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Pro Tips

For using thermal imagers to examine tanks and vessels

Application Note

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Figure 1. Checking tank levels at a natural gas processing facility.

Normally, people in industry use level indicators to tell how much product is inside a tank. So—why do so many of them also use thermal imagers (infrared cameras) to do the same thing? It's because of the horror stories. Past experiences when the level gauge gave a false indication, resulting in either running out of product, or worse, overfilling a tank that was supposed to be empty. As former President Reagan said "Trust, but Verify."

Typical thermal images seem to exhibit "x-ray vision"—they show the contents of the container and give quantifiable verification of the material inside. Of course, x-rays aren't actually involved. Instead, the images show apparent thermal differences. When users apply their knowledge of materials and physics to the thermal differences they see with an imager, they can deduce the level of fluid in the tanks.

Because of that human deductive element, the meaningfulness of the examination depends on the person's knowledge and the type of result they desire. In the illustration of the tank farm, we clearly see the liquid level inside the tanks. That's because the tank contains two different materials: liquid, and air in the headspace.

Since these tanks are located outside, the tanks and their contents undergo thermal cycling. During the daylight hours the tank and contents absorb heat from the sun and the air, as well as from whatever processing might be taking place. During the night, the tank and the contents are giving up heat to the surrounding air. This thermal cycle and the varying thermal capacities of the materials involved all affect how accurately a thermal imager can measure product level.

These metal tanks in particular are un-insulated and highly thermally conductive. As night falls, the headspace begins to cool quickly while the liquid volume cools much more slowly. That makes the thermal gradient between the liquid and headspace readily apparent through a thermal imager. There are typically two times of day when the thermal difference is at its maximum—once during the morning and once during the evening.

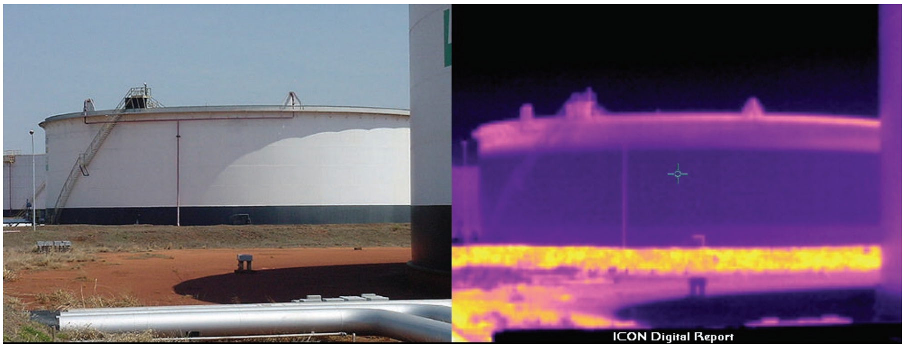

Figure 2. Thermal image of a tank farm, showing how the liquid level is apparent in each tank.

At other times of day, it may not be possible to clearly identify the liquid level with the thermal imager, because the contents and the air in the headspace may approach the same temperature. Reflections from the sunlight during daylight hours can also make it difficult to observe thermal differences.

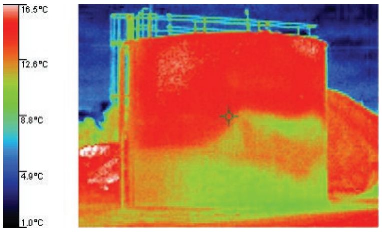

Figure 3. Uneven dry bulk materials or sludge.

Tanks hold materials other than liquids, too. Dry bulk materials tend to pile up against the sides and have very uneven levels. Thermal imagers enable you to see these irregularities (see Figure 3). Also, many liquids contain particulate that may settle out inside the tank, forming a sediment layer. These layers can often be identified as sub straights by the thermal differences they produce.

Understanding what the tank is constructed of is also important. Many tanks have shiny, low emissivity shiny metal surfaces and/or insulated walls that make it difficult or impossible to observe internal thermal differences. These factors are crucial for evaluating what a thermal imager appears to be telling you. Use caution and apply knowledge!

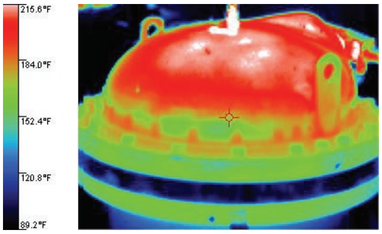

Figure 4. Process reactor vessel.

As an illustration, let's look at a process reactor vessel (see Figure 4). The color temperature bar indicates that dark blue is approximately 95 °F and the top of the scale indicates red at over 200 °F. We see the dark blue band where the lid sits on the vessel, and this band appears to be cool. What we are actually seeing is a very low emissivity band of stainless steel around the top of this otherwise painted vessel. The painted portion has a much higher emissivity, so in contrast it appears the bare stainless steel is cool when it's actually the same temperature (over 160 °F) as the painted portions that it is in contact with: hot enough to seriously burn skin.

Industrial processes often involve other kinds of vessels that don't look like tanks, often referred to as "heat exchangers". The most common is a steam radiator.

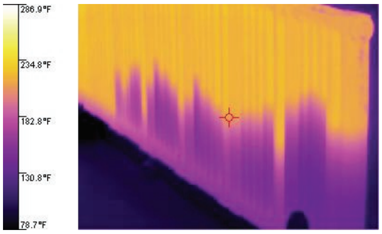

Figure 5. Water condensed in a steam radiator.

In Figure 5 you can clearly see water condensed in the steam radiator. With the infrared thermal camera, you can diagnose problems in processes.

In another process example, there was a thermocouple installed in a stainless steel process line for monitoring the temperature of the process fluid. The process was not functioning properly and the process engineer was having difficulty determining why the temperature of the process stream was lower than expected. When he sampled and measured the process fluid externally, it had the proper temperature.

Since the piping was all stainless steel, the material surface was too reflective to directly observe the fluid level with the thermal imager. The process engineer applied some black electrical tape around the area of the pipe where the thermocouple was installed, improving the emissivity. Now the thermal imager revealed that the pipe was less than 1/3 filled with process fluid. The thermocouple was barely making contact with the fluid, resulting in erroneous temperature measurements of the process. A vapor lock had produced the errant headspace.

While furnaces and ovens are often thought of as vessels and are examined for heat loss, another interesting industrial vessel is a process freezer. The freezer in this example was constructed to flash freeze meat patties. The freezer interior contains a custom spiral conveyor system that continuously inputs hot cooked meat patties from the oven, into a –40 °F chamber to quickly remove the heat from the product.

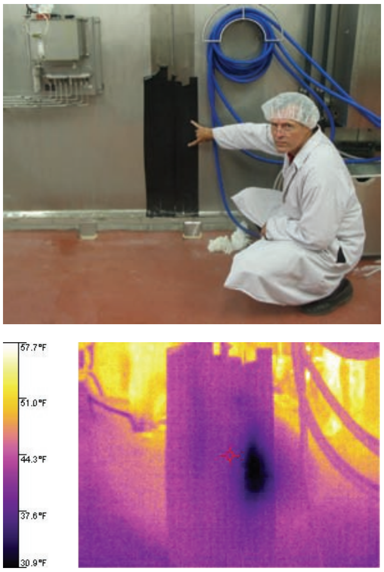

Figure 6. Condensation in a process freezer.

Upon delivery, this industrial freezer exhibited numerous areas of condensation on the exterior surface. The condensation indicated areas where there were voids in the insulation system in the walls. The manufacturer had tried drilling holes in the metal sidewalls of the freezer where the condensation was located, to find the insulation voids, but everywhere they drilled insulation was present.

Figure 7. A hole drilled through the reflective steel revealed the insulation void.

The exterior freezer walls were polished stainless steel and so very highly reflective. The thermographer dried the areas of condensation and placed black tape over them. This allowed the thermal imager to pinpoint the exact location of the coldest spot. When he drilled a 2 inch hole to observe the interior of the freezer wall, he found the exact location of the insulation void.

As these examples illustrate, tanks and vessels come in a wide assortment of styles and configurations from familiar looking tanks, to reactor vessels, to heat exchangers, and to ovens, furnaces and freezers. Even the piping connecting vessels is a vessel.

Thermal imagers can analyze a great many more things than just temperature, once you embrace the spectral and thermal dynamics of your materials and processes. Start by considering how the thermal properties of materials are exhibited in different ways. You can even treat the vessel itself as the product.

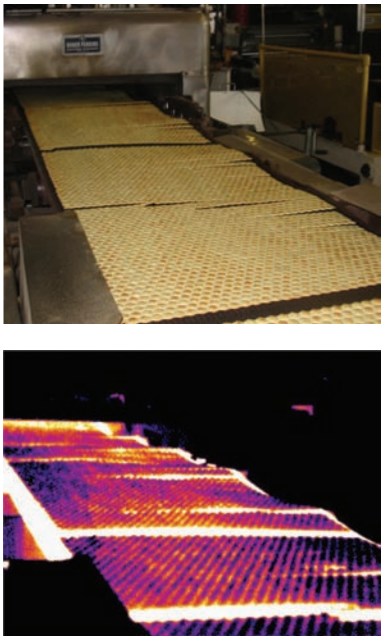

Figure 8. Moisture content in cookie production.

For example, consider a cookie production facility where crackers are being produced (Figure 8). Moisture content in the finished product is like the liquid level in a tank. In both cases, we want to know how much is inside. In this case, we have a fairly uniform mass of product that is passing through an oven. As the product emerges from the oven, the product that contains more moisture appears warmer and the product that contains less moisture appears cooler. This occurs because as the product emerges from the oven, it begins rapidly cooling towards ambient. Where it contains more moisture, it cools more slowly.

A thermal imager can observe the thermal zones of the oven, as well as a map of the moisture distribution of the product.

Moisture content is a most interesting parameter, because moisture can be measured directly using infrared analyzers. When light hits a surface that contains moisture, the moisture absorbs infrared radiation in the region of 1.8 microns. By measuring infrared absorbance, you can measure actual surface moisture. Observing the differences in thermal cooling is very similar. See how the spectral characteristics of materials can overlap and be indicative of one another?

The application of thermal imagers is limited only by the knowledge of the person using the equipment. Thermal imagers are rapidly becoming more economical and easy to use, but the camera is only as good as the person using it. Take time to examine your processes, understand your materials, and think about how the properties you wish to understand relate to the thermal characteristics. Thermal imagers produce useful maps of equipment and processes, as long as one takes time to understand the language.

All objects emit infrared (thermal) radiation. The intensity of the radiation depends on the temperature and nature of the material's surface. At a given temperature, the maximum radiation is achieved when the object has an emissivity of 1. This is referred to as blackbody radiation, because with an emissivity of 1, the object is a perfect radiator. However, in our real work, there are no perfect radiators. Since real materials are less than perfect, the question is: How much less than perfect are they?

Emissivity is defined as the measure of how much less than perfectly a material radiates when compared to a blackbody. When a thermal imager observes the thermal radiation from real objects, part of what it sees is reflected from the object's surface, part is emitted by the object, and part may be transmitted through the object.

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