APPLICATION NOTE

How to use the new arc-flash PPE tables in the 2018 edition of NFPA 70E

by Jim White, Shermco Industries

Once again the NFPA 70E Committee has made significant revisions to the table method in the 2018 edition of NFPA 70E Standard for Electrical Safety in the Workplace. Since the 2000 edition of NFPA 70E the task tables have been both a boon and a bane. They were a boon, because in the absence of an incident energy analysis, the tables were often the only method available to choose arc-rated clothing and PPE. They were a bane, because they were difficult to use in the field and reduced the Hazard/Risk Category (HRC) number by 1, 2 or 3 numbers based on perceived risk.

Editor's note: We recommend obtaining the full NFPA 70E standard as a reference. It can be found at www.nfpa.org

Important note on arc-flash labels

It needs to be stated clearly that the table method is used only if an incident energy analysis has not been conducted. If an incident energy analysis has been performed the estimated incident energy exposure to the worker is calculated and an arc flash hazard warning label is applied to the equipment. Table 130.5(G) has been modified from the existing Table H.3(b) in Annex H and is intended to be used when an incident energy analysis has been performed and the equipment labeled. Since Table 130.5(G) is in the main standard text, it is now part of the standard, instead of the Annex. It is not a mandatory table, though and the 70E says its use "is permitted." Incident energy exposures 1.2 cal/cm2 and below were removed from the table, as the table only applies to arc-rated clothing, equipment and PPE.

Overview of the Table Method

The table method has been reduced to three tables; Table 130.7(C)(15)(a), Table 130.7(C)(15)(b)) and Table 130.7(C)(15)(c). Table 130.7(C)(15)(A)(a) was revised and part of it is now Table 130.5(C). Table 130.5(C) can be used for both the table method and the incident energy analysis method to assist in determining the "likelihood of the occurrence" of an arc flash. This is an extension of the changes made in the 2015 edition of NFPA 70E that looked to OSHA's 29CFR1910.269 Annex E Table 1 and eliminates many of the shortcomings of the old table method, while also providing better safety for those using it.

High level summary of the guidelines:

1. It is permitted to use Table 130.5(C) to determine the likelihood of the occurrence of an arc flash. This table may not be suitable for all work conditions and circumstances and must be used with caution. Best safe work practices would require a complete risk assessment, while using Table 130.5(C) to verify or supplement the results of the risk assessment.

2. Refer to the limits included in Tables 130.7(C)(15)(a) for ac electrical systems or 130.7(C)(15)(b) for dc electrical systems. The limits in these table set the maximum available fault current and the maximum operating time of the overcurrent protective device. The minimum working distance is also given. If any of these conditions are not within the limits of the tables, the table method cannot be used to select arc-rated clothing and PPE. If the limits are within the table requirements, proceed to Table 130.7(C)(15)(c). Note that these values are being estimated and no arc flash warning labels will be present.

   a. A new Informational Note attached to Table 130.7(C)(15)(a) provides some estimated maximum operating times of common overcurrent protective devices. As with all information such as this, those estimates may or may not be appropriate for the conditions of the task being performed. The equipment must meet all the requirements of 130.2(A)(4), Normal Operating Conditions. Some information, such

as the condition of maintenance, may not be known to the technician performing the task. If any of the conditions cannot be met fully, arc-rated clothing and PPE is always going to be required.

b. As a matter of safety, it is best to calculate the maximum available short-circuit current available at the secondary of the transformer's terminal(s) feeding the circuit when using the table method. The 2018 edition of NFPA 70E switched to the phrase "available fault current", meaning the current seen at the point of fault. Available short-circuit current refers to the current that would appear on the transformer's secondary terminal with no impedance. Since an incident energy analysis has not been done, the fault current cannot be estimated, but the short-circuit current can.

c. The available fault current will almost always be lower than the current calculated at the transformer's secondary terminals, due to circuit impedance. Using short-circuit current will provide a conservative selection of arc-rated clothing and PPE. If the short-circuit current provides an arc flash PPE category that is higher than expected, the available fault current must be calculated and appropriate PPE selected from that information.

3. Use Table 130.7(C)(15)(c) to select the appropriate arc-rated clothing, PPE and non-arc-rated PPE for the task and circuit conditions.

   a. Even though there is no longer an arc flash PPE category 0 in the table method, its use is still mandated by 130.7(C)(12), "Clothing and Other Apparel Not Permitted".

Getting into the details when applying the 2018 tables

With any given task, a full risk assessment must be performed and documented. Table 130.5(C) can be part of that risk assessment, but cannot be used as a full arc flash risk assessment. There are some tasks that always present a high risk of injury and these are noted in Table 130.5(C) such as inserting or removing (racking) a circuit breaker or for the task of voltage testing. Wherever the table states the likelihood of occurrence is "Yes", arc-rated clothing and PPE are always required for these tasks. For many of the other tasks though, the table will state "No". Sometimes, Yes is not always yes and No is not always no. The committee added Note * to Table 130.5(C), which states, "*As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible condition or situation, nor does it address severity of injury or damage to health. Where this table identifies "No" as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies "Yes" as an estimate of likelihood of occurrence, it means that additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in 110.1(H)."

Note * contains very important information. By stating that the table's assessment of the likelihood of occurrence cannot cover every possible condition or situation should make everyone's ears perk up. When the table provides a "No" it could mean that further assessment is really required, as the committee cannot foresee every possibility. A "yes" answer indicates the user of the table should apply the hierarchy of risk control methods. PPE is the very last risk control method. 110.1(H) also states that PPE is one of the least reliable methods of controlling risk. All of this needs to be included as part of the risk assessment process.

The condition of maintenance of the equipment is a common reason for PPE and arc-rated clothing to be required for a job. In large industrial facilities where there are electrical engineers and maintenance workers, condition of maintenance may not be an issue, but for smaller industrial facilities and for many commercial sites it can be. If there is any question about the condition of maintenance, the worker is automatically required to wear the PPE specified.

Something else to take note of is that the tasks in Table 130.5(C) are much less specific than in the old table 130.7(C)(15)(A)(a). This is so the table can be applied to more situations that have similar risk. Some tasks indicate that the likelihood of occurrence of an arc flash are very small and states a "No". A quick review of the tasks in this area of the table would confirm that assessment. In the next section down, all the tasks state that the likelihood of occurrence is "Yes", so arc-rated clothing and PPE will always be required for those tasks, regardless of the equipment's condition. The final two sections depend on whether the equipment meets all the conditions for normal operating condition as given in the table. Figure 1 shows a partial Table 130.5(C).

Task	Equipment Condition	Arc flash PPE required
• Reading a panel meter while operating a meter switch. • Performing infrared thermography and other non-contact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers. • Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access. • Examination of insulated cable with no manipulation of cable. • For dc systems, insertion of removal of individual cells or multi-cell units of a battery system in an open rack. • For dc systems, maintenance on a single cell or a battery system or multi-cell units in an open rack.	Any	No

Figure 1
Table 130.5(C) "Likelihood of Occurrence of an Arc Flash Incident for ac and dc Systems" Partial
From 2018 Edition of NFPA 70E

A worker has to assess all factors involved with the equipment and task about to be performed.

- Operating a 40 A circuit breaker in a 480 V lighting panel probably does not present an increased risk of injury due to an arc flash. The panel cover will probably contain most, if not all of the arc and whatever small amount of blast may be created.
  - It would be advisable to wear cotton clothing, leather gloves, hearing protection and UV-rated safety glasses in the unlikely event that a projectile or molten metal could escape the cover.
- If operating a larger frame circuit breaker, especially anything with a frame size of 600 A or greater it would be advisable to wear arc-rated clothing and PPE. It is not mandated by Table 130.5(C), but if the circuit breaker did fail the consequences would far outweigh any consideration given to comfort. A few minutes of discomfort in an arc-rated flash suit and hood is much better than undergoing the pain and suffering of a large-scale burn, not matter how unlikely it may be.

Figure 2 shows Table 130.7(C)(15)(a) "Arc-Flash PPE Categories for Alternating Current (ac) Systems". This table has been condensed from the 2015 Table 130.7(C)(15)(A)(a) ,"Arc-Flash PPE Categories for Alternating Current (ac) Systems". Actually, it might be better to say that Table 130.7(C)(15)(A)(a) was split into two parts, Table 130.5(C) and Table 130.7(C)(15)(a). Table 130.5(C) contains only the likelihood of an arc flash, while Table 130.7(C)(15)(a) only contains the arc-rated PPE category requirements and limits. The committee believes this will simplify using the table method.

Equipment	Arc flash PPE category	Arc-flash boundary
Panelboards or other equipment rated 240 volts and below Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in)	1	485 mm (19 in.)
Panelboards or other equipment rated greater than 240 volts and up to 600 volts Parameters: Maximum of 25 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in)	2	900 mm (3 ft)
600–volt class motor control centers (MCCs) Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in)	2	1.5 m (5 ft)
600–volt class motor control centers (MCCs) Parameters: Maximum of 42 kA available fault current; maximum of 0.33 sec (20 cycles) fault clearing time; minimum working distance 455 mm (18in.)	4	4.3 m (14 ft)
600–volt class switchgear (with power circuit breakers or fused switches) and 600–volt class switchboards Parameters: Maximum of 35 kA available fault current; maximum of 0.5 sec (30 cycles) fault clearing time; minimum working distance 455 mm (18in.)	4	6 m (20 ft)
Other 600–volt class (277 volts through 600 volts, nominal) equipment Parameters: Maximum of 65 kA available fault current; maximum of 0.03 sec (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)	2	1.5 m (5 ft)

Figure 2
Table 130.7(C)(15)(a) "Arc-Flash PPE Categories for Alternating Current (ac) Systems (Partial)
From 2018 Edition of NFPA 70E

Informational Note to Table 130.7(C)(15)(a): The following are typical fault clearing times of overcurrent protective devices:

(1) 0.5 cycle fault clearing time is typical for current limiting fuses when the fault current is within the current limiting range.

(2) 1.5 cycle fault clearing time is typical for molded case circuit breakers rated less than 1000 volts with an instantaneous integral trip.

(3) 3.0 cycle fault clearing time is typical for insulated case circuit breakers rated less than 1000 volts with an instantaneous integral trip or relay operated trip.

(4) 5.0 cycle fault clearing time is typical for relay operated circuit breakers rated 1 kV to 35 kV when the relay operates in the instantaneous range (i.e., "no intentional delay").

(5) 20 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay for motor inrush.

(6) 30 cycle fault clearing time is typical for low-voltage power and insulated case circuit breakers with a short time fault clearing delay without instantaneous trip.

Informational Note No. 1: See Table 1 of IEEE 1584TM, *Guide for Performing Arc Flash Hazard Calculations*, for further information regarding Notes b through d.

Figure 3
Informational Note for Table 130.7(C)(15)(a)
From 2018 edition NFPA 70E

Assuming the worker is performing a task that requires what the 2018 NFPA 70E refers to as "additional protective measures", they would step through the hierarchy of risk control methods. More than one risk control method may need to be used to account for the risk involved in the task. If the use of PPE is indicated, Table 130.7(C)(15)(a) is then used. The first step in using Table 130.7(C)(15)(a) is to find the type of equipment listed, then note the limits given in that portion of the table.

In order to use Tables 130.7(C)(15)(a) or 130.7(C)(15)(b), Section 130.7(C)(15) must be met. Section 130.7(C)(15) states "An incident energy analysis shall be required in accordance with 130.5 for the following:

1. Power systems with greater than the estimated maximum available fault current
2. Power systems with longer than the maximum arc duration
3. Less than the minimum working distance

For conditions 1 through 3 the table method cannot be used. Too many workers attempt to use the table method without consideration of the limits on its use imposed by the NFPA 70E committee. The table method can only be used on lower energy electrical power systems and is not suitable for higher-energy systems. Misuse of the table method will cause serious injury or even death if an arc flash were to occur.

Looking at the equipment type "Panelboards or other equipment rated greater than 240 volts and up to 600 volts" the parameters (limits) are given as "Maximum of 42 kA available fault current; maximum of 0.03 second (2 cycles) fault clearing time; minimum working distance 455 mm (18 in.)

All of these limits are being estimated. It is strongly recommended that when estimating, be conservative. Wearing a extra layer of arc-rated clothing is good insurance if the overcurrent protective device for that circuit decides it doesn't want to cooperate. The Arc Flash PPE Category for this equipment, within the limits given in table 130.7(C)(15)(a), would be category 2, with a 36" arc flash boundary. The table note states, "equipment rated 600 volts and below and protected by upstream current-limiting fuses or current-limiting circuit breakers sized at 200 amperes or less, the arc flash PPE category can be reduced by one number but not below arc flash PPE category 1." As with all things, there is a caveat to this note. The fault current must be great enough to cause the current-limiting fuse into its current-limiting characteristic, otherwise it will respond as a time delay fuse. This could happen if a fuse is protecting a device (such as a motor) connected by a long run of cable. The impedance of the cable will reduce the fault current the fuse sees and possibly keep it from acting as a current-limiting fuse.

A new second Informational Note to Table 130.7(C)(15)(a) provides typical operating (clearing) times for common types of overcurrent protective devices, see Figure 3. Most if these are derived from IEEE 1584, "Guide for Performing Arc Flash Hazard Calculations." This is helpful information for those not familiar with the operating characteristics of these devices, but should also be verified as much as possible.

Table 130.7(C)(15)(b) "Arc-Flash PPE Categories for Direct Current (dc) Systems"

Table 130.7(C)(15)(b) specifies the type of equipment, the parameters (or limitations of the table method), the working distance, the arc flash PPE category and the arc flash boundary, Figure 4.

Equipment	Arc flash PPE category	Arc-flash boundary
Storage batteries, dc switch-boards, and other dc supply sources Parameters: Greater than or equal to 100 V and less than or equal to 250 V Maximum arc duration and mini-mum workind distance: 2 sec @ 455 mm (18 in.)		
Available fault current less than 4 kA	2	900 mm (3 ft)
Available fault current greater than or equal to 4 kA and less than 7 kA	2	1.2 m (4 ft)
Available fault current greater than or equal to 7 kA and less than 15 kA	3	1.8 m (6 ft)

Figure 4
Table 130.7(C)(15)(b), (Partial)
Arc Flash Hazard PPE Categories for Direct Current (dc) Systems
From 2018 Edition of NFPA 70E

One major change in this table is there is no longer an arc flash PPE category 1. All categories are 2 or above. There was a typo in the 2015 edition that was not caught until the 2018 cycle revision.

The notes attached to Table 130.7(C)(15)(b) are also important. (1) states that apparel must be acid resistant if it could be exposed to battery acid. (2) it must also be arc rated. Note 2 states that the arc duration is estimated at 2 seconds if the fault clearing time is not known or there is not an overcurrent protective device. If it is known that the fault clearing time is less than 2 seconds, the actual time may be used.

Informational Notes Nos. 1 and 2 are carried over from the 2015 edition of NFPA 70E.

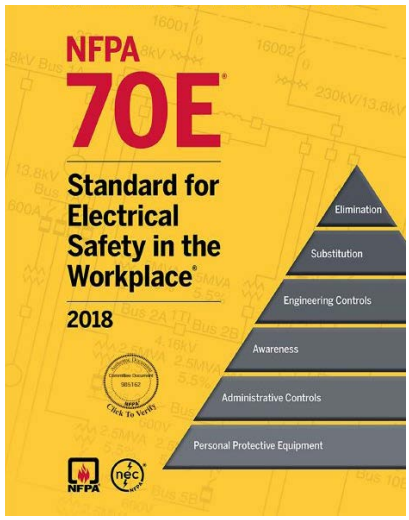

Table 130.7(C)(15)(c) "Personal Protective Equipment (PPE)"

Old Table 130.7(C)(16) remains mostly unchanged from the 2015 edition, but does have some minor changes. The arc flash PPE categories are the same, also. The table was renumbered to 130.7(C)(15)(c) to simplify the table numbering. Using 130.7(C)(15)(c) ensures it is immediately recog-nized as part of the table method.

Once it has been verified that the conditions have been met for using the table method and that the estimated limits are not being exceeded, Table 130.7(C)(15)(c), shown as Figure 5 can be used to determine the appropriate arc-rated clothing, PPE and non-arc-rated PPE for the task.

Arc-Flash PPE Category	PPE
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm² (16.75J/cm²)[a]** Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated face shield[b] or arc flash suit hood Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Heavy-duty leather gloves[s] Leather footwear (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm² (33.5J/cm²)[a]** Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Heavy-duty leather gloves[s] Leather footwear

Figure 5
Table 130.7(C)(15)(c) (Partial)
Personal Protective Equipment (PPE)
From 2018 Edition NFPA 70E

Changes to this table include Table Note c states, "Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood." In previous editions of NFPA 70E only ear canal inserts were allowed for hearing protection. This was due to concerns about the soft parts of hearing muffs melting during an arc event. The committee determined that if the other type of hearing protection are worn under arc-rated PPE, the risk of injury would be mitigated. Another thing to note is that Table Note d states that leather protector gloves are to be worn over rubber insulating gloves when used for arc flash protection. In one of the ASTM F18 Committee I attended many utilities stated they had never observed a hand injury when rubber insulating gloves were worn under leather protector gloves. This may not be universally true, especially when working on low-voltage, higher fault current situations, but the combination has proven effective over time.

Summary

The 2018 table method should prove to be easier to implement in the field and should also allow additional flexibility for those workers using it. It should also prove to be safer, as there are no reductions in PPE category number based on the perceived risk of the task. If arc flash PPE is mandated by the table method, full arc protection is specified. The bulk of the 70E committee seems to believe that the table method as it appears in the 2018 edition of NFPA 70E is going to be the best method to ensure personnel safety when it is needed. There are many facilities that will not be able or are unwilling to perform an incident energy analysis, so the table method will be necessary for some time to come.

Another aspect of the new table method that enhances worker safety is the fact that if any of the specified conditions for normal operating conditions are not met, arc-rated clothing and PPE are mandated.

Companies should train their qualified workers on how to properly use the new table method and ensure each of them demonstrate proficiency in its use. Reference Section 110.2(D)(3): "Retraining in safety-related work practices and applicable changes in this standard shall be performed at intervals not to exceed three years." This is not refresher training, but retraining that covers changes to the current edition of NFPA 70E, changes to a company's work rules and other safety-related information that may need to be provided.

Task	Equipment condition	Arc flash PPE category
Perform infrared thermography and other noncontact inspections outside the restricted approach boundary	Any	No
Reading a panel meter while operating a meter switch	Any	No
Normal operation of a circuit breaker (CB), switch, contractor, or starter	All of the following: • The equipment is properly installed • The equipment is properly maintained • All equipment doors are closed and secured • All equipment covers are in place and secured • There is no evidence of impending failure	No
	One or more of the following: • The equipment is not properly installed • The equipment is not properly maintained • Equipment doors are open and not secured • Equipment covers are off and not secured • There is evidence of impending failure	Yes

Table 130.7(C)(15)(A)(a)

3-Steps to use NFPA 70E Table Method

Step 1 – Determine the requirement for arc-rated clothing and PPE for a listed task

- If task is not listed in Table 130.7(C)(15)(A)(a) the table method cannot be used
- If ALL conditions in the second column are met, arc-rated clothing and PPE are not required by the table method
  - Even if arc-rated clothing and PPE are not required, it may be advisable to use
- If ANY of the conditions in the second column are not met, arc-rated clothing and PPE are required
- If arc-rated clothing and PPE are required, proceed to Table 130.7(C)(15)(A)(b)

Equipment	Arc flash PPE category	Arc-flash boundary
Panelboards or other equipment rated 240 V and below Parameters: Maximum of 25kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 18 inches	1	600 mm (19 in)
Panelboards or other equipment rated > 240 V and up to 600 V Parameters: Maximum of 25kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 18 inches	2	900 mm (3 ft)

Table 130.7(C)(15)(A)(b)

Step 2 – Determine arc-flash PPE category

- As an example, the task will be performed on a 480 V panelboard
- Estimate the available short circuit current and operating time of the overcurrent protective device (OCPD)
  - Available short circuit current and operating time of the OCPD are being estimated. If unable to determine either of these, defer the work until they can be estimated with confidence
- Ensure the limitations of Table 130.7(C)(15)(A)(b) are not exceeded
- Note working distance (18”) and arc flash boundary (3’) in the example
  - Always be aware of body position when working within the restricted approach boundary. As distance to the potential arc source decreases, incident energy increases rapidly (by the square of the distance)

- Set up safety barriers, signs or attendants as needed (Section 130.7(E) "Alerting Techniques")

- Proceed to Table 130.7(C)(16)

Step 3 – Choose arc-rated clothing and PPE and non-arc-rated PPE using Table 130.7(C)(16)

- In the example shown, PPE Category 2 (old HRC 2) is required
- Wear all listed PPE listed in Table 130.7(C)(16)

PPE Category	PPE
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm²** (see note 1) Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated face shield (see Note 2) or arc flash suit hood Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy-duty leather gloves (see Note 3) Leather footwear (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm²** (see note 1) Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated flash suit hood or arc-rated face shield (see Note 2) and arc-rated balaclava Arc-rated jacket, parka, rainwear, or hard hat liner (AN) **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Heavy-duty leather gloves (see Note 3) Leather footwear

Table 130.7(C)(16)

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