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## **Limiting Arc Flash Exposure**

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Exposure to arc flash can be fixed in three ways:

1. Avoiding arc flash hazards.
2. Limiting the level of arc energy discharged.
3. The adequate use of personal protective equipment (PPE).

Arc flash incidents can be cut down by following processes correctly, use of adequate equipment, proper preventive care, planning and coordination of operation, as well as skill improvement and real experience. Also crucial is the mental and physical circumstances of the staff such that the dropping of equipment and tools, accidental touching, etc., are averted. Taking care of the causes of arc flash is the main scheme for averting exposure.

Incidents may happen despite care taken to avert them. In such circumstances, it is always better if the incident energy is low and staff is ready for the worst by implementing adequate PPE.

### **AVERTING ARC FLASH INCIDENTS**

Arc flash can be averted by realizing its causes and taking steps to mitigate them. The different causes of arc flash are listed below. The mitigation steps are discussed in the following paragraphs. Summary of causes:

- Dust, impurities, and corrosion at contact surfaces producing heat, loosening contact and creating sparks.
- Sparks developed during racking of breakers, replacement of fuses, breakers/fuses closing into faulted and energized lines.
- Break down of insulating materials.

- Snapping of leads at connections due to force – human, rodents or birds.
- Incidental touching and dropping of tools, devices or metal parts.

### **PREVENTIVE SERVICE**

Preventive service procedures are developed in most companies that need high reliability of supply or process persistence. Preventive service also gives a safer workplace.

Improve maintenance service when carrying out reviews, preventive service, or even breakdown service by including methodologies that address arc flash hazards. This limits the total cost of applying an arc flash program. Implement the following in service practices:

1. Rodents and birds getting into panels and switchgear are not uncommon. These can cause short-circuits and eventually arc flash. This hazard can be precluded by closing all open areas of devices with wire net or sealant so that they cannot enter.
2. Use terminals that are resistant to corrosion. It can cause snapping of small wires that in turn may cause sparks and fumes when the tip of the wire touches the metal enclosure or other phase conductor. Regularly find corroded terminals and elements if the electrical devices are at a chemical plant or near a marine atmosphere. Electrical contact grease is usually used in joints and terminations. This will cut down corrosion.
3. Find loose and overheated connections. Impurities or dust at the terminal connectors can cause higher contact resistance, heating the terminals. A sign of such situation is coloring of the nearby insulation. Cable insulation heating can damage the insulation - another cause of flashover. Infra-red thermography can give precious information on poor connections and overheated electrical conductors or terminations.
4. If feasible, insulate exposed metal elements. If heat dissipation is not really required from the exposed metal element, and insulating it with some insulating tape or cover is not an issue, then it is better to complete it, rather than to keep them exposed. Insulation prevents arcing. For example, if staff drops an uninsulated spanner, that

touches bare bus bars of two phases, a short circuit current will occur. Nevertheless, this will not occur if the spanner or the bus bar is insulated.

5. Ensure that relays and breakers function properly. Failure could cause prolonged exposure to arc flash that could lead to death. Routine maintenance and relay testing are completed in companies with good maintenance procedures. Relay test frequency may be every few years, depending upon the manufacturer's recommendations and company policy.

6. Contacts pitting takes place when fuses operate. Replace fuse contacts holder or the fuse holder, when unreasonable pitting is detected.

7. When a fuse melts, ensure that the fault has cleared before putting a new fuse. Closing a circuit on to a fault can cause sparks that could lead to arc flash.

8. Control and instrumentation wire should be kept in proper condition. It is not unusual for these wires to become bundled and messy. Occurrence of arc blasts can happen while opening covers of such switchgear/MCC.

9. Check out for excessive moisture or water/ice on insulating surfaces of devices. This may lead to flashover, especially on high voltage devices.

### **WORKING ON LIVE EQUIPMENT**

1. It is always preferred to work on de-energized devices, regardless of the hazard risk category (HRC). When operation on live devices is inescapable, then reasoning and written authorization is needed. Integrate this precautionary step into the work routine.

2. Always use insulated tools. Dropping of tools can lead to momentary faults, sparks and arcs. Insulated tools and devices can help reduce and remove this type of incident.

3. Torque control: When using spanners, wrenches or screwdrivers to fasten or loosen a connection use adequate torque. When excessive force is needed, it is not unusual to lose control. Slipping of screws or nuts and bolts may lead to accidental touching. Fasteners that are corroded or heated can be hard to loosen. Work off line if loosening

is challenging.

4. Do not use paint, cleaning chemicals, spray, etc., on live exposed metal elements. The fumes or spray may be conductive and it may decrease the insulating features of air and allow an arc to strike through. Spraying directly on live conductor can also give a conducting path that will end up in electric shock.

### **CUTTING DOWN INCIDENT ENERGY ON STAFF**

The incident energy exposure can be cut down by appropriate system design or operating sequence. Several ways to cut down the energy on an existing system are shown below:

1. Cut down the fault level
2. Cut down the exposure time
3. Remote operation
4. Remote racking

### **CUTTING DOWN THE FAULT LEVEL**

Fault level can be cut down in the following ways:

1. Change system arrangements to cut down available fault current/smaller kVA transformers.
2. Current limiting fuses/breakers.
3. Current limiting reactors.

### **SYSTEM ARRANGEMENT**

Cutting down the fault level depends on the existing system arrangement. Double ended load centres with closed tie in normal service (Figure 1) are a basic example where the fault level can be decreased by either opening the tie or one incoming

breaker. The short circuit current will be decreased by roughly 50% and the incident short circuit current energy will also be decreased, even though not inevitably in the same proportion. If the bus has two power sources or a source and a normally closed tie as presented in Figure 2, opening one of the sources (or tie) will decrease the fault level while servicing on the devices is completed. For both cases, the loading and relay setting need to be verified to ensure that the opening of a breaker does not overload the other power source.

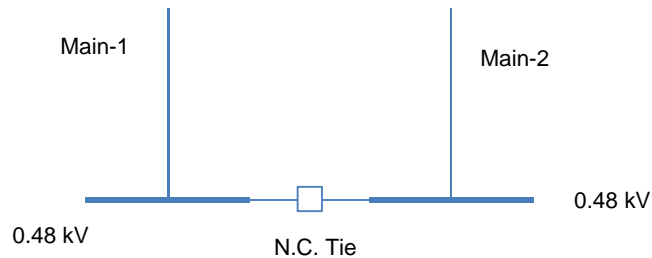


Figure 1. Double-end load center configuration

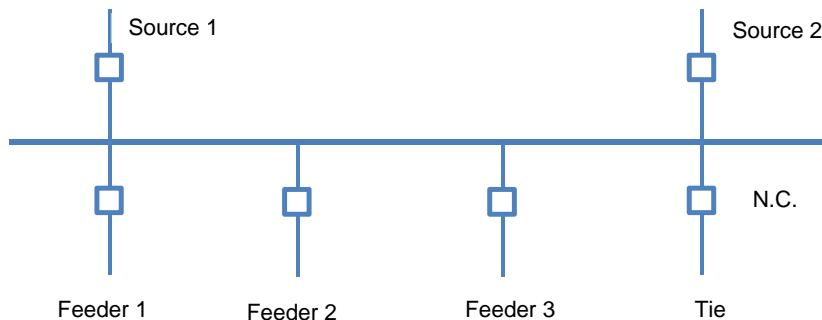


Figure 2. Dual sources

### CURRENT LIMITING FUSES/BREAKERS

Current limiting fuses/breakers put additional resistance within the fuse device while the fuse is melting. This fixes the fault current. Fault currents within the current limiting area of the fuse are usually cleared within half a cycle. Since the incident arc energy is relative to arcing time, current limiting fuses/breakers limit the arc energy.

### CURRENT LIMITING REACTORS

Current limiting reactors bring in extra impedance in the electrical system and are utilized to limit the short circuit current. This not only decreases damages induced by

faults but also lets the utilization of circuit breakers with smaller duty. Fixing the short circuit current can also raise the fault clearing time if the fault current lies in the protective relay inverse time delay characteristics. Hence, protective device coordination assessment is also needed when selecting current limiting reactors.

### **DECREASING ARCING TIME**

Arcing time can be decreased in few ways. Some system settings modifications may be needed for this purpose. Some strategies presented in this paragraph are as follows:

1. Decreasing safety margin for relay and breaker operation with enhanced solid state trip elements.
2. Bus differential protection to mix selectivity with instantaneous tripping.
3. Temporary instantaneous trip setting during work.
4. Retrofit time-overcurrent relays with delayed instantaneous trip element if required.
5. Optical sensor to trip breaker in the case of arc flash.
6. Use smaller fuse size if feasible; smaller current limiting fuses may operate quicker.
7. Fuses will typically be much faster than breakers at high fault currents – even neglecting current-limiting effect this can greatly decrease arc energy.
8. Protective device coordination study to balance improving reliability with decreasing arc flash hazard.

### **DECREASING BREAKER RESPONSE TIME SAFETY LIMIT**

Incident energy grows with time and fault current. Decreasing either or both decreases the incident energy due to an arcing fault. Faster operating relays and trip elements can decrease the arcing time to some degree. In this regard, a protective relaying assessment may be completed in order to check if they can be decreased in time and

pick-up. If a protective device assessment was completed a number of years ago when electro-mechanical relays were the standard, 0.4 second margin between relay was typical. This allowed for breaker operating time, over-travel, and a time safety margin. Breaker times are now typically 5 cycles rather than the 8 cycles of older breakers. Microprocessor relays are now being utilized, for which the over travel has basically been eliminated. The repeatability of the microprocessor relay is better than that of the electro-mechanical relay. Hence, the safety margin can be decreased. The end result is that the relay coordination limits can be 0.2 to 0.25 seconds instead of 0.4 seconds. This is a 25%-35% decrease in arc energy exposure.

### **BUS DIFFERENTIAL PROTECTION**

A major enhancement in clearing time would result if an instantaneous relay could be utilized instead of time-delay relays. Feeders on both low and high voltage systems are likely to have instantaneous settings and hence, would limit the arc exposure time. Nevertheless, a fault on the main bus is usually cleared by time-delay relays for selectivity purposes. In high voltage electrical systems, utilizing bus-differential relaying reduces the arc exposure time to a minimum. The arc energy exposure can easily be 5 to 30 times less than that of the delayed clearing time.

### **TEMPORARY INSTANTANEOUS SETTING**

Replacement low-voltage trip devices have an instantaneous unit that that can be switched on or off. This has a high advantage on the incoming main circuit breakers. In many situations, for coordination reasons, the instantaneous is not set and fault clearing times are delayed for selectivity. A main circuit breaker clearing time with a load centre tie and feeder circuit breakers could easily have a short time setting of 0.4 seconds. If the instantaneous trip could easily be switched on while work is being completed lower fault currents could be tripped and cleared in less than 0.04 seconds. The incident energy exposure is decreased to 10% of its previous figure. During servicing, full selectivity of protective elements may be lost, but the decrease in arc flash exposure makes it worth. The temporary instantaneous protective setting should be switched off and the original protective setting should be fixed for normal service after the work is done. Different instantaneous protective trip elements with increased protection can also be added to shunt trip or transfer trip for added protection during



work processes.

### **RETROFIT INSTANTANEOUS PROTECTIVE TRIP ELEMENT**

If bus-differential protective relaying is not feasible then the main protection relay can be retrofitted with an instantaneous protective element and a safety control switch. As presented in Figure 3, a selector switch can be utilized to place the instantaneous in operation when servicing is being completed. Typically the instantaneous protection would not be operable due to the open contact of the selector switch. Nevertheless, when job is being done on the energized elements, the safety switch would be turned 'ON' and thereby limiting the arc exposure time to the staff should an arcing fault incident happen. The delayed fault clearing time could be in the range of 0.4 to 2.0 seconds on the main breaker instead of 0.1 second.

The delayed trip time largely improves the arc exposure time and amount of radiation a staff would get if the arc blast pressure were not sufficient to propel the staff away from the fault. The time-selective protection arrangement would be eliminated for duration of the job in the sake of safety. The selector switch should be lockable in the servicing place. Ideally, positive feedback from the trip element would be utilized for an indicating light related with the switch to reassert the setting modification was in effect.

Many medium voltage multifunction protection relays have possibilities for different protective settings for different servicing modes. For instance, one group of setting is utilized for normal service; a second group of settings is utilized for emergency mode. Another group setting could be for servicing where the tripping and current pick-up settings are decreased and set as instantaneous. Again, these temporary settings could end in the loss of selectivity with an improvement in human safety.

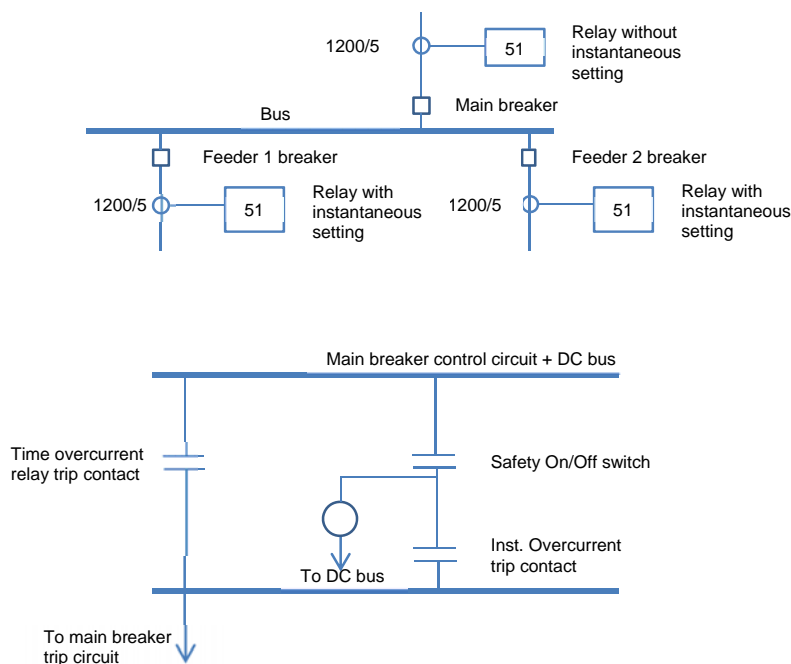


Figure 3. Arrangement to control arc flash exposure on relayed breakers

Figure 3 displays the possible time current curves of a typical load centre. The relay servicing times for both the 100% and 85% fault currents are presented in Table 1. If an instantaneous trip were put on the main circuit breaker at 3 times the long-time pick-up, a short circuit on the bus would be cleared in roughly 0.05 seconds with the incident energy being roughly 1.0 cal/cm<sup>2</sup> instead of the 4.4 and 5.3 cal/cm<sup>2</sup>, as shown in Table 1.

Table 1. Clearing times and Incident Energy for a 1000-kVA load Center

100% Calculated Fault Current			
Clearing Device	kA at 480 V	Operating Time	Cal/cm2
Main	17.3	0.21	4.4
Feeder	23.2	0.05	1.4
Fuse	17.3	0.42	8.8
85% Calculated Fault Current			
Clearing Device	kA at 480 V	Operating Time	Cal/cm2
Main	14.3	0.3	5.3
Feeder	19.7	0.05	1.2
Fuse	14.3	1.0	17.6

### OPTICAL SENSOR TRIP

Some companies have developed an “Arc Guard System TVOC” which has a light

sensor to discover an electrical arc flash. It can be excited by light only or light input monitored with an overcurrent sensor. Its output is utilized to operate a breaker and has an operating time of 10 milliseconds. If auxiliary tripping protection relays are required to operate several breakers at once, then the auxiliary protection relay time has to be factored in to the total clearing time. Installation of the detector and its control wiring could be vital. These should be installed close enough to discover an arc but not be damaged by the initial arc.

### **FUSE RATING AND SPEED**

Fuse ratings could be examined to check if smaller fuses can be utilized. Smaller fuses decrease the exposure time. This can be major when the arcing current or 85% of arcing current is not in the current limiting range of the fuse. The smaller fuse would function faster and decrease the arc energy exposure, should the main circuit breaker fail or should a short circuit happen between the transformer and main circuit breaker. Speed of fuses is picked out to coordinate with other protective elements and the over-current capacity of elements being protected. A weakness of reducing the fuse rating is the chance of fuses not being in a position to distinguish a temporary fault from a persistent fault. A temporary fault, such as those found in overhead distribution lines, live for a few cycles. Some fuses are picked out such that they allow temporary short circuits but clear persistent faults. If the fuse rating is decreased with the aim of decreasing arc flash incident, then the fuse may melt upon temporary short circuits, therefore decreasing the reliability of supply.

Operating fuses can make sparks and may lead to arc flash incidents. Fuses should not be temporarily decreased just for the purpose of operating on live line.

### **TEMPORARY PROTECTION RELAY SETTINGS**

It has to be noted that the act of modifying protective settings on electrical devices could place the staff at risk. While the protective elements are at low voltage a spontaneous short circuit could happen in the switchgear at this moment. Most protection relay resettings are completed with a keypad and not with screwdrivers; the possibility of a short circuit at this moment is really low.

Check protective elements to notice if they can be decreased in time and pick-up. Due to reliability reasons using temporary settings is typically not a favored practice. Tampering with settings of protective elements is prohibited. Nevertheless, if a qualified staff, for instance the engineer, can temporarily give the replacement settings during the job period, then the incident energy can be decreased by decreasing the trip time.

### **PROTECTIVE DEVICE COORDINATION ASSESSMENT**

A protective device coordination assessment is completed to enhance system reliability. This assessment can be completed on a regular basis, maybe every few years or whenever there are modifications in the electrical system. Such assessment could also take into account, the reduction of incident energy from arc flash. The engineer completing the assessment should at the same time check the arc flash hazard, and attempt to minimize the hazard by keeping the arcing time as low as possible.

### **REMOTE FUNCTIONING AND RACKING**

Putting distance between electrical conductors and the staff largely decreases the arc incident energy and the arc blast force. The decrease is not linear. For instance, a staff twice as far as another worker from the arc will get 25 to 50% less energy than the closer operator. New high voltage devices can be made with the breaker “Open” and “Close” switches remote from the breaker element. These could be put on a non-breaker element, in a different control panel, or in a remote room. Older switchgears can be furnished with remote control switches.

New microprocessor-relays can be programmed to manually monitor the switching on of a breaker utilizing a “punch and run” time, that provides the operator 3 to 10 seconds after starting a “close” to evacuate the locality before the breaker is really closed. While totally electrically serviced low voltage breakers are available they are not the standard. Low voltage circuit breakers that are completely electrically controlled would be useful for remotely installed control switches. As the insurance companies and OSHA start to ask improved arc flash safety programs, completely controlled electrically low voltage circuit breakers may become more common.

Putting a circuit breaker in or out of a switchgear cubicle brings out the staff to a potential arc flash incident. While the breaker's mechanical indicator may report that the breaker is completely open, there have been situations where it was not open due to contact or indicator damage. Installing a circuit breaker in a cubicle when it is not in the fully open condition can end in an arc. While the separation from live conductors to the staff can be over an arm's length away, the arc gases can go around the circuit breaker and end in burns. For circuit breakers that are being taken out from a cubicle, verify the next three items before pulling out – the mechanical indicator displays the breaker open, the breaker displaying lights show the circuit breaker open, and the ammeter displays all three phases with zero current.

Using a longer servicing arm to rack in the circuit breaker can provide the required distance. Remotely operated circuit breaker racking mechanisms are usable for some circuit breakers as part of the new element or as retrofits. Installing a barrier such as a closed door or a portable barrier, as presented in Figure 4, would fix the arc flash exposure. While the barrier would stop direct arc injuries, radiant energy burns are still possible and PPE is still required. With a barrier the surface area is enhanced, hence making an issue of the force exerted by the arc blast.

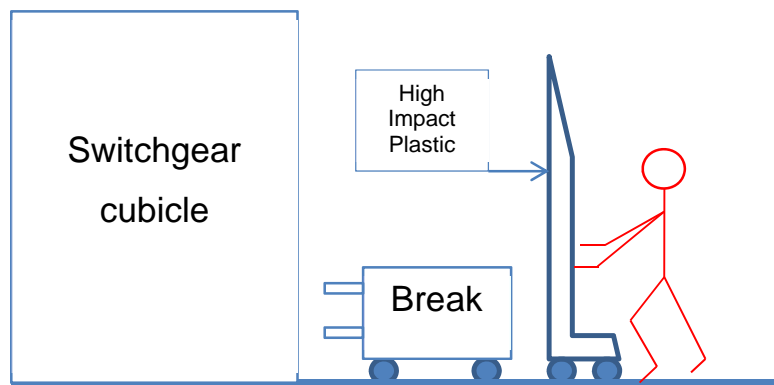


Figure 4. Using a barrier when racking in a circuit breaker

Even though it is not a way to decrease arc incident energy, it is solid practice to utilize the buddy technique. In the case an incident should occur, assistance can be summoned promptly if a second person is around.

## **PERSONAL PROTECTIVE EQUIPMENT**

Personal protective equipment (PPE) is needed by different standards such as NFPA and OSHA to save staff from incidents in the workplace. The type of PPE needed depends upon the incident that has been studied and documented. In the situation of arc flash incident, the main objective of PPE is to decrease burn injury to staff to a level of curable burn.

Personal protective equipment may, or may not, give sufficient protection in the case of arc flash exposure. It is vital that staff understand the use, care and limits. Employers should assure that staff has proper understanding and training on the application of PPE. Staff must not treat PPE as a replacement for common sense and safe work procedures. The most typical and industry accepted PPE that saves the body is flame resistant (FR) clothes. Flame resistance is the feature of a cloth that causes it not to burn in air. This is accomplished by treating the cloth fibre such as cotton with flame retardant chemical substances. Synthetic FR clothing is also widely accepted.

Function of flame resistant fabric:

1. Resistance to flame and self-extinguishing.
2. Gives thermal insulation to the body from heat radiation.

## **PERSONAL PROTECTIVE EQUIPMENT STANDARDS**

Some of the standards on personal protective equipment are quickly shown in the following paragraphs. Note that these are only some of the main rules and not all of them. It is vital that PPE choice and training be completed under the guidance of an experienced safety staff that is aware of all the related standards.

## OSHA

Table 2. Different OSHA standards on personal protective equipment

1910.132(a), 1926.95(a)	<p>Application</p> <p>What: Protection shall be supplied for eyes, face, head and extremities.</p> <p>When: Whenever it is required by reason of hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants in a manner capable of inducing injury or impairment in the function of any part of the body through absorption, inhalation or physical contact.</p> <p>How: Protective clothing, respiratory devices, protective shields and barriers.</p>
1910.132(b), 1926.95(b)	Employee-owned devices: The owner shall be responsible to ensure it adequacy including proper servicing and sanitation.
1910.132(c), 1926.95(c)	Design: PPE shall be of safe design and construction
1910.132(d)	<p>Hazard study and device selection:</p> <ol style="list-style-type: none"> <li>1. Employer shall study the workplace to check if hazards are present or likely to be present, which demand the use of PPE. If hazard exists or may develop, the employer shall: <ul style="list-style-type: none"> <li>- Choose, and have each affected employee use the adequate PPE as per the hazard study.</li> <li>- Convey selection decisions to each affected worker</li> <li>- Choose PPE that adequately fits each involved worker</li> </ul> </li> <li>2. Documentation of hazard study: <ul style="list-style-type: none"> <li>- Written certification</li> <li>- Recognition of workplace assessed</li> <li>- Person certifying the assessment</li> <li>- Date(s) of hazard evaluation</li> </ul> </li> </ol>
1910.132(e)	Defective and damaged devices shall not be utilized.
1910.132(f)	Training: When PPE is required, what PPE is required, how to adequately utilize the PPE, and how to care, service and put away the PPE. Each affected worker shall show an understanding of the training. Retraining may be needed depending upon modifications in workplace or PPE. The needed training shall be certified and documented.
1926.100(a)	Workers operating in area where there is a possible hazard of head injury from impact, or from falling of flying objects, or from electrical shock and burns, shall be protected by protective helmets.
1926.100(b)	Helmets for the protection of workers against impact and penetration of falling and flying objects shall meet the standards listed in American National Standards Institute, Z89.1-1969, Safety Requirements for Industrial Head Protection.
1926.100(c)	Helmets for the head protection of employees exposed to high voltage electrical shock and burns shall meet the standards listed in American National Standards Institute, Z89.2-1971.

## **NFPA 70E**

NFPA 70E Article 220.2(B)(3): Protective Clothing and Personal Protective Equipment for Application with a Flash Hazard Analysis. The management is obliged to carry out an assessment of arc flash hazard, and document the incident energy, in calories per square centimetre, that a staff may be exposed to arc heat on the face and chest. Staff is obliged to wear FR clothes and PPE sufficient to save the body from injury from the computed exposure to heat from arc.

NFPA 70E Article 220.6: Staff must use sufficient PPE on different parts of the body suitable for the work to be completed. Different standard relating to care, testing and utilization of PPE are shown in this paragraph. Please refer to the standards for complete information. Some of the main demands are as follows:

- All staff within the flash protection boundary is needed to wear PPE.
- PPE should cover all other clothing that can be ignited.
- PPE should not limit visibility and movement.
- Non-conductive protective headwear is needed when in touch with live elements or when there is a chance of electrical explosion. The face, neck and chin must be kept safe.
- Eye protection is needed.
- FR clothing should be worn when the calculated incident energy at the body may induce a second degree (curable) burn ( $1.2 \text{ cal/cm}^2$  for arc time higher than 0.1 second or  $1.5 \text{ cal/cm}^2$  for arc time 0.1 seconds or less).
- Leather or FR gloves are needed to protect the hand.
- If incident energy exceeds  $4 \text{ cal/cm}^2$ , heavy duty boots are needed to protect the feet.



## ASTM

American Society for Testing and Materials (ASTM) formulates standards that define the quality of different materials including safety materials such as PPE. The following standards are relevant to arc flash hazard protection elements. ASTM F1506: Standard Performance Specification for Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Arc and Related Thermal Hazards, 2002. This standard defines the demands for flame resistant clothing. There are three basic demands in this standard:

1. The fabric under test must self-extinguish in less than 2 seconds after the ignition source has been removed.
2. Char length for ASTM Test Method D6413 must be less than 6 inches. A fabric specimen of 12 inch length is hung vertically in an enclosed area and the bottom is disclosed to a methane flame for 12 seconds. The length of the fabric destructed by flame is the char length. This test is also known as the standard vertical flame test.
3. Apart from accomplishing these pass/fail tests, the fabric is also tried out for the Arc Thermal Performance Value (ATPV) as per ASTM F1959. Manufacturers are needed to present the test findings to the end users of the material as an Arc rating on a garment label. Any fabric that conforms to the ASTM F1506 follows OSHA 1910.269. This functional specification does not address coated fabrics typically used in rainwear.

ASTM F1959: Standard Test Method for Determining Arc Thermal Performance (Value) of Textile Materials for Clothing by Electric Arc and Related Thermal Hazards. This test examines how much incident energy is deflected by the fabric before the user of the protective clothing may get a second degree burn. The quantity of energy deflected is described as Arc Thermal Heat Performance Value (ATPV). If the fabric breaks open, the figure is also known as the Breakopen Energy Threshold.

ASTM F1891: Standard Specification for Arc and Flame Resistant Rainwear. Become familiar with ASTM F1506 for the three basic demands. Any fabric that conforms to the ASTM F1506 follows OSHA 1910.269.

ASTM F1449: Standard Guide for Care and Maintenance of Flame, Thermally and Arc Resistant Clothing. This standard gives suggestions for the care and maintenance of clothing that is flame, thermal and arc resistive. The guide focuses on the industrial laundering procedure and also defines inspection rules that are important to the performance of clothing.

### **FIRE RESISTANT CLOTHING - ELEMENTS AFFECTING PROTECTION LEVEL FROM ARC**

**Material:** Untreated natural fabrics may keep on burning until the fabric is completely consumed. Synthetic fabrics that are not flame resistant will burn with melting and dripping and may induce severe burns to the skin. Flame resistant fabric will be charred by arc flash heat, but will not keep on burning after the arcing finishes. The burning of garments may induce bigger injury to the skin than direct contact to the heat from the arc.

**Weight:** The weight of FR fabric is defined in weight per unit area (ounces/square yard or g/m<sup>2</sup>). Bigger weights give more thermal insulation.

**Layers:** More layers of clothing keep air space between the layers, therefore providing higher thermal insulation than a single layer. Single, thick clothing give less physical comfort, whereas more layers provide flexibility. Comfort and flexibility are vital in annulling incidents while operating on live devices.

### **MAINTENENCE OF FIRE RESISTANT CLOTHING**

**Laundering:** Get complete directions on care of FR clothing from the manufacturer. Some cleaning chemicals such as chlorine bleach may impact the finish, decrease the fabric strength and take away the color of the cloth. Some manufacturers state that the flame resistance feature is not impacted by the bleach. Follow laundering directions given by the manufacturer.

**Contamination:** Grease, oil, or other flammable materials catch fire quickly and will keep on burning even after the arc finishes. Hence, FR clothing polluted with these substances should not be utilized. Attention should be taken at work to annul polluting

FR clothing from such materials.

Storage: The clothing should be kept in a safe condition so that it is reliable.

### **USEFUL LIFE OF PPE**

The useful life of a PPE may reckon on different elements such as the material with which it is produced, the severity of work activity and the abrasion resistance features of the PPE. Collect data from the manufacturer to decide the useful life. The useful life of a PPE is typically presented following some approximations. It must be noted that if the real circumstances are different from these approximations, then the stated expected life may not be relevant. It is best if the PPE user gets from the manufacturer, the relevant life of the PPE for the proposed application.

Table 3. Expected useful life of FR clothing - examples

<b>Fabric</b>	<b>Industrial Launderings</b>	<b>Expected Service Life (months)</b>
INDURA 100% Cotton	36-50	18-24
INDURA Ultra Soft 88% Cotton 12% High Tenacity Nylon	60-80	28-38

### **PPE SELECTION**

PPE should be selected according to the requirements of the staff and the nature of job performed. Some of the elements are discussed below.

Comfort: It is essential that the staff is not uncomfortable. Otherwise there could be a danger of accidents happening. Comfort is vital both physically and mentally. PPE for great incident energy (hazard/risk category #4 or higher) may have thick and heavy clothing, headgear and gloves. The comfort level may vary from one individual to another. It is essential to make sure that each worker feels as comfortable as possible, wearing the PPE. Various staff may find various materials more comfortable than others. It may be useful to let the staff to try out the PPE to ensure that it is acceptable in terms of comfort. It may take some time before a staff gets used to new PPE. Hence, it is advised that the staff practice wearing the PPE before performing job on live exposed devices. This also assures that the PPE does not intervene with the task.

**Fit:** A loose fitting PPE gives more thermal insulation via the air trapped inside. Nevertheless, it should not be too tight or too loose so as to intervene with the task.

**Layers:** As noted in the previous section, more layers give additional air insulation and higher degree of protection. Multi-layer FR clothing is also more comfortable than a single layer of thick and heavy clothing.

**Materials:** Selection of fabric material can impact both comfort and weight. There are various types of treated cotton and synthetic fabric available from different manufacturers. For multi-layer clothing, the staff may choose to have unprocessed flammable fabric such as cotton or wool for inner garments at lower incident energies.

**Abrasion Resistance:** Some FR clothing is usable with high abrasion resistance quality. Staff that completes heavy duty job need to use this kind of PPE. Clothing without such quality can be easily destroyed, and may fail to properly guard the staff from an arc flash.

## **FR CLOTHING TYPES**

**Vest/Undergarment:** These can be worn underneath shirts, jackets or pants. They give an extra layer of protection. Multi-layered clothing is more elastic, simple to work with and has trapped air to give extra thermal insulation. Combination of vest/undergarment with a shirt enhances the total arc rating.

**Shirt/Pant:** FR shirts and pants can be utilized for incident energy of 4.0 cal/cm<sup>2</sup> or below. These can be multi-layered for greater arc rating.

**Bib Overall:** Bib overalls worn with a shirt gives greater protection to the chest area than a shirt worn with a pant.

**Coverall:** Coveralls are same as shirt and pant.

**Jacket:** These are typically multi-layered and are like multi-layered shirts.

**Hood:** The hood is part of the headgear, has face protection and has FR fabric covering the head, ears, neck and shoulders.

## OTHER PPE

Headgear: The headgear comprises of a non-conductive helmet and hood that covers the head, ears, neck and shoulders. It also has a face shield and chin cover. The face shield absorbs some of the incident energy. Nevertheless, it should not spoil visibility. Safety glasses should be worn underneath the headgear.

Gloves: Gloves give insulation from both electricity and heat. A combination of rubber (worn inside) and leather (worn outside) materials is usually utilized. The gloves should be sufficiently long to cover the sleeves.

Table 4. Voltage Classification of Gloves

<b>Glove Voltage Classification</b>	<b>Maximum Working Voltage</b>	<b>Proof Test kV</b>
Class 00	500	2.5
Class 0	1,000	5.0
Class 1	7,500	10
Class 2	17,000	20
Class 3	26,500	30
Class 4	36,000	40

Boots: Heavy duty shoes or boots should be worn where incident energies are greater than 4 cal/cm<sup>2</sup>.

Hot Stick: Hot sticks are utilized to control fuses and switches. These give insulation from the high voltage elements. They also allow the staff to keep greater working distance, so that the incident energy is lower.

Arc Suppression Blanket: This gives a barrier from arc flash.

Ear Muffs: Arc blast can induce serious ear injuries. Ear muffs should be kept to give sound insulation and decrease the influence.

Mechanical Barriers: As noted in the previous paragraphs, mechanical barriers can give protection from thermal radiation as well as from blast pressure. They can be utilized for racking breakers, but are not suited for most other work.