Water Leaks Detecting by Termographic Image Analysis, In Laboratory Tests

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Abstract: One of the most undesirable failures is water losses due to leaks in the supplying system; there are mainly two types of water losses: the visible and the non-visible. Within the non-visible we have those that are detectable by acoustic methods and those that are not. Here we decide to study new techniques for leak detection, since leaks non-visible are more difficult to find (detect). This is the aim of this paper. In a previous stage we have been studying the possibility of obtaining thermographic images to develop visualization techniques on pipes as an option for leak detection. Analyzing this possibility, with previous studies we have established conditions for taking images for later analysis, which has confirmed the benefits of the use of thermography as a tool. Here we present a case study where images were taken in a controlled atmosphere in a laboratory, using a physical model that contained a buried pipe with a simulated loss of water. During the entire duration of the test, images were taken at a certain interval of time and afterwards the images where analyzed. The results show the benefits and limitations of the technique, which should continue to be studied since thermal imaging cameras and computers to process the images are day by day more powerful and accessible.

Keywords: water distribution systems; water leaks; lab tests; Thermograpic image analysis

1. Introduction

Thermography has shown to provide significant applications in various fields, such as medicine [11], engineering, industry and so on [8]. The laboratory tests have shown too, the benefits of knowing results of real data tested. Thermal cameras enable to investigate some elements invisible to a simple eye at lower cost, when compared with other current non-destructive methods [1]. Trying to identify water leaks in pipes by the use of non-destructive methods is a challenging task for utility companies, such a water supply systems. Thermographic images may produce rich information, which unfortunately, is not always visible [2], several factors can affect the visualization in infrared images, which can't improve contrast in infrared images, such as weather, humidity, wind or elements with (high or low) unusual temperature; also with an untrained eye it might be difficult to ensure whether something happens in the image. The aim of this paper is to discuss the benefits of lab test with thermographic images as non-destructive method. Thermography can be a good ally in non-destructive methods application: it has shown be useful, efficient and cheaper than others but mean make some inversions on this kind of projects.

2. Results processing images

In general, it can be deduced that: at a higher environmental temperature, the images become saturated and the visualization is poorer. More particularly, the non-variant conditions on the images as those taken on the model in a controlled laboratory conditions that generated a uniform temperature atmosphere, it can be seeing in the images where the heat transfer has less changes. Of course this does not allow to work accurately by skewing the expected results.

It happens as shown in appendix A, that under controlled environment as the test Mr-4; for some processes the results are quite good, but in test Mrf-2, the results weren't enough because it was not possible to observe the pipe, just the developed leak. It must be noticed that it was necessary at least a month to prepare another test, affecting the possibility of additional tests.

3. Discussion

3.1. Thermography as a NDT

The thermography has a facility to capture big areas without contact [5]. It works by thermal difference and for this reason we choose it for our purposes. It has three levels of measurement: relativity, differential and absolute; also it has two principal kinds passive and active. It is a multifaceted technique for evaluation as examples: QIT (Quantitative Infrared Thermography), END (Evaluation No Destructive) or NETD (Noise Equivalent Temperature Difference), among others; QIT and END were used as part of our tests in the processes.

As an NDT, the technique has advantages and disadvantages. Nevertheless, given that its positive aspects exceed its negatives and its qualities we decide to use it an NDT tool [3] for leak detection. It can be used the IR images (.jpg) with RGB scale or Grayscale and the thermograms that contain a temperature data per pixel in the image (matrix format) a lot of valuable information; both were used on the different processes on our tests.

4. Materials and Methods

4.1. Laboratory model (case of study)

The knowledge about the WDS sometimes is limited, because of different changes in the net, sectorization, data in the net that has not been actualized, among others. When a leak appears the time to detect it plays an important role [13]; as fast as it is detected, less water is loosed. Working with IR images as a non-invasive method, is a tool that save time and money, working just with the images taken that isolate zones to study a part of the pipe. To prove this hypothesis, it was necessary to divide the work with the physical model in different tests [9, 10].

The physical model is a simple box, with dimensions 100x100x70 cms, filled with earth material similar to the filler, that let us to imitate the working conditions of a pipe in a WDS. Two conditions were simulated: (1) a gravity condition and (2) a pressure condition with a closed re-circulating water circuit, both first working without leak and after with leak. Notice that the second condition was the most representative for the aim of this paper. For this reason, just the results for the second experiment are shown.

Figure 1. The laboratory model working with the Thermographic camera.

4.2. Quality image taken and its variables for leak analysis detection

We work with the camera FLIR series 600, model FLIR sc620. In fact we were working with the camera since few years ago, on different tests made with different aims; those are shown on the table 1. After those tests, the model was defined and projected; eleven tests were designed for this. Once the model was prepared to work, the camera was placed following all the specifications for quality images, always at the same distance of the model. The time between images was the minimum (10 sec), the climate variables were compilated (day temperature, humidity, wind) [6], the resolution of the images chosen was 640 x 480 pixels, a size adequate for being not too big and to conserve enough analysis data. The data base created for climate variables with k-nime software was considered. Just the 10% of the images where analyzed in order to improve the process.

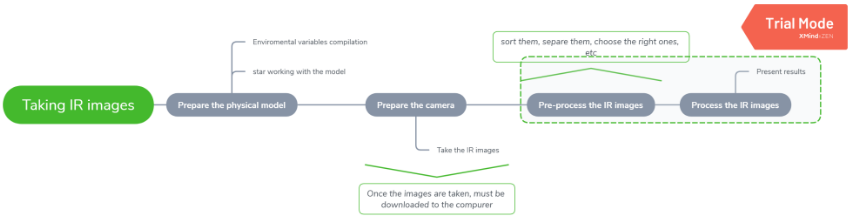


Figure 2. Process followed for taking images on the laboratory model.

Table 1. All the tests done during the investigation.

ID	Images taken	Date (day/month/year)	Study place	Objetive
T-1	18	15/10/2013	Diferent places in the UPV	Camera control
St-3	59	01/10/2014 a 17/02/2014	Site 3 previosly chosen	Identify buried structure
St-4	52	10/01/2014	Site 4 previosly chosen	Identify buried structure
St-2	672	18/10/2013 a 17/02/2014	Site 2 previosly chosen	Identify buried structure
Exp-1	8	17/01/2014	Esplanade UPV	Identify buried structure
Mg-1	24	02/07/2015	Laboratory model: Gravity pipe	Identify buried structure
Mp-1	24	16/07/2015	Laboratory model: buried thermic objects	Determinate the buried pipe colocation distance
Mgf-1	98	07/10/2015	Laboratory model: Gravity pipe with leak	Identify buried structure and leak
Mgf-2	10	08/10/2015	Laboratory model: Gravity pipe, day after	Identify buried structure and leak
Mr-1	51	13/06/2016	Laboratory model: Recirculating pipe, cover surface	Variables study
Mr-2	39	30/06/2016	Laboratory model: Recirculating pipe	Visualize behavior
Mr-3	83	03/08/2016	Laboratory model: Recirculating pipe, termic contrast	Variables study
Mr-4	25	04/08/2016	Laboratory model: Recirculating pipe	Visualize behavior
Mr-4	60	16/08/2016	Laboratory model: Recirculating pipe, termic contrast	Visualize behavior
Mrf-1	15	23/09/2016	Laboratory model: Recirculating pipe with leak	Identify buried structure and leak
Mrf-2	15	10/09/2016	Laboratory model: Recirculating pipe with leak	Identify buried structure and leak

Table 1 shows all the tests made before to work with the laboratory model, observe that many tests were made for the model. In the appendix A, are presented the results of the representative tests for the aim of this paper.

4.3. Image processing.

The aim of the IR processing is the leak visualization [12]; because of this the technician must be the same when processing all the images in order that the criteria do not change. In the IR images were considerate the processes: Visualization, Segmentation, Binarization, Otsu's method and thresholds. For the IR thermograms were used the Flir software and MATLAB algorithms, one of them works choosing a point with a representative temperature and compare it with the medium temperature of the annual historic data base (from year 2012 to 2016) to delimitate the zone where structure lays.

5. Conclusions

The thermography offers a great possibility as NDT, but it is still being developed. With a potential growing by the years to come, it will turn a more powerful tool for NDT techniques in different fields or with different objectives, as fire detection Urban-forest interface [4].

Thermography is a polyvalent tool with a lot of advantages: it can be practical, cheap and useful; it might be not a 100% perfect technique, sure technique, but it can be complemented with others.

The image analysis is subjective with a lot of elements that must be continuously considered. Regarding the camera: focus, tuning variables, distance of the study object. About the place in study: clime, wind, humidity, choose the place and the stuff on it, improve the visualization, etc. Taking clear and well oriented images is of the utmost importance, equipment and structures to place the camera would be useful to get better images on the study area

Working with environmental variables let us to isolate a periodic phenomenon to assist on zone determination using IR images but it happens too that in developed leaks is harder its application due to the thermal equilibrium of the materials. It is necessary to invest more time and resources on this kind of projects, due the leak developed on Mrf-2, found necessary to get the relation between the time getting images and the time of leak developed, to get more info about this. To avoid errors about IR interpretation the capacitation is really benefic in order to identify all the valuable information in the image. This means that the person involved on this kind of process should take periodic training and must manage the camera on regular basis.

Thermography is a punctual tool: it must be used in the moment in a specific place. For this reason it still needs be used with other techniques, to solve problems and give us options for leak detection. It is necessary to continue working with models, or use complementary alternatives as machine learning.

Abbreviations

The following abbreviations are used in this manuscript:

NDT: Non Destructive Test
WDS: Water Distribution Systems
IR: Infrared
QIT: Quantitative Infrared Thermography
END: Evaluation No Destructive
NETD: Noise Equivalent Temperature Difference

Appendix A

Test ID: Mr-4

Description: The water was on recirculation until stabilization.

Date: August 17th, 2016; autumn.

Time: 13:17 hrs.

Environmental temperature: 29.1°C.

Umbral: 105

Notes: The pipe is able to observe once the image has been processed. The Otsu's method can't isolate the pipe region. The rest of the processes can isolate the studies' zones and delimitate the contour of the pipe. The pipe has not leak.

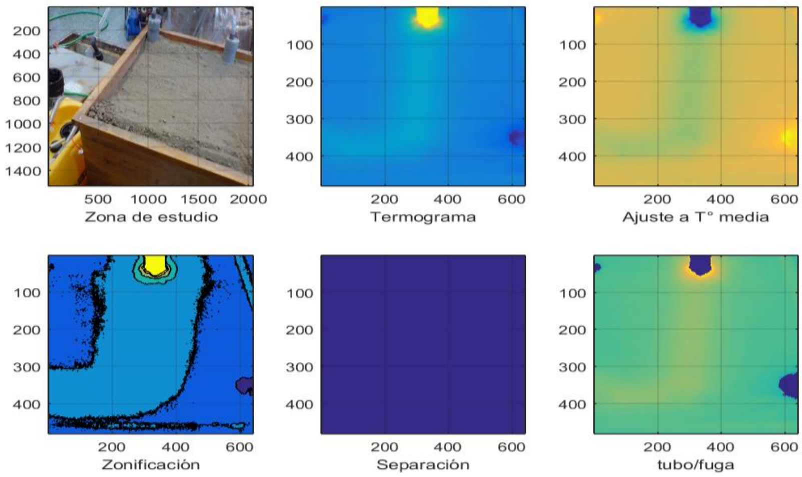
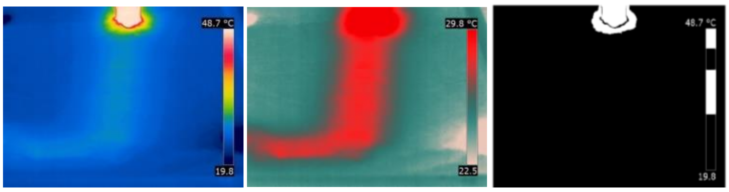


Figure 3. Termogram results with MATLAB algorithms. Test ID: Mr-4.



(a) (b) (c)

Figure 4. Image result as QIR in (a) processed with FLIR software (Greyred scale) in (b), and the result of the Otsu's method in (c). Test ID: Mr-4**.**

Figure 5. Image results with Binarization process. Test ID: Mr-4.

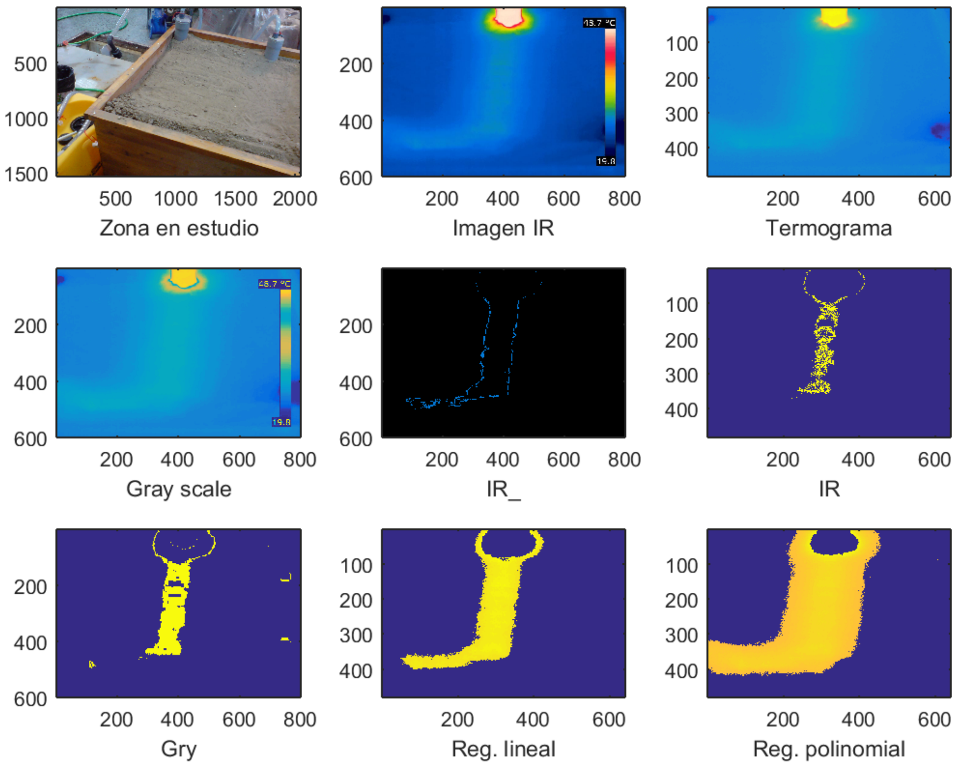


Figure 6. Image results with MATLAB algorithms. Test ID: Mr-4.

Test ID: Mrf-2

Description: The water was on recirculation, the pipe star working with a leak.

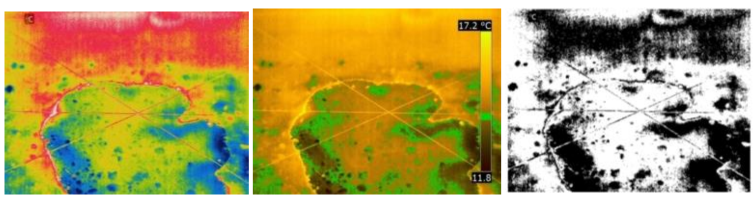
Date: September 10th, 2016; autumn.

Time: 11:55 hrs.

Environmental temperature: 27.2°C.

Umbral: 45.

Notes: The visual inspection shows clearly the contour of the leak. On this test was notice that the time of leak developed was faster that the take of the image, For the size of the model and the pressure of the leak is necessary a more potent infrared camera. Due the imidiatly leak developed was not possible to get more information, just the contours of the change of temperature of the water and the material were the pipa lays. The processes were very different; however the isolate of the study zone can be appreciated very well.



(a) (b) (c)

Figure 7. Image result as QIR in (a) processed with FLIR software (Yellow scale) in (b), and the result of the Otsu's method in (c). Test ID: Mrf-2.

Figure 8. Image results with Binarization process. Test ID: Mrf-2.

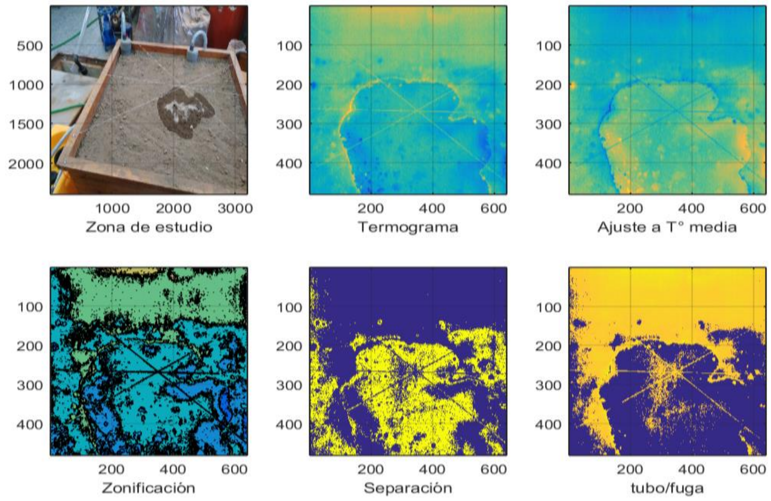


Figure 9. Termogram results with MATLAB algorithms. Test ID: Mr-4.

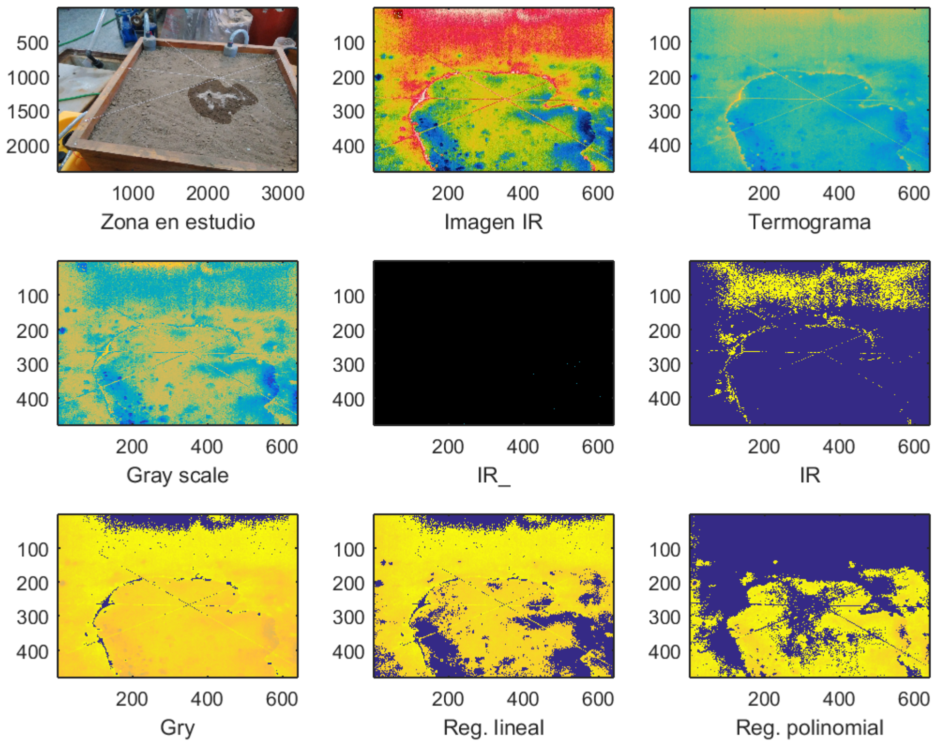


Figure 10. Image results with MATLAB algorithms. Test ID: Mrf-2.

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