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Give Yourself a "Thermal Lobotomy"

Thermal Lobotomy: The 'virtual' act of severing the concepts of reflection from that of emission in order to prevent thermographers from suffering destructive repetitive inspection methodology.

When dealing with low emissivity surfaces thermographers are taught to try to 'eliminate the reflections' and, once they do, to proceed with performing the inspection. While removing the obvious source of reflection is the proper first step, many thermographers then believe that 'the emissivity problem is solved'. This paper will discuss why we need to consider reflectance and emittance as separate issues and why both need to be thought about, and dealt with, accordingly.

Definitions

Brain: An organ usually located in the skull responsible for thought, emotions and body activity. In competent thermographers the brain needs to be present, active and educated.

Brain (Right Side): That side of the brain primarily responsible for intuitive thought and recognition. The right side integrates many inputs at once, processes information diffusely and simultaneously. In thermographers this part of the brain identifies patterns associated with such things as reflections and the signatures of real thermal anomalies.

Brain (Left Side): That side of the brain primarily responsible for logical thought, analysis and time. The left side can only deal with inputs one at a time in a linear and sequential manner. In thermographers this part of the brain deals with the complexities of emissivity and background energy and is utilized when quantitatively evaluating the radiometric computation of temperature.

Lobotomy: The act of physically severing the nerves joining the two sides of the brain in the front cortex in psychotic patients to prevent them from suffering destructive repetitive thoughts.

Thermal Lobotomy: The 'virtual' act of severing the concepts of reflection from that of emission in order to prevent thermographers from suffering destructive repetitive inspection methodology.

Radiance: The total amount of radiant infrared energy that is leaving a surface (per unit area) due to both reflected and emitted components. (Definition restricted to an opaque surface where transmission equals 0).

Background

Thermographers are taught a number of principles in ASNT Level 1 and Level 2 courses that promote an integrated way of thinking about emissivity and reflectivity of surfaces. Kirchhoff's Law states that a = e (absorptivity equals emissivity). The law of conservation of energy for radiation striking a surface states that the r + a + t = 1. The all important principle of infrared radiance from an opaque surface (t=0) combines these equations into r + e =1 or r = 1 - e. The bottom line is that reflective surfaces have low emission. Conversely, efficient emitters are inefficient reflectors. As an extension of this then is that in many situations we assume, quite correctly, that a low emissivity surface

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will appear cooler than a high emissivity surface because the reflected background is often cooler than the low-emissivity "hotspot" we are observing.

But it is easy to slip into complacency that this is always the case, and few of us take the time to think about the meaning behind this relationship. When dealing with lower emittance surfaces many thermographers simply change or control their scan angle or shield the environment to 'eliminate the reflections'. Unfortunately, we can only either (a) eliminate the obvious reflection by changing our scan angle, or (b) reduce the amount of energy being reflected by reflecting a background with a lower temperature. The reality is, however, that we cannot change the reflectivity value of the surface without treating it with some sort of coating. (We are assuming that practicing thermographers know about avoiding extreme scan angles and utilize, where possible, the proper scanning technique of being approximately perpendicular to the surface.)

The Snell Group conducts a Level I class experiment to dramatically illustrate this point. We use a cardboard disc with an aluminized reflective surface on one side and plain paper on the other. We place it on the floor with the aluminum side up and have the students measure the 'apparent temperature'. Students will adjust their camera angle to eliminate any obvious sources of reflection and then make their measurement. We then flip the disc over and have them measure the plain paper side. The readings will often be within a few degrees of one another. We then ask them to take the disc outside (on a clear day) and repeat the exercise. The aluminum side measures an extremely low temperature, often below the measurement limit of the camera (typically -40°C) and the paper side is very close to ambient air temperature.

When they are inside, the students are really measuring the temperature of the floor when observing the plain paper side of the disc. When observing the aluminum side of the disc the 'temperature' may, in fact, read the same as the plain paper side. Many students, however, fail to realize they are actually measuring temperature of the ceiling reflected by the foil side. This only becomes obvious when the disc is taken outside and the 'ceiling' becomes the very cold sky. Equally obvious is the fact that this is an impossible measurement situation: the aluminum surface simply emits too little for a signal to be detectable.

Cold Sky 'Reflections'

After this class exercise it is common for the students to talk about trying to eliminate 'the reflection' of the cold sky. But this is a case where the left side of the brain must predominate and force the right side of the brain to accept that this 'reflection' should not be eliminated. In essence, any situation where the background temperature is very low is a good one because we are better able to evaluate the true signal (due to emission) that remains without the radiance being dominated by reflection. In fact, there is no such thing as "cold sky reflection!" Rather a low emissivity surface appears cooler when "looking at" a cold sky because the energy contributed by reflection is such a small part of the total radiance. What the thermographer must do at this point is determine whether there is any signal left to evaluate by adjusting span and level downward. However, if the 'apparent' blackbody temperature (based on total radiance) is below the lowest detectable limit of the camera, then there is no signal to evaluate. We must either find a way to make the surface emittance higher, or pack up and go home.

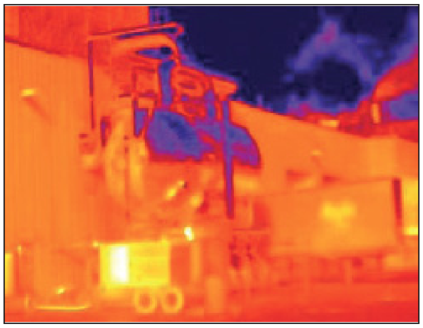

Figure 1

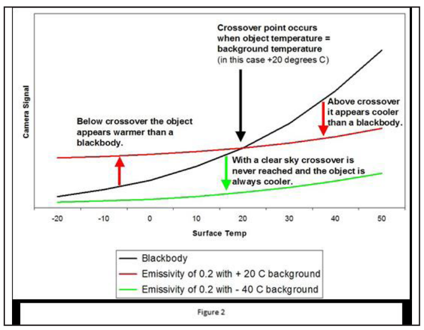

Figure 2

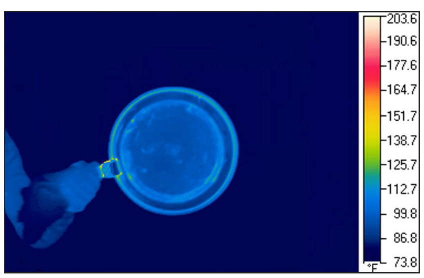

Figure 3a

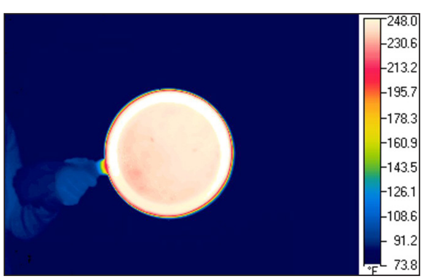

Figure 3b

A practical example is that of performing outdoor inspections of insulated aluminum-clad pipelines or process vessels with a (daytime or nighttime) clear sky. We will typically observe the shiny aluminum showing up as a very cold (Figure 1). The right side of our brain will recognize this as a 'reflection' and we will often change our camera position to eliminate it so that the vessel no longer shows the 'cold' reflection. This is a case however, where we must let the logical side of our brain prevail: if the total radiance is showing 'cold,' then replacing the sky with a warmer background surface actually makes things worse. If we are to have any chance of detecting emitted thermal patterns on the vessel, we must reduce the span and level in order to detect a variation in the emitted signal—while the reflected energy is not dominating the emitted energy (Figure 2).

One significant problem occurs when the sky is the background because it may have a highly variable 'apparent' temperature due to clouds, humidity, pollution or position in the sky. The horizon, for instance, has a higher apparent temperature due to the increased thickness of the atmosphere, and this increase will be seen in a reflection of the horizon as well. It is always a good idea to quickly check the apparent temperature of the entire sky (with emissivity set to 1.0) and observe what variations exist compared to a clear sky. If the entire sky appears very cold and close in value to the 'apparent' object temperature, then we probably do not have enough signal for inspection of that surface (e.g. average sky temperature reads –20°C and object temperature reads –20°C).

Equivalent Surfaces

Another good example of when we must let the logical side of our brain dominate occurs when we are observing surfaces of equivalent radiance. The right side of our brain tells us that these surfaces are the same color and therefore 'must be' the same temperature.

Refer to (Figure 3a) showing a hand and the bottom of an aluminum frying pan. The hand and the aluminum 'appear to be" the same temperature because they are the same color. In reality, however, the frying pan is much higher in temperature as can be observed when we turn the frying pan over and observe the (high emissivity) Teflon side of the pan (Figure 3b). If we were to take this one step further, we would be best to evaluate the aluminum side of frying pan outside with a clear sky as the background. It would appear 'cooler' than the person's hand, but nearly all of the remaining signal would be associated with radiation emitted by the surface, which is exactly what we want when trying to detect "real," or emitted, thermal patterns.

Thermal Shadows

When inspecting very low-emissivity surfaces, we must not let the intuitive side of brain rule. We must think through whether there is, in fact, any emitted signal to be detected and then optimize the camera for span and level on that signal. We must look for thermal shadows, particularly our own, since that means we are blocking out radiation from a background higher than our body temperature. But when we observe a shadow (on a reflective surface), we should look at whether it is a 'cold' shadow or 'warm' shadow. When our body casts a 'cold shadow', as we see in (Figure 4, next page) this tells us that we have a reflected background temperature warmer than our body. When we see a warm shadow this is indicative that the reflected background is cooler

Figure 4

than our body. In either case, the elimination of our 'shadow' does not automatically mean that it is OK to proceed with inspecting a surface that is highly reflective.

Field Inspection Technique

In reality the very coldest 'reflection' (e.g. -40°C apparent temperature) is actually the absence of signal: our camera detects no apparent radiance. This should tell us something (i.e. to quit or change our technique as discussed below). When we try to avoid a "cold reflection," then all we are usually doing is changing our angle so that a warmer object is now in the background and the new source of reflection. (That's like saying that we should use a hot boiler rather than an ambient wall as the background)

If there ever is a chance that we can detect an emitted thermal pattern on a low-emissivity surface, it will only happen when there is a very low background temperature and we've adjusted our span very narrowly and level low enough to observe the cold spots. It is not, however, intuitive to do this.

There are a few instances when poor inspection techniques create a "cold reflection" due to an angular variation of emittance (e.g.:looking upwards at a glass building). In such a case, instead of trying to eliminate the cold sky reflection, we should try to alter our inspection angle to improve emittance.

Summary

It is almost impossible to analyze thermal images without using both the intuitive and logical parts of our brain. During the inspection we must use our intuition to analyze the thermal patterns in the image and react to them by changing such things as our scan angle and span and level. But we must also use the logical and deductive side of our brain—both during the inspection and subsequent analysis—to determine the collective impact of emissivity, reflectivity and background. Post-inspection analysis should include imagery of the potential background sources, illustrating both their size and blackbody apparent temperature.