INFRARED THERMOGRAPHY AND ULTRASOUND BOTH TEST ANALYZING VALVES

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ABSTRACT

The leakage in valves in general could mean high economic loses and also can cause many trouble to any industrial installation or power facilities. Specially in steam valves and traps these must be carefully checked because a wrong close may cause loss of energy. Avoid the leakage is the challenge in any maintenance organization. The test how closed a valve is with infrared thermography offers the users one quite approximate idea of what is the real situation in a valve inspected. Supplementing the infrared inspection with passive ultrasonic test give to whole inspection more precision of what is happening. This work seeks to bring near the infrared thermography with ultrasound with the purpose of understanding that exist an excellent complement between both technologies.

Keywords: Valves leakage/ Infrared Thermography / Passive Ultrasound

1-INTRODUCTION

Valve is a universal device used by all type of industries such as Chemical, Oil Fields, Power Generation, Mining, Marine, Pulp and Paper, Food Industries, etc. There are different types of valves within each industry made of different materials, size and used for different purposes. In some cases a leakage may relatively have no importance in the process itself or in economic losses. In order that the infrared test has success, the existence of thermal contrast, among other things, is required. Therefore, the analysis of valves with infrared is difficult, especially those valves which are mounted in lines and carry fluids at ambient temperature (emissivity problems may also exist). In that case, the acoustic test has no limitation and may be carried out whatever the temperature of the valve to be analyzed. Care must be taken over valves of high temperature not to keep the ultrasound sensor (probe) equipment leaned on the valve a long time since the equipment may be damaged. I may say that one of the limitations of the acoustic test is given by the background noise that takes place inside and outside the system. Sometimes is very difficult to differentiate or subtract it and therefore a thorough analysis of the analyzed valve and the location of it is required. The other limitation of ultrasonic that the equipment has to be in contact with the valve to perform the analysis. (in real world there are many important valve that are nor accessible). Infrared has not that limitation in that case: it is non-contact test. The skillful analysis will be limited to valves installed in lines that carry steam/condense/water and internal leakage only (can use technologies for external leakage toward the exterior from the stem of the valve, valve body, stem packing or the gland with many application in gas pipe lines industries etc). We see steam lines in all types of industries since most of them use this fluid directly or indirectly for production, being the majority of users power plants. The concern of companies is to minimize the loss of fluids.

2- TECHNOLOGY THEORY OVERVIEW

The figure No 1 is detailed the spectrum published by the ASNT in which they show different frequencies and wavelength for most popular NDT. In that table you can see the infrared and ultrasonic energy (8 and 13 position).

2.1 - INFRARED

The thermal radiation is associate with the rate at which energy is emitted by matter as a result of its finite temperature. The mechanism of emission is related to energy released as a result of oscillation or transition of the many electrons that constitute matter. The oscillation is sustained by the internal energy; that means temperature of the matter. (all matter over absolute cero 0 º K radiates energy) In our case matter are valves bodies, pipes etc.
The infrared radiation of matter may be viewed as the propagation of electromagnetic waves (other electromagnetic waves are X ray /UV /radio waves etc), and the formula that related the frequency of the radiation with its wavelength is: $\nu \cdot \lambda = c$. Where c is the speed of light.

$$c = 2.998 \times 10^{8} \text{ m/seg} \quad \text{(speed of light in a vacuum)}$$

The infrared radiation emitted by a heated solid body normally contains a continuous band of wavelengths. The radiation intensity emitted by the solid depends upon the temperature and nature of the surface. At lower temperatures the radiation intensity is low and consists chiefly of longer wavelengths 8-13 microns (µm). (See Plank formula below) At higher temperatures the radiation intensity rapidly increase while the wavelength band shifts towards shorter values. In our case we use an instrument with the sensitivity in wavelength between 2-5 microns (µm).

$$\text{micron} \Rightarrow 1\mu m = 10^{-6} \text{ m}$$

The general and most important expression for infrared are: Total hemispherical emissive power E (W/m2): rate at which radiation is emitted per unit area at all possible wavelengths and in all possible directions.

$$E = \int_{0}^{\infty} E(\lambda)\, d\lambda \qquad (1)$$

Spectral distribution of blackbody emission or Planck law:

$$E(\lambda, T) = \frac{C}{\lambda\,[\exp(C / \lambda T) - 1]} \qquad (2)$$

C / C= radiation constant

Substituting the Planck distribution (2) into (1) we have:

b= blackbody

$$E_b = \int_{0}^{\infty} \frac{C}{\lambda\,[\exp(C / \lambda T) - 1]}\, d\lambda \qquad (3)$$

Integrating this formula from 0 to ∞ we get:

$$E_b = \sigma T^4 \qquad \text{(Stefan- Boltzmann law)} \quad (4)$$

$$\sigma = 5{,}670 \times 10^{-8} \ \text{watt/m}^2 \text{K}^4 \qquad \text{(Stefan-Boltzmann}$$

constant/depends C / C)

With this formula we can calculate the temperature of the blackbody knowing the amount of radiation emitted in all direction and over all wavelengths. This formula is absolute theoretical that's why we have to make some consideration for a real situation:

The radiation leaving from any target surface is call: Radiosity. The radiosity of a surface is equal to the sum of reflected, emitted and transmitted energy. In our case for valves and pipes the transmitted energy is cero. Also target surface properties as Kirchhhoff`s law is:

$$\text{emissivity } (\varepsilon) + \text{reflectivity}(\rho) + \text{transmissivity}(\tau) = 1 \quad \Rightarrow$$

$$\text{emissivity } (\varepsilon) = 1 - \text{reflectivity}(\rho) - 0 \quad \Rightarrow \qquad \text{emissivity } (\varepsilon) = 1 - \text{reflectivity } (\rho)$$

We must take in account this properties of objects /surfaces because in our real world the different objects (pipes, valves etc) are not blackbodies like formula (4) shows (perfect emitter). All the objects emits energy but some emits much better than the others. The emissivity can have values from 0 to 1. A general definition of emissivity could be: the ratio of emissive power of the source (valves/pipes) to the emissive power of blackbody at the same temperature.

- So the Stefan-Boltzman law in a real situation is:

$$E = \varepsilon \sigma T^4 \ \text{(Watt/m2)} \quad (5) \qquad \Rightarrow \quad \text{or} \quad E = (1 - \rho)\, \sigma T^4 \quad \text{(Watt/m2)} \quad (6)$$

Therefore once we set in our infrared camera the correct emissivity, the distance, levels, the environmental conditions etc... we could carry out the infrared test knowing that the camera will measurer E and then the microprocessor will calculate T (temperature) for any point of the scenario Pipe-valve. (Passive infrared) In that context we have T for all the target so we get a thermal profile.(depends the camera we use) That thermal profile (temperature gradient across the valve) give us information about the flow fluid in the system. Insolated valve (non leakage) means no flow through If there is flow the next question is which is the heat rate.(quantify) It can be estimated by experience together with ultrasound or make approximation with thermodynamics calculation.

2.2 ULTRASOUND

The sounds waves have great physics difference with the infrared waves (electromagnetic). The sound waves do not travel in the vacuum: need a medium. (Solid/gas/liquid). All electromagnetic waves like infrared do travel in vacuum. Also the speed of the waves has great differences

The speed of sound waves depends in which media they are traveling. On air at sea level at room temperature the sound waves travel at the speed of 340 m/seg. In water the speed of sound waves it is around 1500 m/seg and average in metals are 6000 m/seg. (almost 20 times more than in air)

Sound is produced by a vibrating body and is itself a mechanical vibration of particles about equilibrium position. The actual particles do not travel through the material away from the sound source. It is energy produced, which causes the particles to vibrate that is moving progressively through the medium.

The characteristics of sound/ultrasound waves can be describe with the dynamic o sonic spectrum.(Fig No 2) In this spectrum we see different frequency application.
The waves we are talking have 3(three) parameters characteristics:

λ = wavelength v = velocity f= frequency

The equation is : $f = v/\lambda$

The velocity is constant and as we mention before and depend of the media they travel. So if we change the frequency the wavelength changes accordingly. Ultrasound travel in fluids as a longitudinal waves that consist of alternate compression and rarefaction zones along the direction of propagation
(In solids also you have Transversal/Rayleigh/and Plate waves)
The air itself carries energy that can be heard. The human audible frequency range is from about cps (cycles per second): 10 Hz to approximately 20 kHz. (Fig No2)
At air limits audible sound wavelength:

λ_{Max} = 340m/seg / 20 Hz = 17 m λ_{min} = 340 m /seg / 20.000 Hz = 0.017m (1.7cm)

Of course the sound intensity is important:

-Sound intensity is: Power: (energy per /unit time)= watts

Power comparison:

-Person Talking: 10^{-6} watts ∴ Light bulb: 100 watts ∴ (1) Human body : 966 watts

(1) human body temperature : 305 º K / average human surface 2 m2 / skin emissivity : 0.98

-Acoustic Intensity : Power/unit area watts/m2

-Threshold of hearing: 10^{-12} watts/m2 = Io

-Loudest(subjective): 1 watts/m2

$$\text{Acoustic intensity } X = 10 \text{ LOG } \left(\frac{I}{Io} \right) \text{ decibels}$$

The frequencies above 20 kHz (maximum human audible frequency) are referred to as ultrasonic. Since we cannot detect this frequency of energy by ear the passive ultrasonic equipment has the ability to transform electronically the emissions generated from the inspection we are doing to various forms of flows into the audible range.(ultrasonic translator)
Why we try to use and ultrasonic instrument to check a leakage in a valve? The main reason is that a leakage produces ultrasound signals. This ultrasound signal is mainly generated for the cavitation or turbulence that can be listening upstream and downstream of the valve we are analyzing (most of times better downstream). When we have turbulence inside a pipe?
Fluid flow in a pipe can be characterized as laminar, turbulent or transitional. (Fig No 3/4) .To better understand the situation can be used the dimensionless Reynolds (Re) number (for circular tubes):

$Re = WD/\nu$ W= velocity fluid D= diameter of pipe ν = kinematics viscosity

$W = Q/A$ Cross section $A = \pi D^2/4$ $\Rightarrow$ $W = 4Q/\pi D^2 \Rightarrow$

$$\Rightarrow \quad Re = 4Q/\nu \pi D \; .$$

So to calculate the Reynolds number for pipe flow we need only the pipe diameter, the flow rate and find kinematics viscosity. Turbulent flows occur at high Reynolds numbers (>4000). Any combination of W, D and ν giving Re>4000 will produce turbulent flow. Frequently, the entire flow is unstable and the flow switches back and forth between turbulent and laminar conditions.

How we said the turbulent flow produces ultrasonic of different frequencies and intensity .The leakage generates big changes in pressure and that means big changes in speed therefore ultrasonic signal appears. (Fig No 4)As highest is pressure differential between upstream downstream the highest probability to get strong ultrasonic intensity in the test area. An isolated valve means not fluid circulation through that is not ultrasonic generate in the place. You may have ultrasonic signal in the test area generated for many another sources.(background noise) The challenge is differentiate between both to establish if your system it is leaking or not. After that the most difficult step is define the severity of leakage.(quantify)

3-ESTABLISH PROCEEDINGS AND TECHNIQUE FOR INSPECTION PROGRAM

3.1-GENERAL GUIDELINES

1- Divide the plant into systems.
2- Divide systems into sectors.
3- Classify valves in the pipeline diagram according to its importance in order to inspect with priority the valves that may cause serious operative problems or big economic losses.
4- Make a list of the valves classified by size and type. Check the existence of twin valves and make sure that they perform the same function in order to make a comparison between them not only in the infrared test but also with the ultrasonic test. Valves can also be classified by diameter or series. (ANSI 150 /300 /600 /900 /1500 /2500).
5- Take in account the type of fluid that flows through the pipe: gas, superheated steam(main steam for generators), saturated steam, etc. Figure No 6 show P (pressure)--V (volume) vaporization diagram. For each point of pressure you have a temperature of saturation. The temperature and pressure both keeps constant till vaporization process finish then we have superheated steam (no humidity). For practical purpose is more useful the T (temperature)--S (entropy) vaporization diagram In this diagram you obtain for each point of T/S: pressure, enthalpy, specific volume, humidity of steam and different points of saturation (steam tables)
6- Check pipe thickness (schedule) upstream and downstream.
7- Take in account if the pipe upstream the valve is insolated all the way up to the heat source.
8- Take in account the distance from the heat source to the valves to be inspected.
9- Take in account the manufacture material of the valves to be inspected (conduction/emissivity) and manufacture standard.
10- Consult about the valves internal drawings, plans o diagrams to be inspected in order to have an idea of their inside outline. ANSI has reported more than 104 different standards for different types of valves.
11- Consult about the valve seniority and the possibility of dirt in the system.
12- Establish the frequency inspection program.

13- Before inspection request the maintenance personnel to remove the thermal insulation (if correspond and if it is possible) from the valves to be inspected upstream as well as downstream. The disclosure of a support for each side of the valve may be agreeable. Preferably find a more extensive area downstream. This is needed for infrared test.
14- Try to check with maintenance personnel when was the last time the valve was open/close. It is important for thermal profile. It could be also important for pressure differentials at the moment of the test. (ultrasound)

15- Make the Infrared Test (3.2). (Fig. 5)

16- Make the Ultrasonic Test (3.3). (Fig.5)

17- Check the test results and give the corresponding advice. Try to determine the heat rate. Define if the severity of the leakage justifies the reparation of the valve. To establish reference gages in which we can determine with precision if a valve has a leak or not is not a very difficult task to make. It is difficult to establish standards that define us the severity or heat rate of the leak. This is owing to the different situations in which the type and size of a valve can be found in a certain installation and the great quantity of variables that intervene in the thermodynamics calculations. A starting point could be considering the heat that the mass flow (steam) add to the pipe which must be equal to heat loss by the pipe itself by any mode of heat transfer (conduction/radiation/convection). In Figure No 7 there is a table that consider a severity project that could be upgrade and develop for valve leakage qualification.

Figure No7

PROJECT TO VALVE LEAKAGE SEVERITY CRITERIA					
A CRITICAL	**B** SERIOUS	**C** INTERMEDIATE	**D** MINOR	**E** NEGLIGIBLE	**F** GOOD VALVE
For qualification take in account among others: Changes in ultrasound level between upstream- down stream Changes in ultrasound level between background -valve area Thermal profile /Steps of changes between upstream and downstream Temperature and pressure of the fluid that pipe transport (enthalpy) T/S fluid diagram location Pipe diameter /Flow when the valve is open/Distance from source temperature Existence of insulation upstream the valve Problems on plant security that can occasion if the leakage persist or grow Problems on plant operations that can occasion if the leakage persist or grow					

18- Make a history sheet of the inspected valves in order to notice failures that can be repeated and originated by a valve not suitable for its function o by causes foreign to the valve itself.
19- Once the valves are repaired, the plant running and before mounting the insulation (if correspond) the most important valves should be tested again. Add the information obtained to the history sheet before mentioned. In this way we can verify that the valves were correctly repaired and the initial diagnosis was correct.

3.2 INFRARED.

1- Make sure that the valve to be inspected is located in a line in which the fluid that carries has the necessary temperature difference to generate thermal contrast in the infrared camera to be used in the test. (Thermography can detect leakage with small thermal differences). It is likely that in this last case, the leakage be identified with the general difference of temperature between downstream and upstream.
2-Take into account the difference of emissivity that may exist between the upstream and downstream pipes and the valve.
3- If the valve is an important one and it is required not only to obtain information of the leakage but also the location of it, uniform paint should be applied to the valve. Use a regular paint (of high emissivity) in order to prevent those micro variations in surface color/conditions that could change the valve real thermal profile. (Sometimes non uniform oxidation or deteriorate aluminum paint) Paint should be, in some cases, appropriate for high temperature.
4- If the valve is of great importance and big, it should be tested from different angles trying to locate the most affected side by the leakage. (For apply sealant injection)
5- In the event that the valve surface/pipe is of low emissivity, make sure that no heat or light sources are present so they may not lead in the camera undesired reflection. (Check the ambient and surroundings temperature). For valves located outsides buildings in very cold and windy atmospheres or with other climatic adverse situations (rain/ snow) should be avoided of carrying out the test in those conditions. (Uninsolated valves or pipes). Do no make the test if the atmospheres between the camera and the valve inspecting present heavy steam, change the angle or wait till you can clean up the area.
6- Once the infrared test is made, analyze them with the appropriate software, taking into account in the analysis and in the findings all the information before mentioned. Also when analyze thermograms you must add to your file the following concepts:
a) If a valve installed in a line that presents upstream-downstream a thermal profile without any step of changes showing ambient temperature values; means that valve is not leaking (no flow) The fluid is condensed upstream for different reasons. It assumes not heat sources near to downstream area.(Figure No 13/14/20)
b) If a valve installed in a superheated steam line present upstream a temperature equal o greater of saturation point for the pressure the line is working and also show an important jump in thermal profile as you reach to downstream side (temperature higher the ambient) that valve is leaking. The jump in temperature means jump in pressure. (P/V--T/S chart) Figure No 6(PV) (Figure No 9)
c) If the valve presents upstream minor temperature that the corresponding to their point of saturation for the pressure that line is working and present downstream a temperature which is sustained only for the conduction (no flow) of the heat from upstream side: that is a non leaking valve. (Uniformity in thermogram upstream) Conduction from upstream to downstream has lower thermal effect in downstream area in relation the effect that can have a leakage situation. A representative case is that the valve will absorb the heat by conduction and pipe down stream reach to ambient temperature. (Figure No 8/15)
d) If the valve present upstream -downstream not temperature changes or the changes are not relevant in relation to temperature-pressure of the heat source. That valve has a big leakage. (Like open valve) It assumes that not heat source near the downstream area .The temperature and pressure upstream will have almost the same value of the source. (Figure No 10/11)

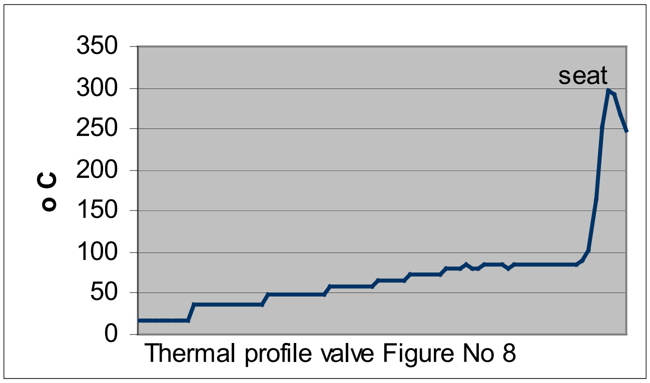
7- If there are doubts about the results of infrared test the ultrasound test should be carried out. It is up to each company to make the ultrasonic confirmation when the thermograms show that there is no leakage at all or there is leakage 100% confirm. If it is no necessary go back to 3.1 GENERAL GUIDELINES point No 17. If you have to do ultrasound, start in point 3.3 ULTRASOUND. (Below)

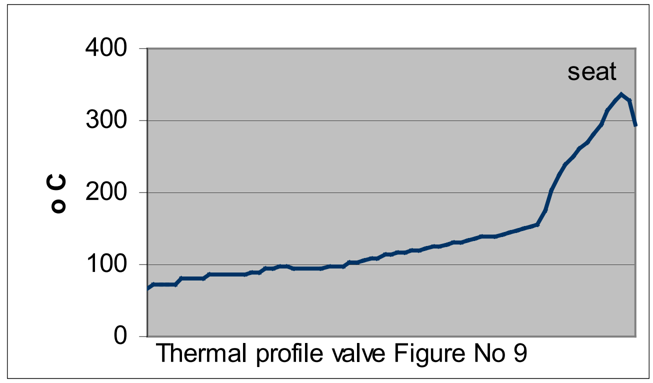
3.3 ULTRASOUND

1- In addition to the upstream and downstream insulation removal, request the maintenance personnel to drill in the insulation holes (if it is possible) of approximately no more than 1 inch at a range of 10-15 diameters (of the pipeline) of the valve downstream as well as upstream. The purpose is to hear the background noise that may be connected with the pipe in which the valve is placed. The module of contact should be placed in these holes in order to listen the ultrasounds and compare them with the corresponding sounds around the valve. Sometimes, it is not necessary to make holes since the sensor can be placed on any accessory and/or associated equipment having no insulation. We are trying to determine the noise level around the valve in fact that it has nothing to do with a possible leakage.
2- Verify with the ultrasonic equipment in three different locations upstream of the valve (with a separation of approximately 2 diameters from the pipeline). Check probable noise intensity variations as you approach the valve.
3- Check with the ultrasonic equipment in three points downstream of the valve. Check probable noise intensity variation as you move away from the valve.
4- Check probable noise variation between the sounds upstream and downstream.
5- Control the sounds in two or three points of the body of the valve. In case that the valve is very big check both sides of it.
6 -As alternative in order to could define with more precision the existence of leakage is use the next valve upstream or downstream that could be block the step of the fluid. (Difficult to do for operation reasons or not existence of valve) The blockade of the fluid upstream or downstream with a valve that has good closing will produce once established the balance of pressures the decrease and disappearance of the ultrasonic that generate the probable leakage. This blockade is also been worth for the infrared test. Only you may be need to wait for more time for the thermal stabilization in the zone of the valve with probable leakage. Then you can compare the information you get on your tests before the valve was block and after the block is made.
7- In all cases, at the moment of making the inspection uses an average frequency. Whenever possible the frequency should be changed. A low one (20-30 kHz) should be used for viscous fluids and a high frequency (40-60 kHz) for low viscosity fluids.
8- Compare the measurements results made in points 1 to 6. Any variation in ultrasound intensity (that has nothing to do with background noise) between upstream and downstream means lose in isolation.(leakage) also any variation upstream or downstream itself could means leakage. In all comparison measurements set the same sensivity for the pistol then you may see the change in ultrasound intensity as you move from one point to another. Make your conclusions. Go back to 3.1 GENERAL GUIDELINES point 17.

4- APPROACH TO PRACTICAL MEASUREMENTS

In all Figures from 8 to 25 (thermograms) below them show temperature spots and its values. Some of them show isotherms (light grey and dark grey) its level is indicating in right scale. Figures No 8 and 9 show two security relief valves. Both valves are working in lines that carry superheated steam at 550 ºC and 170 Kg/cm2.(Water at 170Kg/cm2 has saturation point at 350,7 ºC) Valve No 8 has no leak and valve No 9 has a leak. In valve No 8 we can see as temperature in the upper part of the valve, the temperature is originated by the transmission of heat by conduction from the valve seat upward and laterally. The discharge flange is practically at the temperature of the human body.

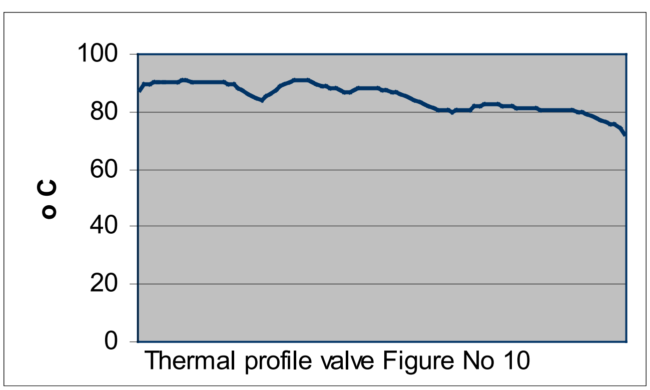


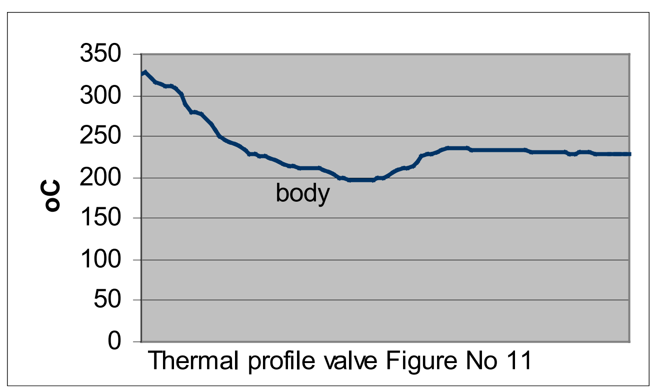


On the other hand, in the valve of figure No 9 we can see how irregular is the distribution of heat in the body. This is due to the fact that there is a leak somewhere in the valve that has a bearing on it. (This is joined to the heat that comes from the seat of the valve by conduction). Even the difference between both thermal profiles is the uniformity that can be seen in the thermogram of valve No 8 (only conduction waves from seat) with respect to No 9. Valve No 9 shows in the discharge flange a temperature of above 73 ºC and this is not normal at ambient temperature on the order of 20ºC of an outside placed valve. (Except that downstream there might be very near a hot body). With regard to the ultrasound made to both valves a high intensity of noise can be detected in the body and the discharge flange downstream originated by the lower pipe that carry-superheated steam at high speed. This produces a very noisy environment. We can detect differences downstream even though both valves are very noisy (background noise originated from main pipe two feet below).

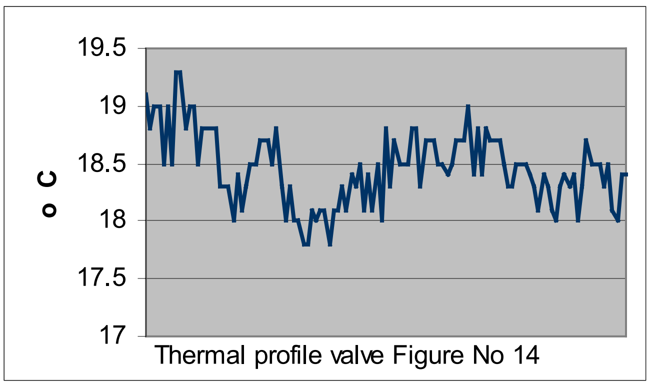
In figure No 10 we can see two drain valves of a small boiler. One of the valves has a very important leak and the other one has no leak at all. (The last one has no profile attached) We can clearly distinguish the valve that has no leak since the steam has been condensed because there is no fluid flow. The indications of the ultrasound are strong in point 1 as well as in point 2. Point four is very quiet, that is to say, the background noise originated in its near valve has little influence.

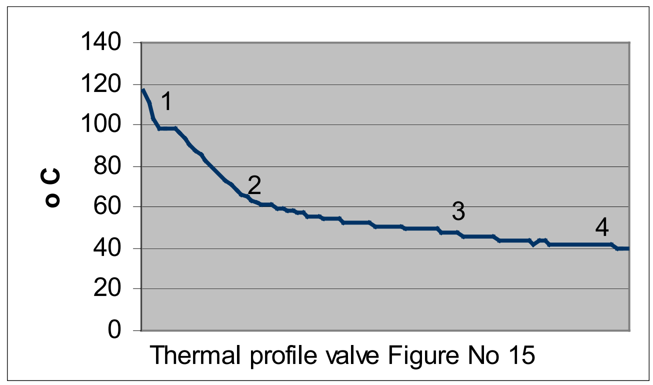
Figure No 11 shows us a superheated steam drain valve at 540 oC/120 Kg/cm2. (Saturation point at 120 kg/cm2 is 323.15 ºC) That valve has a very important leak. The drop of temperature between upstream and downstream is not substantial. Point 2 is colder due to the great amount of metallic bulk of the body of the valve. (Thermal profile shaped valley valve figure No 11). Ultrasound indications for the upstream can consider of high severity and the same thing for downstream. (High flows activity)



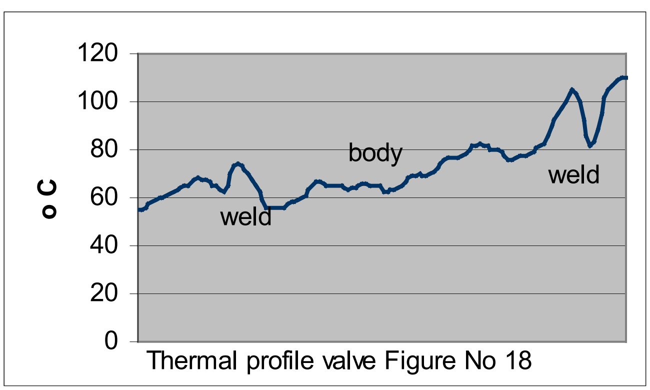


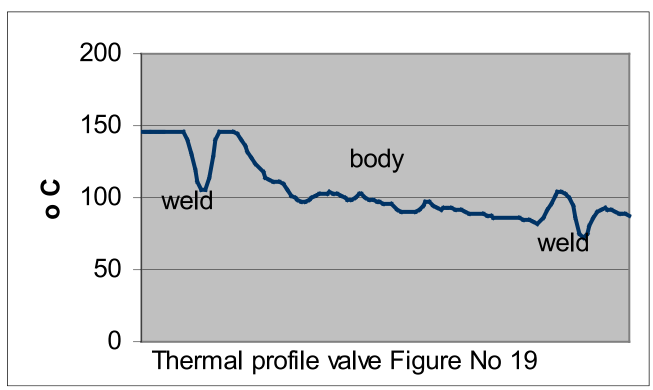
Figures No 12 and 13 show us the same panel of valves corresponding to condensed drainage of a boiler at 240-oC/180 kg/cm2 (saturation point at 180 kg/cm2 is 355.35 ºC) of a Power Plant (6 lines with 2 two valves per line). The thermogram of figure No12 corresponds to the test made before the pre-outage inspection and the thermogram of figure No 13 is the same panel after the valves has been repaired and the boiler is running again. Both thermograms were made with the boiler at the same load and under similar environmental conditions. The ultrasound test made on the panel before the reparation shows in general few differences between one pipe and the other one (some differences existed). Usually, the noise was produced by the flashing of condensed steam on the lower main pipe. The ultrasound test made on the repaired panel shows us the lack of flashing. Certain noises could be heard that I might ascribe them to the probable friction between the pipe and its free support.
In figure No 14 we see another steam drain valve. This is a very clear example of a good valve (isolated). There is no flow of fluid, which with the help of the surrounding environmental conditions and the lack of insulation in the pipe, the steam is condensed and presents upstream and downstream a cold log. The ultrasound test made downstream as well as upstream has no sign of noise. This is helped by the lack of background noise in the place of the valve analyzed.





The valve of the figure 15 is a valve with high uniformity profile upstream that it is sign of isolated valve. The thermal profile as you move downstream is quite good but we understand that the temperature after the second weld should be lower in case of no leakage. (Only thermal conductivity) The indications of ultrasound were practically nonexistence. So the leakage could be intermittent that is to say small drops from time to time. (We do not have the temperature and pressure of line work but is a drain valve working in a system of superheated steam)





Figures No 16 and 17 are shown as to see the difference between the thermogram of a valve with the thermal insulation (on pipe) undismounted and the other thermogram with a valve with dismounted thermal insulation. In both cases, the valves have a leak but the valve without thermal insulation covering the pipe provides us more information for the infrared test. (It is important that in both case the valve itself has any insulation)

Figures No 18 and 19 show two twins drain valves (water), but they have different severity of leak. Both valves perform the same function and they are drain valve of a systems working under the same pressure and temperature. (200 oC/125 kg/cm2 saturation point⇒ 326 ºC) As we can see, valve No 19 has the poorest performance in his thermal profile. The ultrasound test confirms what can be observed in the thermogram. (Valve No 19 has a serious situation as regards the ultrasound severity). Whereas coincident with the thermogram, valve No 18 has a situation in the ultrasound severity of inferior importance almost negligible. (Smaller mass flow) The comparison between both valves helps us to define the situation. (The welds generate valleys in thermal profile because its lower emissivity and higher thickness)

From figure No 20 to figure No 25 we see a leak simulation carried out at a laboratory. (Saturated steam) In the thermograms we have 3 (three) lines. The first line on the left was opened by the workingmen approximately 20 minutes before the moment of making the thermograpy of figure No 20. The other two lines were opened and closed long ago (average 24 hs) and as we can see on these two lines, the saturated steam has been largely condensed. From figure No 21 (2:33 PM), we opened slightly the valve (arrow checkmark in figure No20) from the central line (pretending in this way a leak) and we got the sequence up to figure No 25 (2:41 PM). In figure No 25 the thermogram shows us that the replacement of fluid in line (ϕ ¾ ¨- h: 60cm) has practically been made and therefore the thermogram is completely different in relation thermogram Figure No20 (no leakage). The ultrasonic signal in the situation of Figure No 20 gives us no indication in the valve with arrow checkmark. As we open the valve (only drops water) you hear upstream and downstream the flashing of saturated steam that after the transposition of valve body is converted in condensed water at atmospheric pressure. This leak simulation indicates that in many cases when you have isolate valve you get ambient temperature upstream downstream (figure No20) and when is flow running through the valve the temperature upstream changes dramatically. (Flow activity)

The equipment that have been used to perform these test are:

For infrared test: Agema 470 - 2-5 µm with Irwin 2.02 software in rainbow color scale

For ultrasonic test: UE system Ultraprobe 2000 ultrasonic instrument 20 KHz- 100KHz. Hand held pistol with contact module. (Rod/probe)

5-CONCLUSIONS

The passive test of infrared thermography transforms the radiation visible, which is invisible to the human eyes, and it gives us a thermal map of the valve/pipe. The passive ultrasound test transforms no audible sounds into sounds that can be heard by human ears. The increase in the human sensorial capacity that these technologies give us has an extraordinary advantage over a predictive maintenance program. The information available that we obtain with the use of a standard viewing examination and the sounds heard by our ears is considerably increased with the use of these technologies. So this increase of information makes that the decision taken by the sector be more precise and taken on time with the consequent decrease of costs and the improvement of the safety conditions of the installation. Although no test is conclusive or absolute, the use of these technologies in particular to a valve that shows in advance a loss to the operation personnel is accurate and the information that can be obtained from this examination may be expedient for the organization. It would even be more expedient to establish a valve verification program (pre-outage inspection) before the programmed annual shut down in which a list of valves may be determined and to apply a reparation basis according to the importance, the function performed and the costs associated with its loss. The fact to establish a program using infrared and ultrasound (predictive maintenance) involve the advantage of repairing valves in bad operating conditions (detected in advance) and also not to disassemble unnecessarily those valves (preventive maintenance), which are working in acceptable conditions.

6-ACKNOWLEDGEMENTS

Central Costanera sa Buenos Aires - Argentina **(** Lerin - Traiber - Farinola - Esposito)
Spirax Sarco Argentina sa Buenos Aires - Argentina (Grandi - Miguez)
UE Systems Elmsford - New York - U.S.A **(Goodman**)
Domenech Jorge Campana - Argentina

7 -REFERENCES

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PECO Energy company (Predictive Maintenance Report- Rich Wurzbach)
Elementos de Ingeniería Química (Vian-Ocón)
Ingeniería Acústica (Manuel Recuero)
Curso de Termodinámica(Facorro Ruiz)
Nondestructive evaluation of materials by infrared Thermography (Xavier Maldague)
Practical Applications of infrared Thermal Sensing and Imaging Equipment (Herbert Kaplan)
Infrared Techniques for Identification and Quantification of Valve Leakage (Steve W. Leath)
Ultrasonic leak detection cuts valve maintenance cost (Joseph Dimmick - John Cobb)

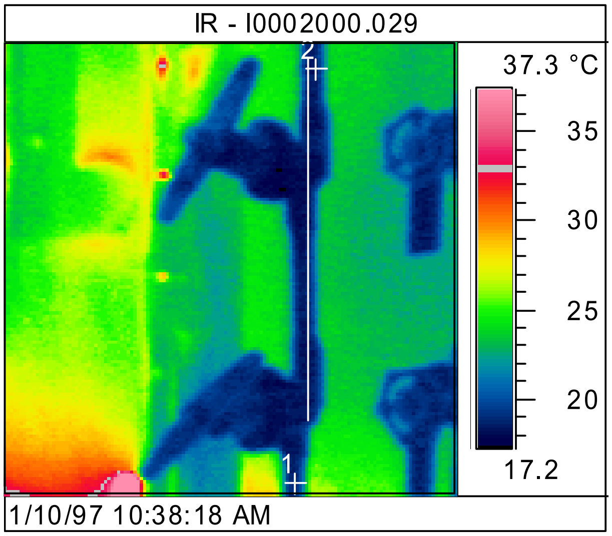
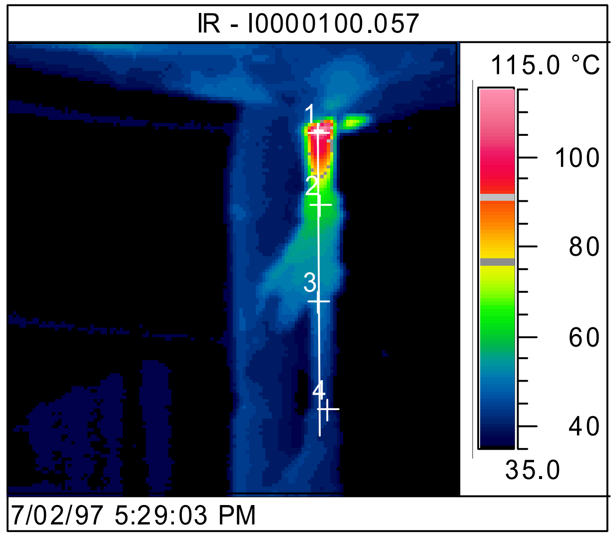


Figure No 14
1: 19 **2:** 19 **3: --- 4: --- 5: --- oC**



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1: 110 **2:** 61 **3:** 51 **4:** 40 **5:---oC**

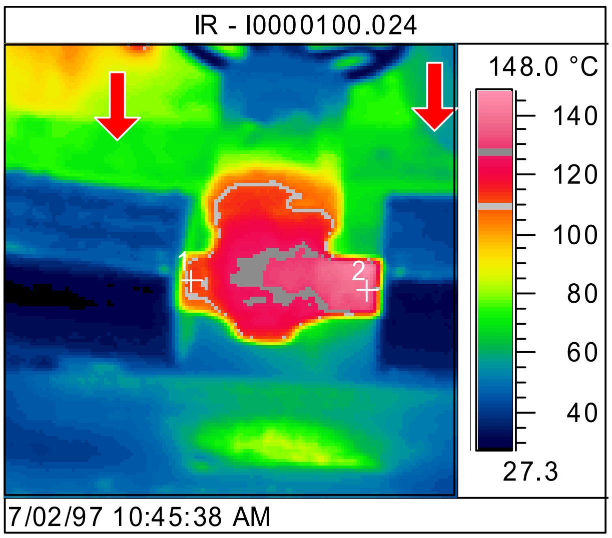
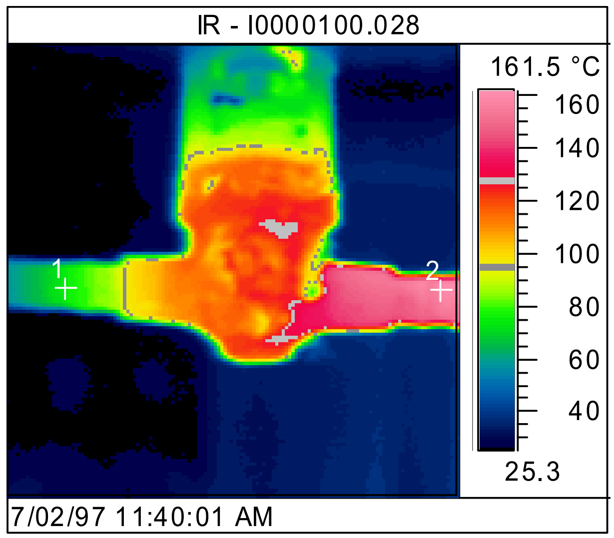


Figure No 17
1:113 **2:**139 **3:--- 4:--- 5:--- oC**



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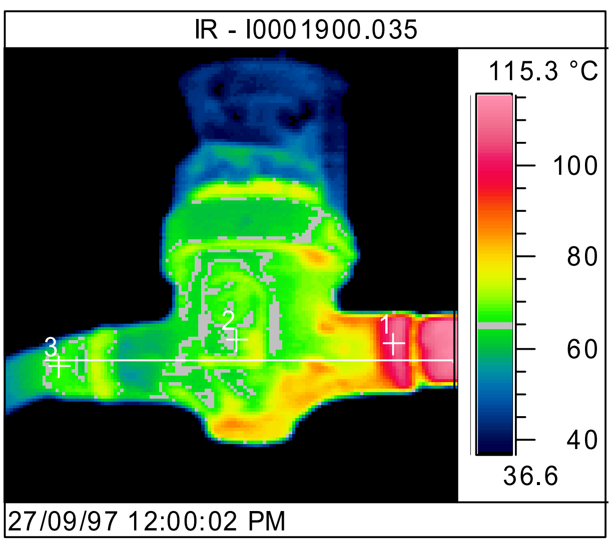

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1:107 **2:** 67 **3:** 69 **4: --- 5:--- oC**

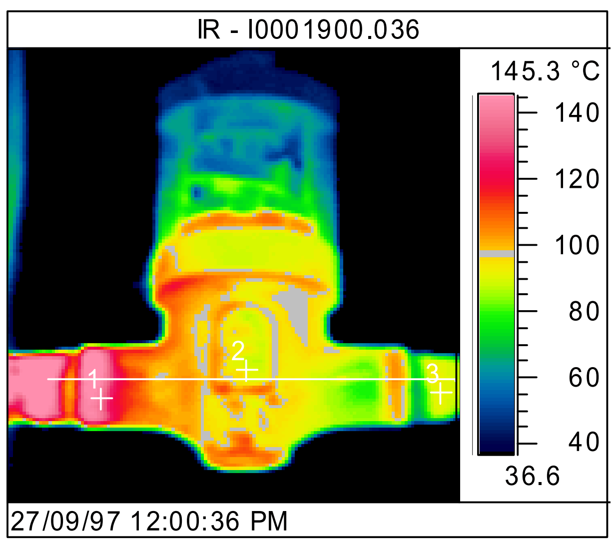

Figure No 19
1: 138 **2:** 90 **3:** 91 **4: --- 5:--- oC**

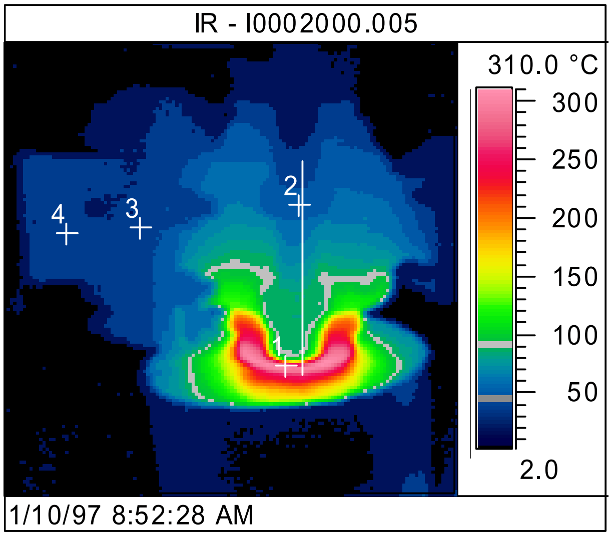

Figure No 8

1: 300 **2:** 49 **3:** 36 **4:** 36 **5:** --- **oC**

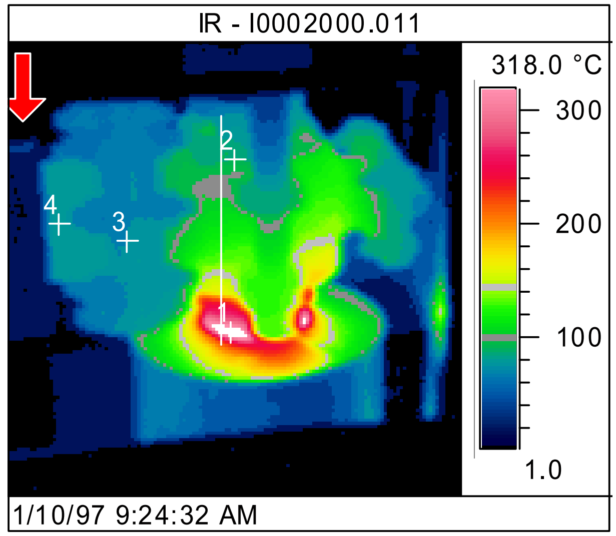

Figure No 9

1: 320 **2:** 90 **3:** 73 **4:** 80 **5:--- oC**

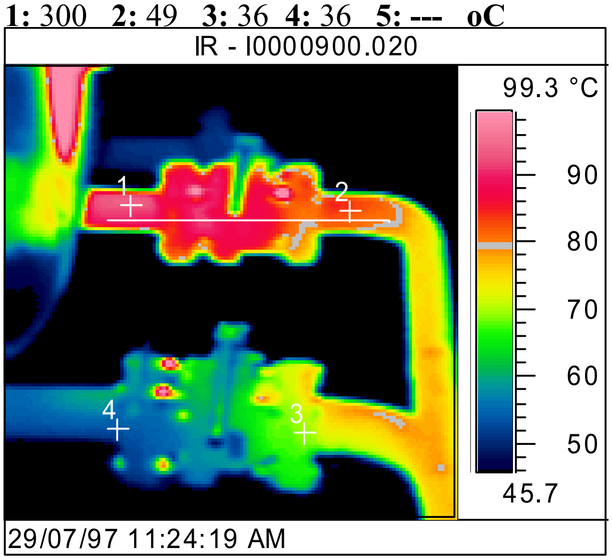

Figure No 10

1: 99 **2:** 88 **3:** 69 **4:** 46 **5:--- oC**

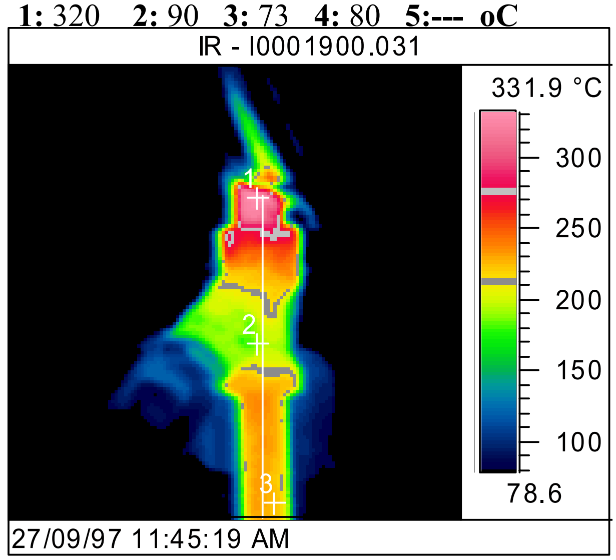

Figure No 11

1: 331 **2:** 190 **3:** 225 **4:--- 5:--- oC**

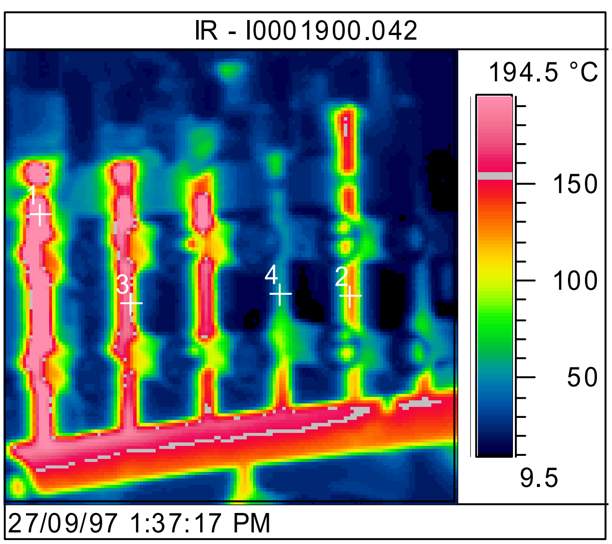

Figure No 12

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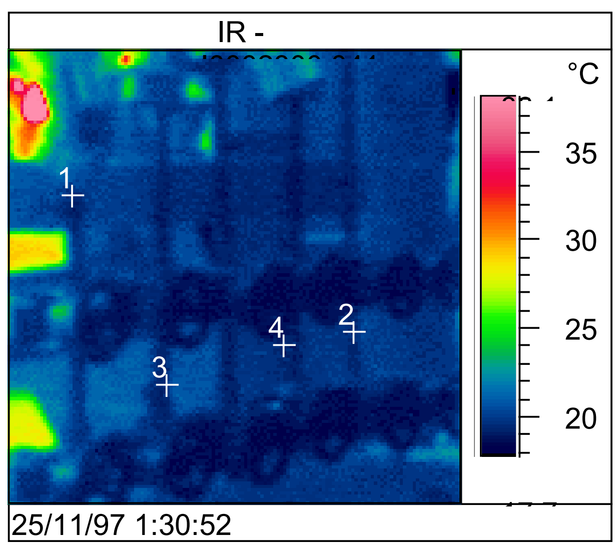

Figure No 13

1: 19 **2:** 19 **3:** 19 **4 :** 19 **5: --- oC**

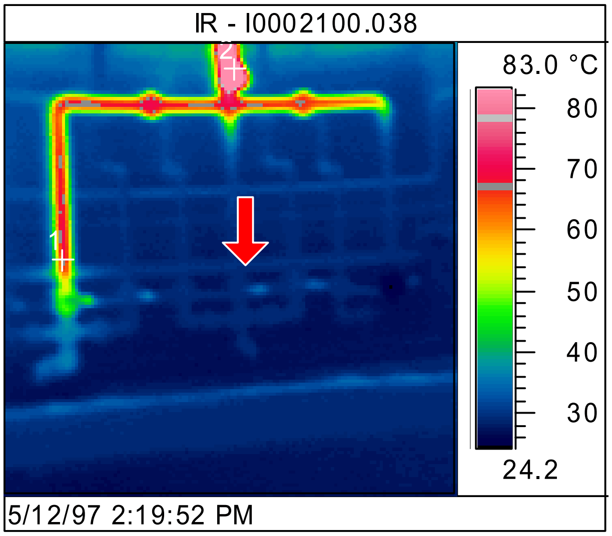

Figure No 20

1: 67 **2:** 85 **3:**--- **4:**--- **5:** --- **oC**

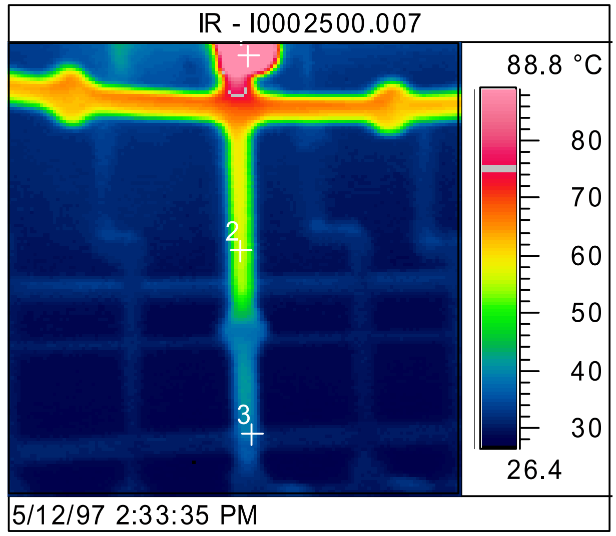

Figure No 21

1: 88 **2:** 56 **3:** 37 **4:** --- **5:** --- **oC**

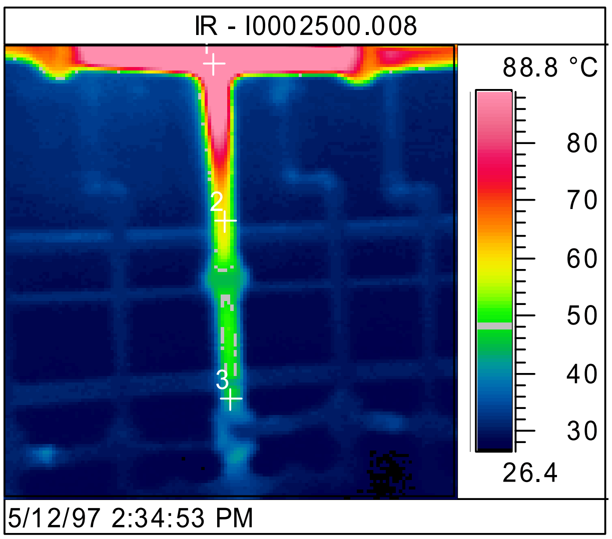

Figure No 22

1: 88 **2:** 59 **3:** 45 **4:**--- **5:**--- **oC**

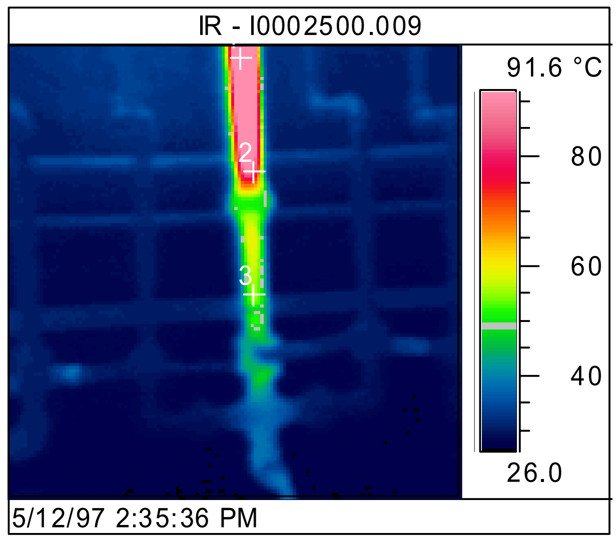

Figure No 23

1: 91 **2:** 80 **3:** 55 **4:** **5:** **oC**

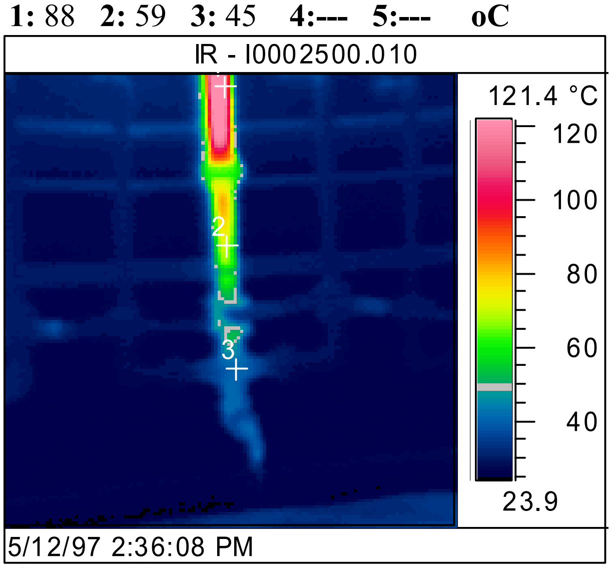

Figure No 24

1: 117 **2:** 68 **3:** 40 **4:** --- **5:**--- **oC**

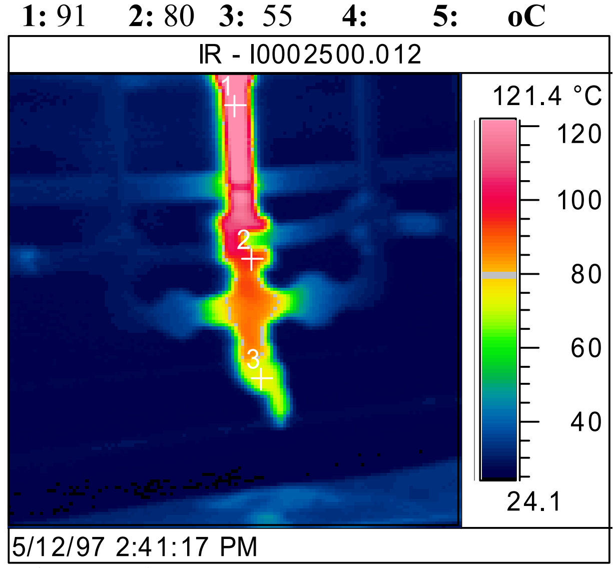

Figure No 25

1: 121 **2:** 96 **3:** 75 **4:** --- **5:**--- **oC**