Analysis Non-Destructive Test of API Five Layer Carbon Steel Pipe Weld Test

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ABSTRACT

This article presents a comprehensive analysis of non-destructive testing methods applied to the welding of American Petroleum Institute five-layer carbon steel pipes in gas piping systems, with a focus on the Integrated Terminal Surabaya. The study emphasizes the critical role of welding processes, particularly Shielded Metal Arc Welding, in ensuring the structural integrity and safety of gas transportation infrastructure. Adhering to industry standards such as American Society of Mechanical Engineers IX, the research evaluates the effectiveness of non-destructive testing techniques, specifically radiography and dye penetrant testing, in identifying weld defects such as porosity and incomplete fusion that may compromise the reliability of welded joints. Radiographic examinations utilize gamma rays to produce detailed images, while dye penetrant tests highlight surface irregularities, both of which are essential for maintaining operational safety in high-pressure environments. The findings reveal that meticulous quality control measures, including pre-weld inspections, real-time monitoring, and rigorous post-weld evaluations, are paramount in preventing catastrophic failures. This study underscores the importance of adhering to established standards and implementing effective non-destructive testing practices to enhance the safety and efficiency of gas piping systems, thereby mitigating risks associated with gas transportation.

I. INTRODUCTION

Welding in gas piping systems is a critical process that ensures the integrity and safety of the infrastructure used to transport gases, such as LPG. The use of carbon steel pipes, specifically those conforming to the API 5L standard, is prevalent due to their strength and durability under high pressure. In the context of the Integrated Terminal Surabaya, the welding processes employed, particularly the Shielded Metal Arc Welding (SMAW), are meticulously regulated to meet industry standards such as ASME IX. This method allows for effective joining of pipes to fittings, including elbows and flanges, which are essential for directing and controlling gas flow. The welding procedure must be carefully monitored to prevent defects such as porosity and incomplete fusion, which can compromise the structural integrity of the piping system. Non-destructive testing (NDT) methods, including radiography and dye penetrant tests, are employed post-welding to identify any potential flaws. Radiography tests utilize gamma rays to produce images of the welds, revealing internal defects, while dye penetrant tests highlight surface irregularities. The findings from these tests are crucial for ensuring that the welded joints are reliable and safe for operation, particularly in high-pressure environments. Thus, the welding practices in gas piping systems not only adhere to strict technical specifications but also prioritize safety and operational efficiency, thereby mitigating risks associated with gas transportation.

Quality control in welding gas piping systems is a critical component in ensuring the safety, reliability, and integrity of infrastructure designed to transport flammable gases. The implementation of rigorous quality control measures throughout the welding process is essential to prevent defects that could lead to catastrophic failures. Industry standards, such as those established by the American Society of Mechanical Engineers (ASME) in the ASME B31.3 Code for Process Piping and the American Petroleum Institute (API) in API 1104, dictate the qualifications of welders, the specifications for materials, and the procedures for welding. These standards provide a framework for ensuring that all welding operations meet the necessary safety and performance criteria. Effective quality control encompasses several key practices, including pre-weld inspections to assess material integrity, real-time monitoring of welding parameters, and post-weld evaluations through non-destructive testing (NDT) methods such as radiography (ASTM E94) and dye penetrant tests (ASTM E165). These NDT techniques are employed to identify potential flaws, such as porosity, incomplete fusion, and surface cracks, which could compromise the structural integrity of the welds. Furthermore, maintaining comprehensive documentation of the welding process and any inspections performed is vital for traceability and compliance with regulatory requirements, as outlined in ASME IX for welding and brazing qualifications.

Radiography test is one of the important non-destructive methods in welding quality evaluation, especially in pipe joints. In the context of testing API five layer (5L) carbon steel pipe with fittings at Integrated Terminal Surabaya, radiography is performed to detect internal defects that may not be visually apparent. The process involves the use of gamma rays, which are fired through the pipe to produce an image on a radiographic film. The results of this test indicate the presence of defects such as porosity and incomplete fusion, which can affect the structural integrity of the welded joint. For example, the resulting radiographic film shows variations in the thickness of the weld wall as well as the presence of pores, which are indicated by differences in the colour and brightness of the film. These tests are crucial to ensure the safety and reliability of piping systems, as defects in joints can result in serious failures in operation, especially in applications involving high pressures, such as in LPG conveyance. Therefore, radiographic testing serves not only as a defect detection tool, but also as a preventive measure in maintaining the safety and operational efficiency of piping systems.

Dye penetrant testing (DPT) is a non-destructive method used to detect subtle surface defects in materials, including welded joints. In the context of testing API 5L carbon steel pipe with flange at Integrated Terminal Surabaya, the process is carried out by spraying a coloured liquid penetrant on the weld surface after a thorough cleaning stage. This liquid penetrant has the capacity to infiltrate cracks or pores on the surface. Following a designated waiting period, during which the penetrant liquid may infiltrate the discontinuity, the surface is then subjected to a second cleaning process prior to the application of the developer liquid. The developer fluid serves to accentuate existing defects by creating a contrast between the clean surface and the defect filled with the penetrant fluid. The results of these tests demonstrated the presence of porosity defects, attributable to gas entrapped in the weld metal prior to the completion of the welding process, in addition to dirt on the weld surface with the potential to compromise the integrity of the joint. These findings emphasise the importance of proper cleaning procedures and management of electrode moisture in the welding process to prevent defects that could affect the quality and safety of the resulting structure. Penetrant testing is thus a vital tool in ensuring the reliability of welded joints, especially in applications involving high pressures such as piping systems for gas.

II. METHODS

This research begins with the meticulous preparation of the welding pipe designated for connection to both the flange and elbow fittings. The initial step involves selecting high-quality carbon steel pipes that conform to the API 5L standard, ensuring they meet the necessary specifications for strength and durability. Prior to the welding process, the pipes undergo a thorough inspection to assess their integrity and surface condition, which includes checking for any pre-existing defects or contaminants that could adversely affect the welding outcome. Following this, the welding procedure is executed using the SMAW technique, adhering to the guidelines set forth by the ASME B31.3. Once the welding is completed, the welded joints are subjected to rigorous evaluation through NDT methods, specifically radiography and dye penetrant tests. The radiographic examination utilizes gamma rays to produce detailed images of the welds, enabling the identification of internal defects such as porosity and incomplete fusion. Concurrently, the dye penetrant test is performed to detect surface irregularities by applying a colored penetrant that seeps into any surface-breaking flaws. After allowing adequate time for penetration, the surface is cleaned and a developer is applied to reveal any defects, thereby facilitating a comprehensive analysis of the welding results

A. *Welding Parameter*

Welding of API 5L carbon steel pipes with elbow and flange type fittings has an ASME IX standard reference which uses SMAW welding with a fixed welding location of 45 ° with a vertical downward welding direction and uses direct current (DC). The welding electrode in this study uses two types of electrodes, namely E 6010 which is used for the weld pool at the root pass and E 7010 - P1 electrode used for the weld pool in the hot pass, fill pass and capping. Pipe to fitting welding parameters can be seen in table 1

TABLE I. WELDING PARAMETER

Welding layers	**Electrod e size**	**Current (A)**	**Potential (V)**	**Travel Speed (mm/mi nute)**	**Heat Input (kJ/mm)**
Root pass	3.2	75-110	22-25	75-95	1.4-2.1
Hot pass	3.2	80-115	22-25	80-100	1.4-1.7
Fill pass	3.2-40	90-130	22-25	80-115	1.48-1.69
Capping	3.2-40	100-130	22-25	85-125	1.55-1.56

Table 1 shows that the parameter values in pipe to fitting welding variable values are different, because each voltage has its own provisions such as 75 - 110 amperes with 22 - 25 volts, while for 100 - 130 amperes with 22 - 25 volts. Parameters on travel speed, and heat input have different values because the values of amperage and voltage are different.

B. *Spesification of Pipe, Flange and Elbow*

The following specifications are shown in the table 2

TABLE II. TABLE TYPE STYLES

Specification	**Pipe**	**Elbow**	**Flange**
Material	• Carbon steel • API 5L grade B PSL 1 • ERW / HFW • Bevel end	• Carbon steel • ASME B16.9	• Carbon steel • ASME B16.5 • Slip on, rised face
Weight	3,267 kg	3,670 kg	22-25
Layer	3 layer polyethylene	3 layer polyethylene	3 layer polyethylene

The dimension piping system this research main pipe shown on figure 1, beside the picture the total length of pipe is 6,000mm, followed by long radian elbow shown on figure 2, and flange on figure 3. Joining of piping is conducting on PT. Patra Badak Arun Solusi it behold between September to December 2022.

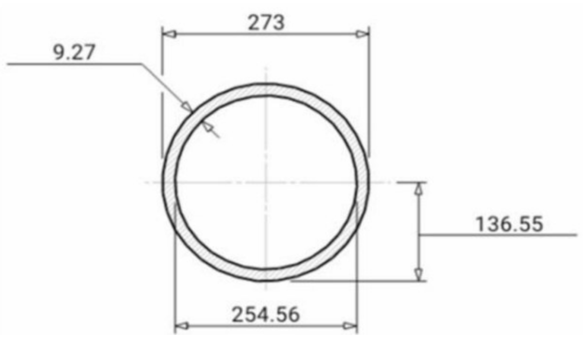

Fig. 1. Dimension of API 5L pipe

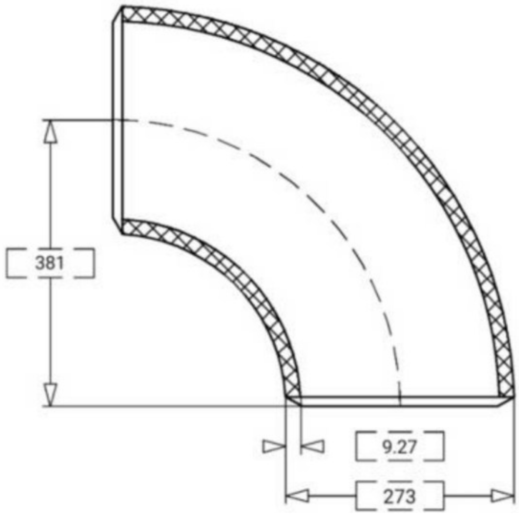

Fig. 2. Dimension of 90° Long Radian API 5L Elbow

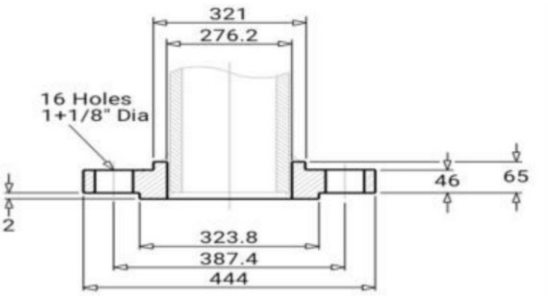

Fig. 3. Dimension of Flange ASME B16.5

III. Result and Discussion

NDT results using radiography test (RT) on pipe to elbow and dye penetrant test (PT) on pipe to flange. The test results have their own parameters due to different materials. The results of the radiography test (RT) on pipe to elbow and dye penetrant test (PT) on pipe to flange are as follows

A. Radiography test

The results of the radiography test contained three radiographic films on one welding of API 5L carbon steel pipe with ASME B16.9 elbow. ASTM class I film is a type of internal and external film in the test that can receive shots with medium speed and very fine grains. The results and explanation of the film in the radiography test in Figure 4 below.

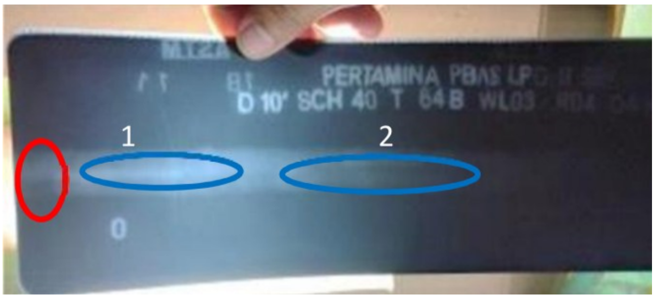

Fig. 4. Point zero radiography film

Figure 4 is the result of radiographic testing on the welding of API 5L carbon steel pipe with ASME B16.9 elbow in the observation of this research Arun Solution there are radiographic film results which can be stated that the welding is less than perfect due to a defect or welding defect due to a defect or welding defect. Welding defects in point 0 radiographic films have different sizes of welding wall thickness on the screen including the wall thickness of the root pass screen to the capping screen. Welding on the root pass screen has different wall thicknesses as shown in number 1 and number 2, where number 1 welding on the root pass screen is thicker than welding on the 2nd root pass screen. The welding on the hot pass screen shown in the red circle has a different thickness, the thickness is different from the welding of the upper edge where the upper edge is thicker than the lower edge. top edge is thicker than the bottom edge of the image which has thinness in the weld. Welding defects in the root pass and fill pass screens are caused because the electrode contains water or the electrode is still moist. Point 0 radiographic film solution is done by drying an electrode using an electrode warmer or can be called an electrode dryer, and re-welding is carried out.

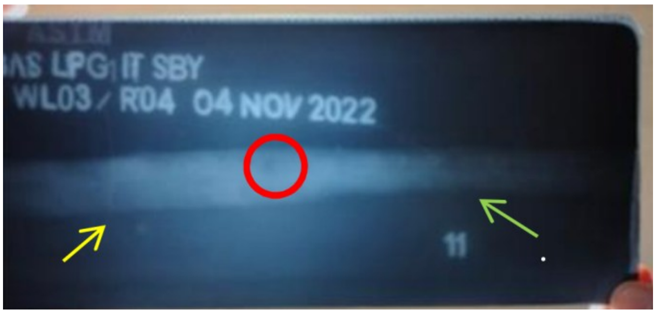

Fig. 5. 0-11th point radiography film

Figure 5 is the result of radiographic testing on the welding of API 5L carbon steel pipe with ASME B16.9 elbow in this study.stated that the welding is less than perfect due to a defect or welding defect. Defects in radiographic films 0-11 there are small holes on the surface of the weld edges or can be called porosity welding defects and welding defects in radiographic films 0-11 there are different sizes of weld widths. The diameter of the welding hole has a size of less than 1mm. The weld hole defect in the 0-11 radiographic film is caused by the inappropriateness of the current in welding such as the ampere voltage that is too large with the slow welding speed of the welder's hand. The weld width marked with a yellow arrow is larger than the weld width marked with a green arrow. The solution in radiographic films 0-11 can be done by reducing the current in welding and adjusting the welding motion. Results of the 2nd radiographic film (placement 11-22)

Fig. 6. 11th point radiography film

Figure 6 is the result of radiographic testing on welding API 5L carbon steel pipe with ASME B16.9 elbow in this study there are results of radiographic film point 11 which can be declared perfect because it does not have defects in welding in the form of holes or differences in the thickness of a thin wall of the welding surface. The thickness of the electrode used in welding is around 3.2mm to 4.0mm so that the welding results look perfect and neat. Welding screens such as root pass, hot pass, fill pass, and capping do not have a different thickness or holes.

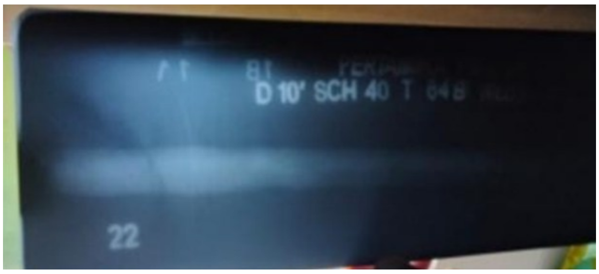

Fig. 7. Radiographic Film at Point 22

Figure 7 is the result of radiographic testing on the welding of API 5L carbon steel pipe with ASME B16.9 elbow in this research project, there are radiographic film results 11-22. which can be declared perfect because it has no defects in welding. The welding area has a solid white color, meaning that the welding has a thickness in the welding and has the same weld width. The welding area is quite perfect but there is a narrowing of the weld area in certain parts which can affect mechanical properties, but this can be tolerated because of the narrowing of the weld area. however, it can be tolerated because the narrowing is not too deep into the surface of the material.

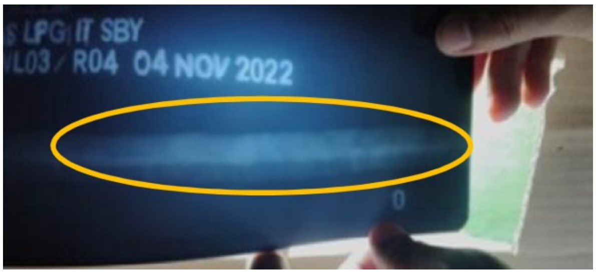

Fig. 8. Radiographic Film at Point 22 to 0

Figure 8 is result of radiographic testing on welding API 5L carbon steel pipe with ASME B16.9 elbow in this study Solution there are radiographic film results at point 22 which can be declared perfect because it has no defects in welding. Welding at point 22 has a high level of thickness so that there is a narrowing of the weld area in certain parts which can affect the mechanical properties of the weld. The welding parameters have the right value so as not to produce a defect in the welding, the current value in amperes uses 75 to 130 with a voltage of 22 to 25.

Figure 7 is the result of radiographic testing on welding API 5L carbon steel pipe with ASME B16.9 elbow in this study there are radiographic film results in incomplete fusion due to cold lap (IFD) defects because it has imperfect properties between two adjacent welds or weld metal and parent metal not fused to the whole surface. The defect on radiographic film 22-0 has an indication length of 50mm and an aggregate length exceeding eight percent of the weld length. Welding defects on 22-0 radiographic film result in different welding wall thicknesses, the thickness of the weld wall is thicker on the upper side than the lower side. The solution to the defects in the 22-0 radiographic film can be done by means of more perfect re-welding.

B. Dye penetrant test

The results of the dye penetrant test on the pipe to flange have defects on the surface of the weld. The weld defect on the pipe to flange has a porosity defect (P). Porosity defects can be caused by the presence of a gas trapped in the weld metal before the gas comes out of the weld surface. Porosity defects can be seen in the picture below

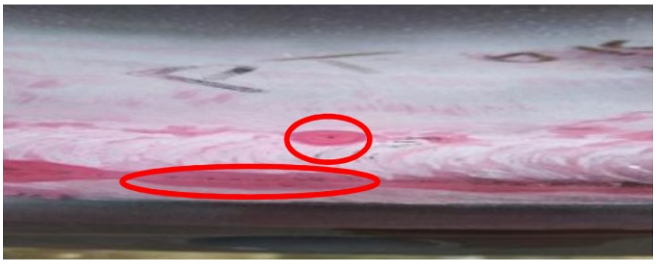

Fig. 9. Defect on Penetrant test

Figure 9 is the result of penetrant testing caused by imperfect welding in terms of electrodes that are still damp, and the presence of a liquid or dirt on the surface of the weld. Weld defects produce pores of 3mm, and the pore size exceeds 25% of the nominal wall thickness being joined. The solution to electrode moisture in penetrant testing defects can be done by drying an electrode using an electrode warmer or can be called an electrode dryer, for a dirt on the surface that causes defects can be cleaned first with an abrasive metal grinding disc.

IV. CONCLUSION

The welding processes utilized in gas piping systems, particularly those involving carbon steel pipes that conform to the API 5L standard, are integral to ensuring the safety and reliability of infrastructure designed for the transportation of gases such as LPG. The investigation conducted at Integrated Terminal Surabaya underscores the critical importance of adhering to established industry standards, including ASME IX and API 1104, which govern the qualifications of welders, material specifications, and welding procedures. The application of SMAW facilitates the effective joining of pipes to fittings, such as elbows and flanges, essential for the proper functioning of gas transport systems. However, the results of rigorous NDT methods, including radiography and dye penetrant tests, reveal the prevalence of defects such as porosity and incomplete fusion, which pose significant risks to the structural integrity of welded joints. These findings highlight the necessity for comprehensive quality control measures throughout the welding process, encompassing pre-weld inspections, real-time monitoring of welding parameters, and post-weld evaluations to mitigate potential failures in high-pressure environments. By integrating stringent quality control practices and employing effective NDT techniques, the reliability and safety of welded joints can be substantially enhanced, thereby contributing to the overall integrity of gas piping systems and ensuring the safe transportation of gases in various industrial applications.

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