ANALYSIS REMANING LIFE ASSESSMENT (RLA) SHELL 1st STAGE SEPARATOR USING API 510 STANDARD

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Abstract

This study aims to conduct a Remaining Life Assessment (RLA) on the shell 1st stage separator. The process is carried out through the stages of calculating the minimum permissible shell thickness, MAWP, corrosion rate, and determining the operational feasibility of the separator. The method used is non-destructive test (NDT) inspection to determine the minimum actual thickness. Calculations were made using the API 510 standard. Based on the evaluation of the minimum thickness and MAWP value, the 1st separator shell is still feasible to operate. The ST corrosion rate that occurred in 2012, 2016, and 2019 was 0.123 mm/year, respectively; 0.007 mm/year; and 0.023 mm/year. While the LT corrosion rate is 0.089 mm/year, RLA analysis shows that the remaining life in 2012 was 93.75 years, 93.42 years in 2016, and 92.63 years in 2019. Thus, the shell 1st stage separator is still feasible to operate.
Keywords: RLA, Corrosion, Shell Separator, NDT, Pressure Vessel

I. Introduction

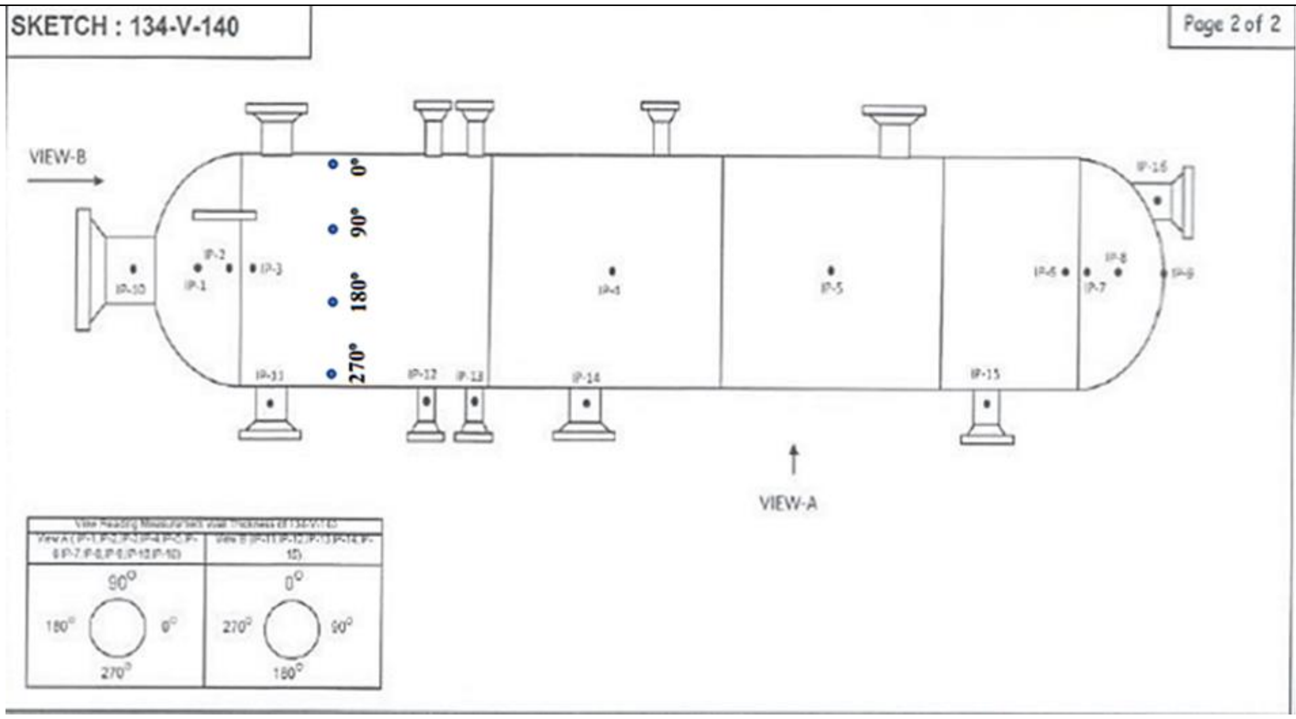
Oil and natural gas are important commodities for Indonesia. These two energies play an important role in people's daily lives. A pressure vessel, or pressure vessel, is a pressure storage device in the form of a closed tube. Pressure vessels can accommodate pressure from within or from outside the vessel (LAI, 2019). Pressure vessels can experience a decrease in quality, which can hinder their performance. This can be caused by corrosion on the pressure vessel.

According to Fontana (1987), the definition of corrosion is damage to a material due to a reaction with the environment. Corrosion is usually associated with metallic materials, but corrosion can occur in metallic and non-metallic materials. Examples of corrosion against non-metals are found in materials such as ceramics, plastic, rubber, and other non-metallic materials (Cicek, 2014). An example of a work accident in the oil and gas industry is an oil pipe leak due to corrosion that occurred in 2021, which was experienced by PT Chevron Pacific Indonesia. The leak was caused by corrosion on February 2, 2021, at Dermaga 4 Pelabuhan Dumai, Riau, resulting in an oil spill reaching 8.4 barrels in these waters. Head of the Special Task Force for Upstream Oil and Gas Business Activities (SKK MIGAS) and Communications Division, Susana Kurniasih, said that the affected areas are sea waters with an affected area of ±358 m^2 and coastal areas with an area affected by oil spills of ±15 m. This incident explains the importance of regular inspections of equipment in the oil and gas industry so that pipe leaks like this can be anticipated (Anisatul Umah, 2021).

One method that can be used to avoid incidents that could result in loss of life or failure that occurs suddenly (catastrophic failure) (Yushandiana, Setiana dan Pujiyulianto, 2020; Pujiyulianto *et al.,* 2022) namely by conducting an assessment called the Remaining Life Assessment (RLA) (Corleto dan Hoerner, 2021)). Remaining Life Assessment (RLA) is an attempt to measure and predict the remaining useful life of a tool. In this way, we can find out the time limit for using a component. Apart from that, this method is also used to identify the condition of equipment and whether it is suitable for use or not for a certain period of time. RLA analysis varies depending on the type of component, operating conditions, and the type of damage mechanism that occurs. RLA is often used in industrial components such as pipes, tanks, pressure vessels, turbines, and other components (Abushik *et al.*, 2018; Zecheru *et al.*, 2018). RLA is important because it is related to the safety aspects of human resources (workers), the reliability of equipment, and the environment (Rozie, 2022). The assessment standard that is often used is the API 510 standard, which is intended for pressure equipment such as pressure vessels and pipes. The API 510 standard can be used as an appropriate guide to evaluate damage and defects in pressure vessel structures, piping systems, and storage tanks (LAI, 2019). Based on this description, this study aims to perform RLA using API Standard 510 on shell 1st stage separator type pressure vessels. Images of the 1st stage separator shell that will be evaluated are shown in **Figures 1a-b.**

The shell 1st stage separator component functions to separate the oil and water fractions before being discharged into the surrounding environment so as not to cause pollution or with the aim of producing a certain liquid according to the desired product in the oil and gas sector. The 1st stage separator shell component has been in operation since 1997, which means that the component has been in operation for ± 22 years until 2019. The Shell 1st Stage Separator at PT. XYZ is designed with a thickness of 31.75 mm and an inner diameter of 2134.11 mm. In detail, the technical specification data is shown in **Table 1.**

Several stages of the RLA process will be carried out, namely evaluating the minimum thickness of the 1st stage separator shell, knowing the MAWP (maximum allowable working pressure) value, and finally evaluating the remaining life assessment (RLA). The end result of the evaluation is to determine the operational feasibility of the component.



(a)

(b)

Figure 1. Shell 1st Stage Separator (a) Shell 1st Stage Separator Technical Drawings and NDT Test Points; (b) Photographs of Shell 1st Stage Separator components in the field.

Table 1. Technical Data Shell 1st Stage Separator

Shell 1st Stage Separator Specifications		
1	Location	PT. XYZ
2	Serial Number.	-
3	Description	1st Stage Production Separator
4	Design Pressure (P)	28,12 kg/cm^2
5	Inside Diameter	2134,11 mm
6	Inside Radius	1067,05 mm
7	Material Shell	SA-516 Gr.70
8	Tensile Stress Shell	1406,156 kg/cm^2
9	Joint Eff. Shell (E)	1,00
10	Corrosion Allowance	3,30 mm
11	Year Built	1997
12	Actual thickness when it built	31,75 mm (1,25 Inch)
13	Previous Inspection	2012, 2016 dan 2019
14	Actual Thickness (2012)	29,90 mm
15	Actual Thickness (2016)	29,87 mm
16	Actual Thickness (2019)	29,80 mm
17	MAWP operations	400 psig = 2.76 Mpa

II. Methodology

2.1 Data Collection

Data collection was obtained from all technical documents for the 1st stage separator components. Apart from technical documents, some data that must be known is inspection data from previous years. The inspection data obtained are data for 2012, 2016, and 2019. All the data needed, both technical data and inspection data, is summarized in **Table 1.** These data are used as a reference for carrying out the testing process and determining the component's remaining life assessment (RLA).

2.2 Evaluation of Remaining Life Assessment (RLA) API 510

The first is collecting actual minimum thickness data from NDT UT testing results (t_{ac_min}) in previous years. After obtaining the minimum thickness results, the second process is to determine the loss that occurs in the component. Loss is calculated based on the actual thickness ($t_{initial}$) from the technical specifications when the component was made, as shown in **Equation 1** below.

$$Loss = t_{initial} - t_{min} \quad (1)$$

The third process is calculating the minimum thickness allowed based on the longitudinal (t^{C}_{min}) and circumferential (t^{C}_{min}) directions. The equation that can be used to determine these two values is shown in **Equations 2-4**.

Minimum thickness in the circumferential direction;

$$t^{C}_{min} = \frac{P.R_c}{(S.E) - (0{,}6.P)} \quad (2)$$

$$R_c = R_i + Loss \quad (3)$$

Minimum thickness in the longitudinal direction;

$$t^{L}_{min} = \frac{P.R_c}{(2.S.E) + (0{,}4.P)} \quad (4)$$

To determine R_C, the loss value used is the maximum loss value. So, the minimum thickness taken is between the longitudinal thickness and the circumferential thickness, namely the thickness that has the largest value. The theory is shown in **Equation 5** as follow.

$$t_{req} = \left[t^{C}_{min}, t^{L}_{min}\right] \quad (5)$$

The final process is determining the suitability of the component based on the minimum allowable thickness (t_{req}) with minimum thickness data from NDT test data, as shown in **Equations 6-7**. If;

$t_{ac\_min} \geq t_{req}$, 'Feasible (6)
$t_{acc\_min} < t_{req}$, 'Not feasible (7)

After determining the feasibility based on thickness, the next evaluation is based on the MAWP value. MAWP determination is based on the API 510 standard using **Equations 8–9**. **Equation 8** is used to calculate the MAWP in the circumferential direction, and **Equation 9** is used to calculate the MAWP in the longitudinal direction.

MAWP is based on circumferential direction:

$$MAWP^C = \frac{S.E.t_{ac\_min}}{(R_i + (0,6.t_{ac\_min}))} \quad (8)$$

MAWP based on longitudinal direction:

$$MAWP^L = \frac{2.S.E.t_{ac\_min}}{(R_i - (0,4.t_{ac\_min}))} \quad (9)$$

The MAWP value that will be used is the minimum MAWP value between the MAWP values in the circumferential and longitudinal directions. This can be seen mathematically in **Equation 10.**

$$MAWP = [MAWP^C, MAWP^L] \quad (10)$$

The final process for determining the feasibility of components based on the MAWP value is shown in equations 11–12. If;

MAWP ≥ MAWP Operation, 'Feasible (11)
MAWP < MAWP Operation, 'Not feasible (12)

After the feasibility evaluation process is based on the thickness and MAWP values, the next step is to calculate the corrosion rate. The equation used to calculate the corrosion rate (CR) is shown in **Equation 13.**

$$CR = \frac{t_{previous} - t_{ac\_min}}{time\ between\ t_{previous}\ and\ t_{ac\_min}} \quad (13)$$

The residual life value (remaining life) of components can be calculated using **Equation 14.**

$$RL = \frac{t_{ac\_min} - t_{req}}{CR} \quad (14)$$

III. Results and Discussions

3.1 Inspection results using NDT UT

NDT testing was done using the ultrasonic testing (UT) method. This test was carried out to determine the thickness of the 1st stage separator shell during the operating period. NDT tests were carried out in 2012, 2016, and 2019. Based on the data collected and summarized in Table 1, it is known that the shell thickness has reduced to a minimum of 29.8 mm at the last inspection in 2019 compared to the initial thickness of 31.75mm, while the minimum thickness in the 2012 and 2016 inspections was 29.90 mm and 29.87 mm. The minimum thickness data from the results of this inspection will be a reference for determining the feasibility of operation and the remaining life of this component. The comparison data for the minimum thickness of the 1st stage separator shell inspection results in 2012, 2016, and 2019 are shown graphically in **Figure 2.**

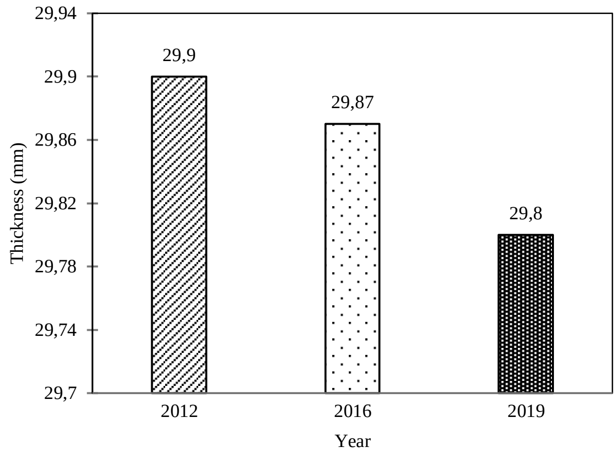


Figure 1. Comparison of the minimum thickness of the 1st stage separator shell in 2012, 2016 and 2019.

3.2 The analysis of the minimum thickness of the shell of the 1st stage separator

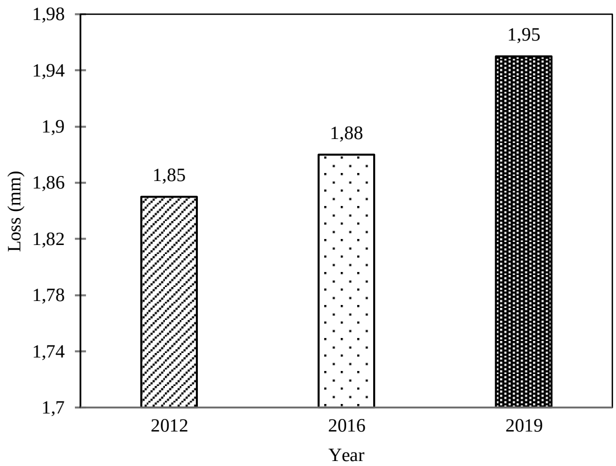


Figure 2. Comparison of loss values at the shell 1st stage separator in 2012, 2016 and 2019

Based on the data in **Table 1**, the material used is SA 516 Grade 70 – Carbon Steel (ASTM) (S.li, "ASME section II: Material Parts", 2015). Based on ASME Section II Part A, the material SA 516 Grade 70 – Carbon Steel (ASTM) has a tensile strength and yield strength of 485–650 MPa and 260 MPa, respectively. This value is used as a reference in calculating the minimum thickness and MAWP.

The obtained minimum thickness (t_{mm}) based on API 510 refers to API 579 of the standard ASME Section VIII Div. 1 year 2019 Part UG-27 (ASME Section VIII Division 1, 2019). The minimum thickness is determined using **Equations 1-4**. The method of using this equation has also been used in several studies (Ismar *dkk.*, 2014). The initial parameter value that is calculated is the loss value. From **Equation 1**, the resulting loss in 2012, 2016, and 2019 is 1.85 mm, 1.88 mm, and 1.95 mm. These results indicate that the loss in 2019 was the largest compared to the loss in the previous year's inspection. This occurs because of the phenomenon of surface thinning due to corrosion, which is increasingly occurring in the 1st stage separator shell. Graphically, the comparison of loss values in the 1st stage separator shell is shown in **Figure 3.**

The minimum thickness (t_{min}) and required thickness (t_{req}) values have been calculated using **Equations 1–5**. The results of the calculation of the minimum thickness in the longitudinal and circumferential directions are 21.59 mm and 10.62 mm. The thickness values in these two directions are determined from inspection data for the smallest minimum thickness, namely 2019. Graphically, the comparison of minimum thickness values is shown in **Figure 4**. The required thickness (t_{req}) can be determined through Equation 5. The required thickness (t_{req}) is obtained from the maximum value between the thickness values in the longitudinal and circumferential directions. Thus, the t_{req} used is the thickness in the longitudinal direction of 21.59 mm.

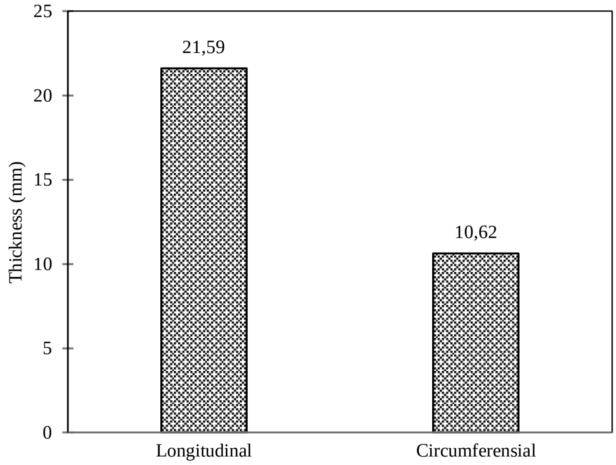


Figure 3. Comparison of the value of the minimum thickness of the 1st stage separator shell in the longitudinal and circumferential directions.

The next stage is the process of evaluating the feasibility of the shell 1st stage separator based on the thickness value (t_{req}) that has been obtained. The determination of feasibility is carried out using **Equations 6-7**. Based on calculations, the actual minimum thickness (t_{ac_min}) inspection results in 2012, 2016, and 2019 still meet eligibility. The detailed comparison results are shown in **Table 2.**

The feasibility value of the actual minimum shell thickness of the 1st stage separator as a result of inspections in 2012, 2016, and 2019 meets the safe requirements to continue the operational process. All of these thickness values are still above the permissible thickness value (t_{req}), which is 21.59 mm. This result is in accordance with the provisions of **Equations 6-7**. Thus, the actual minimum thickness can then be used to evaluate the MAWP, corrosion rate, and remaining life of the 1st stage separator shell component (Khoirul dkk., 2017; Suryono dkk., 2019).

Table 1. The comparison of the feasibility of the actual minimum thickness of the 1st stage separator shell in 2012, 2016, and 2019.

Year	Location	t_{req} (mm)	Minimum actual thickness (mm)	Status
2012	Shell	21,59	29,90	Feasible
2016	Shell	21,59	29,87	Feasible
2019	Shell	21,59	29,80	Feasible

3.3 The MAWP on Shell 1st Stage Separator

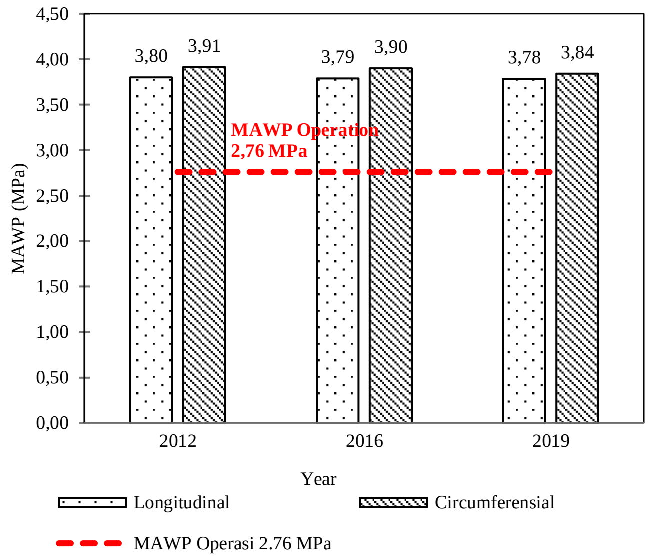


Figure 4. Comparison of the feasibility of MAWP with MAWP Operations on the 1st Stage Separator Shell in 2012, 2016, and 2019.

The next evaluation was the MAWP. The MAWP is calculated by **Equations 8–9**. The calculation results show that the $MAWP^c$ in 2012, 2016, and 2019 was 3.91 MPa, 3.90 MPa, and 3.84 MPa. While the $MAWP^L$ is 3.80 MPa, 3.79 MPa, and 3.78 MPa, based on **Equation 10**, the MAWP value taken is the smallest MAWP value among the MAWP values in the longitudinal and circumferential directions. Therefore, the MAWP values taken are the $MAWP^L$ values in 2012, 2016, and 2019, respectively, with the lowest MAWPL values among all, namely in 2019 of 3.78 MPa. To evaluate feasibility based on MAWP using **Equations 11–12** compared to operating MAWP based on data obtained in **Table 1**, graphically detailed comparisons of $MAWP^C$ and MAWPL values in 2012, 2016, and 2019 with operating MAWP are shown in **Figure 5**. It can be said that all MAWP values are still above the operating MAWP. Thus, these components are still feasible to operate.

3.4 Corrosion Rate Calculation

Corrosion rate calculations refer to API 510. Short-time (ST) corrosion rates, i.e., the two most recent thickness readings or inspections. Meanwhile, the long-term (LT) corrosion rate, which uses the latest thickness reading or inspection and thickness data at the beginning of the component's life (LAI, 2019). The general corrosion rate calculation uses **Equation 13**. The calculation results are shown graphically in **Figure 5**, namely that the short-term (ST) corrosion rate in 2012 was 0.123 mm/year, in 2016 it was 0.007, and in 2019 it was 0.023 mm/year. The ST corrosion rate in 2012 was significantly different compared to the ST corrosion rates in 2016 and 2019. However, in general, the value of the corrosion rate along with the length of operating time will increase when viewed from the ST corrosion rate values between 2016 and 2019. This is due to changes in shell thickness. The greater the thickness reduction, the higher the corrosion rate (Jalaluddin, 2015). In addition, when viewed from the long-term (LT) corrosion rate, this component experiences corrosion with a corrosion rate of 0.089 mm/year. Detailed comparisons of ST corrosion rates in 2012, 2016, and 2019 and LT corrosion rates can be seen in **Figure 6** below.

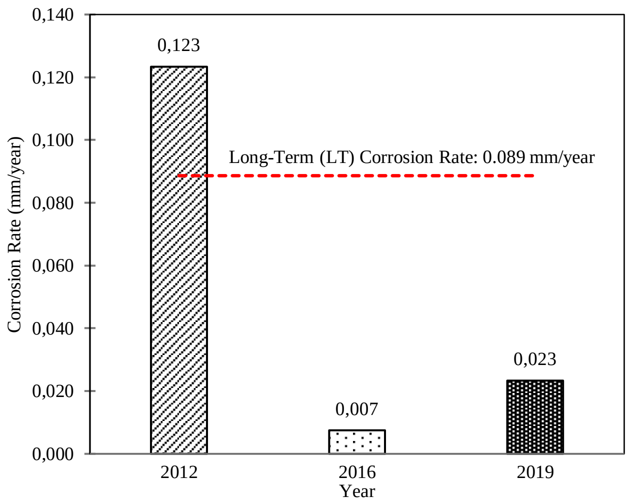


Figure 5. Comparison of 1st Stage Separator shell corrosion rate values in 2012, 2016, and 2019.

The 1st Stage Separator is located onshore in an open environment so that it is exposed to non-uniform temperatures and weather conditions and contains a mixture of oil and water fluids that must be separated. The separation process in the separator also varies, such as the principle of pressure drop, flow turbulence, fluid splitting, and the principle of gravity settling chamber (Proxsis, 2015). So that the operating conditions in this separator can help the growth of the corrosion rate. Meanwhile, crude oil affects the corrosion rate of carbon steel pipes and galvanized pipes. When mixed with water, it will increase the corrosion rate. The level of corrosiveness of petroleum is influenced by the type and composition of crude oil (Hadi and Jumarlis, 2013).

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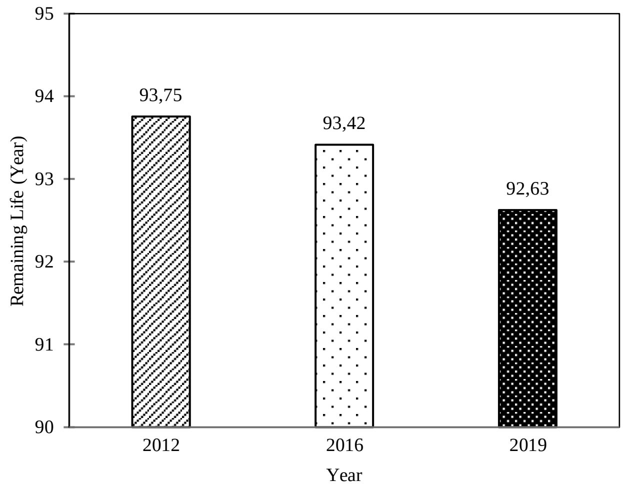

Figure 6. Comparison of the remaining life of the 1st stage separator shell in 2012, 2016, and 2019.

3.5 Remaining Life Assessment (RLA)

Remaining Life Assessment (RLA), or estimation of the remaining life of the 1st stage separator using equation 14. However, the corrosion rate value used is the LT corrosion rate, which is 0.089 mm/year. The LT corrosion rate is used because it can represent the average corrosion rate from the reading of the minimum shell thickness at the last inspection, namely in 2019, compared to the initial thickness of the component made. The RLA calculation results show that the remaining lives of the 1st stage separator components in 2012, 2016, and 2019 are 93.75 years, 93.42 years, and 92.63 years, respectively. Thus, this component can be said to still be suitable for operation in accordance with existing operating provisions and standards. Graphically, a comparison of the remaining life of the 1st stage separator shell is shown in **Figure 7**. A summary of the analysis results in this research using the API 510 standard is shown in **Table 3**.

Table 2. Summary of Operational Feasibility Analysis Results of 1st Stage Separator Components

Description	1st Stage Separator		
	2012	2016	2019
	Shell	Shell	Shell
Operating (year)	15	19	22
t_{ac_min} (mm)	29,90	29,87	29,80
MAWP Operation (MPa)	2,76	2,76	2,76
Inside Radius (mm)	1067,05	1067,05	1067,05
Weld Joint Efficiency	1	1	1
t_{req} (mm)	21,59	21,59	21,59
Metal Loss (mm)	1,85	1,88	1,95
MAWP minimum (MPa)	3,80	3,79	3,78
Corrosion Rate ST (mm/Year)	0,123	0,007	0,023
Corrosion Rate LT (mm/ Year)	0,089	0,089	0,089
Remaining Life (Year)	93,75	93,42	92,63
Safe to Operate, if ; $t_{ac\ min} > t_{req}$	Safe	Safe	Safe

IV. Conclusion

The evaluation of the remaining life of the shell 1st stage separator using the API 510 standard has been carried out. The conclusion from this research is that the total loss in 2012, 2016, and 2019 was 1.85, 1.88, and 1.95 mm, respectively. The corrosion rate (ST) that occurred on the 1st stage separator shell in 2012, 2016, and 2019 was obtained 0.123 mm/year, 0.007 mm/year, and 0.023 mm/year, respectively. While, the value of the corrosion rate (LT) ranges from 0.089 mm/year. Based on that, the evaluation of the minimum thickness and MAWP value, the 1st stage separator shell is still suitable for operation. Analysis of the remaining life of the 1st stage separator shell shows that the remaining life of the 1st stage separator shell in 2012 was obtained 93.75 years, in 2016 it was 93.42 years, and in 2019 it was 92.63 years, respectively. Thus, the 1st stage separator shell can still be operated.

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