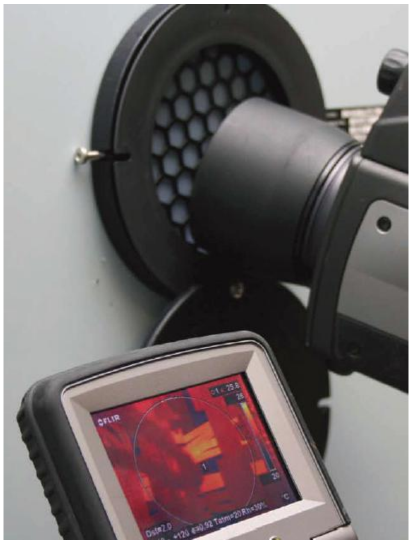
IRISS Windows



IR Inspection windows are used to to facilitate safer, more efficient inspection of energized electrical equipment.

An infrared window (also referred to as a viewport or port) is a generic term used to describe an inspection point that is designed to allow infrared radiation to transmit to the outside environment while maintaining IP or NEMA ingress protection standards.

The infrared window is expected to maintain an "enclosed" and "guarded" condition for the enclosure.

Polymeric Lens Materials

The past several years have seen a move toward the use of transmissive polymers as a lens material due to their inherent resiliency and stability. These materials are unaffected by mechanical stress and will suffer no effects on transmittance. They are stable: nonreactive to moisture, humidity, seawater, and a broad spectrum of acids and alkalis – in short, they are well suited to handle the rigors of the industrial environment.

Polymers are also extremely resilient. Because they are malleable, they will tend to absorb impact rather than shatter. When reinforced, with specially engineered grills, the optic is capable of resisting a sustained load. As a result, the only long wave compatible IR window optic capable of passing industry standard impact tests is a reinforced polymer optic. A reinforced polymer optic can maintain a consistent thickness regardless of window diameter because the cells of the reinforcing material remain a consistent diameter. Consistent optic thickness means consistent transmission rate — regardless of window size.

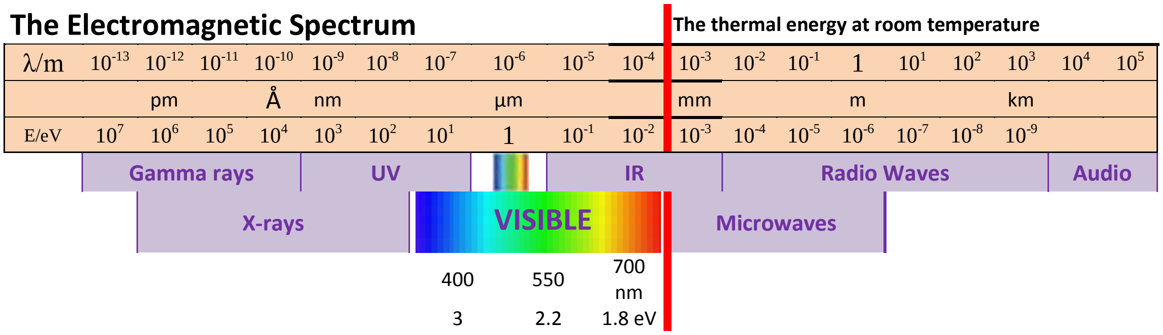
The only applications ill-suited to polymer optics are those in which the ambient temperature (not target temperature) is expected to exceed 200°C (392°F). Even so, polymer windows must meet stringent flammability and impact tests.

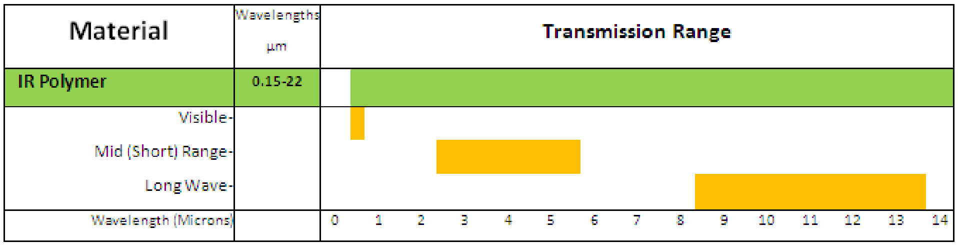
The Science of Infrared Thermography

The electromagnetic spectrum is a continuum made up of cosmic rays, gamma rays, X-rays, ultraviolet light, visible light, infrared radiation, microwaves and radio waves (in order of increasing wavelength and decreasing power). Infrared is that portion of the spectrum between 0.75µm (microns) and 1000µm in wavelength, starting just beyond what the human eye is capable of seeing.

All objects above absolute zero emit infrared radiation. As an object heats up the intensity of emitted radiation increases exponentially and the peak radiation shifts to shorter and shorter wavelengths.

Today's radiometric IR imagers are capable of "seeing" and calculating the emitted radiation from a target object. There are only three sources of this radiation: it can be reflected from other sources; it can be transmitted through the object from a source behind it; or the radiation can be emitted by the object.





Radiometric IR imagers are capable of detecting and calculating the emitted radiation from a target object.

There are only three sources of this radiation:

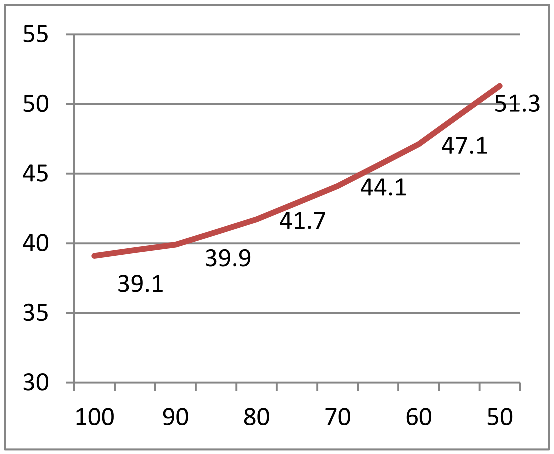
- It can be reflected from other sources
- It can be transmitted through the object from a source behind it
- The radiation can be emitted by the object.

The sum of the radiation leaving the surface of an object equals one: expressed as Watts Emitted (ε) + Watts Transmitted (τ) + Watts Reflected (ρ) = 1.
Therefore, emitted energy, reflected energy and transmitted energy are the only three possible sources of infrared energy coming from a target object.

A perfect emitter is referred to as a ***blackbody***. A blackbody emits 100% of the energy it absorbs. Since by definition there is no reflection or transmission, a blackbody has an emissivity value of 1.

For real-world objects (referred to as ***real-bodies***), emissivity is expressed as the ratio of the radiant energy emitted by that object, divided by the energy that a blackbody would emit at that same temperature.

This graph shows how calculated temperatures can be adversely affected when the imager's emissivity value is set too high. In this example, the emissivity of the target is 0.50; the graph shows the apparent temperature when the imager's emissivity setting is stepped down from 1.0 to 0.50. When emissivity is properly compensated for, the actual temperature is shown to be 12.2° higher.



Magnitude of Error

One of the most misunderstood concepts in thermography is the degree to which errors in emissivity settings (and errors in window transmissivity compensation) will affect temperature and ΔT (difference in temperature) accuracy.

The Stefan-Boltzmann Law states that the radiated infrared energy emitted by a target surface is exponentially related to the absolute temperature of that surface.

$W = \varepsilon\sigma T^4$

Where:

W = Total Radiant Power in Watts/m^2

ε = Emissivity (unitless)

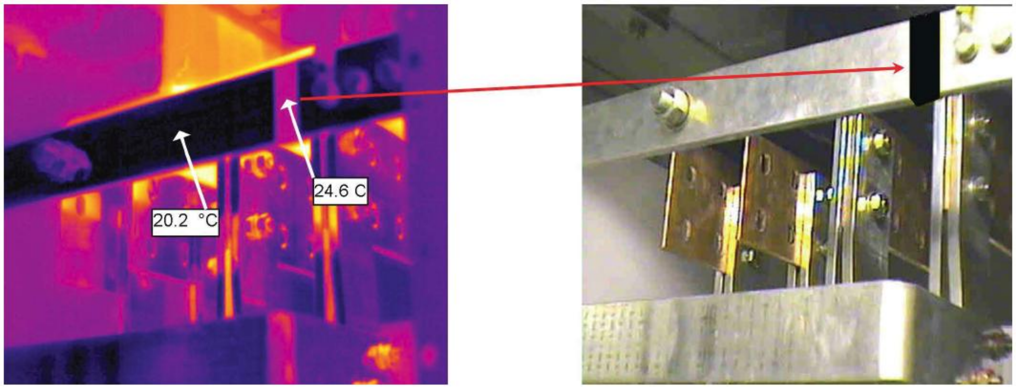
σ = Stefan-Boltzmann Constant ($1.56\text{X}10^{-8}\text{W/m}^2\text{K}^4$)

T = Absolute Temperature in Kelvin

Therefore, as the temperature increases, radiant energy increases proportionally by the absolute temperature to the 4th power. Incorrect camera settings such as emissivity and infrared window transmission rates will result in errant temperature values. Furthermore, because the relationship is exponential, this error will worsen as the component increases in temperature. Consider the effect on ΔT comparisons, which are by their nature a comparison between different temperatures. The resulting calculations are apt to be radically understated, which could easily lead thermographers to misdiagnose the severity of a fault.

Emissivity Standardization

For some components, it can be difficult to determine the correct emissivity value. In the case of a highly polished component like a bus bar, the actual emissivity may be so low as to make temperature measurement impractical. It is necessary to identify and understand the surface of the primary targets. Once identified, those surfaces should be treated with a high-emissivity covering so that all targets have a standardized emissivity. Thermographers can apply electrical tape, high-temperature paint (such as grill paint), or high-emissivity labels (like the IR-ID labels from IRISS). When all targets have a standard emissivity, refection issues are minimized and measurement errors from reflected ambient energy are greatly reduced. High-emissivity targets of varying shapes can also provide a useful point-of-reference both for the thermographer and the technician making repairs.



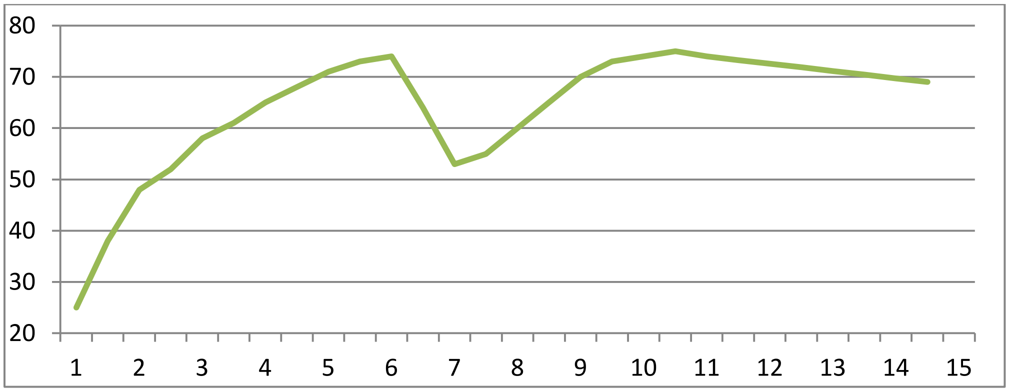
The left image above is a thermogram of the interior of a piece of switchgear. It appears to show a wide variation in temperature. In reality, this switchgear is new and has never been energized. The differences in shading in the thermogram are all due to reflection issues. The image to the right above shows a piece of electrical tape around one area of the busbar. The tape in the thermogram shows the true temperature of the reflective bus. This is a prime example of a thermogram not being worth the paper it’s printed on unless emissivity is known.

IR Window Transmittance

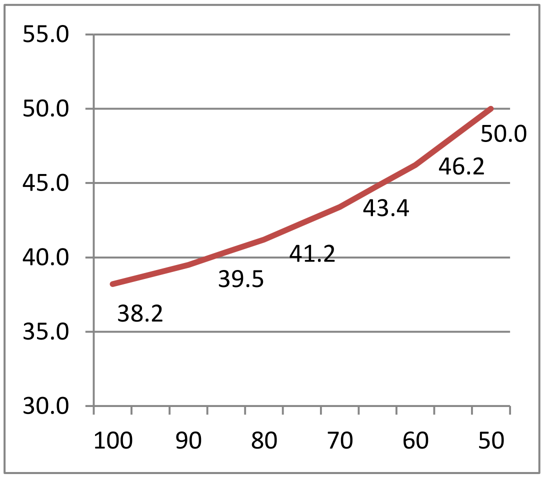
Maintenance professionals can use infrared (IR) cameras to take both qualitative (image only) and quantitative (temperature measurement) images. To ensure that quantitative images are accurate, it is important to understand what other variables in the external environment can lead to possible measurement errors.

In addition to reflection and emissivity, distance, humidity and camera angle can all play an important role in accurate temperature measurement. But when thermographers use IR windows, improper window transmission compensation can easily affect apparent temperature and apparent ΔT calculations by 30% and more.

Infrared inspection windows have become an industry standard way to facilitate infrared electrical inspections while increasing both the safety and the efficiency of the inspection process. While window optics can be made of a variety of different materials, they generally fall into one of two categories: crystal or polymer. IR Polymer windows are used in the Solar Inverter Enclosure. The following graph demonstrates the degree to which the transmission rate of IR Polymer will change across the IR spectrum.



Given the transmission variability across different wavelengths, one needs to define the transmission rate at a specific wavelength. Research shows that this “PdM” wavelength is at about 9µm in the LW band and about 4µm in the MW (SW) band. For accurate temperature calculations, it is irrelevant whether the window’s transmissivity coefficient is 90%, 50%, or something in between. What is important is that the thermographer knows the exact transmission rate. Then when the thermographer enters the correct coefficient into the camera or software, the final temperature calculation will be accurate and reliable. If, however, the thermographer is not aware of the *actual* transmission rate, or does not adjust for it, the errors can be significant.



The graph to the right shows how calculated temperatures can be adversely affected when a thermographer improperly compensates for transmission. In this example, the transmission rate of the IR window is 0.50. The graph shows the apparent temperature when the imager settings are stepped down from 1.0 to 0.50. When transmission is properly compensated for, the actual temperature is shown to be 11.8° higher; very similar to the effects of emissivity compensation.

All window optics will filter, or "attenuate" the amount of infrared radiation that ultimately reaches the imager. In addition, tilting the camera angle 30° to either side of 90° (perpendicular) reduces the temperature by an additional 2-3%. The majority of infrared cameras do not have the ability to compensate for transmission losses from an IR window directly; but almost all software packages do. To make a quick adjustment in the field, simply multiply the transmission coefficient by the target emissivity to arrive at a "calculated emissivity value," and adjust the camera's emissivity setting to this value. For example, an IR window with a 0.55 transmittance rate and a target with an emissivity of 0.95 (electrical tape) would require a camera emissivity setting of 0.49 (0.90 x 0.55 = 0.495) to properly compensate for both transmission and emissivity.

Field of View (FOV) through an IR Window

Measurement Field of View (MFOV)

First, let's examine the camera and lens specifications. We are primarily concerned with the MFOV (Measurement Field of View), also referred to as the ***Spot Size Ratio***.

Every camera defines its FOV across a horizontal/vertical axes. The Instantaneous Field of View (IFOV) is the smallest target the camera can see. Although an IR camera can pick up numerous hot spots, many spots will be too small to measure accurately with a radiometric IR camera (one which displays temperature on the image). The MFOV or Spot Size Ratio is the smallest target the imager can accurately *measure*.

The greater the resolution of the camera: the better the IFOV. For example, one top-selling camera uses a 640 x 480 pixel array. It has a MFOV of 500:1, while a 320 x 240 camera has an MFOV of 200:1. In these examples, a one-inch diameter target could be measured from a distance of 500 inches (41.7 feet) by the higher resolution camera; whereas the other camera would have a maximum distance of 200 inches (16.7 feet).

A telescopic lens (typically a 12° or 7° attached to a standard 24° lens) will also improve FOV by a factor of 2X and 3X respectively. Therefore, a 7° lens used on that high resolution camera would allow measurement of a one-inch target from a maximum distance of 125 feet (1”:500 x 3 = 1500” / 12”).

Think of resolution as the quality of sight. The poorer the quality of sight, the closer you will need to be to see you’re the target (temperature). While looking at the target from far away, high resolution will help, but you may be too far away to see the detail clearly and would require 7° telescopic lens attachment to see clearly.

Window Field of View (WFOV)

Typically, IR cameras have a standard FOV of approximately 24° (horizontal) and 20° (vertical). So, it is advisable to do calculations based on a standard lens (since a wide angle may not always be available).

Note that the calculation assumes that the FOV begins at the panel cover and extends a distance (d) from the panel cover to the targeted components. The length along that FOV is a distance (D). D is calculated by multiplying the distance (d) by the tangent of half the lens angle, then doubling the result.

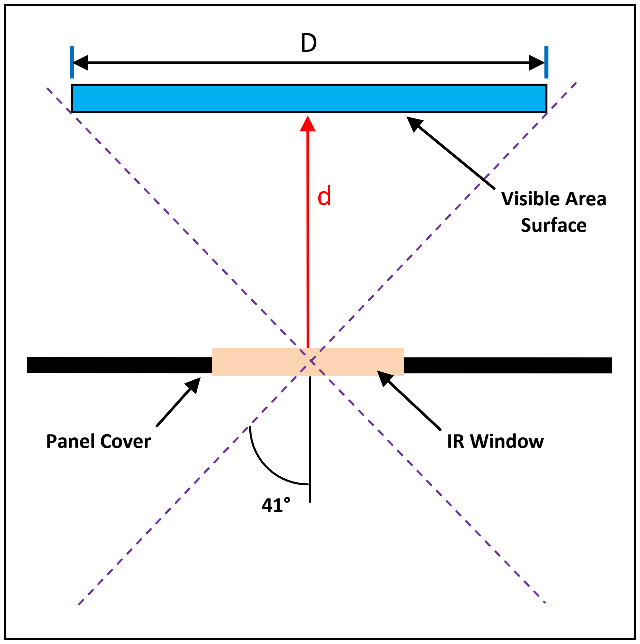
Standard calculations assume that FOV starts at a single point, or vertex of the viewing angle. It does not take window size into account. So for a calculated D of 2.8” add an additional two/four inches when using a two or four inch window (yielding a D of approximately 4.8/6.8”).

The illustration to the right shows the area inside a cabinet that can be viewed through an IR window using a camera with an 82° FOV lens.

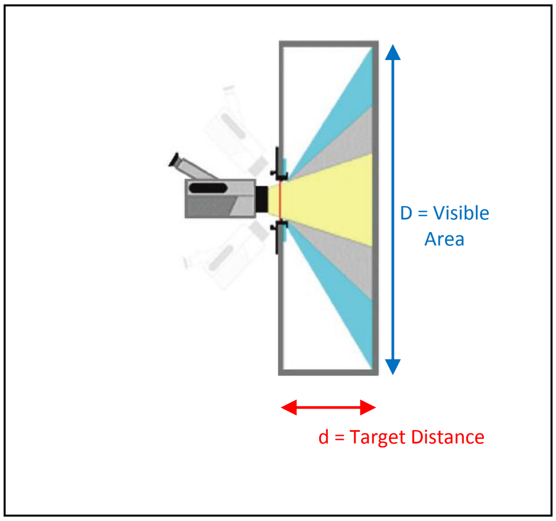
Using a depth of 8.5 inches:

D = 2d x (tangent of 41°)

D = 2*8.5 x 0.87 = 14.8 inches



The calculations above indicate that with an 82° FOV lens, a thermographer can view 14.8 inches horizontally inside the panel. However, this calculation assumes the thermographer holds the camera fixed and perpendicular to the window plane. More likely, the thermographer will vary the viewing angle up to 30° from perpendicular in all directions. This effectively increases the FOV area by a factor of three.



Camera Angled for 2X standard FOV

D = (2*8.5) x 0.87 x 2

D = 29.6 inches

Camera Angled for 3X standard FOV

D = (2*8.5) x 0.87 x 3

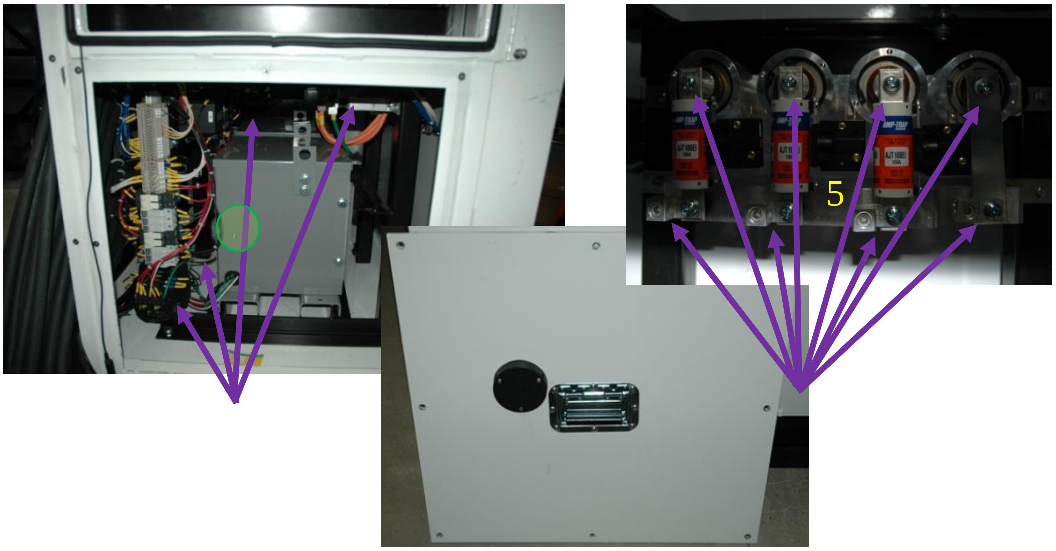
D = 44.4 inches

Identify All Targets:

Start the process by identifying specific targets on each piece of equipment. In addition to fuses and breakers, most infrared surveys focus on bolted connections within the gear, as these areas are considered the weakest points. These areas include:

- Cable connections
- Bus bar connections
- Isolator or circuit breaker connections

The primary targets of interest under Access #8A and Access #8B (viewed through windows 8A1, 8A2, 8B1, and 8B2) are the incoming bolted connections of the DC fuses.



The targets of interest under Access #5 (viewed through window 5) are the connections on the power quality meter, the incoming and load connections on the fuses, the incoming bolted connections on the Strikesorb fuses, and the connection between the Strikesorbs and the Strikesorb fuses.

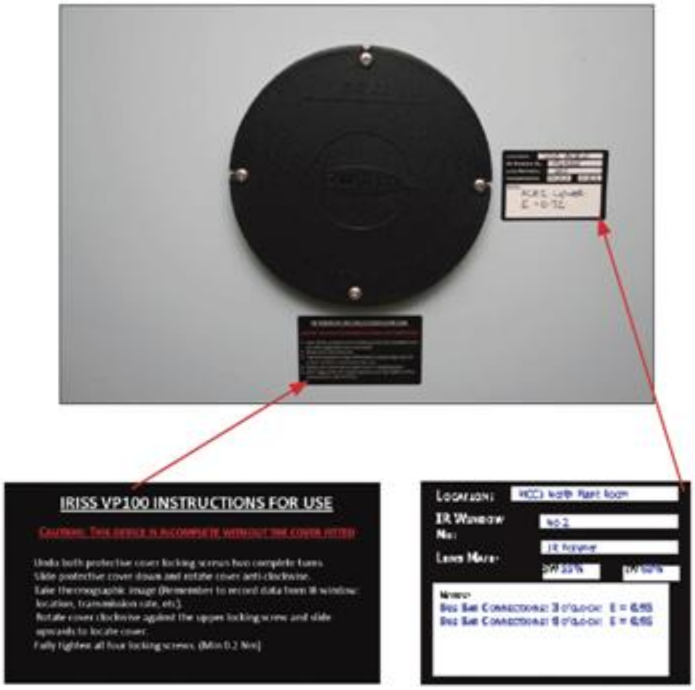
Electrical tape or IRISS IR-ID labels can be utilized to standardize the emissivity (The tape or labels should only be applied while the equipment is de-energized). It is important to have a current photograph of each target since these photos will be used for report templates and future reference.

PPE:

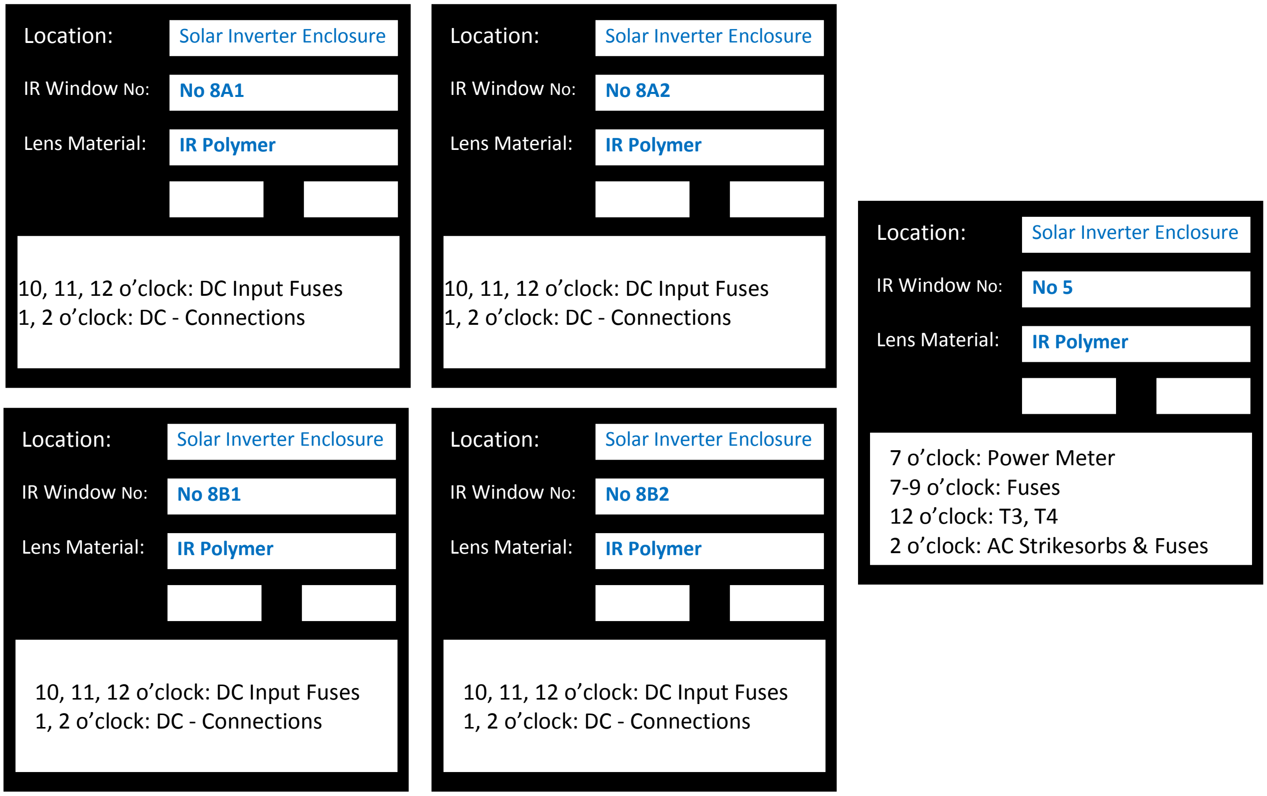
Complete a detailed Risk Assessment (identifying all hazards that may be present) and a detailed Method Statement (detailing how the task will be performed). Make sure that the crew has the correct levels of PPE to complete the task safely. An energized Work Permit will also be required per NFPA 70E/CSA Z462. All work procedures, assessments and permits must be outlined in the Risk and Method statement.

Labeling

An information label is affixed to identify what the window is and how to use it. A second sticker contains the following information that will be critical in performing a thorough and accurate infrared inspection:



- Each inspection window should be given a unique number.
- Document the type of window (MW or LW) and the effective wavelength of the window.
- Record the transmission rate of the window, and the proper transmission compensation value for the MW and LW.
- Record all target data on the on the ID label. The most common method of documenting target location is the clock face method: i.e. bus bar connections at 4 o'clock. It should be noted that there may be multiple targets being surveyed through the IR window.
- Some cameras do not have the ability to adjust the external optics transmission; therefore, thermographers may use the emissivity settings on the camera to cover transmission and emissivity losses. Multiply the target emissivity by the transmission rate of the window.



Location: Solar Inverter Enclosure
IR Window No: No 8A1
Lens Material: IR Polymer

10, 11, 12 o’clock: DC Input Fuses
1, 2 o’clock: DC - Connections

Location: Solar Inverter Enclosure
IR Window No: No 8A2
Lens Material: IR Polymer

10, 11, 12 o’clock: DC Input Fuses
1, 2 o’clock: DC - Connections

Location: Solar Inverter Enclosure
IR Window No: No 8B1
Lens Material: IR Polymer

10, 11, 12 o’clock: DC Input Fuses
1, 2 o’clock: DC - Connections

Location: Solar Inverter Enclosure
IR Window No: No 8B2
Lens Material: IR Polymer

10, 11, 12 o’clock: DC Input Fuses
1, 2 o’clock: DC - Connections

Location: Solar Inverter Enclosure
IR Window No: No 5
Lens Material: IR Polymer

7 o’clock: Power Meter
7-9 o’clock: Fuses
12 o’clock: T3, T4
2 o’clock: AC Strikesorbs & Fuses

IR Window Information Labels

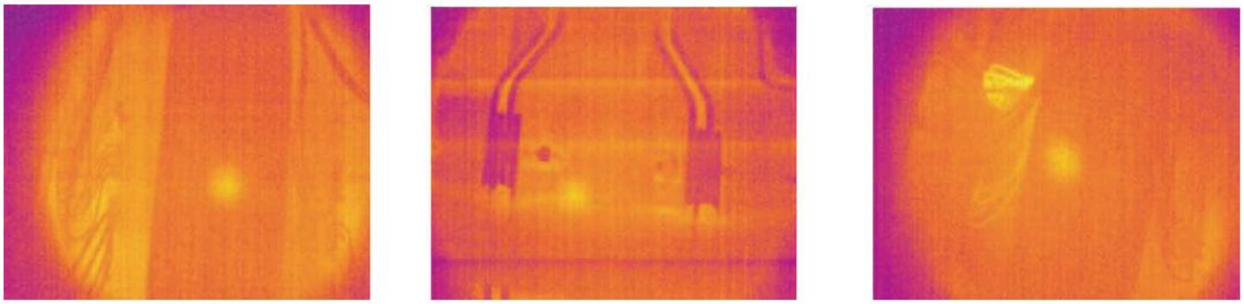
Baseline

Before the Solar Inverter Enclosure is put into service, the thermographer should conduct a benchmark inspection to set the base line. Data for each inspection point should be recorded in a spreadsheet or database for trend analysis over several surveys. There are software programs available to assist with database management and trending of infrared data.

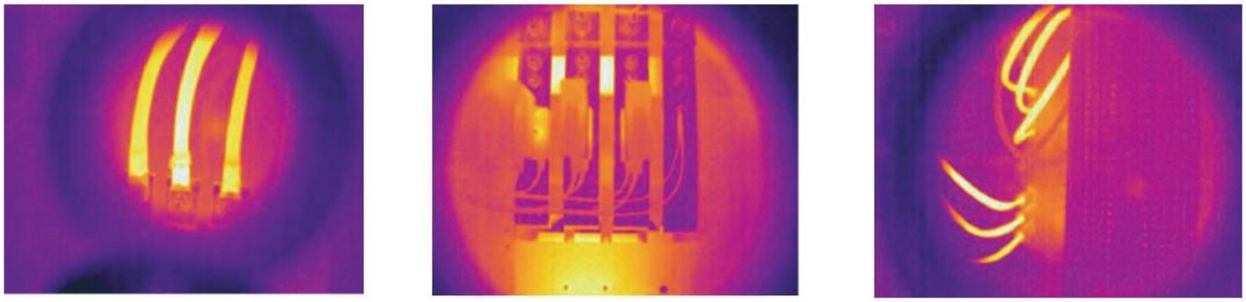
What Can I See Through an Infrared Viewing Pane?

An infrared window allows you to check the condition of electrical conductors and circuit parts. As with traditional thermographic inspections, the camera is very good at detecting and displaying even slight temperature differences very clearly. Therefore, when there is an electrical fault producing a temperature rise, the camera will display the image of the faulty components very clearly. However, if everything is at temperature equilibrium, it is difficult for the camera to display an image showing much of anything.

The images below were taken through an IR window — no apparent faults are present:



The images below were taken through an IR window — temperature rise due to load imbalance and poor connections are evident:



When Should Personnel Utilize PPE?

NFPA 70E/CSA Z462 directs personnel to utilize elevated levels of PPE when they are exposed to energized electrical conductors or circuit parts. Even if the panels are closed, PPE should be worn if there is the potential for an electrical hazard, such as a change-of-state. Use of an IR window maintains an IP65/NEMA 4X seal on the enclosure panel. Therefore, even when open, the window maintains what NFPA terms an “enclosed” and “guarded” condition. Additionally, scanning through an IR window is a noninvasive task that does not create a risk of electrical hazard (no change-of-state). As long as the thermographer is confident that the equipment has been properly installed and maintained, and the equipment is not in danger of changing state. **Then, the HRC for using an IR window would be the same level as “reading a panel meter while operating a meter switch,”** which NFPA rates as HRC 0.

Infrared Inspection Procedure

Thermographer Responsibilities and Minimum Certification Requirements

1. The thermographer will utilize a suitable infrared thermal camera for use of the IRISS windows
2. The equipment to be inspected is operating at an adequate load and sufficient time for recently-energized equipment to produce stable thermal patterns.
3. Document the loading of the unit at the time the inspection took place
4. The thermographer should be minimum Level 1 Certified in infrared inspections, if there is any doubt as to the use of the windows contact the support team at IRISS at (941) 907-9128 for a complete description of operating characteristics and procedures.

Camera Specifications

1. Spectral Range: the infrared imaging system shall operate within 2 to 14 µm. A spot radiometer is not equipped to measure temperatures through the window as there are no emissivity or transmission rate correction factors available in these types of units to correct the displayed temperatures of the unit.
2. Infrared equipment should be able to be placed directly against the window for proper focus and to provide the largest field of view

Inspection Procedures

1. Equipment shall be energized and under adequate load.
2. Subject equipment shall be externally examined before opening or removing any protective covers to determine the possible presence of unsafe conditions. If abnormal heating and/or unsafe conditions are found, the end user shall take appropriate safety precautions prior to starting the infrared inspection.
3. The infrared inspection should be conducted through IRISS permanently installed view ports or infrared transparent windows.
4. Electrical equipment enclosures should not be opened unless line-of-sight access to components is not possible thru the infrared window. If it is necessary to open the enclosure or remove the cover then all applicable precautions should be taken before the environment within the gear is disturbed.
5. Equipment exhibiting anomalies shall be deemed as suspect and covers removed for analysis.

Documentation

1. The thermographer shall provide documentation of all infrared inspections. The following information will be included in a written report to the end user:
2. When performing an infrared inspection, the infrared thermographer will provide information for each exception identified:
3. The serial number of the unit being inspected
4. The location of the window through which the suspected anomaly was identified
5. A description of the anomaly
6. The operating parameters of the asset during the time the inspection was performed.
7. The field-of-view of the infrared imager lens.
8. The Delta T of the anomaly from the other connections visible through the window and defined reference and their temperature difference.

Certifications and Standards

"***What standards and certifications are relevant to infrared (IR) windows?***" This is one the most commonly asked questions when engineers and safety professions begin to investigate IR windows. Trying to sort through the myriad of UL, cUL, IEEE, CSA and other standards can be a daunting task. This is an attempt to clarify some of the most pertinent standards.

UL50V

The UL 50V classification for *Infrared Viewports* is the only standard that relates specifically to infrared windows. It serves more as a classification than an actual standard for performance-of-build characteristics.

Specifically it states: ***Infrared Viewports are a fixed aperture, consisting of one or more openings or a solid infrared transmitting media, surrounded by a mounting bezel or frame, that provide a means for the passage of infrared radiation.***

The UL50V classification is actually a mix of two distinctly different product categories: the *"infrared window"* (also known as IR sight glasses or IR viewing panes) and the *"infrared port."* While both will allow the thermographer to perform infrared inspections of targets located inside an enclosure or behind a barrier, they are mechanically very different. Specifically, IR windows provide a barrier to separate the thermographer from the environment surrounding the target. In contrast, an IR port is essentially a hole. When opened, it effectively removes the barrier between the thermographer and the target. This distinction becomes important when considering the Personal Protective Equipment (PPE) implications of NFPA 70E/CSA Z462.

UL508

UL508 covers industrial control equipment and control panels under 1500 volts. Equipment covered by these requirements is intended for use in an ambient temperature of 0-40°C (32-104°F) unless specifically indicated for use in other conditions.

UL 508A

UL508A covers industrial control panels intended for general use, with an operating voltage of 600 or less. This equipment is intended for installation in ordinary locations, in accordance with the National Electrical Code (ANSI/NFPA 70), where the ambient temperature does not exceed 40°C (104°F).

UL 746C

UL 746C sets the impact and flammability standards for polymeric materials used in electrical equipment up to 1500 volts. Any plastic or polymer forming part of an infrared window must pass flammability tests at room temperature, and must remain intact during an impact test performed at 0°C (32°F). It is worth noting that of the crystal optics capable of transmitting in the long wave portion of the infrared spectrum (8µm to 14µm), there are *no fluoride-based crystals* capable of passing the impact tests required in 746C. However, because they are classified as "glass" under the standard, they are not required to test for impact as long as they are thicker than 1.4 mm.

Ingress Protection/Environmental Rating

IP65 is an international standard (defined in IEC 60529) that classifies products as "dust tight," with complete protection against contact (with parts contained within the enclosure). It also covers resistance to directed water jets. IP testing must be performed and certified by third-party testing labs, such as SIRA. NEMA 4/4X and IP65 are equivalent ratings. It certifies enclosures for indoor or outdoor use; for protection against access to hazardous parts; for ingress of solid foreign objects (windblown dust); for resistance to water ingress resulting from rain, sleet, snow, splashing water, and hose directed water; and from damage due to ice formation. NEMA 4X also must resist corrosion. NEMA ratings can be self-certified when the manufacturer has sufficient data (such as third-party IP tests) to support the definitions. Typically, only viewports that are rated greater than or equal to that of the original enclosure should be used.

Arc Resistance

Per IEEE C37.20.7, arc resistance tests only apply to complete switchgear systems. Arc Resistant Switchgear is tested with any number of accessories in place (with covers closed), and the system must contain, control and redirect the heated gases of the arc blast away from where personnel interface with the equipment. Because of the near-infinite variations in cabinet configuration, geometry and design, the results of one test cannot be assumed to hold true for another cabinet – particularly if that cabinet has no arc resistance features.

Components (such as IR windows) can never carry an arc rating because they have no innate arc resistance characteristics. The features that enable a switchgear system to protect personnel from the effects of an arc blast are a complex series of structural reinforcements, plenums and vent doors that redirect the blast. It is worth noting that all three major brands of IR windows have been a part of successful arc flash tests. However, this does not mean that any of these windows is "arc resistant" in its own right. As stated, it is the switchgear that has been shown to be arc resistant with the components in place.

Standard	Reinforced Polymer
UL 50V	✓
UL 508, 508A	✓
UL746C	✓
IEEE C37.20.2 (a.3.6)	✓
Lloyd's Type Approval	✓
Ingress Protection	IP65/ NEMA 4X
"Passed" 50kVA/63kVA Arc Resistance Tests	✓
Arc Rated	Arc Rated No Component Level "Rating"