NFPA 70E - Arc Flash Hazards (Updated for 2015 Edition)

An Online Continuing Education Course for Engineers

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1. Introduction

NFPA 70E came about because OSHA had difficulty adopting new editions of NFPA 70, The National Electric Code (NEC). Not only that, but some of the requirements of OSHA were different from the requirements of the NEC. So, on January 7, 1976, a new committee, called **'The Committee on Electrical Safety Requirements for Employee Workplaces, NFPA 70E'** was formed

The committee decided that the new standard would consist of four major parts. They are as follows:

1. Installation Safety Requirements.
2. Safety and Work Related Practices.
3. Safety Related Maintenance Requirements.
4. Safety Requirements for Special Equipment.

The First Edition was published in 1979 and only included Part 1. The Second Edition was published in 1981 an included Parts 1 and 2. The Third Edition was published in 1983 and included Parts 1, 2, and 3. The Fourth Edition was published in 1988 with only minor changes. Major changes were introduced in the Fifth Edition published in 1995. It was updated to the requirements of the 1993 NEC as well as the introduction of the concepts '**Limits of Approach**' and '**Flash Boundary Protection**'. The Sixth Edition, published in 2000, included a complete update to the requirements of the 1999 NEC, as well as a new Part 4. The Seventh Edition, published in 2004 emphasizes '**Safe Work Practices**'. On September 5, 2008, the 2009 Edition of NFPA 70E was approved as an American National Standard. Chapter 4 was deleted in the 2009 edition because it was determined that the provisions were covered by the NEC, NFPA70. The 2012 edition of NFPA 70E included some changes, mostly in Chapter 1. Use of GFCIs was added to help protect employees. The 2015 edition reflects a major shift in how stakeholders evaluate electrical risk. In my opinion, one of the major changes was to eliminate the Prohibitive boundary and prohibitive space. With a prohibitive space, it was impossible to even take voltage readings without violating the standard. Overall, the 2015 standard seems to be easier to implement.

With all that in mind, let's look at some parts of NFPA 70E, **Arc Flash Hazards**, that are likely to affect you and your company.

2. Changes from 2004 to 2009 Editions

The 2009 Edition of NFPA 70E was approved as an American National Standard on September 5, 2008. It eliminated Chapter 4 to prevent any confusion or duplication of effort with sections of NFPA 70, the National Electric Code. NFPA 70 is also listed in Annex A, Referenced Publications. As a matter of interest, the publications listed in Annex A are considered a part of the NFPA 70E document.

The 2004 Edition contained an Annex M which was a cross reference table between the 2000 and 2004 editions. It was eliminated. The following annexes were then added:

M. Layering of Protective Clothing and Total System Arc Rating
N. Example Electrical Procedures and Policies for Working Near Overhead Electrical Lines and Equipment
O. Safety Related Design Requirements

Annex D, Incident Energy and Flash Protection Boundary Calculation Methods was expanded and greatly clarified.

3. Some Comments on the 2015 Edition

The major revisions include the following:

1) Safety related maintenance requirements were added.
2) The definition of bare hand work and all references to bare hand work were removed.
3) The definition of Qualified Person was updated.
4) Prohibitive Space Boundary, and thus, Prohibited Space was eliminated.
5) Conditions of maintenance must be included in an Electrical Safety Program.
6) Audits of field work must be done yearly.
7) Information about temporary grounding equipment is now required to be part of the employer's job planning.
8) New requirements were added to clarify the normal operation of equipment.
9) Clarification was added to specify that either the incident energy analysis method or chart derived arc flash PPE requirements can both be used but not both. As a personal note, I would use the most conservative results. As an added note, how could you use both, if the results were different.
10) Labeling of equipment must be updated when necessary.

11) Conductive articles must not be worn within the restricted approach boundary. This includes earrings, rings, watches and metal eyeglass frames.
12) Different tables were generated for AC and DC circuits for determining Arc Flash PPE.
13) New equipment based tables were added for determining the Arc Flash PPE equipment required.
14) Hazard/Risk Category 0 was removed. This makes sense, because if there is no risk of an arc flash, it is not necessary to say so.
15) Insulated tools must now be used in the restricted approach boundary, instead of the limited approach boundary.
16) Barricades must be placed at the furthest distance, either the Arc Flash Boundary or the Limited Approach Boundary.
17) A new requirement was added that the employer must do a risk assessment when cutting into or drilling into places where electrical wiring or equipment might be located.
18) It was clarified that the equipment owner is responsible for maintenance and documentation of electrical equipment.
19) Maintenance of test instruments and test leads was clarified.
20) New section 320.3(A)(1) was added to require a risk assessment on battery systems.

In spite of what seem a lot of changes, the 2015 70E standard, appears to be easier to use. One especially important change was to eliminate Prohibited Boundary and Space. I'm sure that that caused a lot of confusion in the past. It also caused a lot of Qualified People to disobey the standard, and perhaps, even treat it with disrespect. Common sense seems to have been applied as the 27 members of the Correlating Committee on National Electrical Code and 45 members of the Technical Committee on Electrical Safety in the Workplace worked together to write and update this standard.

4. What Is an Arc Flash?

First, an electric arc is a sustained flow of electrical current through air. Welding machines make a controlled arc when they operate. In a controlled arc, the typical voltage drop is 30 to 40 volts. The air is ionized and this allows the current to flow continuously. There is a lot of energy released when an electric arc operates. For a welder, the power is the voltage times the current. That means that a 100-amp arc welder can easily generate 3000 to 4000 watts in an area the size of a pea. Temperatures in excess of 5000° C (9000° F) are easily achieved.

When Arc Flashes occur, the current is limited only by the available current of the electric system. An example from 70E for a 1500 KVA transformer with a 600-volt secondary shows a short circuit current of 26,000 amps. This would give an arc of about 27 Mega Watts.

$$P = \sqrt{3} * V * I = 1.732 * 600 * 26000 = 27.02 * 10^6 = 27 \text{ Megawatts}$$

The typical clearing time would be 6 cycles or 0.1 seconds. That would result in 2.7 Mega Watt – seconds of energy being released.

$W = P * t = 27 * 10^6$ watts * 0.1 sec = $2.7 * 10^6$ watt-sec or joules

2.7 Mega Watt – seconds is 750 Watt – hours (Just divide 2,700,000 by 3600).

$2.7 * 10^6$ watt-seconds * hour/3600 seconds = 750 watt hours

750 watt hours may not seem like much. Since 1 Horsepower is 746 watts, 750 Watt – hours is approximately 1 HP running for 1 hour. At 20 cents per kilowatt-hour, this would only cost 15 cents.

Cost = $0.20/KWH * 0.75 KWH = $0.15

It is amazing how much damage can be done by less than a quarter's worth of electrical energy. But this is happening in 0.1 seconds.

Let's look at this energy in terms of foot pounds. **One HP is defined as 550 ft-lbs/sec**. 550 ft-lbs/sec times 3600 seconds is 1,980,000 ft-lbs of energy. Look at it as a 1.98 * 10^6 lb piece of material lifted one foot off the ground. Then release all that energy in about 1 cubic inch of space in 0.1 seconds. Thinking in foot pounds gives an entirely different perspective. That is what makes an Arc Flash dangerous. That much energy released in that small of a space in that short of a time causes an explosion. Arc Flashes can occur when a line to line or line to neutral (or ground) fault occurs. The Arc Flash will persist until the source of energy is disconnected or until enough material is removed by the arc to cause it to self-extinguish. Personally, I have never seen an arc that self-extinguished, but I do think that it is possible. I saw a case once where an arc sustained itself for ½ hour before the electric company cut the wires leading to the incident. When the power company cut the wires leading to the arc, then it went away. No one was injured in that incident, but the building was severely damaged.

Here's another way to look at energy. **<u>One joule is one watt second</u>** and about **<u>0.75 ft lbs</u>**. So, if one Joule of energy were to hit one cm^2 of your skin, it would be like getting hit with a 0.75 lb brick hitting a one square cm area of your body when dropped from 1 foot. **<u>Five J/cm^2</u>** is said to be the amount of incident energy needed to cause second degree burns. This will be mentioned again later. Much of NFPA 70E uses calories as a unit of measure. Sometimes joules are used as an energy measurement. For using NFPA 70E it is good to know that 1 calorie equals 4.1868 joules and 1 joule equals 0.2388 calories. Fortunately, the area unit that is used is consistently square centimeters. So, we will see joules per square centimeter (joules/cm^2) or calories per square centimeter (cal/cm^2). 5 J/cm^2 is about equal to 1.2 cal/cm^2.

One more reference to en… released when a stick of dynamite explodes. …le of energy when it explodes. That's 1 m… will be mentioned again in reference to the ene…

5. Some Pro…

<u>The temperatures of A…</u> …s happens in less than 0.1 seconds. In most ca… …ast longer, in which case the energy level is … …time. The explosion that occurs has a distinc… …s like, visiting an electric arc furnace and … The arc is contained in the melting vessel, an… …e sound levels can exceed 160 dB. The star… …sound energy, but we can assume the Limited A… …feet 6 inches for the common 480-volt industrial system. If we a… …e Restricted Approach Boundary, it would be 1 foot. To give some idea of what this means, consider that the threshold of human hearing is about 2.9 X 10^{-10} pounds/$inch^2$ which is called 0 dB. 160 dB is about 2.6 X 10^6 pounds/$inch^2$. We get the 2.6 X 10^6 pounds per square inch by knowing that every 3 DB is a doubling of the sound pressure. There are about 53 doublings of pressure as we go from 0DB to 160 DB. Therefore:

160/3 = about 53 and 2^{53} = 9 * 10^{15} and 2.9 * 10^{-10} * 9 * 10^{15} = 2.6 X 10^6 pounds per in^2.

Of course, that 160 dB noise level would occur very close to the actual arc. I'm sure that you would not want to be that close to an actual arc flash. Noise levels do decrease with distance from the source. There can be broken ear drums and permanent hearing damage from