On The Job: In The Field

Confusion About Arc Flash Warning Labels?

DANGER! Incident Energy > 40 cal/cm2

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You look at the arc flash warning label and scratch your head. "Danger! No PPE Category Found." No personal protective equipment (PPE) category? Now what? This type of language is often on arc flash warning labels when the calculated incident energy exceeds 40 calories per centimeter squared (cal/cm^2). What is so special about the number 40? At higher incident-energy levels, blast pressure may become a significant problem. The pressure is the result of an almost instantaneous expansion of melting and vaporizing metal as well as the superheating of the surrounding air. When copper vaporizes, it can expand by a factor of 67,000 times its original volume. Results from arc flash testing in laboratory conditions have shown blast pressure can reach thousands of pounds of force, which can lead to injury and death.

NFPA 70E and the 40 cal/cm^2 question
NFPA 70E, the Standard for Electrical Safety in the Workplace, approaches blast pressure conservatively. Article 130.7, Personal and Other Protective Equipment, provides two fine print notes (FPN). FPN No. 1 addresses the explosive effect and possible injury, and FPN No. 2 specifically references 40 cal/cm2 as an upper limit where emphasis should be placed on de-energizing the equipment.
Is the incident energy greater or less than 40 cal/cm^2?

The Institute of Electrical and Electronics Engineers (IEEE) Std. 1584—Guide for Performing Arc Flash Hazard Calculations contains the most common method for calculating the incident energy. This method uses variables, such as the available short-circuit current and protective--device clearing time to determine the total accumulated incident energy. Unfortunately, the total incident energy is not always a good indicator of the potential for the arc flash to result in a blast.

Incident-energy calculations based on a small short-circuit current with a longer clearing time can produce the same answer as using a large short-circuit current and short duration. The problem is, although both may result in a large calculated incident energy, the first case may just be a long duration event (assuming the arc can sustain) while the second case may be a blast. This is where confusion typically occurs.

Explosion vs. long duration
There was a popular cartoon back in the 1960s where one of the main characters carries a bag of gunpowder with a hole in it. As the character runs off, the gunpowder leaks out of the bag, leaving a trail. Let's assume the trail uses about half of the powder in the bag. The character's rival lights the trail on fire, and it chases the character for a few seconds. Even though half the bag of powder ignites, it does not burn all at once and, therefore, does not result in an explosion. However, when the burning trail reaches the bag containing the other half of the gunpowder, it explodes because the energy is released all at once.

This gunpowder analogy is similar to what can happen when calculations focus only on the total incident energy. The calculations do not differentiate between incident energy from lower short-circuit current with a long duration and greater current with a short duration. One is an explosion, and the other is a slow sizzle.

Are all locations that exceed 40 cal/cm2 explosive? No, but in the absence of a standard to determine which cases could be explosive and which are not, the safest route is to assume all are explosive.

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The secondary side of smaller transformers often exceeds 40 cal/cm^2 and causes people to second-guess blast pressure. Small transformers typically have a lower available short-circuit current on the secondary side that could cause the protective device upstream (usually located on the primary side) to take a long time to operate.

Currently, research continues to provide a better understanding of blast pressure. Ultimately, the goal is to develop better methods for addressing the blast issue. Until then, one of the better known technical papers on the subject is “Pressures Developed by Arcs” by Ralph H. Lee, an early pioneer in arc flash theory and research.

When in doubt

If you are not sure whether your calculations exceed 40 cal/cm^2 and could result in a serious blast pressure, follow NFPA 70E’s lead, and place the equipment into an electrically safe working condition. Come to think of it, that is always good advice, even if the incident energy is less than 40 cal/cm^2.

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