How to spot and address potential process problems using thermal imaging

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Application Note

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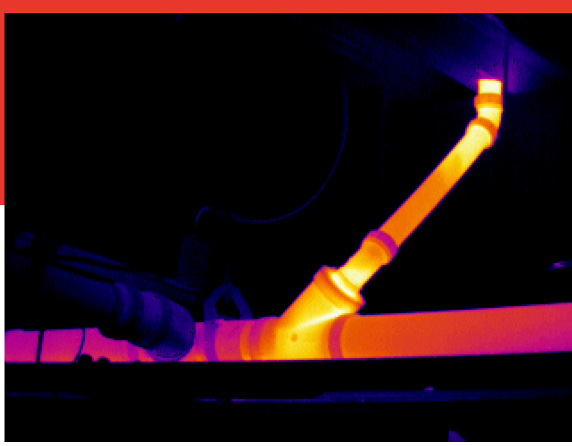
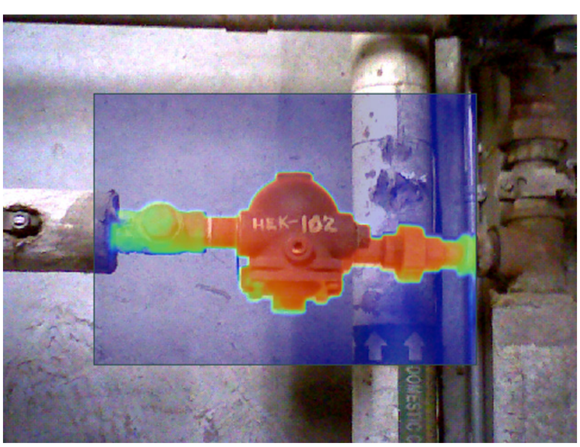
In the past several years, thermal cameras have transformed from a specialist-only device to the perfect tool for process equipment maintenance—from troubleshooting to scheduled maintenance. By using a thermal camera for troubleshooting, the technician can diagnose the root-cause more efficiently while also often identifying other potential problems during the same inspection, PdM-style.



Infrared imaging shows a partial blockage in a process liquid waste drainage line. Failure to recognize a deteriorating situation could result in serious problems.



Correctly operating steam traps should show a temperature differential from one side to the other. All high or low temperatures on both sides of trap may mean that the trap is stuck open or closed.

How thermal cameras work

Unlike regular digital cameras that capture images of the visible light reflected by objects, thermal cameras create pictures by measuring infrared energy or heat. The thermal camera then assigns colors based on the temperature differences it measures. In a "radiometric" imager, each pixel of color on screen represents an individual temperature.

Thermal cameras read the surface temperature of objects. The trick is that surfaces don't all emit thermal energy equally well. Emissivity is the material property that describes the efficiency with which an object radiates or emits heat.

Emissivity is expressed as a value from zero to one-point-zero:

- Shiny metals have low emissivity
- Non-metals or painted or heavily oxidized metals have a higher emissivity

Objects with low-emissivity are—at the same time—highly *reflective* of their thermal surroundings. Because of this, the reflected energy a thermal camera sees may be different than actual temperature. To compensate (and improve temperature accuracy), follow these tips:

- Avoid measuring shiny metal surfaces
- In an electrical cabinet, focus on those object that are highly emissive such as the rubber insulation on the power cable
- Apply black paint or electrician's tape to high-emissivity surfaces where necessary
- Know or control your background temperature

The other way to compensate is to take qualitative readings. In other words, in many cases, you can compare heat signatures between like components or units, or to previous readings on that same object. If the temperature is markedly different, then there may be a problem. Knowing the precise temperature in that case may not be necessary.

Measurement guidelines

To capture the best thermal images, follow these best practices:

- Verify that the target is operating at a minimum 40 % of load (lighter loads don't produce much heat, making it hard to detect problems).
- Within the safe zone of your equipment, get as close to your target as you can.
- Don't "shoot" through doors; thermal gradients within an electrical cabinet make it impossible to understand the thermal impact inside the cabinet.
- Infrared doesn't go through glass or plastic safety shields so you need to work around these items.
- Account for wind and air currents that could cool the abnormal hot spots.
- Account for ambient air temperatures, especially outdoors. Hot/cool weather can mask component temperatures.
- Not all problems are hot! Restricted flow in a cooling system could be indicated by a cooler than normal signature.
- Think about how the equipment in question works and what its heat-related failure signatures are. It is important to understand the base line thermal pattern of the equipment you are thermally scanning.
- Consider sources for reflective infrared radiation when working with low-emissivity assets.
- When trending electrical or mechanical assets it's important to have consistent loads for accurate temperature data over time.

Note: While thermal imaging is non-contact, if you measure live electricity with the enclosure doors removed, NFAP 70E safety standards still apply. Wear appropriate personal protective equipment, try to stay four feet away from the object, and minimize time spent in the arc-flash zone.

Take a baseline image of all motors, to compare over time, and then routinely look for abnormal hot spots on the motor, under full load.

Process applications for thermal imaging

- Measure operational temperatures in motors or other rotating equipment.
- Identify leaks, blockages and settling in sealed vessels, pipes, steam systems, and heat exchangers.
- Capture process temperature readings.

Inspecting motors and other rotating equipment

Key inspection points for motors include:

- Bearings
  - Bearings under equal load should display equal temperatures
  - A hotter bearing on sheave side of motor could indicate over-tightened belts
- Belts
  - Sheaves that are hotter around circumference could indicate slipping belts
  - Belts that do not cool between the motor and blower sheaves could indicate slipping belts
  - Belts with unequal thermal patterns can indicate misalignment
- Couplings
- Electrical connections
- Overall temperature, especially
  - Poor cooling, or
  - Internal problems

Take the time to understand:

- How heat moves in the equipment via conduction and convection,
- How the equipment functions and fails. Understand the manufacture's operating specifications for the equipment

Thermal signatures are often associated with machine health. Normal operation has a verifiable signature and problems often show up as differentials. To understand these, however, requires knowledge of the machine and how it fails.

With the help of your troubleshooting thermal camera, it pays to quickly check the overall motor temperature every so often, especially for smaller motors that may not get the kind of maintenance they should. Often these motors overheat before anyone notices otherwise. Use the motor temperature rating on the nameplate as a guide. Exterior motor temperatures are generally about 36 °F cooler than the interior temperatures.

For a routine or preventive maintenance program, it's ideal to start with a newly commissioned and freshly lubricated motor and take a snap shot of the key inspection points, while the motor is running. Use these images as baselines.

Tip: On new motors, watch the initial motor start up through your thermal camera. A wiring problem, alignment or lubrication issue will show up thermally before permanent damage is incurred.

As the motor ages, the components become worn, and heat-producing friction develops, the housings will begin to heat up. If possible, take additional thermal images at regular intervals, comparing them to the baseline to analyze the motor's condition. When the thermal images indicate overheating, generate a maintenance order.

When you are looking at *small bearings*:

- Compare thermal patterns of one bearing to other similar ones in the same operation.
- Remember that small bearing failures can result in fire, mechanical stress, belt wear and increased electrical loads.

Inspecting small bearings is one of the places infrared shines as a maintenance technology. There is often no other way to inspect these and problems, while they may seem insignificant at first, can be serious. Another benefit is that the inspection is done while the equipment is operating.

When you are looking at *belts* and *sheaves*:

- Guards may restrict your view.
- Be sure to re-inspect belts and sheaves after corrective action is taken. While it is not always possible to get a clear view of the belts, thermography can provide valuable information about the condition of the belt and sheave.

When inspecting pumps and fans, focus on the *coupling*:

- Look for irregularities—a healthy coupling should have a consistent thermal signature. Component wear will cause abnormal heat.
- Alignment issues will show up as excess heat before they cause bearing problems and then irreversible damage.

Inspecting tanks and other sealed vessels

Key inspection points:

- Scan the outside surface of tanks for differences in temperature at different points
- Gaskets, seals, and valves at openings
- Tank levels—locate fluid, solid, "floater" levels and sludge
- Refractory

While most large process tanks have built-in visual or electronic indicators for tracking product levels, they are not always reliable. Thermal inspections can reveal the interface between the liquid and the gas (usually air) in a vessel, indicating how full it is and whether the contents have settled or separated inappropriately. Knowing the correct levels avoids overfilling when a level sensor is faulty and ensures reliable inventory figures for raw materials and/or finished products.

Shafts made of shiny stainless steel can be tricky to measure with thermal cameras. Compensate by measuring close to the coupling.

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Thermal cameras can detect the level of fluid or other substance inside a tank, providing there is a temperature difference between the liquid, the air inside, and the air outside, and providing the tank is not made of a shiny material.

Take Note:

- Gases have a higher heat capacity than the liquids, meaning the liquid products change temperature much more slowly than the gas in the headspace.
- Since most tanks are located outside, their contents heat up during the day due to solar loading, and cool off at night. This temperature difference between the product and the head-space can usually be observed through most tank walls. This technique can work any time during the day but keep in mind that there will be times when the air and liquid or solid will be the same temperature and no apparent level will be visible. The level will start to become visible as the air gains or looses thermal energy.
- A thermal image of a tank that is completely empty or completely full, or that has a shiny reflective skin, will appear uniform and no product level will be apparent. Otherwise, the product level will appear as an obvious thermal separation between the headspace and the product.
- If the tank surface is shiny, or it has insulated walls, it may be difficult to inspect using thermal imaging.

Tank levels

When a tank or silo is changing temperature, it's often possible to see the thermal patterns associated with the various levels inside. Knowing the sludge level, for instance, is invaluable when it comes to operating a continuous process or preparing to clean out a tank. Thermography can also reveal floating materials such as wax and foam as well as layers of different liquids, gases and even solids, such as the layer of paraffin that sometimes forms between the oil and water layers in separators, hindering their normal operation.

Spotting leaky gaskets and seals

Most leaks develop in or around a gasket or seal. Less often, corrosion will cause a weakness to develop and rupture the vessel. To find a leaky gasket or seal, scan the imager along the seal looking for thermal eccentricities. A large change in temperature along the seal or gasket indicates a loss of either heat or cold—the signature of a failure.

Valves

A thermal camera can monitor process control valves for leakage, stiction (sticking) or excess friction. Also, a valve's excitation coil may overheat from working too hard, pointing to a problem such as current leakage or valve size mismatch. When thermography indicates a problem, technicians can follow up by calibrating the valve or the valve's positioner.

Refractories

Under the right conditions, a damaged refractory or liner will show up as hot or cool spots. Most leaks occur because of the failure of a seal or gasket, although sometimes corrosion will lead to a leak in a vessel's wall. Whatever its origin, a leak is likely to manifest itself as a temperature anomaly. When inspecting refractory insulation, look for hot areas associated with refractory thinning or failure. Cold areas associated with internal product build-up.

High temperature refractory is designed to control heat transfer; as it degrades, it allows more heat to transfer to the outside of the device. In some cases, the cooler areas are the ones of interest as they may show product buildup inside a device.

Steam traps, lines, radiators and convectors

Thermal cameras can quickly see the trap and line temperatures into and out of steam traps. Check all transmission lines and follow pipe temperatures to the source of problems.

- If temperature is low in steam pipe, low in trap and low in condensate return, trap may be stuck closed.
- If temperature is high in steam pipe, high in trap, and high in condensate return, trap may be stuck open.

- If temperature is high in steam pipe, high in trap, and slightly lower in condensate return, trap is probably operating properly.

A trap that has failed to open can go undetected for weeks or months and can be very costly. To a thermal camera, these traps will appear warm on both sides. If you find a trap like this, make sure it has not just cycled. If, after a few minutes, it remains hot on both sides, it is probably not working properly.

Heat exchangers/ steam radiators

Thermal inspection of heat exchangers can quickly and safely identify areas of corrosion, mineral deposits, and sludge build-up, as well as a lack of heat transfer due to external damage like hail, abuse, or lack of maintenance. It is important to remember however, that mechanical heat transfer is one area in which clear, sharp lines of temperature difference rarely exist. Unlike the typical "hot spots" one is able to see in overheating or malfunctioning equipment, heat exchangers are constructed to facilitate a diffuse and monolithic temperature exchange. Higher resolution cameras with on-camera level-and-span adjustments typically help with capturing lower thermal differences (called Delta T) often exhibited by blocked passages or clogged strainers of plate-type exchangers.

Inversely, shell-type heat exchangers often times show clear and definitive areas of blockage caused by solid build-up of materials. In these cases, infrared inspection will allow you to diagnose specific areas of trouble.

Conclusion

The missing ingredient in all of the above is personal experience. Troubleshooting by nature is scenario specific. The more time spent using thermal cameras, the better the user becomes at identifying anomalies. That thermal skill, blended into existing knowledge of line and equipment functionality, can make for a formidable troubleshooter and better, long-term maintenance.

Did you know?

1. Not all problems are hot. If a fuse or switch has failed, for example, you may see an uncommonly cold connection.
2. If a panel or other piece of equipment has an internal fan, you won't get an accurate surface temperature reading. (Obviously, take care when disabling a fan critical to equipment cooling.)
3. You can take a thermal camera into messy process areas—just cover the camera with a thin plastic bag. The plastic is transparent to infrared.
4. Over lubrication is just as much of a problem as under lubrication! Similarly, belts can be both over and under tightened.
5. Water holds on to heat far longer than air. That means that after a hot day, the liquid inside a tank will stay warm long after the air has cooled, giving you the greatest thermal differentiation to detect tank levels with.

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