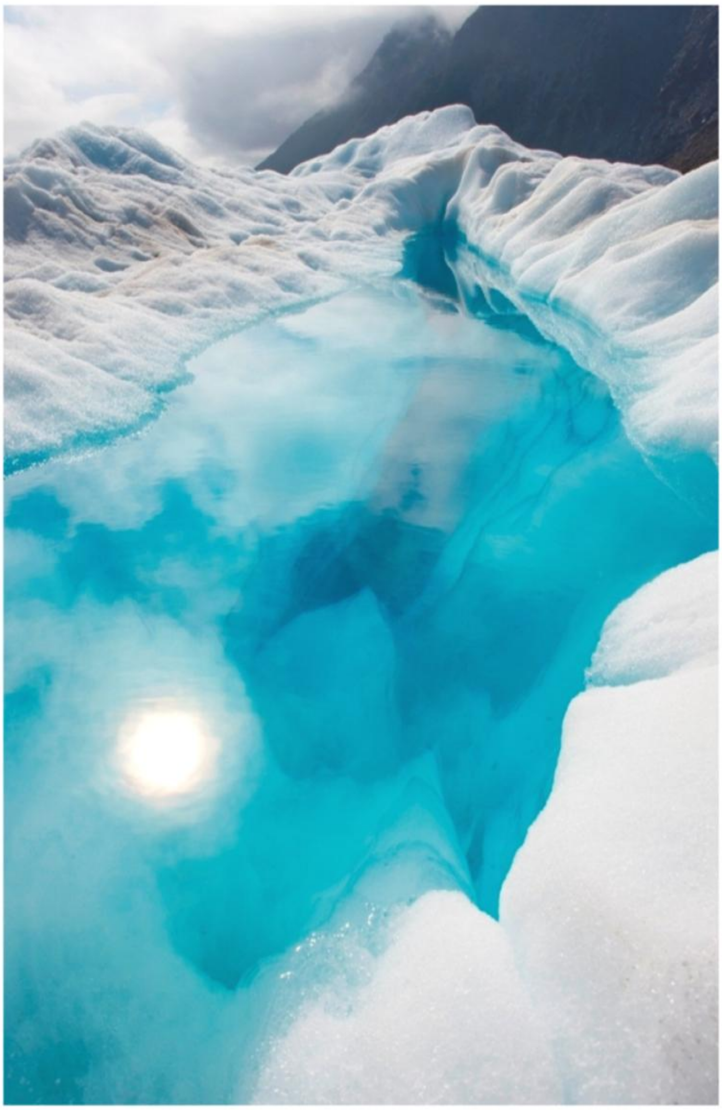

INFRARED IMAGING

SENSORS AND DIGITALIZATION EXPERIMENT NO 2

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Objective

The goal of this practical lab is to study the application of IR imaging with respect to temperature measurement and to observe the influence of various parameters on the efficiency of these measurements.

Introduction

Infrared light or thermography is the use of an infrared imaging and measurement camera to "see" and "measure" thermal energy emitted from an object. Thermal or infrared energy is the light that is not visible because its wavelength is too long to be detected by the human eye; it's the part of the electromagnetic spectrum that we perceive as heat. Unlike visible light, in the infrared world, everything with a temperature above absolute zero emits heat. Even very cold objects, like ice cubes, emit infrared.

Equipment

For the proper realization of the experiments, we will use:

- PC Computer
- IR Camera : FLIR SC6X5
- Hotplate
- Industrial parts and Electronic circuit
- Altair Software - Therma CAM Researcher Professional
- C.A. 1875 tutorial bench
- Halogen Light
- Digital Thermometer

Study of the camera and Altair Software

Once we have the IR camera properly connected, we power on the computer and launch the Altair Software. We notice that the camera takes some time to stabilize (between 1 to 5 minutes).

After the initialization, we acquire our first infrared image as a way of having a first contact.

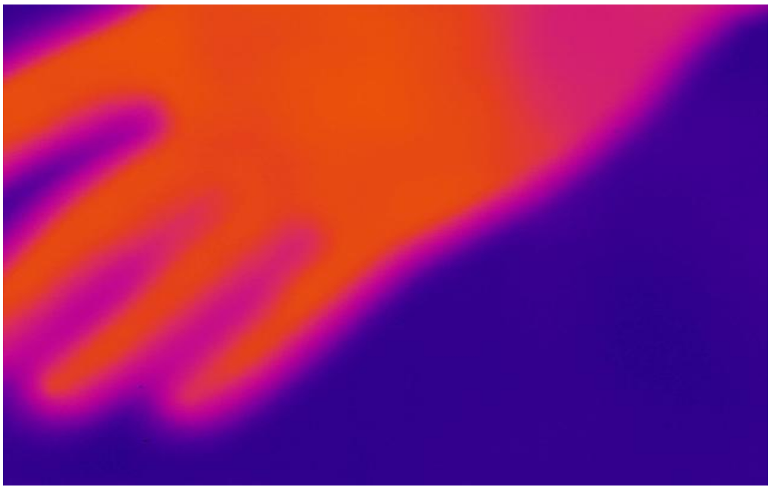


Figure 1 First Sample with IR

Now take the second sample of electronic circuit. We have been told that there is some failure or malfunction of the component that is not working properly and we must recognize and detect the error.

If the component is not working well, there is a possibility that it heats more than it should with the pass of the current. For that reason, we will use our IR camera and the provided software to analyze the whole circuit behavior when it comes to heat.

As we see in the image, our setup consists basically in situating the camera at a reasonable distance of the object to analyze, and then power the circuit which has to be analysed. The setup is labeled in figure 2.

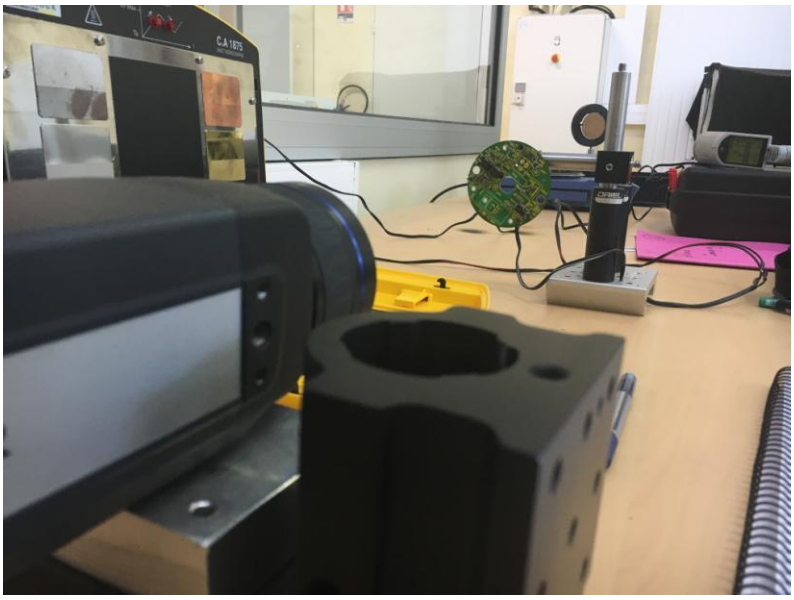


Figure 2 Setup for circuit testing

When we look at the image obtained from the software (figure 3) we can acknowledge that the error is situated in just a certain component: a resistor situated on the right side of the circuit (the brown one):

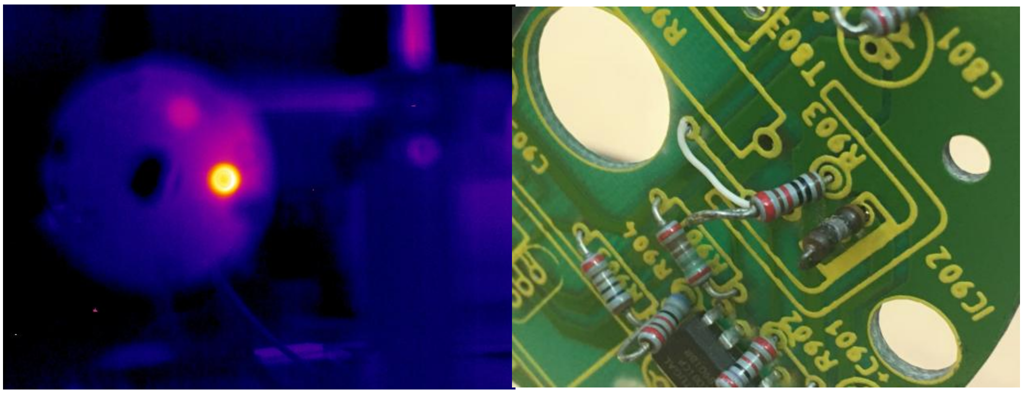


Figure 1 Electronic board error

So, we have finished our first application for thermal and infrared imaging: detecting errors in an electronic circuit that produce heat.

From this point, the Altair software gives us enough tools to determine the exact position of the defect, its maximum temperature, mean temperature of the circuit and profile temperature:

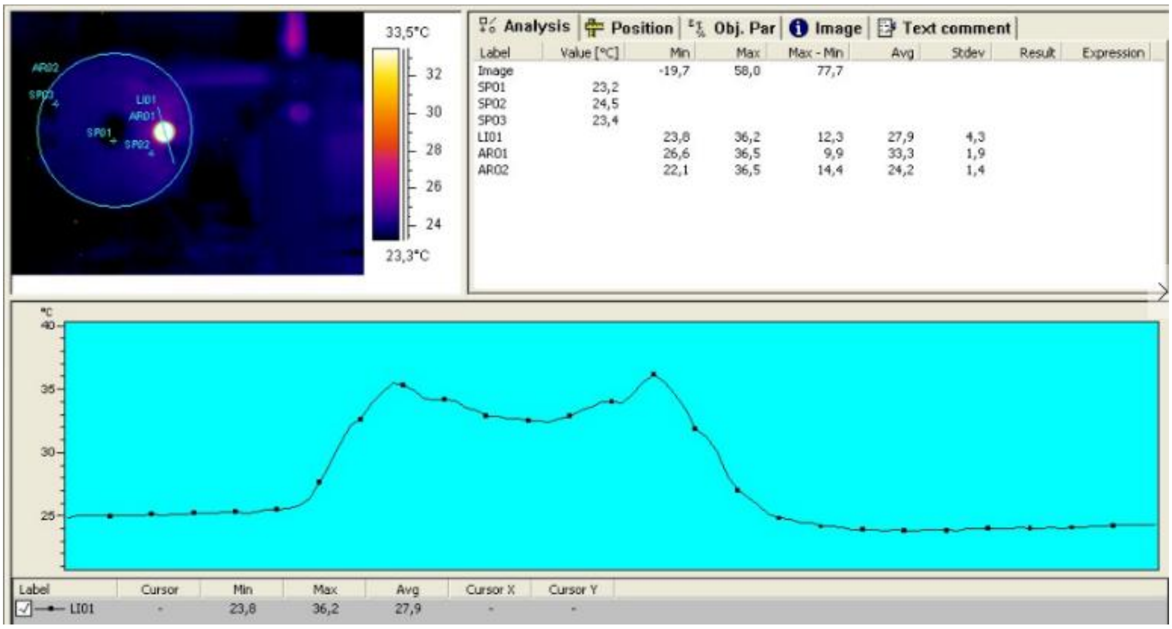


Figure 2 Data Analysis of the whole circuit

As it is clearly seen:

- The defect is on the right side of the circuit.
- The maximum temperature is 36.5ºC (which is the failing component’s temperature)
- The mean temperature of the circuit is 24.2ºC
- The profile is shown below, proving the change in the temperature.

Camera calibration

Using the hot plate and the digital thermometer, we now propose an experimental setup to realize the temperature calibration of the camera.

The idea is simple, we will measure the real temperature of the hotplate on the same point with different temperatures, and also we will acquire images from the IR camera. After that, we will have both real and digital values for a given temperature, and we will be able to plot a graph to show approximately the calibration curve of our camera.

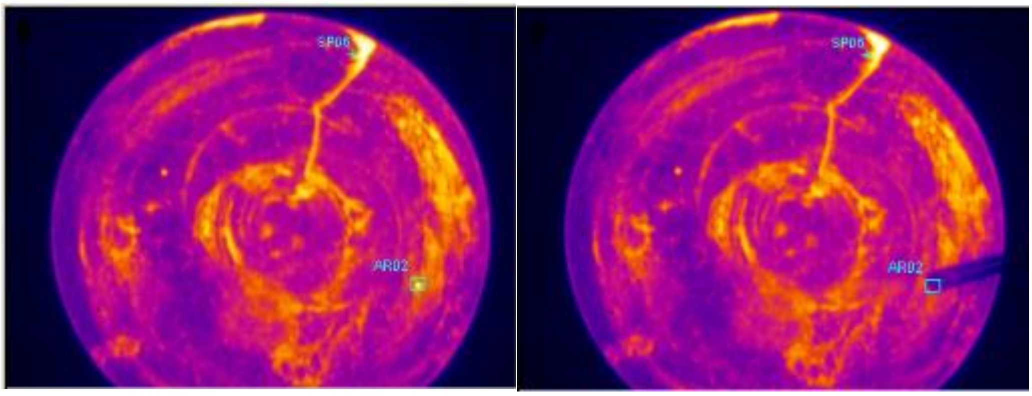


Figure 5 Measuring temperature for the same point digitally and physically

After acquiring different measurements, we are able to present the curve of calibration that our IR camera is having. We must say that we started taking measurements at 150ºC, as It would have taken a lot of time for the plate to cool down and start from lower temperatures.

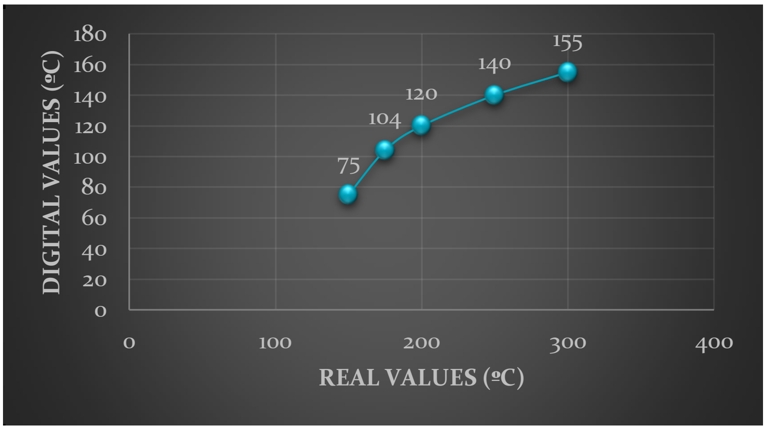


Figure 6 Real values vs Digital values of temperature

As we observe, the values are almost divided by 2 when passing from the real value to the digital one, this is a very bad result, as this means the camera is not calibrated at all.

In our opinion, the infrared source (the hot plate) is not a good source for our experiment, because even if the whole surface is at the same temperature, the emissivity of each point is different, and so the camera understands those different points, indeed, with different temperature.

Estimation of emissivity

We will use for that our tutorial bench, that comprises a hot plate with several targets having different surface conditions and made of different materials, along with test screens that are affixed to the front of the bench using magnets.

Figure 7 C.A.1875 Tutorial Bench

If we take a shot of the bench with the IR camera before staring it, we observe that although one of the materials has a lower temperature, almost all are relatively cold.

Once we start the bench and the temperature is stabilized at 50ºC, we can take the real image of the materials heated:

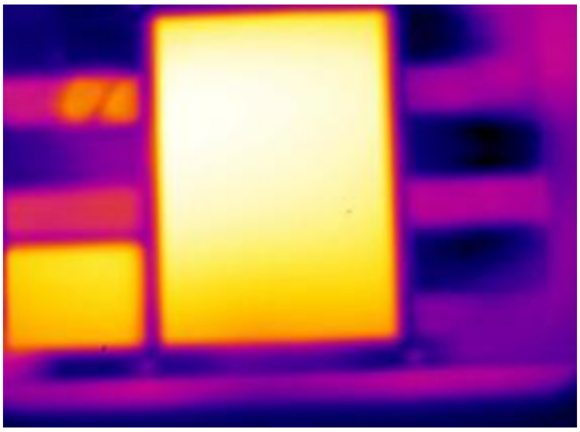
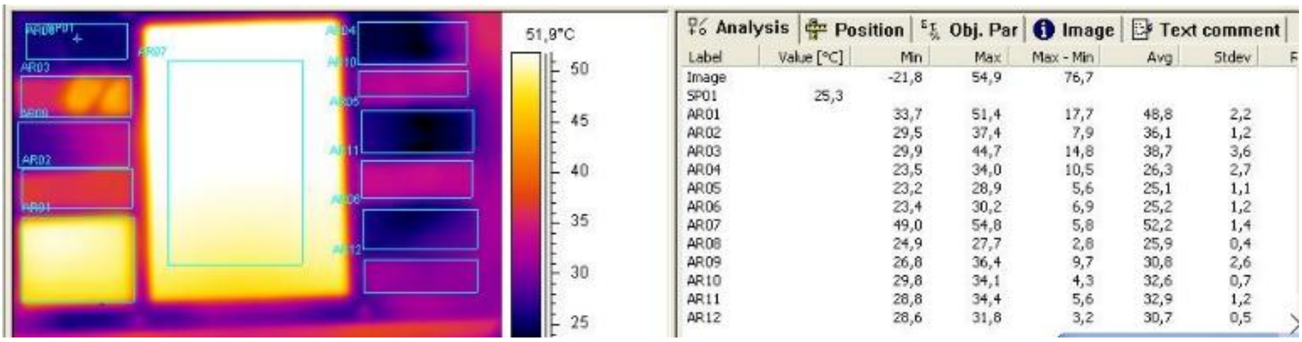


Figure 8 Various metals of temperatures



Label	Value [°C]	Min	Max	Max - Min	Avg	Stdev
Image		-21,8	54,9	76,7		
SP01	25,3					
AR01		33,7	51,4	17,7	48,8	2,2
AR02		29,5	37,4	7,9	36,1	1,2
AR03		29,9	44,7	14,8	38,7	3,6
AR04		23,5	34,0	10,5	26,3	2,7
AR05		23,2	28,9	5,6	25,1	1,1
AR06		23,4	30,2	6,9	25,2	1,2
AR07		49,0	54,8	5,8	52,2	1,4
AR08		24,9	27,7	2,8	25,9	0,4
AR09		26,8	36,4	9,7	30,8	2,6
AR10		29,8	34,1	4,3	32,6	0,7
AR11		28,8	34,4	5,6	32,9	1,2
AR12		28,6	31,8	3,2	30,7	0,5

Figure 9 Data for each metal of the bench

From the data we have, and following the suggestion from our professor, we know we can acquire an idea of which would be the coefficients of emissivity of each of the materials present in the bench if we make a relation of their temperature with the black plate temperature, such that we find these results (average temperatures have been taken):

$$\varepsilon \sim \frac{temp.material}{temp.black\ plate}$$

Polished steel:

$$\varepsilon = \frac{32.4}{52.4} = 0.62$$

Stainless steel:

$$\varepsilon = \frac{33.7}{52.4} = 0.64$$

Laminate:

$$\varepsilon = \frac{49}{52.4} = 0.93$$

Red copper:

$$\varepsilon = \frac{32.4}{52.4} = 0.56$$

Brass:

$$\varepsilon = \frac{32.4}{52.4} = 0.6$$

Aluminum:

$$\varepsilon = \frac{32.4}{52.4} = 0.58$$

Transmission and reflection coefficients

We propose an experimental setup for determining the transmission coefficient of the glass plate, as well as for black PVC.

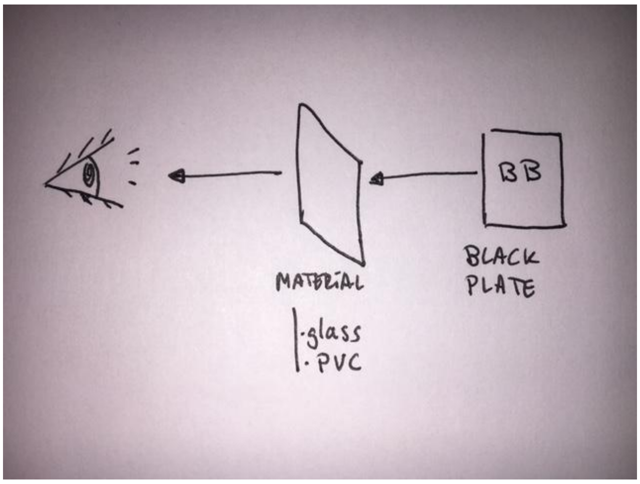


Figure 10 Proposed Diagram

If we compare how the light goes through both materials, we will be able to have an idea of the transmission coefficient that these materials will have:

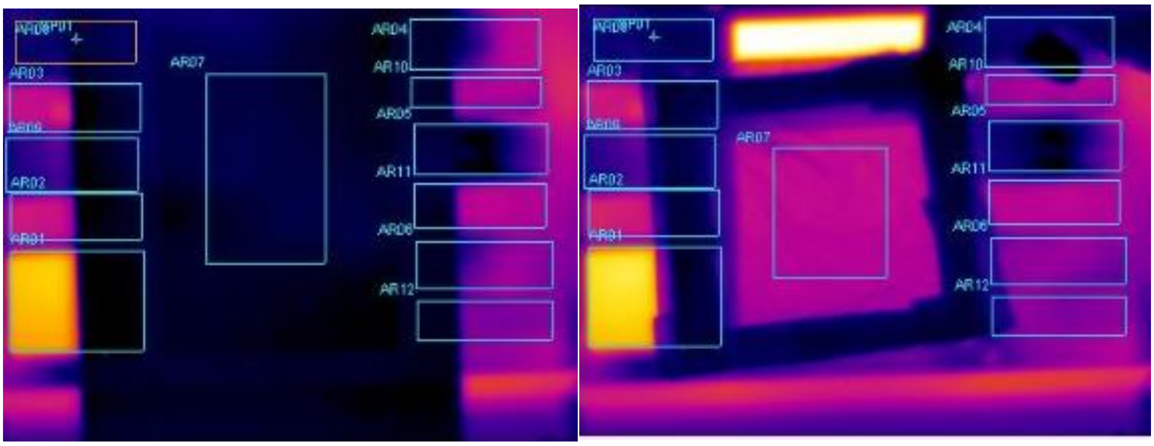


Figure 3 Glass and PVC in front of black plate

Comparing now both intensities perceived by the IR camera from both materials and how the black plate was acknowledge before, we proceed:

An idea of which could be the transmission coefficient could be taken with:

$$\tau \sim \frac{temp.\, black\ plate\ covered}{temp.\, black\ plate\ uncovered}$$

Thus, we can compute for both materials:

Glass:

$$\tau = \frac{24.3}{54.3} = 0.447$$

PVC:

$$\tau = \frac{33.2}{54.3} = 0.61$$

What we can conclude, is that even if the coefficients are not computed in an exact way, we see that while in the visible domain is the glass the one transparent and the PVC more opaque, that is not preserved once we get into the infrared domain, such that is the PVC the one that has a better transmission coefficient, being the glass almost opaque.

Now we move to the estimation of the reflection coefficients, for which we define another experimental setup.

In this case, what we propose to do is understanding that the plates in the bench are not uniform, meaning this that each metal of the bench is divided into a polished and a non-polished part.

We know that the non-polished parts are the ones that avoid the reflection (they are usually used for that), while the polished ones reflect normally.

That means we could establish a ratio, as we did previously, between both parts of each metal that showed the reflection. In this particular case, we will exemplify our procedure with the red copper plate, such that:

$$reflection\, ratio \sim \frac{temp.polished\ part}{temp.non-polished\ part}$$

For the red copper:

$$reflection\, ratio = \frac{26.3}{32.6} = 0.8$$

Even if we get wrong results, as we think the reflection coefficients should be lower, this is a good way to characterize the reflection factor between polished and non-polished surfaces of the same material.

Active thermography

For this part of the laboratory, we will use a halogen light as infrared source.

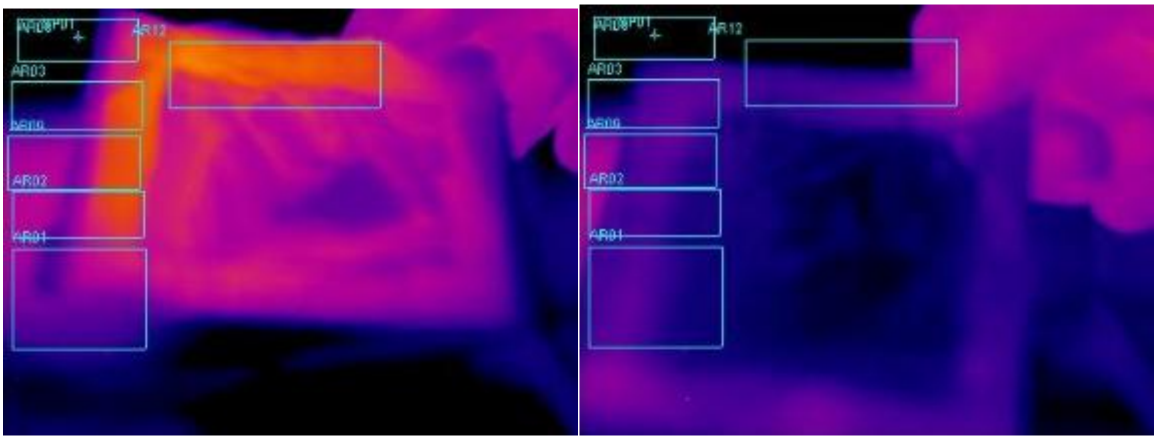


Figure 4 Effects of halogen light on PVC

As we see, If we turn on the halogen, the pvc is exposed to thermal radiation. And when we turn off the light, it rapidly disappears. One of the applications for this could be checking which parts of some objects reflect, for any reason, more than others the infrared light.

Conclusion

We have conducted various experiments on different materials to find the emissivity, reflection coefficient and transmission coefficient with respect to infrared imaging. The observations are plotted in graphs and the results are calculated accordingly with respect to the emissivity of the black body.