SMART™

Incorrect Temperature Measurements: "The Importance of Transmissivity and Infrared Windows"

By: Name and Company withheld by request

Abstract

Infrared (IR) windows save lives. Most Thermographers today are thankful to perform their scans without the danger and time of removing heavy panels. But just as the thermal imager is a tool - so is the IR Window. And as with any tool, it must be used correctly to get the desired results. Standardization is the key to getting repeatable results and accurate measurements. Many applications that benefit from infrared analysis do not require exact temperature measurements. For instance: Using thermography to conduct insulation surveys on building envelopes does not require concise temperature data; neither does locating a loose fuse clip. But when temperature is used as a criticality for major repairs (shut down required), it is imperative that your data is accurate.

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Do you know your IR Windows Transmissivity rate? Perhaps a better question is: Have you calculated your IR windows transmission with your camera? Though I had never measured, I “knew” my windows transmitted near 95%. That is what the salesman had said and, it’s how it had always been done. This assumption likely put workers at risk and cost my customer money.

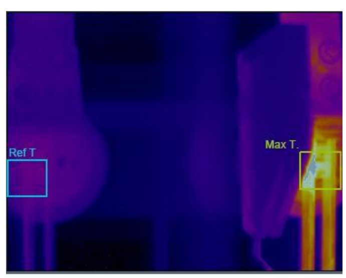
This paper is comprised of my official report, the actions taken, and subsequent changes in plant policy to amend any missed opportunities. It is intended to educate thermographers and those whom they support on the importance of accurate temperature measurement through Infrared Viewing Panes.

Official Report Excerpt: Summer 2009

At approximately 9:30AM on Monday morning, I began the quarterly inspection of the plants main switch gear (23KV incoming line, distribution switches). All Inspections on the main switch gear were made via 3 inch Calcium Fluoride (CaF_2) Crystal Infrared Viewing Panes. The Imager used was a FLIR 695 with standard Emissivity set at 0.92.

Upon completion, I was troubled to find a total of 3 anomalies (hot spots) in the switches. I captured my images and data and noted the Inspection point numbers. Upon completion of the inspection, I called the PdM Program Manager (PM) and briefed him on the unusual and serious nature of the findings. Serious-because company best practices for a 10°F ΔT (Differential temperature) or higher, on 23KV equipment is “CRITICAL”. And unusual- because the switchgear had been inspected by me approximately 3 months prior in the quarterly scan. I had used all of the same inspection points and had observed no anomalies.

I reported the following to the PM: Isolation switch number one (Switch# 1) has a 30°F ΔT on the “C” phase Disconnect contact.

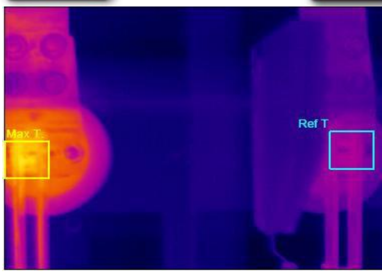


Label	Value
Max T. : max	154.1°F
Ref T : max	123.9°F

Delta T	30.19°F

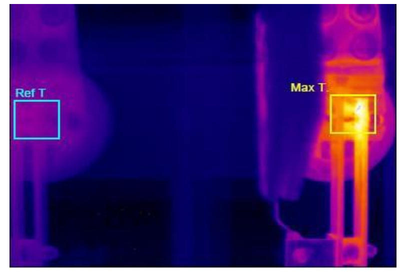
Image 1

Isolation Switch Number Two (Switch 2) has two hot spots: the first anomaly (21 °F ΔT) on the Phase “A” Disconnect contact (Image 2). The second anomaly (30°F ΔT) on the phase “C” Disconnect contact (Image 1).



Label	Value
Max T. : max	146.0°F
Ref T : max	124.8°F
Delta T	21.19°F

Image 2



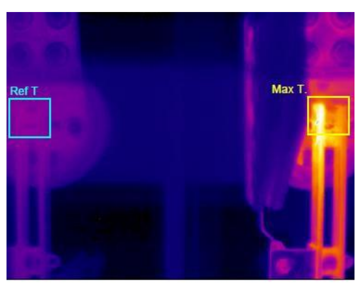
Label	Value
Max T. : max	146.9°F
Ref T : max	117.3°F
Delta T	29.51°F

Image 3

Immediately following my phone call, I generated an official report, wrote the work orders, and entered all data into our system. I sent the report to all concerned parties and requested an immediate meeting. During the meeting it was decided to monitor all anomalies daily until a power outage could be scheduled. Since the substation was shared equipment; the city utilities bore some responsibility for the equipment as well as the repair. We decided the City Utilities would be called in to help assess the situation.

As my schedule dictated, I was off site the following day. I was emailed a memo that stated
City Utilities arrived around 9AM and conducted an IR scan with their own personnel and equipment. The Utility measured slightly above my measurements but the anomaly did not meet their criticality limits for repair (>50°F ΔT). They did not capture images thus I received a second hand report of their findings. If we wanted the anomaly corrected, we had to do it ourselves.

Back on site Wednesday morning, I performed a complete scan of all incoming line switchgear. Though all anomalies were still present, I found that switch #1's anomaly had doubled to >60°F ΔT!



Label	Value
Max T. : max	179.6°F
Ref T : max	119.1°F
Delta T	60.54°F

Image 4

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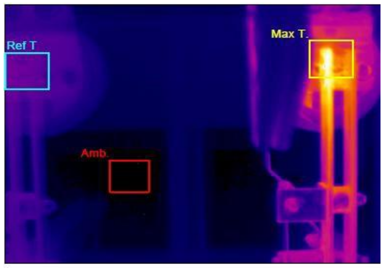
A quick look at the production rate verified that the loading of the switch had not increased. Once again I generated a report and notified the PM. The Utility Company was contacted but not receptive.

The next morning, Thursday, I came in early and scanned the equipment before sunrise. I found and reported that Switch No. 1 had increased to nearly 75°F ΔT. (Image 5) This anomaly had risen 150% in just 3 days!



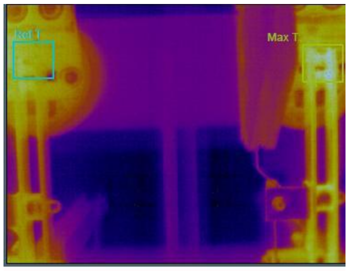
Label	Value
Max T. : max	211.2°F
Ref T : max	137.4°F
Amb. : max	118.6°F
Delta T	73.73°F

Image 5

I captured the images and send out the report. In less than an hour a meeting was held. Reports were sent, calls were made, and the corporate office got involved. Management ordered a decrease in the production rate immediately. No one was willing to let a 75°F ΔT remain in the Incoming Power switch that fed half of the plant. Not on their watch.

The plan was to take Switch #1 offline during a 2 hour power outage that evening. As is sometimes the case, paperwork and part acquisition delayed the repair. Finally, the switch was thrown around 2:00AM Friday morning.

I arrived on site Friday morning just as the electricians were clearing locks and tags and preparing to bring the switch back on line. After the switch was loaded, I scanned the anomaly and reported that Switch #1 appeared to have no hot spots. Repairs, though costly, were successful.



Label	Value
Max T. : max	110.9°F
Ref T : max	110.0°F
Delta T	0.92°F

Image 6

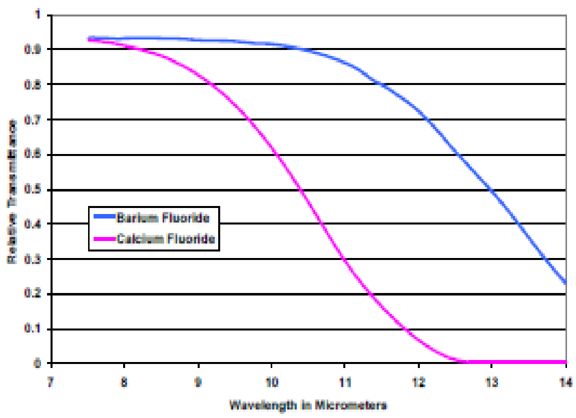
I attended the post repair meeting on Friday. Everyone was in good spirits; “Mission Accomplished” seemed to be the theme. We had just discovered and repaired the most dangerous hot spot our Main Switchgear had ever “seen.” It was decided that the switch #2 hotspots would be monitored daily by the onsite technician’s until a scheduled outage. A new policy was also adopted that put the Main Incoming Switch Yard on a monthly route versus the quarterly scan. (I recommend this to every plant I consult with now).

In less than a month I had transferred up the chain of command. I made sure my replacement knew the history and the potential volatility of the Switch Yard. Switch #2 continued to be monitored on a daily basis. The temperatures rose and fell but never over 50°F ΔT; and definitely not the magical 75°F ΔT that had caused such a stir. I was given word that an emergency outage had given the electrician’s time to repair Switch#2 a short time later. My contact at the site verified that all previous anomalies in the 23KV Main Incoming Switch Yard had been eliminated.

Enlightened

Some months later I read a surprising report, Titled: Transmission Stability and Infrared Windows: The Effects of Transmissivity on Data Accuracy. As I read his paper the above incident was the first thing on my mind. I had to wonder, had I given the most accurate information to my customer? It upset me to think I had reported incorrect data; I was responsible for the IR program and I should have known this information.

According to the report, transmission rates are typically variable across the infrared spectrum (as shown in Madding, 2004 1), yet the manufacturer’s specified transmission rate is generally relevant for a specific wavelength. So, while a Crystal may indeed have a 95% transmission rate in the short wave, most industrial IR camera operate in the long-(mid) wave or 8-14 µm.



After reading the report, I decide to put the Calcium Fluoride Crystal to the test. My test was somewhat like my daily camera calibration – rudimentary but effective.

*Side bar: I calibrate my IR camera each morning with a coworkers tear duct. I know human skin to be around .98 EM. If I get within +/-2% of 98.6°F (average human temperature), I trust my equipment to be calibrated to an effective degree.

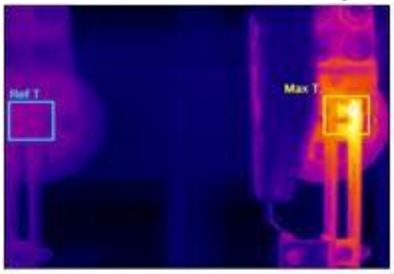
To test my window in the office, I used a simple method known as the “coffee cup test.” I powered-up my imager and grabbed a 3” Calcium Fluoride IR window.

*Note: Polymer and Germanium windows will have some transmission loss as well. The transmissivity rate is not important (to a degree) as long as it is known and will not change.

1. Fill a cup with hot water, and place an Emissivity Label on it (No Emissivity target?—use electrical tape)
2. Set the camera’s Emissivity to 1.00
3. Measure the temperature of the target without the window (Temp= 160°F)
4. Then place the window (I used a 3” CaF2) in front of the camera and measure (Temp= 120°F)!
5. Lower the camera’s emissivity until the adjusted temperature is the same as the original temperature (.55 EM)
6. I recorded the new rate for future reference. I later estimated what my true temperatures were for the Main Switch Yard anomalies.

Using the imager’s software, I was able to change the flawed temperature readings I had collected by inputting the correction of .55 Emissivity. The results confirmed the “coffee cup test” and the fact that I had erred in my original calculations. Thermography software as well as many cameras themselves also provides a way to correct for transmission losses. For additional tips contact your window or camera manufacturer. Additional tips can also be found at http://www.iriss.com

Below are the switch #1 images after Emissivity correction.



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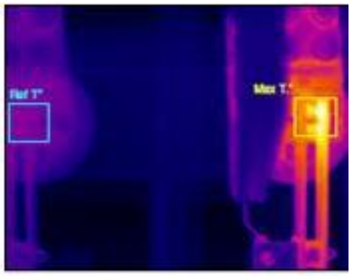
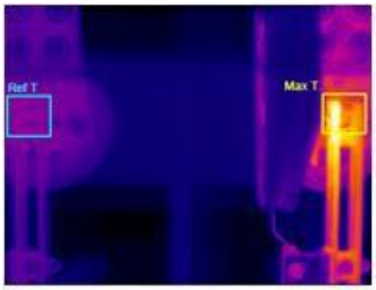
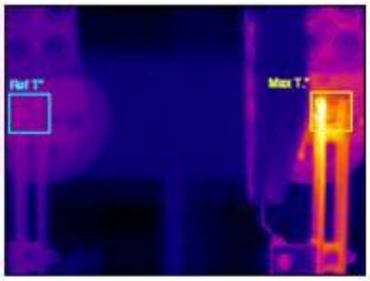


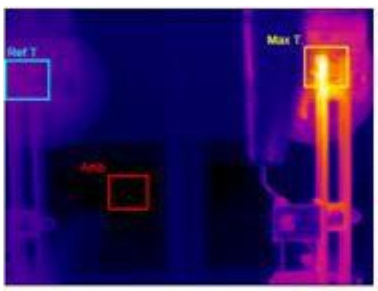
Label	Value
Max T.* : max	191.8°F
Ref T* : max	147.5°F
Delta T	44.29°F



Label	Value
Max T. : max	179.6°F
Ref T : max	119.1°F
Delta T	60.54°F



Label	Value
Max T.* : max	239.7°F
Ref T* : max	150.2°F
Delta T	89.52°F



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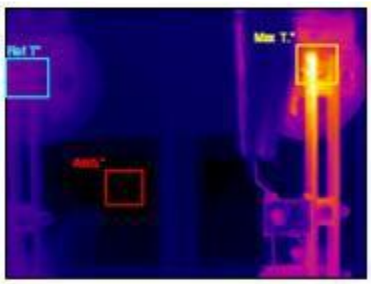

Label	Value
Max T.* : max	285.1°F
Ref T* : max	177.8°F
Amb.* : max	149.4°F
Delta T	107.24°F

Summary

It was apparent to me that the Utility Co. should have aided in or completed this repair themselves. (I cannot imagine a 50°F ΔT, on 23kV switchgear being considered anything but "CRITICAL.") But I could not undo the past. I had erred in my own measurements and so had the utility. All anomalies were corrected and paid for by my customer. I felt obligated, however, to insure future scans (mine and my colleagues) did not suffer from the misinformation regarding transmission rates in IR windows.

Due to the incident being studied post repair, my "experiment" could not be considered scientific. I was unable to use the same crystal as the images were captured through. My crystal window was new. Though it was of the same brand, size, and model installed in the Switches, I was also unable to recreate any defects the window had due to age, high frequency, noise, vibration, moisture, etc.

This paper should serve as a testament to the predictive maintenance strategies used in industry today. Though it was not the focal point of this particular paper, the use of Infrared Thermography and Infrared Windows saved my customer incalculable resources that day. When a Mega Plant loses its incoming line, everything stops. Tens of thousands of production dollars may be subtracted by the day, hour or even minute. And, I cannot speculate as to the toll on the plant’s safety had an arc flash transpired. This problem was caught while in failure mode - very low on the P-F Curve. However, the system worked. The technology that the plant invested in paid for itself that day.