Journal of Vocational Studies on Applied Research

Reliability Analysis of Fire Water Line

Sutrisno[1], Didik Ariwibowo[1*], Seno Darmanto[1], Wiji Mangestiyono[1], and Galih Satria Hendri Saputra[2]

[1]Mechanical Design Engineering Industrial Technology Department Vocational School of Diponegoro University Jl. Hayam Wuruk No.4, Kampus UNDIP Pleburan, Semarang, Indonesia
[2]Undergraduate Student of Mechanical Design Engineering Industrial Technology Department Vocational School of Diponegoro University Jl. Hayam Wuruk No.4, Kampus UNDIP Pleburan, Semarang, Indonesia

e-mail:didik.ariwibowo@live.undip.ac.id

Abstract- *The purpose of this research is to analyze the reliability of fire water as water distribution for emegency condition. To determine the remaining usefull life (RUL) of fire water line , this research will apply counting process so that the rate of remaining usefull life (RUL) of fire water line can be known. The data used as basis for calculation is failure data gained from technical division databases from 2018. The data obtained will be processed using visual inspection and ultrasonic thickness test method to produce remaining usefull life of fire water line. From 5 example fire water line, only 3 needed replace of fire water line cause less than 10 year. RUL to 9 year at 10" and 12" Train C/D, 2.45 year at 14" Train C/D, 8 year at 10" and 12" Utilities I. The mathematical modeling will be verified using visual thickness and ultrasonic Test method to ensure Reamaining useful life of fire water line at Badak LNG. Visual inspection refer to API 571 and ultrasonic test refer to API 570 and ASME B31.3*

Keywords *–remaining usefull life, fire water line, reliability, API 570, ASME B31.3*

Submission: May 11, 2020 Correction: October 19, 2020 Accepted: October 31, 2020

Doi: http://dx.doi.org/10.14710/jvsar.2.2.2020.6-9

[How to cite this article: Sutrisno, Ariwibowo, D., Darmanto, S., Mangestiyono, W., and Saputra, G.S.H. (2020). Reliability Analysis of Fire Water Line. *Journal of Vocational Studies on Applied Research,* 2(2), 6-9. doi: http://dx.doi.org/10.14710/jvsar.2.2.2020.6-9]

1. Introduction

Several fire water pipes rupture and leak were occurred in 2014 and 2015 at Train A/B/C/D.These cases occurred on 24" of fire water pipesto Train A/B and C/D. On fire water pipe at Train A/B, it was found crevice and internal corrosions that lead to pipe leakage. While, at Train C/D, crackswere found along the pipe seam joint. Based on construction data, as mention on PTB Memorandum No. 405/BM33/2009-334, fire water pipes for size of 14" to 24" were constructed by ERW (electric resistant welding) pipe type that may lead to pipe burst. These problems causing to downgrade situation that increase risk level due to lack of fire water pressure in case of emergency [1][2]

To overcome the problem, observer conducted remaining useful life assessment program to assess the degradation of the pipes and to determine a life extension program for piping with less than 10 years estimated remaining lifetime. In 2018, there are 5 areas were assessed as detailed in Table 1.

To estimate the remaining useful life, data that gathered from fire water pipe of Train C is also represented fire water pipe of Train D because their installation years are the same, namely in 1983. While, for pipe size 2" - 4", only one pipe size that assessed in each area, but it represented other sizes. For example, 3" pipe at Train C is represented all the pipe size 2" - 4" at Train C and Train D. In the same manner, pipe size of 10" is represented 12" pipe at the same area.

Table 1. 5 Assessed areas in 2018

No	Area	Pipe Size	Sample Size
1	Train C/D	2", 3", 4", 6", 10", 14"	3", 6", 10", 14"
2	Train E	2", 3", 4", 6", 10", 14"	3", 6", 10", 14"
3	Utilities I	10", 12"	10"
4	Utilities II	2", 3", 4", 10", 14"	4", 10", 14"
5	Loading Dock I	10", 12"	10"

2. Material & Method

To assess current condition of fire water pipes, sample pipes for each pipe size in every area were inspected. The sample pipe lengths were varies from 30 cm to 50 cm. There were two stages of assessment conducted [3].

a. Visual Inspection

Based on previous experienced, it is known that stagnant water inside fire water pipe may lead to internal corrosion problem. Internal corrosion will produce scale

and also deposit that causing metal thinning and reducing pipe diameter. Small pipe diameter is more critical to this problem compare to the larger pipe. In this assessment, pipe with nominal diameter of 6 inch or less wereinternally inspect to check their internal condition.

b. Thickness Measurement

Thickness measurements were conducted to all sample pipe points by using B-scanning method with 100% coverage area. This measurement is aimed to investigate remaining thickness of pipe.

Based on the remaining thickness measurement result (t_{actual}), the remaining useful life of pipe was predicted by considering its corrosion rate start from installation year. The formula for these calculations is based on API 570 as follows [4]:

$$Corrossion\ Rate = \frac{t_{initial} - t_{actual}}{time\ (year) between\ t_{initial}\ and\ t_{actual}}$$

$$Remaining\ Life = \frac{t_{actual} - t_{required}}{corrossion\ rate\ [inches\ (mm)\ per\ year]}$$

where,

$t_{initial}$ is the thickness at initial installation (mm)

t_{actual} is the actual thickness that measured at the time of inspection (mm)

$t_{required}$ is the thickness measurement computed by the design formula before corrosion allowance and manufacturer's tolerance are added (mm)

Thickness measurement was performed by ultrasonic measurement to the sampling points. The result of the thickness measurement can be seen at Tabel 2:

Table 2. Thickness measurement at sampling points

	Sampling Point	Size	Sch.	Initial Thick.	Min. Thk.Req.	Install Year	Insp. Year	Inspection Area			
								0 to 3	3 to 6	6 to 9	9 to 12
C	HR 307	3"	STD	5.486	0.8301	1983	2018	4.89	4.890	5.06	5.169
	WS 031	6"	STD	7.112	1.1559	1983	2018	5.73	5.940	5.73	6.090
	HV 303	12"	30	8.382	1.8074	1983	2018	3.16	3.160	3.16	3.160
	WH 610	14"		7.925	2.0246	1983	2018	2.41	2.440	2.44	2.419
E	Close to E4-E-14	3"	STD	5.486	0.8301	1990	2018	6.21	3.840	3.56	3.940
	HV 509	6"	STD	7.112	1.1559	1990	2018	5.9	5.999	5.93	6.030
	HV 507	12"	30	8.382	1.8074	1990	2018	5.84	8.410	9.08	8.510
	HV 514	14"	520	7.925	2.02	1990	2018	7.72	5.730	7.56	7.659
U1	HV 1106	10"	30	7.798	1.5902	1977	2018	2.6	2.770	2.82	3.170
U2	Close to Boiler 22	4"	STD	6.02	0.9387	1990	2018	2.83	3.029	3.03	3.029
	HV 1206	12"	30	8.382	1.8074	1990	2018	5.01	5.309	6.2	5.309
	HV 1204	14"	520	7.925	2.02	1990	2018	7.12	6.829	6.01	6.469
LD1	HV 1611	10"	30	7.798	1.5902	1977	2018	5.89	6.110	5.79	5.790

In conducting this research, a descriptive analysis based on field test result. From the test results obtained, it can be calculated the value of the corrosion rate and lifetime value of the pipe. To obtain the results of corrosion rates and pipe life values can be calculated using the following formula.

$$t_m = t + c$$

$$t = \frac{PD}{2(SE + PY)} \dots\dots\dots\dots\dots (1)$$

$$t = \frac{P(d + 2c)}{2(SEW + P(1 - Y))} \dots\dots\dots\dots\dots (2)$$

3. Result & Discussion

3.1. Fire Water Pipe of Train C/D

3.1.1. Visual Inspection

Visual inspection were conducted to 3" and 6" pipes diameter. The conditions of internal pipes are shown in Figure 1.

As shown from Figure 1, internal pipes are still in a good condition. General corrosion occurred on the pipe internal surface slightly. A very thin scale layer was found along the surface area. There was no deposit found that could reduce flow rate of fire water.

Figure 1. Internal Pipe Condition 3" and 6"

3.1.2. Thickness Measurement

Four different pipe samples (3", 6", 12", and 14") were inspected to measure their remaining thickness. Considering the lowest thickness of each pipe size, then the remaining useful life could be estimated by calculating the corrosion rate started from its installation year based on Equation 1 and Equation 2. The calculation was performed with design pressure that applied to the pipe is 12.1 kg/cm^2. Based on the calculation results as shown in Table 3, it can be concluded that 3" and 6" fire water line of Train C/D is still fit for utilization up to 10 years with acceptable internal condition. However, pipe with diameter 12" and 14" should be replaced immediately because it experienced metal thinning badly.

Table 3. Remaining Life Calculation of Fire Water Pipe Train C/D

No.	Pipe Size	Min. Thk. Req. (mm)	Initial Thk. (mm)	Min. Thk. Remaining (mm)	Corossion Rate (mm/year)	Remaining Life (year)
1	3"	0.8301	5.486	4.89	0.01702	238
2	6"	1.1559	7.112	5.73	0.03949	116
3	12"	1.8074	8.382	3.16	0.14920	9
4	14"	2.0246	7.925	2.41	0.15757	245

In addition, during inspection of 14" of fire water pipe of Train C/D, it was found that this pipe was constructed by using ERW type pipe. Additional test, Radiographic Examination, was also conducted to ensure that this pipe is ERW (electric resistance welding) type. This finding confirmed the information that during the construction of Train A/B/C/D, specification of fire water pipe with size of 14" up to 24" are SCH 10 API 5L-B **ERW**. While the current PTB spec is PIPE BE STD CS API 5L-B **SAW** [5]. Refers to ASME B31.3, ERW pipe has less welding joint efficiency than SAW [6]. Therefore, as also on memorandum 405/BM33/2009-334, ERW pipe potentially lead to pipe burst with combination to internal corrosion. Since 14" fire water pipe of Train C/D is heading toward KOD Plant-21, it is strongly recommended to replace the pipe by using current specification pipe.

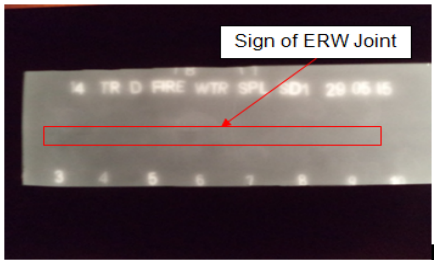

Figure 2. Radiographic Examination of 14" Train C/D

3.2. Fire Water Pipe of Train E

3.2.1. Visual Inspection

Visual inspections was conducted to pipes with diameter 4" and 6". The conditions of internal pipes are shown by Figure 3.

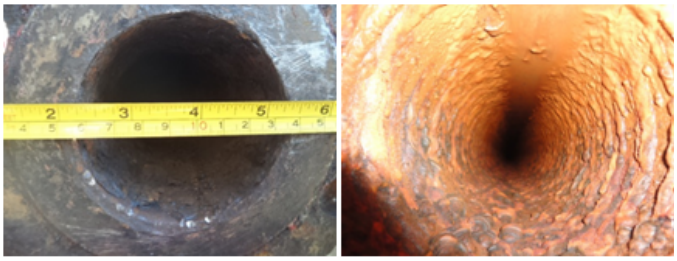

Figure 3. Internal Pipe Condition 3" and 6"

As shown by Figure 3, internal pipes are still in a good condition. General corrosion occurred on the pipe internal surface [7]. On 3" pipe, a very thin scale layer was found along the surface area. There was no deposit found that could reduce flow rate of fire water. While, on 6" pipe, it was found scale and deposit with 5 mm thickness, which is considered acceptable.

3.2.2. Thickness Measurement

Four different pipe samples (4", 6", 12", and 14") were inspected to measure their remaining thickness. Considering the lowest thickness of each pipe size, then the remaining useful life could be estimated by calculating the corrosion rate started from its installation year based on Equation 1 and Equation 2. The calculation was done with design pressure that applied to the pipe is 12.1 kg/cm^2. Based on the calculation as shown by Table 4, it can be concluded that all of the pipes are corroded. However, based on their remaining thickness, all pipes are still acceptable to be operated until more than 10 years.

Table 4. Remaining Life Calculation of Fire Water Pipe Train E

No.	Pipe Size	Min. Thk. Req. (mm)	Initial Thk. (mm)	Min. Thk. Remaining (mm)	Corossion Rate (mm/year)	Remaining Life (year)
1	3"	0.8301	5.486	3.8	0.05879	49
2	6"	1.1559	7.112	5.9	0.04329	110
3	12"	1.8074	8.382	5.84	0.09079	44
4	14"	2.02	7.925	7.72	0.00732	47

3.3. Fire Water Pipe of Utilities I

For utilities I, the only pipe that was assessed for its remaining life is 10 inch pipe. The assessment was done by using B-scanning method. Considering the lowest thickness, then the remaining useful life could be estimated by calculating the corrosion rate started from its installation year based on Equation 1 and Equation 2.The calculation was done with design pressure that applied to the pipe is 12.1 kg/cm^2. As shown by Table 5, the pipe was badly corroded and the remaining life estimated is to be 8 years. Since the 10" pipe is represented 12" pipe, then 10" and 12" are recommended to be replaced.

Table 5. Remaining Life Calculation of Fire Water Pipe Utilities I

No.	Pipe Size	Min. Thk. Req. (mm)	Initial Thk. (mm)	Min. Thk. Remaining (mm)	Corossion Rate (mm/year)	Remaining Life (year)
1	10"	1.5902	7.798	2.6	0.12678	8

3.4 Fire Water Pipe of Utilities II

3.4.1. Visual Inspection

Visual inspection was conducted to pipe with diameter 4". The condition of internal pipeis shown by Figure 4.

Figure 4 . 4" Pipe Internal Condition

As shown by Figure 4, internal pipe of 4" pipe was badly corroded. It was found scale, which is corrosion product of steel, and also deposit. Thickness of scale and deposit that were found is 1.5 cm. Water stagnant inside the pipe is suspected to be the root cause. Scale and deposit lead to pipe diameter reduction (30% of initial diameter). Assuming that pressure of fire water system is maintained constant, this condition will lead to flow rate (Q) reduction up to 50%. In case of fire, the piping system will not able to supply 10 liters/min.m^2 of water for major equipment as required on PTB General Specification. By the result of 4" pipe internal assessment, it is recommendedto replace all 2" – 4" pipes at Utilities II.

3.2.2. Thickness Measurement

Three different pipe samples (4", 12", and 14") were inspected to measure their remaining thickness. Considering the lowest thickness of each pipe size, then the remaining useful life could be estimated by calculating the corrosion rate started from its installation year based on Equation 1 and Equation 2. The calculation was done with design pressure that applied to the pipe is 12.1 kg/cm^2. Based on the calculation as shown by Table 6, it can be concluded that all of the pipes are corroded. However, based on their remaining thickness, all pipes are still able to be operated until more than 10 years.

Table 6. Remaining Life Calculation of Fire Water Pipe Utilities II

No.	Pipe Size	Min. Thk. Req. (mm)	Initial Thk. (mm)	Min. Thk. Remaining (mm)	Corossion Rate (mm/year)	Remaining Life (year)
1	4"	0.9387	6.02	2.83	0.11393	17
2	12"	1.8074	8.382	5.9	0.04329	110
3	14"	2.02	7.925	7.12	0.02875	77

3.5. Fire Water Pipe of Loading Dock 1

For loading dock 1, the only pipe that was assessed for its remaining life is 10" pipe. It is also represented 12" pipe at this area. The assessment was done by using B-scanning method. Considering the lowest thickness, then the remaining useful life could be estimated by calculating the corrosion rate started from its installation year based on Equation 1 and Equation 2 .The calculation was conducted with design pressure that applied to the pipe is 12.1 kg/cm^2. As shown by Table 7, the pipe was badly corroded and the remaining life estimated is to be 86 years.

Table 7.Remaining Life Calculation of Fire Water Loading Dock 1

No.	Pipe Size	Min. Thk. Req. (mm)	Initial Thk. (mm)	Min. Thk. Remaining (mm)	Corossion Rate (mm/year)	Remaining Life (year)
1	10"	1.5902	7.798	5.89	0.04654	86

4. Conclusions

Based on the inspection results and also data analysis, there are several importance points that should be considered, as follow:

- Generally, internal condition of fire water pipeis considered to be in good condition, except 4" inch pipe at Utilities II that experienced bad scaling that lead to reduction of its diameter
- There are several pipe lines that have remaining life less than 10 (ten) years, they are 10" and 12" pipe of Train C/D, 14" pipe of Train C, and 10" and 12" pipe of Utilities I

It was confirmed that ERW pipe type on 14" pipe of Train C is ERW type that may lead to similar burst problem as occurred in 2014 and 2018

5. Acknowledgment

This work was supported in part by Vocational School of Diponegoro University.

References

[1] Hamdun, Ibnu. 2011. Laporan Praktikum Non Destructive Testing (NDT) Magnetic Particle Inspection (MPI)

[2] Sudarmawan, Panji. 2013. Laporan Praktikum Non Destructive Testing Ultrasonic Testing (UT)

[3] API 574, 2009. Inspection Practices for Piping System Components, Washhington DC

[4] API 570, 2009. Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping System, API Publishing Services, Washington DC

[5] PT Badak LNG, PTB General Specification Piping Material Class

[6] ASME B31.3, 2004. Process Piping, New York

[7] API 571, 2003. Damage Mechanisms Affecting Fixed Equipment in the Refining Industry, Washington DC