EXISCAN

Arc Resistance & IR Windows

Abstract

"How can a crystal or polymer optic stand up to the enormous blast-pressure, heat and molten shrapnel produced by an arc flash?" This is a question that many engineers ask when they begin researching infrared windows. Part of the reason for the question is a misconception that the infrared window can somehow hold back the blast forces generated from an arc flash.

In fact, the role of the IR window, is not one of "protection," but of prevention. Furthermore, there is no standard for arc resistant infrared windows, although windows are tested as a part of the larger system that is arc resistant switchgear, to prove that the windows will not be a source of weakness in that system. But that is not the same as being arc resistant in and of themselves.

This paper will explore the dangers of arc flash and the forces that the resulting arc *blast* produces. The reader will also gain an understanding of the considerable safety benefits, and arc flash risk control, that infrared windows provide, as well as the realistic limitations of the devices and their role in arc resistant switchgear and MCCs.

Arc Flash Statistics:

- There are one to two arc flash related fatalities daily across North America[1]
- An estimated five to ten arc flash explosions occur daily across the US[2]
- 2,000 workers are treated in specialized burn trauma centers each year as a result of arc flash injuries[1]. These high-tech facilities only treat the most devastated burn victims -- those who have sustained incurable third-degree burns over *more than half* of their body.
- Arc flash injuries are actually much higher than reported because workers receiving treatment for trauma and burns that do not require burn unit attention (i.e. second degree burns or third degree burns covering less than half their body) are admitted to standard hospitals which do not track these injuries as arc flash related.

What is an arc flash?

NIOSH (National Institute for Occupational Safety and Health) definition of an arc flash:

> *"An arc flash is the sudden release of electrical energy through the air when a high–voltage gap exists and there is a breakdown between conductors."*[2]

The causes of arc flash are many, ranging from rodents, to insulation breakdown, to dust and contaminants. However the predomination of causes are human initiated and occur when the panel covers are not in place, or during panel removal or reapplication or when opening or closing equipment doors.

In less than 1/1000th of a second, the center of an arc flash can reach temperatures of 35,000°F / 19427°C [3]-- nearly four times the temperature of the surface of the sun (roughly 9,000°F / 4982°C). This rapid heating causes copper bus bar to turn from solid to plasma state in a fraction of a second, expanding 67,000 times. At that rate, a pea sized piece of copper will expand to the size of a rail car.

This instantaneous expansion of machine parts and the surrounding air creates an "arc blast" carrying a pressure wave of thousands of pounds of force, super-heated gases and molten shrapnel.[4] The bomb-like blast can be as powerful as three sticks of dynamite blowing up just an arm's length from the worker. It's not surprising that victims of arc blast trauma report horrific burns, shrapnel wounds, damaged internal organs, hearing loss, blindness and lung damage.

No Two Arc Blasts are Created Equal:

The IEEE (Institute of Electrical and Electronics Engineers) states "it should be realized that [an arc flash] does not always behave in a repeatable manner."[5]

It goes on to explain that test results can be impacted by design characteristics ranging from dimensions and structure of enclosure, to partition architecture, bus bar orientation, pressure relief devices and insulation systems. For this reason, results from tests on one system cannot be extended to another system, even if the two systems appear to be very similar.

The power of an arc blast will also vary widely depending on the amount of fault current / incident energy available. This can be profoundly effected by the reliability, condition and configuration of safety devices such as current limiting fuses and breakers. Studies have found that 22% of devices in the field, operate less than optimally; and 10.5% of the units tested failed to clear the fault.[6] Even the slightest reduction in effectiveness of these devices can easily double or triple the incident energy levels of an arc flash -- keep in mind these devices are designed to clear in milliseconds. Meanwhile, if a breaker fails completely, a worker could be overwhelmed with 15 to 20 times the anticipated incident energy levels.[6]

IR Window with metal cover closed and secured

Arc Resistance Versus Arc Avoidance:

Every industrialized country has instituted electrical safety standards to ensure workplace safety. Most of these standards are similar to the US standard: NFPA 70E Electrical Safety in the Workplace. In fact, many, like Canada's CSA Z462 are based in part or in whole on the NFPA 70E standard. As such, many / most of these international standards will have a large degree of focus on protecting workers from the effects of arc flash by seriously limiting the worker's exposure to "energized electrical conductors or circuit parts" over 50 volts. Eliminating the exposure, and therefore the risk, is at the heart of the ANSI Z10 Risk Control Hierarchy (sometimes referred to as the "Hierarchy of Risk").

The Risk Control Hierarchy systematically reduces risk to its lowest practicable level by prioritizing ways to mitigate a given risk. Higher priority and weight are given to methods that seek to control risk by proactive means as close as possible to the root cause. Meanwhile lower priority is placed on reactive methods of controlling damage *after* an incident has occurred. Specifically, Risk Control Hierarchy ranks the most effective to least effective ways to reduce risk as follows: [7]

> *"An electrical safety program shall identify a hazard/risk evaluation procedure to be used..."*
>
> *-- NFPA 70E, Article 110.7 (F)*

1. Elimination -- remove the hazard
2. Substitution -- replace higher risks with lower risks
3. Engineering Controls -- reinvent ways to limit/prevent the risk
4. Awareness -- raise knowledge of risks and consequences thereof
5. Administrative Controls -- create regulations, work processes, etc.
6. PPE -- use Personal Protective Equipment as *last defense*

An effective electrical safety program will include components of multiple levels of risk control, including PPE; but the most prized level of control is risk elimination. With this in mind, it is not surprising that OSHA specifically states "...with respect to arc-flash burn hazard prevention, the general provisions for the selection and use of work practices... generally require de-energization of live parts before an employee works on or near them." [8]

Arc Flash Protection:

If we accept that the best way to protect personnel from arc flash related injury is to eliminate the hazards which might cause the arc flash, then it is necessary that we proactively eliminate risk increasing behaviors: specifically we must eliminate the practice of allowing workers to be exposed to energized components -- ie. we must keep energized equipment "enclosed" and "guarded" (per NFPA 70E) whenever possible.

Using devices such as infrared windows (IR windows / infrared sightglasses) maintain the enclosed and guarded state and allow thermographers to perform their task without creating the electrical hazard inherent in opening and closing equipment. In most cases, opening energized applications 600V and higher, carries a Hazard/Risk Category (HRC) classification of three or four (on a scale of zero to four). [9] Conversely, closed panel work similar to thermography through an IR window, like reading a panel meter, only requires an HRC class zero.

NFPA specifically states that absent the introduction of electrical hazards such as those outlined in the HRC Tables, “under normal operating conditions, enclosed energized equipment that has been properly installed and maintained is not likely to pose an arc flash hazard.” [10]

By removing high-risk, hazard-inducing activities, IR windows help to eliminate risks and thereby proactively protect workers by reducing risk in the most efficient manner. However, the word “protect” must be used with caution since there is not a window on the market that has been proven to actually offer “protection” to workers in the exceedingly unlikely event that an arc flash were to occur during inspection.

Arc resistant switchgear and similar systems utilize engineering controls, such as barriers, compartmentalization, and pressure relief mechanisms to redirect arc flash / arc blast gasses and forces away from panels where personnel are most likely to be interacting with equipment. In so doing, these *engineering controls* (in Risk Control Hierarchy terms) offer *reactive* protection to personnel from the effects of the arc flash / arc blast.

Arc Resistant Infrared Windows:

So where did the term “arc resistant IR window” come from?

Some infrared windows, such as the XIR and XP series IR windows have gone through “arc resistance testing.” In actuality, it is more accurate to say that those IR windows were in place as part of the system of arc resistant switchgear -- and it was that switchgear, with IR windows in place, that was arc resistance tested per the ANSI/IEEE C37.20.7, EIC 298, and IEC 62271-200 standards for performing arc fault testing on switchgear.

The standards are clear in there intention to apply only to the *system* of a piece of switchgear and all of the components in place at the time of the test. It implicitly does not extend any “arc resistant” ratings to the individual components which happened to be in place during the test. In fact the standards point out that the results of the tests cannot be loosely applied to other systems outside the parameters of the one tested. Therefore, even a simple variation in components used, geometry of the enclosure or construction of the enclosure would require retesting to be certain that the new system would protect users.

Any attempts to extend the results of an arc resistance test to a similar, but non-arc-resistant system (one that has no pressure relief mechanisms such as vents, plenums, etc.) is in clear opposition to the standard. The pressure relief system of the arc resistant system is integral to the arc rating of the system. Without the pressure mitigation, the switchgear is incapable of containing and redirecting the heat and pressures of the arc blast. In fact it is common for a switchgear manufacturer to sell essentially the same substation assembly in a non-arc-resistant version as well as an arc resistant version -- the primary difference being that the compartments all connect to a pressure relief system in the arc resistant model.

IR windows are not tested to withstand unvented blasts in equipment has no arc resistance features. Yet the vast majority (more than 90%) of equipment in the field is not arc resistant. Unfortunately, some consumers assume that an “arc resistant IR window” has been shown to withstand arcing faults on the broad spectrum of non-arc-resistant equipment. The tests do not prove this.

Another source of confusion is an expectation on the part of some consumers that the IR window optic (as opposed to a window that is closed with the cover properly secured and sealed) has been proven in arc resistance tests to protect the thermographer. But these tests are performed with the protective cover *closed*. As stated previously, arc resistant switchgear dramatically limits and redirects the pressure wave away from the panel where the window is installed. Even so, in these tests, the window’s optic is typically compromised. However, because the cover is closed, the blast is contained during the test.

Impact Resistance Versus Arc Resistance

IEEE impact resistance standards for switchgear dictate that “a transparent material covering an observation opening and forming a part of an enclosure ... must be able to withstand a 3.4 J (2.5 ft-lbf) impact and a 445 N (100 lbf) load without cracking, shattering or dislodging.” [11]

Arc resistance tests (like IEEE C37.20.7) are performed with the window cover closed and locked. Therefore the ability of the optic to withstand any blast forces are <u>*not*</u> *checked. Instead the test is designed to certify that the window housing and cover are sufficient to keep heated gases from escaping from an arc resistant enclosure.*

Why Use an Infrared Window?

Use of an infrared window will remove more than 99% of arc flash triggers during an infrared electrical inspection. By removing the hazards, infrared windows are providing the highest level of “protection” per the Risk Control Hierarchy as prescribed by NFPA.

Unfortunately, no infrared window on its own is capable of offering an arc resistant or similar level of protection in the event of an arc flash incident. However, they can be an effective part of a switchgear or MCC system that is designed to redirect the heat and pressure of the arc blast away from the panel that the IR windows are attached to.

Companies that are interested in controlling the risk of catastrophic arc flash events should seriously consider the benefits that infrared windows offer:

- They provide a safer, more efficient work process that will allow thermographers to obtain their images and data while remaining separated from energized electrical conductors.
- They do not raise the risk of creating an electrical hazard, and instead eliminate the typical high-risk behaviors that can create an arc flash incident.
- The inspection windows provide an easy way for companies and personnel to comply with regulatory (OSHA/CSA) and insurance mandates, while requiring a minimum level of PPE protection.

References:

[1] *CapSchell Group*

[2] *NFPA 70E; Electrical Safety in the Workplace; Annex K.3; 2009*

[3] *NIOSH; Arc Flash Awareness; DHHS (NIOSH) Publication No. 2007-116D; 2007*

[4] *NFPA 70E; Electrical Safety in the Workplace; Annex K.4; 2009*

[5] *IEEE.37.7 Standard; Guide for Testing Metal-Enclosed Switchgear Rated Up to 38kV for Internal arcing Faults; Section 1.2.4; 2007*

[6] *K. Heid, R. Widup; Field Measured Total Clearing Time of Protection Devices & its Effect on Electrical Maintenance; from the Proceedings of the 2009 IEEE IAS Electrical Safety Workshop; St. Louis, MO, 2009*

[7] *ANSI / AIHA Z10 Standard; American National Standard for Occupational Health & Safety Management Systems; 2005*

[8] *OSHA 1910.303, Linhardt interpretation*

[9] *NFPA 70E; Electrical Safety in the Workplace; Section 130.7(C)(9); 2009*

[10] *NFPA 70E; Electrical Safety in the Workplace; Article 100 FPN No. 1; 2009*

[11] *IEEE C37.20.2; IEEE Standard For Metal Clad Switchgear; Section A.3.6 ; 1999*

For More Information

For additional information on this and related topics, visit Exiscan at www.Exiscan.com. or email us at info@Exiscan.com.

Exiscan manufactures a line of robust infrared windows for use in industrial and facilities maintenance settings.