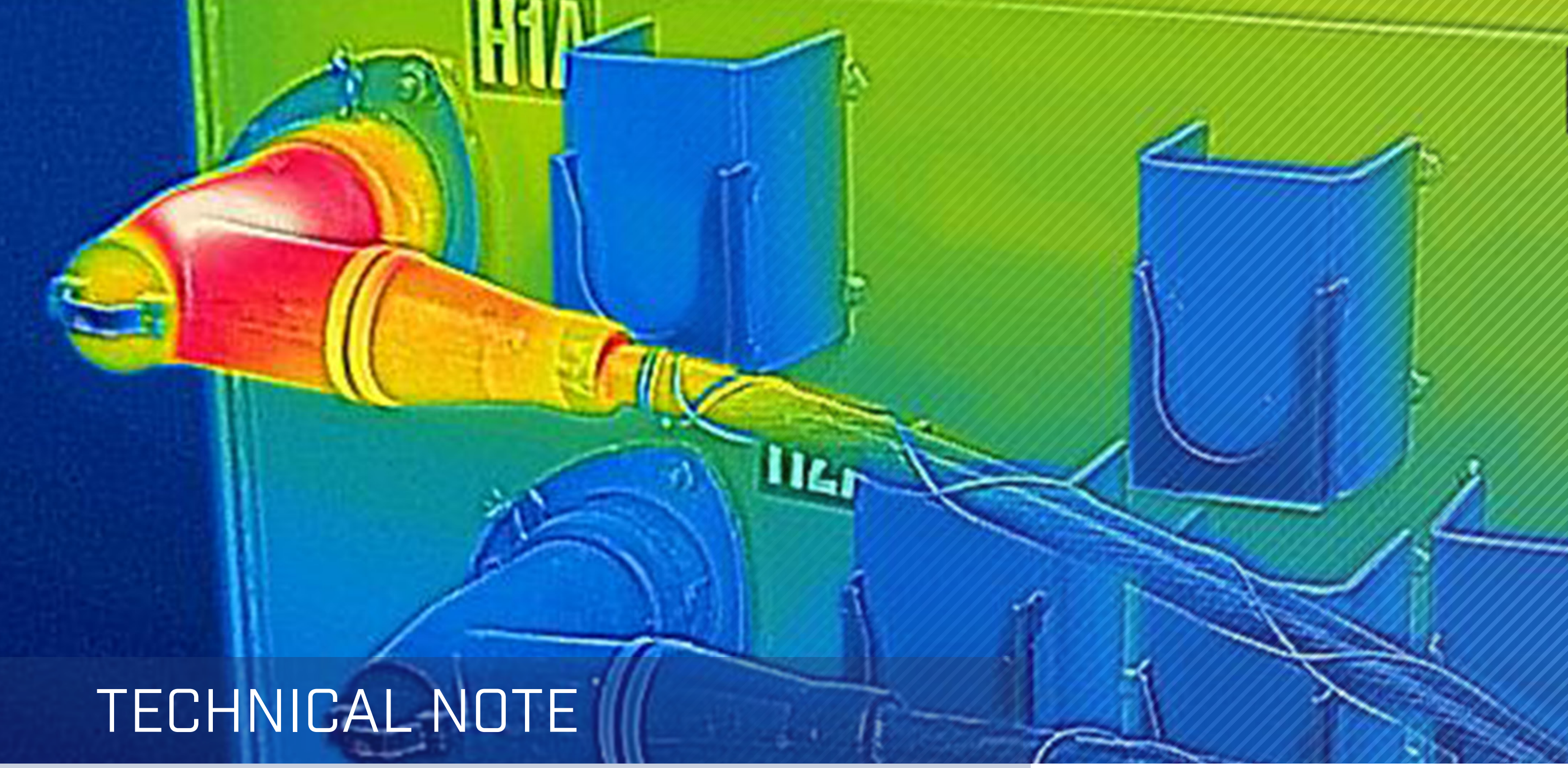

TECHNICAL NOTE

The secret to a good thermal image

FLIR T540 Professional
Thermal Imaging Camera

The use of thermal cameras has spread to many professional environments in recent years. They are easy to handle, and thermal images are quick to take. Images can also be attached to reports easily, e.g., for an inspection of an electrical installation or building as evidence of work carried out or of any faults or deviations identified. However, people often forget that an image to be used as evidence or even proof before the courts must meet certain requirements: this is not achieved with a quick snapshot. So, what characterizes a really good thermal image?

BACKGROUND

During the practical exercises in our thermography training classes we notice, time and time again, how difficult some participants find choosing the optimal camera settings for different tasks. Not everyone has a background in, for example, amateur photography (more on the difference between thermography and photography in the next section), and to take a good and meaningful thermal image you need some knowledge of photography, including its practical application. For this reason, it is hardly surprising that thermographers, particularly those without training, repeatedly produce reports with thermal images that are devoid of meaning or even support the wrong conclusions and are fit only for the waste bin.

Unfortunately, such reports are found not only in companies in which thermography is more of an added bonus but also in businesses where these reports may be part of a critical process monitoring or maintenance program. There are two main reasons for this: either the users don't know what a good thermal image is or how to take one, or—for whatever reason—the job is not being done properly.

A GOOD IMAGE

As thermography and photography are related, it makes sense to take a look at what is important to professional photographers. How do they characterize a good image?

Three aspects can be pointed out as the most important:

1. An image has to touch the observer in some way. That means it needs to be unusual, striking, or unique, and has to arouse interest and, depending on the genre, emotion.
2. The composition and balance must be in harmony; the image detail and content must go together aesthetically.
3. The lighting must be interesting, such as back lighting or side lighting that casts dra- matic shadows, or evening light or other pleasing illumination—whatever fits the over- all effect that the photographer wants.

To what extent can these concepts be applied to thermography?

With thermography, the motif should also be interesting. In other words, our aim is to de- pict an object or its condition. Emotions are not required—facts have priority in thermal images (assuming they are not an art project!). In everyday working life, it is important to illustrate thermal patterns clearly and to facilitate temperature measurements.

The thermal image must also have suitable image detail and display the object at an ap- propriate size and position.

Without external illumination, neither visual sight nor photography is possible because what we see with our eyes or capture with a camera is reflected light. In thermography, the camera records both emitted and reflected radiation. Therefore, the relationship and intensity of the infrared radiation, both emitted by the object and by the surrounding environment, are important. Brightness and contrast in the image are then adjusted by changing the displayed temperature interval.

The comparison between photography and thermography can be summarized in a table using a few keywords:

PHOTOGRAPHY	THERMOGRAPHY
Interesting motif	The object to be examined
"Tells a story"	"Presents facts"
Aesthetically pleasing	Clear heat patterns
Emotive	Objective
Image detail	Image detail
Focus	Focus
Lighting	Emission and reflection
Brightness	Brightness
Contrast	Contrast

As with photography, in thermography there are countless possibilities for editing images—provided they are saved as radiometric images. However, not all settings can be changed, and not all image errors can be corrected.

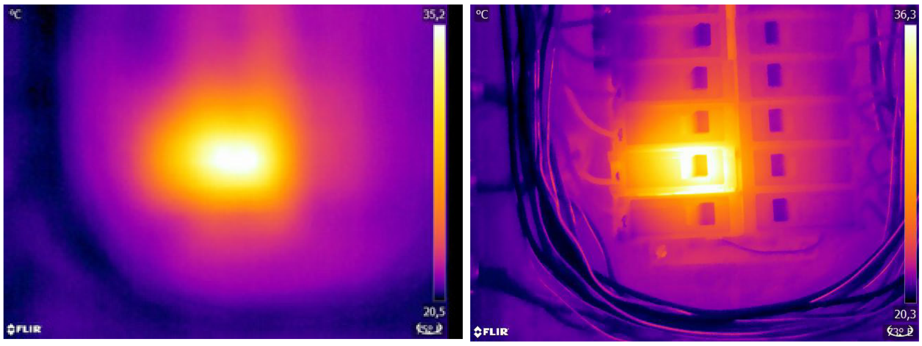

Figure 1 Only hazy "patches of heat" can be seen in the unfocused image (left). The focused image (right) clearly shows which object is being observed and where the object is warm.

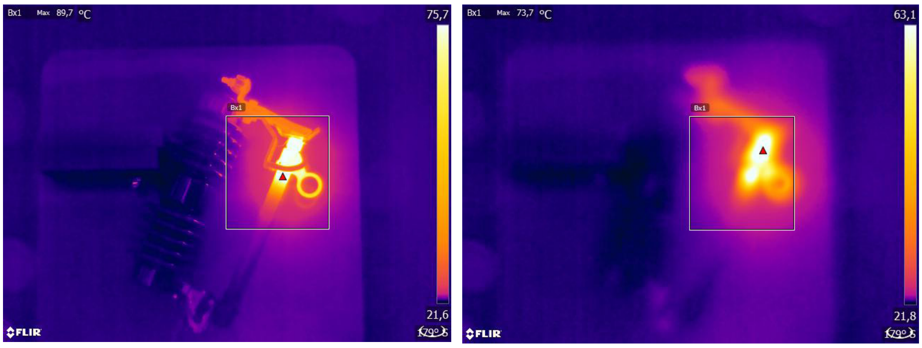

Figure 2 Focused thermal image (left) with a maximum temperature of Tmax = 89.7°C (193.5°F) and an unfocused thermal image (right) with a maximum temperature of Tmax = 73.7°C (164.7°F).

THE THREE UNCHANGEABLES— THE BASIS FOR A GOOD IMAGE

1. Focus

A professional thermal image is always focused and sharp, and the object and heat pat- tern must be clear and easy to recognize.

A blurred image not only comes across as unprofessional and makes it harder to identify the object and any faults (see Figure 1) but can also lead to measurement errors (see Figure 2), which are more serious the smaller the measurement object. Even if all other parameters are set correctly, the measurement values from an unfocused thermal image are highly likely to be incorrect.

Of course, the size of the detector matrix also plays a role in image quality. Images taken by cameras with small detectors (i.e., with fewer pixels) are more blurred or "grainier" and give the impression that they are not focused (see Figure 3). It should also be noted that not every camera can be focused, and in this case the only means of focusing the camera is by changing the distance from the object.

2. Temperature range

For hand-held uncooled microbolometer cameras, the "exposure" is essentially preset by the image frame rate. This means that it is not possible to choose for how long—and therefore how much—radiation hits the camera detector. For this reason, an appropriate temperature range must be

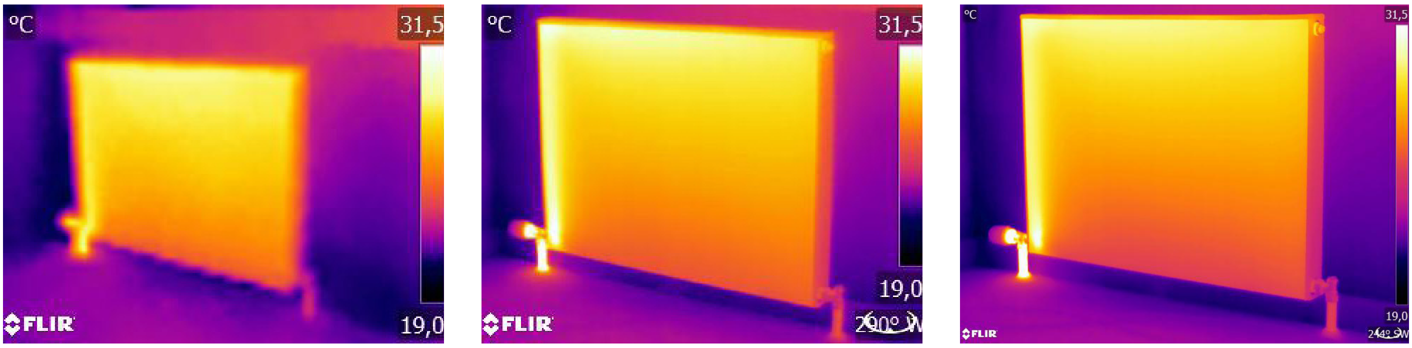

Figure 3 The same radiator from the same distance with the same settings, taken by three different thermal cameras: FLIR C2 (left), FLIR T440 (middle), and FLIR T640 (right).

Figure 4 Images from a FLIR T440 with temperature ranges of –20 to +120°C, (left, –4 to +248°F), 0 to +650°C (middle, +32 to +1202°F) and +250 to +1200°C (right, +482 to +2192°F). All other settings are unchanged.

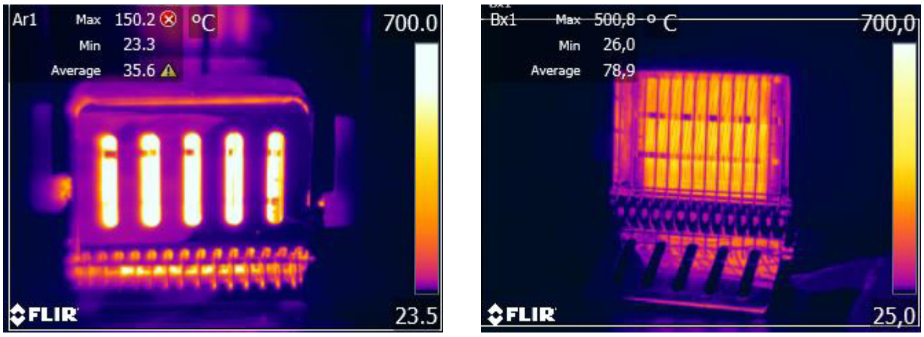

Figure 5 An image of the same object taken with different temperature ranges: –20 to 120°C (left, –4 to +248°F) and 0 to 650°C (right, +32 to +1202°F). The temperature in the left image is displayed with a warning sign (a red circle with a white cross) because the measured values are outside the calibrated range.

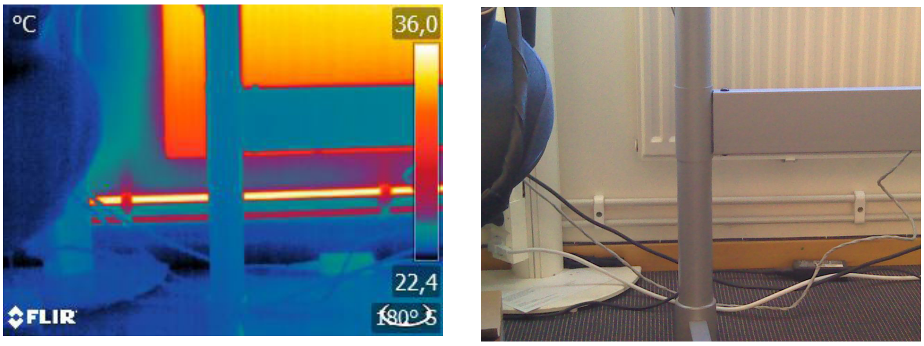

Figure 6 "Thermographic inspection" of an inaccessible object.

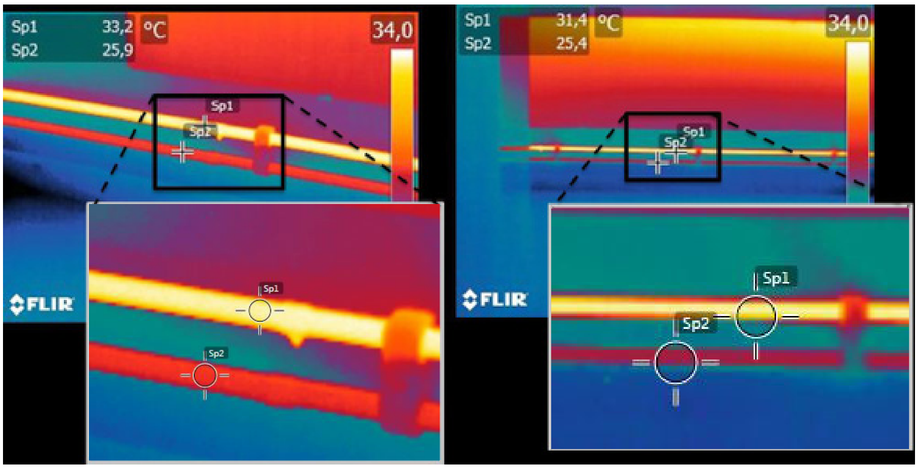

Figure 7 Supply and return lines from radiators in an open-plan office. The left image was taken from a distance of 1 m: the measurement spot is filled and the temperature measurement is correct. The right im- age was taken from a distance of 3 m: the measurement spot is not completely filled and the measured temperature values are incorrect (31.4 and 24.4°C (88.5 and 75.9°F) instead of 33.2 and 25.9°C (91.8 and 78.6°F)).

selected that matches the amount of incident radiation. If a temperature range is selected that is too low, the image will be oversaturated, as objects with higher temperatures emit more infrared radiation than colder objects. If you select a temperature range that is too high, the thermal image will be "underexposed," as can be seen in Figure 4.

To take an image or temperature measurement, the lowest possible temperature range available on the camera should be selected. However, it must also include the highest temperature in the image (see Figure 5).

Depending on the camera model and configuration options, overdriven and under-driven areas can be displayed in a contrasting color.

3. Image detail and distance from the object

Illumination in photography corresponds in thermography to the interplay of radiation from the object and reflected radiation from the surrounding environment. The latter is unwanted because interfering—or, at the very least, spot—reflections need to be avoided. This is achieved by choosing a suitable position from where to take images. It is also advisable to select a position from which the object of interest can be seen clearly and is not hidden. This may seem obvious but in the building sector, for example, it is common to find reports in which pipes or windows to be investigated are hidden behind sofas, indoor plants or curtains. Figure 6 illustrates this situation—which occurs all too regularly.

It is also important that the object under investigation, or its areas of interest, take up the whole thermal image. This is particularly true when measuring the temperature of small objects. The spot tool must be completely filled by the object to enable correct temperature measurements. Since the field of view and therefore the spot size are determined by both the distance to the object and the camera's optics, in such situations the distance to the object must either be reduced (get closer!) or a telephoto lens must be used (see Figure 7).

THE CHANGEABLES—IMAGE OPTIMIZATION AND TEMPERATURE MEASUREMENT

1. Level and span

After choosing the appropriate temperature range, you can adjust the contrast and brightness of the thermal image by changing the temperature intervals displayed. In manual mode, the false colors available in the palette can be assigned to the temperatures of the object of interest. This process is often referred to as "thermal tuning." In automatic mode, the camera selects the coldest and warmest apparent temperatures in the image as the upper and lower limits of the temperature interval currently displayed.

A good or problem-specific scaling of the thermal image is an important step in the interpretation of the image, and is, unfortunately, often underestimated (see Figure 8).

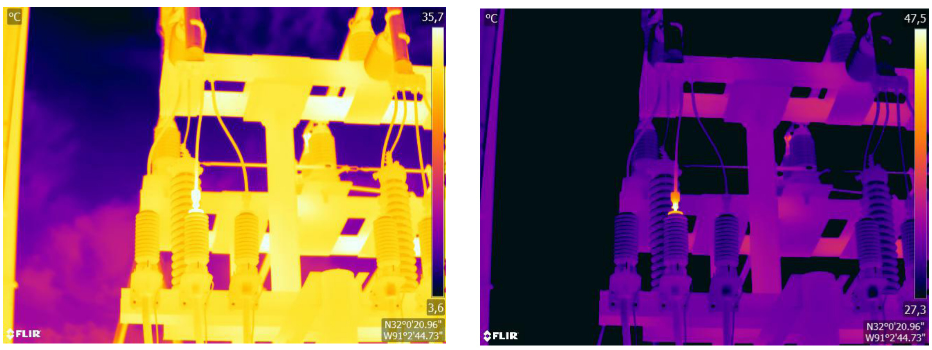

Figure 8 A thermal image in automatic mode (left) and in manual model (right). The adjusted tempera- ture interval increases the contrast in the image and makes the faults clear.

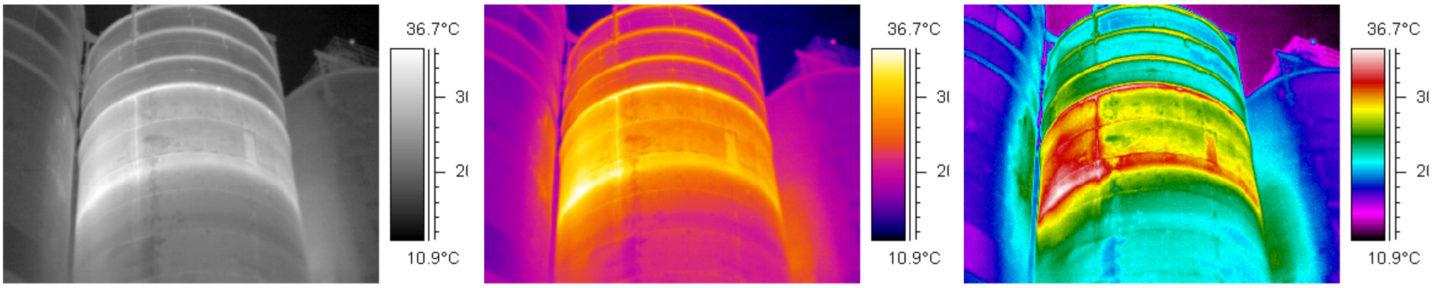

Figure 9 Gray, iron, and rainbow palettes (left to right).

2. Palettes and isotherms

Palettes represent intervals with the same apparent temperatures using different sets of colors. In other words, they translate specific radiation intensities into colors that are specific to a particular palette. Frequently used palettes include the gray, iron, and rainbow palettes (see Figure 9). Gray tones are particularly suited to resolving small geometric details but are less suited to displaying small differences in temperature. The iron palette is very intuitive and also easy to understand for those without much experience in thermography. It offers a good balance between geometric and thermal resolution. The rainbow palette is more colorful and alternates between light and dark colors. This results in greater contrast, but this can lead to a noisy image for objects with different surfaces or many temperatures.

The isotherm is a measuring function that displays a given interval of the same apparent temperature or radiation intensity in a color that is different from the palette. It allows you to emphasize temperature patterns in the image (see Figure 10).

3. Object parameters

As we have seen, the appearance of thermal images is dependent on the thermographer's technique and choice of settings, and the look of saved radiometric images can be altered by editing. However, it is also possible to change the settings that are relevant for the calculation of temperatures. In practice, this means that the emissivity and reflected apparent temperature can be altered retrospectively. If you notice that these parameters have been set incorrectly or want to add more measurement spots, the temperature measurement values will be calculated or recalculated according to the changes (see Figure 11).

TAKING IMAGES—PRACTICAL TIPS

The following list includes some practical tips. However, note that this is not a comprehensive description of the thermal imaging procedure.

- Ensure that the camera is saving radiometric images.
- Choose an appropriate position from which to take images:
  - Observe the radiative situation.
  - Check that the object is clearly visible and displayed at an appropriate size and position.
- If you change the emissivity, monitor the temperature range and make sure that it remains appropriate.
- Focus.
- Use a tripod to minimize camera shake.
- Carry out thermal tuning.
- Take note of the object description, object size, actual distance, environmental conditions, and operating conditions.

It is easier to edit the thermal image when it is saved or "frozen" (in "Preview"). Also, since you don't have to do everything on site, you can leave dangerous zones immedi- ately after taking the image. If possible, take a few more images than you need—including from different angles. This is preferable to taking too few! You can then choose the best image afterwards, at leisure.

CONCLUSION

Taking a good thermal image does not require any magic tricks—solid craft and sound work is all that is required. Many of the points mentioned may seem trivial and "old news," particularly to amateur photographers. Of course, the equipment plays a role easier to ensure sharp images. Better, i.e. high-definition, cameras allow the fast localization of even small anomalies, and without focusing capabilities it is always difficult to capture a sharp image. However, high-end cameras are no guarantee of good images if used incorrectly. The basis for good, professional work is education and training in thermography, exchange of knowledge with other thermographers, and, of course, practical experience.

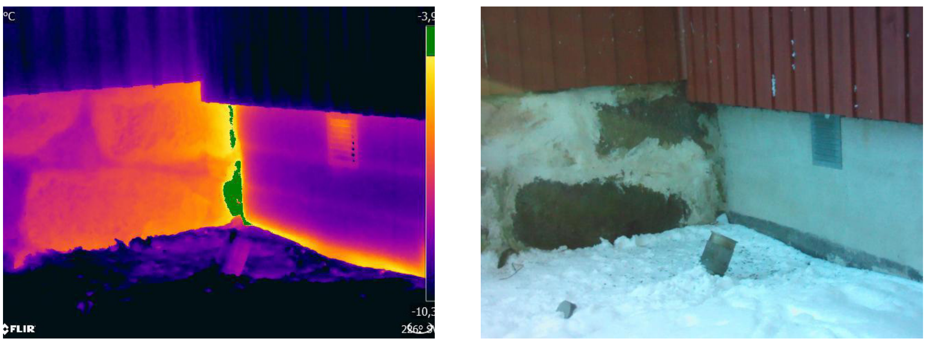

Figure 10 Foundation wall: connection between the old (left in image) and the new (right in image) parts of the building. The isotherm highlights an area of air leakage.

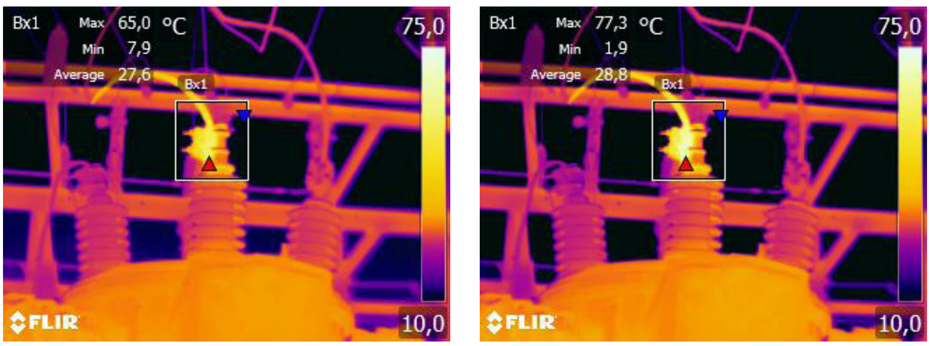

Figure 11 Change in emissivity for a saved image. The maximum temperature is 65.0°C (149°F) for ε = 0.95 in the left image and 77.3°C (171.1°F) for ε = 0.7 in the right image.

For more information about thermal imaging cameras or about this application, please visit:

www.flir.com/instruments

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Date created: July 2017
17-2217_EMEA