



Evaluating NFPA 70E Arc Flash Hazard Category Tables

By Albert Marroquin

One of the most important steps in the process of communicating safety to electrical personnel about the dangers associated with different energized equipment tasks, is to classify the tasks using the category levels described in NFPA 70E Table 130.7(C)(11). This table describes five different hazard/risk category levels (0 to 4) which are used to describe the hazard/risk level of different tasks.

The difficult part of an arc flash hazard evaluation, however, is to determine how to classify the tasks to be performed for different types of equipment that are operating at different voltage levels. For this purpose, NFPA 70E 2004 provides two methods for the classification of the risks associated with working on energized equipment.

One alternative is to use Table 130.7(C)(9)(a) to determine the arc flash risk level associated with a particular energized equipment task. This is a “lookup” table that lists different tasks to be performed on energized equipment and their associated risk levels. The other alternative is to perform a more labor intensive flash hazard analysis using the more rigorous calculation guidelines provided by the IEEE 1584 2002 Standard and/or NFPA 70E 2004 Annex D.

The purpose of this article is to help shed some light into the assumptions and generalizations utilized by the NFPA 70E Table 130.7(C)(9)(a) and to describe its limitations and shortcomings which may lead to an improper selection of the Personal Protective Equipment (PPE) required for the task.

When to Use the PPE Tables?

Ever since NFPA 70E 2004 was first published, many discussions have taken place about the validity of the use of Table 130.7(C)(9)(a); however, it is clear that there are situations which require the use of this table. Such situations include the need to perform emergency work on energized equipment without proper arc flash hazard labels.

The table is also useful for determining the PPE required for performing equipment inspection (as is the case when a flash hazard analysis needs to be performed). Arguably, the tables may also be utilized as part of a simplified safety program for facilities with small number of buses (simple radial systems with less than 20 buses).

Limitations of Table 130.7(C)(9)(a) for MCCs

Table 130.7(C)(9)(a) lists and classifies tasks to be performed on equipment like panelboards, switchboards, Motor Control Centers (MCCs), switchgears and motor starters. As an example of these tasks, the table classifies the “insertion or removal of individual starter “buckets” from MCC” (600 V class) as a task with hazard/risk Category 3 ($8 < \text{cal/cm}^2 < 25$).

This task is accompanied by footnote 4 which indicates that the maximum available bolted short-circuit current limit is 65 kA and that the maximum fault clearing time (arcing time) should be about 0.33 seconds or 20 cycles. The category level provided by the table can be validated by using power systems analysis software. The program has been configured to use the IEEE 1584 2002 method. Figure 1 shows a typical MCC configuration with an arc fault simulation at bus MCC-1.

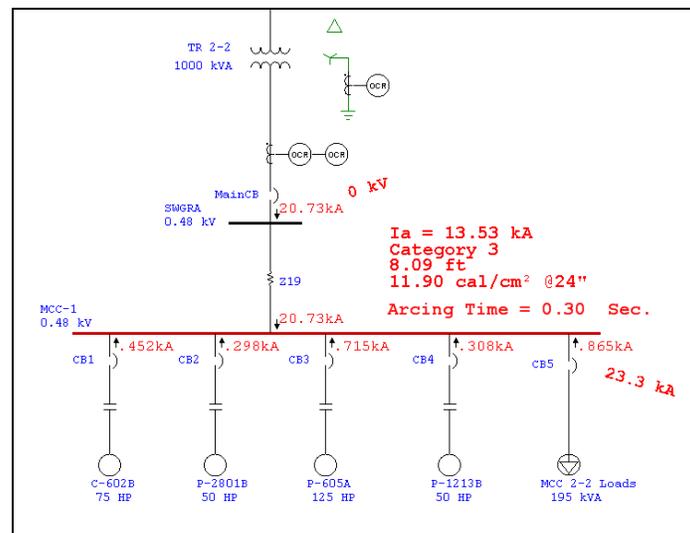


Figure 1: Arc flash simulation for a typical MCC2

The simulation is performed using typical values for the gaps (distance between energized bare conductors in mm) as published in IEEE 1584. The working distance has been assumed to be 24 inches (the NFPA 70E Table does not provide any flash protection boundary or working distances).

The MCC has a maximum available bolted short-circuit current of 25 kA. As it may be seen from the displayed results on the one-line diagram of Figure 1, the program determined a hazard/risk Category Level 3 for the faulted location (MCC-1). This category level agrees with the one listed in the table.

A different simulation was performed for the same MCC, but this time using the maximum available bolted short-circuit current of 65 kA. The use of the maximum values of short-circuit current reveals that the incident energy level could easily reach Category 4 or higher. Table 1 lists the results of the simulations performed for the MCC. Table 1 also shows the working distances and the fault clearing time for each simulated case.

Table 1: Incident Energy for a fault at MCC-1 for different working distances

Case ID	Ibf at Fault Location (kA)	Main Breaker Fault Clearing Time (sec)	Working Distance (inch)	Incident Energy at MCC-1 (cal/cm ²)	Hazard/Risk Category
Case 1	23.3	0.300	24	8.61	3
Case 2	23.3	0.300	18	13.81	3
Case 3	64.8	0.300	24	24.31	3
Case 4	64.8	0.330	18	38.98	4

Note: Ibf denotes a bolted 3-phase short-circuit current.

The results of Table 1 show that the NFPA 70E Table 130.7(C)(9)(a) may suggest the use of a PPE rating which may not be adequate for the task. The typical working distance according to IEEE 1584 2002 is 18 inches for a 0.480 Volt MCC; however, Case 4 shows that the incident energy level for an 18 inch working distance is close to exceeding the limit of Category 4 (40 cal/cm²).

In this case, the main problem of the table is that it does not list the working distance which is one of the most dominant factors in the calculation. This means that even if the available bolted fault current and the fault clearing time stay within the noted limits, the table may not provide adequate protection since the working distance is not specified. The table results are greatly generalized in this case and it may not be prudent to use the table to recommend PPE for this task on MCCs.

Limitations of Table 130.7(C)(9)(a) for MV Switchgear

We can take a second example for another very common task. Table 130.7(C)(9)(a) describes tasks for energized work on metal clad switchgear above 1 kV. In this case, we can take a 4.16 kV switchgear with typical working distance and conductor gaps based on IEEE 1584 2002 (WD =18 inches and Gap =102 millimeter). Table 130.7(C)(9)(a) recommends PPE rated for Category 4 for the insertion or removal of circuit breakers from cubicles with the doors open. Figure 2 shows a diagram for typical medium voltage switchgear and the simulated arc flash results for two different locations within the equipment.

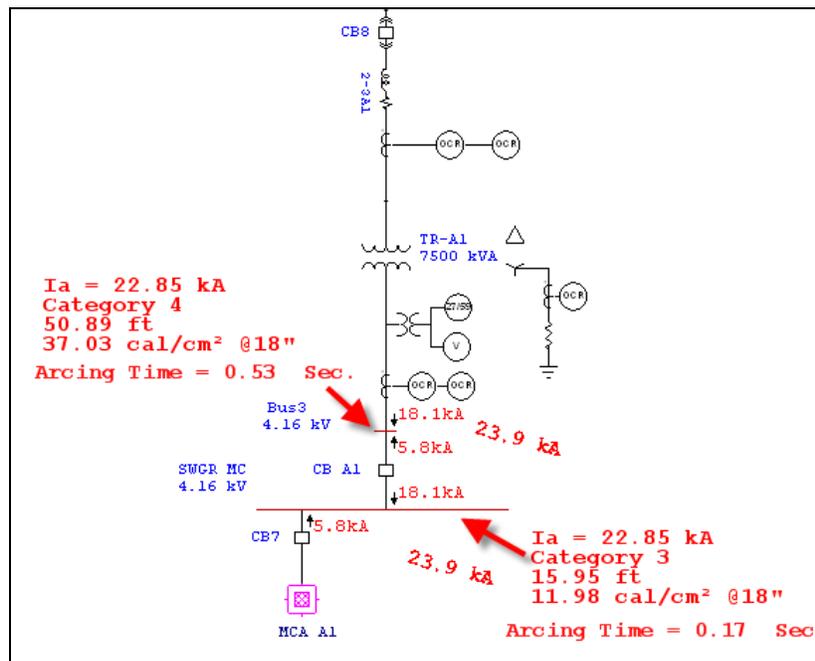


Figure 2: Arc flash simulation for a typical MV switchgear

The incident energy has been calculated for two different cubicles. One of them is a load CB cubicle and for this location the incident energy is within Category 3 limits. However, for the Main CB cubicle, the potential incident energy release is almost beyond that of Category 4. These results are in agreement with those recommended by Table 130.7(C)(9)(a); however, any variation in the clearing time or bolted short circuit current may cause the incident energy to exceed Category 4 levels.



In this case, the table fails to establish the limits for the bolted fault current and clearing time since there is no footnote which defines these limits for this task. Again, it is not a good idea to use the table to determine the PPE required for this task.

Summary of Task Category Comparisons

The previous examples illustrated the potential differences between the table recommended PPE rating and the one determined from the flash hazard analysis. Table 130.7(C)(9)(a) lists several other tasks and their hazard/risk categories. Table 2 presents a brief summary of comparisons made between the NFPA 70E table categories vs. those obtained by the using the IEEE 1584 2002 method. This table is not comprehensive and its only purpose is to show a summary of a few of the comparisons made for tasks at different voltage levels.

Table 2: Summary of comparisons made between Table 130.7(C)(9)(a) and IEEE 1584 results

Task	Equipment Type	Voltage Level	NFPA 70E Table 130.7(C)(9)(a) Category	IEEE 1584 2002 Calculated Category	Max Ibf at Fault Location (kA)	Fault Clearing Time (sec)
Removal of bolted covers (to expose bare energized parts)	Panelboard	< 240	1	0	25	0.03
Work on energized parts, including voltage testing	Panelboard Switchboard	> 240	2	0 & 1	25	0.03
insertion or removal of individual starter "buckets" from MCC	MCC	< 600	3	3, 4, & >4	65	0.330
inserting or removal (racking) of CB from cubicles, doors open ²	Switchgear	< 600	3	3, 4, & >4	65	1.000
inserting or removal (racking) of CB from cubicles, doors open ¹	Switchgear	> 1000	4	3, 4, & >4	25	0.530

Note: The IEEE 1584 2002 results were obtained using only typical gaps and working distances for the type of equipment being modeled. The maximum bolted fault current and clearing times are taken from notes 1, 2, 3, 4 & 5.

Note 1: 36 inch working distance.

Note 2: 24 inch working distance.

As it can be seen from the results shown in Table 2, the hazard/risk categories obtained using Table 130.7(C)(9)(a) may be less conservative for tasks expected to be within Category 3 & 4 levels. For tasks involving Categories 0, 1 & 2, it may be possible to use the tables as long as the available bolted short-circuit current and the arcing time are within the limits specified in the footnotes. The comparisons presented in Table 2 help to demonstrate why it is preferable to perform a flash hazard analysis instead of using Table 130.7(C)(9)(a) exclusively.

The previous analysis of the table category levels suggest that they may not be adequate for tasks which may involve Categories 3 & 4, but that it may be conservative enough for tasks listed with Category 0, 1 & 2; however, a check of the Time Current Characteristic curves (TCCs) of the protective device which is expected to clear the arc fault should be done regardless of the expected task hazard level since variations in the short-circuit current levels and clearing times can result in higher arc flash energies.

Quick Check Method

Figure 3 depicts a quick method to check if a combination of bolted fault current and arcing time yield incident energy levels below the PPE rating.

The green and purple curves in the TCC view of Figure 3 represent an incident energy level of 25 cal/cm² for 600 V class MCCs and switchgear. The curves were generated using typical working distances of 24 and 18 inches and it was also assumed that the systems were ungrounded (this yields more conservative results). The curves show the relationship between bolted fault current and the fault clearing time. If the bolted fault current increases, then the clearing time required should be less so that the incident energy level is not exceeded.

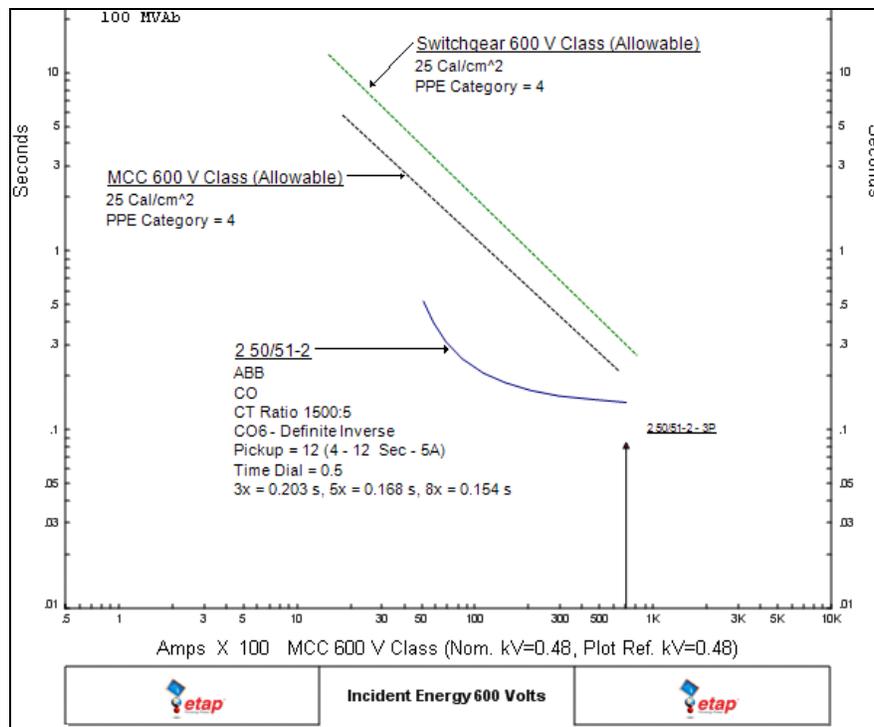


Figure 3: Incident Energy curves for typical LV MCC and Switchgear

The right hand side end of the curves represents the maximum bolted fault current and corresponding arcing time combination that yields 25 cal/cm² (onset of Category 4 level).

An overcurrent relay curve is shown below the incident energy curves. The bolted fault current is shown below as an arrow. As long as the fault current and the TCC curve are below the incident energy curve, then the incident energy should be less than the allowable limit.

A set of curves of this type can be developed for each of the types of equipment listed in Table 130.7(C)(9)(a).

Arc Flash Hazard Analysis is Imperative

From the previous discussion, we may conclude that the best approach for determining the rating of the PPE to be used for working on energized equipment is to perform an actual flash hazard analysis because the NFPA 70E tables do not contain enough details about several important parameters like working distances and equipment configuration (grounding and gaps between conductors).



Variations in these parameters may cause the incident energy exposure to be much larger than the level suggested by the table. Since it is necessary to continue to use the NFPA 70E tables under some circumstances, then care must be taken to make sure that they are only applied under the conditions and limitations stated in the table footnotes and it is also important to consider the effect of the variables not listed in the table(s).

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