> The requirement is intended to prohibit the types of fabrics shown in the Duke Power Company videotape to be expected to cause more severe injuries than would otherwise be anticipated. These include such untreated materials as polyester and rayon, unless the employee is otherwise protected from the effects of their burning. [59 FR 4389, as corrected at 59 FR 33658]

The Duke video indicated that rayon ignites easily in the presence of electric arcs (269-Ex. 12-12). Existing §1910.269(l)(6)(iii) and final paragraph (g)(3) prohibit clothing that can ignite and continue to burn, in addition to fabrics that can melt onto the skin in the presence of electric arcs. The evidence in the record indicates that rayon meets this criterion. Therefore, OSHA is not removing rayon from the list of prohibited fabrics.

When flame-resistant clothing is required. Proposed paragraph (g)(4) would have required employees to wear flame-resistant clothing whenever: (1) the employee was subject to contact with energized circuit parts operating at more than 600 volts (proposed paragraph (g)(4)(i)); (2) an electric arc could ignite flammable material in the work area that, in turn, could ignite the clothing of an employee nearby (proposed paragraph (g)(4)(ii)); or (3) molten metal or electric arcs from faulted conductors in the work area could ignite the employee's clothing (proposed paragraph (g)(4)(iii)). A note to proposed paragraph (g)(4)(iii) indicated that this provision would not apply to conductors capable of carrying, without failure, the maximum available fault current for the time the circuit

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protective devices take to intercept the fault. In such instances, conductors would not melt from the fault current and, therefore, could not ignite the employee's clothing. The conditions listed in proposed paragraph (g)(4) address several burn accidents examined by OSHA involving ignition of an employee's clothing (Exs. 0002, 0003, 0004).[344]

OSHA reworded the introductory text to paragraph (g)(4) in the final rule to clarify what clothing must be flame-resistant and to make it consistent with provisions in final paragraphs (g)(5)(i) through (g)(5)(v) that permit some types of non-flame-resistant clothing in lieu of arc-rated clothing in certain conditions. (See the discussion of the difference between flame-resistant and arc-rated clothing under the summary and explanation for final paragraph (g)(5), later in this section of the preamble.) The language in final paragraph (g)(4) makes it clear that only the outer layer of clothing must be flame-resistant. This requirement recognizes that some companies successfully use 100-percent cotton T-shirts under FR shirts. (See, for example, Tr. 1345 – 1346.) NFPA 70E-2004 also recognizes the use of non-flame-resistant clothing under flame-resistant clothing as providing adequate protection against electric-arc hazards in certain situations (Ex. 0134). In any event, final paragraph (g)(3) prohibits the use of flammable layers of clothing beneath flame-resistant outer clothing whenever doing so poses a burn hazard.

For reasons explained later, OSHA is adopting in the final rule paragraphs (g)(4)(i) through (g)(4)(iii) (including the note) largely as proposed. The Agency is adding a new paragraph (g)(4)(iv) that requires employees to wear flame-resistant

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[344]See, for example, the four accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=596304&id=14418776&id=170238109&id=202043758.

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clothing whenever the incident heat energy estimated under paragraph (g)(2) exceeds 2.0 cal/cm^2. See the explanation of this new paragraph later in this section of the preamble.

Several rulemaking participants argued that some employers are providing adequate protection for their employees by requiring them to wear 100-percent cotton (that is, that flame-resistant clothing is unnecessary). (See, for example, Exs. 0187, 0238, 0506; Tr. 543 – 544.) For instance, Mr. Jonathan Glazier with NRECA stated:

> Many utilities now allow their employees to wear 100 percent natural fiber clothing. This means cotton and, in colder climates, wool or cotton/wool blends. One hundred percent natural fiber clothing complies with OSHA's current 1910.269, if it is thick enough not to ignite and to continue burning, but this will change if the new proposal becomes final.
>
> Proposed Sections 1910.269(l)(11)(4)(a) and 1926.960(g)(4)(i) would require wearing FR clothing -- that's FR clothing, not merely clothing that will not melt or ignite and continue to burn, but FR clothing -- when an employee is "subject to contact with energized circuit parts operating at more than 600 volts."
>
> Arguably, this means that 100 percent natural fiber clothing cannot be worn by employees doing rubber glove work on parts energized above 600 volts. This will require many utilities that have been successfully allowing 100 percent natural fiber clothing to move to the more expensive and, let's face it, more [problematic] FR clothing. [Tr. 543 –544]

The evidence in the rulemaking record clearly shows that flame-resistant clothing is necessary for the protection of employees when the conditions addressed by final paragraph (g)(4) are present. (See, for example, Exs. 0002, 0003, 0004.[345]) Sixteen of the 100 arc-related burn accidents in Ex. 0004, covering the period from 1991 to 1998, involved the ignition of an employee's clothing. Two additional burn accidents involved

[345]See the 16 accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=14418776&id=170611057&id=170191050&id=170203871&id=14241863&id=14277487&id=170193353&id=170061972&id=880658&id=170238109&id=170053128&id=170720957&id=880112&id=202043758&id=14373245&id=596304.

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hydraulic fluid that ignited when an aerial lift approached too close to an energized line (Ex. 0004[346]). The burning fluid can ignite flammable clothing. Five of these 18 accidents occurred when an employee contacted or came too close to an energized part; 3 accidents involved conductors or equipment that could not carry fault current; and 3 accidents involved flammable materials ignited by an electric arc. OSHA acknowledges that some, or potentially all, of these injuries could occur even if the employees had been wearing flame-resistant clothing. However, flame-resistant clothing can minimize the extent of the injury.

As noted by Dr. Thomas Neal, much of the energy in a typical electric arc is concentrated over one part of the body, and other parts of the body receive less energy (Tr. 496 – 497).[347] When an employee's clothing ignites, the employee receives burns from the burning clothing, as well as from any other heat sources in the area, such as an electric arc or fire. In such cases, the ignition of clothing exacerbates the extent of any burn injury that may occur. (See, for example, Tr. 188 – 189, 215, 228.) For this reason, OSHA concludes that preventing clothing ignition in the scenarios in which it is most likely to occur will significantly enhance employee protection. In only one of the 18 incidents mentioned previously was there an indication that the clothing melted, indicating that the clothing probably consisted of one of the fabrics explicitly prohibited

[346]See the two accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200671253&id=201340395.

[347]Thomas Neal has a Ph.D. in analytical chemistry. He worked for E. I. du Pont de Nemours and Company for 30 years, primarily in the field of protective clothing. He has worked with ASTM to develop standards for arc testing and has substantial experience with protective garments used for arc-flash protection (Tr. 491 – 492).

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by the note to final paragraph (g)(3). Although it is not clear whether the remaining injured employees were wearing 100-percent cotton clothing, it is likely that they were. The record indicates that use of 100-precent cotton clothing is standard practice for electric utilities that do not require their employees to use flame-resistant clothing. (See, for example, Exs. 0173 ("Much of the workforce across the nation uses 100% cotton for their uniforms"), 0187 ("A large number of electric utilities already are providing or requiring their employees to wear flame-resistant clothing or 100 percent cotton clothing").) Because some 100-percent cotton clothing poses an ignition hazard, which final paragraph (g)(4) would likely prevent, OSHA concludes that use of 100-percent cotton in lieu of FR clothing would not adequately protect employees in the situations addressed by paragraph (g)(4).

Pacific Gas and Electric Company requested an exemption from the FR clothing requirements for live-line barehand work (Ex. 0185). The company argued that the conductive suits used for this work provide primary protection for employees and that the electrocution hazard (not the burn hazard) is the primary concern in this type of work (*id*.).

Employers use the conductive clothing described by Pacific Gas as a form of shielding to minimize potential differences and body current for employees performing live-line barehand work (Ex. 0041). The clothing assists in bonding the worker to the energized part and keeps the worker from experiencing minor electric shocks as he or she moves along a conductor. Where the conductive fibers that make the suit conductive break, hot spots can develop (*id*.). It is important for this clothing to be flame-resistant material, or these hot spots could ignite the clothing. Consensus standards require that

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conductive clothing used in live-line barehand work be flame-resistant; therefore, conductive clothing manufactured with FR fabric with interwoven conductive fibers is readily available (269-Ex. 60;[348] Ex. 0041). Accordingly, OSHA has decided against exempting live-line barehand work from final paragraph (g)(4).[349]

EEI argued that proposed paragraph (g)(4) was too vague, commenting:

> [The requirements in this paragraph] call for determinations for which objective criteria are absent.… For example, on what basis is an employer to determine that an electric arc could ignite a flammable material that could in turn ignite the clothing of an employee? What kind of calculations does this require, especially considering that it is virtually impossible to predict the movement of an electric arc? Likewise, how is an employer to determine that an employee's clothing could be ignited by molten metal? In sum, the standard calls for speculation, not an objective determination, and therefore does not satisfy due process requirements. [Ex. 0227]

OSHA disagrees with EEI's comment that the requirement for flame-resistant clothing is vague. The Agency believes that employers can determine the presence of each of the conditions listed in final paragraph (g)(4) through a reasonable assessment of what conditions they can expect when an electric arc occurs. This assessment should be part of the hazard assessment required by final paragraph (g)(1). For purposes of final paragraph (g)(4)(i), if the employee is using the rubber glove work method within reaching distance of circuit parts energized at more than 600 volts or if the employee is

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[348]IEC 60895-2002, *Live working - Conductive clothing for use at nominal voltage up to 800 kV a.c. and ± 600 kV d.c.*, is the international standard for conductive clothing. IEEE Std 516-2009 references this standard (Ex. 0532). Since 1987 when IEC first adopted its standard, IEC 895-1987, *Conductive clothing for live working at a nominal voltage up to 800 kV a.c.*, the consensus standard required conductive clothing to be flame-resistant (269-Ex. 60).

[349]Note that estimates of incident energy for live-line barehand work may assume that the arc is most likely to form at objects at potentials different from the worker, such as grounded objects.

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using the live-line tool work method underneath parts energized at more than 600 volts, OSHA will consider the employee to be "exposed to contact" with those parts. The proposed rule used the phrase "subject to contact," which the Agency has changed in the final rule to the phrase "exposed to contact." (See the discussion of that phrase under the summary and explanation of final §1926.960(b)(3) earlier in this section of the preamble.) That change should clarify the meaning of this paragraph.

For purposes of final paragraph (g)(4)(ii), OSHA will be looking for flammable material, such as insulating hydraulic fluid, in the work area close to where an arc may occur. In such situations, the arc can be expected to ignite the fluid, with the burning fluid then igniting an employee's flammable clothing.

For purposes of final paragraph (g)(4)(iii), if there are conductors, such as pole grounds, that energized parts may contact during the course of work and if these conductors cannot carry the fault current, then OSHA expects the employer to assume that molten metal or arcing from the faulted conductor could ignite the flammable clothing of a nearby employee. As explained in the note to final paragraph (g)(4)(iii), the employer can presume that conductors do not pose ignition hazards related to molten metal or arcing if they are capable of carrying, without failure, the maximum available fault current for the time the circuit protective devices take to interrupt the fault.

Paragraph (g)(4)(iii) of the final rule, which is being adopted without substantive change from the proposal, requires flame-resistant clothing where "[m]olten metal or electric arcs from faulted conductors in the work area could ignite the employee's clothing." The Southern Company objected to the requirement in proposed paragraph (g)(4)(iii) that employees wear flame-resistant clothing if molten metal could ignite their

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clothing (Ex. 0212). The company maintained that "it is difficult to determine where molten metal may pose a risk" (*id.*).

OSHA notes that the prepositional phrase "from faulted conductors in the work area" modifies "molten metal" as well as "electric arcs." Thus, employers must provide flame-resistant clothing where employees are working close to equipment, such as pole grounds, that cannot carry fault current. The test is not whether employees are working in areas where an electric arc could eject molten metal onto them; it is whether the employee is working near a conductor that cannot carry fault current. Consequently, OSHA is not adopting the recommendation of Southern Company to eliminate this requirement from paragraph (g)(4)(iii).

Final paragraph (g)(4)(iv) provides that, if the incident heat energy estimated under paragraph (g)(2) exceeds 2.0 cal/cm^2, then the employer must ensure that employees wear flame-resistant clothing.

The foregoing explanation is not an exhaustive discussion of all of the scenarios that would require flame-resistant clothing under final paragraph (g)(4). The Agency expects employers to use the hazard assessment required by final paragraph (g)(1) to determine if any of the conditions listed in final paragraphs (g)(4)(i) through (g)(4)(iv) are present.

Many commenters opposed the 600-volt threshold in the requirement for flame-resistant clothing in proposed paragraph (g)(4)(i). (See, for example, Exs. 0128, 0166, 0186; Tr. 537 – 538.) These commenters argued that severe arc-flash hazards occur at voltages lower than 600 volts. For example, Mr. Paul Hamer commented:

> Many systems and equipment operating at 600 volts and below have severe arc-flash hazards and [require] the use of flame-resistant clothing for

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> personnel protection. Low-voltage motor control centers, panelboards, switchboards, and switchgear are commonly used in electrical power generation, transmission, and distribution systems. See the requirements of NFPA 70E-2004, which include systems operating at 600 volts and below. [Ex. 0228]

TVA recommended lowering the threshold to 480 volts, explaining:

> Our conclusion is that FR clothing must be worn to protect employees from arc flash hazards on circuits operating at 480 V or more. We have experienced serious injuries in accidents involving 480 V circuits. In 23 arc flash accidents recorded between 1981 and 2003 in our company, 52 percent (23 cases) [were] on 480 V circuits. The 1584 IEEE Guide for Performing Arc-Flash Hazard Calculations lists in its Annex C, 49 arc flash cases. Of these cases, 46 percent of the accidents involved either 480 V or 600 V systems. These statistics show that employees working on circuits operating at 480 V or 600 V are at a significant risk of arc flash injury.
>
> We believe the 480 V arc flash hazard is as great as or greater than the higher voltage arc flash hazard. At transmission voltages, the arcs generally present a lower risk of injury because of the distance the employee is to the arc (MAD), the arc being phase-to-ground, the arc being in open air, and the other reasons stated in our comments to other sections of this rule. The magnitude of the heat energy in 480 V arc flash accidents is greater because of the following:
>
> 1. The single phase fault typically propagates to three phase fault.
>
> 2. The clearing times in generating plants are typically longer.
>
> 3. The arc flash energy is typically forced into one direction (arc in a box).
>
> It is recommended that the final rule require the employee to wear flame resistant clothing any time he or she is subject to contact with live parts energized at 480 V or more. [Ex. 0213]

These commenters misunderstood the proposed rule. Paragraph (g)(3) of the final rule contains a prohibition against wearing clothing that could melt onto an employee's skin or that could ignite and continue to burn when exposed to flames or the incident heat energy estimated under final paragraph (g)(2). Thus, final paragraph (g)(3) indirectly requires flame-resistant clothing when the incident heat energy could melt clothing onto an employee's skin or ignite an employee's clothing. Paragraph (g)(4) of the final rule supplements paragraph (g)(3) and requires flame-resistant clothing under other conditions

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likely to ignite flammable clothing. Thus, final paragraph (g)(4)(i) requires flame-resistant clothing when an employee is exposed to contact with energized parts operating at more than 600 volts, regardless of the estimated incident heat energy.

NFPA 70E-2004 Section 130.3 requires employers to conduct an arc-flash hazard analysis and determine the arc-flash protection boundary to protect employees from being injured by electric arcs (Ex. 0134).[350] That section defines the arc-flash protection boundary as the distance at which the incident energy equals 1.2 cal/cm^2 or, if the clearing time is 0.1 seconds (6 cycles) or less, 1.5 cal/cm^2 (*id.*). A few commenters urged the Agency to consider an arc-flash boundary requirement similar to the one in NFPA 70E. (See, for example, Exs. 0128, 0130, 0235.) For instance, the Dow Chemical Company commented:

> Dow recommends that OSHA change the trigger for wearing FRC from "contact with energized circuit parts operating at more than 600 volts" to "work within the electric arc flash hazard distance when there is a substantial potential for an arc flash" …. NFPA 70E uses the electric arc flash hazard distance as the trigger for wearing FRC, and it provides guidance in how to determine the electric arc flash hazard distance. [Ex. 0128]

In response to these comments, OSHA is adding a requirement, in final paragraph (g)(4)(iv), that employees wear clothing that is flame-resistant where the incident heat energy estimated under final paragraph (g)(2) exceeds 2.0 cal/cm^2. Although NFPA 70E-2004 sets the arc-flash protection boundary at lower levels, Section 130.7(C)(14)(b) of that standard[351] permits employees to wear "nonmelting flammable natural materials" (in

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[350]Section 130.5 of NFPA 70E-2012 contains an equivalent requirement.

[351]NFPA 70E-2012 no longer explicitly permits "nonmelting flammable materials" for exposures from 1.2 to 2.0 cal/cm^2; however, NFPA 70E-2012 Table 130.7(C)(15)(b) apparently permits such fabrics for certain exposures above 1.2 cal/cm^2. (*Continued*)

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lieu of flame-resistant clothing) where the incident-energy level is 2.0 cal/cm^2 or less.[352] New paragraph (g)(4)(iv) should make it clear that employees must wear flame-resistant clothing whenever the incident heat energy would be sufficient to ignite flammable clothing, regardless of voltage. For consistency, OSHA is making a corresponding change in final paragraph (g)(5), which requires employers to ensure that each employee exposed to hazards from electric arcs wears protective clothing and other protective equipment with an arc rating greater than or equal to the heat energy estimated under final paragraph (g)(2) *whenever that estimate exceeds 2.0 cal/cm^2*. The Agency believes that final paragraphs (g)(4)(iv) and (g)(5) must have the same incident-energy threshold; otherwise, the final rule would require clothing to be arc rated, but not flame resistant, when the estimated incident energy was 2.0 cal/cm^2 or less. (As noted under the summary and explanation for final paragraph (g)(5), later in this section of the preamble, all arc-rated clothing is flame resistant. Thus, if the final rule required arc-rated clothing when the estimated incident energy was 2.0 cal/cm^2 or less, it also would effectively require flame-resistant clothing at these exposures.) Therefore, under the final rule, whenever paragraph (g)(4)(iv) requires clothing to be flame resistant, that clothing must also have an arc rating under paragraph (g)(5).

Consequently, the latest edition of NFPA 70E does not conflict with OSHA's decision to require flame-resistant clothing for estimated incident heat energy exposures exceeding 2.0 cal/cm^2.

[352]Although OSHA has not stated the requirement in final paragraph (g)(4)(iv) in terms of a boundary, the area inside which flame-resistant clothing is required extends to the boundary where the estimated incident energy equals 2.0 cal/cm^2.

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Selecting arc-rated protective clothing and other protective equipment.

Paragraphs (g)(3) and (g)(4) of final §1926.960 will protect workers against burns from the ignition or melting of clothing. These provisions do not address the protection of workers from the incident heat energy in an electric arc, which is the purpose of paragraph (g)(5).

Much of the flame-resistant clothing available today comes with an arc rating.[353] In basic terms, an arc rating indicates that a fabric should not transfer sufficient thermal energy to cause a second-degree burn when tested under standard laboratory conditions that expose the fabric to an electric arc that radiates an energy at or below the rating.[354] Proposed paragraph (g)(5) would have required that employees exposed to hazards from electric arcs wear clothing with an arc rating greater than or equal to the heat energy estimated under paragraph (g)(2). This clothing will protect employees exposed to heat energy from sustaining severe burn injuries in areas covered by the clothing.

Several rulemaking participants argued that OSHA should not require protection based on unreliable estimates of incident energy. (See, for example, Exs. 0183, 0229, 0233.) For instance, Mr. Jonathan Glazier with NRECA commented:

> [E]stimates of maximum amounts of heat energy are inherently unreliable. Accordingly, such estimates do not provide an adequate foundation for a

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[353]The ASTM standards governing arc rating require the tested fabric to be flame resistant. Thus, no non-flame-resistant clothing has an arc rating.

[354]ASTM F1506-02a^{e1}, *Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*: defines "arc rating" as "the maximum incident energy (E_I) resistance demonstrated by a material prior to breakopen or at the onset of a second-degree burn" (Ex. 0061). The latest version of that consensus standard, ASTM F1506-10a, contains a differently worded, but equivalent definition.

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> protective clothing requirement. In other words, it makes no sense to require clothing to protect against second degree burns from an amount of energy that cannot be calculated reliably. For that reason, OSHA should drop the protective clothing requirement of 1910.269(l)(11)(v) and 1926.960(g)(5). [Ex. 0233]

As explained under the discussion of final paragraph (g)(2) earlier in this section of the preamble, OSHA concludes that there are incident heat energy calculation methods that can provide reasonable estimates of incident energy for all types of arc exposures employees experience. Therefore, the Agency concludes that it is reasonable to select arc-rated clothing and other protective equipment on the basis of those estimates.

EEI argued that "OSHA has not shown that the risk of harm would be materially reduced by using the methods specified in the proposal" and that "there simply is not substantial evidence that wearing clothing with an appropriate arc rating … would eliminate or substantially reduce employee exposure to a burn injury from a flame or electric arc" (Ex. 0227).

OSHA disagrees with EEI. There is substantial evidence in the record that selecting protective clothing and other protective equipment with an arc rating based on a reasonable estimate of incident energy will substantially reduce injury from electric arcs. To understand how arc-rated clothing and other protective equipment substantially reduces injury, one must first examine how burn injuries occur. The skin absorbs heat energy; and, after absorbing a certain amount of energy, the skin sustains burn injury. According to Dr. Thomas Neal, the human body begins to get a burn at 1 to 2 cal/cm^2 (Tr. 433). At low levels of heat, the body sustains a first-degree burn, like a sunburn, with redness and minor pain, but no blistering. An incident heat energy level of 1.2 cal/cm^2 is the threshold at which the burn injury becomes a second-degree burn (Exs. 0134, 0425). Second-degree burns involve swelling and blisters, along with greater pain and redness.

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As the skin absorbs more energy, the burn gets worse, involving more layers of skin, until it reaches a full-thickness, or third-degree, burn. The most serious burns require prolonged hospitalization and skin grafts and result in permanent scarring (Ex. 0373; Tr. 219).

Figure 11 shows a simplified diagram of a worker exposed to an electric arc.[355] This diagram shows the boundary (depicted by a broken circle) where the estimated incident energy equals a clothing rating that meets, but does not exceed, the rating required by final paragraph (g)(5). Inside the broken circle, the incident energy is greater than the estimate; outside the circle, the incident energy is less than the estimate.

[355]In all likelihood, an electric arc would be larger than the small-diameter sphere depicted in Figure 11. However, the estimated energy is the same at all points that are the same distance from the arc, and the diagram is valid for any spherical arc.

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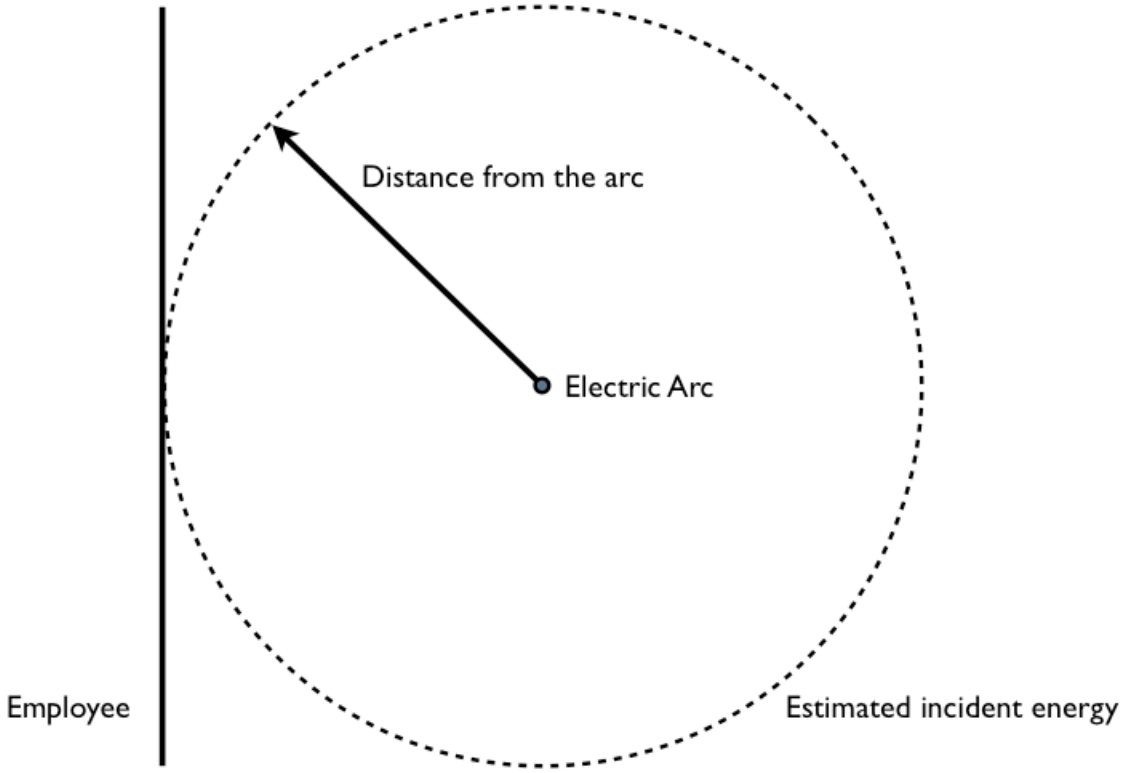


Figure 11—Employee Exposed to Electric Arc

The arc rating of protective clothing and other protective equipment is an indication of the relative protection it provides from incident energy. Dr. Thomas Neal explained that "the arc rating … is defined as the level of … exposure at which you would expect 50 percent probability of a burn injury" (Tr. 444). The ASTM standard clarifies that the rating is at "the onset of a second-degree bum" (Ex. 0061). Thus, in Figure 11, the employee has a 50-percent chance of barely receiving a second-degree burn at the point where the broken circle touches the employee. (That is, the probability that the incident energy will be equal to or greater than 1.2 cal/cm^2 is 50 percent.) As Dr. Neal explained, the chance of barely sustaining a second-degree burn drops quickly with a reduction in incident energy (Tr. 443 – 445). The probability of receiving a second-degree burn while wearing a particular arc-rated garment typically drops to 1 percent with a reduction in incident energy of a few calories below the arc rating of the clothing

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(*id*.). For example, with the NFPA 70E Annex D method, the incident energy is inversely proportional to the square of the distance from the arc to the employee. If the distance from the arc to the employee is 455 millimeters (18 inches), the incident energy drops nearly 10 percent at a distance of 150 millimeters (6 inches) from the point where the circle touches the employee.

From this, OSHA concludes that an employee wearing arc-rated protection in accordance with the final rule should receive, at worst, a second-degree burn over a relatively small portion of his or her body at the estimated incident-energy level. In addition, because arc-rated clothing and other protective equipment that complies with final paragraph (g)(5) will block a substantial portion of the heat energy, any injury that occurs will be substantially less severe than would occur without arc-rated protection at all or with arc-rated protection with a rating lower than the estimated heat energy. Consequently, the Agency concludes that the severity of injury will be reduced when an employee is wearing protective clothing and other protective equipment with an arc rating greater than or equal to the actual incident-energy level experienced by the employee. Although an employee will receive a more severe burn injury if the incident energy exceeds the arc rating of the protection than if it does not, OSHA concludes that estimates of incident heat energy prepared in compliance with final paragraph (g)(2) will relate reasonably well to the incident energy actually experienced by employees in the event of an arc. Also, even if the incident energy actually exceeds those estimates, arc-rated protection will still reduce the extent and degree of injury (see Tr. 535: "MR. WALLIS [asking question]: 'Would arc [rated] clothing reduce the extent and degree of injury, even if the arc energy is higher than the employer's estimate?' DR. NEAL

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[responding]: 'Yes, it would.'"). The reduction in these effects occurs because arc-rated protective clothing and other protective equipment blocks the amount of heat that gets through to the employee's skin (Tr. 471 – 472).

Protecting the entire body. OSHA did not propose to require a specific level of protection for skin not covered by clothing. However, in the preamble to the proposal, the Agency requested comments on whether the standard should require protection for an employee's entire body.

TVA recommended that the rule address unprotected skin as follows:

> Due to our experience with arc flash accidents, we believe that the employee's hands and arms require some level [of] protection. Our procedure requires the employee to wear the long sleeved FR shirt with the sleeve down and buttoned. [W]e do not consider a short sleeve FR shirt to provide adequate arc flash protection to the employee's arms. We also require employees to wear leather gloves or voltage rated gloves with leather protectors when in arc flash exposure situations. The electric utility industry has arc flash exposures that could result in 3rd degree burns to unprotected parts of the body that could cause serious injury. It is recommend[ed] that the final rule require employees to wear a long-sleeved FR shirt with its sleeve[s] down and buttoned in potential arc flash situations. The rule should also require leather gloves, if voltage rated gloves are not being worn. [Ex. 0213]

Forty-six of the 100 arc-related burn accidents in Exhibit 0004 involved burn injuries to an employee's arms.[356] Five of those 100 accidents involved burns to an employee's leg.[357] Forty of those 100 accidents involved burns to an employee's head.[358]

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[356]See, for example, the nine accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=170097497&id=170054258&id=170614002&id=14225569&id=201140522&id=170152540&id=170071138&id=170738165&id=170250062.

[357]See the five accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=170361026&id=170389811&id=201791803&id=14490114&id=596304.

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The accidents in the rulemaking record and TVA's experience clearly indicate a need to protect all parts of the employee's body. Employees with uncovered skin are at risk of severe injury or death. Requiring protection only for areas covered by clothing would lead to the absurd possibility that an employer would be in compliance if an employee worked without clothing. Therefore, OSHA concludes that the standard should address not only the rating of the clothing, but the extent of protection needed for the employee's body. Accordingly, paragraph (g)(5) in the final rule requires that, when employers must provide arc-rated protection to employees, the protection must cover the employee's entire body, with a few exceptions described later.

There is evidence in the record that some types of nonarc-rated clothing and protective equipment provide suitable protection from arc-related burn injuries on areas not typically covered by clothing, for instance, the hands and feet. (See, for example, Exs. 0186, 0212, 0213; Tr. 433 – 435.) As noted in the preamble to the proposal, although neither rubber insulating gloves nor leather protectors have arc ratings, their weight and thickness typically provide greater protection from electric arcs than light-weight flame-resistant clothing (70 FR 34868). The accident data support this conclusion—none of the burn injuries to employees' hands described in the record involved an employee wearing rubber insulating gloves. In addition, NFPA 70E-2004 recognizes the protection afforded by rubber insulating gloves (Ex. 0134). Heavy-duty leather work gloves with a weight of

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[358]See, for example, the nine accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=170097497&id=170054258&id=14225569&id=170631469&id=170071138&id=170738165&id=170611057&id=200962322&id=170764021.

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407 gm/m^2 (12 oz/yd^2) provide protection up to about 14 cal/cm^2 (Ex. 0134; Tr. 434).[359] Therefore, the final rule recognizes the protection afforded by rubber insulating gloves with protectors, as well as heavy-duty leather work gloves. Under final paragraph (g)(5)(i), the employer need not ensure the use of arc-rated protective gear over the employee's hands when the employee wears rubber insulating gloves with protectors or, if the estimated incident-energy exposure is 14 cal/cm^2 or lower, if the employee wears heavy-duty leather work gloves with a weight of at least 407 gm/m^2 (12 oz/yd^2).

NFPA 70E recognizes "[h]eavy-duty work shoes" as providing "some arc flash protection to the feet" and generally requires this type of shoe when the exposure is above 4 cal/cm^2 (Ex. 0134).[360] As OSHA found no evidence in the record of an employee sustaining burn injuries to the feet in an arc-related accident, the final rule recognizes the protection afforded by heavy-duty work shoes. Final paragraph (g)(5)(ii) provides that employees wearing heavy-duty work shoes or boots do not need to use arc-rated protection on their feet.

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[359]In a note to Section 130.7(C)(13)(c), NFPA 70E-2004 states that "[i]nsulating rubber gloves … provide hand protection against the arc flash hazard" (Ex. 0134). OSHA anticipates that there is a limit to the amount of protection afforded by rubber insulating gloves, but there is no information in the record to indicate what that limit might be. However, that section in the NFPA standard requires leather protectors to be worn over rubber insulating gloves for purposes of arc-flash protection. (NFPA 70E-2012 contains an equivalent requirement and note.)

[360]NFPA 70E-2004 requires heavy-duty work shoes for tasks in hazard-risk category 2 and higher (Ex. 0134). Table 130.7(C)(9)(a) generally requires hazard-risk category 2 protection when the incident energy is more than 4 cal./cm^2, but less than 8 cal./cm^2 (*id.*). NFPA 70E-2012 additionally requires heavy-duty work shoes for "all exposures greater than 4 cal/cm^2."

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Many rulemaking participants opposed requiring arc-rated protection for the head,[361] arguing that faceshields could interfere with vision and make the work more dangerous. (See, for example, Exs. 0167, 0175, 0186, 0233.) For instance, Ms. Salud Layton with the Virginia, Maryland & Delaware Association of Electric Cooperatives commented, "Employing the use of a faceshield may cause more of [a] hazard than benefit by reducing peripheral vision and nuisance distraction to the employee while work is being performed on energized facilities" (Ex. 0175).

Other rulemaking participants supported a requirement for faceshields or other forms of arc-rated head and face protection. (See, for example, Exs. 0130, 0241; Tr. 461 – 463.) NIOSH explained their position as follows:

> NIOSH recommends that the use of arc-rated face protection be included in sections 1910.269(l)(11) and 1926.960(g)(5). An arcing-fault can injure an employee's face and eyes, and typical non-arc-rated safety eyewear is inadequate. Arc-rated face shields and hoods are available that offer protection levels that can be matched to the rating of any arc-rated fire resistant clothing. NFPA 70E-2004 requires a wraparound face shield of appropriate arc-rating that protects forehead, ears, and neck … for heat energy exposure levels above 4 calories/cm^2, and a flash suit hood of appropriate arc-rating … for levels above 8 calories/cm^2 (see NFPA 70E-2004, page 33, table 130.7(C)(10)). [Ex. 0130]

IBEW supported a requirement for arc-rated head and face protection, but only in certain circumstances (Exs. 0230, 0505). The union explained its position and rationale as follows:

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[361] In the preamble and regulatory text, the term "protection for the head" means protection for the entire head, from the neck up. It includes protection for the neck, face, and ears. In contrast, the term "head protection" as used in §§1910.135 and 1926.100 and in final §1910.269 and subpart V, means protection provided for the head by a hardhat, which generally does not protect the face or neck.

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IBEW submits that while face shields may provide effective protection in some work environments, they are not appropriate means of protection for all aspects of transmission and distribution work.

[F]ace shields are designed to be attached to the employee's hard hat.… They provide a complete shield from above the employee's forehead to below his or her chin. Because they only protect the front of the employee's head, however, Dr. [Thomas] Neal recommends that they be worn in combination either with a "bee keeper's hood," of the type used by firefighters, or with a lighter-weight and cooler advancement, a balaclava, or ski-type mask.…

Dr. Neal testified that although he knows utilities have purchased face shields, he does not know how they have been used. In particular, he could not say whether they are being used by anyone doing line work. Nor did he have any familiarity with what it would be like to perform line work while wearing the face shield, either alone or in combination with a balaclava.…

A face shield is appropriate PPE for an electrician in a power plant racking a breaker in or out of its enclosure. In that situation, it usually takes only minutes to accomplish the task. Further, the electrician would generally be on solid footing – either on the plant floor or a platform – when wearing the shield to perform the energized work. The shield is also practical PPE when setting or removing a meter, where, again, the employee would be donning the face shield for a short period of time.

These two work situations sharply contrast with that of climbing a pole, working up a pole surrounded by wires, braces, brackets, and transformers, and descending the pole. In these types of work situations, wearing the face shield for lengthy periods would create additional safety problems, including issues with mobility, heat, and vision, that could more than offset the shield's arc protection factor.

To summarize, although face shields are designed to provide important protection against arc flash hazards, the record fails to demonstrate the feasibility of requiring them in every instance of energized work. Indeed, simply examining the conditions under which employees work on electrical lines shows that it would be impractical to require their use as PPE in all situations. [Ex. 0505]

OSHA agrees with IBEW that wearing arc-rated head and face protection is likely to cause more problems for overhead power line work than for in-plant work. For instance, faceshields and other forms of arc-rated head and face protection potentially can interfere with climbing and descending a pole (Ex. 0505). However, the Agency does not believe that this interference necessarily creates a greater hazard. Power line workers

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generally must wear hardhats under existing §§1910.135 and 1926.100. Because it is suspended below the employee's hardhat, a faceshield does not extend significantly beyond the edge of the hardhat. Consequently, a faceshield worn alone with a hardhat should not be substantially more of an impediment to climbing than the hardhat alone. Perhaps a beekeeper-type hood, which extends on all sides beyond a hardhat, would interfere more substantially with climbing and descending poles; however, Dr. Neal noted that newer forms of arc-rated protection, such as a balaclava (a garment that looks like a ski mask and that an employee wears beneath a hardhat), can provide nearly the same protection as a hood without the hood's bulk (Tr. 438 – 440). In addition, as discussed in the summary and explanation for final §1926.954(b)(3)(iii), the final rule generally requires employers to protect employees against falling while climbing or descending poles. Therefore, OSHA concludes that suitable head protection should not interfere with climbing or descending poles enough to pose a significant hazard.

If an employee is working so close to "wires, braces, brackets, and transformers" that a faceshield would interfere with his or her performance, as IBEW argues, the objects would also be close enough to endanger the employee's face as the employee is working. In any event, it is unclear how a faceshield, or even a faceshield with a balaclava, would interfere significantly with the mobility of an employee performing overhead line work. Thus, OSHA concludes that employers can find suitable head and face protection that will interfere minimally with a worker's mobility and allow the worker to perform his or her job safely and efficiently, without posing a significant hazard to the worker.

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As discussed later in this section of the preamble, OSHA examined the heat stress issue raised by some commenters and concludes that, although heat stress can be a significant hazard, there are feasible means of abating the hazard for employees wearing arc-rated protective garments and head and face protection. In fact, Dr. Neal testified that faceshields would not contribute significantly to heat-stress hazards because "air is going to be moving inside the shield" (Tr. 478). As explained later, employers need not use arc-rated head protection or a faceshield until the estimated incident-energy level is greater than or equal to 9 cal/cm^2 for most forms of overhead line work. At higher levels, employers must take heat-stress abatement measures when warranted by environmental conditions.

A beekeeper-type hood likely would interfere with peripheral vision. However, as noted earlier, employers can achieve similar protection with a faceshield and balaclava combination, which should not interfere with an employee's peripheral vision.

Dr. Neal noted that clear faceshields do not provide much protection from arc-related burn injuries, however (Tr. 433 –434). In response to questions about whether arc-rated faceshields could reduce visibility, especially at night, Dr. Neal testified:

> MR. BYRD: Does that shield -- Is that designed primarily for daylight work?
>
> DR. NEAL: Well, it's designed for work where you have light, yes. Could be daylight; it could be artificial light.
>
> MR. BYRD: I guess what I'm asking: If I had a car break a pole off at two o'clock in the morning and I'm having to wear some kind of shield, do I have to have a tinted shield and also a clear shield? Do you make the clear shields as well?
>
> DR. NEAL: Yes, I think there are companies that make both types of shields. But, no, the clear shield is -- The tinted shield takes care of the function of the clear shield, which is actually to protect you from projectiles.

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MR. BYRD: Well, I guess what I'm looking at is visibility in repairing that pole and the lines that are energized. If I have a shield on that is designed for daylight and I put that in, it's kind of like sunglasses or your safety glasses that are tinted. If I put those on at night, I'm totally blind now. So I would have to have a shield for nighttime use as well.

DR. NEAL: Well, those sunglasses actually are much darker than the shield that I had here. It's not really designed for day work, but you may find that -- You know, I think when you are doing work at night, you have to add light in most cases.

MR. BYRD: We do.

DR. NEAL: Yes. So I think whatever you add for doing the work normally would suffice for most of the shields. It's something you would have to try, and you would say, well, no, I'm not getting enough light. So you may have to do something different there. [Tr. 511 – 513]

Based on this evidence, OSHA concludes that employers can find suitable arc-rated head and face protection that does not significantly interfere with an employee's vision and that normally does not require supplemental lighting beyond what they would otherwise supply.

For the foregoing reasons, OSHA concludes that suitable arc-rated head and face protection does not necessarily pose greater hazards than working without it and that a requirement for employees to wear such protection when warranted by arc hazards generally will be technologically feasible and reasonable for overhead line work. Because the evidence, including IBEW's comments, suggests that overhead line work is the most problematic type of work for purposes of wearing arc-rated head and face protection, the Agency comes to the same conclusion for the other types of work addressed by §1910.269 and Subpart V.

Dr. Neal testified that he believed that employees should wear head and face protection "[a]nytime there is a risk of a heat exposure over [1.5 to] 2 calories, … where you are just on the edge of getting a second degree burn" (Tr. 462). He also noted,

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however, that his opinion is at odds with "some of the standards that exist today, [in which] this is not required until you get to about 8 calories" (*id.*). For instance, Table 130.7(C)(10), Protective Clothing and Personal Protective Equipment (PPE) Matrix, in NFPA 70E-2004, requires faceshields for hazard-risk category 2, which generally corresponds to an incident-energy level of 5 to 8 cal/cm^2, and flash-suit hoods for hazard-risk category 3 and higher, which generally corresponds to an incident-energy level of 9 cal/cm^2 and higher (Ex. 0134).[362]

[362]NFPA 70E-2012, in Table 130.7(C)(16), requires an arc-rated faceshield for hazard-risk category 1, which generally corresponds to an incident-energy level of 1.2 to 4 cal/cm^2, and an arc-rated flash suit hood or arc-rated faceshield and arc-rated balaclava for hazard-risk category 2 and higher, which generally corresponds to an incident-energy level of 5 to 8 cal/cm^2. However, as explained later in this section of the preamble, this edition of NFPA 70E does not account for any reduction in incident heat energy at the employee's face in comparison to the level of incident heat energy at the working distance (generally the employee's chest). OSHA concludes that not accounting for this reduction would require more protection against incident heat energy than necessary. As explained under the heading *Heat stress*, later in this section of the preamble, heat stress is a genuine concern of many rulemaking participants. Requiring a level of head and face protection higher than the likely incident energy at employees' heads would unnecessarily increase heat stress for employees. As further explained in that section of the preamble, OSHA also concluded that: heat stress is a widely recognized hazard; employers covered by the final rule already have an obligation under the general duty clause of the OSH Act to abate these hazards; and employers covered by the final rule already are addressing heat-stress issues in their workplaces. Despite these conclusions, the Agency believes that, for work covered by the final rule, paragraphs (g)(5)(iii) through (g)(5)(v) strike a more reasonable balance between the need for protection against incident energy from electric arcs and the need to protect employees against heat stress. The final rule achieves this balance by requiring a level of protection commensurate with the incident energy likely at the employee's head.

Note that OSHA's finding regarding the need for faceshields applies only with respect to their use as protection from incident energy. As noted under the heading *Protecting employees from flying debris from electric arcs*, OSHA's existing general PPE requirements in §§1910.132 and 1926.95 require employers to address nonthermal hazards, including physical trauma hazards posed by flying debris, associated with employee exposure to electric arcs.

(*Continued*)

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For the three-phase exposures addressed by the incident-energy calculation methods given in NFPA 70E-2004, Annex D, the Agency concludes that these are reasonable thresholds for requiring head and face protection (*id*.).[363] It is apparent that NFPA 70E-2004 Table 130.7(C)(10) sets protective equipment requirements for the worst-case exposures for the methods in Annex D of that standard, that is, exposures involving three-phase arcs in enclosures. The Agency believes that such exposures are more likely to involve convective heat energy, which can transfer to the area behind a faceshield, and to involve the back of the head due to reflected heat energy. In addition, Annex D presumes a distance from the employee to the arc of 455 millimeters (18 inches).

As explained previously in this section of the preamble, much overhead line work poses hazards involving exposure to single-phase arcs in open air. In such exposures, there is little or no reflected or convective heat energy. In addition, as also noted earlier, OSHA concluded that a reasonable distance from the employee to the arc for these exposures is 380 millimeters (15 inches), measured from the crotch of the employee's

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Note also that OSHA's findings regarding head and face protection apply only to electric power generation, transmission, and distribution work covered by the final rule. NPPA 70E-2012, like subpart S of OSHA's general industry standards, requires employers to deenergize electric circuits before employees work on them except under limited circumstances. Thus, heat stress hazards for work performed under NFPA 70E-2012 and Subpart S should not be as pervasive as under this final rule, which generally permits employees to work on energized circuits without restriction.

[363]NFPA 70E-2004, Annex D describes the Doughty, Neal, and Floyd and IEEE 1584 methods in addition to the Lee method. See the summary and explanation for final paragraph (g)(2), earlier in this section of the preamble, for a discussion of these methods (Ex. 0134). Annex D in NFPA 70E-2012 adds a method, from the NESC, for single-phase arcs in open air.

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hand to the chest.[364] (See Table 14, earlier in this section of the preamble.) OSHA estimates that the employee's face will likely be at least 455 millimeters (18 inches) from the arc.[365] Because the heat energy from a single-phase arc in air drops in inverse proportion to the square of the distance, the roughly 20-percent increase in distance (from 380 to 455 millimeters) results in a drop in incident energy of nearly 30 percent (Ex. 0430). Therefore, because the incident energy at the employee's head will be more than 30 percent lower than the estimated incident energy, which OSHA based on the exposure at the employee's chest, OSHA concludes that the thresholds for requiring head and face protection for exposures involving a single-phase arc in air can be higher than the threshold for requiring head and face protection for three-phase exposures. The final rule adopts the following ranges for head and face protection:

[364]OSHA concluded that 380 millimeters (15 inches) is a reasonable distance for rubber insulating glove work. For work with live-line tools, OSHA concluded that the distance is greater than 380 millimeters. (See the summary and explanation for final §1926.960(g)(2) earlier in this section of the preamble.)

[365]With the employee's hands out directly opposite the chest, the distance from the chest to the arc is 380 millimeters (15 inches), and the distance vertically from that point on the chest to the employee's chin is about 255 millimeters (10 inches). The distance from the chin to the arc is the hypotenuse of the right triangle with those two sides, or about 455 millimeters (18 inches).

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Exposure	Minimum Head and Face Protection		
	None*	Arc-Rated Faceshield with a Minimum Rating of 8 cal/cm^2 *	Arc-Rated Hood or Faceshield with Balaclava
Single-phase, open air	2 – 8 cal/cm^2	9 – 12 cal/cm^2	13 cal/cm^2 or higher†
Three-phase	2 – 4 cal/cm^2	5 – 8 cal/cm^2	9 cal/cm^2 or higher‡

*These ranges assume that employees are wearing hardhats meeting the specifications in §1910.135 or §1926.100(b)(2), as applicable.

†The arc rating must be a minimum of 4 cal/cm^2 less than the estimated incident energy. Note that §1926.960(g)(5)(v) permits this type of head and face protection, with a minimum arc rating of 4 cal/cm^2 less than the estimated incident energy, at any incident energy level.

‡Note that §1926.960(g)(5) permits this type of head and face protection at any incident energy level.

OSHA chose the 5- and 9-cal/cm^2 thresholds for three-phase arcs to match the thresholds in NFPA 70E-2004, as recommended by NIOSH (Ex. 0134). The 9- and 13-cal/cm^2 thresholds for exposures involving single-phase arcs in open air account for the lack of reflected and convective heat on the employee's head, as well as the 30-percent reduction in incident energy expected at the employee's head.

Final paragraph (g)(5)(iii) does not require arc-rated protection for the employee's head when the employee is wearing head protection meeting §1926.100(b)(2) and the estimated incident energy is less than 9 cal/cm^2 for exposures involving single-phase arcs in open air or 5 cal/cm^2 for other exposures. Final paragraph (g)(5)(iv) permits the employer to protect the employee's head using a faceshield with a minimum arc rating of 8 cal/cm^2 if the employee is wearing head protection meeting §1926.100(b)(2) and the

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estimated incident-energy exposure is less than 13 cal/cm^2 for exposures involving single-phase arcs in open air or 9 cal/cm^2 for other exposures. Paragraph (g)(5)(v) permits a reduction of 4 cal/cm^2 in the arc rating of head and face protection for single-phase arcs in open air (the difference between the two sets of thresholds). For example, if the estimated incident energy for an exposure involving a single-phase arc in open air is 13 cal/cm^2, the head protection provided to the employee must have an arc rating of at least 9 cal/cm^2.

Other issues relating to the selection of protective clothing and other protective equipment. Ms. Susan O'Connor with Siemens Power Generation contended that there were factors to consider other than incident heat energy in the selection of arc-rated protection, commenting:

> We do not believe that protective clothing decisions should be made solely based on a numerical calculation-especially when such calculation methods are suspect as to their range of error. There are certainly hazards that would be created by utilizing this equipment. This clothing is heavy, hot, and bulky. It is not unreasonable to foresee that heat stress, and injuries related to lack of mobility or visibility would increase when using this equipment. Likewise, the heat calculations make no allowances for the inherent risk of a task. Opening a bolted panel on a piece of equipment is riskier than opening a hinged panel. (A bolted panel could be fumbled into live bus causing a fault, while this is nearly impossible with a hinged panel). Racking a breaker out with the enclosure door open is riskier than with the door closed. (The closed door will contain much of the fault energy should it occur thereby protecting the employee) However, if we rely solely on the heat calculation these two sets of scenarios would require identical PPE. [Ex. 0163]

As explained earlier, OSHA already considered issues related to the mobility and vision of workers using arc-rated head and face protection and concluded that such items generally will not create more hazardous conditions for employees. For similar reasons, the Agency also concludes that mobility is not generally a concern for arc-rated protection. Even the highest-rated clothing is not significantly heavier than winter

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weather clothing (see, for example, Tr. 440[366]), and line workers are currently performing tasks in winter clothing in cold weather. In addition, evidence in the record indicates that at least one utility requires its employees to use some of the heaviest weights of arc-rated clothing, and this utility did not report any problems with worker mobility (Exs. 0213, 0215). As explained later in this section of the preamble, the Agency also concludes that heat stress should not affect the selection of arc-rated protection under final paragraph (g)(5) as there are other ways of mitigating that hazard when necessary.

As discussed under the summary and explanation for final paragraph (g)(2), earlier in this section of the preamble, OSHA concluded that it is unreasonable to reduce estimated incident-energy levels simply because an employee is working in a situation in which there is a low risk that an electric arc will occur. The Agency similarly concludes that it unreasonable to select arc-rated protection based on how likely an arc is to occur. OSHA does not dispute that there is a higher risk of an arc occurring when an employee is racking a circuit breaker than when an employee is opening a hinged panel.[367] Three of the arc-related burn accidents in Ex. 0004 occurred as employees were racking breakers.[368] None of the burn accidents involved an employee opening or closing a hinged cover on enclosed equipment. As explained in the summary and explanation for

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[366]According to Dr. Thomas Neal, manufacturers make suits rated at 100-cal/cm^2 from material weighing 610 gm/m^2 (18 ounces/yd^2) (Tr. 440). That weight is less than twice the weight of denim material, which is about 375 gm/m^2 (11 ounces/yd^2) (269-Ex. 12-12. See, also, 59 FR 33659).

[367]Racking a circuit breaker is the process by which a circuit breaker is inserted and removed from the circuit breaker cubicle.

[368]See the three accidents described at http://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=14328736&id=200962322&id=170197156.

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final paragraph (g)(2), if there is no reasonable likelihood that an electric arc will occur, OSHA will consider the employee to have no electric-arc exposure, and the employer need not provide the protection required under final paragraph (g)(4)(ii), (g)(4)(iv), or (g)(5).[369] OSHA believes that opening a hinged cover on a dead-front panelboard generally would not result in employee exposure to electric-arc hazards under final paragraph (g)(2). However, if there is a reasonable likelihood that an electric arc will occur in the employee's work area, then protection against the full incident heat energy of the arc is necessary. Otherwise, when an arc does occur, the employee could receive severe burn injuries.

Three commenters wanted OSHA to clarify that paragraph (g)(5) only requires protection to the extent that compliant clothing is reasonably available (Exs. 0170, 0222, 0237). These commenters expressed concern that the standard would require employers to implement potentially costly abatement measures to reduce incident energy to levels for which clothing is available (*id.*). For example, Mr. Chris Tampio with the National Association of Manufacturers commented:

> The proposal does not explain how the rule would be interpreted in situations where compliance with the proposed arc-rated clothing requirements is infeasible because there is no clothing available to protect against that level of heat energy (and still permit the employee to perform the required work). We believe it is critical that OSHA clarify that compliance with the proposed rule would be considered infeasible under those circumstances, and that the agency would not require the employer to exhaust other feasible measures. Otherwise, we are concerned that employers could be required to engage in very expensive retrofitting of electrical installations so as to reduce the maximum heat energy that

[369]Paragraphs (g)(4)(i) and (g)(4)(iii) involve exposures that OSHA has determined expose employees to electric arcs or flames, namely, contact with energized circuit parts operating at more than 600 volts and molten metal or electric arcs from faulted conductors in the work area that could ignite the employee's clothing.

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might be released by an arc flash to a level where suitable [flame-resistant or arc-rated] clothing would be reasonably available.

The extremely costly measure of retrofitting equipment is not accounted for in the agency's economic analysis for this rulemaking, would substantially raise the costs of compliance with the proposed standard, and might invalidate the agency's entire economic analysis for this proposal. OSHA has a duty to promulgate rules that are both technically and economically feasible, and a duty to base its decisions on the best available information relating to the economic consequences of the intended regulation. Executive Order … No. 12866, titled "Regulatory Planning and Review", … include[s] a requirement that each agency assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs. Additionally, the U.S. Supreme Court and various Courts of Appeals have held that OSHA regulations must be technically *and economically* feasible.…

In order to meet these legal requirements, OSHA must either clarify that no retrofitting is required or adequately address the economic impact of retrofitting electrical equipment due to the infeasibility of providing protective equipment and clothing that can withstand arc-flash hazards. [Ex. 0222; footnotes omitted; emphasis included in original.]

The final rule generally requires that employers provide protection with an arc rating at least as high as the incident energy estimated under final paragraph (g)(2). When the initial estimated incident energy is extremely high, employers can either provide protection with an arc rating that is at least as high as the estimate or take measures to reduce the estimated incident energy. Those measures include changes to the installation and changes to work procedures. For example, installing current-limiting fuses is one way that will reduce incident energy by changing the installation (Tr. 498), and performing the work from a remote position (Tr. 499) and installing heat-shielding barriers (Tr. 210, 266) are ways that will reduce incident energy by changing work procedures.

The Agency examined the rulemaking record and concluded that retrofitting would rarely be necessary to permit compliance with this final rule. Employees perform

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much of the work covered by the final rule on overhead transmission and distribution lines. Several rulemaking participants noted that work on the vast majority of overhead line installations will not require the highest-rated protection available. Mr. James Tomaseski, representing IBEW testified:

> From the tables that are proposed in Appendix F, … we looked at those as common exposures out on distribution lines. [I]n discussions that I have had with utility employers and engineers, and so forth, about these values, I have not heard anybody yet say that they would have to be in hoods working on their distribution circuits" (Tr. 939 – 940).

There is no evidence in the record that estimated incident-energy values for overhead power line installations are likely to exceed the values in Table 6 and Table 7 in final Appendix E. The highest estimated incident-energy level listed in those tables is 12 cal/cm^2, and protection with this rating is readily available (see, for example, Tr. 412 – 414).

Underground distribution systems potentially expose employees to higher incident-energy levels. IBEW noted, for example, that "replacing fuses in underground distribution systems" is one type "of short duration [job] with a possible high hazard arc energy level" (Ex. 0230). However, although the three-phase arc-in-a-box exposures faced by employees working on underground installations may be high, much of the work performed in these locations is on deenergized circuits (269-Ex. 8-5).[370] For the

[370]Existing §1910.269(t)(7) already requires protection from hazards posed by energized cables in a manhole. This requirement provides that, where a cable in a manhole has one or more abnormalities that could lead to or be an indication of an impending fault, the defective cable must be deenergized before any employee may work in the manhole, except when service load conditions and a lack of feasible alternatives require that the cable remain energized. In that case, employees may enter the manhole provided they are protected from the possible effects of a failure by shields or other devices that are capable of containing the adverse effects of a fault in the joint.

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remaining work, which potentially exposes employees to relatively high incident-energy levels, employers will have to choose between providing arc-rated protection appropriate for those levels and reducing the incident-energy level through the installation or work methods changes noted previously. The Agency estimates that, for underground exposures, employers will be able to institute measures, such as increasing working distances, that do not involve substantial expense.

Potential incident-energy exposures for electric power generation installations also can be quite high, but the record shows that employers can implement relatively simple controls to reduce those exposures to levels for which adequately rated protection is readily available. Table 15 summarizes incident-energy estimates for a TVA nuclear generation plant (Ex. 0215).

Table 15—Distribution of Incident Energy at TVA Generation Plant

Incident Energy (E) at 455 mm (18 inches), cal/cm^2	Number of Buses	Percent of Buses
$0.0 < E \leq 4.0$	26	15
$4.0 < E \leq 8.0$	48	29
$8.0 < E \leq 30.0$	22	13
$30.0 < E \leq 50.0$	32	19
$50.0 < E \leq 75.0$	7	4
$75.0 < E \leq 100.0$	15	9
$100.0 < E \leq 162.4$	18	11

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TVA instituted engineering or administrative controls to reduce all incident-energy levels to 100 cal/cm^2 or less.[371] These controls included:

- Using remote-control voltage test equipment,
- Resetting circuit breaker trip devices,
- Installing current limiting devices,
- Using robotics,
- Employing remote control devices to operate equipment, and
- Developing procedures that increase the working distance between the worker and the arc (*id*.).

Two of these methods, resetting circuit-breaker trip devices and increasing the working distance, do not involve heavy capital outlays. The record identifies other simple methods for reducing incident-energy levels, such as setting up a circuit for work by temporarily adjusting relays (Tr. 940), changing operating procedures to eliminate or minimize the time two sources of power remain tied together (Ex. 0425),[372] and using shields or barriers to block incident energy before it reaches the employee (Ex. 0445). Because they do not make permanent changes to the installation, these methods also do not involve capital expenditures.

The Agency decided to adjust its regulatory analysis to accommodate the extra measures that employers likely will take to reduce incident-energy levels below 100

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[371]The highest arc rating for clothing is 100 cal/cm^2 (Tr. 440).

[372]In a network setting, more than one source can supply a circuit. Diverting one or more of those sources, by switching them so that they do not supply power to that circuit, can reduce the incident-energy level.

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cal/cm^2. To account for the costs of adopting incident-energy-control measures for electric power generation installations, OSHA included costs for reducing incident-energy exposures that, when combined with OSHA's estimated costs for calculating incident energy, correspond to TVA's estimate of $300 per employee for firms in industries with generation installations. Because TVA included incident-energy reduction costs in its estimate, OSHA's cost estimates also account for additional engineering controls that employers with power generation installations might need to implement to reduce the incident energy of particular circuits to no more than 100 cal/cm^2 (the maximum level for which protective clothing and equipment are generally available). In addition, in some cases, employers will be able to institute measures, such as resetting breakers or increasing working distances, that do not involve substantial expense. (See Section VI, Final Economic Analysis and Regulatory Flexibility Analysis, later in this preamble.)

A note following final paragraph (g) explains that Appendix E to final Subpart V contains information on the selection of appropriate protection. This appendix contains information on the ignition threshold of various fabrics, techniques for estimating available heat energy, and means of selecting protective clothing and other protective equipment to protect employees from burn injuries resulting from electric arcs. OSHA adopted this note substantially as proposed, except as necessary to reference the appropriate appendix (Appendix E).

Heat stress. Many commenters argued that arc-rated protection would subject employees to heat-stress hazards. (See, for example, Exs. 0099, 0152, 0169, 0238; Tr.

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406, 1105.) Mr. Jean Thrasher with Community Electric Cooperative, for instance, commented:

> An already existing hazard in the utility industry is heat stroke and heat exhaustion. If the calculated arc thermal value results in a requirement for multiple layers of FR clothing, there WILL BE hospitalizations from heat stroke and heat exhaustion. Many manufacturers gloss over or try to hide this concern by claiming they have engineered "cool and comfortable" FR clothing. The simple fact is that in summer, in 90° + heat with 80% or higher humidity *multiple layers* of any type clothing are too much, especially considering the linemen already are wearing solid rubber from shoulder to fingers on both arms. [Ex. 0152; emphasis included in original]

EEI expressed concern that, in proposing the arc-protection requirements in Subpart V, OSHA did not consider "the impact that excessive clothing could have on employees working in high temperatures" (Ex. 0227).

There is considerable evidence in the record related to heat-stress hazards. (See, for example, Exs. 0227, 0268, 0363, 0364; Tr. 431 – 461, 1106 – 1110.) Record evidence suggests that heat stress can result in:

- Heat cramps (Ex. 0268; Tr. 1106),
- Heat exhaustion (*id.*),
- Heat rash (*id.*),
- Heat stroke (*id.*),
- Fainting (Ex. 0268),
- Loss of concentration (*id.*), and
- Unsafe behaviors (Tr. 1109 – 1110).

EEI submitted a State of California Finding of Emergency that reported on occupational heat-related illnesses in that State (Ex. 0268). That document reported that "[s]tatistical information from the California Division of Workers Compensation's report on

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occupational injuries in heat-related illness from 2000 – 2004 [found] that at least 300 … cases of heat-related illness annually [were] recorded by employers or are the subject of claims for Workers Compensation Insurance" (*id*.). EEI noted that heat stress would cause unsafe behaviors, which could lead to accidents involving contact with energized parts, an outcome these commenters contended presents a serious hazard that OSHA should address in the final rule in the context of arc-rated protection (Ex. 0227; Tr. 1109 – 1110).

OSHA acknowledges that heat stress can pose serious hazards to employees. As EEI noted, OSHA has several documents available that discuss heat-stress hazards and mitigation measures (Ex. 0478). In fact, the Agency has a Web page devoted to this topic (http://www.osha.gov/SLTC/heatstress/index.html).

Dr. Thomas Neal explained that "heat stress is an occurrence when the human body core temperature goes over its normal temperature, which we normally state [is] 98.6 degrees F" (Tr. 446). He further described the hazard of heat stress as follows:

> When the work you are doing generates more heat than can escape through your clothing, that heat can only go to your body. So what happens is your body, a fairly sizeable mass that it is, begins to heat up, and if you continue that process for a period of time, your body will basically heat up to a point where you are into a heat stress condition that can be dangerous.
>
> Heat builds up, and the core temperature of your organs and your brain heat up, and just a few degrees above 98.6, and it's been shown that your judgment can be impaired, and the core temperature, if it reaches up to … 105, it can actually become a life threatening situation. [Tr. 447]

Dr. James Lancour, testifying for EEI, addressed the factors that can contribute to heat stress:

> Information gleaned from the literature clearly demonstrates the following:

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> One, heat stress job-risk factors include: hot work environments, the metabolic rate required by the worker to perform the task, the type of protective clothing that is worn by a worker, exposure time, and the age and physical condition of the worker.
>
> Two, as metabolic requirements necessary to perform a given task increase, the exposure time at a given temperature necessary to minimize heat stress decreases.
>
> Three, the amount of clothing worn by a worker tends to increase the risk of heat stress.
>
> Four, as the temperature of the work environment increases above about 30 degrees Centigrade, or 88 degrees Fahrenheit, there is a sharp increase in heat-related illnesses. [Tr. 1108 – 1109]

The record also clearly shows that electric power generation, transmission, and distribution workers perform tasks outdoors in hot and humid environments. (See, for example, Exs. 0169, 0183, 0220, 0233; Tr. 406, 1003.)

In view of this evidence, OSHA agrees that heat stress poses a significant hazard to employees covered by this final rule. The Agency does not dispute that electric power generation, transmission, and distribution work can be physically demanding and that employees perform this work in hot and humid weather. OSHA also agrees with the testimony of its expert witness, Dr. Mary Capelli-Schellpfeffer, that heat stress "is not a new topic" for employers with employees who perform this type of work and that "strategies to manage thermal hazards, and … heat thermal stress, are well appreciated across geographic domains," north and south (Tr. 234 – 235). Drs. Neal, Lancour, and Capelli-Schellpfeffer noted that employers in this industry must deal with heat-stress hazards even if employees are not wearing arc-rated protection (Tr. 198, 478 – 479, 1129).

Evidence in the record also indicates that there is a range of measures that employers can take to mitigate heat-stress hazards, including:

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- Rest breaks (Ex. 0268; Tr. 198 – 199),
- Supplying sufficient amounts of water (Ex. 0268; Tr. 199),
- Using cooling vests (Tr. 199),
- Supplying ambient cooling (Tr. 198),
- Providing shade (Ex. 0268), and
- Acclimatizing employees to the heat (Ex. 0268).

Evidence in the record indicates that employers already are using some of these measures (Tr. 1129 – 1130).

Dr. Neal described the body's metabolic process, which controls how the body responds to heat, as follows:

> If the heat generation from metabolic activity is greater than the heat loss through clothing or through parts of the body, obviously, also that are not clothed, then you have heat stress. Conversely, if the opposite happens, if your heat generation by metabolic activity is less than the heat loss through your clothing and uncovered parts of your body, then you have hypothermia.
>
> So your body operates in a narrow zone, and needs to do that to function effectively. Obviously, both heat stress and hypothermia are dangerous when you move away from that normal zone.…
>
> [There are] two main ways the body loses heat, and this comes from a North Carolina State University study of several years ago. One is what we call dry heat transfer, just air moving through my clothing, my body basically giving up heat as that happens. If I am cold, that is what is happening or, if I am in a comfort zone, that's pretty much what is happening.
>
> If I get hotter, then I begin to perspire and go into the evaporative heat transfer process, which is a very effective way of losing heat.… So then I am in a discomfort zone …. Finally, if I get to the point where I can't los[e] enough heat by sweating and by dry heat transfer to maintain my body temperature, I go into a heat stress situation where my core temperature begins to rise. [Tr. 448 – 449]

Dr. Neal then described how arc-rated clothing affects this process:

> Flame resistant shirts, pants, coveralls that you wear are basically like any other clothing article. They are breathable. We actually measure that in terms of air permeability, and they are typically lighter weight or similar weight than

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conventional cotton work apparel like jeans or cotton shirts that would be worn as nonmeltable work clothing.

So they don't really function any different when you are wearing them. You may feel different. Again, somebody tells me it's not as comfortable as his cotton shirt, I'm not going to argue that, because he has to be the judge of what is comfortable. But it is not anymore prone to heat stress is my point on that.

… The heat stress potential for the wearer [of] FR clothing would be typically less than or equivalent [to] typical conventional work clothing.… I'm talking about regular shirts, pants, and coveralls that you would wear for protection, and it would give you something up to maybe 8 calories or so of protection, single layer-wise.

* * *

When arc flash suits basically have higher ratings like 25 or 40 calories, 100 calories, 60 calories—there are many different levels that are fairly high—well, there are multiple layers that are used to create those levels of protection. So heat, obviously—and there are hoods involved in those. So in those cases, obviously, the heat stress potential does go up. [Tr. 449 – 451]

Dr. Neal presented two tables, one showing metabolic rates for different tasks and the other showing heat-loss values for various types of protection (Ex. 0363). OSHA is reproducing these tables here as Table 16 and Table 17, respectively.

Table 16—Metabolic Rates for Various Tasks

Task	Metabolic Rate (W/m^2)
Standing	70
Walking at 1.3 m/s (4.4 ft/s)	180
Tennis	260
Heavy labor	320 – 440
Wrestling	500

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Table 17—Typical Heat Loss Values Through Clothing

Clothing Material	Total Heat Loss (W/m^2)
205-gm/m^2 (6-oz/yd) Meta-aramid FR Woven Fabric (for example, NOMEX)	747
205-gm/m^2 (6-oz/yd) Cotton T-shirt Knit	688
Lightest 8-cal/cm^2 FR Shirt-Pants Fabric	500 to 600
40-cal/cm^2 systems	300 to 400
Firefighter turnout, breathable	150 to 250
100-cal/cm^2 arc-flash suits	150 to 250
Firefighter turnout, nonbreathable	80 to 120

OSHA presumes that electric power work is equivalent to heavy labor, with a metabolic rate of 320 to 440 watts/meter^2. As demonstrated in Table 17, even 8-cal/cm^2 clothing does not interfere with heat loss significantly more than normal (non-flame-resistant) work clothing. Thus, the Agency concludes that employers can treat clothing with an arc rating of 8 cal/cm^2 or less the same as normal work clothing with respect to its contribution to heat stress and that clothing with an arc rating of 8 cal/cm^2 or less should not require any significant changes to measures employers already are taking to protect electric power workers from heat stress generally (Tr. 503 – 504).

Employers with employees who are in protection with arc ratings between 8 and 25 cal/cm^2 will need to start planning for, and implement, heat-stress mitigation strategies beyond the strategies used for employees wearing normal work clothing (*id.*). These employers may need to choose among such mitigation strategies as: providing the

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lightest-weight arc-rated clothing for the estimated incident-energy level, ensuring that employees take extra rest breaks, and reducing the incident energy using the methods described previously. However, employers will need to take these measures only when the ambient temperature warrants such actions.

As shown in Table 16 and Table 17, when the estimated energy level rises above 25 cal/cm^2, employers likely will need to implement a variety of heat-stress reduction measures, except for short-duration tasks. An employee who is performing heavy labor has a metabolic rate of 320 to 440 watts/m^2 (Table 16). Protection rated at 40 cal/cm^2 provides for a heat loss of 300 to 400 watts/m^2 (Table 17). However, tasks requiring this level of protection[373] are normally of short duration (Tr. 202). Such tasks include racking circuit breakers (Tr. 381), replacing fuses in an underground installation (Ex. 0230), and removing or installing socket-type meters (*id.*). Dr. Capelli-Schellpfeffer also testified that, even when employees are wearing this level of protection, "at one to two minutes, three minutes, four minutes, in that ballpark, [it] is very, very uncommon to appreciate that there would be any thermal challenge significant enough to take … an employee to a heat stress condition" (Tr. 202 – 203). Dow Chemical Company similarly commented that arc-rated clothing "is only needed when an employee is working where there is a

[373]Dr. Capelli-Schellpfeffer described this level of protection as "fully enclosing FR protective clothing," which includes a protective hood (Tr. 202). Dr. Neal testified that a faceshield attached to a hard hat and a balaclava could be used in lieu of a hood for exposures up to about 40 cal/cm^2 (Tr. 439).

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substantial potential for an arc flash, which typically should be for very short periods of time" (Ex. 0128).[374]

Mr. Wilson Yancey with Quanta Services maintained that "[o]n transmission work, employees often experience potential fault currents that would require multiple layers of FR clothing, plus a 40 calorie space suit with hood and shield, to provide the necessary protection" (Ex. 0169). In addition, EEI presented information contending that clothing rated for more than 100 cal/cm^2 might be necessary when employees work on 15-kilovolt distribution circuits with varying fault current levels (Ex. 0227). However, OSHA concludes that neither of these cases represents typical exposures for distribution or transmission systems. As explained earlier, under the summary and explanation for paragraph (g)(2) of the final rule, the NFPA 70E Annex D calculation method EEI used to arrive at its 97- to 153-cal/cm^2 estimates is extremely conservative and likely would produce extremely elevated estimates at voltages of more than 15 kilovolts. EEI's corresponding estimate, based on Table 8 in proposed Appendix F, was only 5 cal/cm^2 (*id.*), which, as explained earlier, would not require employers to put employees in protection that would cause concerns about heat stress. There is no evidence in the record that fault currents on transmission circuits typically are higher than the fault currents listed in Table 7 of final Appendix E or that incident-energy estimates likely would be higher than the values in that table.

[374]OSHA interprets this comment as applying to tasks performed in a generation plant or substation, as the Agency does not believe that Dow Chemical performs maintenance on utility-type transmission or distribution installations.

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As explained under the heading *Other issues relating to the selection of protective clothing and other protective equipment*, earlier in this section of the preamble, the Agency concluded that most exposures on overhead transmission and distribution systems, where employees perform much of the work covered by the final rule, are no higher than 12 cal/cm^2. Furthermore, as noted by Dr. Capelli-Schellpfeffer, the types of tasks that require protection rated at more than 25 cal/cm^2 are typically of short duration and will not require measures to reduce heat stress (Tr. 202 – 203). Thus, the final rule will not result in employers having to take additional measures to protect workers from heat stress in most cases. When incident energy requires protection rated at more than 8 cal/cm^2, but no more than 12 cal/cm^2 (the highest level in Table 6 and Table 7 in final Appendix E), employers might have to take some additional measures to protect employees in elevated ambient temperatures from heat stress. (See, for example, Tr. 503 – 504.) Even under these conditions, the Agency concludes that these measures should not be extreme because the clothing weight should be only slightly higher than 8-cal/cm^2 clothing,[375] and because affected employers already institute measures under these conditions to mitigate heat-stress hazards (Tr. 197 – 198, 1129 – 1130).

Heat stress is a widely recognized hazard, and employers covered by the final rule already have an obligation under the general duty clause of the OSH Act to abate these hazards.[376] As noted earlier, the record indicates that employers covered by the final rule

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[375]Clothing rated 15 to 20 cal/cm^2 is available in weights of 300 gm/m^2 (8.8 oz/yd^2), less than typical jeans-weight material (370 gm/m^2, or 11 oz/yd^2) (Ex. 0363).

[376]See, for example, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=24008.

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already are addressing heat-stress issues in their workplaces. Depending on the level of protection afforded to comply with final paragraph (g)(5), employers may have to adjust their heat-stress programs, but the Agency believes that employers will be able to provide compliant protection under paragraph (g)(5) without necessarily exposing employees to dangerous heat-stress conditions. Moreover, OSHA believes that EEI's concerns about heat stress from arc-rated protection causing unsafe acts are groundless even if the protection could increase heat stress experienced by employees, because employers can take measures to abate the heat-stress hazard.

In summary, the Agency agrees with IBEW's posthearing brief on the subject of heat stress:

> Another issue raised during the hearing was the specter that wearing FR clothing increases the risk of heat stress for employees working in hot climates. While the record is replete with reference to heat stress, material about its attendant hazards, and advice about how to avoid it, see, e.g., Ex. [0478] (EEI Post-Hearing Comments; references to materials on OSHA's website), there is absolutely no evidence in the record that employees wearing FR clothing are necessarily at greater risk of suffering heat stress than employees working in similar conditions but wearing regular work clothes.
>
> Heat stress is a function of a number of different factors, including not only the kind of clothing the employee is wearing, but the heat load of the particular operation in which the employee is involved, the level of exertion associated with the employee's tasks, his or her physical condition and diet, and such environmental conditions as temperature and humidity. [Tr.] 198, 234[,] 1349-51; Ex. [0363]. Dr. Capelli-Schellpfeffer explained that the extent to which clothing poses a heat stress problem is less a function of the FR rating than the degree to which it encloses the body and prevents it from cooling. Thus, for most FR clothing worn during routine operations, if the clothing is not "enclosing" and the body has the ability to cool naturally, its FR nature will not pose any more of a heat stress threat than any other clothing. [Tr.] 200-01, 249. Thomas Neal, of Neal Associates, added that although heavier clothing may contribute to heat stress, the availability of lighter weight FR clothing is minimizing that issue. Ex. [0363]. And representatives of both the utility industry ([Tr.] 388 (ElectriCities)) and electrical contractors ([Tr.] 1349, 1350, 1351) concurred that although they certainly have had experience with heat stress, they were unaware of any situation that would not have occurred if the employee had not been wearing FR clothing. In fact, Quanta's Wilson Yancey noted that of the 6000 company employees who

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worked during last summer's extreme hurricane season, there was not one case of heat stress that he would attribute to FR clothing. [Tr.] 1350.

This is not to disregard the fact that heat stress is an issue for electrical transmission and distribution workers – whether or not they are wearing FR clothing. The record shows, however, that there are industrial hygiene strategies for minimizing the possibility that employees working in hot, humid conditions experience heat stress, which utility and contractor employers either do or should utilize. These strategies include controlling the amount of time a particular employee performs a particular task, rotating employees, permitting cooling rests, ensuring adequate fluid intake, and utilizing light-weight, layered systems of arc-rated clothing. [Tr.] 198-99[,] 460; Ex. [0363].

Where the arc hazard analysis dictates putting employees in such highly rated FR clothing that heat stress or other performance impediments become a real problem, the answer may be to employ other strategies for protecting the employee from the threat. For example, an arc hazard analysis showed Gallatin Steel that it needed to develop alternative switching procedures to minimize employee exposure to arc flashes. Ex. [0460]. NIOSH recommends establishing "flash protection boundaries" from which employees can maintain a sufficient distance from the exposure that they will not require protective clothing. Ex. [0130]. See also [Tr.] 498-99 (examples from other industries that have employed methods to lower heat energy estimates). [Ex. 0505]

Are FR and arc-rated clothing personal protective equipment? As described earlier, OSHA is requiring employers, in certain situations, to ensure that their employees (1) wear flame-resistant clothing and (2) wear protective clothing and other protective equipment with an arc rating greater than or equal to the heat energy estimated under paragraph (g)(2) of the final rule. In the preamble to the proposal, OSHA stated that it considered the protective clothing required by proposed paragraph (g) to be PPE (70 FR 34868). As the preamble noted, the protective clothing would reduce the degree of injury sustained by an employee when an electric arc occurs and, in some cases, would prevent injury altogether (*id*.).

Many rulemaking participants objected to OSHA's classification of arc-rated clothing as PPE. (See, for example, Exs. 0125, 0157, 0170, 0172, 0185, 0207, 0209,

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0504, 0506; Tr. 544 – 547, 1123 – 1124.) For instance, Mr. Jonathan Glazier with NRECA commented:

> To avoid any confusion, NRECA requests that OSHA reiterate its longstanding position that FR clothing is not PPE. That is, FR clothing, when it is not used as protective clothing, is not PPE even though it also has a protective value. For an example of OSHA's longstanding position on FR clothing as not being PPE, see the statement in the July 31, 1995 letter from John B. Miles, Jr., Director, Directorate of Compliance Programs, to Mr. Jack Callaway, Director of Environment Affairs, Sho-Me Power Electric Cooperative, that the Power Generation, Transmission, and Distribution standard section "1910.269 (l)(6)(iii) is not a personal protective (clothing) equipment requirement." [Ex. 0233]

The letter of interpretation referred to by Mr. Glazier simply states that existing §1910.269(l)(6)(iii), which prohibits the use of clothing that could increase the extent of an injury in the event of an arc exposure, is not a ***requirement*** for PPE. The letter does not state that FR clothing itself is not PPE. An OSHA memorandum to the field describes this Agency policy more explicitly:

> The Apparel Standard is intended to provide worker protection from exposure to the secondary hazard of the employee's clothing burning or melting and making even worse any injuries caused by primary exposure to the electric arc or flame. While OSHA requires, with exceptions, that employers provide and pay for PPE, paragraph 1910.269(l)(6)(iii) is silent on these points. Note that this Apparel Standard is not considered a personal protective equipment (PPE) *standard*; however, it may apply to personal protective equipment. [Emphasis added.] For example, paragraph 1910.269(l)(6)(iii) applies to an employer who provides personal protective clothing worn by an employee, who is exposed to the hazards of electric arcs or flames, for protection against cold or rain.
>
> Because it is not a PPE requirement, the Apparel Standard does not address whether or not an employee's clothing must cover all exposed parts of the employee's body. The Apparel Standard, by itself, does not prohibit employers from purchasing flame-retardant-treated short sleeve shirts or from altering flame-retardant-treated long sleeve shirts to shorten the sleeves. However, such practices are discouraged. Flame-retardant-treated clothing provides a measure of protection to an employee exposed to an electric arc.
>
> From this standpoint, flame-retardant-treated clothing which covers not only the body and legs, but also the arms provides better protection to the employee.

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> Note: An employer would be in a citable posture for violation of [§1910.132] of the Subpart I *Personal protective equipment* standard when it is a generally accepted safe work practice of the industry to wear clothing which covers the arms, legs or other exposed surfaces of the body to protect an employee in a particular workplace application and the employee does not do so. [Memorandum for: Regional Administrators, From: James W. Stanley, dated August 10, 1995, Subject: Guidelines for the Enforcement of the Apparel Standard, 29 CFR 1910.269(l)(6), of the Electric Power Generation, Transmission, and Distribution Standard;[377] emphasis included in original]

This memorandum makes it clear that, while OSHA does not treat existing §1910.269(l)(6)(iii) as a PPE requirement, some FR clothing may be PPE for purposes of other OSHA standards.

Some rulemaking participants maintained that OSHA did not define PPE or argued that the Agency was defining PPE to include FR clothing for the first time in this rulemaking. (See, for example, Exs. 0207, 0222, 0233; Tr. 568.) For instance, the Small Business Administration's Office of Advocacy commented: "OSHA declares in a single sentence in the preamble that it now views protective clothing as PPE, a position that OSHA has previously not asserted" (Ex. 0207; footnote omitted). Mr. Chris Tampio with NAM argued:

> The basic Personal Protective Equipment (PPE) standards for general industry and construction are found in Sections 1910.132 and 1926.95, respectively, and have been in existence for over 30 years. To the best of our knowledge, these provisions have not been interpreted to require fire-resistant or arc-rated clothing to address arc flash hazards. If OSHA already interpreted Section 1910.132 or 1926.95 to require fire-resistant or arc-rated clothing to address arc flash hazards, there would have been no reason to propose the clothing requirements in the current rulemaking. Accordingly, should the final rule contain provisions requiring arc flash hazard assessments and FR/AR

[377]The full text of this memorandum is available at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=21878.

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clothing, it is essential for OSHA to insert language into the final rule and the preamble to the final rule clarifying that the agency's interpretations of Sections 1910.132 and 1926.95 remains unchanged – that they do not require flame-resistant and arc-rated clothing in connection with any arc flash hazards that may exist outside the activities covered by Section 1910.269 and Subpart V.

* * *

OSHA's discussion of the clothing requirements in the preamble to this rulemaking demonstrate that fire-resistant clothing is … not considered PPE under Section 1910.132:

> OSHA's existing clothing requirement in § 1910.269 [which incorporates the personal protective equipment requirements of Subpart I of Part 1910 by reference into Section 1910.269(g)(1)] does not require employers to protect employees from electric arcs through the use of flame-resistant clothing. It simply requires that an employee's clothing do no greater harm. Because of the serious nature of the still remaining risk to power workers from electric arcs, the Agency believes that the standard should be revised to require the use of flame-resistant clothing, under certain circumstances, to protect employees from the most severe burns.

Section 1910.132, "General Requirements [for PPE]", is OSHA's general PPE standard which requires that PPE shall be used wherever necessary by reason of workplace hazards. Because 1910.269 already incorporates § 1910.132, there would be no reason to revise §1910.269 (or Subpart V) to require the use of FR/AR clothing, or to perform an economic impact analysis of the additional burden of that requirement, if FR/AR clothing was already required by §1910.132 (or §[1926].95) to address the arc flash hazard.

… In [a] 1999 rulemaking, OSHA issued [a notice of proposed rulemaking] to address the issue of whether an employer would be required to pay for the PPE required by § 1910.132. The scope of that preamble and the technical and economic feasibility analysis for that proposal were limited to head, eye, hand, face and foot protection, and some forms of protective clothing (other than arc-rated or fire-resistant clothing). There was no mention of its application to fire-resistant or arc-rated clothing for electrical workers. The NAM respectfully submits that, to this day, as the subject rulemaking acknowledges, OSHA has never interpreted § 1910.132 or 1926.95 to require fire-resistant clothing or arc-rated clothing to address arc flash hazards.

In light of this well-established interpretation of §§ 1910.132 and 1926.95, we respectfully submit it may not be materially changed except through notice and comment rulemaking that clearly announces to all interested parties that such an enormous change is under consideration. It is well-established that agency interpretations, even when reasonable constructions of its rules, trigger notice and comment requirements under the APA when the interpretation represents a

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> significant change from a previous, definitive interpretation. *See Alaska Professional Hunters Association, Inc. v. FAA*, 177 F.3d 1030, 1034 (D.C. Cir. 1999). [Ex. 0222; footnotes omitted; emphasis included in original.]

First, the Agency considers irrelevant the argument that, if §§1910.132 and 1926.95 already cover arc-rated clothing, OSHA does not need separate requirements for such clothing in Subpart V and §1910.269. The regulated community could construe existing §1910.269(l)(6)(iii), because it explicitly covers electric-arc hazards for work performed under §1910.269, to preempt application of §1910.132(a) to electric-arc hazards in electric power generation, transmission, and distribution work. Consequently, OSHA needed to revise §1910.269, as it proposed to do, to clarify that employees must use arc-rated clothing for work covered by that standard.

Second, the commenters' statements about current OSHA policy are wrong. The Agency currently considers FR clothing to be PPE; OSHA is not establishing new policy on that issue in this final rule. The Agency has issued, and the Occupational Safety and Health Review Commission has upheld, citations against employers for violating §1910.132(a) by not providing flame-resistant clothing to employees. (See, for example, *Lukens Steel Co.*, 10 BNA OSHC 1115 (No. 76-1053, 1981) (Section 1910.132 required the use of "protective equipment, including … flame retardant clothing" for employees exposed to burn hazards at a steel-producing facility).) In addition, the Agency has issued several letters of interpretation stating that, under certain circumstances, §1910.132(a) or §1926.95(a) require FR clothing. (See, for example, letters of interpretation dated

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March 7, 2006, to Mr. Joseph P. Zemen[378] (FR clothing in plants processing flammable materials) and February 29, 2008, to Mr. Brian Dolin[379] (protection against arc-flash hazards for work covered by 29 CFR Part 1926, Subpart K).)

In the recently completed rulemaking on employer payment for personal protective equipment (72 FR 64342), some commenters suggested "that FR clothing is not PPE." (72 FR 64353). OSHA rejected that argument, noting:

> If OSHA determines in [the Subpart V] rulemaking that FR clothing is required, it will then become subject to the PPE payment provisions of this rule …. [*Id.*]

Thus, it is clear that the Agency considers flame-resistant clothing to be PPE. In this regard, this rulemaking does not establish new policy or revise longstanding policy, as the commenters suggested.[380]

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[378]This letter is available at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=25366.

[379]This letter is available at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=25973.

[380]Mr. Tampio also argued that FR clothing is not considered electrical protective equipment under §1910.335 (Ex. 0222). This argument is not relevant to this discussion. However, note that OSHA agrees with Mr. Tampio that FR clothing is not electrical protective equipment. This equipment, covered by §§1910.137 and 1926.97 in this final rule, protects employees from electric shock. FR clothing, whether arc-rated or not, does not provide protection against electric shock.

In addition, Mr. Tampio argued that the hazard assessment and training requirements in §1910.132 apply only to head, eye, hand, face, and foot protection. OSHA also agrees with this statement, but again finds it irrelevant. The limitation of the PPE hazard assessment and training provisions, contained in §1910.132(g), has no bearing or effect on the types of PPE covered by the general requirement to provide PPE in §1910.132(a). The preamble to the Subpart V proposal requested comment on whether to extend the hazard assessment and training requirements of §1910.132 to electrical protective equipment, which is another form of PPE covered by §1910.132(a) (70 FR 34893).

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Consistent with past policy, OSHA believes that it is reasonable and appropriate to treat FR and arc-rated clothing required under final paragraph (g) as PPE. FR clothing required by paragraph (g)(4) of the final rule will protect against the ignition of clothing, and arc-rated clothing, as required by paragraph (g)(5) of the final rule, will protect against heat-related hazards caused by electric arcs. Dr. Mary Capelli-Schellpfeffer explained that electric arcs can "occur unintentionally in man-made systems" and represent "a common electrical fault condition which may lead to a failure in the power system" (Ex. 0373). She explained that, when an employee is repairing an electrical installation, "[i]f the installation remains energized, or is not in an electrically safe working condition, the risk of electric arc persists, and may be increased as a result of the post-fault status" (*id*.). As Dr. Capelli-Schellpfeffer noted, the causes of electric arcs include: transient overvoltage disturbances, such as lightning and switching surges; mechanical damage from foreign sources, such as digging or vehicles; shorting by tools or metal objects; mechanical failure of static or structural parts; and insulation breakdown (*id*.). Thus, electric arcs commonly result from the breakdown of equipment in the process of generating, transporting, or using electricity or from the process of repairing an electrical installation.

Dr. Capelli-Schellpfeffer also described the thermal hazards posed by electric arcs, explaining:

> With temperatures rising in and around an arc, burn hazard is present from ohmic heating due to electrical power flow; ignition and combustion of nearby materials, notably including worn clothing and adjacent equipment; and sprayed or blown hot or melting installation elements moved by the mechanical forces in the electric arc event. Additionally, radiation is another major source of heat. [Ex. 0373; see, also, Tr. 178 – 188.]

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Thus, thermal hazards posed by electric arcs arise not only from the processes but are a direct result of the rapidly changing environment that results from a fault in an electrical system.

Dr. Capelli-Schellpfeffer also described the injuries that can result from electric arcs:

> The injuries that accompany high temperature exposures at the body surfaces are commonly referred to as skin burns. When these injuries are distributed within the body we still call them skin burns, and the burn generally refers to a physical chemical change.
>
> As many appreciate from the experience of sunburn, this kind of condition is painful, and when the trauma is more severe, the pain is extraordinary, and of course the medical treatment is extensive. [Tr. 188]

As noted earlier, she graphically depicted these injuries with a photograph of the victim of an electric arc, which she explained as follows:

> [T]he extent of the injury that can follow an arc exposure is readily appreciated. Eyes, ears, faces, skin, limbs, and organs are affected. Basic bodily function, including the ability to breathe, eat, urinate, and sleep are completely changed. [Tr. 186]

Thus, thermal injuries from an electric arc occur when an employee's body absorbs the heat from the arc.

In light of the foregoing discussion, OSHA concludes that FR clothing and arc-rated clothing will protect against "hazards of processes or environment" and are designed to protect against hazards "encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation or physical contact." Thus, OSHA is reiterating that FR clothing and arc-rated clothing are PPE as §§1910.132(a) and 1926.95(a) generally describe that term.

Mr. Jonathan Glazier with NRECA argued that FR clothing is not protective (Ex. 0506; Tr. 544 – 545). At the hearing, Mr. Glazier testified:

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> The FR nature of clothing offers no protective value. It refers merely to the clothing's inability to melt or ignite and remain ignited. We should be aware of the difference between the attribute of FR and the attribute of protection.
>
> It gets confusing, because arc protective clothing, which sounds like it may be personal protective equipment, and OSHA says it is personal protective equipment in the preamble ….
>
> It gets confusing, because arc protective clothing is first FR. That is, all arc protective clothing is also FR, and I am told that all FR clothing sold nowadays has an arc protective rating.[381] But still, there is a difference between the FR attribute and the arc protective attribute. [Tr. 544 – 545]

OSHA disagrees with Mr. Glazier. FR clothing, even without an arc rating, protects employees against burns caused by radiant and convective heat as well as burns caused by potential ignition of clothing that is not flame resistant. Dr. Thomas Neal testified that FR clothing "not only [does not] ignite and, basically, eliminate[s] the burning clothing on the body syndrome, but [it] also provide[s] a level of protection by blocking heat from reaching the body" (Tr. 472). Dr. Capelli-Schellpfeffer similarly testified that "FR clothing … is protective and designed to resist ignition and block heat transfer" (Tr. 189). An arc-rating on FR clothing is a measure of how much incident energy can be present before the wearer will just barely sustain a second-degree burn (Ex. 0061). Clearly, arc-rated clothing and FR clothing (even without an arc rating) protect employees from being burned by electric arcs and are, therefore, protective.

Mr. Frank White with ORC Worldwide expressed concern that OSHA would consider untreated cotton clothing to be PPE (Ex. 0235). He noted that Table 10 in proposed Appendix F listed untreated cotton clothing as "protective" for incident energy

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[381]OSHA is aware that some FR clothing, such as children's FR sleepwear and certain types of FR clothing made specifically for protection from contact with molten metal, are not arc rated.

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up to 2 cal/cm^2 and that "at higher incident energy exposures a [T]-shirt is listed as the first layer of protective clothing, followed by other layers of FR clothing" (*id*.). Mr. White also interpreted Table 11 from proposed Appendix F, which listed ignition thresholds for various weights of cotton fabrics, as indicating that these fabrics provide "protection from heat energy below the ignition threshold" (*id*.).

Untreated cotton can ignite and continue to burn when subjected to incident heat energy above its ignition threshold (Tr. 467 – 469, 472). OSHA does not consider cotton clothing, which can ignite and pose a hazard itself, as constituting protective clothing with respect to electric arcs common to work covered by the final rule. Therefore, OSHA did not include Table 10 or Table 11 from proposed Appendix F in final Appendix E. (See also the summary and explanation for the appendices to Subpart V, later in this section of the preamble.) Finally, even though wearing cotton clothing as one layer in a clothing system can effectively increase the arc-rating of a the system, OSHA does not consider cotton clothing to be protective.[382]

Some commenters maintained that OSHA needed to conduct a separate rulemaking to determine whether FR clothing is PPE. (See, for example, Exs. 0170, 0183, 0202, 0207, 0222, 0229, 0233, 0239, 0240.) For instance, Mr. Alan Blackmon with Blue Ridge Electric Cooperative commented that, if "OSHA institutes an arc protective clothing requirement, its nature as PPE or non-PPE should be the subject of public notice

[382]Note that, even if cotton clothing in these circumstances were PPE, §§1910.132(h)(4)(ii) and 1926.95(d)(4)(i) exempt "everyday clothing" from the employer-payment requirements in §§1910.132(h) and 1926.95(d).

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and comment. It is not enough for OSHA merely to issue a pronouncement in the Preamble of this rulemaking" (Ex. 0183).

The U.S. SBA's Office of Advocacy suggested that "the issue of protective clothing as PPE [was] not … fully vetted in the rulemaking process" and recommended that "OSHA address the issues of protective clothing, PPE, and employer payment for PPE in the PPE rulemaking process and not finalize these provisions prior to that rulemaking's conclusion" (Ex. 0207).

As noted earlier, existing OSHA policy treats FR clothing (whether or not it is arc rated) as PPE. OSHA's statement in the preamble to the proposed rule simply reaffirmed that position. Although the Agency does not believe notice and comment is necessary on this issue (see, for example, 5 U.S.C. 553(b) (APA notice and comment requirements do not apply "to interpretative rules")), affected parties had clear notice in the preamble to this rulemaking that the Agency was considering whether employers would have to pay for the arc-rated clothing required by the final rule (an issue discussed later in this section of the preamble). OSHA believes that the public also had clear notice that the Agency considered FR clothing to be PPE and had ample opportunity to challenge the Agency on that point as it relates to this rulemaking. Consequently, OSHA concludes that there is no need to conduct further rulemaking related to the issue of whether FR clothing is PPE.

Who should pay for the PPE required by paragraph (g) of the final rule? As explained earlier, OSHA considers FR clothing and arc-rated clothing required by the final rule to be PPE. The proposed rule did not specify whether employers would have to provide protective clothing at no cost to employees. However, OSHA noted in the

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preamble to the proposal that it was considering including an employer-payment requirement in the final rule and sought comments on the issue.

The preamble to the proposal also noted that OSHA had proposed regulatory language for the general PPE standards to clarify that employers generally are responsible for the cost of PPE (70 FR 34869, citing 64 FR 15402, Mar. 31, 1999). OSHA published the final rule on employer payment for PPE on November 15, 2007 (72 FR 64342). The final rule on employer payment for PPE requires employers to pay for the PPE used to comply with OSHA standards, with a few exceptions, including (1) everyday clothing, such as longsleeve shirts, long pants, street shoes, and normal work boots; and (2) ordinary clothing, skin creams, or other items, used solely for protection from weather, such as winter coats, jackets, gloves, parkas, rubber boots, hats, raincoats, ordinary sunglasses, and sunscreen. (See 29 CFR 1910.132(h); 29 CFR 1926.95(d).)

In the PPE-payment rulemaking, OSHA explained the rationale behind its decision to require employers generally to pay for PPE, as follows:

> 1. The OSH Act Requires Employer Payment for PPE
>
> OSHA is requiring employers to pay for PPE used to comply with OSHA standards in order to effectuate the underlying cost allocation scheme in the OSH Act. The OSH Act requires employers to pay for the means necessary to create a safe and healthful work environment. Congress placed this obligation squarely on employers, believing such costs to be appropriate in order to protect the health and safety of employees. This final rule does no more than clarify that under the OSH Act employers are responsible for providing at no cost to their employees the PPE required by OSHA standards to protect employees from workplace injury and death.
>
> * * *
>
> 2. The Rule Will Result in Safety Benefits
>
> Separate from effectuating the statutory cost allocation scheme, this rule will also help prevent injuries and illnesses. OSHA has carefully reviewed the rulemaking record and finds that requiring employers to pay for PPE will result in

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significant safety benefits. As such, it is a legitimate exercise of OSHA's statutory authority to promulgate these ancillary provisions in its standards to reduce the risk of injury and death.

There are three main reasons why the final rule will result in safety benefits:

• When employees are required to pay for their own PPE, many are likely to avoid PPE costs and thus fail to provide themselves with adequate protection. OSHA also believes that employees will be more inclined to use PPE if it is provided to them at no cost.

• Employer payment for PPE will clearly shift overall responsibility for PPE to employers. When employers take full responsibility for providing PPE to their employees and paying for it, they are more likely to make sure that the PPE is correct for the job, that it is in good condition, and that the employee is protected.

• An employer payment rule will encourage employees to participate wholeheartedly in an employer's safety and health program and employer payment for PPE will improve the safety culture at the worksite.

* * *

3. Clarity in PPE Payment Policy

Another benefit of the final PPE payment rule is clarity in OSHA's policy. While it is true that most employers pay for most PPE most of the time, the practices for providing PPE are quite diverse. Many employers pay for some items and not for others, either as a matter of collective bargaining or long standing tradition. In some cases, costs are shared between employees and employers. In other workplaces, the employer pays for more expensive or technologically advanced PPE while requiring employees to pay for more common items. However, in some workplaces exactly the opposite is true. [72 FR 64344]

OSHA concludes that there is no evidence in the Subpart V rulemaking record to persuade the Agency that any of these reasons are invalid with respect to FR and arc-rated clothing. As explained later, OSHA considered and rejected nearly all of the arguments against an employer-payment requirement for FR and arc-rated clothing in the PPE-payment rulemaking. As noted previously, OSHA specifically considered FR clothing in the PPE-payment rulemaking and concluded in the preamble to the final PPE-

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payment rule that, "[i]f OSHA determines in [the Subpart V] rulemaking that FR clothing is required, it will then become subject to the PPE payment provisions of this rule, unless the final §1910.269 and Part 1926 Subpart V standards specifically exempt FR clothing from employer payment" (72 FR 64353). Therefore, the default position for the Subpart V rulemaking is that employers must pay for the FR and arc-rated clothing required by this final rule unless the Agency adopts provisions specifically exempting this clothing from the general PPE-payment rule. Also, for reasons described later, OSHA concludes that such an exemption is neither necessary nor appropriate for the FR or arc-rated clothing required under paragraph (g) of this final rule. The general PPE-payment rule, including all exceptions, applies to the FR and arc-rated clothing used to comply with this final rule. (See 72 FR 64369.)

Several rulemaking participants supported requiring employers to pay for the FR clothing and arc-rated clothing required by the final rule. (See, for example, Exs. 0130, 0164, 0197, 0211, 0230, 0505; Tr. 819 – 820, 834, 897 – 898.) These rulemaking participants gave several reasons for supporting an employer-payment requirement:

- Many employers already are providing this protective clothing (Exs. 0230, 0505; Tr. 897 – 898),
- Employers are more likely to properly train employees in using PPE (Ex. 0211),
- Employers are more likely to select, and ensure that employees wear, proper protective clothing (Exs. 0197, 0211, 0230),
- Employers are more likely to properly maintain the protective clothing (Exs. 0130, 0211, 0230), and

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- The OSH Act requires employers to pay for this type of protection (Tr. 848 – 849).

Other commenters opposed an employer-payment requirement. (See, for example, Exs. 0099, 0125, 0146, 0169, 0173, 0186, 0201, 0209, 0222; Tr. 546 – 547.) These rulemaking participants presented the following reasons for not imposing such a requirement:

- The difficulty and expense contractors would have buying protective clothing for employees who move from employer to employer (Exs. 0169, 0186),
- Employees take better care of clothing when they pay at least a portion of the cost (Exs. 0099, 0186),
- Employers consider protective clothing a "tool of the trade" that employees must bring with them to the job (Ex. 0222; Tr. 295 – 297),
- FR and arc-rated clothing only provides secondary protection (Exs. 0209, 0210), and
- Protective clothing is personal because employees can wear it off the job (Exs. 0125, 0146, 0173, 0209, 0222).

OSHA examined several of these arguments in the PPE-payment rulemaking. For example, the Agency explained how employers could handle the problems associated with transient workforces:

> If the employer retains ownership of the PPE, then the employer may require the employee to return the PPE upon termination of employment. If the employee does not return the employer's equipment, nothing in the final rule prevents the employer from requiring the employee to pay for it or take reasonable steps to retrieve the PPE, in a manner that does not conflict with federal, state or local laws concerning such actions. In these situations, OSHA notes that the employer is not allowed to charge the employee for wear and tear to the equipment that is related to the work performed or workplace conditions. As suggested by National

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> Tank Truck Carriers, Inc., a written agreement, for example, between the employer and employee on the matter may be an effective method of ensuring that the employer's expectations of the employee are clear and unambiguous …. Another acceptable alternative is a deposit system that provides an incentive for employees to return the equipment. However, the Agency cautions that the deposit system must not be administered in a fashion that circumvents the rule and results in an employee involuntarily paying for his or her PPE.
>
> In some situations, an employer may prohibit an employee from using PPE that the employer has paid for while working for another employer …. Conversely, an employer may allow an employee to use employer-owned PPE while working for another employer …. Since the employer has retained ownership of the PPE, he or she can stipulate where it is used. OSHA does not object to either of the aforementioned practices. [72 FR 64359]

The same solutions apply here. OSHA notes that the record in this rulemaking describes another possible solution for contractors employing unionized labor. Mr. Jules Weaver with Western Line Constructors Chapter testified that "[t]here are certain parts of the country in our industry, IBEW and [NECA], have a … safety fund, and the contractors pay into it, and they provide FR clothing for individuals" (Tr. 307). Thus, although providing employees with PPE, including FR clothing and arc-rated clothing, might be challenging for employers with transient workforces, the Agency believes that there are reasonable compliance options available.

In the PPE-payment rulemaking, the Agency rejected an argument that employees take better care of PPE than employers, explaining: "OSHA is also not swayed by [the] arguments that employees are in a better position to maintain, use, and store PPE. In fact, the existing PPE standards place on employers the responsibility for ensuring proper fit, use, and maintenance of PPE" (72 FR 64380). The same rationale applies to the argument in this rulemaking that employees take better care of protective clothing when they pay for all, or a portion, of it. The OSH Act and the PPE standards at §§1910.132 and

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1926.95 make the employer, not the employee, responsible for the care and maintenance of PPE.

In the PPE-payment rulemaking, the Agency decided not to exempt "tools of the trade," stating:

> As discussed previously and noted by many commenters, in some trades, industries, and/or geographic locations, PPE for employees who frequently change jobs can take on some of the qualities of a "tool of the trade." In other words, the PPE is an item that the employee traditionally keeps with his or her tool box. This may be because the PPE is used while performing some type of specialized work, such as welding or electrical work, or because it is a tradition in the industry, such as in home building. OSHA has not included an exception to the payment requirement for tools of the trade because, among other things, of the difficulty of defining, with adequate precision, when an item of PPE is or is not a tool of the trade. However, because the rule does not require employers to reimburse employees for PPE they already own, it recognizes that some employees may wish to own their tools of the trade and bring that equipment to the worksite.
>
> OSHA has further emphasized in the regulatory text that employees are under no obligation to provide their own PPE by stating that the employer shall not require an employee to provide or pay for his or her own PPE, unless the PPE is specifically excepted in the final rule. These provisions address the concern that employers not circumvent their obligations to pay for PPE by making employee ownership of the equipment a condition of employment or continuing employment or a condition for placement in a job. OSHA recognizes that in certain emergency situations, such as response to a natural disaster, where immediate action is required, it may be necessary for employers to hire or select employees already in possession of the appropriate PPE. As a general matter, however, employers must not engage in this practice. Taking PPE-ownership into consideration during hiring or selection circumvents the intent of the PPE standard and constitutes a violation of the standard. [72 FR 64358 – 64359]

The same rationale applies here.

OSHA also rejects the argument that, because FR and arc-rated clothing is secondary protection, the Agency should not require employers to pay for it. As noted earlier, PPE is part of a hierarchy of controls. OSHA standards typically require other forms of controls, such as engineering and work-practice controls, in preference to PPE. In many cases, PPE supplements engineering controls and forms a second line of defense

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to protect employees in the event that other types of controls do not provide complete abatement of the relevant hazard. For example, existing §§1910.67(c)(2)(v) and 1926.453(b)(2)(v) require employees working from aerial lifts to wear personal fall protection equipment because that PPE would protect the workers in case the engineering controls (that is, the guardrails or bucket walls on the aerial lift platforms or buckets) do not provide sufficient protection. (See, also, the preamble to the final rule on respiratory protection, 29 CFR 1910.134 and 29 CFR 1926.103, which notes: "Respiratory protection is a backup method which is used to protect employees from toxic materials in the workplace in those situations where feasible engineering controls and work practices are … not in themselves sufficient to protect employee health …." (63 FR 1156 – 1157, Jan. 8, 1998).) Consequently, OSHA standards often consider PPE "secondary" protection. FR and arc-rated clothing is not unique in this regard. In any event, where this final rule requires FR or arc-rated clothing, OSHA determined that it is necessary for employee protection (as described previously) and, thus, the rationale for requiring employers to pay for this type of PPE still applies.

In the PPE-payment rulemaking, OSHA also considered exempting types of PPE that were "personal in nature."[383] However, instead of exempting all such personal PPE, the Agency chose to evaluate various types of personal PPE individually. First, OSHA chose not to require employer payment for everyday clothing or ordinary clothing used

[383]For the purposes of this discussion, OSHA considers PPE that is "personal in nature" to be PPE fitted to an individual employee and not shared by other employees and that the employee can use off the job.

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solely for protection from weather. The Agency explained the reasoning for this decision as follows:

> OSHA does not believe that Congress intended for employers to have to pay for everyday clothing and ordinary clothing used solely for protection from the weather. While serving a protective function in certain circumstances, employees must wear such clothing to work regardless of the hazards found. OSHA is exercising its discretion through this rulemaking to exempt jeans, long sleeve shirts, winter coats, etc., from the employer payment requirement. As stated, this is consistent with OSHA's intent in the proposal and is also supported by the rulemaking record. A number of commenters stated that OSHA should exempt these items from the employer payment requirement ….
>
> Thus, OSHA is not requiring employers to pay for everyday clothing even though they may require their employees to use such everyday clothing items such as long pants or long-sleeve shirts, and even though they may have some protective value. Similarly, employees who work outdoors (e.g., construction work) will normally have weather-related gear to protect themselves from the elements. This gear is also exempt from the employer payment requirement. [72 FR 64349]

The PPE-payment rule also exempts nonspecialty safety-toe protective footwear, provided the employer permits employees to wear it off the jobsite.[384] OSHA explained this exemption as follows:

> OSHA has historically taken the position that safety-toe protective footwear has certain attributes that make it unreasonable to require employers to pay for it in all circumstances …. Safety footwear selection is governed by a proper and comfortable fit. It cannot be easily transferred from one employee to the next. Unlike other types of safety equipment, the range of sizes of footwear needed to fit most employees would not normally be kept in stock by an employer and it would not be reasonable to expect employers to stock the array and variety of safety-toe footwear necessary to properly and comfortably fit most individuals.
>
> Furthermore, most employees wearing safety-toe protective footwear spend the majority of their time working on their feet, and thus such footwear is particularly difficult to sanitize and reissue to another employee. Other factors

[384]The PPE-payment rule provides additional exemptions for such items as nonspecialty prescription safety eyewear. However, the rationale behind those exemptions sheds no additional light on whether FR and arc-rated clothing should or should not be subject to the general employer-payment requirement.

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> indicate as well that employers should not be required to pay for safety-toe protective footwear in all circumstances. Employees who work in non-specialty safety-toe protective footwear often wear it to and from work, just as employees who wear dress shoes or other non-safety-toe shoes do. In contrast, employees who wear specialized footwear such as boots incorporating metatarsal protection are likely to store this type of safety footwear at work, or carry it back and forth between work and home instead of wearing it.… OSHA does not believe that Congress intended for employers to have to pay for shoes of this type.
>
> For all of these reasons, OSHA has decided to continue to exempt nonspecialty safety shoes from the employer payment requirement. OSHA, however, also wants to make clear that this exemption applies only to non-specialty safety-toe shoes and boots, and not other types of specialty protective footwear. Any safety footwear that has additional protection or is more specialized, such as shoes with non-slip soles used when stripping floors, or steel-toe rubber boots, is subject to the employer payment requirements of this standard. Put simply, the exempted footwear provides the protection of an ordinary safety-toe shoe or boot, while footwear with additional safety attributes beyond this (e.g., shoes and boots with special soles) fall under the employer payment requirement. [72 FR 64348]

FR and arc-rated clothing is not "everyday clothing" or "ordinary clothing … used solely for protection from weather" as OSHA used those terms in the exemptions from the PPE-payment rule. This is not clothing that employees would purchase on their own to wear every day or to wear for protection against the weather. Although employees could wear it off the job, FR and arc-rated clothing command a premium above the price of normal clothing. OSHA estimates that a single set of flame-resistant apparel costs $191.75, on average. (See Section VI, Final Economic Analysis and Regulatory Flexibility Analysis, later in the preamble.) OSHA estimates that normal work clothing would cost half that amount. Winter-weather gear that is flame-resistant or arc-rated commands a greater premium. Evidence in the record indicates that non-FR winter wear may cost about $60 to $120, whereas similar FR winter wear could cost as much as $300 (Tr. 1024 – 1026).

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In addition, FR and arc-rated clothing provides more than incidental protection. As explained earlier, manufacturers design these garments specifically to protect against clothing ignition and incident heat energy. Consequently, OSHA determined that the rationale for exempting "everyday clothing" and "ordinary clothing … used solely for protection from weather" from the final PPE-payment rule does not apply to FR or arc-rated clothing, and OSHA is not interpreting these exemptions specified in the PPE-payment rule as covering the FR and arc-rated clothing required by final §1926.960(g).

FR and arc-rated clothing shares some attributes with nonspecialty safety-toe protective footwear. Employers normally may not keep in stock the range of sizes of pants, shirts, and other clothing needed to fit most employees,[385] and it would not be reasonable to expect employers to stock the array and variety of clothing necessary to properly and comfortably fit most individuals. In addition, employees who work in FR or arc-rated clothing may sometimes wear it to and from work, just like employees who wear ordinary clothing.

On the other hand, FR and arc-rated clothing does not have some of the other characteristics that formed the basis of OSHA's decision to exempt nonspecialty safety-toe protective footwear from PPE-payment requirements. FR clothing is not exempt from requirements for employer payment in other workplaces, such as steel plants, where an OSHA standard, such as §1910.132(a), requires it. Furthermore, employers can sanitize this clothing easily for use by other employees. In fact, evidence in the record indicates

[385]There are ways to provide FR and arc-rated clothing to employees that do not require the employer to maintain stocks of clothing, including using a clothing rental or uniform service and providing a clothing allowance so that employees can purchase their own clothing (Tr. 1134).

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that some employers currently use uniform-supply companies to provide and launder FR and arc-rated clothing (Ex. 0230). In addition, employers can purchase arc-rated clothing in a wide variety of ratings and are in a better position to make purchasing decisions with respect to arc rating than employees, which is not true of nonspecialty safety-toe protective footwear. OSHA concludes that FR and arc-rated clothing do not have all the attributes on which the Agency based its rationale for exempting nonspecialty safety-toe protective footwear; and, therefore, OSHA is not granting a similar exemption from the employer payment requirements for this clothing.

Moreover, OSHA believes that the record in this rulemaking demonstrates that, similar to most OSHA requirements for PPE, employee safety will significantly benefit from a requirement that employers provide FR and arc-rated clothing at no cost to employees. Employers generally need to ensure that the clothing worn by employees has an arc rating at least as high as the employer's incident-energy estimates. Selecting the proper clothing sometimes will involve determining the rating of an entire clothing system; such a determination is likely beyond the capability of individual employees, but is within an employer's capability. For example, Dr. Thomas Neal testified:

> [T]he only sure way [to obtain a rating for a layered clothing system] is to measure the arc rating for the system. [I]t's not [a] situation where you could have an arc rating for three different layers that you put those on top of each other, just add them together. That doesn't work. [Tr. 500]

In addition, as discussed later in this section of the preamble, clothing maintenance can substantially impact the ability of FR and arc-rated clothing to protect employees. Employers are in a better position to make purchasing decisions based on clothing maintenance needs than employees.

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While considerations regarding clothing selection and maintenance address principally arc-rated clothing, the Agency believes that requiring employers to purchase arc-rated but not FR clothing would cut too fine a line through OSHA's rationale. It is OSHA's understanding that most FR clothing, especially work clothing, has an arc rating (Tr. 545), and the Agency believes that employers will use arc-rated clothing (which is always flame-resistant) to meet the requirement in final paragraph (g)(4) for FR clothing. In this regard, it seems unlikely that employers will purchase one set of clothing to meet final paragraph (g)(4) and a different set of clothing to meet final paragraph (g)(5).

Some employers recommended that OSHA exempt clothing of various types, or having a specified minimum arc rating, from any requirement that employers pay for FR or arc-rated clothing. (See, for example, Exs. 0125, 0149, 0167; Tr. 295 – 297.) For instance, Mr. Ward Andrews with Wilson Construction recommended that employees come to the job in a minimum level of protective clothing and that employers pay for any higher level of protection needed for a particular exposure (Tr. 295 – 297). He justified his recommendation as follows:

> [I]t is our belief that journeyman linemen should come to work with basic tools. And we believe a Level one FR garment would be a basic tool to do his everyday task.
>
> [O]ur position is that they should come to work with those basic tools. And that is the minimum level one protection for the average distributional circuit here in America.
>
> * * *
>
> So we agree that at level one, basic [attire] should be clothing, as part of their job requirement, to step on. And then as they associate a job with hazards, and a higher level of protection needs to be provided, then surely that contractor should provide those additional levels.
>
> [W]e look [at] a journeyman lineman today, and we realize that he brings in his climbing belt, his positioning belt, his skid, his line boots. I believe that his

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positioning belt falls under—his line belt is a positioning belt, which is considered personal protective equipment. They provide that as tool that they bring to the job. So once again, I think that's evidence to—the same thing as a shirt, a very basic component that they should wear as journeyman lineman.

They provide their own raingear. They provide their own clothing right now. Your rule as proposed would say the most outer garment should be FR resistant. I believe that these basic tools that they now require, they should still provide, and you should give them time to buy FR raingear and clothes. [Tr. 295 – 297]

This argument is identical to the argument made for tools of the trade. In the PPE-payment rulemaking, OSHA rejected that argument for tools of the trade, as described earlier, and the Agency rejects this argument as it applies to FR and arc-rated clothing for the same reasons.

For the foregoing reasons, OSHA determined that employers must provide FR and arc-rated clothing at no cost to employees, and OSHA is not exempting this protective clothing from the PPE-payment rule. The requirements in §§1910.132(h) and 1926.95(d) apply to FR and arc-rated clothing; and, therefore, OSHA is not adding PPE-payment provisions to §1910.269 or Subpart V.[386]

Some employees performing work covered by this final rule may already own FR or arc-rated clothing. The PPE-payment requirements in §§1910.132(h)(6) and 1926.95(d)(6) provide that, when an employee provides adequate protective equipment that he or she owns, the employer may allow the employee to use it and need not reimburse the employee for the equipment. However, those provisions also prohibit the employer from requiring an employee to provide or pay for his or her own PPE, unless

[386]OSHA does not consider the FR and arc-rated clothing required by this final rule to be the type of everyday or ordinary clothing exempted from the PPE-payment rules in §§1910.132 and 1926.95.

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the PPE-payment requirement exempts the PPE. Accordingly, paragraph (h)(6) of §1910.132 and paragraph (d)(6) of §1926.95 apply to the FR and arc-rated clothing required by this final rule.

Maintenance of FR and arc-rated clothing. Some rulemaking participants stressed the importance of proper maintenance of the FR and arc-rated clothing required by the standard (Exs. 0130, 0186, 0325; Tr. 830 – 831, 834 – 839). For example, NIOSH stated that "[c]lothing maintenance is required for arc-rated FR clothing to provide continued protection at its rated arc thermal performance value" (Ex. 0130). Mr. Eric Frumin with UNITE HERE testified:

> Regarding the FR uniform programs in which the employees wash the garments themselves, there are number of factors that make it difficult or impossible for employees themselves to preserve the FR characteristics of the garments, contamination of the garment, inadequate training about the proper care of the garment, how do you maintain the physical integrity of it, the proper materials to use for repairing defects, proper laundering techniques, what kinds of cleaning agents or bleaching agents to avoid and so forth.
>
> And of course maintaining a proper number of garments to be available so that workers always have them.…
>
> A number of these problems are mentioned in the standard, [ASTM] 1449 and recommends the use of professional laundering services. Likewise NIOSH in its comments for this hearing said, "The emphasis that manufacturers place on proper laundering to maintain the FR characteristics of their garment suggests the need for professional laundering." So these are important things for OSHA to be mindful of as far as possibly assur[ing] that quality of the FR garments is maintained even when employees are washing the garments themselves.
>
> Now I would like to address that question of maintenance of consistent high quality laundering of FR clothing. Employers have a critical role to play here and that's envisioned in the ASTM standard. Likewise, NFPA 70E talks about the need specifically for careful inspection of clothing and kinds of interferences, contamination, damage and takes the position that defective clothing shall not be used. Very important. [Tr. 835 – 836]

Mr. Frumin cited two examples of a contract uniform service that failed to properly maintain the FR clothing they serviced (Tr. 836 – 838). Mr. John Devlin with the Utility

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Workers Union of America also described examples of inadequate maintenance of FR clothing:

> This shirt was sent in several times and it continually came back with a hole that was never repaired even though it was requested twice. These pants were sent out twice with the repair tag for the frayed bottoms of the trousers to be either shortened or repaired in some manner. The answer that Cintas did was they sent back a pair of new trousers. The only problem there was no belt loops. [Tr. 821]

Mr. Frumin urged OSHA to "require … employers to obtain with each delivery a certification from their suppliers that the correct number of garments has been provided, that they are free of defects and contamination that could compromise the FR protection" (Tr. 838).

The record indicates that there are a variety of methods currently in use to maintain FR and arc-rated clothing. Some employers have their employees launder and maintain this clothing. (See, for example, Tr. 305 – 306, 1192 – 1193.) Other employers hire laundering or uniform services to perform those functions. (See, for example, Tr. 388, 821.) OSHA stresses that §§1910.132(a) and (b) and 1926.95(a) and (b) require employers to properly maintain FR and arc-rated clothing required by this final rule. These provisions make PPE maintenance the responsibility of employers, not employees. The Agency is declining to adopt Mr. Frumin's suggestion to require employers to have suppliers certify that each delivery of FR clothing is free of defects and contamination because OSHA believes that it is the employer's responsibility to ensure proper maintenance of PPE. There are ways of ensuring proper maintenance of FR and arc-rated clothing that do not rely on the certification of a supplier. For example, employers can inspect this clothing before accepting it, and they can return it to the supplier if they find defects or contaminants on the clothing. In any event, the responsibility for maintaining PPE rests squarely with the employer under existing OSHA standards.

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The Agency is not prohibiting home laundering of FR and arc-rated clothing. However, to comply with §1910.132 or §1926.95, employers cannot simply instruct employees to follow manufacturers' instructions.[387] If employers rely on home laundering of the clothing, they must train their employees in proper laundering procedures and techniques, and employers must inspect the clothing on a regular basis to ensure that it is not in need of repair or replacement. Evidence in the record indicates that some employers already are performing these functions. (See, for example, Tr. 1193.)

Protecting employees from flying debris from electric arcs. Two rulemaking participants recommended that OSHA require protection from flying debris that results from electric arcs (Exs. 0340, 0342, 0378; Tr. 253 – 268, 274 – 283). Mr. Nestor Kolcio with 2K Consultants argued that a substantial number of injuries result from the flying debris, which he called "fragmentation" or "shrapnel," released in an electric arc-flash incident (Ex. 0342). Using OSHA's preliminary regulatory analysis as a baseline, he estimated that 17 injuries from flying debris occur annually in work covered by the final rule (*id*.). He stated that these injuries result from work activities such as pulling fuses and end caps, working on dead-front transformers, installing lightning arresters, and operating load-break switches (*id*.). Mr. Jim Stillwagon with Gary Guard described injuries that occurred from flying debris caused by electric arcs, including an eye injury and a chest injury in which debris "settled in the [worker's] aort[ic] valve" (Tr. 276 –

[387]See also a memorandum from Richard E. Fairfax, Director, Directorate of Enforcement Programs, and Steven Witt, Director, Directorate of Cooperative and State Programs, dated March 19, 2010, detailing OSHA's enforcement policy for flame-resistant clothing in oil and gas drilling, well servicing, and production-related operations http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=27296.

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280). Mr. Kolcio and Mr. Stillwagon recommended that OSHA require protection, in the form of shields on live-line tools, from injuries caused by flying debris resulting from electric arcs that occur when employees are using live-line tools (Tr. 268, 274 – 275). Mr. Kolcio also noted that the existence of IEEE and ASTM standards covering these shields, as well as various scientific papers, indicated the need for such protection (Tr. 265 – 267).

OSHA agrees with Messrs. Kolcio and Stillwagon that electric arcs pose hazards in addition to the thermal hazards addressed by the final rule. Dr. Mary Capelli-Schellpfeffer testified that electric arcs can result in "sprayed or blown hot or melting installation elements, moved by the mechanical forces in the electric arc event" (Tr. 187). Also, NFPA 70E-2004 warned that "[d]ue to the explosive effect of *some arc events*, physical trauma injuries could occur" (Ex. 0134; emphasis added).[388] OSHA expects that the hazard analysis required by paragraph (g)(1) in the final rule will identify nonthermal hazards, including physical trauma hazards posed by flying debris, associated with employee exposure to electric arcs. Although the final rule does not address these hazards, OSHA's existing general PPE requirements, for example, §§1910.132 and 1926.95, require employers to address them. Those standards require employers to provide shields and barriers necessary to protect employees from physical trauma hazards. However, as noted by NFPA 70E, not all arc events pose physical trauma hazards from flying debris; therefore, this protection will not always be necessary, and the Agency concludes that this final rule does not have to address these hazards further.

[388]NFPA 70E-2012 contains the same warning in Informational Note No. 1 to Section 130.7(A).

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Compliance deadlines for certain provisions in paragraph (g). The final rule includes a new paragraph (g)(6) setting a compliance deadline of January 1, 2015, for the requirement in paragraph (g)(2) that the employer make reasonable estimates of incident energy and a compliance deadline of April 1, 2015, for: (1) the requirement in paragraph (g)(4)(iv) that the employer ensure that the outer layer of clothing worn by an employee is flame-resistant when the estimated incident heat energy exceeds 2.0 cal/cm^2 and (2) the requirement in paragraph (g)(5) that the employer ensure that each employee exposed to hazards from electric arcs wears the necessary arc-rated protection. These deadlines are described more fully in Section XII, Dates, later in this preamble.

Fuse handling, covered conductors, non-current-carrying metal parts, and opening circuits under load. The remaining provisions in final §1926.960 deal with handling fuses, covered (noninsulated) conductors, non-current-carrying metal parts, and opening and closing circuits under load. To protect employees from contacting energized parts, paragraph (h) of final §1926.960 requires employers to ensure that employees installing and removing fuses use tools or gloves rated for the appropriate voltage if one or both terminals are energized at over 300 volts or if exposed parts are energized at more than 50 volts. When an expulsion fuse operates on a fault or overload, the arc from the fault current reacts with an agent in the tube. This reaction produces hot gas that blasts the arc through the fuse tube vent or vents, and with it any loose material in its path. The arc blast or particles blown by the blast could injure employees' eyes. Employers must ensure that employees do not install or remove such fuses using rubber insulating gloves alone. Therefore, final paragraph (h) also requires employees installing or removing expulsion-type fuses with one or both terminals energized at more than 300 volts to wear

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10. Costs Associated With Arc-Hazard Assessment

Paragraph (g)(1) of final §1926.960 requires the employer to assess employee workplace exposures to hazards from flames or from electric arcs. Paragraph (g)(2) of final §1926.960 requires the employer to make a reasonable estimate, for each exposed employee, of the incident heat energy associated with hazards from electric arcs. The FEA estimates the cost for both provisions simultaneously in this section because, as part of the effort to calculate incident energy, the employer necessarily must assess the hazards to employees. The FEA also uses the term "arc-hazard assessment" to refer to both requirements.

For the proposed rule, the PRIA used an approach based on the CONSAD report [5], calculating annual costs on a per-project and per-employee basis. Some commenters questioned this approach, which projected a cost of $2 per project. (See, for example, Exs. 0208, 0505.) OSHA modified the PRIA methodology for arc-hazard assessment and instead is calculating primarily one-time costs on a per-firm basis. OSHA modified the methodology because it is not necessary to recalculate the costs for each project; the Agency believes that, except with respect to power generation installations as discussed later, a system-wide calculation is a more logical outcome of the rule.[556]

OSHA also is not accounting for costs to contractors in the final rule (a second modification from the PRIA). The Agency believes that, as utilities will need to perform the calculations on their own systems either in-house or using engineering consultants,

[556]Since employers do not need to perform extensive recalculations of their systems annually, as assumed in the PRIA, the estimated annualized cost of this provision is substantially less than the estimated cost in the PRIA.

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utilities will provide information on potential heat energy to contractors, even though the final rule does not explicitly require utilities to do so. Otherwise, host employers would incur costs associated with those estimates twice, once when the host employer generates the estimate and a second time when the contractor passes the costs of generating the estimate back to the host employer.

As in the PRIA, OSHA estimates that 75 percent of small utilities and 85 percent of large utilities already performed the necessary calculations and will not incur costs under the rule. For the remaining utilities, which will have to estimate the available heat energy that would result from electric arcs, the approach will likely vary depending on the size of the utility. OSHA believes that small utilities would likely hire a consultant to perform the calculations for them, while large utilities would likely use commercially available software and perform the calculations in-house.

OSHA estimates that the 25 percent of small utilities that do not already perform the calculations will hire a consultant to provide estimates of incident-heat-energy exposures. OSHA estimates that it will take a consultant 28 hours to perform the calculations at a rate of $250 per hour, for an average cost of $7000 per affected utility and a total of approximately $1.2 million for all affected small utilities.[557] When OSHA annualized this cost at 7 percent over 10 years, it results in annualized costs for affected small utilities of approximately $0.03 million.

[557]While small utilities have the option of using the tables OSHA provides, this FEA conservatively assumed they will use the more expensive option of hiring consultants.

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Large utilities are more likely than small utilities to face situations not covered by the tables in Appendix E. These utilities can perform the calculations using several different methods. The proposed rule allowed employers to use Allen Privette's Heat Flux Calculator, a free software program widely available on the Internet, to perform the calculations. After considering comments from rulemaking participants, OSHA determined that the Heat Flux Calculator is not a reasonable method for estimating incident energy regardless of exposure or voltage. (See the discussion of final §1926.960(g)(2) in Section V, Summary and Explanation of the Final Rule, earlier in this preamble.) Many utilities already use a more reliable means of calculating incident heat energy, but some utilities will have to buy software to estimate incident heat energy. OSHA estimates that 15 percent of large utilities will need to purchase software, at a cost of approximately $2,500 per firm [7].

For the large utilities buying software, an engineer will have to input parameters into the software to determine the incident-heat energy that would result from electric arcs. These parameters include fault current, the expected length of the electric arc, the distance from the arc to the employee, and the clearing time for the fault. OSHA estimates that performing this task for all affected large-utility employees will require 500 engineering hours per affected firm, at the estimated hourly rate for an engineer of $47.17. This determination results in engineering costs of $25,970 per affected firm, and total engineering costs for all affected firms of $6.5 million. Consistent with the ratio of engineering time to clerical time used in the PRIA, these same firms will also incur clerical costs, equivalent to 25 hours of clerical time at a wage of $28.75 per hour, or $719 per utility. This determination results in total clerical costs for all affected firms of

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approximately $0.2 million. Summing software, engineering labor, and clerical labor costs for all affected large firms results in total costs of $6.7 million and annualized costs of $2.1 million.

TVA estimated that costs should be about $300 per employee (Ex. 0213). The PRIA estimated 2 hours of engineering time per employee and $2 per project.[558]

The Agency concluded that, because electric utilities will likely perform calculations on a per-circuit, rather than per-project or per-employee, basis and because the number of circuits operated by a utility is generally proportional to the size of that utility, the costs should be based on the number of hours the utility will take to perform the calculations as determined by the size of the utility. Consequently, the per-employee basis used by TVA and the per-employee and per-project basis used by the PRIA are generally unsuitable for estimating costs related to calculating incident energy.

However, TVA's description of the methodology it used in calculating incident energy suggests that TVA included costs associated with lowering incident energy at a nuclear power generation plant. As explained in the summary and explanation for final §1926.960(g)(5), in Section V, Summary and Explanation of the Final Rule, earlier in this preamble, OSHA believes that any such measures requiring substantial expenditures are likely to be necessary only for electric power generation installations. To account for the costs of adopting incident-energy-control measures for electric power generation

[558]OSHA believes that (with the exception of power generation facilities, as discussed later) it likely overestimated the cost of performing the calculations, particularly with respect to distribution installations. This belief is based in part on expert opinion provided to ERG, which suggested that the calculations would require substantially fewer hours than indicated by TVA [8].

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installations, OSHA included costs for reducing incident-energy exposures that, when combined with OSHA's estimated costs for calculating incident energy, correspond to TVA's estimate of $300 per employee for firms in industries with generation installations.

Thus, OSHA included costs in this FEA to account for additional engineering controls that employers with power generation installations might need to implement to reduce the incident energy of particular circuits to no more than 100 cal/cm^2 (the maximum level for which protective clothing and equipment are generally available). Such engineering controls might include installing current-limiting devices, resetting circuit breaker trip devices, and using remote control operating and test equipment.

To estimate the cost of these potential engineering controls, OSHA relied on the TVA estimate that the arc-hazard assessment will cost about $300 per employee. For each relevant industry affected by the need to implement these potential controls (the utilities in the Electric Power Generation industry (NAICS 221100), all Industrial Power Generators (Various NAICS), and Major Publicly-Owned Utilities (NAICS 2211) judged to operate power generation installations), TVA's total estimated costs for the arc-hazard assessment were higher than the costs estimated by OSHA for this assessment. OSHA attributed the difference in cost between the two estimates to the additional engineering controls that OSHA identified for the final rule. TVA stated in its comments to the proposed rule that TVA based its estimates "on all circuits" (including, presumably, circuits that require a reduction in incident energy using engineering controls) and that its estimates did not include the cost of purchasing arc-flash protective equipment (Ex. 0213).

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To account for the additional engineering control costs, OSHA increased the cost of the arc-hazard assessments (which include the cost for engineering controls) for utilities having power generation installations above what OSHA already estimated for the assessment so that the total averaged $300 per power worker employee, consistent with TVA's cost estimate. (For example, for a given industry, if the cost of the arc-hazard assessment, without the engineering controls adjustment, amounted to $150 per employee, OSHA increased the cost by $150 per employee to account for the adjustment.) OSHA also assumed that existing compliance rates associated with these engineering controls are identical to the compliance rates estimated for the unadjusted arc-hazard assessment (that is, the compliance rate estimated for the arc-hazard assessment without the addition of engineering controls).

To calculate the percentage of firms in the Major Publicly-Owned Utilities industry that operate generating plants (and thus power generation installations), OSHA first cross-referenced OSHA's estimate of 277 firms that are in the Major Publicly-Owned Utilities industry against the 2008 EIA Form 860 database, which provides a nationwide census of generating plants by owner [49]. This comparison showed that 106 of the firms that are in the Major Publicly-Owned Utilities industry and that are under the scope of the final rule own generating plants. OSHA then assumed that the distribution by size of this subset would mirror that of the entire Major Publicly-Owned Utilities population, resulting in an estimated 13 small firms and 93 large firms that are Major Publicly-Owned Utilities with generating facilities.

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As indicated in Table 39, the Agency estimates that the annualized one-time cost for these engineering controls is approximately $26,737 for small firms and $2,123,110 for large firms, for a total of $2,149,847 for all affected firms.

Summing software costs, engineering labor, clerical labor, consulting, and incident-energy reduction costs for both small and large firms results in total estimated costs for all affected firms of $10.6 million. When this one-time cost is annualized at a 7-percent interest rate over 10 years, the resulting annualized costs are approximately $1.5 million as shown in Table 39. Table 39 also shows the costs of compliance for each affected industry.

TVA asserted that the costs associated with arc-hazard assessments recur annually (Ex. 0213). TVA indicated that performing such a calculation, while time consuming initially, is not nearly as time consuming when performed on an ongoing basis. TVA suggested the ongoing cost would be only 3 percent of the initial cost (*id*.).

As explained later, the Agency took a more conservative approach by assuming annual ongoing costs of 10 percent of the initial cost. This approach includes an annual assessment to examine any changes in conditions and the costs of a potential recalculation of the system. (See Table 40.)

One commenter suggested that liability costs would rise due to consultants underestimating incident heat energy (Ex. 0178).

OSHA believes that this comment is speculative and without merit. Moreover, as a practical matter, the typical consultant would likely carry personal liability insurance and, therefore, factors this cost into his or her consulting fees (which the Agency is assuming will be $250 an hour, on average). Also, the commenter did not establish why

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these determinations present a new source of liability, as firms (whether consultants or utilities) that perform such calculations now are liable for any flawed estimates given to others.

Another commenter suggested that electrical contractors may find it especially demanding to comply with the arc-hazard assessment provision because of the difficulties involved in training a highly mobile workforce to understand a constantly changing variety of electrical systems and because of the difficulties resulting from contractors' working for a variety of utilities (Ex. 0501).

OSHA believes that the commenter's concerns are groundless. First, as stated earlier, the Agency accounted for any costs related to training and included in its calculations the costs specific to each affected industry. Second, as also stated earlier, the Agency expects that host employers will pass information related to potential heat-energy hazards to the contractors during the exchange of information between host employers and contract employers, as doing so is in their economic self-interest. As such, varying work situations and a mobile workforce should not pose major issues for contractors.[559]

[559]The commenter also stated that electrical contractors would incur a special burden in conjunction with the final rule's arc-flash protective equipment requirements. As discussed later, the Agency is costing eight pairs of flame-resistant clothing, which should be sufficient to cover the different situations contractors might face.

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Table 39—Annualized One-Time Costs Associated with Arc-Hazard Assessment

Small Firms							
Industry code	Industry name	Compliance rate (%)	Firms using consultant (% of Small)	Consulting hours per firm	Total consulting costs	Incident-energy reduction costs	Total annualized costs — small firms
NAICS 234910	Water, Sewer, and Pipeline Construction	NA	NA	NA	NA	NA	NA
NAICS 234920	Power and Communication Transmission Line Construction	NA	NA	NA	NA	NA	NA
NAICS 234930	Industrial Nonbuilding Structure Construction	NA	NA	NA	NA	NA	NA
NAICS 234990	All Other Heavy Construction	NA	NA	NA	NA	NA	NA
NAICS 235310	Electrical Contractors	NA	NA	NA	NA	NA	NA
NAICS 235910	Structural Steel Erection Contractors	NA	NA	NA	NA	NA	NA
NAICS 235950	Building Equipment and Other Machine Installation Contractors	NA	NA	NA	NA	NA	NA
NAICS 235990	All Other Special Trade Contractors	NA	NA	NA	NA	NA	NA
NAICS 221110	Electric Power Generation	75	25	28	$553,000	$25,461	$82,360
NAICS 221120	Electric Power Transmission, Control, and Distribution	75	25	28	$563,500	NA	$80,230
NAICS 2211	Major Publicly Owned Utilities	75	25	28	$57,750	$1,276	$8,404
Various	Industrial Power Generators	NA	NA	NA	NA	NA	$0
SIC 0783	Ornamental Shrub and Tree Services	NA	NA	NA	NA	NA	NA
Total					$1,174,250	$26,737	$170,994

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Table 39—Annualized One-Time Costs Associated with Arc-Hazard Assessment (Continued)

Large Firms

Industry code	Industry name	Compliance rate (%)	Firms purchasing software (% of Large)	Software cost per firm	Total software cost	Firms with engineering hours (% of large)	Engineering hours per firm	Total engineering costs	Clerical hours per firm	Total clerical costs	Incident-energy reduction costs	Total annualized costs — large firms
NAICS 234910	Water, Sewer, and Pipeline Construction	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAICS 234920	Power and Communication Transmission Line Construction	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAICS 234930	Industrial Nonbuilding Structure Construction	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAICS 234990	All Other Heavy Construction	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAICS 235310	Electrical Contractors	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAICS 235910	Structural Steel Erection Contractors	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAICS 235950	Building Equipment and Other Machine Installation Contractors	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAICS 235990	All Other Special Trade Contractors	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAICS 221110	Electric Power Generation	85	15	$2,500	$116,250	15	500	$1,207,532	25	$33,424	$1,388,374	$390,909
NAICS 221120	Electric Power Transmission, Control, and Distribution	85	15	$2,500	$341,250	15	500	$3,544,692	25	$98,115	NA	$567,240
NAICS 2211	Major Publicly Owned Utilities	85	15	$2,500	$91,500	15	500	$950,445	25	$26,308	$82,382	$163,825
Various	Industrial Power Generators	85	15	$2,500	$73,875	15	500	$767,367	25	$21,240	$652,353	$215,679
SIC 0783	Ornamental Shrub and Tree Services	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total					$622,875			$6,470,036		$179,088	$2,123,110	$1,337,652

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Table 39—Annualized One-Time Costs Associated with Arc-Hazard Assessment (Continued)

All Firms		
Industry code	Industry name	Total annualized costs — all firms
NAICS 234910	Water, Sewer, and Pipeline Construction	NA
NAICS 234920	Power and Communication Transmission Line Construction	NA
NAICS 234930	Industrial Nonbuilding Structure Construction	NA
NAICS 234990	All Other Heavy Construction	NA
NAICS 235310	Electrical Contractors	NA
NAICS 235910	Structural Steel Erection Contractors	NA
NAICS 235950	Building Equipment and Other Machine Installation Contractors	NA
NAICS 235990	All Other Special Trade Contractors	NA
NAICS 221110	Electric Power Generation	$473,269
NAICS 221120	Electric Power Transmission, Control, and Distribution	$647,470
NAICS 2211	Major Publicly Owned Utilities	$172,228
Various	Industrial Power Generators	$215,679
SIC 0783	Ornamental Shrub and Tree Services	NA
Total		$1,508,646

Notes: (1) Totals may not equal the sum of the components due to rounding.

(2) "NA" = Not Applicable.

(3) All Industrial Power Generators are large establishments.

Sources: ERG estimates, Cress [7], U.S. Census [43, 44, 45, 46].

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OSHA also accounted for the periodic costs associated with updating arc-hazard assessments, as necessary. As explained in discussion of final §1926.960(g)(2) in Section V, Summary and Explanation of the Final Rule, earlier in this preamble, while commenters' concerns that employers would need to constantly update their incident-energy estimates are baseless, periodic updates may be necessary under certain limited circumstances. As mentioned earlier, OSHA estimates that this periodic labor cost is equal to 10 percent of the total one-time consulting, engineering, and clerical costs indicated in Table 39. When OSHA annualized the present value of this recurring labor cost[560] at 7 percent over 10 years, total annualized costs for all affected industries are $0.7 million. When OSHA included these periodic costs with the one-time arc-hazard assessment costs calculated earlier, total annualized arc-hazard assessment costs are approximately $2.2 million, as shown in Table 40.

[560]OSHA computed the present value for 9 years of costs, beginning with the year after the arc-hazard assessment provision goes into effect and lasting through year 10.

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Table 40—Total Annualized Costs Associated with Arc-Hazard Assessment

Industry code	Industry name	Annual labor costs (years 2 - 10)	Present value of labor costs (years 2 - 10)	Total annualized updating cost	Total annualized arc-hazard assessment costs
NAICS 234910	Water, Sewer, and Pipeline Construction	NA	NA	NA	NA
NAICS 234920	Power and Communication Transmission Line Construction	NA	NA	NA	NA
NAICS 234930	Industrial Nonbuilding Structure Construction	NA	NA	NA	NA
NAICS 234990	All Other Heavy Construction	NA	NA	NA	NA
NAICS 235310	Electrical Contractors	NA	NA	NA	NA
NAICS 235910	Structural Steel Erection Contractors	NA	NA	NA	NA
NAICS 235950	Building Equipment and Other Machine Installation Contractors	NA	NA	NA	NA
NAICS 235990	All Other Special Trade Contractors	NA	NA	NA	NA
NAICS 221110	Electric Power Generation	$179,396	$1,092,340	$155,525	$628,793
NAICS 221120	Electric Power Transmission, Control, and Distribution	$420,631	$2,561,221	$364,660	$1,012,130
NAICS 2211	Major Publicly Owned Utilities	$103,450	$629,909	$89,685	$261,913
Various	Industrial Power Generators	$78,861	$480,183	$68,367	$284,046
SIC 0783	Ornamental Shrub and Tree Services	NA	NA	NA	NA
Total		$782,337	$4,763,654	$678,237	$2,186,883

Notes: (1) Totals may not equal the sum of the components due to rounding.
(2) "NA" = Not Applicable.
Source: ERG estimate.

11. Costs for Providing Arc-Flash Protective Equipment

The final rule requires affected employers to ensure that employees exposed to certain hazards wear flame-resistant clothing. The final rule also requires employers to ensure that each employee exposed to electric-arc hazards wears clothing with an arc rating greater than or equal to the applicable estimate of incident heat energy. Generally, the arc-rated clothing must cover the employee's entire body, although there are limited situations in which the final rule does not require arc-rated protection for the employee's hands, feet, or head. As previously mentioned in this analysis, OSHA uses the term

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"flame-resistant clothing" to refer generally to the flame-resistant and arc-rated clothing, and the term "arc-flash protective equipment" to refer to the flame-resistant and arc-rated clothing and equipment, required by §1926.960(g).

OSHA estimated the average costs associated with providing the clothing that will be necessary to achieve full compliance with the final rule to involve resources equivalent to those associated with the following case example. An employer could generally achieve compliance with the final rule's clothing provisions by purchasing eight sets of flame-resistant clothing per employee and one switching coat or flash suit for every three employees.

OSHA estimated a single set of flame-resistant clothing to cost $191.75 [13]; and, with eight sets provided for each employee (at a total cost of $1,534.00 per employee), the Agency assumed that the useful life of this apparel was 4 years [5]. OSHA estimated a switching coat or flash suit to cost about $226.00 [19] and to have an expected life of 10 years [5]. Because use of the switching coat or flash suit will be intermittent, OSHA estimated that employers will need to provide only one switching coat or flash suit for every three affected employees [5].

Frank Brockman of the Farmers Rural Electric Cooperative Corporation commented on the costs of flame-resistant apparel (Ex. 0173). Mr. Brockman estimated that the cost of flame-resistant clothing would be in excess of $1,000 per employee.

OSHA notes that the cost estimate used in this FEA ($1,534.00 per employee for flame-resistant clothing exclusive of switching coats) is consistent with Mr. Brockman's estimate.

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Employers generally will substitute flame-resistant clothing for clothing that the employee or the employer would already be providing. OSHA did not include in this analysis the savings associated with employees' no longer needing to purchase and launder the clothing that employees would otherwise wear.

The final rule does not require employers to launder protective clothing for employees. To the extent that employers choose to begin laundering clothing or provide laundering services for employees in conjunction with providing flame-resistant clothing, the cost is not attributable to this final rule; and OSHA regards any such costs as transfers from employers to employees rather than additional costs to society.

Based on research conducted by CONSAD, OSHA estimates that most establishments in all affected industries already provide employees with flame-resistant clothing that fully complies with the requirements of the final rule [5]. These establishments, therefore, will incur no additional costs to achieve compliance with the final rule's requirements for flame-resistant clothing.

For each affected industry, OSHA estimated rates of current compliance with the final requirements to provide arc-rated clothing. Within each industry, the Agency estimated rates of current compliance separately for establishments based on their size. Among construction contractors, the estimated average rate of current compliance for establishments with fewer than 20 employees is 50 percent. The average rate of current compliance among construction-contractor establishments with 20 or more employees is an estimated 75 percent. Among electric utilities and other electric power generators, current compliance is an estimated 80 percent for establishments with fewer than 20 employees and 90 percent for establishments with 20 or more employees [5].

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In his comments, Frank Brockman of the Farmers Rural Electric Cooperatives Corporation estimated that the flame-resistant clothing provision of the rule would affect 25 percent of the relevant workforce, for an implied compliance rate of 75 percent (Ex. 0173). This estimate is similar to the compliance estimates developed by CONSAD [5], which range from 50 percent to 90 percent depending on the industry and establishment size, for an industry-wide average of 78-percent compliance.

The total estimated annualized cost of compliance for providing flame-resistant clothing is approximately $15.6 million, as shown in Table 41. The total estimated annualized cost of compliance for providing switching coats or flash suits is approximately $0.4 million as shown in Table 42. Table 41 and Table 42 also show the costs of compliance for each affected industry. Together, the total estimated annualized cost of providing flame-resistant apparel and switching coats is approximately $16.0 million.

In addition to clothing and switching coats or flash suits, the final rule requires the provision of face and head protection for workers in certain circumstances, typically when the workers perform energized work on equipment in enclosures and when work involves exposures to three-phase arcs. OSHA did not estimate costs in connection with face and head protection for the PRIA. To estimate the number of affected Electrical Power-Line Installers and Repairers (SOC 49-9051) for the final rule, OSHA calculated the number of line installers and repairers (that is, 51,440) as a percentage of total employment in NAICS 221100 – Electric Power Generation, Transmission and Distribution (that is, 395,570) [39, 40], and assumed that this percentage (that is, 13 percent) was similar across all affected NAICS. OSHA believes that none of these

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workers currently use arc-rated face and head protection. To estimate the number of affected Electrical and Electronics Repairers working in generating stations, substations, and in-service relays (SOC 49-2095), OSHA calculated the number of Electrical and Electronics Repairers (that is, 17,240) as a percentage of total employment in NAICS 221100 – Electric Power Generation, Transmission and Distribution (that is, 395,570) [40, 41] and assumed that this percentage (that is, 4 percent) was similar across all affected NAICSs. OSHA believes that the use of arc-rated face and head protection is fairly common by these workers and estimates current compliance among the affected industry groups to range from 50 to 90 percent (equivalent to the compliance rates for flame-resistant clothing (Table 41) and switching coats or flash suits (Table 42).

Based on publicly available information from vendors of electrical protective equipment, OSHA estimates that a faceshield costs $86.50 (with a useful life of 2 years), and that head protection such as a balaclava costs $29.75 (with a useful life of 2 years) [11, 12]. Testimony suggesting that faceshields might run $60 and that balaclava might run $30 corroborates these cost estimates (Tr. 479).

When OSHA annualized the costs of arc-rated face and head protection at a 7-percent interest rate over the useful life of the equipment, the resulting total estimated costs are approximately $0.9 million for faceshields and $0.3 million for head protection, as shown in Table 43 and Table 44, and Table 45 and Table 46, respectively. These tables also show the costs of compliance for each affected industry.

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Summing the costs for flame-resistant clothing, switching coats or flash suits, faceshields, and head protection results in total estimated annualized costs of approximately $17.2 million.[561]

Using Mr. Brockman's (Ex. 0173) approach to calculating costs for flame-resistant clothing, along with OSHA's estimate of the number of affected workers, results in a "Brockman" estimate of $48.9 million.[562] However, Mr. Brockman did not annualize his estimated costs. Doing so using an interest rate of 7 percent over the 4-year expected life of flame-resistant clothing[563] results in an annualized cost estimate of $14.4 million. OSHA notes that this estimate is less than both OSHA's estimate of annualized costs for flame-resistant clothing alone $15.6 million) and OSHA's estimate of annualized costs for all arc-flash protective equipment ($17.3 million). As such, OSHA's estimate is entirely reasonable.

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[561]While the final rule added some minor cost elements to the costs estimated in the proposal, the higher estimated cost of protective clothing in the FEA, relative to the PRIA, is due primarily to the higher estimated unit cost for the eight pairs of flame-resistant clothing.

[562]In his comments, Mr. Brockman calculated costs for workers in all affected establishments. This approach was erroneous, however, because the protective-clothing provisions of the final rule do not cover employees in the Ornamental Shrub and Tree Services industry. OSHA excluded the tree-care employees from Mr. Brockman's calculation to arrive at a corrected estimate, using Mr. Brockman's analysis, of $48.9 million.

[563]Mr. Brockman apparently estimated a cost for flame-resistant clothing only, but not other equipment such as switching coats or flash suits, as Mr. Brockman's estimate referred only to OSHA's proposed 4-year useful-life estimate for flame-resistant clothing, not OSHA's proposed 10-year useful-life estimate for switching coats or flash suits (Ex. 0173; 70 FR 34915 – 34916).

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One commenter emphasized that workers typically wear multiple layers of clothing and complained that the proposal would require additional costs for the various layers of clothing (Ex. 0186).

The final rule clarifies that only the outer layer of clothing must be flame-resistant.

Another commenter suggested the cost analysis should account for "selecting and fitting" of apparel (Ex. 0240).

The commenter's use of the terms "selecting and fitting" here is somewhat ambiguous; in any event, the Agency already accounted for the key informational element in selecting and fitting apparel—the arc-hazard assessment. OSHA believes that once employers perform this assessment, any other elements of selecting and fitting clothing (such as selecting brand or vendor or size) is a negligible part of the overall cost.

Some commenters argued that flame-resistant clothing required special laundering and that this would be an additional cost. (See, for example, Ex. 0186.)

OSHA concludes that there is no additional cost associated with laundering the flame-resistant clothing required by the final rule. First, as stated, the final rule does not require employers to launder protective clothing for employees; and, therefore, while employers may choose to launder protective clothing for their employees, the rule does not impose the cost of laundering on employers. Second, according to the record, employers or their employees can generally follow the manufacturers' care instructions that come with the clothing (Tr. 305 – 306, 1373 – 1374), and there is generally no additional cost to employees over that of laundering normal (that is, non-flame-resistant) clothing. Even if employees needed some training on how to care for flame-resistant

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clothing to ensure that the clothing does not lose its flame-resistant properties (as some commenters argued (Ex. 0186)), the training provisions of the final rule (costed previously in this analysis) would cover this cost (that is, the Agency assumes all employers will give their employees the requisite training to come into compliance with the standard).

One commenter argued that the life of flame-resistant clothing was less than the 4-year period used by OSHA in its calculations (Ex. 0173). A witness at the 2006 public hearing testified that the life of flame-resistant clothing varied considerably and might well last more than 4 years; this witness spoke of the enhanced durability of newer flame-resistant materials that were emerging at the time of the hearing (Tr. 1374). (See, also, Tr. 1192.) One commenter believed that OSHA should assume that employees require a slightly larger number of sets of clothing (Ex. 0186). Other commenters stated that less clothing would be adequate (Ex. 0099; Tr. 387, 828, 1374). Another commenter mentioned a possible range of 5 to 14 sets (Tr. 309).[564] Other commenters stated that the estimate does not take into account all types of clothing required, such as winter wear (see, for example, Ex. 0173).

OSHA notes that its estimate of eight sets is in the middle of the number of sets recommended by the commenters. Moreover, as indicated in the PRIA, OSHA significantly increased its initial estimate of clothing costs in response to comments from

[564]OSHA examined the effect of changing the costs for flame-resistant clothing using either end of this range—the costs range from $9.8 million for 5 sets to $27.3 million for 14 sets (with OSHA's estimate of $15.6 million for 8 sets between the two ends). As discussed under the heading "Economic Feasibility and Impacts," later in this section of the preamble, costs must increase substantially beyond this range to raise an issue regarding economic feasibility.

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SERs during the SBREFA Panel process. For the FEA, the Agency is basing its estimates on a cost of $1,534.00 per employee for eight sets of flame-resistant clothing (using the estimated cost of $191.75 per set), or on an annualized cost of approximately $452.88 per employee. The Agency believes this final estimate is reasonable and captures the *average cost* of all flame-resistant clothing required by the new provisions of the final standard. In this regard, the record indicates that annual employee stipends to cover all flame-resistant clothing typically run $125 – 250 (Tr. 828). This evidence supports the conclusion that OSHA's estimate is reasonable, if not conservative.

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Table 41—Annualized Costs Associated with Providing Flame-Resistant Clothing

Industry code	Industry name	Employees affected (%)	Compliance rates (%)	Sets of FRC provided per employee	Cost per set of FRC	Useful life of FRC with 8 sets/ employee (years)	Annualized compliance costs
NAICS 234910	Water, Sewer, and Pipeline Construction	100	50/50/75/75	8	$191.75	4	$176,836
NAICS 234920	Power and Communication Transmission Line Construction	100	50/50/75/75	8	$191.75	4	$4,623,876
NAICS 234930	Industrial Nonbuilding Structure Construction	100	50/50/75/75	8	$191.75	4	$211,993
NAICS 234990	All Other Heavy Construction	100	50/50/75/75	8	$191.75	4	$1,115,554
NAICS 235310	Electrical Contractors	100	50/50/75/75	8	$191.75	4	$3,388,729
NAICS 235910	Structural Steel Erection Contractors	100	50/50/75/75	8	$191.75	4	$57,243
NAICS 235950	Building Equipment and Other Machine Installation Contractors	100	50/50/75/75	8	$191.75	4	$53,637
NAICS 235990	All Other Special Trade Contractors	100	50/50/75/75	8	$191.75	4	$170,375
NAICS 221110	Electric Power Generation	100	80/80/90/90	8	$191.75	4	$1,719,508
NAICS 221120	Electric Power Transmission, Control, and Distribution	100	80/80/90/90	8	$191.75	4	$2,923,654
NAICS 2211	Major Publicly Owned Utilities	100	80/90	8	$191.75	4	$392,232
Various	Industrial Power Generators	100	90	8	$191.75	4	$786,729
SIC 0783	Ornamental Shrub and Tree Services	NA	NA	NA	NA	NA	NA
Total							$15,620,365

Notes: (1) Totals may not equal the sum of the components due to rounding.

(2) "NA" = Not Applicable.

(3) For most NAICSs, compliance rates are for small unionized establishments, small nonunionized establishments, large unionized establishments, and large nonunionized establishments, respectively. Major Publicly Owned Utilities (NAICS 2211) and Ornamental Shrub and Tree Services (SIC 0783) only have compliance rates for small and large establishments, and Industrial Power Generators only have a compliance rate for large establishments.

Sources: CONSAD [5], Grainger [13], U.S. Census [43, 44, 45, 46].

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Table 42—Annualized Costs Associated with Providing Switching Coats or Flash Suits

Industry code	Industry name	Employees affected (%)	Compliance rates (%)	Switching coat or flash suit per employee	Cost per switching coat or flash suit	Useful life of switching coat or flash suit (years)	Annualized compliance costs
NAICS 234910	Water, Sewer, and Pipeline Construction	100	50/50/75/75	0.33	$226.00	10	$4,146
NAICS 234920	Power and Communication Transmission Line Construction	100	50/50/75/75	0.33	$226.00	10	$108,414
NAICS 234930	Industrial Nonbuilding Structure Construction	100	50/50/75/75	0.33	$226.00	10	$4,971
NAICS 234990	All Other Heavy Construction	100	50/50/75/75	0.33	$226.00	10	$26,156
NAICS 235310	Electrical Contractors	100	50/50/75/75	0.33	$226.00	10	$79,454
NAICS 235910	Structural Steel Erection Contractors	100	50/50/75/75	0.33	$226.00	10	$1,342
NAICS 235950	Building Equipment and Other Machine Installation Contractors	100	50/50/75/75	0.33	$226.00	10	$1,258
NAICS 235990	All Other Special Trade Contractors	100	50/50/75/75	0.33	$226.00	10	$3,995
NAICS 221110	Electric Power Generation	100	80/80/90/90	0.33	$226.00	10	$40,317
NAICS 221120	Electric Power Transmission, Control, and Distribution	100	80/80/90/90	0.33	$226.00	10	$68,550
NAICS 2211	Major Publicly Owned Utilities	100	80/90	0.33	$226.00	10	$9,197
Various	Industrial Power Generators	100	90	0.33	$226.00	10	$18,446
SIC 0783	Ornamental Shrub and Tree Services	NA	NA	NA	NA	NA	NA
Total							$366,245

Notes: (1) Totals may not equal the sum of the components due to rounding.

(2) "NA"=Not Applicable.

(3) For most NAICSs, compliance rates are for small unionized establishments, small nonunionized establishments, large unionized establishments, and large nonunionized establishments, respectively. Major Publicly Owned Utilities (NAICS 2211) and Ornamental Shrub and Tree Services (SIC 0783) only have compliance rates for small and large establishments, and Industrial Power Generators only have a compliance rate for large establishments.

Sources: CONSAD [5], Lab Safety Supply [18], U.S. Census [43, 44, 45, 46].

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Table 43—Annualized Costs Associated with Providing Arc-Rated Faceshield for Electrical Power-Line Installers and Repairers

Industry code	Industry name	Employees affected (%)	Cost per faceshield	Useful life of faceshield (years)	Compliance rate (%)	Annualized compliance costs
NAICS 234910	Water, Sewer, and Pipeline Construction	0	NA	2	NA	NA
NAICS 234920	Power and Communication Transmission Line Construction	13	$86.50	2	0/0/0/0	$216,130
NAICS 234930	Industrial Nonbuilding Structure Construction	0	NA	NA	NA	NA
NAICS 234990	All Other Heavy Construction	0	NA	NA	NA	NA
NAICS 235310	Electrical Contractors	0	NA	NA	NA	NA
NAICS 235910	Structural Steel Erection Contractors	0	NA	NA	NA	NA
NAICS 235950	Building Equipment and Other Machine Installation Contractors	0	NA	NA	NA	NA
NAICS 235990	All Other Special Trade Contractors	0	NA	NA	NA	NA
NAICS 221110	Electric Power Generation	13	$86.50	2	0/0/0/0	$233,674
NAICS 221120	Electric Power Transmission, Control, and Distribution	13	$86.50	2	0/0/0/0	$399,296
NAICS 2211	Major Publicly Owned Utilities	13	$86.50	2	0/0	$53,391
Various	Industrial Power Generators	0	NA	NA	NA	NA
SIC 0783	Ornamental Shrub and Tree Services	0	NA	NA	NA	NA
Total						$902,492

Notes: (1) Totals may not equal the sum of the components due to rounding.

(2) "NA" = Not Applicable.

(3) For most NAICSs, compliance rates are for small unionized establishments, small nonunionized establishments, large unionized establishments, and large nonunionized establishments, respectively. Major Publicly Owned Utilities (NAICS 2211) and Ornamental Shrub and Tree Services (SIC 0783) only have compliance rates for small and large establishments, and Industrial Power Generators only have a compliance rate for large establishments.

Sources: BLS [39, 40], Grainger [11], U.S. Census [43, 44, 45, 46].

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Table 44—Annualized Costs Associated with Providing Arc-Rated Faceshield for Electrical and Electronics Repairers Working in Generating Stations, Substations, and in-Service Relays

Industry code	Industry name	Employees affected (%)	Cost per faceshield	Useful life of faceshield (years)	Compliance rate (%)	Annualized compliance costs
NAICS 234910	Water, Sewer, and Pipeline Construction	0	NA	NA	NA	NA
NAICS 234920	Power and Communication Transmission Line Construction	4	$86.50	2	50/50/75/75	$21,289
NAICS 234930	Industrial Nonbuilding Structure Construction	0	NA	NA	NA	NA
NAICS 234990	All Other Heavy Construction	0	NA	NA	NA	NA
NAICS 235310	Electrical Contractors	0	NA	NA	NA	NA
NAICS 235910	Structural Steel Erection Contractors	0	NA	NA	NA	NA
NAICS 235950	Building Equipment and Other Machine Installation Contractors	0	NA	NA	NA	NA
NAICS 235990	All Other Special Trade Contractors	0	NA	NA	NA	NA
NAICS 221110	Electric Power Generation	4	$86.50	2	80/80/90/90	$7,917
NAICS 221120	Electric Power Transmission, Control, and Distribution	4	$86.50	2	80/80/90/90	$13,461
NAICS 2211	Major Publicly Owned Utilities	4	$86.50	2	80/90	$1,806
Various	Industrial Power Generators	0	NA	NA	NA	NA
SIC 0783	Ornamental Shrub and Tree Services	0	NA	NA	NA	NA
Total						$44,472

Notes: (1) Totals may not equal the sum of the components due to rounding.

(2) "NA" = Not Applicable.

(3) For most NAICSs, compliance rates are for small unionized establishments, small nonunionized establishments, large unionized establishments, and large nonunionized establishments, respectively. Major Publicly Owned Utilities (NAICS 2211) and Ornamental Shrub and Tree Services (SIC 0783) only have compliance rates for small and large establishments, and Industrial Power Generators only have a compliance rate for large establishments.

Sources: BLS [40, 41], Grainger [11], U.S. Census [43, 44, 45, 46].

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Table 45—Annualized Costs Associated with Providing Arc-Rated Head Protection for Electrical Power-Line Installers and Repairers

Industry code	Industry name	Employees affected (%)	Cost per balaclava	Useful life of balaclava (years)	Compliance rate (%)	Annualized compliance costs
NAICS 234910	Water, Sewer, and Pipeline Construction	0	NA	NA	NA	NA
NAICS 234920	Power and Communication Transmission Line Construction	13	$29.75	2	0/0/0/0	$74,334
NAICS 234930	Industrial Nonbuilding Structure Construction	0	NA	NA	NA	NA
NAICS 234990	All Other Heavy Construction	0	NA	NA	NA	NA
NAICS 235310	Electrical Contractors	0	NA	NA	NA	NA
NAICS 235910	Structural Steel Erection Contractors	0	NA	NA	NA	NA
NAICS 235950	Building Equipment and Other Machine Installation Contractors	0	NA	NA	NA	NA
NAICS 235990	All Other Special Trade Contractors	0	NA	NA	NA	NA
NAICS 221110	Electric Power Generation	13	$29.75	2	0/0/0/0	$80,368
NAICS 221120	Electric Power Transmission, Control, and Distribution	13	$29.75	2	0/0/0/0	$137,330
NAICS 2211	Major Publicly Owned Utilities	13	$29.75	2	0/0	$18,363
Various	Industrial Power Generators	0	NA	NA	NA	NA
SIC 0783	Ornamental Shrub and Tree Services	0	NA	NA	NA	NA
Total						$310,395

Notes: (1) Totals may not equal the sum of the components due to rounding.

(2) "NA" = Not Applicable.

(3) For most NAICSs, compliance rates are for small unionized establishments, small nonunionized establishments, large unionized establishments, and large nonunionized establishments. respectively. Major Publicly Owned Utilities (NAICS 2211) and Ornamental Shrub and Tree Services (SIC 0783) only have compliance rates for small and large establishments, and Industrial Power Generators only have a compliance rate for large establishments.

Sources: BLS [39, 40], Grainger [12], U.S. Census [43, 44, 45, 46].

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Table 46—Annualized Associated with Providing Arc-Rated Head Protection for Electrical and Electronics Repairers Working in Generating Stations, Substations, and in-Service Relays

Industry code	Industry name	Employees affected (%)	Cost per balaclava	Useful life of balaclava (years)	Compliance rate (%)	Annualized compliance costs
NAICS 234910	Water, Sewer, and Pipeline Construction	0	NA	NA	NA	NA
NAICS 234920	Power and Communication Transmission Line Construction	4	$29.75	2	50/50/75/75	$7,322
NAICS 234930	Industrial Nonbuilding Structure Construction	0	NA	NA	NA	NA
NAICS 234990	All Other Heavy Construction	0	NA	NA	NA	NA
NAICS 235310	Electrical Contractors	0	NA	NA	NA	NA
NAICS 235910	Structural Steel Erection Contractors	0	NA	NA	NA	NA
NAICS 235950	Building Equipment and Other Machine Installation Contractors	0	NA	NA	NA	NA
NAICS 235990	All Other Special Trade Contractors	0	NA	NA	NA	NA
NAICS 221110	Electric Power Generation	4	$29.75	2	80/80/90/90	$2,723
NAICS 221120	Electric Power Transmission, Control, and Distribution	4	$29.75	2	80/80/90/90	$4,630
NAICS 2211	Major Publicly Owned Utilities	4	$29.75	2	80/90	$621
Various	Industrial Power Generators	0	NA	NA	NA	NA
SIC 0783	Ornamental Shrub and Tree Services	0	NA	NA	NA	NA
Total						$15,295

Notes: (1) Totals may not equal the sum of the components due to rounding.

(2) "NA" = Not Applicable.

(3) For most NAICSs, compliance rates are for small unionized establishments, small nonunionized establishments, large unionized establishments, and large nonunionized establishments, respectively. Major Publicly Owned Utilities (NAICS 2211) and Ornamental Shrub and Tree Services (SIC 0783) only have compliance rates for small and large establishments, and Industrial Power Generators only have a compliance rate for large establishments.

Sources: BLS [40, 41], Grainger [12], U.S. Census [43, 44, 45, 46].

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(3) *Loose conductors*. When lines or equipment are connected to or disconnected from energized circuits, an employee shall keep loose conductors away from exposed energized parts.

(f) *Conductive articles*. When an employee performs work within reaching distance of exposed energized parts of equipment, the employer shall ensure that the employee removes or renders nonconductive all exposed conductive articles, such as keychains or watch chains, rings, or wrist watches or bands, unless such articles do not increase the hazards associated with contact with the energized parts.

(g) *Protection from flames and electric arcs*. (1) *Hazard assessment*. The employer shall assess the workplace to identify employees exposed to hazards from flames or from electric arcs.

(2) *Estimate of available heat energy*. For each employee exposed to hazards from electric arcs, the employer shall make a reasonable estimate of the incident heat energy to which the employee would be exposed.

> **Note 1 to paragraph (g)(2):** Appendix E to this subpart provides guidance on estimating available heat energy. The Occupational Safety and Health Administration will deem employers following the guidance in Appendix E to this subpart to be in compliance with paragraph (g)(2) of this section. An employer may choose a method of calculating incident heat energy not included in Appendix E to this subpart if the chosen method reasonably predicts the incident energy to which the employee would be exposed.
>
> **Note 2 to paragraph (g)(2):** This paragraph does not require the employer to estimate the incident heat energy exposure for every job task performed by each employee. The employer may make broad estimates that cover multiple system areas provided the employer uses reasonable assumptions about the energy-exposure distribution throughout the system and provided the estimates represent the maximum employee exposure for those areas. For example, the employer could estimate the heat energy just outside a substation feeding a radial distribution system and use that estimate for all jobs performed on that radial system.

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(3) *Prohibited clothing*. The employer shall ensure that each employee who is exposed to hazards from flames or electric arcs does not wear clothing that could melt onto his or her skin or that could ignite and continue to burn when exposed to flames or the heat energy estimated under paragraph (g)(2) of this section.

> **Note to paragraph (g)(3):** This paragraph prohibits clothing made from acetate, nylon, polyester, rayon and polypropylene, either alone or in blends, unless the employer demonstrates that the fabric has been treated to withstand the conditions that may be encountered by the employee or that the employee wears the clothing in such a manner as to eliminate the hazard involved.

(4) *Flame-resistant clothing*. The employer shall ensure that the outer layer of clothing worn by an employee, except for clothing not required to be arc rated under paragraphs (g)(5)(i) through (g)(5)(v) of this section, is flame resistant under any of the following conditions:

(i) The employee is exposed to contact with energized circuit parts operating at more than 600 volts,

(ii) An electric arc could ignite flammable material in the work area that, in turn, could ignite the employee's clothing,

(iii) Molten metal or electric arcs from faulted conductors in the work area could ignite the employee's clothing, or

> **Note to paragraph (g)(4)(iii):** This paragraph does not apply to conductors that are capable of carrying, without failure, the maximum available fault current for the time the circuit protective devices take to interrupt the fault.

(iv) The incident heat energy estimated under paragraph (g)(2) of this section exceeds 2.0 cal/cm^2.

(5) *Arc rating*. The employer shall ensure that each employee exposed to hazards from electric arcs wears protective clothing and other protective equipment with an arc rating greater than or equal to the heat energy estimated under paragraph (g)(2) of this

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section whenever that estimate exceeds 2.0 cal/cm^2. This protective equipment shall cover the employee's entire body, except as follows:

(i) Arc-rated protection is not necessary for the employee's hands when the employee is wearing rubber insulating gloves with protectors or, if the estimated incident energy is no more than 14 cal/cm^2, heavy-duty leather work gloves with a weight of at least 407 gm/m^2 (12 oz/yd^2),

(ii) Arc-rated protection is not necessary for the employee's feet when the employee is wearing heavy-duty work shoes or boots,

(iii) Arc-rated protection is not necessary for the employee's head when the employee is wearing head protection meeting §1926.100(b)(2) if the estimated incident energy is less than 9 cal/cm^2 for exposures involving single-phase arcs in open air or 5 cal/cm^2 for other exposures,

(iv) The protection for the employee's head may consist of head protection meeting §1926.100(b)(2) and a faceshield with a minimum arc rating of 8 cal/cm^2 if the estimated incident-energy exposure is less than 13 cal/cm^2 for exposures involving single-phase arcs in open air or 9 cal/cm^2 for other exposures, and

(v) For exposures involving single-phase arcs in open air, the arc rating for the employee's head and face protection may be 4 cal/cm^2 less than the estimated incident energy.

Note to paragraph (g): See Appendix E to this subpart for further information on the selection of appropriate protection.

(6) *Dates*. (i) The obligation in paragraph (g)(2) of this section for the employer to make reasonable estimates of incident energy commences January 1, 2015.

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(ii) The obligation in paragraph (g)(4)(iv) of this section for the employer to ensure that the outer layer of clothing worn by an employee is flame-resistant when the estimated incident heat energy exceeds 2.0 cal/cm^2 commences April 1, 2015.

(iii) The obligation in paragraph (g)(5) of this section for the employer to ensure that each employee exposed to hazards from electric arcs wears the required arc-rated protective equipment commences April 1, 2015.

(h) *Fuse handling*. When an employee must install or remove fuses with one or both terminals energized at more than 300 volts, or with exposed parts energized at more than 50 volts, the employer shall ensure that the employee uses tools or gloves rated for the voltage. When an employee installs or removes expulsion-type fuses with one or both terminals energized at more than 300 volts, the employer shall ensure that the employee wears eye protection meeting the requirements of Subpart E of this part, uses a tool rated for the voltage, and is clear of the exhaust path of the fuse barrel.

(i) *Covered (noninsulated) conductors*. The requirements of this section that pertain to the hazards of exposed live parts also apply when an employee performs work in proximity to covered (noninsulated) wires.

(j) *Non-current-carrying metal parts*. Non-current-carrying metal parts of equipment or devices, such as transformer cases and circuit-breaker housings, shall be treated as energized at the highest voltage to which these parts are exposed, unless the employer inspects the installation and determines that these parts are grounded before employees begin performing the work.

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(k) *Opening and closing circuits under load*. (1) The employer shall ensure that devices used by employees to open circuits under load conditions are designed to interrupt the current involved.

(2) The employer shall ensure that devices used by employees to close circuits under load conditions are designed to safely carry the current involved.

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Appendix E to Subpart V of Part 1926—Protection from Flames and Electric Arcs

I. Introduction.

Paragraph (g) of §1926.960 addresses protecting employees from flames and electric arcs. This paragraph requires employers to: (1) assess the workplace for flame and electric-arc hazards (paragraph (g)(1)); (2) estimate the available heat energy from electric arcs to which employees would be exposed (paragraph (g)(2)); (3) ensure that employees wear clothing that will not melt, or ignite and continue to burn, when exposed to flames or the estimated heat energy (paragraph (g)(3)); and (4) ensure that employees wear flame-resistant clothing[1] and protective clothing and other protective equipment that has an arc rating greater than or equal to the available heat energy under certain conditions (paragraphs (g)(4) and (g)(5)). This appendix contains information to help employers estimate available heat energy as required by §1926.960(g)(2), select protective clothing and other protective equipment with an arc rating suitable for the available heat energy as required by §1926.960(g)(5), and ensure that employees do not wear flammable clothing that could lead to burn injury as addressed by §§1926.960(g)(3) and (g)(4).

[1]Flame-resistant clothing includes clothing that is inherently flame resistant and clothing chemically treated with a flame retardant. (See ASTM F1506-10a, *Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards*, and ASTM F1891-12 *Standard Specification for Arc and Flame Resistant Rainwear*.)

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II. Assessing the workplace for flame and electric-arc hazards.

Paragraph (g)(1) of §1926.960 requires the employer to assess the workplace to identify employees exposed to hazards from flames or from electric arcs. This provision ensures that the employer evaluates employee exposure to flames and electric arcs so that employees who face such exposures receive the required protection. The employer must conduct an assessment for each employee who performs work on or near exposed, energized parts of electric circuits.

A. *Assessment guidelines*.

Sources electric arcs. Consider possible sources of electric arcs, including:

- Energized circuit parts not guarded or insulated,
- Switching devices that produce electric arcs in normal operation,
- Sliding parts that could fault during operation (for example, rack-mounted circuit breakers), and
- Energized electric equipment that could fail (for example, electric equipment with damaged insulation or with evidence of arcing or overheating).

Exposure to flames. Identify employees exposed to hazards from flames. Factors to consider include:

- The proximity of employees to open flames, and
- For flammable material in the work area, whether there is a reasonable likelihood that an electric arc or an open flame can ignite the material.

Probability that an electric arc will occur. Identify employees exposed to electric-arc hazards. The Occupational Safety and Health Administration will consider an employee exposed to electric-arc hazards if there is a reasonable likelihood that an

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electric arc will occur in the employee's work area, in other words, if the probability of such an event is higher than it is for the normal operation of enclosed equipment. Factors to consider include:

- For energized circuit parts not guarded or insulated, whether conductive objects can come too close to or fall onto the energized parts,
- For exposed, energized circuit parts, whether the employee is closer to the part than the minimum approach distance established by the employer (as permitted by §1926.960(c)(1)(iii)).
- Whether the operation of electric equipment with sliding parts that could fault during operation is part of the normal operation of the equipment or occurs during servicing or maintenance, and
- For energized electric equipment, whether there is evidence of impending failure, such as evidence of arcing or overheating.

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B. *Examples*.

Table 1 provides task-based examples of exposure assessments.

Table 1—Example Assessments for Various Tasks

Task		Is Employee Exposed to Flame or Electric-Arc Hazard?
Normal operation of enclosed equipment, such as closing or opening a switch.	The employer properly installs and maintains enclosed equipment, and there is no evidence of impending failure.	No
	There is evidence of arcing or overheating.	Yes
	Parts of the equipment are loose or sticking, or the equipment otherwise exhibits signs of lack of maintenance.	Yes
Servicing electric equipment, such as racking in a circuit breaker or replacing a switch.		Yes
Inspection of electric equipment with exposed energized parts.	The employee is not holding conductive objects and remains outside the minimum approach distance established by the employer.	No
	The employee is holding a conductive object, such as a flashlight, that could fall or otherwise contact energized parts (irrespective of whether the employee maintains the minimum approach distance).	Yes
	The employee is closer than the minimum approach distance established by the employer (for example, when wearing rubber insulating gloves or rubber insulating gloves and sleeves).	Yes
Using open flames, for example, in wiping cable splice sleeves.		Yes

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III. Protection against burn injury.

A. *Estimating available heat energy*.

Calculation methods. Paragraph (g)(2) of §1926.960 provides that, for each employee exposed to an electric-arc hazard, the employer must make a reasonable estimate of the heat energy to which the employee would be exposed if an arc occurs. Table 2 lists various methods of calculating values of available heat energy from an electric circuit. The Occupational Safety and Health Administration does not endorse any of these specific methods. Each method requires the input of various parameters, such as fault current, the expected length of the electric arc, the distance from the arc to the employee, and the clearing time for the fault (that is, the time the circuit protective devices take to open the circuit and clear the fault). The employer can precisely determine some of these parameters, such as the fault current and the clearing time, for a given system. The employer will need to estimate other parameters, such as the length of the arc and the distance between the arc and the employee, because such parameters vary widely.

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Table 2—Methods of Calculating Incident Heat Energy from an Electric Arc

1. *Standard for Electrical Safety Requirements for Employee Workplaces*, NFPA 70E-2012, Annex D, "Sample Calculation of Flash Protection Boundary."
2. Doughty, T.E., Neal, T.E., and Floyd II, H.L., "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600 V Power Distribution Systems," *Record of Conference Papers IEEE IAS 45th Annual Petroleum and Chemical Industry Conference*, September 28 – 30, 1998.
3. *Guide for Performing Arc-Flash Hazard Calculations*, IEEE Std 1584-2002, 1584a-2004 (Amendment 1 to IEEE Std 1584-2002), and 1584b-2011 (Amendment 2: Changes to Clause 4 of IEEE Std 1584-2002).*
4. ARCPRO, a commercially available software program developed by Kinectrics, Toronto, ON, CA.
*This appendix refers to IEEE Std 1584-2002 with both amendments as IEEE Std 1584b-2011.

The amount of heat energy calculated by any of the methods is approximately inversely proportional to the square of the distance between the employee and the arc. In other words, if the employee is very close to the arc, the heat energy is very high; but if the employee is just a few more centimeters away, the heat energy drops substantially. Thus, estimating the distance from the arc to the employee is key to protecting employees.

The employer must select a method of estimating incident heat energy that provides a reasonable estimate of incident heat energy for the exposure involved. Table 3 shows which methods provide reasonable estimates for various exposures.

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Table 3—Selecting a Reasonable Incident-Energy Calculation Method[1]

Incident-Energy Calculation Method	600 V and Less[2]			601 V to 15 kV[2]			More than 15 kV		
	1Φ	3Φa	3Φb	1Φ	3Φa	3Φb	1Φ	3Φa	3Φb
NFPA 70E-2012 Annex D (Lee equation)	Y-C	Y	N	Y-C	Y-C	N	N[3]	N[3]	N[3]
Doughty, Neal, and Floyd	Y-C	Y	Y	N	N	N	N	N	N
IEEE Std 1584b-2011	Y	Y	Y	Y	Y	Y	N	N	N
ARCPRO	Y	N	N	Y	N	N	Y	Y[4]	Y[4]

Key:

1Φ: Single-phase arc in open air
3Φa: Three-phase arc in open air
3Φb: Three-phase arc in an enclosure (box)
Y: Acceptable; produces a reasonable estimate of incident heat energy from this type of electric arc
N: Not acceptable; does not produce a reasonable estimate of incident heat energy from this type of electric arc
Y-C: Acceptable; produces a reasonable, but conservative, estimate of incident heat energy from this type of electric arc.

Notes:

[1]Although the Occupational Safety and Health Administration will consider these methods reasonable for enforcement purposes when employers use the methods in accordance with this table, employers should be aware that the listed methods do not necessarily result in estimates that will provide full protection from internal faults in transformers and similar equipment or from arcs in underground manholes or vaults.

[2]At these voltages, the presumption is that the arc is three-phase unless the employer can demonstrate that only one phase is present or that the spacing of the phases is sufficient to prevent a multiphase arc from occurring.

[3]Although the Occupational Safety and Health Administration will consider this method acceptable for purposes of assessing whether incident energy exceeds 2.0 cal/cm^2, the results at voltages of more than 15 kilovolts are extremely conservative and unrealistic.

[4]The Occupational Safety and Health Administration will deem the results of this method reasonable when the employer adjusts them using the conversion factors for three-phase arcs in open air or in an enclosure, as indicated in the program's instructions.

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Selecting a reasonable distance from the employee to the arc. In estimating available heat energy, the employer must make some reasonable assumptions about how far the employee will be from the electric arc. Table 4 lists reasonable distances from the employee to the electric arc. The distances in Table 4 are consistent with national consensus standards, such as the Institute of Electrical and Electronic Engineers' *National Electrical Safety Code*, ANSI/IEEE C2-2012, and *IEEE Guide for Performing Arc-Flash Hazard Calculations*, IEEE Std 1584b-2011. The employer is free to use other reasonable distances, but must consider equipment enclosure size and the working distance to the employee in selecting a distance from the employee to the arc. The Occupational Safety and Health Administration will consider a distance reasonable when the employer bases it on equipment size and working distance.

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Table 4—Selecting a Reasonable Distance from the Employee to the Electric Arc

Class of Equipment	Single-Phase Arc mm (inches)	Three-Phase Arc mm (inches)
Cable	NA*	455 (18)
Low voltage MCCs and panelboards	NA	455 (18)
Low-voltage switchgear	NA	610 (24)
5-kV switchgear	NA	910 (36)
15-kV switchgear	NA	910 (36)
Single conductors in air (up to 46 kilovolts), work with rubber insulating gloves	380 (15)	NA
Single conductors in air, work with live-line tools and live-line barehand work	$MAD - (2 \times kV \times 2.54)$ ($MAD - (2 \times kV / 10)$)†	NA

*NA = not applicable.

†The terms in this equation are:

MAD = The applicable minimum approach distance, and

kV = The system voltage in kilovolts.

Selecting a reasonable arc gap. For a single-phase arc in air, the electric arc will almost always occur when an energized conductor approaches too close to ground. Thus, an employer can determine the arc gap, or arc length, for these exposures by the dielectric strength of air and the voltage on the line. The dielectric strength of air is approximately 10 kilovolts for every 25.4 millimeters (1 inch). For example, at 50 kilovolts, the arc gap would be 50 ÷ 10 × 25.4 (or 50 × 2.54), which equals 127 millimeters (5 inches).

For three-phase arcs in open air and in enclosures, the arc gap will generally be dependent on the spacing between parts energized at different electrical potentials.

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Documents such as IEEE Std 1584b-2011 provide information on these distances. Employers may select a reasonable arc gap from Table 5, or they may select any other reasonable arc gap based on sparkover distance or on the spacing between (1) live parts at different potentials or (2) live parts and grounded parts (for example, bus or conductor spacings in equipment). In any event, the employer must use an estimate that reasonably resembles the actual exposures faced by the employee.

Table 5—Selecting a Reasonable Arc Gap

Class of Equipment	Single-Phase Arc mm (inches)	Three-Phase Arc mm[1] (inches)
Cable	NA[2]	13 (0.5)
Low voltage MCCs and panelboards	NA	25 (1.0)
Low-voltage switchgear	NA	32 (1.25)
5-kV switchgear	NA	104 (4.0)
15-kV switchgear	NA	152 (6.0)
Single conductors in air, 15 kV and less	51 (2.0)	Phase conductor spacing
Single conductor in air, more than 15 kV	Voltage in kV × 2.54 (Voltage in kV × 0.1), but no less than 51 mm (2 inches)	Phase conductor spacing

[1]Source: IEEE Std 1584b-2011.

[2]NA = not applicable.

Making estimates over multiple system areas. The employer need not estimate the heat-energy exposure for every job task performed by each employee. Paragraph (g)(2) of §1926.960 permits the employer to make broad estimates that cover multiple system areas provided that: (1) the employer uses reasonable assumptions about the energy-

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exposure distribution throughout the system, and (2) the estimates represent the maximum exposure for those areas. For example, the employer can use the maximum fault current and clearing time to cover several system areas at once.

Incident heat energy for single-phase-to-ground exposures. Table 6 and Table 7 provide incident heat energy levels for open-air, phase-to-ground electric-arc exposures typical for overhead systems.[2] Table 6 presents estimates of available energy for employees using rubber insulating gloves to perform work on overhead systems operating at 4 to 46 kilovolts. The table assumes that the employee will be 380 millimeters (15 inches) from the electric arc, which is a reasonable estimate for rubber insulating glove work. Table 6 also assumes that the arc length equals the sparkover distance for the maximum transient overvoltage of each voltage range.[3] To use the table, an employer would use the voltage, maximum fault current, and maximum clearing time for a system area and, using the appropriate voltage range and fault-current and clearing-time values corresponding to the next higher values listed in the table, select the appropriate heat energy (4, 5, 8, or 12 cal/cm^2) from the table. For example, an employer might have a 12,470-volt power line supplying a system area. The power line can supply a maximum fault current of 8 kiloamperes with a maximum clearing time of 10 cycles. For rubber glove work, this system falls in the 4.0-to-15.0-kilovolt range; the next-higher

[2]The Occupational Safety and Health Administration used metric values to calculate the clearing times in Table 6 and Table 7. An employer may use English units to calculate clearing times instead even though the results will differ slightly.

[3]The Occupational Safety and Health Administration based this assumption, which is more conservative than the arc length specified in Table 5, on Table 410-2 of the 2012 NESC.

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fault current is 10 kA (the second row in that voltage range); and the clearing time is under 18 cycles (the first column to the right of the fault current column). Thus, the available heat energy for this part of the system will be 4 cal/cm^2 or less (from the column heading), and the employer could select protection with a 5-cal/cm^2 rating to meet §1926.960(g)(5). Alternatively, an employer could select a base incident-energy value and ensure that the clearing times for each voltage range and fault current listed in the table do not exceed the corresponding clearing time specified in the table. For example, an employer that provides employees with arc-flash protective equipment rated at 8 cal/cm^2 can use the table to determine if any system area exceeds 8 cal/cm^2 by checking the clearing time for the highest fault current for each voltage range and ensuring that the clearing times do not exceed the values specified in the 8-cal/cm^2 column in the table.

Table 7 presents similar estimates for employees using live-line tools to perform work on overhead systems operating at voltages of 4 to 800 kilovolts. The table assumes that the arc length will be equal to the sparkover distance[4] and that the employee will be a distance from the arc equal to the minimum approach distance minus twice the sparkover distance.

The employer will need to use other methods for estimating available heat energy in situations not addressed by Table 6 or Table 7. The calculation methods listed in Table 2 and the guidance provided in Table 3 will help employers do this. For example,

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[4]The dielectric strength of air is about 10 kilovolts for every 25.4 millimeters (1 inch). Thus, the employer can estimate the arc length in millimeters to be the phase-to-ground voltage in kilovolts multiplied by 2.54 (or voltage (in kilovolts) x 2.54).

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employers can use IEEE Std 1584b-2011 to estimate the available heat energy (and to select appropriate protective equipment) for many specific conditions, including lower-voltage, phase-to-phase arc, and enclosed arc exposures.

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Table 6—Incident Heat Energy for Various Fault Currents, Clearing Times, and Voltages of 4.0 to 46.0 kV: Rubber Insulating Glove Exposures Involving Phase-to-Ground Arcs in Open Air Only*† ‡

Voltage Range (kV)**	Fault Current (kA)	Maximum Clearing Time (cycles)			
		4 cal/cm^2	5 cal/cm^2	8 cal/cm^2	12 cal/cm^2
4.0 to 15.0	5	46	58	92	138
	10	18	22	36	54
	15	10	12	20	30
	20	6	8	13	19
15.1 to 25.0	5	28	34	55	83
	10	11	14	23	34
	15	7	8	13	20
	20	4	5	9	13
25.1 to 36.0	5	21	26	42	62
	10	9	11	18	26
	15	5	6	10	16
	20	4	4	7	11
36.1 to 46.0	5	16	20	32	48
	10	7	9	14	21
	15	4	5	8	13
	20	3	4	6	9

Notes:

*This table is for open-air, phase-to-ground electric-arc exposures. It is not for phase-to-phase arcs or enclosed arcs (arc in a box).

†The table assumes that the employee will be 380 mm (15 in.) from the electric arc. The table also assumes the arc length to be the sparkover distance for the maximum transient overvoltage of each voltage range (see Appendix B to this subpart), as follows:

4.0 to 15.0 kV	51 mm (2 in.)
15.1 to 25.0 kV	102 mm (4 in.)
25.1 to 36.0 kV	152 mm (6 in.)
36.1 to 46.0 kV	229 mm (9 in.)

‡The Occupational Safety and Health Administration calculated the values in this table using the ARCPRO method listed in Table 2.

**The voltage range is the phase-to-phase system voltage.

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Table 7—Incident Heat Energy for Various Fault Currents, Clearing Times, and Voltages: Live-Line Tool Exposures Involving Phase-to-Ground Arcs in Open Air Only[*] [†] [‡] [#]

Voltage Range (kV)[**]	Fault Current (kA)	Maximum Clearing Time (cycles)			
		4 cal/cm^2	5 cal/cm^2	8 cal/cm^2	12 cal/cm^2
4.0 to 15.0	5	197	246	394	591
	10	73	92	147	220
	15	39	49	78	117
	20	24	31	49	73
15.1 to 25.0	5	197	246	394	591
	10	75	94	150	225
	15	41	51	82	122
	20	26	33	52	78
25.1 to 36.0	5	138	172	275	413
	10	53	66	106	159
	15	30	37	59	89
	20	19	24	38	58
36.1 to 46.0	5	129	161	257	386
	10	51	64	102	154
	15	29	36	58	87
	20	19	24	38	57
46.1 to 72.5	20	18	23	36	55
	30	10	13	20	30
	40	6	8	13	19
	50	4	6	9	13
72.6 to 121.0	20	10	12	20	30
	30	6	7	11	17
	40	4	5	7	11
	50	3	3	5	8
121.1 to 145.0	20	12	15	24	35
	30	7	9	15	22
	40	5	6	10	15
	50	4	5	8	11
145.1 to 169.0	20	12	15	24	36
	30	7	9	15	22
	40	5	7	10	16
	50	4	5	8	12

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Table 7—Incident Heat Energy for Various Fault Currents, Clearing Times, and Voltages: Live-Line Tool Exposures Involving Phase-to-Ground Arcs in Open Air Only—Continued

Voltage Range (kV)**	Fault Current (kA)	Maximum Clearing Time (cycles)			
		4 cal/cm^2	5 cal/cm^2	8 cal/cm^2	12 cal/cm^2
169.1 to 242.0	20	13	17	27	40
	30	8	10	17	25
	40	6	7	12	17
	50	4	5	9	13
242.1 to 362.0	20	25	32	51	76
	30	16	19	31	47
	40	11	14	22	33
	50	8	10	16	25
362.1 to 420.0	20	12	15	25	37
	30	8	10	15	23
	40	5	7	11	16
	50	4	5	8	12
420.1 to 550.0	20	23	29	47	70
	30	14	18	29	43
	40	10	13	20	30
	50	8	9	15	23
550.1 to 800.0	20	25	31	50	75
	30	15	19	31	46
	40	11	13	21	32
	50	8	10	16	24

Notes:

*This table is for open-air, phase-to-ground electric-arc exposures. It is not for phase-to-phase arcs or enclosed arcs (arc in a box).

†The table assumes the arc length to be the sparkover distance for the maximum phase-to-ground voltage of each voltage range (see Appendix B to this subpart). The table also assumes that the employee will be the minimum approach distance minus twice the arc length from the electric arc.

‡The Occupational Safety and Health Administration calculated the values in this table using the ARCPRO method listed in Table 2.

#For voltages of more than 72.6 kV, employers may use this table only when the minimum approach distance established under §1926.960(c)(1) is greater than or equal to the following values:

72.6 to 121.0 kV	1.02 m	169.1 to 242.0 kV	1.72 m	420.1 to 550.0 kV	3.62 m
121.1 to 145.0 kV	1.16 m	242.1 to 362.0 kV	2.76 m	550.1 to 800.0 kV	4.83 m
145.1 to 169.0 kV	1.30 m	362.1 to 420.0 kV	2.50 m		

**The voltage range is the phase-to-phase system voltage.

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B. *Selecting protective clothing and other protective equipment*.

Paragraph (g)(5) of §1926.960 requires employers, in certain situations, to select protective clothing and other protective equipment with an arc rating that is greater than or equal to the incident heat energy estimated under §1926.960(g)(2). Based on laboratory testing required by ASTM F1506-10a, the expectation is that protective clothing with an arc rating equal to the estimated incident heat energy will be capable of preventing second-degree burn injury to an employee exposed to that incident heat energy from an electric arc. Note that actual electric-arc exposures may be more or less severe than the estimated value because of factors such as arc movement, arc length, arcing from reclosing of the system, secondary fires or explosions, and weather conditions. Additionally, for arc rating based on the fabric's arc thermal performance value[5] (ATPV), a worker exposed to incident energy at the arc rating has a 50-percent chance of just barely receiving a second-degree burn. Therefore, it is possible (although not likely) that an employee will sustain a second-degree (or worse) burn wearing clothing conforming to §1926.960(g)(5) under certain circumstances. However, reasonable employer estimates and maintaining appropriate minimum approach distances for employees should limit burns to relatively small burns that just barely extend beyond

[5]ASTM F1506-10a defines "arc thermal performance value" as "the incident energy on a material or a multilayer system of materials that results in a 50 % probability that sufficient heat transfer through the tested specimen is predicted to cause the onset of a second-degree skin burn injury based on the Stoll [footnote] curve, cal/cm^2." The footnote to this definition reads: "Derived from: Stoll, A. M., and Chianta, M. A., 'Method and Rating System for Evaluations of Thermal Protection,' Aerospace Medicine, Vol 40, 1969, pp. 1232-1238 and Stoll, A. M., and Chianta, M. A., 'Heat Transfer through Fabrics as Related to Thermal Injury,' Transactions—New York Academy of Sciences, Vol 33(7), Nov. 1971, pp. 649-670."

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the epidermis (that is, just barely a second-degree burn). Consequently, protective clothing and other protective equipment meeting §1926.960(g)(5) will provide an appropriate degree of protection for an employee exposed to electric-arc hazards.

Paragraph (g)(5) of §1926.960 does not require arc-rated protection for exposures of 2 cal/cm^2 or less. Untreated cotton clothing will reduce a 2-cal/cm^2 exposure below the 1.2- to 1.5-cal/cm^2 level necessary to cause burn injury, and this material should not ignite at such low heat energy levels. Although §1926.960(g)(5) does not require clothing to have an arc rating when exposures are 2 cal/cm^2 or less, §1926.960(g)(4) requires the outer layer of clothing to be flame resistant under certain conditions, even when the estimated incident heat energy is less than 2 cal/cm^2, as discussed later in this appendix. Additionally, it is especially important to ensure that employees do not wear undergarments made from fabrics listed in the note to §1926.960(g)(3) even when the outer layer is flame resistant or arc rated. These fabrics can melt or ignite easily when an electric arc occurs. Logos and name tags made from non-flame-resistant material can adversely affect the arc rating or the flame-resistant characteristics of arc-rated or flame-resistant clothing. Such logos and name tags may violate §1926.960(g)(3), (g)(4), or (g)(5).

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Paragraph (g)(5) of §1926.960 requires that arc-rated protection cover the employee's entire body, with limited exceptions for the employee's hands, feet, face, and head. Paragraph (g)(5)(i) of §1926.960 provides that arc-rated protection is not necessary for the employee's hands under the following conditions:

For any estimated incident heat energy	When the employee is wearing rubber insulating gloves with protectors
If the estimated incident heat energy does not exceed 14 cal/cm^2	When the employee is wearing heavy-duty leather work gloves with a weight of at least 407 gm/m^2 (12 oz/yd^2)

Paragraph (g)(5)(ii) of §1926.960 provides that arc-rated protection is not necessary for the employee's feet when the employee is wearing heavy-duty work shoes or boots. Finally, §1926.960(g)(5)(iii), (g)(5)(iv), and (g)(5)(v) require arc-rated head and face protection as follows:

Exposure	**Minimum Head and Face Protection**		
	None*	**Arc-Rated Faceshield with a Minimum Rating of 8 cal/cm^2 ***	**Arc-Rated Hood or Faceshield with Balaclava**
Single-phase, open air	2 – 8 cal/cm^2	9 – 12 cal/cm^2	13 cal/cm^2 or higher†
Three-phase	2 – 4 cal/cm^2	5 – 8 cal/cm^2	9 cal/cm^2 or higher‡

*These ranges assume that employees are wearing hardhats meeting the specifications in §1910.135 or §1926.100(b)(2), as applicable.

†The arc rating must be a minimum of 4 cal/cm^2 less than the estimated incident energy. Note that §1926.960(g)(5)(v) permits this type of head and face protection, with a minimum arc rating of 4 cal/cm^2 less than the estimated incident energy, at any incident energy level.

‡Note that §1926.960(g)(5) permits this type of head and face protection at any incident energy level.

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IV. Protection against ignition.

Paragraph (g)(3) of §1926.960 prohibits clothing that could melt onto an employee's skin or that could ignite and continue to burn when exposed to flames or to the available heat energy estimated by the employer under §1926.960(g)(2). Meltable fabrics, such as acetate, nylon, polyester, and polypropylene, even in blends, must be avoided. When these fibers melt, they can adhere to the skin, thereby transferring heat rapidly, exacerbating burns, and complicating treatment. These outcomes can result even if the meltable fabric is not directly next to the skin. The remainder of this section focuses on the prevention of ignition.

Paragraph (g)(5) of §1926.960 generally requires protective clothing and other protective equipment with an arc rating greater than or equal to the employer's estimate of available heat energy. As explained earlier in this appendix, untreated cotton is usually acceptable for exposures of 2 cal/cm^2 or less.[6] If the exposure is greater than that, the employee generally must wear flame-resistant clothing with a suitable arc rating in accordance with §1926.960(g)(4) and (g)(5). However, even if an employee is wearing a layer of flame-resistant clothing, there are circumstances under which flammable layers of clothing would be uncovered, and an electric arc could ignite them. For example, clothing ignition is possible if the employee is wearing flammable clothing under the flame-resistant clothing and the underlayer is uncovered because of an opening in the flame-resistant clothing. Thus, for purposes of §1926.960(g)(3), it is important for the

[6]See §1926.960(g)(4)(i), (g)(4)(ii), and (g)(4)(iii) for conditions under which employees must wear flame-resistant clothing as the outer layer of clothing even when the incident heat energy does not exceed 2 cal/cm^2.

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employer to consider the possibility of clothing ignition even when an employee is wearing flame-resistant clothing with a suitable arc rating.

Under §1926.960(g)(3), employees may not wear flammable clothing in conjunction with flame-resistant clothing if the flammable clothing poses an ignition hazard.[7] Although outer flame-resistant layers may not have openings that expose flammable inner layers, when an outer flame-resistant layer would be unable to resist breakopen,[8] the next (inner) layer must be flame-resistant if it could ignite.

Non-flame-resistant clothing can ignite even when the heat energy from an electric arc is insufficient to ignite the clothing. For example, nearby flames can ignite an employee's clothing; and, even in the absence of flames, electric arcs pose ignition hazards beyond the hazard of ignition from incident energy under certain conditions. In addition to requiring flame-resistant clothing when the estimated incident energy exceeds 2.0 cal/cm^2, §1926.960(g)(4) requires flame-resistant clothing when: the employee is exposed to contact with energized circuit parts operating at more than 600 volts (§1926.960(g)(4)(i)), an electric arc could ignite flammable material in the work area that, in turn, could ignite the employee's clothing (§1926.960(g)(4)(ii)), and molten metal or electric arcs from faulted conductors in the work area could ignite the employee's clothing (§1926.960(g)(4)(iii)). For example, grounding conductors can become a source of heat energy if they cannot carry fault current without failure. The employer must

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[7]Paragraph (g)(3) of §1926.960 prohibits clothing that could ignite and continue to burn when exposed to the heat energy estimated under paragraph (g)(2) of that section.

[8]Breakopen occurs when a hole, tear, or crack develops in the exposed fabric such that the fabric no longer effectively blocks incident heat energy.

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consider these possible sources of electric arcs[9] in determining whether the employee's clothing could ignite under §1926.960(g)(4)(iii).

[9]Static wires and pole grounds are examples of grounding conductors that might not be capable of carrying fault current without failure. Grounds that can carry the maximum available fault current are not a concern, and employers need not consider such grounds a possible electric arc source.

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