STUDY OF A PIPE INNER CONDITIONS USING A THERMOGRAPHIC METHOD

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ABSTRACT

Pipeline inspection has been more significant in industries as the safety of the pipeline system has been a very crucial aspect that needs an extra precaution. There is a few records of accidents occurred that are cause by the failure of the pipeline system. It has been proves that a regular inspection is a crucial activity in industrial practice. Thermography is one of the Non Destructive Testing (NDT) method used to carry out the inspection over a system or specimen. Thermography inspection is consider as one of the versatile NDT because the inspection is carry out without damaging the physical properties, function, and the quality of the inspected part. This work presents experimental works on studying the effectiveness of the thermography method in accessing the internal conditions of the pipe components.

ABSTRAK

Pemeriksaan saluran paip merupakan perkara penting dalam industri-industri oleh kerana keselamatan sistem saluran paip menjadi satu aspek pencegahan tambahan yang sangat yang penting. Ada beberapa rekod kemalangan yang berlaku berpunca dari kegagalan sistem saluran paip. Ia telah membuktikan bahawa satu pemeriksaan berkala adalah satu kegiatan penting yang diamalkan dalam industri. Thermografi ialah salah satu kaedah Ujian Tanpa Musnah (NDT) yang digunakan bagi menjalankan pemeriksaan ke atas sesuatu sistem atau spesimen. Pemeriksaan thermografi mempertimbangkan sebagai salah satu kaedah NDT ampuh kerana pemeriksaan melaksanakan tanpa merosakkan sifat fizikal, fungsi, dan kualiti bahagian diperiksa. Kerja ini membentangkan keberkesanan kaedah termografi dalam mengakses keadaan dalaman komponen-komponen paip melalui kajian kerja eksperimen.

Keywords: NDT, pipe line inspection, thermography

INTRODUCTION

In processing plants, power plants, drilling platforms and other engineering facilities, the safety of the working place is much depending on the reliability of the structure and the operating parameters of the systems. In general the facilities in oil and gas and power plant industries are mostly affiliated with the piping system which are designed to transport the liquid, powder and gas materials such as fossil fuels, and steam. In order to ensure the safety of the working area, a lot of safety precautions are in dealing with the piping system and it is most crucial issues in power plant or oil & gas platform. Piping system is the key consideration for safety and reliability of an operation in most processing facilities. It is therefore important to monitor such components. For piping inspection there is a lot of method has been develop ever since the development of non-destructive testing method. The method is range from ultrasonic, radiography, visual optical, eddy current, liquid penetrant, magnetic particle, and infrared thermography. Thermography is one of the Non Destructive Testing (NDT) method used to carry out the inspection over a system or specimen. Thermography inspection is consider as one of the Non Destructive Testing method because the inspection is carry out without damaging the physical properties, function, and the quality of the inspected part. Thermography is a study of temperature profile of a surface or point. Infrared thermography (IRT) was at first an invention for military applications. However, due to the rapid development of thermal cameras since the 1970s, this technology has been increasingly used in civilian areas (Schlichting et al., 2012). In recent year thermography method has been widely applied in many Engineering applications especially for inspection purpose. Thermography has several advantages, such as non-contact inspection and detection capability of subsurface failure and thus it has been widely applied for non-destructive testing (An et al., 2012; Duan et al., 2013).

The aim of this study is to establish the method of an inspection of an internal surface condition of a pipe by using a thermographic method.

MATERIALS AND METHOD

Material and Specimen Fabrication

For this experiment the material used is galvanized steel. Galvanized steel is belong in the steel categories which are well known for its reliability in manufacturing. Apart from that steel are also widely used in power plant and drilled platform facilities in Malaysia. It has been a very common material applied in many engineering design especially in automotive where most of the stock production car are using steel as the material used in designing the chassis body. Galvanized steel is coated steel which are design to prevent the corrosion. It is also widely use in water transportation. Table 1 shows some important properties of the material.

Specimens were fabricated from a pipe which cut into 4 pieces and having a length of 5 cm each piece. The specimen undergoes four stages of cutting process in order to create and artificial defect to represent the actual defect in the real application. The defect made is a drilled hole, welded defect, and a line defect. For the drilled hole there are 3 different sizes of holes with different depth. And for the line defect the cutting process is done only at both end of the tube pipe. All of these defects are produce inside the tube pipe to represent the subsurface defect. There are 3 types of artificial discontinuities made for each specimen tube, namely, hole, welded slug and straight line. Figure 1, 2 and 3 show the finished specimen.

Table 1: Mechanical Properties of low carbon steel (Gustavsson et al., 1994; Usamentiaga et al., 2013)

Properties	Measured Value
Melting point	788°F
Density	7.86 kg/m^3 at 20°C
Thermal expansion coefficient	11.7 per °K
Thermal conductivity	50W/(m.K)
Tensile Strength	350 MN/m
Modulus of elasticity	210Gpa
Modulus of rigidity	44Gpa
Emissivity	0.28 at 38°C

The holes are drilled with a same depth but with different diameter. During the process there is a slight different in depth even though the depth is set to be identical. It is a tough process to make the hole with a different depth as the thickness of the steel tube is too small. The objective of this discontinuities represent in a holes form is to observe the thermal behaviour of the material with a different size of discontinuities. Slug is made by using the arc welding equipment. The slug represents some kind of scaling discontinuities which are very common type of discontinuities found in the pipeline. Scaling is a defect form by the build-up of material flowing along with the liquid in the pipe where the thickness of the pipe is increasing and thus increasing the resistance to the liquid flow. There is no significant of existing discontinuities is presented by this artificial defect. But the line is purposely made with a different depth between these two discontinuities at the both end of the tube. The width of the discontinuities is identical but the depth is totally different. The objective of this discontinuities made is to observe the thermal behaviour of the material with a different defect depth.

Figure 1: Holes discontinuities.

Figure 2: Steel tube for welded slug and straight line discontinuities.

Figure 3: Welded slag discontinuities.

Experimental Setup

The method used for this project is Pulse Active Thermography where the principles behind this method is using an external heat sources to stimulate the heat onto the tested specimen in order to study the thermal anomaly presented in the infrared camera. This method had been used gloriously for a years in NDT practices. This method is chose by considering all the potential advantages offered by which this method is able to be used to examine the subsurface defect exist in the tested specimen where it is complying the requirement of this project of studying the pipe inner condition using thermography method. Apart from that it is a non-contact, reliable, fast procedure, and no dismantling of the tested specimen is needed. Also, active thermography is a clean and non-intrusive technology, which has been proven successful for non-destructive testing (Gustavsson et al., 1994). The propagation of heat depends on many material properties, such as thermal conductivity or density, but also on subsurface anomalies which result in temperature differences on the surface target (Xavier, 1993). As for addition there is much other alternative method to stimulate the heat. Most of which can be classified as optical, mechanical or inductive (Gustavsson et al., 1994).

Heat Source Use

In choosing the type of heat source the specification is need to satisfy the power requirement for heating up the specimen. It has been a significant step to be taken in choosing the heat source with a certain specification as every type of material having its own power requirement of the heat source in order to heat up the specimen. For this project the material used is galvanized steel so the power required to heat up this specimen should be sufficient to heat up this type of material. The power output of the heat source is considered as changing variable where the amount of power able to be change for a certain type of result desire. For this experiment the amount of heat source power is keep constant with 300watt. If the power is not sufficient enough to heat up the specimen the distant of the spotlight and the tested specimen should be reduce. The heat source specification is as follows (see Figure 4):

1) Power: 300 Watt
2) Model: self-fabricated

3) Heat source: Halogen lamp
4) Stand holder: clip

Infrared camera

The camera used in this work is A40 FLIR Infrared camera. The camera is use to capture the image of the heated specimen. The camera is equipped with the tripod and a connecting cable for the laptop. Figure 5 shows the camera.

Figure 4: Heat source used.

Figure 5: A40 FLIR infrared camera

Figure 6: Stand holder and clip.

Figure 7: Image acquisition computer.

Figure 8: Halogen lamp fabricated with bracket.

Figure 9: Thermocouple (K –type) reader for the surface temperature measurement.

The setting of the camera need to be calibrate to a suitable setting accordingly. It comprises of the following:

i. Stand holder and clip : to hold specimen, see Figure 6.
ii. Laptop : to acquire image from infrared camera, see Figure 7.
iii. Halogen lamp with bracket: to heat up the pipe, see Figure 8.
iv. Thermocouple (K –type): to measure the surface temperature, see Figure 9.

Experiment procedure

The procedure of the infrared image acquisition is the following, see Figure 10.

i. Generate a thermal transient on the surface of the pipe by using the halogen lamp, see Figure 11. The distance of the halogen lamp and the tested specimen is 5 cm.
ii. Observe the temperature distribution of the specimen with the IR camera and note abnormal temperature patterns resulted from the increasing of surface temperature. Note that the temperature profile having a different thermal contrast for different thickness.
iii. Image processing and data acquisition.
iv. Image interpretation and analysis.

Figure 10: Experiment arrangement.

Figure 11: Heating up specimen

RESULTS AND DISCUSSION

Holes

In the image the point of defect is denoted by point A. The heat source is already in operation. The temperature of the defect is detected to be 24°C from the software. The surrounding area of the defect shows a darker contrast where the thickness of the surrounding part is in original thickness. Logically the colour tone should be identical for the whole pipe but for this image the pipe has experience a temperature increase. The objective of this experiment is to observe the change in thermal contrast in parallel with the increasing temperature. Figure 12 to Figure 20 show the response of the specimens after exposing them to various times of a heating exposure. As the exposure times increased, the rate of temperature change is rapidly increased during the first one minute and slowly increased after that.

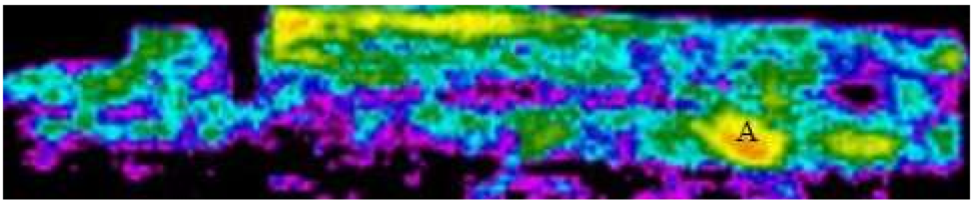

Figure 12: Thermogram after heating exposure (0 second); temperature at point A = 24°C.

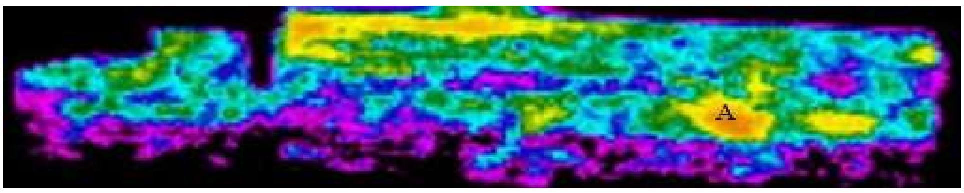

Figure 13: Thermogram after 55 second heating exposure; temperature at point A = 30°C.

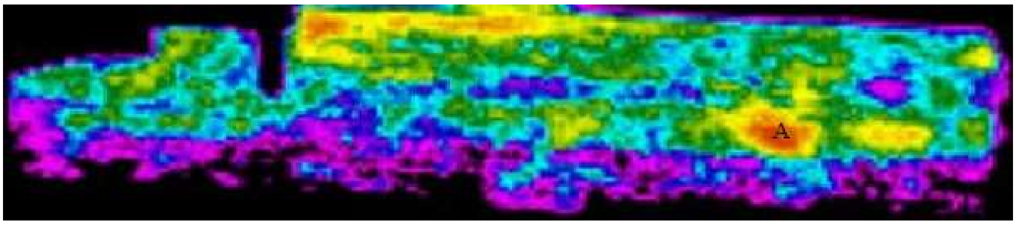

Figure 14: Thermogram after 1 minute 20 second heating exposure; temperature at point A = 36.4°C.

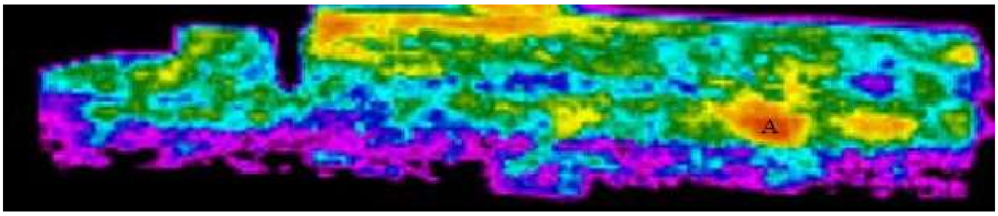

Figure 15: Thermogram after 2 minute 54 second heating exposure; temperature at point A = 37.3°C.

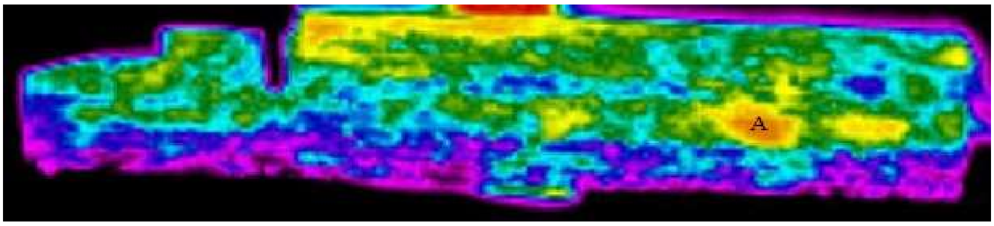

Figure 16: Thermogram after 4 minute 24 second heating exposure; temperature at point A = 40.2°C.

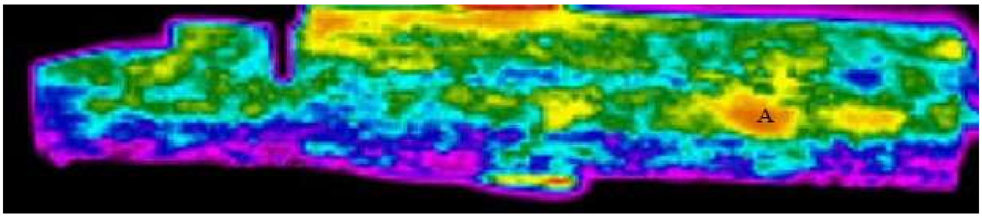

Figure 17: Thermogram after 6 minute 7 second heating exposure; temperature at point A = 43.3°C.

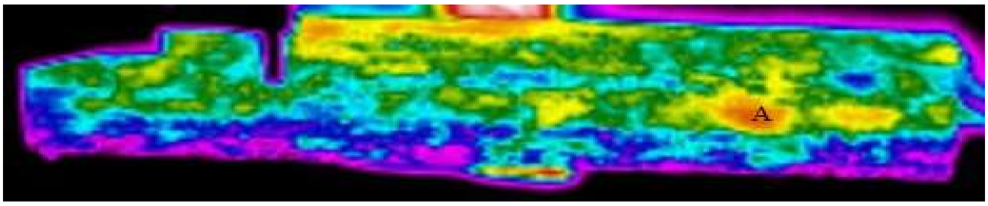

Figure 18: Thermogram after 7 minute 48 second heating exposure; temperature at point A = 45.7 °C.

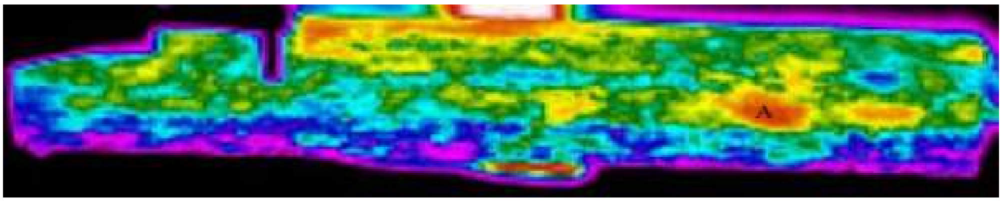

Figure 19: Thermogram after 10 minute 4 second heating exposure; temperature at point A = 47.1 °C.

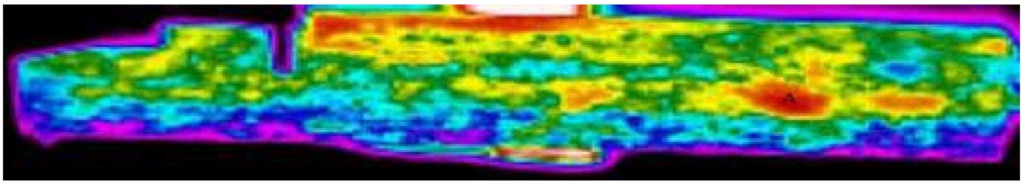

Figure 20: Thermogram after 11minute 30 second heating exposure; temperature at point A = 49 °C.

Welding slag

For this experiment the defect made is in form of welding slag. The welding slag is made at the edge of the pipe where the welding slag is purposely done in the internal part of the pipe. The objective of this experiment is to observe the temperature change for the increasing thickness of the pipe thickness. Logically the thickness of the pipe will be increasing if the welding process is applied to the surface of the pipe. The thermal contrast of the defect should be darker than the surrounding area of the defect. Figure 21 to Figure 29 show the response of the specimens after exposing them to various time of a heat radiation. As the exposure time increased, the rate of temperature change was increased rapidly during the first 3 minutes and slowly decreased after that.

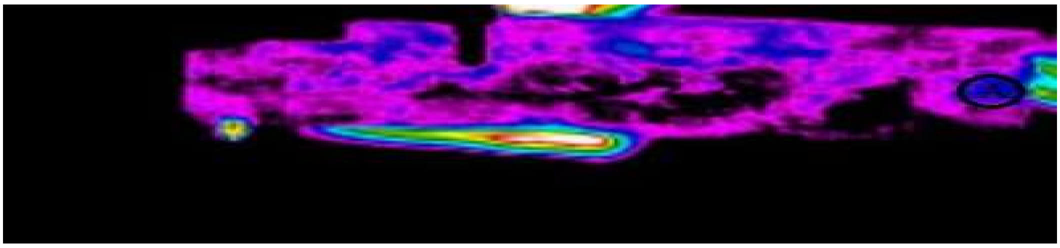

Figure 21: Thermogram at 0 second; temperature at point A = 25.7°C.

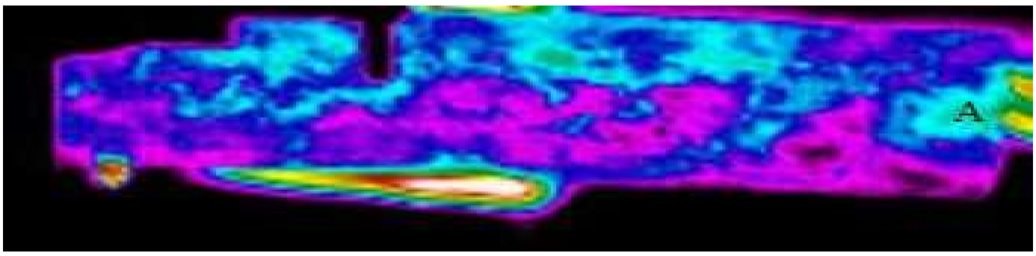

Figure 22: Thermogram at 2 minute 4 second; temperature at point A = 36.2 °C.

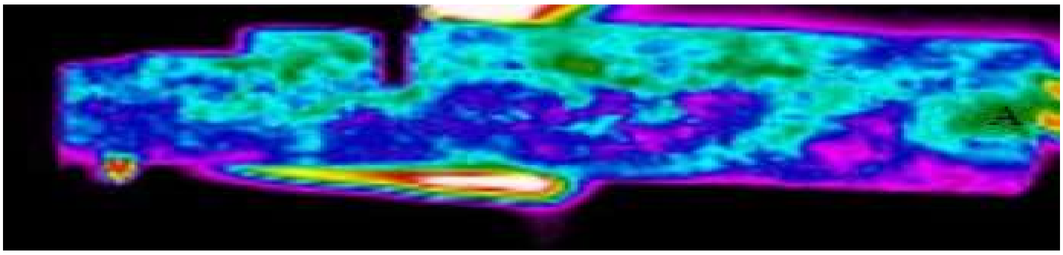

Figure 23: Thermogram at 3 minute 36 second; temperature at point A = 37.9°C.

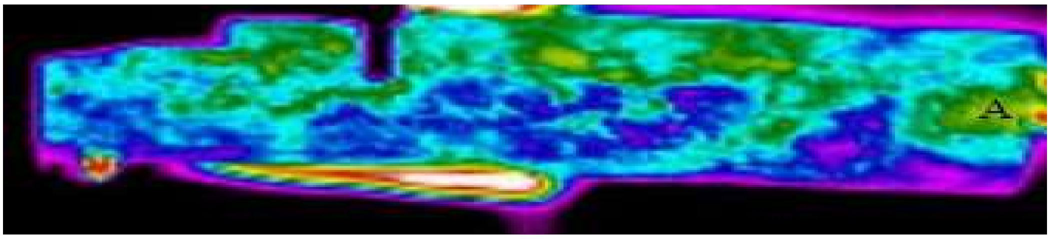

Figure 24: Thermogram at 5 minute 9 second; temperature at point A = 40.3 °C.

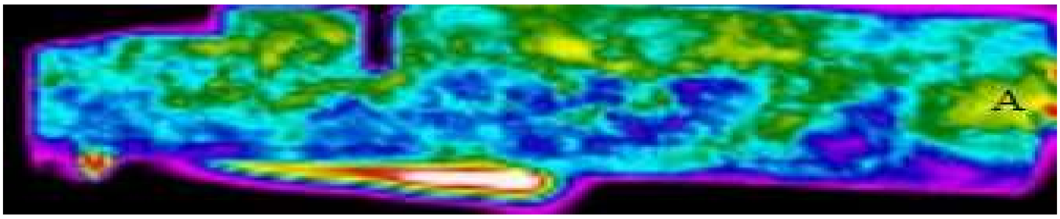

Figure 25: Thermogram at 7 minute 11 second; temperature at point A = 42.3°C.

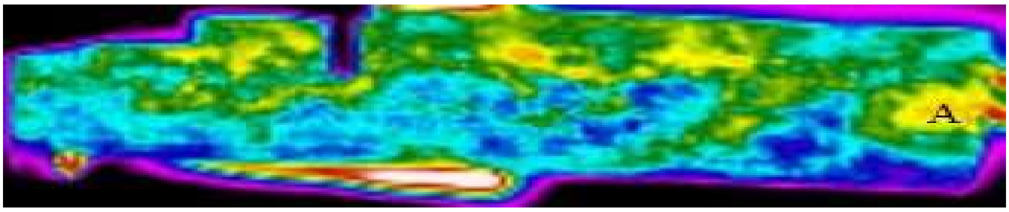

Figure 26: Thermogram at 9 minute 22 second; temperature at point A = 44.5°C.

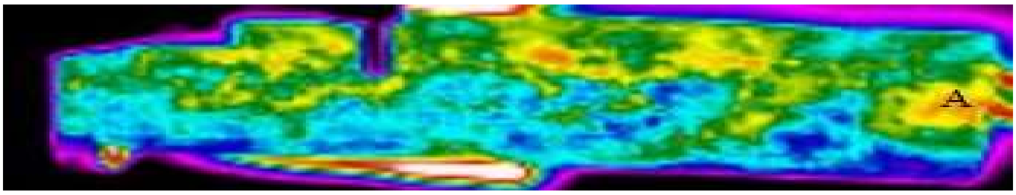

Figure 27: Thermogram at 12 minute 6 second; temperature at point A = 46.1°C.

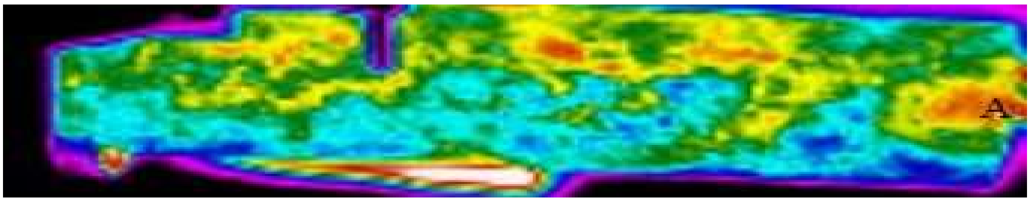

Figure 28: Thermogram at 14 minute 6 second; temperature at point A = 47 °C.

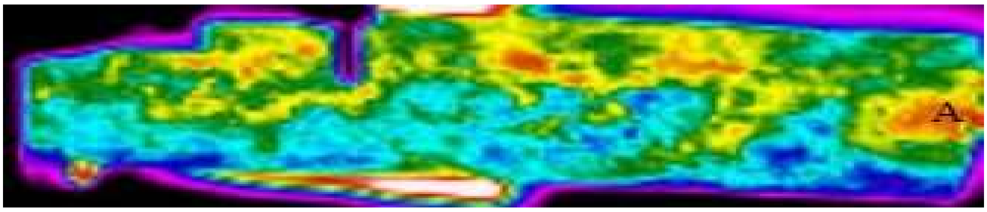

Figure 29: Thermogram at 15minute 25second; temperature at point A = 48.4°C.

From the above results, it was required about a minute in detection of a hole defect while 3 minutes for a slag defect. This is due to some heat energy needed to warm up the slag as it is a body of metal.

CONCLUSION

The objective of this work was to study the pipe inner condition by utilizing the thermography method which based on the thermal contrast change for the pipe material which has been fabricated with artificial defect. It was found that the different thickness of the pipe will resulted with a different thermal contrast. The thicker part of the pipe showed a darker thermal contrast as compare with the artificial defect. The artificial defect showed a brighter thermal contrast than the original pipe and with a higher temperature reading than the surrounding area of the defect. The temperature reading from the software was also verified from the thermocouple measurement and the percent accuracy are relatively low.

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