Do environmental influences such as the sun and wind have an effect when performing an infrared (IR) thermography survey? The answer can be as complex as the environment. Factors such as survey severity criteria guidelines, direct or indirect measurement, equipment type and load, and the severity of the environmental parameters all influence the thermographer's evaluation of potential problems. Thermographers working outdoors on breezy days or in areas with nearby cooling fans or blowers are faced with the challenge of the effects of convective heat transfer. It should be no surprise that the temperature rise of a hot spot can be reduced by the wind or fans.

Then why is the wind often ignored when performing thermographic surveys? Most thermographers simply do not know how important wind is in cooling down a hot spot. Also, how should they compensate for convective cooling effects? This article presents some interesting data using a simple experiment of blowing air on a hot spot simulated on a fuse cutout.

The sun also can be a strong influence on outdoor thermographic surveys from both reflective and warming standpoints. Solar reflective effects have been widely discussed. Use of long-wave cameras (8-12 mm) is the optimal solution for solar reflection problems. With short-wave cameras (3-5 mm), thermographers have had good success by changing position with respect to the target, surveying at night, and learning to interpret reflections.

Solar warming can be a more subtle effect, especially for hot spots that are thermally isolated from the surfaces the IR camera sees. For these indirect targets, temperature rises of a few degrees Fahrenheit can indicate significant problems. Transient solar loading can wipe out these small temperature rises and they will not be seen.

One utility found that great care must be taken when performing thermographic surveys on underground equipment that is heavily electrically insulated. The electrical insulation also serves well as a thermal insulator, making these underground components indirect targets. Just a few minutes of exposure to sunlight made thermography impossible on these underground components. It is possible that by waiting long enough for thermal equilibrium, perhaps several hours, that the rise due to the internal problem would be re-established on top of the solar loading. But most thermographers do not have that kind of time. It is simpler and quicker just to shield the components from direct sunlight.

For indirect targets that soak in sunlight such as oil filled circuit breakers (OCBs), thermographers need to compare apples to apples--that is, be sure when comparing OCBs that they are equally solar loaded and have been for some time. More work needs to be done in this area, but thermographers have had success in documenting major problems indicated by small temperature rises for equipment in full sunlight.

**Wind effects** We set up an experiment in our student laboratory that allowed students to vary and measure wind speed blowing on a simulated hot spot on an actual fuse cutout. We recognized the possibility of deriving some good data from this experiment. We were able to control wind speed from 1 mph to more than 30 mph. A squirrel cage blower provided the wind onto a Type XS 14.4 kV 100 A fuse cutout. The wind was aimed at the top of the cutout, nominally centered on the knurled brass piece. We taped Scotch Brand 88 black vinyl electrical tape to this piece to increase the emissivity to 0.95 and to attach a type K thermocouple.

Regulated 18 V dc variable power supplies provided power to both the squirrel cage blower and the heat source mounted internally near the top of the fuse cutout. We used a pocket wind meter to measure wind speed. We first heated the cutout without any wind, allowing 1 hr to attain thermal stability.

The size, shape, orientation to the wind, and surrounding structures all affect convective cooling.

We did experiments with initial temperature rises varying from 130 F down to 45 F by varying the power to the heat source. We then applied power to the squirrel cage blower to achieve various wind speeds ranging from 1 mph to 25 mph. Temperatures were measured with both an IR camera and a dual thermocouple setup.

The experiments show for several power inputs that the influence of wind is quite strong, even for low wind speeds. The temperature rise was cut in half with just a little over a 3 mph breeze. The stronger the wind, the cooler the hot spot, up to a point. As the curves show, the largest changes occur at lower wind speeds. Our data show that between 50 and 55 mph, the wind has cooled the hot spot to ambient for the power levels we used.

Cooling by convection depends on many factors, not the least of which is shape. The size, shape, orientation to the wind, and surrounding structures all affect convective cooling. Whether the hot spot is emanating from a recessed area in the component as is often the case with hinges, for example, could make a tremendous difference in interpretation. Such a region may be shielded from the wind, and largely unaffected by it.

What does all this mean for thermographers? Here are our recommendations for dealing with wind, whether from natural sources or generated within your facility:

- Buy an anemometer. Pocket size units are quite accurate and cost about $100. Use it on surveys. Note that getting the actual wind speed on the hot spot can be difficult. Do not place the anemometer within inches of energized equipment. Try to get enough measurements to ensure confidence of the range of wind speeds the hot spot sees. Recognize the shape and orientation of the hot spot component relative to any surrounding structures. These factors strongly affect wind effects.
- Within a facility, blowing air can affect measurement on components inside normally closed cabinets. Opening the door can allow cooling air to enter. We have found some hot spots can be significantly cooled this way. If there is air blowing on cabinet doors, we recommend shooting them just after opening, before cooling can take place.
- If possible, measure component temperatures on the leeward (downwind) side of the hot spot. There will be a temperature difference from the windward to the leeward side of the hot component. Measuring out of the wind gets you closer to the no-wind condition.
- "f you are using severity criteria, find out if they are for no wind or light breeze. If they are for no wind, even a slight breeze can throw you off by a factor of two on temperature rise. " The higher the DT for a given wind speed, the higher the power dissipation in the hot spot. For a 100 A current to generate 30 W of power, the resistance would be 3000 micro-ohms.This resistance level would be a problem in medium- to high-voltage circuitry.
- We did all measurements under steady-state conditions. Steady state means the heat capacity (thermal mass) of the component does not enter into the physics of what is happening. When making measurements in a variable wind, or if the wind changes from high to low or vice versa, this is nonsteady state; the heat capacity of the component must be considered. This complicates matters considerably. High heat capacity components will be slower to heat up after the wind dies down and slower to cool down when the wind picks up.

**Solar effects** The sun can be a great help to thermographers in transient heating/cooling applications such as roof moisture surveys. For steady-state heat flow applications, the sun can cause problems in measurement. The effect of solar reflection creating false indications or masking true hot spots has been widely discussed. In this article, we will concentrate on the effects of solar loading on indirect measurements, particularly those underground components that the sun illuminates only when the thermographer opens a door or cover.

When normally closed compartments are opened, environmental effects such as airflow mentioned above and the sun if outside may cause problems. Underground switchgear is normally heavily insulated. A hot spot simulated in a high voltage elbow, a typical component, with an internal temperature rise of 133 F as measured by thermocouple, has an external hot spot temperature rise of only 17 F.

Heating was simulated with an internal source under laboratory conditions. In this condition, a thermographer aware of indirect measurement criteria would easily determine a problem condition.

But what happens if we allow the part to be warmed by the sun? We did not calibrate the lamp to deliver exactly equivalent solar radiance to the elbow. Rather we wanted to show that the effects of solar warming as the variation in ambient solar radiance can be considerable. The lamp delivered more energy than would the sun. However, we have observed this effect under actual solar loading conditions.

To compare our results of solar warming of both a good and bad elbow, we added a good elbow to the setup. The good elbow is at an angle and slightly above the bad elbow. With the sun shining on the elbow, there is considerable glint or reflection, as a 3-5 mm bandpass camera was used. After warming, we shielded the elbows from the lamp. In both cases, we could not tell the good elbow from the bad elbow. The heating by the lamp with or without the glint masked the problem. The lamp was on only for a few minutes. Lamp intensity was greater than that of the sun, but our experience has shown it takes only a few minutes for actual solar effects to produce similar effects.

Documenting electrical load, wind, and sun conditions can go a long way to help trend problems over time.

The bottom line is that for normally shaded components where the problems are indirect thus low temperature rise, the sun should not shine on them.

Indirect measurements where the hot spot is thermally isolated from the surface viewed by the camera are more susceptible to wind and sun than direct measurements. They have a much lower temperature rise and can be masked more easily. Attempting to quantify these effects can result in some degree of frustration. Even under controlled conditions there are many variables to consider. Documenting electrical load, wind, and sun conditions can go a long way to help trend problems over time. **MT**

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