

# Can your Infrared Camera Find Every Electrical Problem?

Joe DeMonte

Infrared Training Center  
FLIR Systems, Inc.

## ABSTRACT

There are good days and there are bad days. In the life of an electrical thermographer, we hope that our infrared technology will save the day and point us to hot connections and electrical components. At times, this task seems fairly straightforward. Find a heated connection, and it must be a loose connection. Can we find every problem? When we find a problem, can we accurately diagnose the root cause with just an Infrared Camera?

Low emissivity coupled with average thermal sensitivity could lead us astray. Small problems located on a clean copper bus may be overlooked.

Low emissivity coupled with forced convection (wind and ventilation) might reduce thermal contrast enough to mask a problem from our very eyes.

Low emissivities coupled with low load... well you probably understand the point of this paper by now. I will discuss and demonstrate what to look for, and give you some tips that might find a small problem that would have otherwise escaped detection.

**Keywords:** emissivity, thermal sensitivity, electrical load, convective cooling, indirect measurements, severity criteria, infrared, thermography.

### 1. WHAT IF I DON'T SEE ANY HOT SPOTS WITH MY IR CAMERA?

When I started in this business, I was told to look for something out of the ordinary. Look for the object that is hot when it shouldn't be. My old camera had its strong points and its good points. The thermal sensitivity of my system gave me fits when I tried to monitor a 4160 Volt Emergency Breaker. The issue was on a silver coated four bolt connection on the line side of the breaker. It would be there one week, and then it would be gone the next! Why did it disappear? Load varied with the equipment lineup, and the emissivity of the four bolt pad was extra low. Fortunately we had recorded load along with every IR scan.

A simple demonstration can show how difficult it can be for even modern IR cameras to find a small temperature difference. The camera I used for the following series is a FLIR Systems Model E2 with a thermal sensitivity of 0.12K and a spectral range of 7.5-13 $\mu$ m. Two aluminum plates of low emissivity, a variable temperature hot plate, and a wooden kitchen table are the props as shown in Figure 1.

The first example (Figure 2) shows an IR picture of my hand on the table (left) and the heating left behind after touching the table for around five seconds (right). As can be seen, the table has a high emissivity and will show slight temperature changes with good contrast.

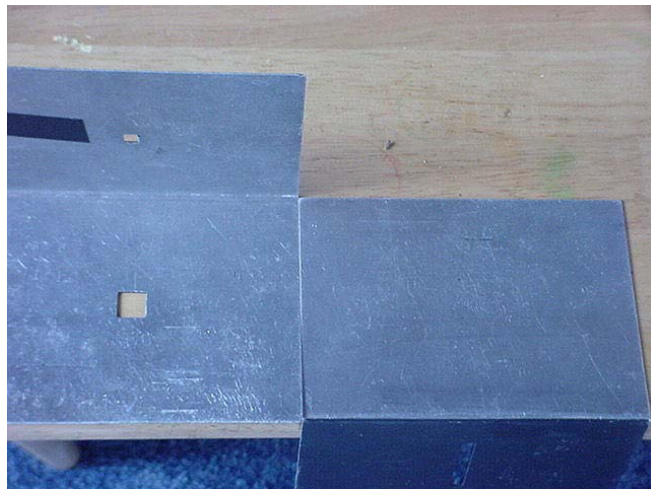


Figure 1. A table and two uncoated aluminum plates

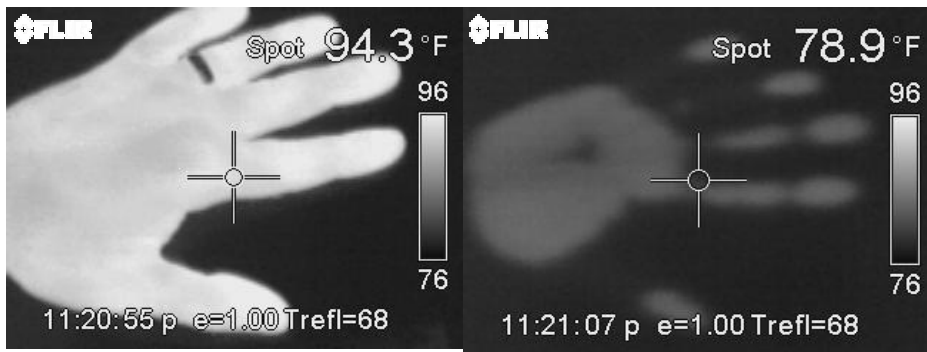


Figure 2 Hand on the table (left). Thermal signature of hand on table (right).

The next part (Figure 3) shows the same hand touching the lower emissivity aluminum plate, and my fingers touching the table simultaneously to show the difference in contrast between the aluminum and table. In the right hand image you can see the rafters of my work shed reflecting off of the aluminum, but can you see any noticeable increase in the thermal signature on the aluminum? The table shows a clear signature, but not the aluminum. Let's do a comparison.

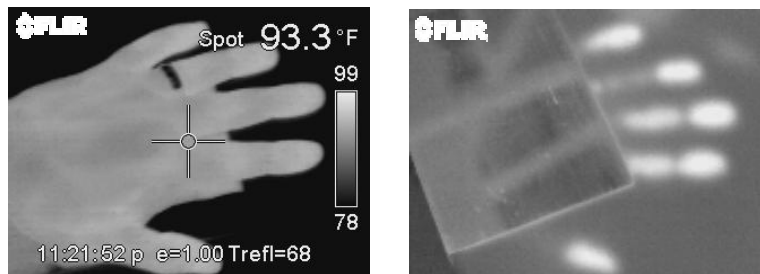


Figure 3. Hand on the aluminum and table (left). Thermal signature of hand on the aluminum and the table (right).

Since every good thermographer lives to compare like objects when determining severity, let's compare two aluminum plates. One plate is kept at room temperature and the other will be touched by my hand (Figure 4). Is there an apparent difference? We know that there is a true temperature difference since my hand was hotter than the aluminum.

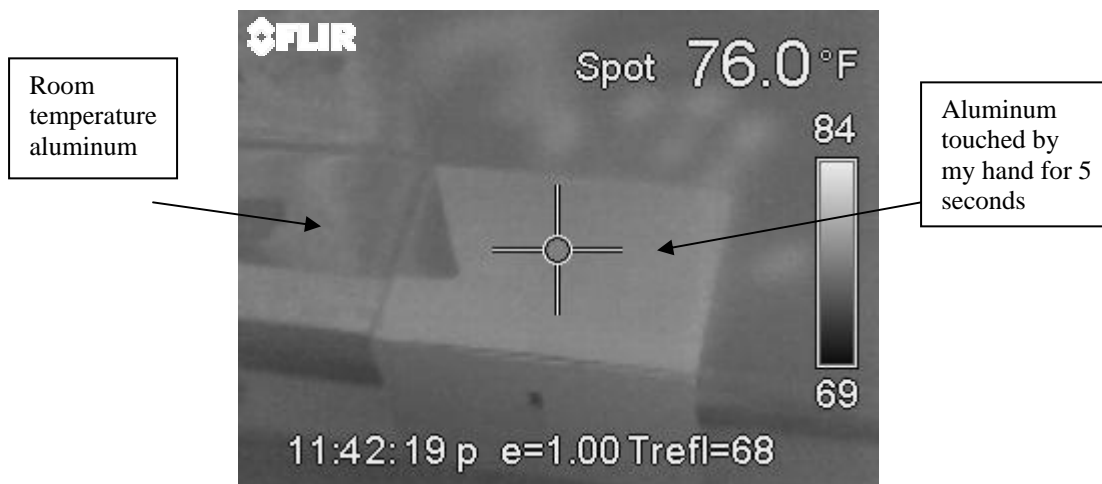


Figure 4. Comparison of room temperature plates, one heated by my hand for 5 seconds

Now let's crank up the heat by using a heating plate on one aluminum plate. I placed the aluminum on a dial controlled heating plate and placed the temperature on low. The IR camera was left with an emissivity of 1.00

to give us the apparent temperature of the heating plate and aluminum (Figure 5, top). A room temperature aluminum plate is then used to compare with the aluminum on the hot plate (Figure 5, bottom).

As we can see, both plates continue to reflect something warm and give a false indication as to what the actual temperatures are. What are they reflecting? We are looking at the reflected radiation from my workshop roof and rafters. The uninsulated roof interior is hot due to heating by the summer sun! Even with a room temperature of 88°F, the aluminum can take on the appearance of being 20F° hotter than actual. There is no perceived difference in temperature between the two pieces of aluminum, even when one is heated to above 118°F. (Note: As we are dealing with temperature differences as well as actual temperatures, we will use °F to indicate temperature and F° to indicate temperature differences.)

My next step is to heat the uncoated plate further and continue to use the FLIR E2. The following sequence of images (Figures 6.1 through 6.4) shows how low emissivity can throw us off track.

We finally see a “difference” between the two aluminum plates. The problem is that I had to increase the heat and raise the temperature of the aluminum plate by over one hundred degrees Fahrenheit. In Figure 6.4, we can tell that the aluminum plate on the left looks slightly hotter than the one on the right. Imagine these plates to be two aluminum buss bars side by side, and we could say that there is an anomaly present. Comparing the apparent temperatures with our infrared camera (Figure 6.3 and figure 6.2), we see a difference of 113°F minus 103°F, or 10F°. According to most severity criteria, this would be a minor to

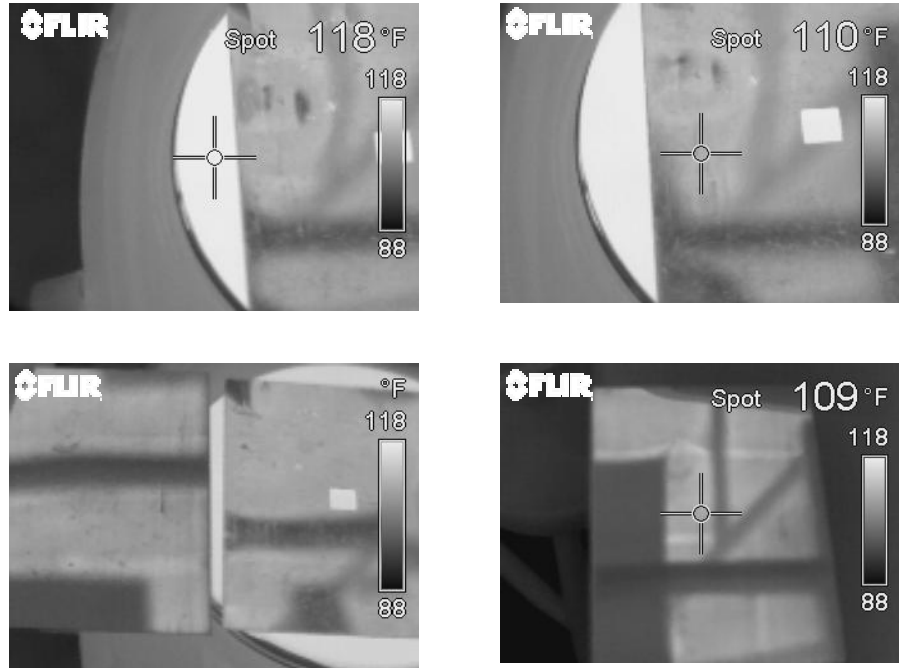


Figure 5. Apparent temperature of the hot plate, 118°F (top, left) and the apparent temperature of the aluminum, 110°F (top, right). Room temperature plate compared to the aluminum on hot plate (bottom, left) and the apparent temperature of the room temperature plate, 109°F (bottom, right).

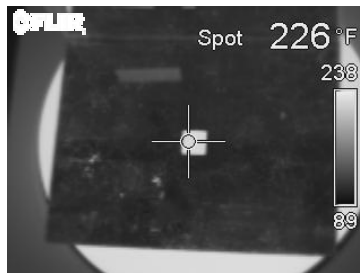


Figure 6.1: Hot plate, apparent temperature, 226°F.

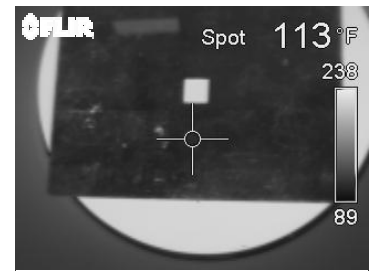


Figure 6.2: Aluminum, apparent temperature, 113°F.



Figure 6.3: Room temperature aluminum, apparent temperature, 103°F



Figure 6.4: Comparison of hot aluminum (left) and room temperature aluminum (right)

moderate problem. I then placed two strips of black electrical tape on each of the aluminum plates, and dialed the emissivity of the FLIR E2 to 0.95. This should give us a better understanding of what the actual difference in temperature is for the two plates (Figure 7).

The tape on the hot aluminum appears hot to the camera, but the aluminum still looks cool. Amazingly the tape on the room temperature aluminum appears cooler than the aluminum. Why? The aluminum is so reflective it is indicating the hot interior roof temperature of almost 118°F, whilst the tape indicates the actual temperature of only 91.3°F. Our actual temperature difference turns out to be 198°F minus 91.3°F = 106.7°F.

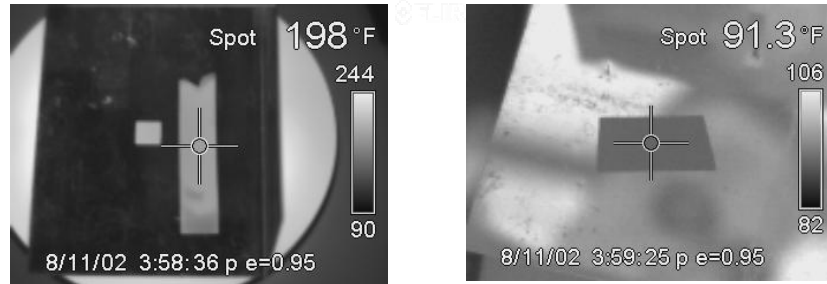


Figure 7. Corrected temperature for the hot plate, 198°F (left) and corrected temperature for room temperature, 91.3°F (right).

The uncorrected difference of 10 F° has an actual corrected value of over 10 times higher! What severity criteria table would call that moderate?

Let's now compare our above findings with a typical Severity Criteria table as shown in Table 1. There are numerous sets of temperature severity criteria available to the thermographer. Unfortunately, they often do not account for all factors including indirect measurements, environmental effects, load, equipment criticality, and uncorrected temperatures. According to Table 1, a 29F° (16C°) temperature rise “over similar” represents a critical problem. Using temperature only as severity criteria can get us into trouble, as the following example shows.

<b>Temperature difference (Delta T) based on comparisons between similar components under similar loading.</b>		
<b>Over Similar</b>	<b>Over Ambient</b>	
1C° – 3C° 1.8 F°–5.4F°	0C° – 10C° 0 F° – 18F°	Possible deficiency; warrants investigation
4C° – 15 C° 7.2 F°–27 F°	11C° – 20C° 19.8F° – 36F°	Indicates <u>probable</u> deficiency; repair as time permits
----	20C° – 40C° 36F° – 72F°	Monitor continuously until corrective measures can be accomplished
> 16C° >29F°	> 40C° > 72F°	Major discrepancy; repair immediately

Table 1. A Typical Severity Criteria table for electrical components showing temperature rise in both Celsius degrees (C°) and Fahrenheit degrees (F°)

Our uncorrected difference (rise above similar component) when looking at the aluminum without tape and setting the emissivity to 1.00, was 10F°. Comparing this to the above guidelines puts our measured anomaly in the PROBABLE DEFICIENCY category. Further testing and/or an increased thermal survey monitoring should be the next step. The corrected temperature difference of 106.7F° gives a completely different answer. From Table 1, this

is a MAJOR DISCREPANCY and calls for a REPAIR IMMEDIATELY. Lesson learned: Use only actual, corrected, temperatures to find the temperature rise.

## 2. LOOK OUT! THERE'S A 5C° TEMPERATURE RISE! RUN FOR IT!

The Severity Criteria table has the right idea. A greater than 4C° rise between two similarly loaded components requires the thermographer to investigate the anomaly further. My experiments show that actual differences of over 100F° are required to make the aluminum “appear” to be only 5C° hotter. Could we use the generic Severity Criteria specs for comparing two electrical components that have a high emissivity? Probably not, as the criteria would end up classifying everything as severe. Take a look at the substation disconnects illustrated in the thermogram of Figure 8.

Using emissivity of 0.9 due to the heavy oxidation on the target, the calculated actual rise in temperature is 16.2C° between the hot connection on the right and the reference connection on the left. This places us in the MAJOR DEFICIENCY category. The thermographer’s field experience shows this disconnect should be classified as a PROBABLE DEFICIENCY, not a CRITICAL or MAJOR DEFICIENCY.

Experience has taught this individual that this is not a serious problem, and he does not have to act on it immediately. The thermogram was taken under no wind, high load conditions. Wind and load play major roles IR surveys. Both can cause the temperature rise to change by factors of 3, 4 or even more. See Madding et al in this proceedings (1). We know that severity criteria exist from all sorts of different organizations and for all sorts of equipment. Most generic Severity Criteria guidelines work well for low emissivity indoor electrical components that are being viewed DIRECTLY. Indirect measurements pose a completely different set of severity criteria (2, 3). My advice is that you should take existing criteria and modify it for your components, or devise your own. Avoid severity criteria based on temperature rise alone. Never use the same set of severity criteria for direct and indirect targets. Lucier gives some good advice on developing severity criteria in his paper (4).

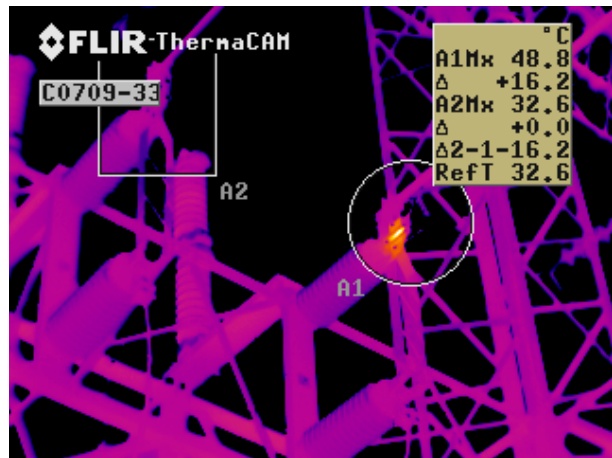


Figure 8. Thermogram of disconnects in a substation.

## 3. SUMMARY

Remember that dealing with low emissivity not only can reduce the apparent severity of the anomaly, but it can completely mask some problems. The objects in question will have to get fairly hot before an IR camera detects it, if at all. A good rule of thumb is to avoid evaluating low emissivity targets altogether. Increase their emissivity if at all possible. Unoxidized metals fall into this category. Fortunately, oxidized metals will have higher emissivities and can usually be evaluated. The problem is the emissivity is dependent on the degree of oxidation, and can range from about 0.3 to 0.9. Nonmetals generally have emissivities in the 0.8 to 0.95 range and are readily evaluated.

The environment can work against us by actually lowering the temperature of our components through convection (wind). Load on a component can get low at times, and also lead to lower temperatures due to less heat as electrical components warm up typically due to resistance heating. The higher the load, the higher the heat generated. A connection in critical repair-it-now categories will show up very easily to the IR camera thanks to GREATLY increased radiation it will emit, providing its emissivity is reasonably high (above 0.6).

High emissivity objects in contact with the low emissivity object will clue us in to where the problem is, and it will show slight temperature rises easily. If most of our components have insulated cables attached to the connection, or are covered in Bakelite or other plastic, we can use the high emissivity to find even the slightest problem.

Until every component is infrared friendly, we have to work up enough experience with the components we are asked to monitor. If possible, measuring the actual emissivity of your typical components will aid you in your analysis of any perspective problem.

#### **4. REFERENCES**

1. Madding, Robert P., Leonard, Ken and Orlove, Gary L.; “Important measurements that support IR surveys in substations”; Proc. InfraMation; Vol. 3; October, 2002; in press.
2. Madding, Robert P.; “Finding Internal Electrical Resistance from External IR Thermography Measurements on Oil-filled Circuit Breakers During Operation”; Proc. InfraMation; Vol. 2; October, 2001; pp37-44
3. Madding, Robert P., Ayers, David and Giesecke, Jon; “Oil Circuit Breaker Thermography”; Proc. InfraMation; Vol. 3; October, 2002; In press.
4. Lucier, Ron; “How to guarantee your failure as an IR thermographer”; Proc. InfraMation; Vol. 3; October, 2002; in press.

#### **5. ACKNOWLEDGEMENTS**

I wish to thank the Infrared Training Center, FLIR Systems, Inc. for their support in time and resources that gave me the opportunity to do the research and write this paper.

