FLYWHEEL: JURNAL TEKNIK MESIN UNTIRTA

Homepagejurnal: http://jurnal.untirta.ac.id/index.php/jwl

Analysis Of Welding Results On A Pressure Vessel Using Radiography Test Method At PT. DIHI

Muhammad Hidayahtullah[1], Slamet Wiyono[1*],

[1] *Department of Mechanical Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Banten, Indonesia*

*Corresponding author: maswie@untirta.ac.id

ARTICLE INFO

Received 12/08/2023
revision 09/09/2023
accepted 21/09/2023
Available online 25/10/2023

ABSTRACT

This research presents the conclusions of the testing conducted at PT. Daekyung Indah Heavy Industry, focusing on the Quality Control process applied to pressure vessels. The Quality Control process involves Non-Destructive Testing (NDT) using the Radiography Test (RT) method. This testing is performed using gamma rays generated by Iridium-192 and applied to a vertical pressure vessel intended to function as a Gas Dehydration Filter. The area under examination is one of the Weld Parts with NC Code on Manhole M1 24 Inch, with SA516-70N material and a thickness of 18 mm, and the entire testing process is conducted with reference to ASME BPVC Section VIII Division I UW-52 as the standard. The test results indicate that out of the 7 areas tested, 5 areas showed indications of defects. Among the 5 areas with defects, there was 1 porosity defect in area A-B and 4 slag inclusion defects in areas B-C, D-E, F-G, and G-A. The repair process required for both types of defects is the removal of the weld groove followed by re-welding until no defects remain in the repaired weld joints.

Keywords: *ASME, Non Destructive Test, Pressure vessel, Quality Control, Radiography Test, Weld.*

1. INTRODUCTION

In a fabrication process, especially for making tools with high accuracy, of course, requires a very tight QC or Quality Control process so that the products produced can fulfil the specifications given by the clients. Quality Control is a process that has the purpose to monitor the quality of products that are produced to all factors involved in the production process. Quality Control has several steps starting from the monitoring, testing, and inspection of all production stages. The purpose of Quality Control is to prevent the occurrence of products that do not meet the desired quality standards or avoid products with low quality on an ongoing basis so that companies can controlling the quality of products so that the consumers feel satisfied and the company does not experience losses (1).

PT Daekyung Indah Heavy Industry is a company that engages in fabrication such as making a Pressure Vessel, Tower/Column, Shell and Tube Heat Exchanger, Storage Tank, Reactor, Steel structure, and many others. Before taking the form of a pressure vessel or tank, the raw material in the form of slabs or sheets will be formed through a machining process in accordance with the product design. after that the parts that have been formed will be connected using a welding process to become the final product such as Pressure Vessel and so on. Please note that the results of this welding are very vulnerable to defects which are caused by several factors such as environmental factors,

human error, welding techniques that are not in accordance with the welded material (2).

1.1 Radiography Test

Radiography Test (RT) is a type of welding inspection that is used to penetrate into the weld using X-rays or gamma rays capable of penetrating almost all types of metals, except lead and some other materials. As such, this technique is able to detect defects that may be present within the metal wall or in the material itself. This test itself has several advantages and disadvantages when compared to other tests. The following are the disadvantages and advantages of this test.

A. Advantages of Radiography Test

1. Produces a permanent image on film that is viewable for a long time.
2. Allows to identify the inside of the material or object being tested.
3. Can clearly detect the visual of damage to an object that is difficult to see by eye.
4. Provides accurate data on fabrication faults in the object.
5. Can be used on various types of objects with various shapes.

B. Disadvantages of Radiography Test

1. Cannot be used on objects with a complicated shape.
2. The instruments required to perform this test are relatively expensive such as the testing tools and iridium material used as the primary material.
3. There is a risk of X-ray or gamma ray exposure to the body of the examiner.

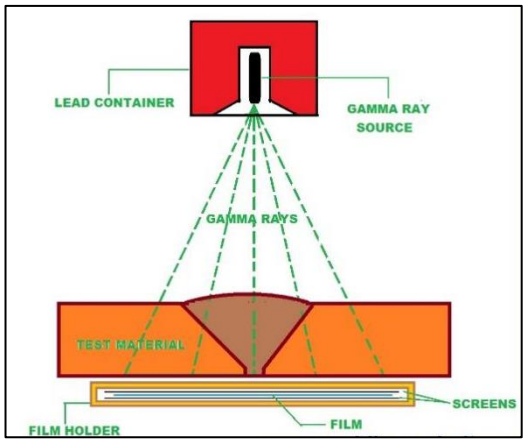

Figure 1. Concept of Radiographic Testing.

Because defects in welding can affect the performance of the resulting product, a tight inspection process is needed to detect defects in the product. One of the inspection processes carried out at PT Daekyung Indah Heavy Industry on its products is Radiography Test (RT). Radiography testing is an important test because it is needed to detect defects in the inner part of the welding groove that cannot be seen visually. The results of this test will determine if the product is in the accepted or rejected category based on the ASME VIII UWS2 standard which is the standard used by the company. If the product is still in the accepted category or in good condition, it will directly enter the finishing stage such as blasting and painting processes. Otherwise, if the product is rejected, the repairing stage will be implemented first and then it will be tested again until the product has passed the quality control stage and entered the finishing stage.

1.2 ASME Section VIII Division 1 UW-52

In this testing, the whole process is regulated and adjusted based on ASME (American Society of Mechanical Engineers) standards which is an organisation that provides services in the field of engineering especially mechanical engineering such as quality learning, code and standard development, certification, research, conferences, and publications. The organisation was founded in 1880 and is internationally acclaimed as a developer of standards relating to the state of the art, science, and practice in mechanical engineering. Because this test is applied to pressure vessel products, boilers, and other similar products, the standard used is ASME BPVC (Boiler and Pressure Vessel Code) Section VIII Division 1 UW-52. The BPVC standard provides a set of codes and standards that relate to the guidance in the manufacturing, construction process, and operation of boilers and pressure vessels. While for section VIII explains about any inspection or testing procedures that needed to be carried out and codes UW-51 and UW-52 are procedures and acceptance criteria of defects found after radiographic testing [6].

The calculations below are carried out in determining the criteria or tolerance limits set out in ASME BPVC Section VIII Division 1 UW-52.

1. For (T) values less than or equal to ¾ inch (19 mm), the maximum limit of the largest dimension of the defect is ¼ inch (6 mm). If the largest dimension or length of the defect is more than ¼ inch or 6 mm, the weld needs to be repaired.
2. For values (T) between ¾ inch (19 mm) and 2 ¼ inch (57 mm), the length of the detected defect has a tolerance limit of 1/3 T. If the length of the detected defect dimension is greater than 1/3 T, the weld needs to be repaired.
3. For (T) values greater than 2 ¼ inches (57 mm), the tolerance limit of the largest dimension of the defect is ¾ T. If the value of the largest dimension of the detected defect is greater than the value of ¾ T, the weld must be repaired.

2. METHODOLOGY

2.1. The Flow of The Testing Process

In this experiment, there are 5 stages which are the main focus of the testing flow. The first is preparing the equipment for testing, second is preparing the object to be measured (especially the surface of the part to be tested), third is conducting radiographic testing, fourth is interpretation of the result, and the last is concluding the test result so that it can be decided if the product being tested fulfils the standard.

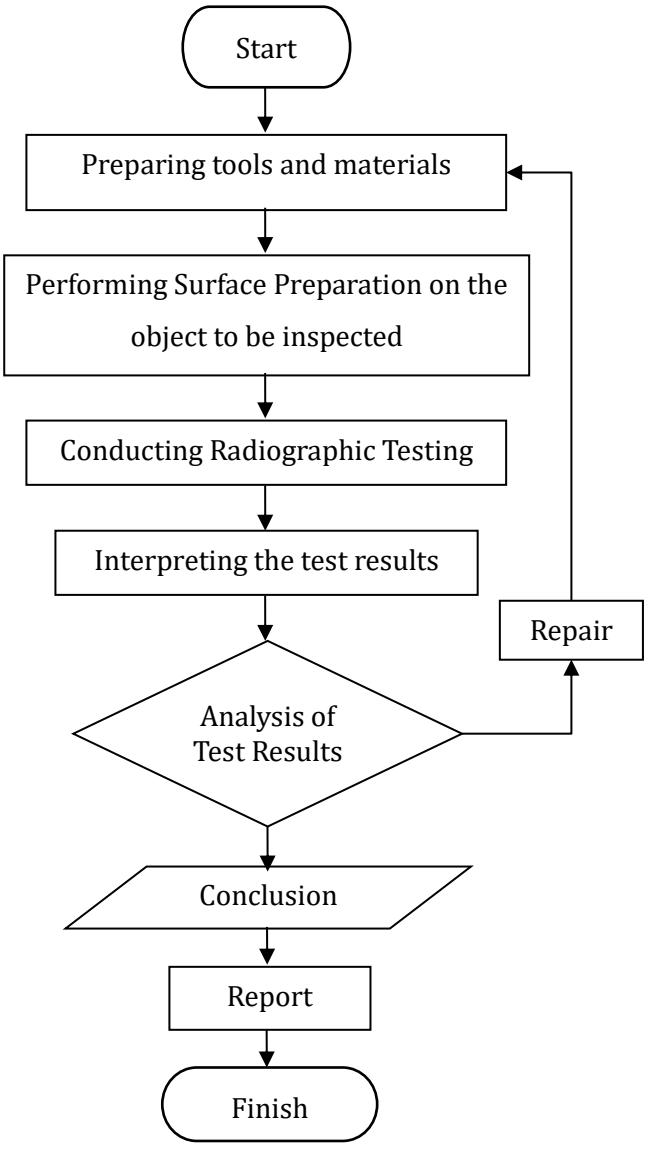

Figure 2. Flowchart of The Experiment.

2.2. Pressure Vessel Specification

In this radiography test, it will be applied to the welding results of a vertical pressure vessel product that functioned as a Gas Dehydration Filter. In the initial design of this product, there are predetermined data ranging from the type of material to be used, design data, the type of inspection and testing required and so on based on ASME Section VIII standards. The specifications or data of the pressure vessel can be seen in the table below.

Table 1. Pressure Vessel Specification.

No.	Parameter	Data
1.	*Pressure Vessel Orientation*	Vertikal
2.	Pressure Design	950 psig
3.	Temperature Design	200 °F
4.	Length	10072 mm
5.	Diameter	1680 mm
6.	*Head Thickness* (*after forming*)	46,75 mm
7.	*Shell Thicknes* (*after forming*)	46,75 mm
8.	Material	SA516 – 70N

2.3. Testing Procedure

In this test, we will employ non-destructive testing (NDT) using the radiography test (RT) method to ascertain the nature of welding defects present within the welding groove. This aims to determine the appropriate repair method required to ensure the produced product complies with established standards and regulations. The radiography test method we will utilize utilizes gamma rays generated by Iridium-192 to penetrate into the welding groove, with results visible on radiographic film. The following is the procedure for conducting radiography testing (RT):

A. Preparing tools and material.

Before commencing the testing, it is essential to prepare the necessary tools and materials. This includes ensuring the suitability and functionality of the tools and equipment, among other considerations. In this test, we are using a gamma ray source system, which has specifications as seen in Table 2 below.

Tabel 2. Tool Specification.

Information	Data
Name	Sentinel 880 Series Delta
Isotope Capacity	• 5,55 TBq (150 Ci) Ir-192 • 5,55 TBq (150 Ci) Se-75
Total Weight	52 lb
Density Material Range	2.71 g/cm^3 – 8.53 g/cm^3

B. Inspection

The inspection process is conducted on one of the manholes located on the pressure vessel. This testing focuses on the welding groove with the code NC, which refers to the welding that joins the flange with the shell manhole. The welding performed at this point utilizes the GTSM welding type, with a material thickness of 18 mm for the shell manhole, and the material type used is SA516-70N. For further clarity, please refer to the image below.

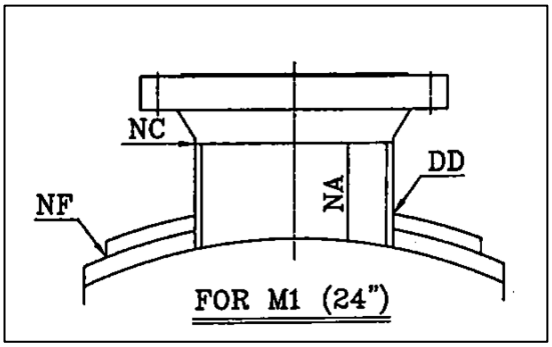

Figure 3. Weld Part Manhole M1 24".

Below is the radiographic testing procedure in accordance with ASME BPVC Section VIII Division I UW-52 standard.

1. Clean the surface of the welding groove.
2. Determine the starting and ending points of the test based on the diameter or length of the welding groove.
3. Attach the IQI Penetrameter in the middle of the testing area.
4. Install lead markers on the film according to the product information and test specifications, then place them on the IQI Penetrameter.
5. Install the guide tube from the Gamma Ray Source System at a distance of 15 inches and aim it at the attached film.
6. Ensure all equipment is properly set up, then retreat approximately 4-5 meters from the testing area.
7. Calculate the exposure time using a calculator, set the stopwatch, and activate the Gamma Ray Source System using the remote control.
8. After the specified time, turn off the machine using the remote control, and wait for the radiation to dissipate.
9. Carefully retrieve the film and store it securely.
10. Repeat the test in other areas until all welding grooves are recorded on the film.

C. Interpretation of Test Results

After inspecting the pressure vessel, the next step is the process of reading the films obtained from the testing. Before reading the test results, these films must be processed first to produce quality images that are easy to read by the examiner or inspector. This process is called immersion processing because the films obtained after the inspection process will be immersed in a chemical solution. This immersion process stimulates the silver halide crystals in the emulsion to form black silver precipitates in the areas exposed to radiation. After processing, the films are washed and dried. Once dry, the test results can be read by placing the films on an LED light to clarify any defects detected on the film.

3. RESULTS AND DISCUSSION

In the interpretation of the results, we will observe the film produced with LED Light. The film will show the condition on the inside of the welding result so that if there is a defect in that part, it will look like a darker area compared to other areas which we will then measure and see whether the magnitude of the defect is still within the tolerance limit or not. The following is an example of the reading of several films obtained from the test results with the help of LED Light.

1. M1/24" NC (A – B)

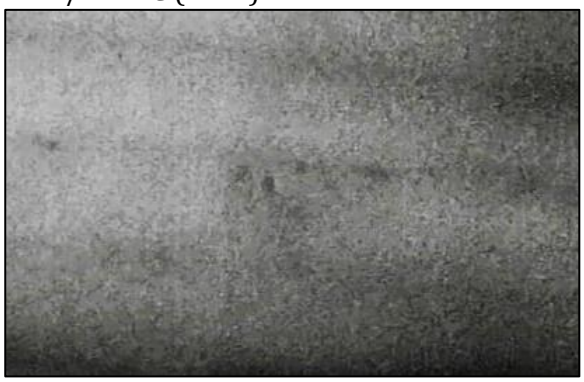

Figure 4. Test Results on M1/24" NC (A – B).

2. M1/24" NC (C – D)

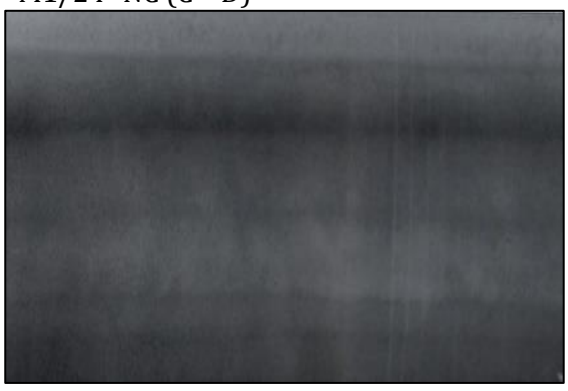

Figure 5. Test Results on M1/24" NC (C – D).

3. M1/24“ NC (D – E)

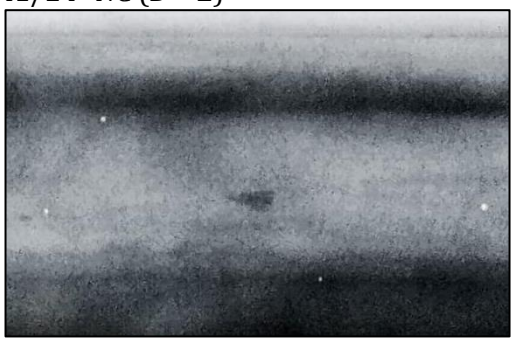

Figure 6. Test Results on M1/24” NC (D – E).

3.1. Radiographic Testing Results.

After analysing the defects detected from the test results as in some of the samples above. The results of the analysis will be recapitulated and compiled in tabular form. This aims to make it easier to understand how the final results and conclusions obtained from the test results as shown in Table 3.

Table 3. Radiographic Testing Results.

Project JGC	: D2212 /	Type of Material : SA516 – 70N	
Lokasi	: Cilegon	Thickness	: 18 mm
Date 2023	: 06 / 07 /	*Accept*. Code VIII	: ASME
No. Wo	: 13 – V – 1108 B		
No. Joint	: M1/24” NC		

Area	Type of Defect	Defect Size	*Acceptance Criteria*	
			Accept	*Repair*
A – B	*Porosity*	11 mm	✓	
B – C	*Slag Inclusion*	27 mm		✓
C – D	-	-	✓	
D – E	*Slag Inclusion*	18 mm		✓
E – F	-	-	✓	
F – G	*Slag Inclusion*	20 mm		✓
G – A	*Slag Inclusion*	75 mm		✓

After testing and interpreting the results, a conclusion is obtained from the test results that have been carried out. In this radiography test, because the diameter of the manhole is large enough to cause testing in the weld groove to be divided into 7 areas so that all weld areas can be properly covered by the film. In reading the test results this time, we use the ASME standard precisely in ASME Section VIII UW-52 as an acceptance criteria or parameter that determines whether the welding results that have been carried out are still within the allowable tolerance limits or not.

Referring to Table 3, it can be seen that from the test results in 7 (seven) areas that have been determined, there are 5 areas that indicate defects in the sub-surface based on the results of radiographic testing. Of the five areas indicated by the defect, there is only 1 area, namely area A - B, which is still within the permissible tolerance limit. This also indicates that the results of the welding still have many defects and cannot continue the pressure vessel production stage to the finishing stage.

3.2. Analysis of the Causes of Failure

The causes of these defects consist of two types, namely human error and equipment error. How these can lead to defects in the final welding result will be described in the points below.

1. Human Error

Human errors are mistakes made by humans in performing a task or job. These errors can occur due to several factors such as fatigue, lack of training, rushing, and so on. However, in our case this time, fatigue and rushing are the main causes of our case. This is because PT Daekyung Indah Heavy Industry is a company engaged in the fabrication of chemical equipment, so the level of production capacity that exists in the company depends on market demand for the needs of these tools. Currently, the demand for such equipment is increasing due to the addition of several plants from several large companies such as PT Pertamina, PT Jadestone Energi, and so on, so that production activities at PT DIHI also increase along with the increasing number of orders resulting in additional shifts or working hours of PT DIHI employees. In addition, the company was previously affected by Covid - 19 which resulted in production activities being halted until the previous parent company released ownership of the company to the new owner and started operating again in October 2022. This caused the number of employees under the new company management to be less when compared to the old management, besides that the company also carried out massive branding to attract clients so as to increase the company's production activities with the aim of restoring the company's performance as before. The workload experienced by employees is divided into 2 (two) types.

a. Physical workload, As a welder of course in working sometimes in a difficult working position because you have to adjust the position of the welding being carried out, besides that the welder must also be in that position for a long period of time because the welding groove is

quite long so that it will cause considerable physical fatigue. Therefore, when employees' working hours increase, it will result in greater physical fatigue compared to normal working hours. This will greatly affect the fitness and health of the welder itself. As a result, the work results can be less than optimal as happened in the welding results above (3).

b. Mental workload, In addition to physical loads, mental loads also affect the welding results of the welder. Generally, a welder will be required to produce a welding groove that complies with the standards used. This is because the standards used are internationally based, so the inspection process of welding results or quality control carried out will be very strict so that it is not uncommon for the welding results to be considered rejects so that they need to be repaired and add to the work of the welder. This will affect the mental burden of a welder, because it always works under pressure and is required to produce good welding results without any errors (3).

2. Tools Factor

Due to the high intensity of work from increased production activities, it will also affect the reliability of the tools used. Often the welding machine used is damaged as a result of very intense use or exceeds its capacity. For example, in a MIG (Metal Inert Gas) welding machine, if the use is excessive or above the limit performance of the machine itself, it will cause several cases such as overheating which will result in deformation of the wire feeder component (4). As a result, the component cannot work properly. If the machine components used are not optimal, it will certainly cause less than optimal welding results.

3.3. Solution to the problem

After knowing the factors that most affect the occurrence of defects in welding results. Next, we will discuss solutions to problems experienced by the product. It is intended that the products made can still meet the standards and in accordance with client requests. Please note that the solutions presented will be divided into 2 (two), namely solutions to overcome defects that occur, and solutions to reduce the occurrence of the same thing in the future. The following is the solution to the problems encountered.

1. Solutions for Defects that Occur.

Based on the standard used, namely ASME, welding results that experience defects must be repaired until the welding groove is completely free of defects or defects either visually or as a whole. For visual defects, usually the type of repair carried out is related to defects on the surface of the weld groove. how to overcome it is by smoothing the surface of the weld groove again if the defects that occur are still in the mild category such as spatter, or a less good shape. If it falls into the medium or heavy category, it needs to be remelted or removed with a gouging machine and then welded again. The same is done if the indicated defect is on the inside of the surface. As we already know after testing. The welding groove that we tested, namely the welding groove in the M1/24 'manhole, to be precise on the weldpart with code NC, is known to have defects on its surface, namely 1 (one) porosity in the A - B area and 4 (four) slag inclusions in the B - C, D - E, F - G, G - A area. Based on ASME standards, the repairing process will be carried out until there are absolutely no defects detected in the welding groove. The process is the same, namely by destroying the welding groove again, especially at points where there are defects with a gouging machine, then the welder will return to welding in the groove. After that, testing will be carried out again to review whether the repair results are good or not. This will continue to repeat if the repair results still have defects that exceed the tolerance limit because sometimes even though it has been repaired there are still defects detected, even though the number is less [6].

2. Solution to Reduce the Chance of Defects Occurring

After knowing the factors that influence the cause of the many defects in the weld groove, we also need to overcome this. This is very important because the repair process requires a lot of money, so if there are many indications of welding defects, the costs required for repair can swell and will affect the company's finances. To avoid this, of course, we need to focus on eliminating the factors previously described.

a. Balancing the workload. Every workload received by employees must be appropriate and balanced against the physical and mental abilities of workers who receive the workload so that there is no excessive fatigue and risks to employee health. If the company is increasing its production, then the addition of employees needs to be done so that the workload of employees can remain balanced (5).
b. Giving appreciation. Appreciation of work results is very important in maintaining mental health at work. Employees who feel appreciated will feel more motivated and feel valued. This certainly has a good impact on the work of the employee because there is an increase in the quality of the employee's mental (5).
c. Create a maintenance strategy that suits the field conditions. If the workload has been adjusted, the risk of overworking the machine will be reduced. Therefore, the next focus is to

reorganise the strategy of welding machine maintenance according to the conditions in the field. Having a maintenance strategy that suits the field conditions, will have an impact on the work efficiency of the maintenance department. For example, developing a regular and strict schedule according to working hours or conditions in the field, then consistently procuring quality spare parts so that damage can be handled immediately (5).

4. CONCLUSION

After completing an internship at PT. Daekyung Indah Heavy Industry and compiling a report, several conclusions were drawn:

1. In the Radiography Test process, testing is conducted rigorously and must comply with the standards used, from procedures to acceptance criteria. Additionally, inspectors conducting the testing must have official certifications, which also apply to the authorities responsible for radiography testing. The testing procedure begins with preparing the equipment to ensure it functions properly and meets standards. Furthermore, the item to be tested, especially the welded joints, needs to be cleaned beforehand to improve testing accuracy. Inspection follows the procedures outlined in ASME BPV Section V, Article 2 Edition 2021, starting with cleaning the surface of the welded area to be tested. Then, the starting and ending points of the test are determined based on the diameter or length of the weld groove. Next, the Image Quality Indicator (IQI) is placed in the middle of the testing area, and lead markers are placed on the film according to the product information being tested. The guide tube from the Gamma Ray Source System is then installed at a distance of 15 inches and directed towards the film. All equipment is double-checked for proper installation, and individuals must keep a safe distance of approximately 4-5 meters from the testing area. Exposure time is calculated, and a stopwatch is set accordingly. The Gamma Ray Source System is activated using remote control, and after a specified time, the machine is turned off, and the films are retrieved and stored safely. This process is repeated for other areas until all weld grooves are recorded on the film for evaluation. After testing, the next step is analyzing the test results. Analysis must also comply with ASME VIII UW 52 standards, which determine whether detected defects fall into the categories of accept, accept with repair, or reject.
2. Radiography testing is crucial because welded joints in products are highly susceptible to defects, which can impact the strength of the weld joints. This testing method offers advantages over others because it penetrates welded joints, making defects within them clearly visible. Due to its effectiveness, radiography testing is frequently used on all welded joints in fabricated products, including those at PT. Daekyung Indah Heavy Industry.
3. Test results on the pressure vessel revealed defects in 5 out of 7 designated areas, based on radiography testing results, with 1 porosity defect detected in area A - B and 4 slag inclusion defects detected in areas B - C, D - E, F - G, G - A. The repair process required for both defects is the removal of the weld groove followed by re-welding until no defects remain in the repaired weld joints .

REFERENCES

[1] ASME (American Society of Mechanical Engineers). 2021. Section VIII: Rules for Construction of Pressure Vessels Division 1, UW-52, New York

[2] Maretno A. Analisa Beban Kerja Fisik dan Mental dengan Menggunakan Work Sampling dan NASA TLX Untuk Menentukan Jumlah Operator Analysis Physical and Mental Workload Uses Work Sampling and NASA TLX To Decide Operator Number. 1990;54–62.

[3] Prasmoro AV. Analisa sistem perawatan pada mesin las MIG dengan metode Failure Mode and Effect Analysis: Studi kasus di PT. TE. Oper Excell J Appl Ind Eng. 2020;12(1):13.

[4] Sikumbang RW, Fahri MK, Abizar H. Vocational Education National Seminar (VENS) Pengaruh arus listrik terhadap hasil cacat las pada pengelasan SMAW. 2022;66–70.

[5] Taslim R, Afifah AU. Pengukuran Beban Kerja Fisik dan Mental Welder dengan Metode Nordic Body Map dan Metode Nasa TLX. Semin Nas Teknol Informasi, Komun dan Ind ISSN 2579-5406. 2021;13(November):199–206.

[6] Yul O:, Tampai S, Sumarauw JSB, Pondaag JJ, Ekonomi F, Bisnis D, et al. Implementation of Quality Control on Clean Water Production in Pt. Air Manado. J EMBA. 2017;5(2):1644–52.