Diesel Electrical Maintenance Committee

Infrared Thermography In Locomotive Electrical Maintenance

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Infrared Thermography – Just What Is It

First of all prior to going into the uses of Infrared thermography in locomotive Electrical Maintenance we need to understand what thermography is and rather than try and muddle it, I will just give you a portion of the Wikipedia definition which does match most other definitions I have seen.

"Thermography

From Wikipedia, the free encyclopedia

Infrared thermography, thermal imaging, and thermal video, are examples of infrared imaging science. Thermal imaging cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14,000 nanometers or 0.9–14 µm) and produce images of that radiation, called thermograms. Since infrared radiation is emitted by all objects near room temperature, according to the black body radiation law, thermography makes it possible to see one's environment with or without visible illumination. The amount of radiation emitted by an object increases with temperature; therefore, thermography allows one to see variations in temperature. When viewed through a thermal imaging camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermography is particularly useful to the military and to security services.

Thermography has a long history, although its use has increased dramatically with the commercial and industrial applications of the past fifty years. Government and airport personnel used thermography to detect suspected swine flu cases during the 2009 pandemic.[1] Firefighters use thermography to see through smoke, to find persons, and to localize the base of a fire. Maintenance technicians use thermography to locate overheating joints and sections of power lines, which are a tell-tale sign of impending failure. Building construction technicians can see thermal signatures that indicate heat leaks in faulty thermal insulation and can use the results to improve the efficiency of heating and air-conditioning units. Some physiological changes in human beings and other warm-blooded animals can also be monitored with thermal imaging during clinical diagnostics.

The appearance and operation of a modern thermographic camera is often similar to a camcorder. Often the live thermogram reveals temperature variations so clearly that a photograph is not necessary for analysis. A recording module is therefore not always built-in.

The CCD and CMOS sensors used for visible light cameras are sensitive only to the nonthermal part of the infrared spectrum called near-infrared (NIR). Thermal imaging cameras use specialized focal plane arrays (FPAs) that respond to longer wavelengths (mid- and long-wavelength infrared). The most common types are InSb, InGaAs, HgCdTe and QWIP FPA. The newest technologies use low-cost, uncooled microbolometers as FPA sensors. Their resolution is considerably lower than that of optical cameras, mostly 160x120 or 320x240 pixels, up to 640x512 for the most expensive models. Thermal imaging cameras are much more expensive than their visible-spectrum counterparts, and higher-end models are often export-restricted due to the military uses for this technology. “

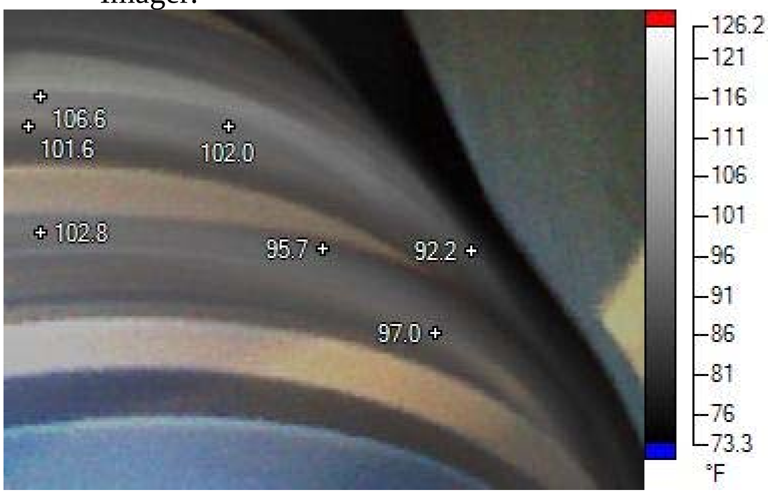
In a nutshell based on the above definition the first thought that comes to mind is that basically a Thermal Imaging Camera is essentially an infrared heat gun on steroids. While there is a lot of truth in this it does so much more than an infrared heat gun could possibly give you.

When we decided to get into thermal imaging we noted that there is a multitude of suppliers with the two major suppliers of this technology in the handheld type of thermal imagers that can be more easily cost justified are FLIR and FLUKE. Which of the two is the better product will not be debated here. We opted at the time to go with FLUKE mainly due to a history of success with other instruments put out by FLUKE so all images and thermographs will be shown from the FLUKE TI-25 Thermal Imager and FLUKE Smartview software.

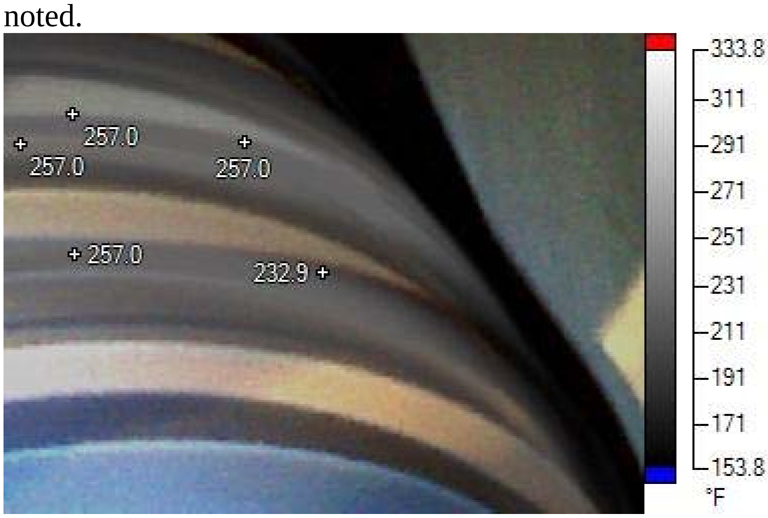
Uses of Infrared Thermography On Locomotives

Electrically on locomotives the following are some of the major uses on locomotives.

1. Examining slip rings for hot spots in the rings. Over time slip rings have shown themselves to be problematic with previous papers from this committee on this exact problem. Unlike an infrared heat gun, a thermograph gives you an overall picture of what is happening exactly overall live and this makes it very easy to spot problems as evidenced by the attached thermograph. This is a capture of the thermograph annotated using the desktop software included with the Thermal Imager.

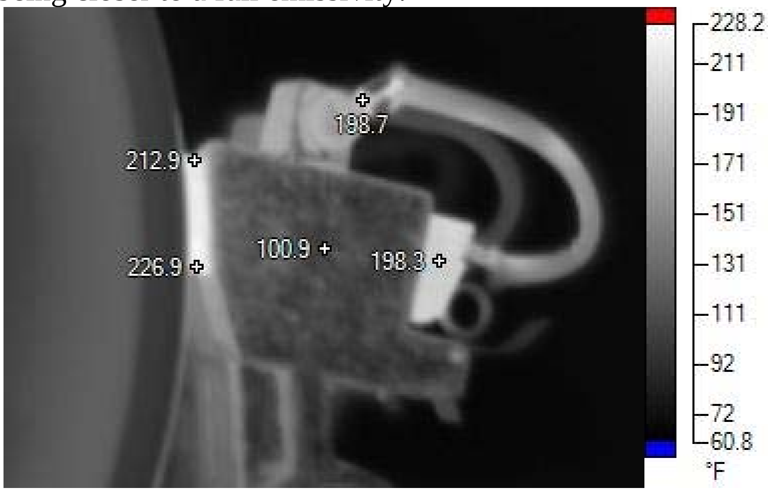


Unfortunately, while I was playing with the Thermograph once again I found out I was not as smart as I thought and still had a lot to learn. Like any thermal device, emissivity needs to be accounted for if you are looking for absolute temperatures of a subject. The initial emissivity setting for the thermal imager is set at 0.95 which does not properly reflect true temperatures of the locomotive slip rings and once emissivity was corrected to 0.10 which would be a truer representation of the heat the following readings were noted.



I apologize to our friends the brush manufacturers for thinking what an easy life brushes have at temperatures just over 100 degrees F.

Temperatures noted on a thermograph of a slip ring brush are as follows with carbon being closer to a full emissivity.



2. Checking for bad joints/high resistance connections on high voltage power cables. Over time we have seen with traction motor glad hand connections high resistance develop either at the point where the glad hands join or right in the glad hand itself. Over time as we moved to bolted connectors this problem has abated but using a thermal camera gives you an overall view of the leads and lugs at a glance. In the attached thermograph you can see the general heating in traction motor cables with the unit loading.

3. Contactors and relays high resistance contacts and/or connections. A general look with a thermal imager in any electrical cabinet under loaded conditions on the contactors or relays. To demonstrate this attached is a thermograph of cooling fan contactors on an SD60 unit with fan test engaged.

In this image you can see the general heat increase when the cooling fan test is in progress. This again gives a very quick indication of the relative state of the wiring and contacts, which in this case shows no major problems.
A general shot of an electrical cabinet showed the following.

As can be noted two warmer spots were noted. The first spot under the rubber insulation at 95 deg F showed no problems other than the effect of wrapping wiring in insulating rubber whereas the other point at 94 deg F. did have a suspect fast-on connector.

4. Last but not least at least for us Canucks is the operation of many of the heaters including blow down heaters on the locomotive. While checking blow down heaters on a locomotive can be done with an infrared heat gun, if you already have the thermal imager it will very quickly give you a direct indication of the heater function and heat dissipation into the surrounding components. This can be seen in the attached thermograph.

You can very quickly see proper heater operation and note that heat is properly being conducted into the blow down valve itself.

Limitations Of Thermal Imaging

As noted above in the discussion on slip rings if we are looking for absolute temperatures as with any device that uses infrared to measure temperature we must take into account the emissivity of the material that is being measured. Most metals have an emissivity much less than 1 and this can vary depending on the condition of the metal or other material being measured.

Attached is a definition of emissivity for clarification.

“Emissivity

From Wikipedia, the free encyclopedia

The **emissivity** of a material (usually written *ε* or *e*) is the relative ability of its surface to emit energy by radiation. It is the ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature. It is a measure of a material's ability to radiate absorbed energy. A true black body would have an emissivity of 1.0, while any real object would have an emissivity of less than 1.0 . Emissivity is a dimensionless quantity, so it does not have units.

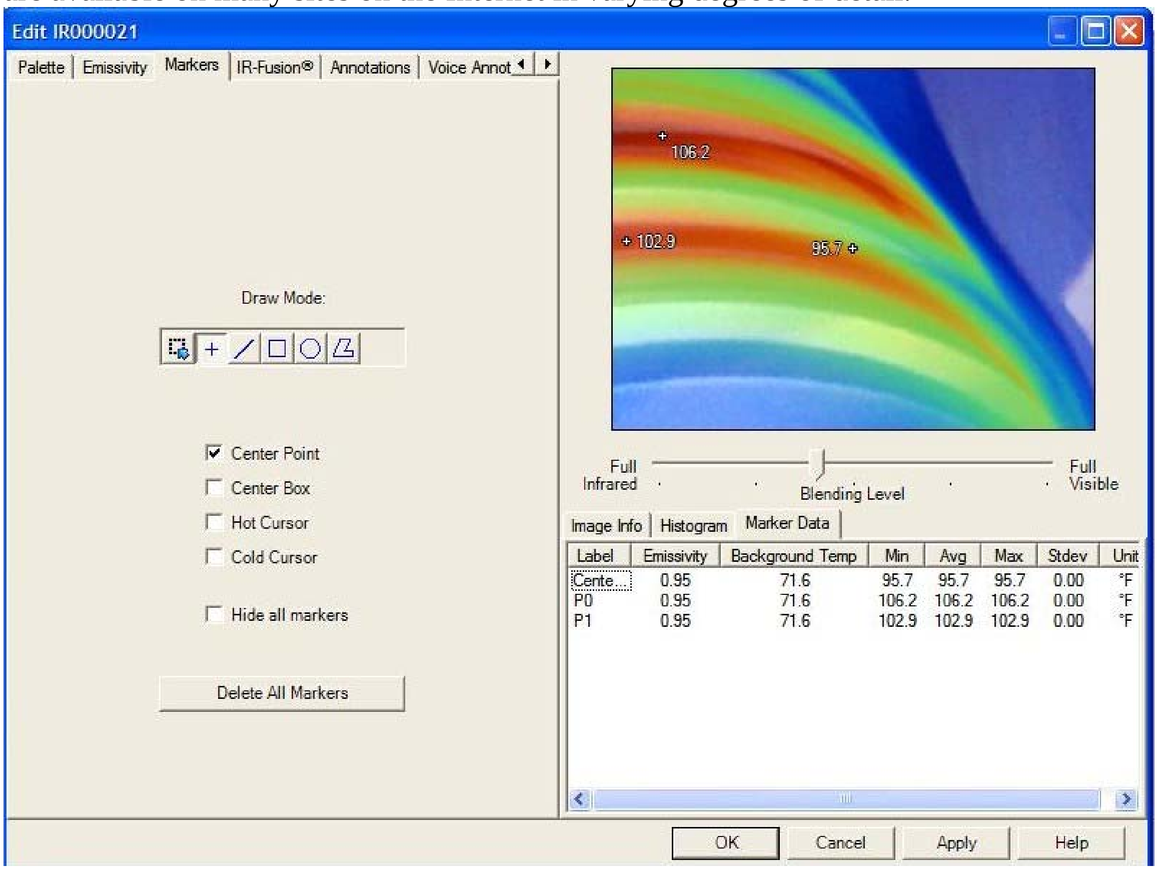
In general, the duller and blacker a material is, the closer its emissivity is to 1. The more reflective a material is, the lower its emissivity. Highly polished silver has an emissivity of about 0.02.

Emissivity depends on factors such as temperature, emission angle, and wavelength. A typical engineering assumption is to assume that a surface's spectral emissivity and absorptivity do not depend on wavelength, so that the emissivity is a constant. This is known as the "grey body assumption".

Although it is common to discuss the "emissivity of a material" (such as the emissivity of highly polished silver), the emissivity of a material does in general depend on its thickness. The emissivities quoted for materials are for samples of infinite thickness (which, in practice, means samples which are optically thick) — thinner samples of material will have reduced emissivity.

When dealing with non-black surfaces, the deviations from ideal black body behavior are determined by both the geometrical structure and the chemical composition, and follow Kirchhoff's law of thermal radiation: emissivity equals absorptivity (for an object in thermal equilibrium), so that an object that does not absorb all incident light will also emit less radiation than an ideal black body.”

With a thermal saved thermal image, if there is a need to determine exact temperatures the emissivity can be set on any point in the thermograph using the desktop software included. Further in live view with the thermal imager the emissivity can be set based on the material you are looking at. Emissivity tables are available on many sites on the Internet in varying degrees of detail.



The good news is, while this may critical in some instances, in pretty well all cases where we will use a thermal imager for maintenance purposes this is not an issue. When as maintenance personnel we start looking for problems the absolute value of the temperature is not nearly as critical as changes in a component or wiring relative to surrounding parts of the component or the wiring. In other words, if you are looking at connection points or contacts other like parts will be subject to the same differentials due to emissivity and the differential in temperature is the key.

Conclusions And Final Thoughts

Based on everything I have seen with this device, if used as a differential temperature tool it is invaluable. When used as such minimal training is required. In addition, the power of the desktop software enhances the usefulness of the images immensely and I know of no other piece of test equipment that can do what the thermal imager can do relative to spotting many problems before they become a failure.