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Analysis of Welding Disabilities on Carbon Steel Pipes with SMAW Reviewed From Radiography Test Results

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Abstract

Welding is one method of joining two or more materials by heating or merging the base material and electrode that act as adhesive or glue. Known welding defect have been found in pipe weld joint during work of pipeline construction so repair must be carried out and it causes loss of cost and time. This welding aims to join two pieces of seamless carbon steel pipe with beveled ends with outside diameter 60.3 mm and thickness 3.91 mm. Welding process is SMAW (shield Metal Arc Welding) by using two class type of welding wire that is welding wire A5.1 AWS E7016 for weld pass root and welding wire A5.1 AWS E7018 for weld pass fill and cap. The welding results were tested with NDT method using radiography test types of gamma-ray ir-192. Radiography test method used is film radiography. From the results of radiographic film interpretation which refer to acceptance criteria standart API 1104, found porosity weld defects in the weld pass fill. Based on the type of welding defect that occurs, analysis of several causes of defects was carried out and it was found the biggest cause occurrence of welding defects. This happens caused the preheat process on material and welding wire is not carried out so the cooling process in welding is too fast and uneven . Based on this, repair must be carried out by adding a preheat process to the welding wire by baking the welding wire up to 80˚C for 2 hours using baking oven and transffered it to drying oven for temperature maintenance. After testing the welded joints that have been repaired, the test results shows the weld joint pass the acceptance criteria. This analysis aim to determine the causes of weld disabilities on carbon steel pipes with SMAW reviewed from radiography test result so that weld joint repairs can be done and avoid this from repeated.

Keywords: Welding Defect, Pipe Welding, Pipeline, Radiography test

INTRODUCTION

Transportation of gas is gathering, transmission, or distribution of gas by pipeline or the storage of gas[1]. In the gas distribution industry, gas transportation is one of them using the pipeline as a gas distribution medium to industrial companies that require gas for the industry either used as fuel generator or vehicle. Pipeline is all parts of physical facilities through which gas moves in transportation, including pipe, valves, fittings, flanges (including bolting and gaskets), regulators, pressure vessels, pulsation, dampeners, relief valves, and other appurtenances attached to pipe, compressor units, metering stations, regulator station, and fabricated assemblies[1]. PT. PGN (Perusahaan Gas Negara) is a state-owned company engaged in the distribution of gas in construction work using a subsidiary company called PT. PGN SOLUTION in pipeline construction work. At the time of construction, pipe material used are seamless pipe made of carbon steel API 5L grade B with pipe tip cut to form bevel. Each pipe rod is joined by using SMAW (Shield Metal Arc Welding) which is welding using elektrode welding wire and in welding of pipes with diameter ranging from size 60.3 mm to bottom using welding wire AWS E7016 and AWS E7018. Welding results were tested by NDT, using the radiography test method. Each welding refers to a welding procedure called WPS (Welding Procedure Specification).

On the pipes weld joint, it is known that there are weld defects after interpretation of the film result of radiography test[2][3]. Due to defects, the welding work is unacceptable and re-welding is necessary by removing or by passing the defective material, this results a loss in terms of cost and time.

To correct the failure of welding defects in this case, this research analyzed the results of NDT in the form of radiography test which finally referred to changes in heat treatment factors performed. This is different from several studies that have been carried out such as changing the variation of current and electrode[4], changes in groove and gap[5], and changes in the difference in welding sequence[6].

LITERATURE REVIEW

1. Welding

Welding is one of the techniques of joining metals by melting some of the parent metal and fill metal with or without pressure and with or without metal enhancers and producing a continuous joinion, melting or melting workpieces and additional materials caused by heat coming from an electric arc[7]. Welding has a broad scope in construction work including plate welding, channel pipe welding, bridge

construction, shipping construction, steel frame construction, tank construction or pressure vessels, etc. In addition to new construction, welding is also used to repair or even carry out maintenance work. Each welding construction work is regulated in its code and standard, each of which depends on the type of work and is set out in a welding procedure that is regulated before the welding construction work is carried out as a reference or welding procedure

2. Acceptance Standards for NDT (Non Destructive Test)

The acceptance standards presented in this section apply to imperfections that lie at the time of the radiography test. This can also be applied to visual inspection. NDT cannot be used to select welding that is undergoing destructive testing[8]. All NDT methods are limited to information that can be derived from the indications produced. Therefore the company can reject any weld that does not seem to meet this acceptance standard if the depth of imperfection can be detrimental to welding[8].

2. 1. Porosity

Porosity is defined as a gas trapped by a welded metal that hardens before the gas has the opportunity to rise to the surface of the welded liquid pool and exit. Porosity is generally spherical but has elongated or irregular shapes like wormholes. If the size of the indication of the Radiography Test produced by the pore or worm hole is measured, the maximum dimension of the indication must be in accordance with the criteria given [8].

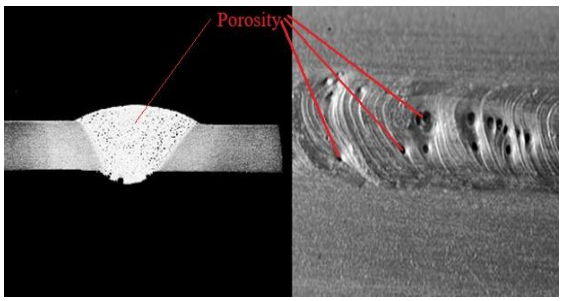


Figure 1. Weld Porosity on Pipe[9]

2. 1. a. Individual or Scattered Porosity

Individual Porosity or Scattered Porosity is considered defective if there are the following conditions:

a. Individual pore size exceeds 3 mm,

b. The individual pore size exceeds 25% of the thickness of the specified joint thickness,

c. Distribution of porosity distribution exceeds the concentration permitted by Figure 2.

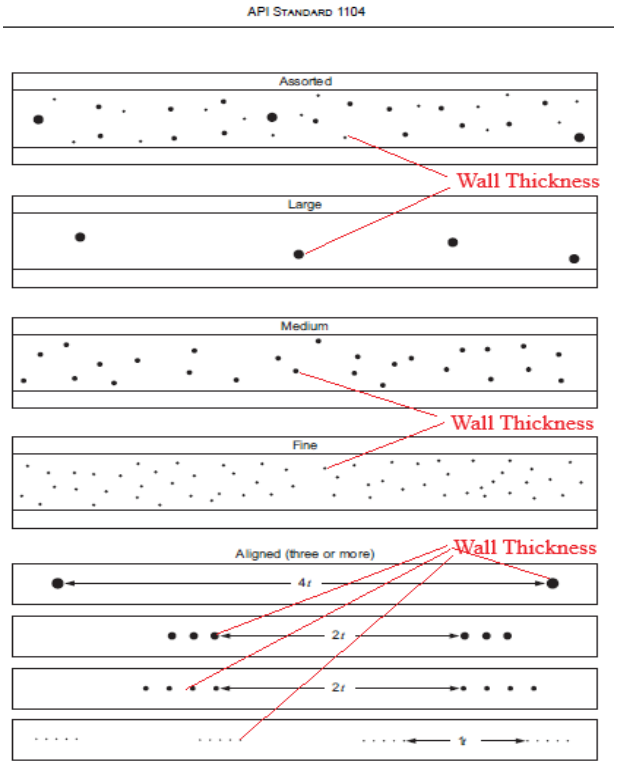


Figure 2. Maksimum distribusi of Gas Pockets : WallThickness (*t)* less than/equal to 12.7 mm [8]

2. 2. Slag Inclusion

A slag inclusion is defined as a nonmetallic solid entrapped in the weld metal or between the weld metal and the parent material. ESI (elongated slag inclusions) for example, continuous or broken slag lines or wagon tracks are usually found at the fusion zone. ISI (isolated slag inclusions) are irregularly shaped and may be located anywhere in the weld. For evaluation purposes, when the size of a radiographic indication of slag is measured, the indication's maximum dimension shall be considered its length[8].

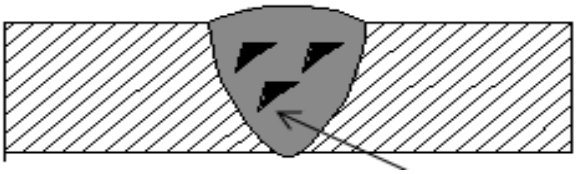


Figure 3. Slag Inclusion Ilustration[10]

2. 2. a. Small Diameter Pipe

For pipe with a specified OD (outside diameter) 60.3 mm to bottom, slag inclusions shall be considered a defect should any of the following conditions exist:

- The length of an ESI indication exceeds three times the thinner of the specified wall thicknesses joined,
- The width of an ESI indication exceeds 1.6 mm,

- The aggregate length of ISI indications exceeds two times the thinner of the specified wall thicknesses joined and the width exceeds one-half the thinner of the specified wall thicknesses joined,

The aggregate length of ESI and ISI indications exceeds 8 % of the weld length.

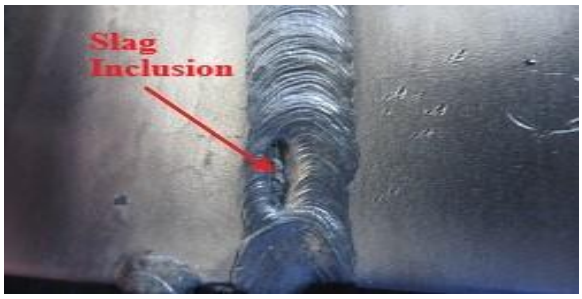


Figure 4. Slag Inclusion Photo[11]

3. Preheat

Preheat is defined as the heat given to the metal to be welded or metal for welding to maintain preheat temperature [12]. The definition of preheat temperature is the temperature of the parent metal around the area to be welded before the welding begins. Preheating can use various methods including induction heating, heating on the surface, using a gas burner, oxy-gas flame, electrical blanket, thermos baking, oven. The purpose of preheat is that :

a. Reduces humidity from the welding area and,

b. To reduce the temperature gradient.

4. Radiography Test

Radiography test are one of the NDT that use x-rays or gamma rays which are able to penetrate almost all metals so that they can be used to reveal defects or mismatches behind the material walls or in materials[13]. Radiography uses penetration of radiation directed at the material.

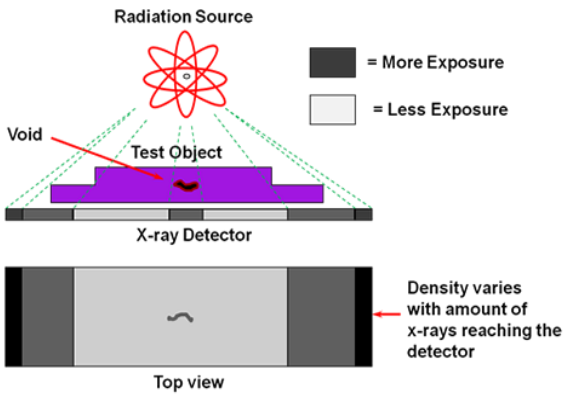


Figure 5. Radiography Test Method[14]

The intensity of the radiation that will be fired at the material depends on the specific gravity and thickness. The results of the tests will be displayed on film or by computer. The material is placed between the radiation source and the film.

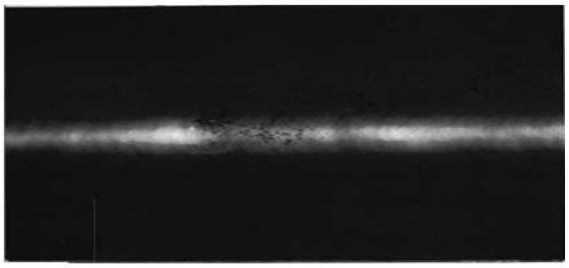


Figure 6. Radiography Test Film Result[15]

RESEARCH METHODS

1. Materials and Test Object

1.a. Carbon steel pipe with beveled ends API 5L grade B

Pipe is a tubular product made as a production item to be marketed[1]. Pipe material used is seamless carbon steel with beveled ends. Seamless pipe are tubular products that are forged without weld seam[1]. Pipe spesification and type/grade is API 5L Grade B.. Tests are carried out on pipe with geometric shapes as can be seen in figure 7 and figure 8.

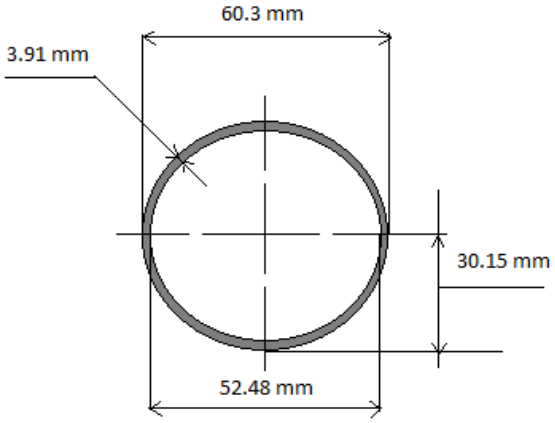


Figure 7. Pipe Looks Front

The physicality of pipe is as follows :
1. Pipe diameter : 60.3 mm
2. Pipe thickness : 3.91 mm

Figure 8. Pipe Looks sideway

1.b. Welding Wire AWS E7016 & E7018

Welding wire used is A5.1 (carbon steel covered) AWS E7016 and AWS E7018. Based on the welding wire code shows :

E → Electode of SMAW
70 → Tensile strength of 70,000 Psi
1 → All welding positions
6/8 → Moderate weld penetration,

AC/DC+ power, low hydrogen.

A5.1 AWS classficiation	Type of coating	Welding Position	Welding Current
E6010	High cellulose sodium	F, V, OH, H	DC+
E6011	High cellulose potassium	F, V, OH, H	AC, DC+
E6012	High titania sodium	F, V, OH, H	AC, DC-
E6013	High titania potassium	F, V, OH, H	AC, DC±
E6018	Low-hydrogen potassium, iron powder	F, V, OH, H	AC, DC+
E6019	Iron oxide titania potassium	F, V, OH, H	AC, DC±
E6020	High iron oxide	H-Fillet F	AC, DC- AC, DC±
E6022	High iron oxide	F, H-Fillet	AC, DC-
E6027	High iron oxide, iron powder	H-Fillet F	AC, DC- AC, DC±
E7014	Iron powder, titania	F, V, OH, H	AC, DC±
E7015	Low-hydrogen sodium	F, V, OH, H	DC+
E7016	Low-hydrogen potassium	F, V, OH, H	AC, DC+
E7018	Low-hydrogen potassium, iron powder	F, V, OH, H	AC, DC+
E7018M	Low-hydrogen iron powder	F, V, OH, H	DC+
E7024	Iron powder, titania	H-Fillet, F	AC, DC±
E7027	High iron oxide, iron powder	H-Fillet F	AC, DC- AC, DC±
E7028	Low-hydrogen potassium, iron powder	H-Fillet, F	AC, DC+
E7048	Low-hydrogen potassium, iron powder	F, V, OH, H, V-down	AC, DC+

Welding Positions: F=Flat, H=Horizontal, V=Vertical, OH=overhead; (Source: AWS A5.1:2004)

Figure 9. AWS A5.1 Clasification[12]

2. Testing Equipment and Devices

The basic equipment or components for testing consisting of :

1. Welding machine

Figure 10. Welding Machine[16]

2. WPS (Welding Procedure Specification)

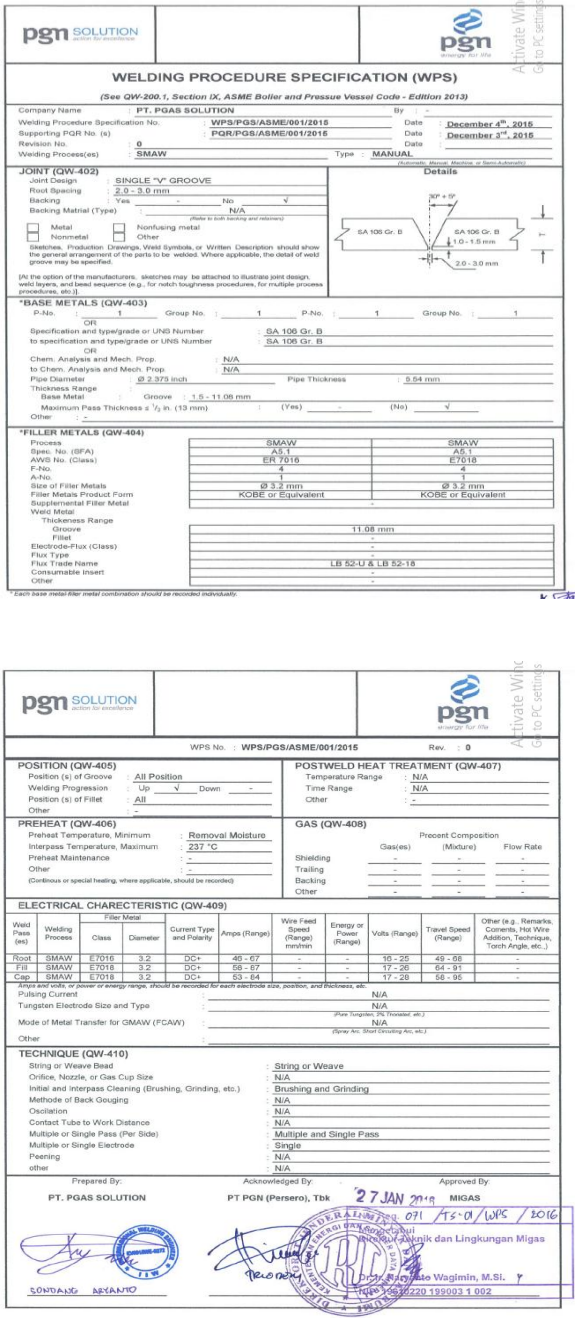


Figure 11. WPS (Welding Procedure Specification)

3. Welding aids :

a. Welding cable and wire holder

Figure 12. Welding Wire and Wire Holder[17]

b. Welding hammer and wire brush

Figure 13. Welding Hammer and Wire Brush[18]

e. Mass clamps

Figure 14. Mass Clamps

4. Camera radiography

Figure 15. Camera Radiography

5. Electrode baking oven and electrode drying oven

Figure 16. Electrode Baking Oven and Electrode Drying oven

3. RESEARCH PROCEDURE

The procedure carried out in this experimental method consists of four stages, namely:

1. Analysis Results of Radiography Test. Interpret the initial results of the radiography test film in the event of a welding failure and read the results of the radiography test report to find out the types of defects that occur so that the causes of defects can be detected.
2. Welding.
   Welding according to WPS or the same welding procedure when welding fails, including the same material, welding wire and welders, but with variable changes based on the results of the radiography test analysis.
3. RadiographyTest.
   Testing by NDT using the radiography test method to find out the results of welding and printing in the film. In the film will see the results of the inside of the weld and basic material.
4. Analysis The Final Results of RadiographyTest. After obtaining the results of the radiography test film, compare the results of the report the first welding film was found weld defects with the results of the second film after the changes were made.

RESULTS AND DISCUSSION

1. Results of Radiography Test Analysis

Here is the initial result radiography test of weld joint :

Chart 1. Initial Test Results of Weld Joint

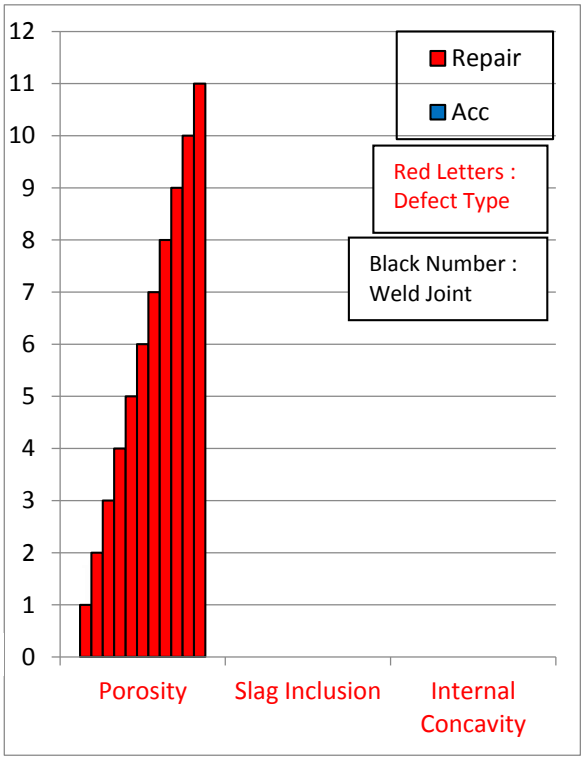


Table 1. Initial Test Result of Weld Joint

No	Weld Joint	Result
1	J02 CV	Repair
2	J07 ML	Repair
3	J12 CV	Repair
4	J14 CV	Repair
5	J43 CV	Repair
6	J45 CV	Repair
7	J02 BV	Repair
8	J12 BV	Repair
9	J14 BV	Repair
10	J43 BV	Repair
11	J45 BV	Repair

Based on the results of radiography test in Chart 1 it can be seen that the failure during welding is caused by the type of weld defect, porosity. Porosity is defined as a gas trapped by a hardened metal weld before the gas has the opportunity to rise to the surface[8]. Based on the causes that occur, a changes of non essential variables is considered and carried out such as change root spacing, change position of welder, addition preheat maintenance, add retainer, change electrical characteristic, addition cleaning methode, addition methode back gouge, change weave/string, and re-checking of the welding wire material.

This is the welding wire material data:

Welding Wire-AWS : E7018 & E6018
Welding Type : SMAW
Tensile Strength : 70Ksi & 60Ksi
Welding Position : All Positions

Composition :

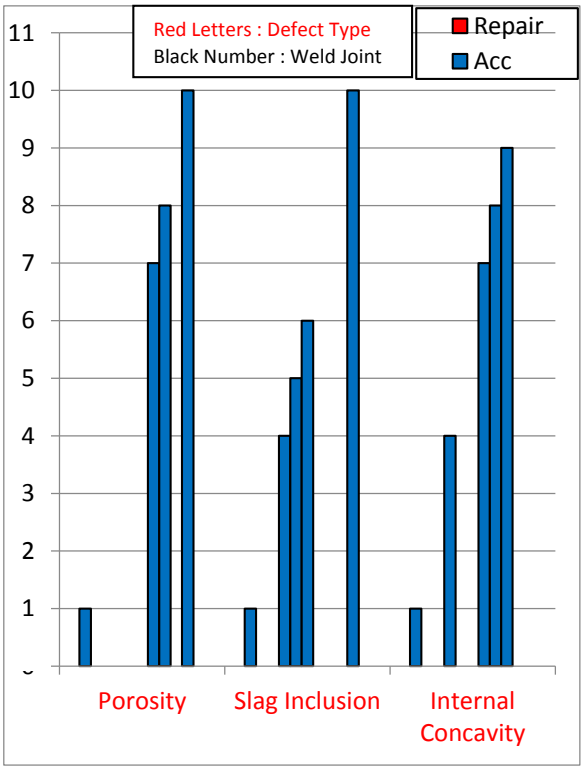
- Calcium Carbonate 30%
- Fluorspar 20%
- Ferromanganese 5%
- Potassium Silicate 15%
- Iron Powder 30%
- Celulose

Shielding : CO 80%, CO2 20%
Type of Coating : Iron Powder-Low H
Penetration : Medium
Las current : AC / DC+
Iron Powder : 25% -40%

Then it is known that the welding wire material contains celulose which is low hydrogen. Based on this matter, it leads to giving additions of heat treatment in the form of preheat on welding wire which functions to improve the quality of welding wire so that water absorption does not occur which can cause the function of the coating not to be maximal. When water absorption occurs in the welding wire it can cause the welding arc not stabilize, faster cooling process and greater air contamination.

In this case preheat is carried out using electrode baking oven. Welding wire is baked to a temperature of 80˚C[19] in the baking oven and transferred to drying oven so a temperature is maintained at 80˚C[19]. By doing this, the water will not be absorbed into the weld wire and if water absorbed in the weld wire, the water will come out through the evaporation process. Result of welding joint were tested with radiography test. The results can be seen in Chart 2.

Chart 2. Test results of weld joint after re-welding.



It can be seen from the test results of weld joint after re-welding, the welding results are indeed still have a welding defect. This is because the final result of weld joint is repairs from failed welded joint material so that it does not get maximum results but the test results shows weld joint pass the acceptance standard criteria and may continue to the next work process.

CONCLUSION

1. The weld defects is porosity, this is caused by the filler metals material of welding wire is hardened before the gas is able to escape from the welding fluid.
2. Preheat needs to be carried out on welding wire if the type of welding wire is low hydrogen or containing celulose even though it is not written on the WPS.
3. It needs to be updated in the future to addition preheat on WPS to avoid welding defects in weld joint so losses in term of time and cost not occurs.

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