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Thermal Imaging

White Paper:
Locating Levels in Tanks and Silos Using Infrared Thermal Imaging

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Locating Levels in Tanks and Silos Using Infrared Thermal Imaging

Abstract

Infrared thermal imaging is a powerful tool for locating and verifying levels in tanks and silos. Other level indication instruments are often not sufficiently reliable in many situations, or positive verification of the instrumentation readings is required. When properly used, thermal imaging can reveal not only the liquid/gas interface, but also sludge buildup and floating materials such as waxes and foams. Similar techniques can be used to locate levels and bridging problems in silos containing fluidized solids.

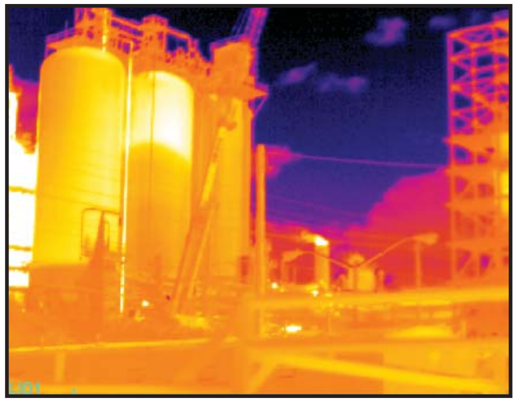
This paper discusses the parameters and limitations that must be addressed, shows techniques that can be employed, and illustrates the discussions with numerous thermal images.

Background

Instrumentation for locating levels in tanks and silos is often unreliable. The need for precise information about levels remains necessary, or even critical, in many instances. For example, in one situation a thermographer was employed to verify a liquid level in a large storage tank along the Gulf Coast prior to the arrival of a tanker ship. In continuous processes the operator must know how much capacity is available in each tank. Without that knowledge production may be impeded or, if an overflow occurs, a potentially dangerous situation created.

Sometimes traditional level indicating instruments simply cannot determine levels. Foams and waxes, for instance, are difficult to detect and measure accurately. A paper mill experienced a situation in which a tank was believed to be sized improperly, when in fact it was simply full of foam rather than liquid. De-foaming the tank proved more cost effective than unnecessarily replacing it with a larger one! A petrochemical plant hired a contractor to clean out a large tank. When the manway door was opened, sludge, which had settled to a depth high above the door, oozed forth creating a dangerous and environmentally damaging situation. For industries needing to comply with the safety and process requirements of OSHA 1910, thermography may prove to be a particularly cost-effective tool to use.

Levels can be seen in two tanks (left and center), along with differing solar influences, while the right tank appears to be full.



Sludge completely covers the manway opening in this tank in a paper mill. Anticipating this condition will result in maintenance strategies that are safe and cost effective.

Each of these situations represents a real instance where infrared could have been used to provide or verify information about the condition inside the tank or silo. Level location as well as verification of other level indicating instruments continues to be an important need in industry.

Thermal Imaging as a Method for Determining Levels

Most of the time, the materials in a tank or silo, whether solids, liquids, or gases, behave differently when subjected to a thermal transition. The materials often have differing thermal capacitance characteristics. Gases typically change temperature much more easily than liquids. Water, for instance, has a thermal capacity that is 3500 times greater than air. One Btu of energy added to a cubic foot of water will raise its temperature 0.016°F while the same energy added to the same volume of air results in a 55°F increase!

While the thermal capacity of solids may be similar to liquids, the different way in which heat is transferred permits them to be distinguished with an infrared camera. Solids, such as sludge, are influenced primarily by conductive heat transfer. Fluids (non-solids), on the other hand, are strongly influenced by convective heat transfer. The result is that the layer of solids in close contact with the tank wall, despite its often high thermal capacitance, heat and cool more rapidly than the liquid portion because they do not mix in the same way the liquid does.

One issue is whether the tank/silo is half-full or half-empty. This determination requires further research by the investigator of the materials, container housing and environmental circumstances.

Necessary Environmental Conditions

Key to determining levels is to observe the tank or silo during a thermal transition. If viewed with an infrared camera while at a thermal steady state with the surroundings, no differences will be seen. In fact, tanks and silos that are full or empty often appear identical with no indication of a level. Interestingly, it is difficult to find tanks or silos that are not in transition, although it may not always yield a detectable image. Outdoors, the day/night cycle often provides sufficient driving force to create detectable differences. Even indoors, variations in air temperature are often sufficient to make thermal transitions apparent.

Environmental conditions can have a direct influence on the ability to detect levels by thermal imaging. Wind, precipitation, ambient air temperature, and solar loading can all, separately or together, create or negate differences on the surface. Other factors to be considered include the temperatures of the products being stored in or moved through the tanks and silos, as well as the rates at which they are moving. Many tanks are insulated, although rarely to the extent that they will always and entirely obliterate the thermal patterns caused by levels. When insulation is covered with unpainted metal cladding, care must be taken to increase emissivity, as discussed later.

Thermal Patterns of Materials in Different Forms

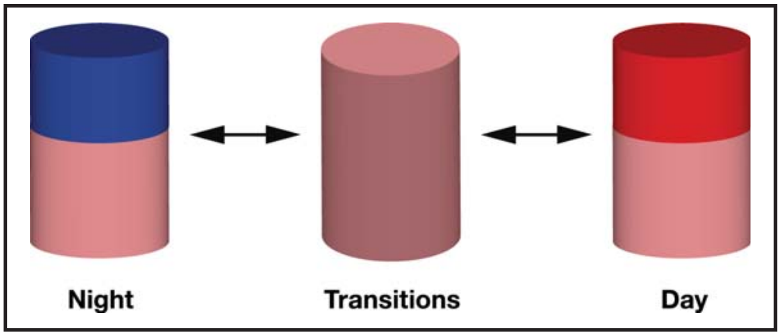
The most obvious pattern is a result of a liquid/gas interface. In a situation where the product is not heated, the gas typically responds quickly to the transient situation, while the liquid responds more slowly. During the day, the gas may be warmer than the liquid;at night it is cooler.

Liquid/sludge relationships may be more difficult to discern. A larger transient may be required to create a detectable image. Thin layers of sludge may also be indistinguishable from the tank bottom. Sludge buildup in the center of the tank (i.e. not in contact with the wall) is simply not detectable, although product buildup on the sidewalls is often quite obvious.

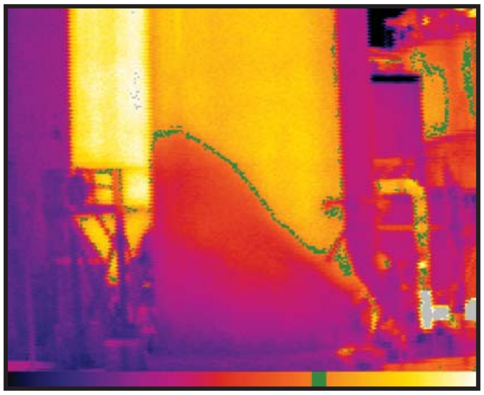
Foams are often not difficult to distinguish from liquids but may appear similar to gases. Care should be taken when pushing the tank through a rapid thermal transition to reveal the thermal differences. Locating levels associated with floating materials, such as waxes, will typically require more persistence, skill and a greater rate of transitional heat transfer, but the results can be startling.

Whether or not liquid/liquid interfaces, such as a mix of oil and water, can be seen depends entirely on their differing thermal capacities and, to a lesser extent, their viscosity. Simple experiments suggest it is fairly easy to locate the interface of oil and water, but further work needs to be done in the field to validate this technique.

As it transitions from night to day, a simple liquid/gas interface influenced by the outdoor temperature ends up with both liquid and gas at the same temperature twice. In large tanks, the liquid does not change temperature greatly, but the gas typically does.



Sludge buildup in this tank is substantial, approximately 20’ deep, a condition that had not been well understood. The outflow is pumped on the right side.



Some solids, such as coal ash, plastic pellets, powdered lime and wood chips, behave as fluids and are designated as “fluidized solids.” While heat transfer in such materials is still primarily conductive, mass transfer of heat by the material’s movement can be significant. For instance, hot ash or lime blown into a silo carries its process heat to the silo. Fluidized solids tend to behave similarly to liquids in the way they respond to gravity, except for the fact that they can “bridge” across areas where liquids typically would not. In fact, locating bridging of fluidized materials is a valuable use for thermography.

Issues to be Considered

Some tanks are covered in cladding, often unpainted aluminum or stainless steel. Detecting the kind of fine temperature differences necessary to reveal levels on surfaces such as these—ones having low emissivity and high reflectivity—is nearly impossible. The radiant difference is simply not detectable. The problem, however, is most often easily rectified by applying a high emissivity target vertically. A painted stripe or a piece of tape on the tank, for instance, can work very well. For outdoors work, use light colors and/or the shady side of the equipment to avoid solar loading.

Occasionally tanks are heated or cooled with a jacket. These often cause thermal imaging cameras to be ineffective for level determination . In some instances it may be possible to see the structural "stand offs" between the tank wall and the jacket.

Tanks that are insulated can also prove challenging. Thankfully, insulation levels are typically not great enough that they preclude seeing levels; rather the insulation changes the thermal dynamics to the point where a detectable level may not be obvious as often. Simple techniques, explained below, can help enhance thermal differences so that they can be detected. In some instances it may be possible to cut small "plugs" out of the insulation at various levels that would more clearly reveal the tank temperatures.

Although solar loading can enhance a pattern, more often it can cause subtle thermal patterns in a tank or silo to be obliterated. It may be possible to view the container on the shady side, but sometimes it may be necessary to return when the sun's affect is lessened.

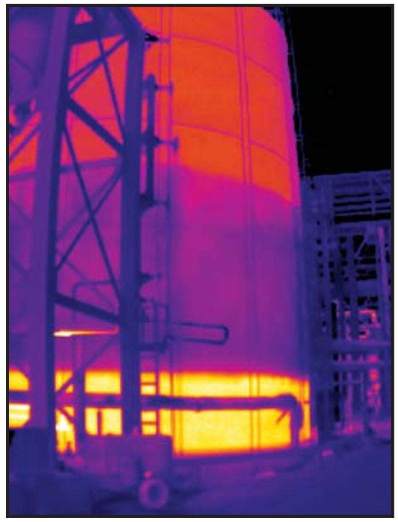
Spheroid tanks offer another type of challenge in that, when viewed from one point, their reflectance varies widely over their curved surface. It is not unusual to find the tops of such tanks appearing cooler while the bottom appearing warmer; all too often both patterns are related more to reflectance than emission.

Tanks located inside of buildings are not subjected to diurnal heating cycles. Some thermal cycling usually does take place, but it may not be enough to make the radiant differences detectable. Again, simple techniques, explained below, can be used very effectively to enhance surface temperature differences.

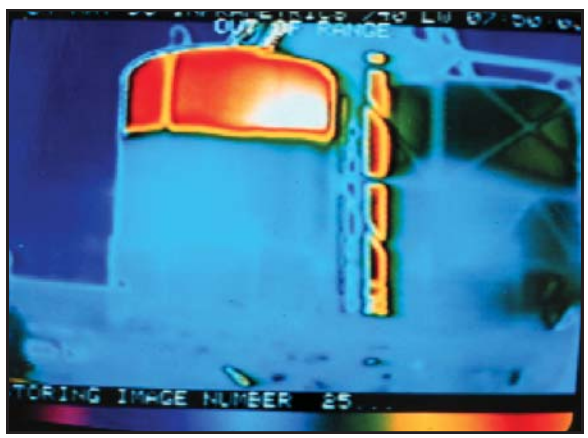
Simple Techniques to Enhance Thermal Patterns

Often thermal patterns can be enhanced by using simple techniques to increase transient heat transfer. It may be possible to add heating or cooling directly into or to the surface of the tank/silo. The gas head in the tank responds more quickly than the liquid. As discussed above, solids may respond in a more complex manner.

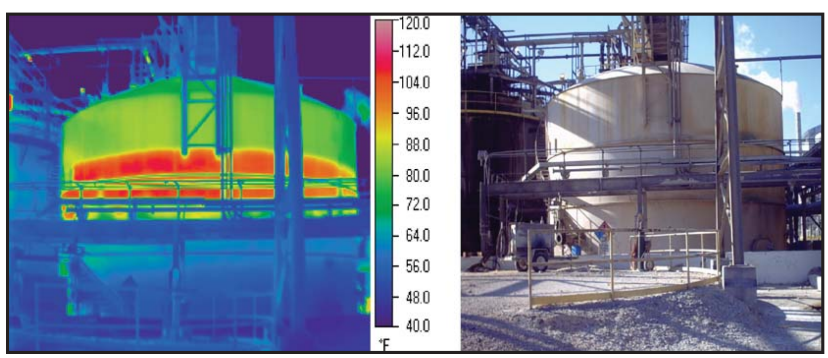
An industrial hot air gun can be used to heat the surface of small to medium sized tanks. Heating even a narrow area may dramatically reveal a level. Cooling can be provided simply by wetting the surface with water. As evaporation takes place, cooling drives transient heat flow and reveals or enhances the levels.



In this black liquor tank, both the gas/soap and the soap/liquid interfaces are visible here. The level indication equipment had been reading the gas/soap level rather than the liquid level.



Two silos are being filled, on alternate days, with lime from a kiln. The tank on the right had been filled the previous day while the one on the left was being filled with hot product at the time the image was taken.



Thermography is an important, cost-effective tool to verify or locate tank levels. A straightforward gas/liquid interface is shown here.

While these techniques may not seem feasible for large tanks, such is not the case. Cooling in particular can easily be supplied with a stream of cold water hosed onto the tank surface. Add the element of time for the cooling to take effect and, in many cases, the image becomes readily apparent.

Conclusion

Many industries have a critical need to determine levels in tanks and silos and to validate the already existing level-indication instrumentation. Infrared thermal imaging provides a simple, cost-effective means of doing both. Conditions often allow for levels to be seen at almost any time of the night or day and throughout the year. While levels are not always immediately obvious, persistence, careful infrared imaging and simple enhancement techniques can often produce remarkable results.

Acknowledgements

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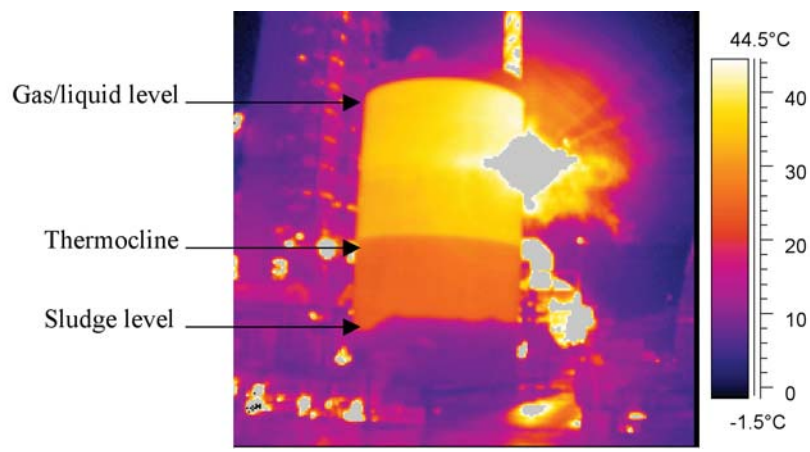

An unusual pattern can be seen in this tank where a thermocline (a temperature gradient layer) has established itself in the liquid. (A flare in the background caused the bright spot on the right side of the thermal image). (Courtesy Greg McIntosh, Snell Infrared Canada)

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