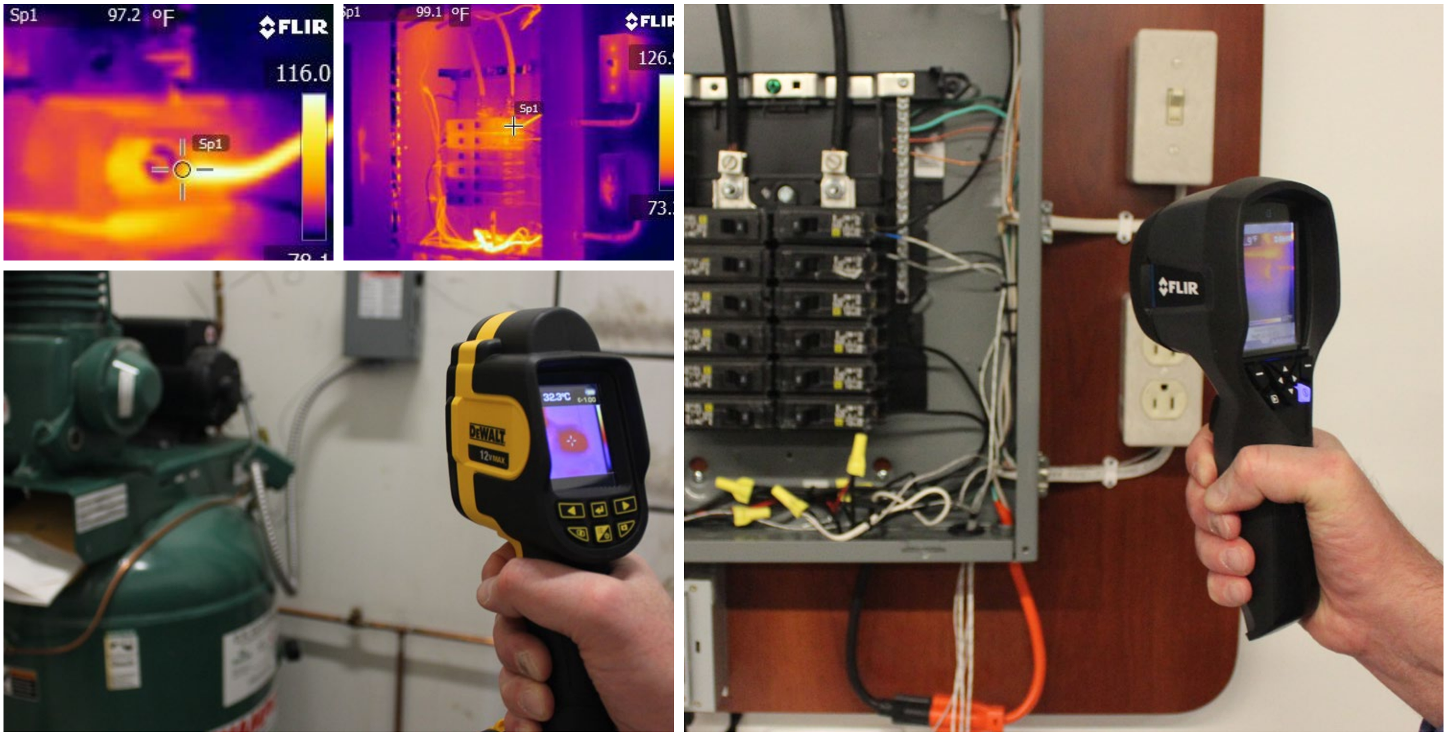
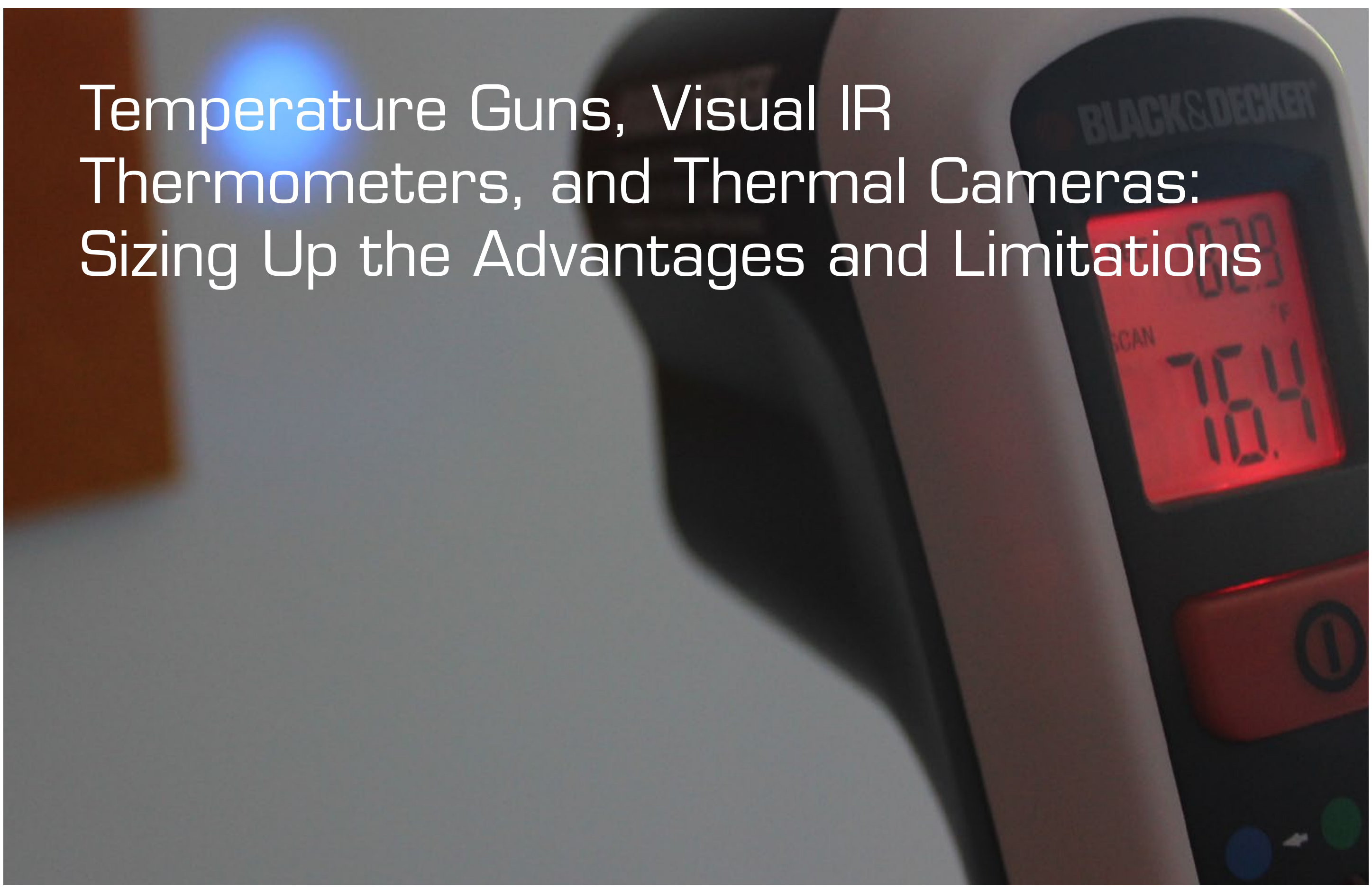
Technical Note





Temperature Guns, Visual IR Thermometers, and Thermal Cameras: Sizing Up the Advantages and Limitations

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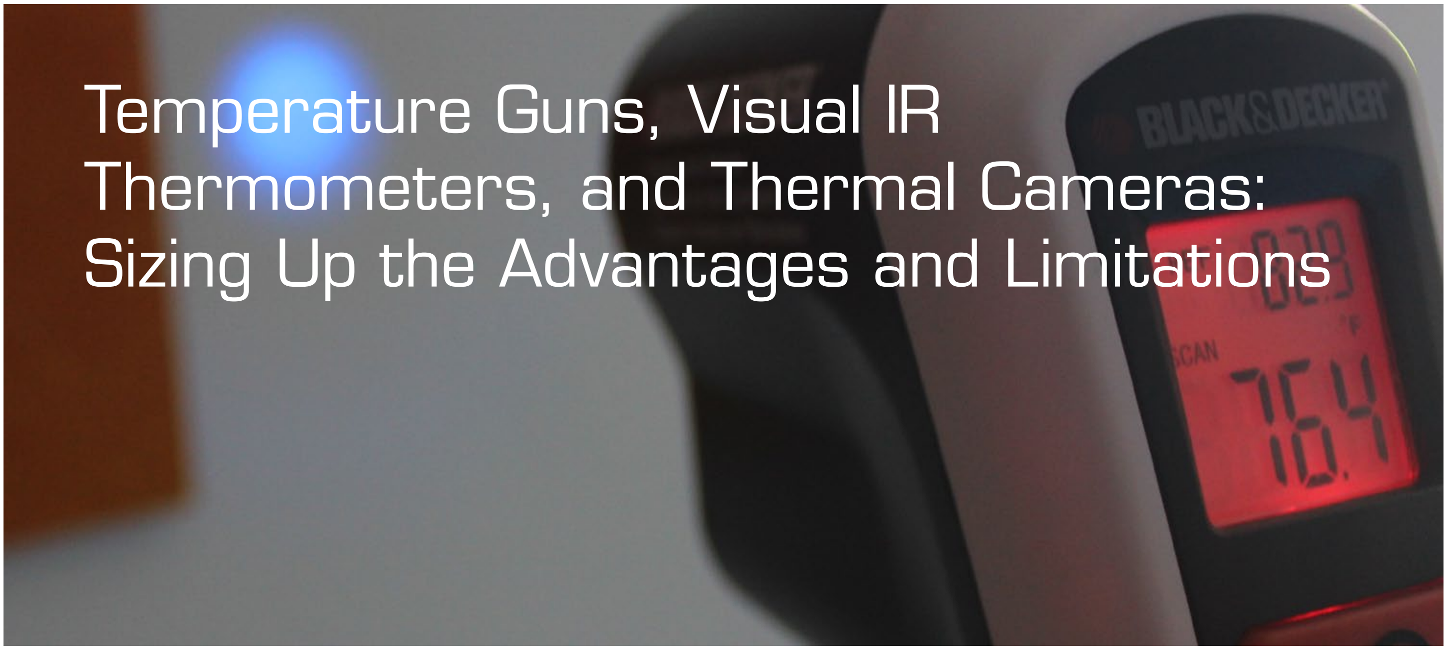


A broad range of new products are out on the market to help you measure temperatures and find heat issues that signal potential trouble. From basic IR temperature guns and thermal leak detectors to IR imaging thermometers and high-performance thermal imaging cameras, there's such a wide choice that it can be challenging to sort out which tool will deliver the reliability, quality, and measurement distance you need for your application (Figure 1). Fortunately, the Infrared Training Center has a firm grasp of the subject.

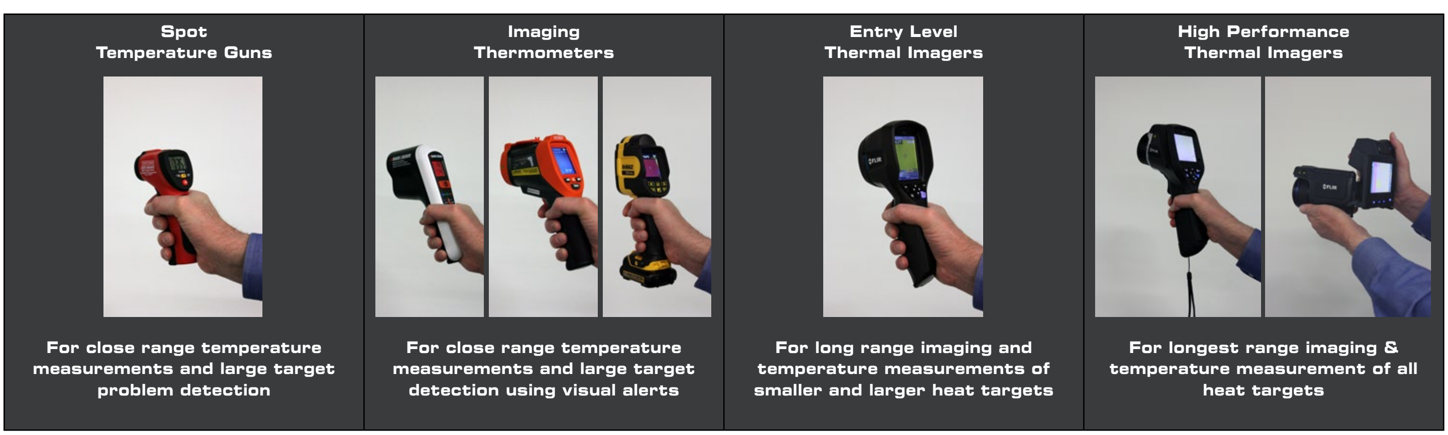
Over the years, ITC's industry-expert instructors have trained tens of thousands of technicians how to most effectively use thermal imaging and related instruments to find equipment and building problems. We know a lot about non-contact temperature measurement. That's why we've created this ITC paper to provide you with a quick overview of how these various technologies differ from one another and what they're ideally suited for. We'll also help you understand some potentially important performance limitations as well as a some basic physics you'll need to know to capture accurate measurements.

Spot Temperature Guns (aka spot meters, temp guns, IR temperature guns, infrared thermometers, spot radiometers)

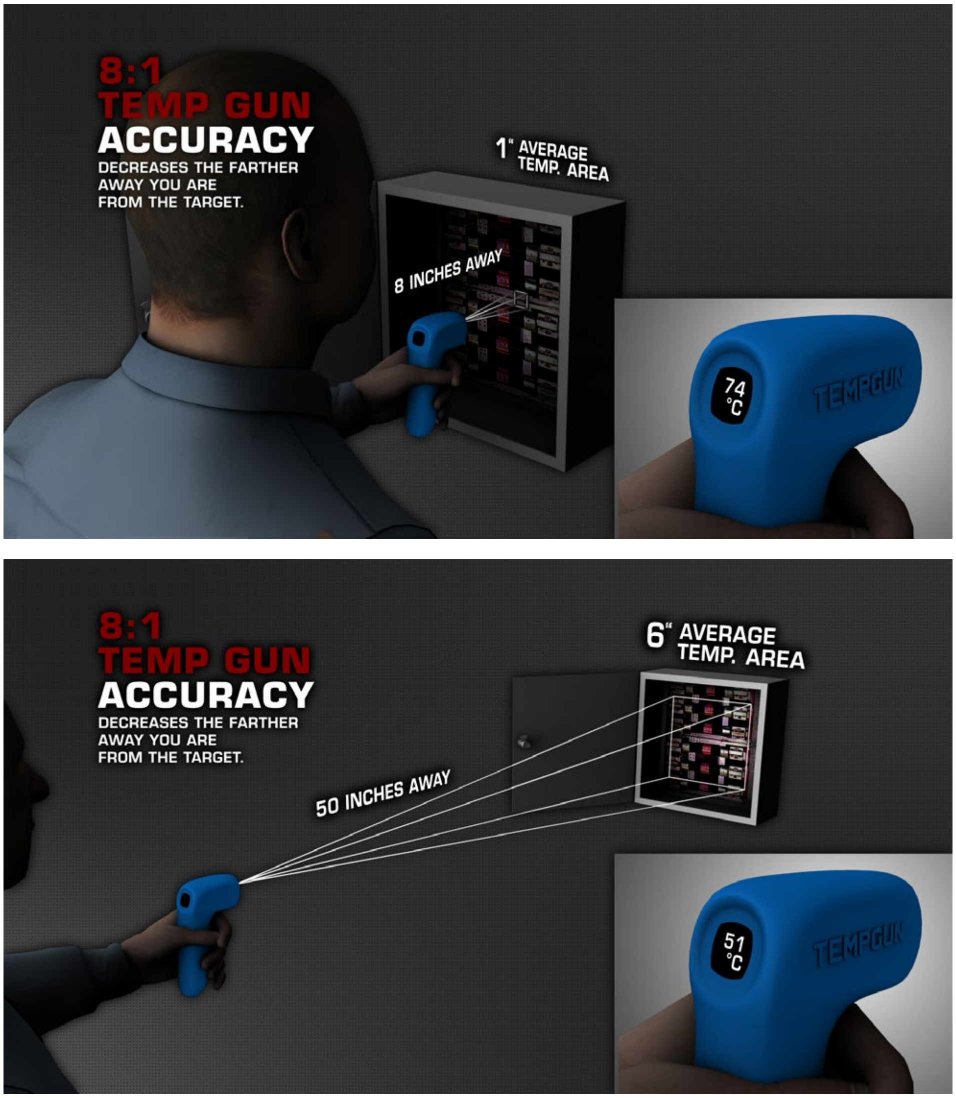
Spot temperature guns (or spot radiometers) are low cost test and measurement instruments that use a single element detector to sense energy emitting from the surface you're aiming at, which shows up as a temperature reading on the IR thermometer's display (Figure 2). This simple technology has been around a long time and many technicians find them useful enough to keep one handy in their toolbox. But there are two important factors about these devices that often get overlooked: one is working distance, which we'll address now; the other is emissivity, which we'll review later.

Infrared Thermometer with 8:1 Spot Size Ratio
Figure 2.

Most of today's temp guns feature a laser pointer to help show you where you're aiming. However, there's a



The Wide World of Non-Contact Temperature Measurement Tools
Figure 1.



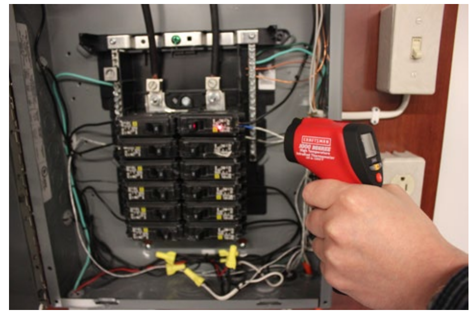
Illustrations of 8:1 Temp Gun at 8 inches and 50 inches away
Figure 3.

common misconception that the laser dot is the actual spot size of the object being measured, regardless of your distance to it. But that's not the case. In fact, we have found that there is a good chance that the temperature measurement could be quite a bit off the mark if you believed that assumption. That's why users need to take the device's spot size ratio (SSR) into account. Typically printed on the side of most IR thermometers, it's easy to find.

Depending on the measuring tool, you might be working with a spot size ratio anywhere from 6:1 to 50:1. Generally, the higher the spot size ratio, the better. That means if you wanted to measure a 1" component using a 12:1 spot radiometer, for example, you'd need to be within a foot of the target in order to capture an accurate temperature. Here's another example.

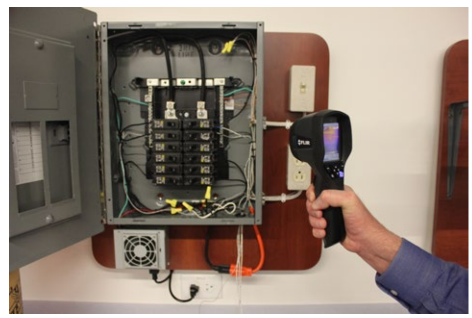
Let's say you're working four feet (48 inches) from energized electrical gear using an IR thermometer with a spot size ratio of 8:1. The diameter of the spot size would then be 6" and the reading would turn out to be an average of the temperatures present within that 6" area (Figure 3). So if you were attempting to inspect a quarter-inch wire under this scenario and it had spiked to 80°C, you may have missed it since the measurement would have averaged out lower, potentially leading you to believe that there was no problem. In order to get a more accurate reading, you would have had to get within a couple of inches, which in some situations could be dangerous.

According to manufacturer specifications, take a look at Figure 4 to see how close you would need to be to accurately measure a quarter-inch energized electrical wire connection



8:1 SSR = 2" from target

6:1 SSR = 1.5" from target



50:1 SSR = 12.5" from target

230:1 SSR = 57.5" from target

310:1 SSR = 77.5" from target
Figure 4. Note: Breaker panel above is touch safe.

with each of the tools shown. Note: The breaker panel pictured is "touch safe" and is used for lab workshops at ITC.

The NFPA (National Fire Protection Association) standard for electrical safety in the workplace is to stay a minimum of four feet from live equipment. As you can see, some of the instruments above can help keep you within a safer range when you're looking to verify temperature accuracy. Those that aren't able to detect accurate temperatures from four feet away could still be useful from that distance if they have a way to display an image of a hotspot clearly enough to show you where a problem might be brewing that needs further investigation. While spot radiometers cannot produce an image, it is technically possible to scan a piece of equipment at close range with one and find some major temperature issues, if you're able to do so within safe working distance standards. Though their accuracy can decrease the farther you get from the source, temperature guns can be helpful for obtaining averaged temperature data on larger objects if you know where to point them.

To learn more about the NFPA 70E: Standard for Electrical Safety in the Workplace®, visit http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=70e.

Thermal Leak Detectors

A Thermal Leak Detector works in much the same way other spot radiometers do. It appears to be optimized for light duty do-it-yourself inspections or perhaps light commercial use for finding conditions such as air leaks coming through windows, doors and HVAC duct joints. Like many spot meters, the Thermal Leak Detector has a 6:1 spot size ratio, so you wouldn't want to use it to get the precise temperature of a small electrical target. But it does have some clever alarms that instantly alert you to where there might be potential energy leaks and other heat issues. For instance, when anything you're scanning is within its default temperature range, it shines a green light on the area. If the Thermal Leak Detector senses a colder temperature, it automatically switches to blue (Figure 5). For warmer temperatures, it turns red. Since these tools are typically marketed as a low cost building inspection tool, precision measurements aren't as critical because you're simply looking for differences in temperature.

Thermal Leak Detector Showing Blue Alert for Cooler Reading
Figure 5.

Infrared Video Thermometer with 50:1 SSR
Figure 6.

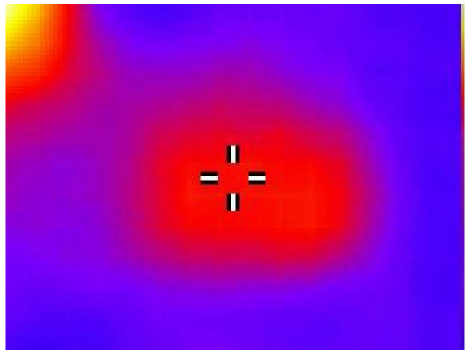
Infrared Video Thermometers

Digital infrared video thermometers generally use the same single spot measurement fundamentals but offer a digital camera visible image as a reference to help identify the object being measured (Figure 6). Designed for commercial users, they allow you to freeze and save video or a still of the problem area along with the resulting temperatures that were captured. Some models even let you capture time versus temperature data and offer other features industrial users might find useful. These devices typically have better distance-to-target performance than low cost IR thermometers (50:1 and up) and higher temperature measurement ranges. Because they typically sell for more than $400 dollars they probably exceed the DIY user's needs and price threshold.

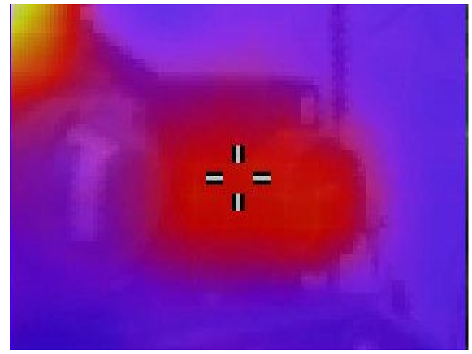
Imaging Thermometers (aka Visual IR Thermometers)

A low resolution thermal map variant of visual or video thermometers is also now on the market. Typically priced under a thousand dollars, imaging thermometers use a low resolution thermal sensor to help you find and visualize problems as opposed to simply measuring spots. The tools we have looked at have a lower resolution

With a 6:1 spot size ratio, this device is better suited for large targets.
Figure 7.



Thermal map alone doesn't have the resolution to provide a meaningful image.



Blended thermal and visible image is necessary to help locate problem targets.

two-dimensional 15 x 15 array (e.g. 15 x 15 or 225 pixels) that reveals hot or cold spots in a similar fashion to conventional thermal imagers. For some users, the lower spatial resolution can be a significant limitation as the thermal map image needs to be overlaid onto a visual picture in order to help orient you to the problem's location (Figure 7). But you can still detect hot or cold areas on larger targets with one and even some smaller targets if you can get close enough for a good reading.

Again, the primary challenge we see with lower thermal pixel arrays (e.g. 15 x 15) on visual thermometers is working distance and how that relates to accuracy, especially compared to spot radiometers or modern thermal cameras with SSRs in the 50:1 range or better. The visual IR thermometers we have reviewed test out at a spot size ratio of 6:1. So, using our ¼" electrical component example again, we needed to be 1.5" from it to obtain the most accurate temperature. So, for high voltage equipment, this probably isn't the right tool. But for large targets and general measurements on surfaces like motors and HVAC ducts, it works fine on such applications.

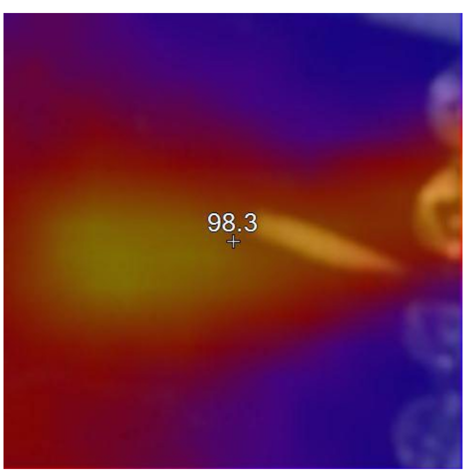
Given that Imaging Thermometers are priced close to conventional, entry level thermal imagers, we compared the two technologies to help you understand the differences relative to spot size (working distance), resolution, sensitivity and emissivity control. Sensitivity is important to the thermal camera discussion since it impacts image quality. It doesn't apply to traditional spot temperature guns, of course, because they can't produce a picture to help you "look" for problems.

Thermal Imaging Cameras

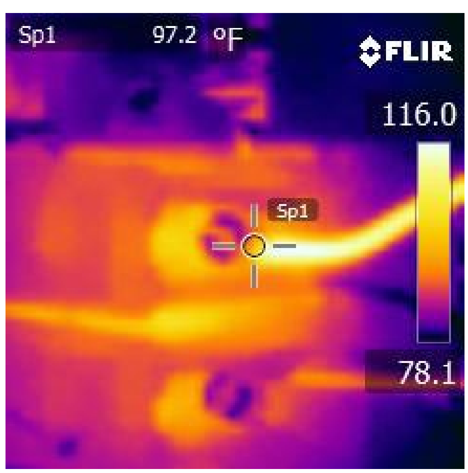
Thermal imaging cameras are the next step up in the visual thermometer category. These devices have larger, two-dimensional thermal sensor arrays (e.g. 60 x 60 pixels or greater) that produce recognizable thermal images and are carefully calibrated for non-contact temperature measurement.

Some models have integrated visible light cameras and some don't. This additional feature is typically used to capture reference photos for reporting purposes. Whether you'll need the visible image really depends on how well the thermal image alone shows the problem at hand and how effectively that serves your application. With SSRs typically greater than 50:1, thermal imagers are designed to help users find problems and measure temperatures quickly from a safer distance.

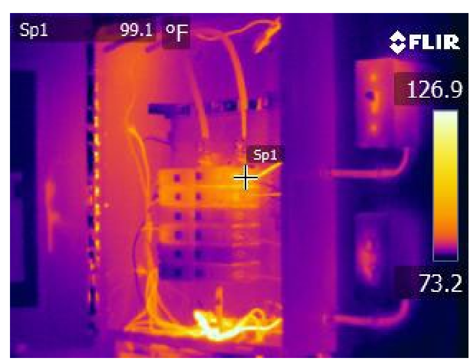
In comparing the two technologies, we used an Imaging Thermometer with a manufacturer specified 15 x 15 (225pixels) and a tested spot size ratio that we determined to be 6:1 and a FLIR thermal imaging camera with a manufacturer specified 60 x 60 thermal resolution (3600 pixels) and a spot size ratio of 50:1. To provide additional context, we also compared the i3 with the more expensive FLIR E60 thermal imager, which has 320 x 240 resolution (76,800 pixels) and a spot size ration of ~230:1. Our



At the determined SSR, the imaging thermometer needed to be positioned within 1.5 inches of the 1/4" wire connection to capture the temperature most accurately. Figure 8.



At the specified SSR, the i3 captures its most accurate reading as far as 12.5" away and also resolves the image clearly.



Using its specified SSR, the E60 captures its most accurate measurement as far as 57.5 inches away and offers an even sharper image quality due to its 320 x 240 resolution and higher sensitivity.

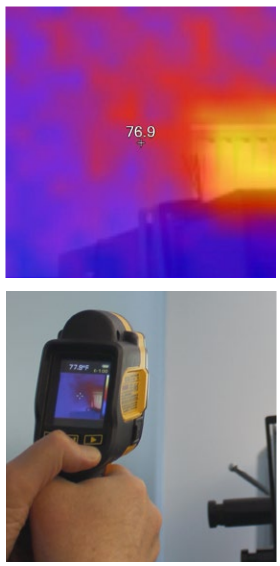
The i3 can measure accurately over 8 times the distance of the typical imaging thermometer.
Figure 9.

From 30" away, we looked at both from a detection only standpoint. We could still see the thermal image of the 1" target clearly with the i3 (right) but could only faintly detect it with the Imaging Thermometer, which had the IR blended with its visible picture (left).

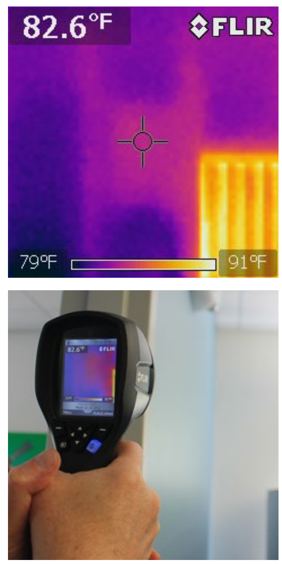
target for all three tools was the same energized 1/4" copper wire (Figure 8).

We also tested and found that the i3 thermal imager displayed and measured a 1" target with relatively accurate results from 50 inches away, which we could expect with the manufacturer-specified high spot size ratio of 50:1 To get a similar temperature with an imaging thermometer, we had to position the tool within 6" of that same target (Figure 9). The target had a 5°C (9°F) temperature difference from its surrounding area. Perhaps the most important attribute of a troubleshooting device is its ability to find problems. In the thermal imaging camera world, this is typically a function of resolution and sensitivity. The greater the sensitivity of the thermal camera, the greater ability to see details that can help you discern subtler temperature differences. Figure 10 shows comparison images from three tools aimed at a wall with missing insulation.

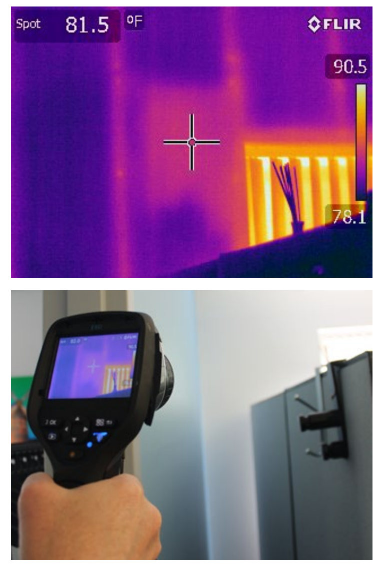
Which tool is going to work best for a specific application really boils down to what information you want a non-contact temperature measurement tool to provide. Do you want the device primarily to quantify temperatures as accurately and easily as possible for detailed documentation? Or are you looking for one simply to help find and troubleshoot temperature differences that show heat-related problems regardless of the actual numbers? There is a difference, and this is where the distinction among true thermal imagers, temperature guns and imaging thermometers comes into play.



Missing insulation with imaging thermometer.
Figure 10.



Missing insulation with i3 thermal imaging camera.



Missing insulation with E60 thermal imager.

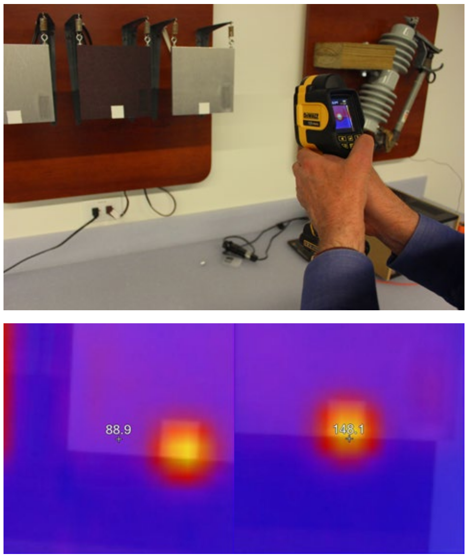
Some of these technologies will provide more reliable data than others. And some may miss many thermal anomalies altogether, which could leave the user with a false sense of security. So it's important to define the size of the object or area you're trying to measure, how many and how often you need to survey, the distance you have to be to safely detect target temperatures, the level of accuracy required, and whether you want to see a picture of the problem as a thermal or visible image (or both) to help show what you've found.

Those parameters will help you narrow the playing field so you'll be able to choose the one that's going to ensure your inspections will be thorough and efficient enough for your application.

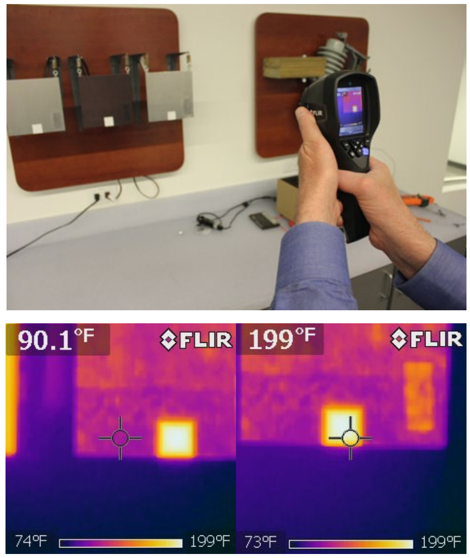
Emissivity

Speaking of parameters, we mentioned emissivity earlier as an important factor of non-contact temperature measurement. So here's a short physics course on the subject. The amount of infrared energy emitted by an object is proportional to its temperature and ability to emit the energy. In the pictures on the next page, for example, we show a piece of metal that's an excellent heat reflector but not as good of an energy emitter as a rough-surfaced or flat-painted surface. Because it's shiny, its reflected heat can throw off the reading of the object, providing misleading information.

Several of the devices we've discussed offer a way to adjust the emissivity parameter so you can dial in the best

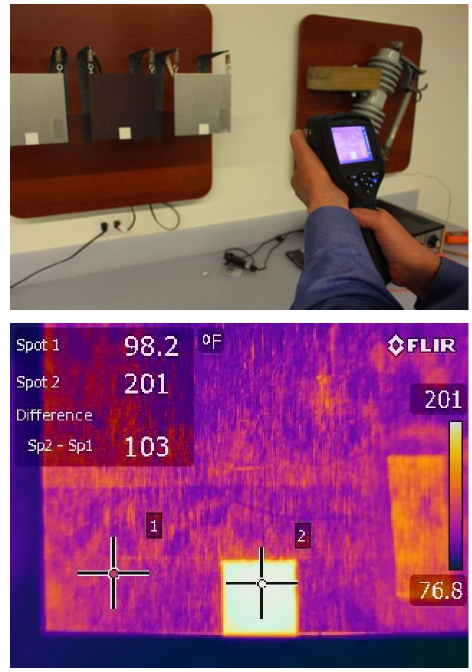


Imaging Thermometer



i3 Thermal Camera

Readings on the white tape portion of surface (right) yields proper emissivity and a more accurate temperature of the target, whereas the shiny surface on the left produces erroneous reading.
Figure 11.



E60 Thermal Camera

setting for the surface material to get a correct temperature measurement. However, some tools only offer a fixed emissivity locked in at .95, which assumes 95% of the energy that the device is detecting is not reflected. That means the temperatures of shiny surfaces like aluminum and other metals would be based more on the reflected heat than the emitted energy, and would therefore show up largely erroneous under that fixed setting.

In Figure 11, we have a piece of metal heated to around 200°F. Most of it is a shiny surface but a portion has white tape on it to create a flat, non-reflective surface. With the emissivity of the imaging thermometer, and thermal imagers both at .95, which is appropriate for the tape, you can clearly see the measurement difference. The emissivity of the tape's flat surface provides the more accurate temperature reading.

It's a basic explanation and example but it demonstrates how extremely important it is to consider a non-contact temperature measurement tool that offers the flexibility to select the proper emissivity.

To learn more about emissivity, reflected temperature and other parameters that can affect the accuracy of thermal inspections, please explore the classes, online presentations, and other resources available through the ITC web site at www.infraredtraining.com.

The Infrared Training Center

The greater your knowledge about thermal imaging, the greater the dividends you'll realize for your company and your career. The ITC offers classes for practically every application, from free online courses to advanced training that can certify you as a thermography expert, qualifying you to take a leadership role in your internal IR program.

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