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Infrared Scanning of Furnaces

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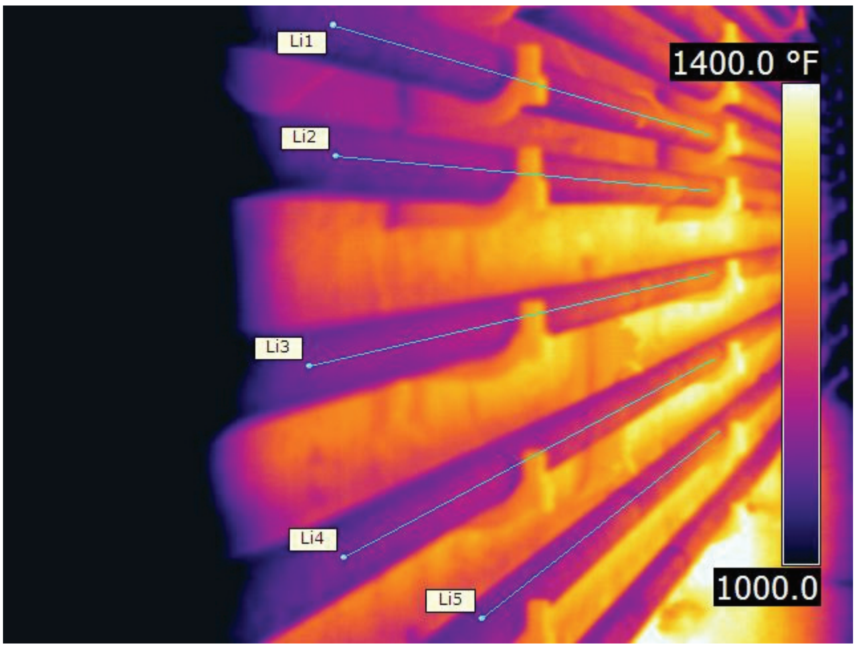


Infrared Scanning of Furnaces

This document outlines a recommended procedure for the monitoring of furnaces. The document describes:

1. Camera Calibration
2. Personnel Training
3. The Scanning Process
4. Image Analysis and Report Generation

Camera Calibration

The camera utilized for internal furnace monitoring must have the temperature range capability and be equipped with a "flame suppression" filter to allow for viewing "through" the flame(s). It is also highly recommended that a heat shield be used during the operation of the camera.

It is the recommendation of all manufactures of Infrared Scanning devices that a camera should have a calibration check conducted to ensure that the unit is operating with its published specifications. This is particularly important to ensure that quality assurance and maintenance programs are provided with reliable information. An infrared device should have the calibration verified every 12 months. The verification must be conducted for each temperature range, filter and lens that may be associated with the camera.

Also note that the camera is not intrinsically safe and all appropriate precautions must be taken.

Personnel Training

The thermographic monitoring of furnaces requires in depth understanding of the science of infrared and the various furnace characteristics that will affect temperature readings as acquired by an infrared camera. There for it is strongly recommended that the thermographer have as a minimum, a Level I certification as outline by the recommendations of the American Society of Non Destructive Testing (ASNT) SNT-TC-1A. The training program covers:

- Basic camera operations
- Infrared Theory
- Heat transfer Theory
- Scanning processes
- Sources of error
- An overview of various Infrared Applications

An onsite course has the added benefit of allowing the students direct experience to their specific application in which the camera will be utilized.

The Scanning Process

Several steps are required to complete the monitoring of the furnaces skin tubes. They are:

- Determining the emissivity of the tubes
- Acquiring the images
- Analyzing the images
- Producing a report.

Camera Preparation

The camera should be in proper operating condition before it is used for any inspection process:

- Ensure all batteries are fully charged
- Check that the storage medium has been emptied of images from any previous scans
- Check that the lens is clean of debris from any previous scans (follow the proper procedure to accomplish this. Note: the lens should not be cleaned too often!)
- Attach the recommended heat shield to the camera.

Emissivity Determination

Before temperature measurement assessment can be conducted on the furnace tubes, the emissivity factor for the material must first be determined

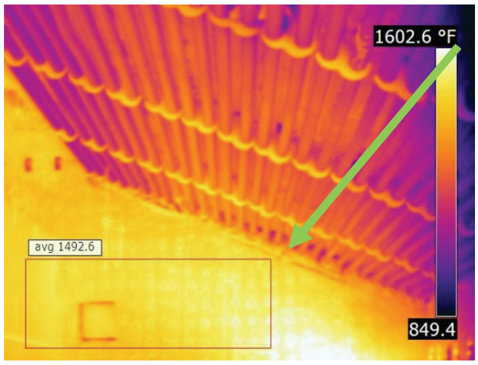
The most important parameter that must be established to yield accurate temperature measurements is the emissivity of the material that is being monitored. The recognized procedure for determining the emissivity of a target is:

1. Measure a representation infrared reflected energy as a temperature (Reflected Temperature) that is impinging on the target. This is accomplished by:

    a. Focusing on the opposite wall from the viewport through which the operator is viewing

    b. Establishing the emissivity setting on the camera to 1.00

    c. Measure the average temperature of a representative area on the far wall (using an average area function on the camera, if so equipped or calculating the average (mathematical mean) using several spot temperatures.

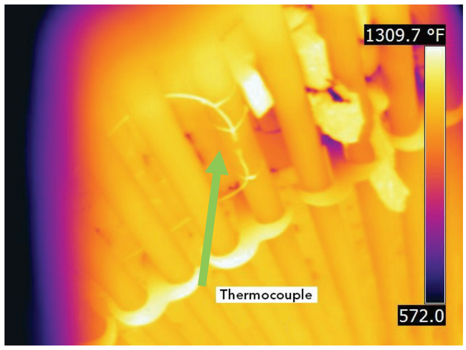


2. Measure the temperature of the target using either:

    a. A secondary surface of known emissivity that is in intimate contact with the surface.

    b. Thermocouple

3. From step 2, ensure that the temperature of the target is significantly different (+/- 15°C) from the reflected temperature as measured in step 1.



4. Measure the temperature of the surface with the infrared camera.

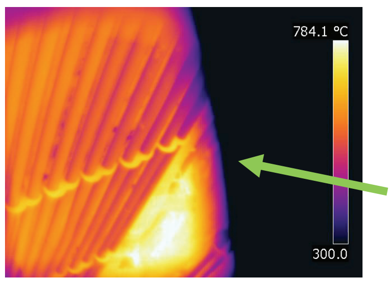
5. Adjust the emissivity setting on the camera until the temperature read out matches (or is as close as possible) to the temperature as measured in step 2. This is the emissivity setting to be used for the furnace skin tube monitoring.

6. The above process can be conducted by capturing corresponding images of the back wall for the determination of the Reflected temperature and a second image of the thermocouple to conduct the emissivity determination. The images can then be loaded onto FLIR image analysis software to complete the steps.

7. This process should be conducted routinely to ensure proper temperature measurement is acquired for subsequent scanning.

Acquiring the images:

1. Acquire the appropriate wok permits, should any be required because of the non-intrinsic nature of the camera.
2. Ensure the appropriate Personnel Protection Equipment is being used.



3. Pre-plan the inspection route. Ensure the view ports are accessible for the day of the inspection.
4. Turn the camera on prior to initiating the scanning process and ensure it is functioning properly. Saving and recalling a test image is recommended as verification of the cameras' operation.
5. Upon opening the view port, conduct a visual inspection and note any obvious physical issues (digital camera images may be of an asset). Specifically identify any problems with:
6. Burners
7. Furnace refractory
8. Surface of the furnace tubes
9. The viewport will restrict the scene complete view that the infrared cameras lens capability. The imagery will appear to have a "tunnel" look to them as the side walls encroach into the image.
10. When capturing any image, it is imperative that the basic "rules" of the objects characteristics are followed. Proper FOcus, Range and Distance (FORD) of the targets are established by the operator.
11. Utilizing the *"date"* naming convention on the camera will be advantageous for image data management.
12. For example: IR_2009-07-06_018.jpg is easier to determine its "capture date" then: IR-04199.jpg.
13. Capture an image or images of the far furnace wall to be used for the subsequent calculation of the Reflected Temperature. It is advisable to make this determination in the field and to enter the calculated result into the appropriate parameter in the camera.
14. Capture images of the tubes within the furnace. For consistent analysis results, the images for each section of the furnace should be captured at the same location and angle as best as possible. It may be appropriate to design a "jig" that can be used to establish the same Field of View (FOV) for each specific view port. This will assist in the semi-automatic analysis and report generation of the scan.
15. Angle of observation is critical in this application since the emissivity measured in the above procedure will vary (decrease) as the angle increases. In other words, as the images are captured further into the furnace the emissivity will decrease which results in an increase in the effect of the reflected energy from the far refractory wall. This must be understood during the analysis of the image data.
16. Reflections from the side wall of the viewing port may cause high energy "spikes" to be captured by the infrared camera. These situations should also be noted to ensure that they are not miss-interpreted during the analysis stage.
17. Once the survey has been completed, all images should be moved from the camera onto a computer into an appropriate folder. Verify that the image files have been properly copied then delete the images from the camera media disk for future use.
18. Recharge the batteries so that they are ready for the next survey.

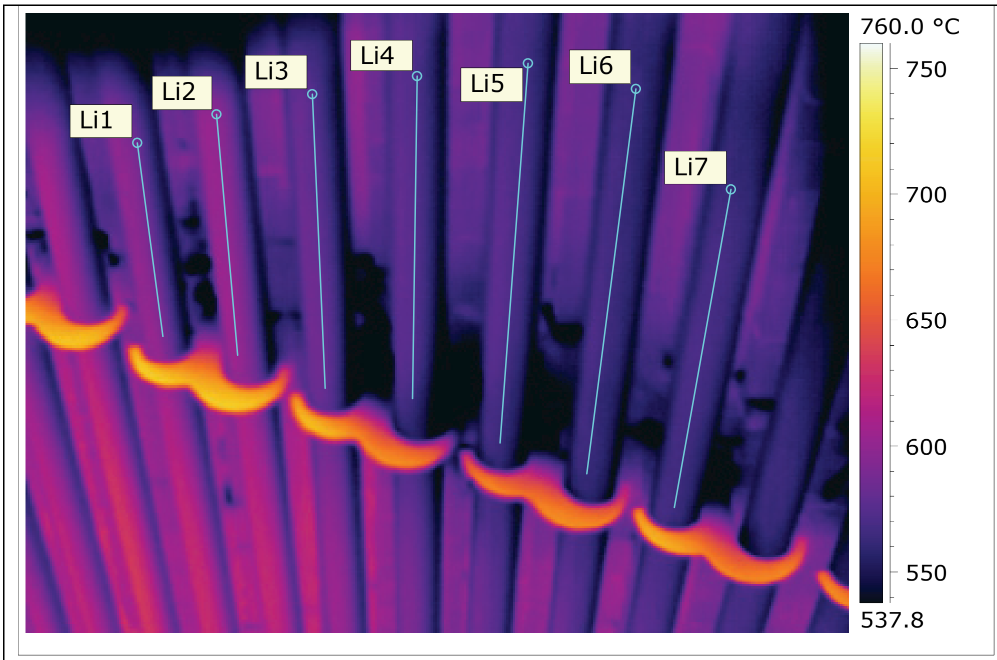
Analyzing the Images and Producing a Report

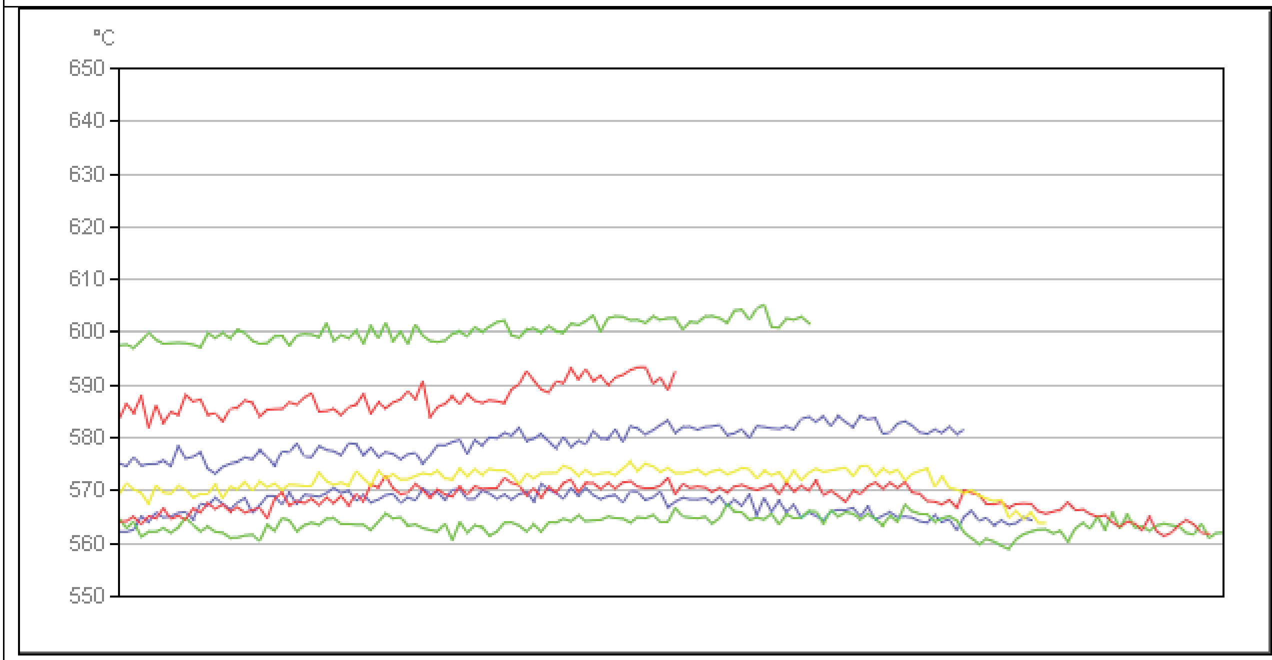
The best way to analyze the images captured by the infrared camera is to use the software specifically designed for the camera model. For the FLIR family of cameras, 2 software packages are best suited for the analysis of the images captured. ThermaCAM Researcher or FLIR Reporter is the analysis packages of choice. Since a formal report is most likely required, FLIR Reporter software is the recommended analysis package, particularly if the recommended "jig" is used to ensure repeatable field of view image capture. The FLIR Reporter software can then be established to virtually automatically analysis the images.

Image Analysis

1. Recall the image into the analysis software
2. Verify that the proper analysis parameters have been set for the particular image. In particular the emissivity and the background temperature
3. Image *Thermal Tuning* will be a great asset in helping to "view" minor variations along the furnace tubes.
4. The best analysis tool for the scrutiny of the furnace tubes is a line profile. The line profile can be drawn along the tube. The line is best situated along the center of the tube to reduce any lateral emissivity variations as the result of the circular shape of the tubes and the fact that emissivity may vary with changing angle.
5. Individual profiles should be established on all the tubes to allow for easy comparisons.
6. Analysis of the images requires:
    a. Infrared Knowledge
    b. Basic Heat Transfer Theory.
    c. Furnace Operation
    d. Metallurgy Basics
    e. Experience

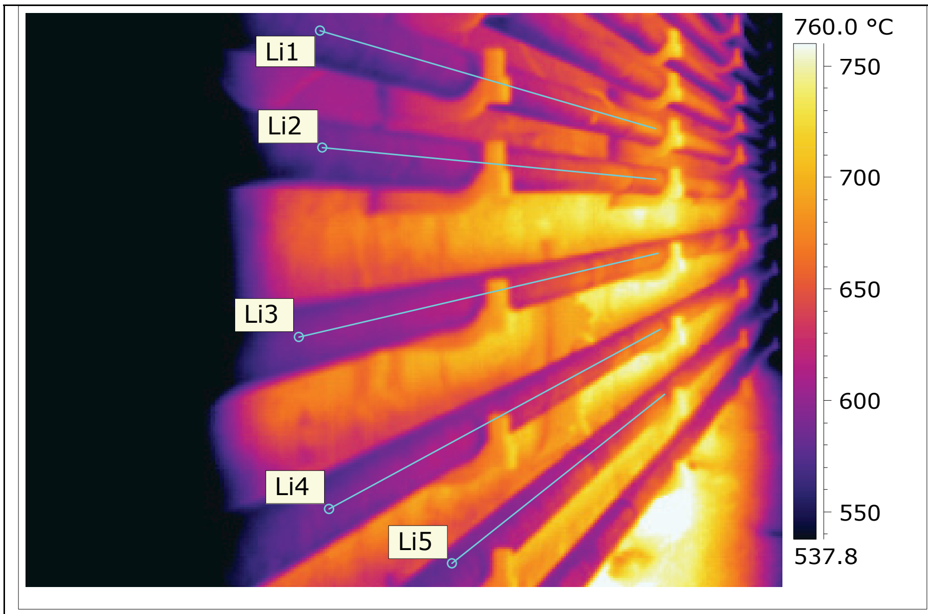
The proper image analysis can only be conducted when all of the above are considered together. If only one aspect is considered in the analysis, inconsistent and incorrect conclusions may be made. For example, when monitoring a thermal pattern, not only is the infrared energy being emitted by the target is important, but the reflected energy must be considered otherwise, one may think that the temperature variations maybe the result of a process issue when in fact the profile is a result of energy from the furnace wall reflecting of the objects. (see example #2 below).

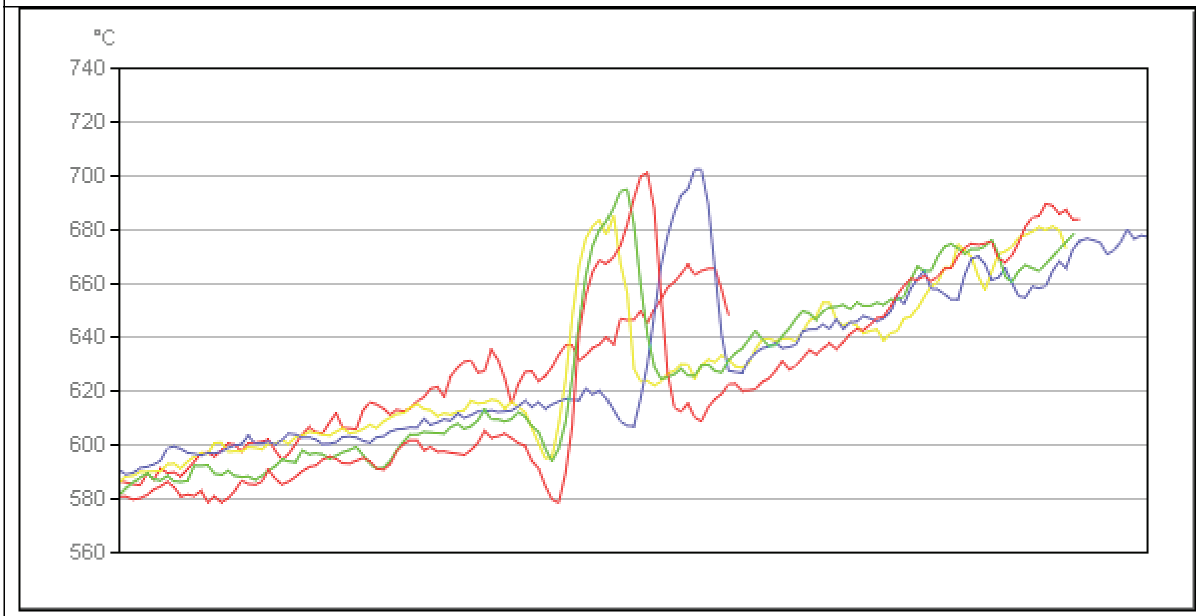




Example # 1

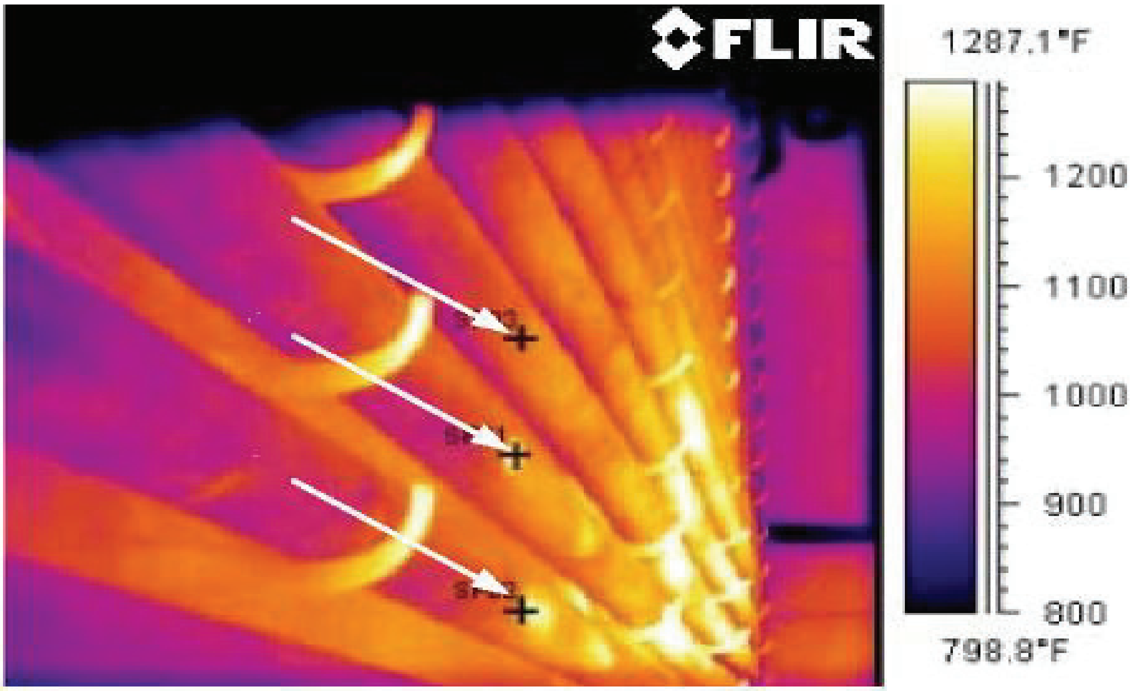
Normal expected temperature profiles showing uniform performance.





Example #2

Initial observation of the profiles, it would appear that the actual temperature of the tube skins is increasing. In actual fact, the apparent temperature is increasing because the viewing angle is increasing, reducing the effective emissivity of the surface, thus increasing the reflective energy from the back furnace wall.



Spot 1: 1277 °F Spot 2: 1255 °F Spot 3: 1100 °F

Example # 3

Localized "hot spots" maybe the result of surface slag/fouling or internal coking of the tube. A visual inspection would verify if the observed thermal anomaly is a surface issue. If not, then the increased temperature will be the result of internal coking resulting in a decrease in heat transfer through the tube.

Report Generation

Generating a report of the findings of the survey and subsequent analysis can be a tedious and time consuming process. In some cases, this is an inevitable. The ways that the process can be expedited is:

- If a consistent field of view can be established, use a software package that allows a "*template*" to be designed that contains the analysis tools (profile lines) in the proper location. The report can then be generated in a semi-automatic way in a few minutes
- Break the report generation into smaller consistent components of similar types of analysis then assemble the final report.
- Use camera built-in functions that allow for identifying information to be entered directly into the camera at image capture time. Then this data can be automatically inserted into the report.

Conclusion

Proper maintenance of furnace and furnace tubes can be enhanced with a properly designed and implemented infrared scanning regime. To reap the maximum benefits of the infrared scanning program, the overall process must itself be reviewed on a routine basis and modifications applied as better understanding of the specific dynamics of each furnace is understood.

