Thermography: Seeing the Unforeseen

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Imagine having the ability to tell if a motor or a bearing were about to fail just by looking at it. Over the past 5 years, a thermography program has proven to be a cost-effective means to inspect electrical and mechanical equipment to do just that. The hot mill at ArcelorMittal Burns Harbor has continued the use and expansion of thermography throughout the mill with great success. Several findings have led to significant savings in both downtime and equipment damage, and have proven that just one person with the right equipment and training can make a big difference.

Thermography can provide the ability to accurately capture and analyze temperatures at a safe distance with no need to touch the equipment. The ability to perform tests at a distance provides safety advantages over most non-destructive testing, such as vibration, where sensors must be physically attached to equipment to obtain readings. Routine screening can be difficult due to working in extreme conditions. By using thermography, testing can be routine. Today, with the rapid evolution of technology, thermal imaging cameras have become a cost-effective option for a productive preventive maintenance program.

The Program

It's been 10 years since ArcelorMittal Burns Harbor's hot mill bought its first thermal camera. At that time, the technology was groundbreaking and having one camera was a substantial investment. Due to a hefty price tag, cost justification analyses were performed before approval. The new cameras were handheld units. Early units were large, cumbersome and had limited visibility; therefore, they were not always safe in an industrial environment. Up until this point, due to a combination of high cost and lack of trained personnel who could efficiently operate the equipment, most organizations utilized outside contractors to perform thermal imaging. Technology evolves quickly — current cameras are smaller, lighter, provide clear images and are extremely easy to use, allowing for complete thermal imaging of the mill.

Due to affordability, the hot mill now owns and operates several thermal cameras. Also, cameras with new interfaces have become profoundly more user-friendly. With these developments in the technology of the camera, the implementation of an in-house thermography program can provide a rapid return on investment.

What Is Temperature? Temperature is a measure of the kinetic energy created by vibrations of microscopic particles in an object. It is measured with a thermometer, which is broadly defined as a device that consists of a sensor that changes with a fluctuation in temperature and means of converting this variance into a numerical value. Mercury thermometers and infrared cameras function on this principle. The mercury in the bulb expands a predictable amount with a temperature change, and the attached scale converts this change to a number. All objects above the temperature of absolute zero vibrate. This vibration produces infrared energy that is proportional to its temperature,

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which means the higher the temperature of an object, the more movement: thus, more infrared energy is emitted. Infrared cameras and temperature guns detect the amount of infrared energy that is emitted and convert it to a numeric value.

Infrared radiation exists in the electromagnetic spectrum between visible light and microwaves. Like visible light, infrared radiation can be absorbed, reflected, refracted and emitted. Understanding the similarities between visible light and infrared radiation is essential because not all objects are reliable infrared sources.

In an industrial environment, thermography can be used for a wide range of problem detection strategies on electrical and mechanical systems. Thermography has very appealing characteristics of being both non-destructive and accurate. Like all measurement devices, it is essential to have an operator who understands the function and limitation of the equipment. Temperature guns and thermal cameras have their advantages, but they are only effective when the operator understands how to properly use the equipment.

Temperature guns are inexpensive and easy to use. However, most people do not take the time to understand how the measurement is taken and end up misusing the equipment. For example, when an inexperienced operator is given a gun, he or she will aim across the room, placing the laser on the area of interest. The assumption is the gun is testing an area that is precisely the size of the laser beam, but the truth is far more complicated.

Spot Size Ratio — The temperature gun will return the average temperature of a spot. The size of the spot will change with the distance between the gun and the measured object. Spot size ratio is key in understanding how much area is measured. The ratio varies by make and model of temperature gun and can normally be found printed on the gun itself. For example, a gun that is 10:1 means that for every 10 inches of distance between the gun and the measured object, the spot measured increases one inch in diameter. Therefore, a person taking a reading from across the room is, in fact, measuring the average temperature of an extensive area.

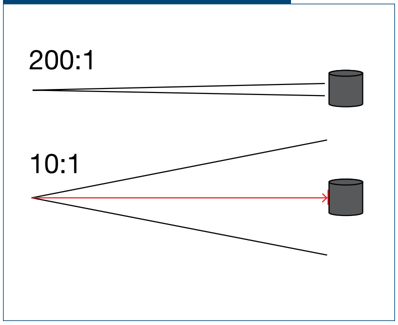
The thermal camera allows the user to have a smaller spot size (for instance, 200:1) as well as letting the user see the surrounding area. This is important, because surrounding objects can affect infrared energy. Simply put: what you see is not always what you have. Factors such as emissivity, distance and humidity influence all infrared measurement tools. The use of the thermal camera by a trained operator makes error detection reliable. The temperature gun will return the average temperature of a spot. The size of the spot will change with the distance between the gun and the measured object.

Fig. 1 is a basic example of how a temperature gun's reading fans out over distance. The further away one is from an object, the less accurate the measurements will be. This is true for both temperature guns and thermal cameras. However, the detector in the thermal camera allows the user to be much further away and still take accurate readings.

Looking at Figs. 2 and 3, the advantages of a thermal camera can easily be seen. Both measurements were taken at the same distance, but the thermal camera reads a higher temperature. The difference in readings are a result of varied spot sizes. The camera's spot size is the size diameter of the circle in the middle of the cross-hairs; the spot is only measuring the electrical tape.

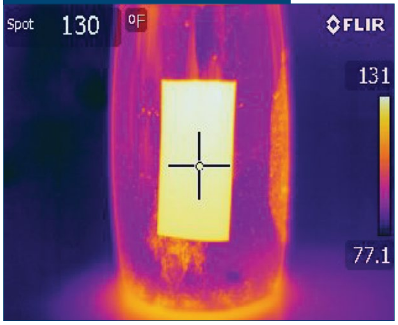
In comparison, the temperature gun is sampling an area of roughly an inch. Thus, the gun is not only reading the electrical tape but the roller element's surface as well. The surface of the roller element has an extremely low emissivity and reflects the infrared

Figure 1



Spot size ratio (distance: diameter of the spot): the top 200:1 is an infrared camera and the bottom 10:1 is a standard temperature gun.

Figure 2

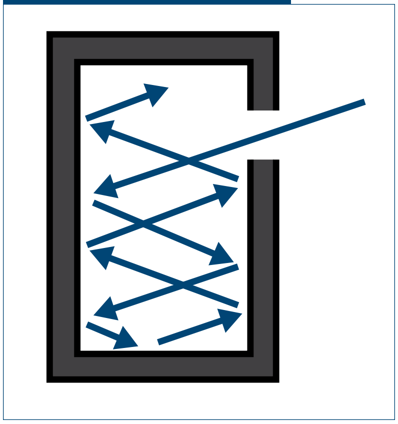


Temperature reading from 3 feet with an infrared camera.

Figure 3

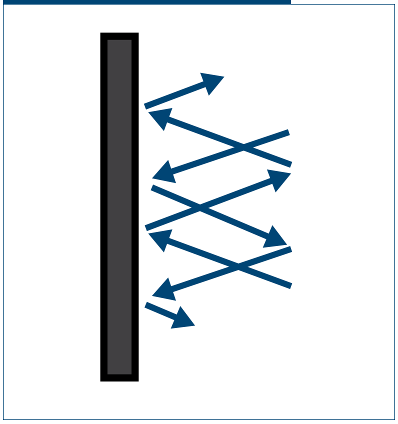
Temperature reading from 3 feet away with a standard temperature gun.

Figure 4



An example of a black body, an object that absorbs incidental radiation.

Figure 5



An example of a reflector, an object that reflects incidental radiation.

Figure 6

A roller element that contains both emissive and reflective surfaces that was heated to 115°F.

ratios from the surroundings, giving a lower temperature than what is actually present.

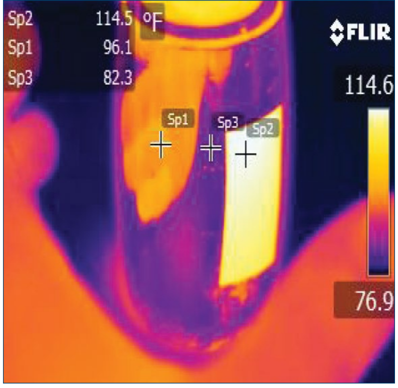
Thermal imaging provides the opportunity to view a wide area, increasing the chance of finding the source of a heat-related problem. For example, when inspecting a breaker panel with a thermal camera, an operator has temperature measurements of the entire panel with a single image, allowing problem areas to be quickly identified. The operator of a temperature gun would have to scan every square inch of the panel and make a map of the temperature readings to get a good idea of the panel's heat signature and source. This gives the thermal camera operator a clear advantage over the operator of a temperature gun because less time is spent tabulating readings.

Emissivity — Emissivity is a measure of how much an object's dispersed infrared energy came from the object itself, versus how much it transmits or reflects from other sources. It is important to know the emissivity of the object being read to get a correct temperature. Failure to calculate this value accurately will result in false readings; therefore, almost all thermal cameras and temperature guns have some ability of adjustment to compensate for emissivity.

An object that is a perfect absorber of all incidental radiation is known as a black body (Fig. 4). This means that its radiation is 100% emitted from the object and none of the energy is transmitted or reflected from other sources. To simplify this, a black body only emits its own energy. A black body's readings are the most accurate from a thermal measuring device.

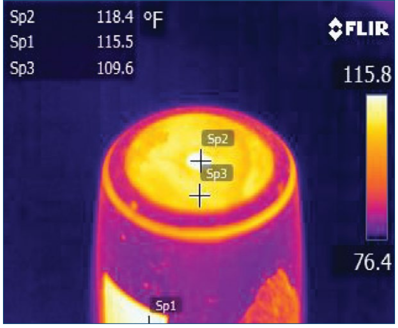
The opposite of a black body is a reflector. A reflector diverts all incidental radiation and emits none of its own. Think of it like a mirror, which reflects visible light and emits none its own. When an infrared

Figure 7



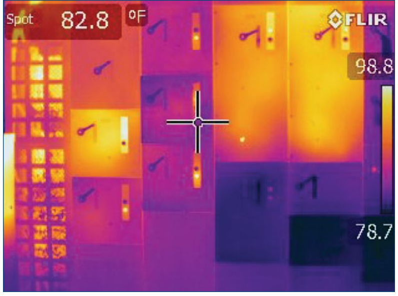
An infrared image of a roller element showing the differences in temperature between emissive and reflective surfaces.

Figure 8



In infrared image of the top of a roller element showing how a hole or cavity can affect readings.

Figure 9



An infrared image gives a broad view of the equipment allowing one to quickly identify hot spots.

measurement is taken from a reflector, it is not a measurement of the object itself but all the energy that is reflecting off it (Fig. 5). Accurate readings will never be attained from objects with high reflective properties; it is important to avoid measuring these objects or implement controls to improve accuracy.

Materials with dull surfaces like wire insulation are ideal for taking infrared readings because they are suitable emitters. Bare copper wire and metal connections for electrical cables are good reflectors. However, it is important to understand readings from these surfaces can be unreliable because of the uncertainty of the source of radiation.

Knowing the properties of the measured object will increase the accuracy of the reading. When measuring an electrical connection, readings should be taken at the wire insulation and not the copper connection. If there is uncertainty of the properties of an object, there is a simple test that can be performed: While maintaining the aim on the same target, shift the camera to read from a different angle. If the reading changes, the object has low emissivity. What the camera is measuring is not the infrared generated from the object, but a reflection. A good reading will not change when the position is changed.

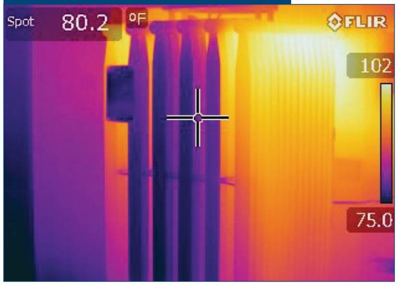
Application of Emissivity — As a demonstration, a roller element from a bearing was heated to a temperature of about 115°F (Fig. 6). In Fig. 7, three different readings were taken from the roller. Which one is accurate?

In situations like this, there is an easy method to accurately determine the temperature of the object. A piece of electrical tape attached to the object (not recommended for hot electrical circuits) will have an accurate known reference of between 0.95 and 0.97 (95–97%) emissivity.

In Fig. 7, one can see the electrical tape that spot 2 is on. This roller element has been heated to 115°F, so where do the other two readings come from? Spot 1 is the reflection of a hand in the reflective surface and spot 3 is the reflection from the room and other background radiation. The camera clearly shows the differences in the surfaces, making it very easy to determine actual temperatures.

In the absence of electrical tape, another way to accurately determine the temperature of an object is to use a cavity (Fig. 8). The roller element also has a small cavity located on top that allows for an accurate reading. The cavity is useful because it acts like a smaller black body allowing accurate readings.

Figure 10



An infrared camera allows for quick detection of problems.

Figure 11

A lead and lag pump set. Both pumps are running but only one is moving fluid.

Advantages — One of the most useful features of a thermal camera is that one gets the full picture when looking at an object. If there is an issue with an electrical panel and it is decided to inspect it with a temperature gun, one would have to scan every square inch of that panel and record the readings so that an accurate map of the problem is obtained. The thermal camera makes the picture. With one quick view of this panel (Fig. 9), one can see what is switched on and what is off.

As another example, Fig. 10 shows a transformer's cooling fins. In cases where there are several sets of these at the mill, it would be difficult to look at each one with a temperature gun. Each fin would need to be measured individually and the fins in the middle are difficult to reach without interference and would take an impractical amount of time. With one view, the camera determines that several of the cooling fins have restricted flow.

What to Do With the Technology? Fig. 11 shows a lead lag pump configuration. During daily inspections, checks are performed to see which pumps are running based on the heat signature. For two consecutive days, it was noticed that both pumps were running. On closer inspection, a problem with the system was discovered. The pump on the far right was running but not outputting any fluid. The temperatures of the oil lines on that pump were cooler than that of the system oil temperature. This signaled that the pump did not have circulation. The millwright who came to look at the pump found an air bubble in the pump. The pump was then cleared and restored to normal operation.

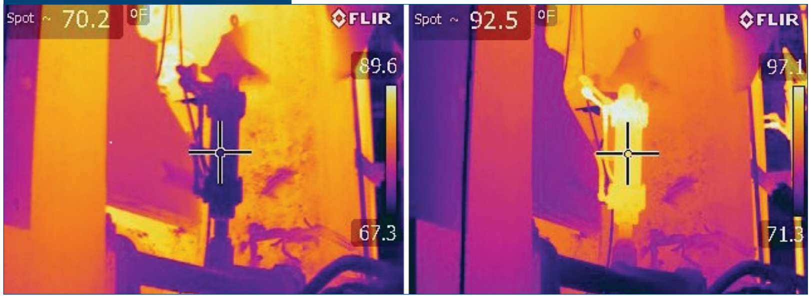
Because the air-locked pump was the lead pump in the configuration, it could never make the system pressure demand, so the lag pump was supplying all the oil. Thermography simplified the inspection process, identifying both pumps running, resulting in further investigation and a quick resolution.

A thermal camera allows the user to inspect equipment from a safe distance. Here is an applicable workplace scenario: From an upper catwalk, an inspection of the roll bearings on a mill stand was performed.

Figure 12

This work roll failure was detected from a distance of 50 feet.

Figure 13

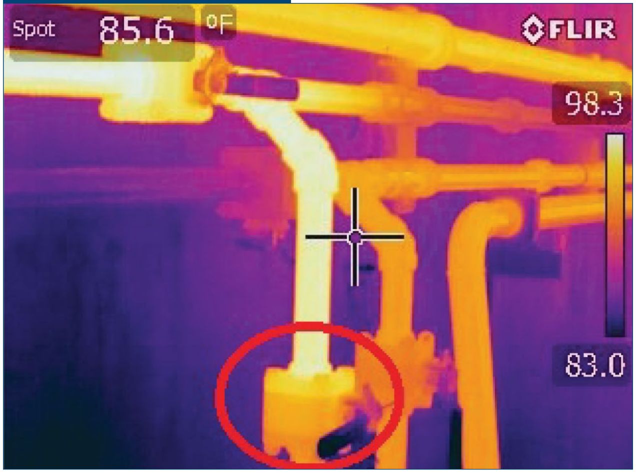


Thermography can be used to quickly identify valve and cylinder failure.

From 50 feet away, a work roll bearing at an unusually high temperature was found (Fig. 12). Upon inspection, it was noticed that the roll was thrusting about 2 inches when loaded. This roll was very close to failure. Because the problem was caught early, a plan for repair was made before the roll failed and a strategy was formulated to change the roll. Due to the early detection, 45 minutes of production time were saved.

Often when completing inspections on the floor, requests are taken to inspect equipment that isn't part of the routine. For instance, the author was asked to help identify if a hydraulic fluid was "blowing by" in the hydraulic cylinders in the mill stands. By using the thermal camera, a quick assessment could be made. The cylinders had not exercised in over a day because it was a downturn. Therefore, both cylinders should have been at ambient temperature (70°F). Hydraulic oil is 90°F. It was possible to detect which cylinder had hydraulic oil flowing because the thermal camera made it easy to see which cylinder was at ambient temperature (Fig. 13, left) and which had 90°F hydraulic oil (Fig. 13, right), indicating flow through the cylinder.

Figure 14



The failure of a quarter-turn ball valve is causing heat as the fluid blows by the valve.

Additionally, thermography helped detect a faulty valve. One of the systems was losing pressure. Upon closer inspection, a quarter-turn isolation ball valve was the culprit. After walking the whole system with the camera, this valve (Fig. 14) was discovered and a massive jump in temperature was observed. The temperature rise was due to the friction generated by the fluid going around the ball, allowing the fluid to bypass the system and return to the tank. In addition to the heat, one could hear the fluid blowing through the valve but the odds of a ball valve failing were low. Thermography was the best available option to prove the valve failure and resolve the issue quickly.

Conclusions

A task that had only been done by outside contractors is now done in-house and better suits the department. Not only were the cost of inspections cut, but the inspections can also be performed more frequently, which allows for problems to be discovered and resolved quickly.

As the program expands, more people have access to infrared cameras and associated training. New advantages to using this technology are being discovered and as a result, the plant's operations are more efficient. Infrared cameras are now standard equipment used in the maintenance and operating departments and have made a big impact on troubleshooting abilities. The initial cost of equipment and training are offset by their usefulness, making an in-house infrared program a smart option for any maintenance program.

Acknowledgments

The authors wish to express their gratitude to Amanda Bookholt, Jolice Pjeta and other colleagues for their support, collaboration and advice. ✦

This paper was presented at AISTech 2018 — The Iron & Steel Technology Conference and Exposition, Philadelphia, Pa., USA, and published in the Conference Proceedings.