OSHA and NFPA 70 Safer by Design "The History of IRISS Infrared Windows"

By Martin Robinson, CMRP Level III Thermographer President, IRISS Inc.

Abstract:

As CEO and Founder of IRISS, Inc., I am often asked how and why I designed our product line the way I did. As is common with such product development processes, there was no single epiphany which unveiled today's design to me. Instead, I arrived at our best-in-class design through an evolution of enhancements, each improving on the previous generation.

Today, I take pride in the fact that IRISS is making safe and accurate thermography available to companies around the world.

White paper

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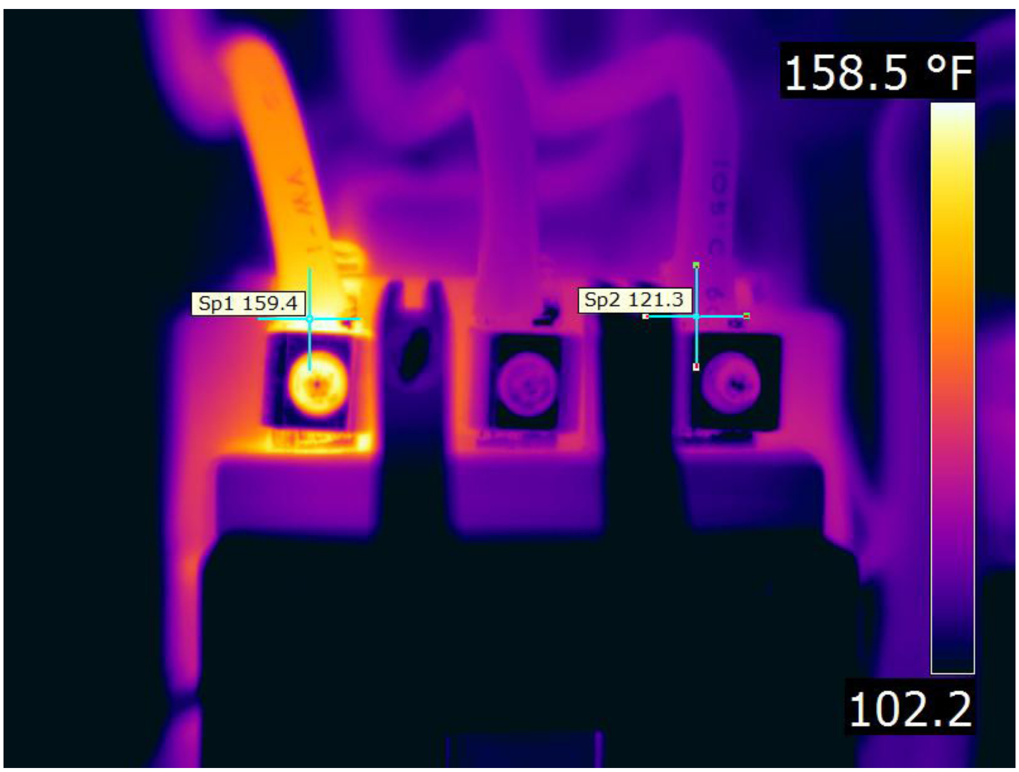
Introduction

In 1995, I started an infrared survey company specializing in Automotive Research and Development applications. Because there were very few qualified thermographers at the time, we quickly found ourselves being commissioned by facilities maintenance companies to survey electrical distribution systems within office buildings and manufacturing facilities. By the end of 1996, electrical distribution surveys became our core business, accounting for 95% of our workload.

During this transition into electrical thermography, one thing that became abundantly clear was that infrared cameras can only measure what they can "see" – this is commonly referred to as "direct temperature measurement." It was also clear that for meaningful data and recommendations, equipment must be surveyed under full load. Electrical faults hide easily when equipment is running at minimal load, and they will experience a rapid drop-off in temperature when de-energized, or off-line, even momentarily. As a result, an effective survey required doors and panel covers to be opened or removed while electrical equipment was operating under full load.

Unfortunately, performing open-panel inspections under peak load is risky business; over 99% of arc flash and electrical hazards posed during an IR inspection are made possible when panel covers and doors are removed or opened. Open-panel energized inspections, therefore, pose very real hazards to personnel, plant assets and process uptime, thereby representing a risk to company profits. Such risks were not acceptable to my clients, my staff, or to me.



To control the risks posed by energized electrical equipment there are generally 4 choices:

1. Conduct surveys during non-peak hours or during outages. This would reduce the impact of a potential accident on production uptime for our client. However, it would not reduce the risks to personnel or plant assets. Additionally, the severity of faults will not be evident, if they are visible at all, under semi-loaded conditions.

2. Conduct surveys after de-energizing equipment. Unfortunately, this is not an option in many cases due to a lack of redundancy which would impact the uptime and profitability of the plant during inspection. Again, the data obtained would be questionable at best due to the rapid cooling of faulty connections and components.

3. Inspect the exterior of the closed cabinets; a technique loosely referred to as a “cable and covers” or “indirect” infrared inspection. This type of inspection has serious limitations and will allow many faults to hide, but would still show warm isolator covers, switches, cables, etc. However, it does not show the cause of the anomalies and can lead to an unnecessary shutdown to allow for direct temperature measurements to be completed.

4. Utilize an infrared window during survey and inspection. This technique, long-used in R&D laboratories, assists in the calculation of temperatures inside an enclosed tank which could contain a vacuum, a gas, or hazardous materials. Infrared windows (also referred to as IR windows, viewports and sightglasses), allow the thermographer to identify fault conditions while keeping the electrical equipment in an enclosed and guarded condition. Because the window maintains an IP65/NEMA 4 seal, the process is entirely non-invasive and the state of the inside of the cabinet is not changed or influenced at all by the thermographer. As a result of eliminating the high-risk behavior of opening covers and removing panels during the infrared inspection, the risks posed by inspection and potential human error are actually eliminated, making the process no more risky than performing a visual inspection through a viewing pane. Keeping the cabinet closed also dramatically reduces many false positives caused by reflection issues. Overall, the use of IR Windows can make surveys less time consuming and safer for less experienced thermographers. Finally, the data can be very accurate as long as the thermographer compensates for the attenuating effects of the additional optic.

Because of the safety and technical advantages of IR windows, I began to source them from HVIR for my clients. However, my customers found them to be cost prohibitive and could not warrant the capital expenditure in most cases despite their unanimous agreement that the windows were beneficial to their infrared inspection programs.

Necessity – The Mother of Invention

It was in the best interest of everyone involved if my customers could utilize IR windows. Yet, it was simply not feasible due to the expense of the solution. Therefore, it became apparent that the market needed a cost efficient solution.

In 1997 I decided to produce a line of low-cost infrared inspection windows, high-emissivity target labels (that I designed for bus bar joint inspections) and other specialty tools to assist thermographers with conducting safe and accurate infrared electrical inspections. I branded the suite of solutions "IRISS," which stands for Infrared Inspection Support Solutions.

The first IRISS infrared inspection windows were the VPC Crystal Windows. The original VPC series was produced using Aluminum housings and incorporated Calcium Fluoride, Barium Fluoride or Sapphire crystal optics.

In 1999, we enhanced the safety of the product by switching to non-conductive materials – the aluminum IR window covers and bodies were replaced with the same UL 94V approved plastics used in switchgear contactors. The benefits of plastics have long made it a standard material used in the electrical equipment. In addition to its insulating qualities, the plastics selected for our windows did not corrode or react with acids or alkalis. The injection molding process also made it possible to mass produce the bodies, thereby reducing the per-unit costs of the windows, making the safety and efficiency of IR windows even more affordable and within reach of more companies.

More Challenges and Continuous Improvement

The plastic IR window housings were a great success. Based on the experience my team and I had using the windows on a daily basis in our diverse client locations, we continued to improve the design to enhance the safety, durability and usability of the product.

Soon the plastic-bodied windows became our standard while we continued to use various crystal optics. During this time, camera manufacturers began adopting long wave (7–14 microns) infrared cameras as the industry standard. As a result of this technological market shift, our choices for optics were quickly restricted. IRISS discontinued the use of sapphire IR windows as this material is only transmissive in the medium wave infrared spectrum (3–5 microns), and is non-transmissive in the long wave. Barium Fluoride was also reclassified as a carcinogenic material and it was immediately disqualified as a viable solution due to the associated health risks for our manufacturing personnel and for the thermographers who would use the product.

The only remaining cost-effective choice at the time was Calcium Fluoride. Unfortunately, we were also starting to notice consistent issues among the Fluoride family of crystals – both in our own and all Fluoride crystals from other manufacturers. And to make matters worse, Calcium Fluoride was showing itself to be the worst of all the common Fluoride optics. The inherent failure modes were:

1. Breakage through impact
2. Transmission loss through water ingress, and attack from acidic/alkali environments (regardless of coatings or treatments)
3. Transmission loss through mechanical stress (high frequency noise and vibration)

The Quest for an Industrial Grade Window

I had achieved my initial goal of designing the lowest priced infrared inspection windows in the world and I was confident that the quality of my windows was at least as good as any other on the market (if not slightly better due to improvements in body designs, usability, etc.) As a Level III thermographer who was using the windows daily, and as the owner of an inspection company whose credibility and reputation was on the line with every inspection my team performed, I was not satisfied with using any Fluoride optics. I was not content with the technical performance and margin of error which is inherent in Fluoride lenses as they age. I was also not content with the lack of long-term survivability of the windows in real-world use. Ultimately, I was not satisfied with the implications to the safety of my thermographers due to the lack of impact resistance.

In an ongoing effort to continually improve product performance, I began to search for a material that would be suited to the industrial environment. The new optic had to be impact resistant and flame resistant. The material would have to have a high melting point and excellent chemical compatibility. It would have to be unaffected by moisture, acids or alkalis, salt water, and humidity. Additionally, the material could not degrade due to environmental vibrations or high frequency noise.

In 2003, I found a material with IR Transmissive polymers that was impact resistant and had a higher melting point than the Lexan and Plexiglass which had been trusted world-over in switchgear viewing panes. Its transmission rate is unaffected by acids, alkalis, moisture, saltwater, humidity, vibration and high frequency noise. These very same polymers have been in use for decades in extreme environments with no structural or transmission degradation. The material was also cost effective and tests proved that I could be confident in its performance. I had found my grail!

The VPF series of IR windows were launched. The windows are UL Certified to UL508 & 508A, and for IP65/NEMA 4 in open and closed positions.

The transmission rates were higher than Calcium Fluoride at 9 microns (my chosen long wave infrared benchmark point), but more importantly, the transmission rate was stable and therefore thermographers could compensate for the attenuation of data accuracy and trending of the temperature calculations. Due to the enhanced manufacturing procedures and lower material costs, we were able to reduce the per unit price of the new VPF windows to a point that they were less than half the price of anything else on the market. As such, more companies could perform inspections and surveys on far more assets with safety and more efficiency than ever before in industrial applications.

Standards Compliance

In 2004, I began researching the industry's recognized standards to be sure that our window were bestin- class in every possible way. I quickly found that there was an almost total lack of understanding in the market regarding what standards should be applicable to infrared windows; and equally confusing was the fact that the standards organizations had little to no direction since infrared windows were, at that time, still a relative novelty outside of research and development. I discovered that UL only certified switchgear to 1500 Volts, and there was no classification for "infrared windows." Due to the general lack of direction for what standards specifically should apply to my products, I concluded that the only responsible thing to do was to benchmark my windows to other standards for similar items used in switchgear and other electrical applications.

For medium and high-voltage applications, I looked to the IEEE standards and found very clear requirements that visual inspection panes (typically made of polycarbonate - which is non-transmissive in the infrared spectrum) should not crack, shatter or dislodge when impacted or loaded from the inside and outside of the viewing pane (no exemption for crystals exists in the IEEE standards). The reason for such requirements is obvious, and because an IR window is simply an inspection window used by thermographers, I felt that this would be the most relevant of the IEEE standards to test to. The VPF windows exceeded the standards for impact, but we added a plastic reinforcing grill to the polymer to help withstand the load requirements. The new reinforced windows were introduced as the VPFR series. As a result of the reinforced optic, the IRISS windows were now the only infrared inspection windows with the impact resistance and structural integrity of the standard visual inspection windows used in lockout/tagout (LOTO) verification. Ironically, many companies had been opting for the crystal windows to serve double duty for thermography and visual inspection on medium and high-voltage applications in unwitting violation of the IEEE standards, since crystals easily shatter, crack and dislodge at far lower impact and load forces than required in the standard.

By sizing the reinforcing grills to 5/8 inch (IP2X), we were also able to comply with the IEEE's requirement for maximum allowable hole size so that even in a damaged state our windows would still allow companies to operate within IEEE standards. We now had the only IR window which was designed to be failsafe.

In 2005, we then tested the new VPFR to the UL 746C standard for optics used on control panels. This standard tested the lens assembly for flammability at room temperature, and for impact resistance at 0°C. To add additional structural integrity to the robust reinforced optic, the VPFR now included a plastic coated Aluminum grill. For the coating, I again opted for the same type of plastic used in the contactors of most switchgear which insulated to 30kV/mm, and thereby electrically isolated the grills so that additional grounding was not required. The lens system easily passed these tests and is the only infrared window lens system in the world that holds this certification.

During this process I discovered that crystal optics are exempt from UL impact testing – apparently, crystals are classified as "glass," and glass thicker than 1.4 mm is not required to pass a UL impact test. I still find it unbelievable that no consideration is given to ensure that a material which a worker will place his eyes in front of has no safety testing requirements in the event of an impact from the inside of an electrical cabinet as required by IEEE!

Soon after that I decided to add an additional reinforcing grill on the inside of the window, effectively sandwiching the polymer, further improving the VPFR series of IR windows.

Always up for more challenges, the windows were then subjected to a series of 50kA arc fault tests. In these tests our infrared windows were fitted to arc resistant switchgear. The switchgear was then subjected to an arc flash event. In these tests, IRISS windows have performed flawlessly and have been shown to maintain their integrity during the blast so that the elaborate safety mechanisms in the arc resistant gear could redirect and mitigate the forces of the blast. Despite the confusion around the topic, passing arc resistance tests does not give the windows in question any "arc rating." Only the system at large, of which the window is a component, can receive such a rating since component-level rating does not exist. For example, how many "arc resistant bolts" or "arc resistant panel meters" have you seen advertised? There are a lot of bolts and meters on arc resistant switchgear and those bolts and meters would have certainly been involved in the tests as well.

Versatility Opens New Doors

Because the reinforced polymer optic maintains its resiliency and strength in a variety of sizes and shapes, we soon found that we could fabricate custom windows for a variety of applications where thermographers were previously unable to use windows for one reason or another. Using stamped steel, we have made IR windows in virtually every size and shape imaginable.

To eliminate the risk of dislodging breakers due to the removal of covers during IR inspections of breaker connections, we make custom dead-front panels for power distribution panels. These custom deadfronts feature a continuous window along the columns of the breakers, allowing thermographers to inspect breaker connections with the panel in place. Safer and far more efficient than removing panels, now thermographers can inspect connections under full load without risking process uptime.

Some clients have requested custom windows to allow them to “see” through guards to inspect mechanical applications such as couplings, or even complex systems of machinery which are guarded behind Lexan shields.

A large mining company lost a critical motor due to commutator block issues. We made commutator block covers which are formed to fit the curve of the motor bell. The thermographers at this mining facility now monitor their commutator blocks monthly for potential slippage using these block covers. Security camera housings and lens protectors are also a simple extension of the principals used in our Windows.

Mission Accomplished

Over the span of a little more than a decade I have designed and manufactured a line of infrared inspection windows that I am truly proud of. IRISS designs are based on my personal real world experience (as a Level III Thermographer) while using the products on a daily basis, and based on the input of my service team and clients. As a result, they are:

- The most cost-effective IR windows on the market
- The only impact resistant and most resilient IR windows in the industry
- Versatile and Customizable
- Technically superior in the industrial environment due to the inherent stability of the polymer’s transmission rate and general resiliency
- Designed failsafe for added safety
- Flame resistant per UL and IEEE standards, with a higher melting-point than polycarbonate, which is a trusted industry standard for visual inspection panes
- Non-conductive, like everything else you touch on switchgear
- Made of industrial-grade plastics and stainless steel for decades of service without corrosion or breakage in most industrial or building maintenance settings
- Truly worthy of the industry’s only Unconditional Lifetime Warranty

In short, IRISS products and solutions are designed and field tested by a Level III thermographer for useby other thermographers who value safety, efficiency and accuracy. By their very nature IRISS products are simply safer by design.