Study of Failure Risk on the Utilities Unit of Oil Production PT Kilang Pertamina International RU IV Cilacap by Using Failure Mode and Effect Analysis (FMEA) Method

Rachmat Sugiarto and Mas Agus Mardyanto
Department of Environmental Engineering, Institut Teknologi Sepuluh Nopember Surabaya (ITS)
e-mail: mardyanto@enviro.its.ac.id

***Abstract*—The Utilities Unit at Pertamina RU IV Cilacap is all materials/media/facilities needed to support refinery processing operations such as electricity, steam, cooling water, clean water, compressed air, fuel, and raw water. The Utilities Unit is one of the units that has an important role in oil production at PT Pertamina International Refinery RU IV Cilacap, so it is necessary to maintain the quality and quantity of production so that there is no sudden shutdown in the Utilities Unit. Failures that may occur can be detrimental in terms of very expensive equipment repairs and can hinder the process of existing facilities such as the cessation of water treatment. Using the Fishbone Analysis and Failure Mode and Effect Analysis (FMEA) method, this research determines the risk of failure in the petroleum processing process at the Utilities unit of PT Pertamina International RU IV Cilacap Refinery. The greatest risk of failure that arises based on the calculation of the Risk Priority Number (RPN) value will be used to determine alternative recommendations for improvements. The source of failure is obtained from 2 factors, namely from the machine and material factors. The Material factor is characterized as an aspect of product quality determined by the parameter indicators of each product, while the machinery factor can be classified as an aspect of the operating conditions of each unit. The biggest risk of failure based on the Risk Priority Number (RPN) results in the Sea Water Desalination unit with a value of 60 (low category). The suggested mitigation is by checking and monitoring chemical injections and cleaning evaporators.**

Keywords—Failure Mode and Effect Analysis (FMEA), Fishbone Analysis, Risk Priority Number (RPN), Utilities Unit.

I. INTRODUCTION

PETROLEUM is a key natural resource in Indonesia, serving both domestic needs and contributing to foreign exchange through exports. With the country's growing economy and construction activities, the demand for energy, primarily from petroleum, is on the rise. The total amount of oil produced from the depths of the ground in various parts of Indonesia around 915,798 million barrels/day [1]. The current domestic demand for gasoline is 1.4 million barrels per day.

The PT Kilang Pertamina Internasional RU IV Processing Unit is a significant refinery in Indonesia with the country's largest production capacity of 348,000 barrels/day. It plays a crucial role by supplying 34% of the national fuel demand and 60% of Java Island's fuel demand.

The Utilities Unit at Pertamina RU IV Cilacap provides essential materials and facilities like electricity, steam, cooling water, clean water, compressed air, fuel, and raw water to support refinery processing. Procuring utilities independently is crucial for continuous supply, especially in fuel oil and petrochemical refinery operations. The Utilities Unit plays a vital role in oil production at PT Kilang Pertamina International RU IV Cilacap, emphasizing the need to maintain production quality and quantity to avoid unplanned shutdowns in both the Utilities Unit and other production units [2].

Oil refineries, being complex industrial facilities, face routine challenges due to asset failures, leading to significant accidents. The potential consequences including expensive equipment repairs and disruptions to facility processes, highlight the need to study component failures in production equipment. Failure mode and effects analysis (FMEA) is a widely employed reliability management technique across industries to ensure safety and reliability. FMEA helps evaluate damage risk, identify causes, and develop prevention strategies. In this study, FMEA is applied to determine critical components in the utility unit, aiming to understand and

Table 1.
Data Collection

Data Type	Data Duration	Data origin
Material Balance on each processing unit in the Utilities Unit	(April 2022 – April 2023)	PT Refinery Pertamina International RU IV Cilacap
Operating Conditions at each processing unit in the Utilities Unit	(April 2022 – April 2023)	PT Refinery Pertamina International RU IV Cilacap
Product quality in each processing unit in the Utilities	(April 2022 – April 2023)	PT Refinery Pertamina International RU IV Cilacap

Table 2.
Specifications for Water Condensate Sea Water Desalination Unit

Item	Value
pH	8.5 – 9.5
Conductivity @ 25° C	Max 10 µmhos
Hardness Total	Max 1 ppm as CaCO3

Table 3.
Specification for Product Quality Sea Water Desalination Unit

Item	Value
pH	6.5 – 8.5
Conductivity @ 25° C	Max 25 µmhos
Hardness Total	Max 1 ppm as CaCO3
Chloride	Max 4 ppm

Table 4.
Operation Condition Sea Water Desalination

Parameter	Min	Max	UoM
Conductivity Product		25	uS/cm
Level Blowdown SWD		80	%
Recirculation Flow	250		m3/hr
Temperature Outlet SWD		95	ºC
Vacuum		100	mmHG

Table 5.
Product Quality Softener

Parameter	Target	UoM
pH	6.5-8.5	
Conductivity	25	µmhos
Hardness Total	max 1	ppm
Chloride	max 4	ppm
Fe	max 0.02	ppm
Silica	max 0.02	ppm

Table 6.
Operation Condition Softener

Parameter	Min	Max
Product Water to Soft	900	1500

Table 7.
Product Quality Deaerator

Parameter	Target	UoM
pH	8.3-10	
Conductivity	Max 10	µmhos
Hardness Total	max 0.5	ppm
Chloride	max 4	ppm
Fe	max 0.05	ppm
Silica	max 0.01	ppm
Residual O2	0.2-0.6	ppm

Table 8.
Operation Condition Deaerator

Parameter	Min	Max	UoM
Deaerator Outlet Temperature	135	145	deg C
Deaerator Level	65	90	%
Press BFW	80.5		kg/cm2.g

Table 9.
Feed Quality Boiler

Parameter	Target	UoM
pH @ 25 °C	8.3 – 10	
Hardness	max 0.5	ppm
Conductivity @ 25 °C	max 10	µmhos

Table 10.
Steam Drum Boiler

Parameter	Target	UoM
pH	8.5-9.5	
Conductivity	10	µmhos
Fe	max 0.02	ppm
Silica	max 0.02	ppm

Table 11.
Blowdown Boiler

Parameter	Target	UoM
pH	9.8 – 10.5	
Conductivity @ 25 °C	500	µmhos
Hardness	Max 0.1	ppm
Phospate	10 – 15	ppm
Silica	Max 5	ppm
Cl	Max 30	ppm
Total Alkalinity	Max 150	ppm
Residual 02 Scavenger	Min 0.01	ppm

prevent failures in the manufacturing equipment .[3]

II. RESEARCH DESCRIPTION

A. Data Collection

In this study, all data were obtained from PT Pertamina International Refinery RU IV Cilacap. Secondary data collected can be seen in Table 1.

B. Data Processing and Problem Identification

After obtaining secondary data, the next step is determining machines that has problems. To find this problem, the Fishbone Analysis method. Observation and calculation of the average of each parameter in the sub-cause are then conducted. The next step is finding the biggest problem at each machine and identifying any possible risks happen due to this problem. Finally, mitigation suggestions are given to prevent a decrease in product quality and quantity.

C. Conclusion and Suggestions

Conclusions are the made by considering conducted calculation and analyses. Suggestion for mitigation of the problems as well as suggestion for further research are given.

III. RESULT AND DISCUSSION

A. Fishbone Analysis

A fishbone diagram, a cause-and-effect analysis tool, is utilized to illustrate the intricate interactions of causes contributing to a specific problem or event. This diagram serves as a theoretical framework to explore the sources of innovation. In this context, the fishbone diagram is employed as a graphical tool to investigate and analyze the fundamental causes of the origin and development of general-purpose technologies (GPTs) [4]. The fish bone diagram is shown in Fig 1.

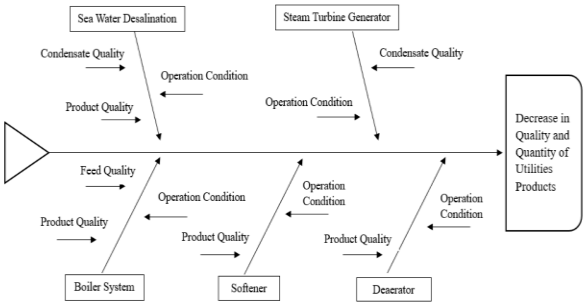

Figure 1. A Fishbone Diagram Analysis to Show Failure and Effect of Each Process.

In this fishbone diagram there are five machines, the first is a sea water desalination machine. In this machine there are three sub-causes, including condensate quality, product quality, and operation condition. For each sub-cause there are quality standards that have been set by PT Kilang Pertamina International RU IV Cilacap itself. The standard can be seen in table 2 until table 14.

Table 13.
Condensate Quality Steam Turbine Generator

Parameter	Target	UoM
pH	8.5-9.5	
Conductivity	10	µmhos
Hardness Total	Nill	ppm
Chloride	max 4	ppm

Table 14.
Operation Condition Steam Turbine Generator

Parameter	Min	Max	UoM
Vacuum STG	50	200	mmHg
Level Surface Condenser	50%	100%	%
Axial Vibration	-15	15	mills

Table 15.
Description of Severity Scale

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The ideal condition to be achieved does not affect the next process	Conditions that create risk can affect the next process, still within the limits of quality standards	Conditions create a risk of causing the function of the unit to be disrupted, it is still the quality standard	Conditions below the quality standard limits, causing production results that will not meet quality standards	The condition is far below the quality standard, causing the production results to not meet the quality standard

B. Failure Mode and Effect Analysis (FMEA)

FMEA helps examine causes of defects, evaluate risks causing work accidents, and facilitates action to avoid identified work accident hazards [5]. The method is user-friendly for risk identification and measurement. It is often to use a scale of 5 for overall severity, occurrence, and detection assessments to ensure consistency in risk analysis [6]. Description of Severity Scale can see Table 15.

Severity assessment for the sea water desalination unit focuses on categories impacting utility unit processing:

Table 16.
Severity of Condensate Quality Unit SWD

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The average value of pH, conductivity, and Hardness in the condensate is not more than 8.9-9.1; 0-2.5 μS/cm; 0-0.25 ppm	The average value of pH, conductivity, and Hardness in the condensate is not more than (8.8-8.89 and 9.11-9.3); 2.6-5 μS/cm; 0.2.6-0.5	The average value of pH, conductivity, and Hardness in the condensate is not more than (8.7-8.79 and 9.31-9.4); 5.1-7.5 μS/cm; 0.51-0.75 ppm	The average value of pH, conductivity, and Hardness in the condensate is not more than (8.5-8.69 and 9.41-9.5); 7.51-10 μS/cm; 0.751-1 ppm	The average value of pH and conductivity, and Hardness in the condensate is outside the range of 8.5-9.5; 10 μS/cm; 1 ppm

Table 17.
Severity of Operation Condition Unit SWD

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The average value of pH, conductivity, Hardness, and Cl are not more than 7.4-7.6; nill μS/cm; 0-0.25 ppm; 0-0.005 ppm	The average value of pH, conductivity, Hardness, and Cl are not more than (7.1-7.39 and 7.61-7.9); 0.1-3.5 μS/cm; 0.26-0.5ppm; 1-2 ppm	The average value of pH, conductivity, Hardness, and Cl are not more than (6.8-7.09 and 7.91-8.2) and 3.51-7.5 μS/cm; 0.51-0.75ppm; 2-3 ppm	The average value of pH, conductivity, Hardness, and Cl are not more than (6.5-6.79 and 8.21-8.5) and 7.51-10 μS/cm; 0.76-0.99 ppm; 3-4 ppm	The average value of pH, conductivity, Hardness and chlorides are outside the range of 6.5-8.5 and 10 μS/cm; ≥1 ppm: 4 ppm

Table 18.
Severity of Product Quality Unit SWD

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The average value of pH, conductivity, Hardness, and Cl are not more than 7.4-7.6; nill μS/cm; 0-0.25 ppm; 0-0.005 ppm	The average value of pH, conductivity, Hardness, and Cl are not more than (7.1-7.39 and 7.61-7.9); 0.1-3.5 μS/cm; 0.26-0.5ppm; 1-2 ppm	The average value of pH, conductivity, Hardness, and Cl are not more than (6.8-7.09 and 7.91-8.2) and 3.51-7.5 μS/cm; 0.51-0.75ppm; 2-3 ppm	The average value of pH, conductivity, Hardness, and Cl are not more than (6.5-6.79 and 8.21-8.5) and 7.51-10 μS/cm; 0.76-0.99 ppm; 3-4 ppm	The average value of pH, conductivity, Hardness and chlorides are outside the range of 6.5-8.5 and 10 μS/cm; ≥1 ppm: 4 ppm

condensate quality, operation condition, and product quality. The assessment begins with the condensate quality category. Severity of Condensate Quality Unit SWD can see Table 16.

Severity value given for this category is 5 (very bad) because of pH = 8.38 (outside the range of pH as shown in Table 2). Severity of Operation Condition Unit SWD can see Table 17.

The severity value for this category is 5 (very bad risk scale) because of Recirculation Flow parameter = 240.86 m3/hr and the vacuum parameter = 106.07 mmHg (outside the range as shown in table 4). Severity of Product Quality Unit SWD c an see Table 18. In this category the severity value given for this category is 5 (Very Big scale) because of conductivity = 10.66 μS/cm (outside the range of conductivity as shown in Table 3). Severity of Product Quality Unit Softener can see Table 19.

Table 19.
Severity of Product Quality Unit Softener

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The of average from pH, conductivity, Silica, Cl, and Fe is not more than 7.4-7.6; 0-6.25 μmhos; 0-0.005 ppm; 0-1 ppm; 0-0.005 ppm	The of average from pH, conductivity, Silica, Cl, and Fe is not more than (7.1-7.39 and 7.61-7.9); 6.26-12.5 μmhos; 0.0051-0.01 ppm; 1-2 ppm; 0.0051-0.01 ppm	The of average from pH, conductivity, Silica, Cl, and Fe is not more than (6.8-7.09 and 7.91-8.2); 12.51-18.75 μmhos; 0.011-0.015 ppm; 2-3 ppm; 0.011-0.015 ppm	The average from pH, conductivity, Silica, Cl, and Fe is not more than (6.5-6.79 and 8.21-8.5); 18.75-25 μmhos; 0.016-0.02 ppm; 3-4 ppm; 0.016-0.02 ppm	The average from pH, conductivity, Silica, Cl, and Fe out of range from 6.5-8.5; 25 μmhos; 0.02 ppm; 4 ppm; 0.02 ppm

Table 20.
Severity of Operation Condition Unit Softener

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The average value of Product Water to Softener are not more than 1200-1300 ton	The average value of Product Water to Softener are not more than (1100-1199) & (1300-1375) ton	The average value of Product Water to Softener are not more than (1000-1099) & (1376-1450) ton &	The average value of Product Water to Softener are not more than (900-1000) & (1450-1500) ton	The average valu Product Water to Softener are outsi the range of 900-1 ton

Table 21.
Severity of Product Quality Unit Deaerator

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
Average value of pH, conductivity, Silica, Cl, and Fe, Residual O2, and hardness is not more than (9.1-9.2); 0-2.5 μmhos; 0-1 ppm; 0-0.015; 0.2-0.3 ppm; 0-0.15 ppm	Average value of pH, conductivity, Silica, Cl, and Fe, Residual O2, and hardness is not more than (8.8-9.09 and 9.21-9.5); 2.51-5 μmhos; 1-2 ppm; 0.016-0.025; 0.31-0.4 ppm; 0.16-0.25	Average value of pH, conductivity, Silica, Cl, and Fe, Residual O2, and hardness is not more than (8.5-8.79 and 9.51-9.79); 5.1-7.5 μmhos; 2-3 ppm; 0.026-0.035;0.41-0.5 ppm; 0.26-0.35	Average value of pH, conductivity, Silica, Cl, and Fe, Residual O2, and hardness is not more than (8.3-8.49 and 9.8-10); 7.51-10 μmhos; 3-4 ppm; 0.036-0.05; 0.51-0.6 ppm; 0.36-0.5	Average value of pH, conductivity, Silica, Cl, and Fe, Residual O2, and hardness is out of range in (8.3-10); 10 μmhos; 4 ppm; 0.05 ppm; 0.01 ppm; (0.2-0.6) ppm; 0.5 ppm

In this category, the severity value given for this category is 3 (Medium risk scale) because of pH = 7.11; conductivity = 9.48 μmhos; Silica = 0.015; Chloride = 1.32; and Fe = 0.014. Severity of Operation Condition Unit Softener can see Table 20.

Table 22.
Severity of Operation Condition Unit Deaerator

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The average value of Deaerator Outlet Temperature; Deaerator Level; Press BFW are not more than 138-142°C; 74-81%	The average value of Deaerator Outlet Temperature; Deaerator Level; Press BFW are not more than (137-137.9°C) & (142.1-143°C)-140°C; (71-73.9)&(81.1-84)%	The average value of Deaerator Outlet Temperature; Deaerator Level; Press BFW are not more than (136-136.9°C) & (143.1-144°C); (68-70.9)&(84.1-87)%	The average value of Deaerator Outlet Temperature; Deaerator Level; Press BFW are not more than (135-135.9°C) & (144.1-145°C); (65-67.9)&(87.1-90)%	The average value of Deaerator Outlet Temperature; Deaerator Level; Press BFW are outside range from 135-145°C; 65-90%; 80.5 kg/cm2.g;

Table 23.
Severity of Feed Quality Boiler

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
Average value of pH, conductivity, and Hardness not more than (9.1-9.2); 0-2.5 µmhos; 0.15 ppm	Average value of pH, conductivity, and hardness not more than (8.8-9.09 and 9.21-9.5); 2.51-5 µmhos; 0.16-0.25	Average value of pH, conductivity, and hardness not more than (8.5-8.79 and 9.51-9.79); 5.1-7.5 µmhos; 0.26-0.35	Average value of pH, conductivity, and hardness not more than (8.3-8.49 and 9.8-10); 7.51-10 µmhos; 0.36-0.5	Average value of pH, conductivity, and hardness outside the range of (8.3-10); 10 µmhos; ppm; 0.5 ppm

Table 24.
Severity of Condition Operation Boiler

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The average value of Boiler Drum Pressure, Level Steam Drum Boiler, Pressure FO, and Combustion Air are not more than 57.5-60.5 kg/cm^2; 33-38%; ; 3.2-4.9 t/hr; 40-50 t/hr	The average value of Boiler Drum Pressure, Level Steam Drum Boiler, Pressure FO, and Combustion Air are not more than (57-57.49)&(60.51-61) kg/cm^2; (31-32.9)&(38.1-40)%; 4.91-6.6 t/hr; 51-60 t/hr	The average value of Boiler Drum Pressure, Level Steam Drum Boiler, Pressure FO, and Combustion Air are not more than 56.5-56.99)&(61.1-61.5) kg/cm^2; (29-30.9)&(41-43)%; 36.6-40.75; 6.61-8.3 t/hr; 61-70 t/hr	The average value of Boiler Drum Pressure, Level Steam Drum Boiler, Pressure FO, and Combustion Air are not more than (56-56.49)-(61.6-62) kg/cm^2; (28-28.9)&(43.1-45)%; 8.31-10 t/hr; 71-80 t/hr	The average value of Boiler Drum Pressure, Level Steam Drum Boiler, Pressure FO, and Combustion Air are outside range of 56-62 kg/cm^2; 28-45%; 2-6.5 kg/cm^2; 3.2-10 t/hr; 40-80 t/hr

Table 25.
Severity of Steam Drum Product Quality Boiler

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The average value of pH, conductivity, Silica, and Fe is not more than (8.9-9.1); 0-2.5 µmhos; 0-0.005 ppm; 0-0.005 ppm	The average value of pH, conductivity, Silica, and Fe is not more than (8.8-8.89 and 9.11-9.3); 2.51-5 µmhos; 0.0051-0.01 ppm; 0.0051-0.01 ppm	The average value of pH, conductivity, Silica, and Fe is not more than (8.7-8.79 and 9.31-9.4); 5.1-7.5 µmhos; 0.011-0.015 ppm; 0.011-0.015 ppm	The average value of pH, conductivity, Silica, and Fe is not more than (8.5-8.69 and 9.41-9.5); 7.51-10 µmhos; 0.0151-0.02 ppm; 0.0151-0.02 ppm	The average values of pH, conductivity, Silica, and Fe are outside the range of (8.5-9.5); 10 µmhos; ppm; 0.02 ppm; 0.02 ppm

Table 26.
Severity of Blow Down Product Quality Boiler

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
Average value of pH, conductivity, Silica, Cl, and PO_4, Residual O_2, hardness, and Alkalinity not more than (10-10.3); 0-125 µmhos; 0-1.25 ppm; 0-7.5 ppm; 0.0025 ppm; 0-0.15 ppm	Average value of pH, conductivity, Silica, Cl, and PO_4, Residual O_2, hardness, and Alkalinity not more than (9.3-9.99 and 10.31-9.5); 126-250 µmhos; 1.26-2.50 ppm; 7.6-15 ppm; 0.0026-0.005 ppm; 0.16-0.25	Average value of pH, conductivity, Silica, Cl, and PO_4, Residual O_2, hardness, and Alkalinity not more than (8.5-8.79 and 9.51-9.79); 251-375 µmhos; 2.51-3.75 ppm; 15-22.5 ppm; 0.0051- 0.0075 ppm; 0.26-0.35	Average value of pH, conductivity, Silica, Cl, and PO_4, Residual O_2, hardness, and Alkalinity not more than (8.3-8.49 and 9.8-10); 376-500 µmhos; 3.76-5 ppm; 22.6-30 ppm; 0.0076-0.01 ppm; 0.36-0.5	Average value of pH, conductivity, Silica, Cl, and PO_4, Residual O_2, hardness, and Alkalinity outside the range of (9.8-10.5); 500 µmhos; 5 ppm; 30 ppm; 10-15 ppm; 0.01 ppm; 0.1 ppm; 150 ppm

The severity value given for this category is 4 (large risk scale) because of pH = 10; Conductivity = 134.6 µmhos; Silica = 1.9; Chloride = 19.6; Phosphate = 11.5; Residual O_2 = 0.044; Hardness = nill; Alkalinity = 15.3.

Table 27.
Severity of Condensate Quality Steam Turbine Generator

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
Average of pH, conductivity, Hardness, Cl on the content, and the Hardness on the condensate is not more than 8.9-9.1 and nill µS/cm; nill; 0-1 ppm	Average of pH, conductivity, Hardness, Cl on the content, and the Hardness on the condensate is not more than 8.8-8.89 and 9.11-9.3 and 0.1-3.5 µS/cm; 1-2 ppm	Average of pH, conductivity, Hardness, Cl on the content, and the Hardness on the condensate is not more than 8.7-8.79 and 9.31-9.4 and 3.51-7.5 µS/cm; 2-3 ppm	Average of pH, conductivity, Hardness, Cl on the content, and the Hardness on the condensate is not more than 8.5-8.69 and 9.41-9.5; and 7.51-10 µS/cm; 3-4 ppm	Average of pH, conductivity, Hardness, Cl on the condensate content outside the range of 8.5-9.5 and 10 µS/cm; nill; 4 ppm

The s everity value for this category is 2 (Good scale) because of the Product Water to Softener parameter with the average value of 1,100 ton. Severity of Product Quality Unit Deaerator can see Table 21.The severity value given for this category is 2 (small risk scale) because of ph = 8.87; conductivity = 6.48 µmhos; silica = 0.007; Chloride = 1.24 ppm; Fe = 0.034; Residual O2 = 0.39; hardness = 0.2. Severity of Operation Condition Unit Deaerator can see Table 22.

Table 28.
Severity of Condition Operation Steam Turbine Generator

Risk Magnitude Scale				
1	2	3	4	5
Environmental Condition Scale				
5	4	3	2	1
Very Good	Good	Middle	Bad	Very Bad
The average value of Vacuum STG; Level Surface Condenser; Axial Vibration not more than 110-140 mmHg; 65-85%; ((-3)-3)) mills	The average value of Vacuum STG; Level Surface Condenser; Axial Vibration not more than (90-109) &(141-160) mmHg; (60-64.9%)&(85.1-90)%; ((-7)-(-2.9)&(3.1-7) mills	The average value of Vacuum STG; Level Surface Condenser; Axial Vibration not more than (70-89)&(161-180) mmHg; (55-59.9)&(90.1-95)%; ((-11)-(-6.9))&(7.1-11) mills	The average value of Vacuum STG; Level Surface Condenser; Axial Vibration not more than (50-69)&(181-200) mmHg; (50-54.9)&(95.1-100)%; ((-15)-(10.9))&(11.1-15) mills	The average value of Vacuum STG; Level Surface Condenser; Axial Vibration are outside the range of 50-200 mmHg; 50-100%; -15 - 15 mills

Table 29.
Assessment of Occurrence

Occurrence	Probability of Risk Occurrence	Ranking
Never	Impossible/least expected failure	1
Seldom	Failure can be resolved and does not affect the next process	2
Often enough	Failures affect continuing processes but not to a large extent or to have a significant impact	3
Often	Failure affects the continued process and has a big impact	4
Very often	Failure is inevitable	5

Determination of occurrence assessment starts from SWD.

Table 30.
Occurrence of Sea Water Desalination

No	Potential Causes	Frequency of Failures (Off Spec)				
		1	2	3	4	5
		0-20% In 12 month	21-40% In 12 months	41-60% In 12 months	61-80% In 12 months	81-100% In 12 months
1	Product Quality	✓				
2	Operating Conditions				✓	
3	Condensate Quality			✓		

The severity value for this category is 5 (very bad risk scale) because of Pressure BFW is 79.3 kg/cm2.g (outside the range as shown in Table 8). Severity of Feed Quality Boiler can see Table 23. The severity value given for this category is 5 (very bad risk scale) because of ph = 7.6 and hardness = 1.18 ppm (outside the range as shown in Table 9). Severity of Condition Operation Boiler can see Table 24.The severity scale in this unit is on a scale of 4 (Large Scale) because of the boiler drum pressure is 60 kg/cm² and level steam drum boiler is 33.8 t/hr. Severity of Steam Drum Product Quality Boiler can see Table 25.

The severity value given for this category is 3 (medium risk scale with an average value of pH = 8.8; conductivity = 4.4; hardness = zero; Silica = 0.013; Fe = 0.013. Severity of Blow Down Product Quality Boiler can see Table 26. The severity value given for this category is 4 (large risk scale) because of pH = 10; Conductivity = 134.6 µmhos; Silica = 1.9; Chloride = 19.6; Phosphate = 11.5; Residual O2 = 0.044; Hardness =

Table 31.
Occurrence of Softener

No	Potential Causes	Frequency of Failures (Off Spec)				
		1	2	3	4	5
		0-20% In 12 months	21-40% In 12 months	41-60% In 12 months	61-80% In 12 months	81-100% In 12 months
1	Product Quality	✓				
2	Operating Conditions	✓				

Table 32.
Occurrence of Deaerator

No	Potential Causes	Frequency of Failures (Off Spec)				
		1	2	3	4	5
		0-20% In 12 months	21-40% In 12 months	41-60% In 12 months	61-80% In 12 months	81-100% In 12 months
1	Product Quality	✓				
2	Operating Conditions		✓			

Table 33.
Occurrence of Boiler System

No	Potential Causes	Frequency of Failures (Off Spec)				
		1	2	3	4	5
		0-20% In 12 months	21-40% In 12 months	41-60% In 12 months	61-80% In 12 months	81-100% In 12 months
1	Product Quality				✓	
2	Operating Conditions		✓			
3	Condensate Quality	✓				

nill; Alkalinity = 15.3. Severity of Condensate Quality Steam Turbine Generator can see Table 27.

The severity value given for this category is 5 (Very Large risk scale) because of Hardness = 0.04 (outside the range of hardness as shown in table 13). Severity of Condition Operation Steam Turbine Generator can see Table 28.

The severity value for this category is 3 (medium) because of axial vibration parameter with an average value of -2.11 mills. The average parameters of surface condenser level are 59.72% and vacuum STG with average is 119.74 mmHg. Finally, a keyword timeline analysis is carried out to examine the thematic emphasis and offer a chronological map of topic evolution [3]. Assessment of Occurrence can see Table 29.

Determination of occurrence assessment starts from SWD. Occurrence of Sea Water Desalination can see Table 30.
In product quality, total data samples are 2950, off spec data are 13 times, so the total failure percentage is 0.44%. Therefore, it belongs to the first scale. In the operating conditions, especially on the recirculation flow and vacuum temperature parameter, total data are 366, off spec data are

Table 34.
Occurrence of Steam Turbine Generator

No	Potential Causes	Frequency of Failures (Off Spec)				
		1	2	3	4	5
		0-20% In 12 months	21-40% In 12 months	41-60% In 12 months	61-80% In 12 months	81-100% In 12 months
1	Product Quality	✓				
2	Operating Conditions		✓			

Table 35.
Detection Rating Range

Occurrence	Probability of Risk Occurrence	Ranking
Never	Impossible/least expected failure	1
Seldom	Failure can be resolved and does not affect the next process	2
Often enough	Failures affect continuing processes but not to a large extent or to have a significant impact	3
Often	Failure affects the continued process and has a big impact	4
Very often	Failure is inevitable	5

238 times, so the total failure percentage is 65%. Lastly for the condensate quality, total data are 972 samples, off spec data are 426 times, the total failure is 44%, so that it is considered as scale three. Occurrence of Softener can see Table 31.

There are total Silica and Fe parameter of 4,120 and 4,123 samples, with a total of 309 and 120 off-spec data. So that a large percentage of failure is obtained, which is equal to 7% and 2.86%, such that it is under category of the first scale. Furthermore, in the operating conditions, especially on the product water to softener, a total of 399 sample tests were obtained with 77 data outside the quality standard. So that the total failure percentage is 19%. So that both are classified on a scale of first on occurrence. Occurrence of Deaerator can see Table 32.

In a year, product quality data includes 4,029 samples for conductivity, with 10 off-spec samples, resulting in a failure percentage of 0.25%, placing it in the first scale. For operating conditions, specifically press BFW, 366 tests reveal 106 data outside the quality standard, leading to a total failure percentage of 29%. Both incidents are classified as first scale occurrences. Occurrence of Boiler System can see Table 33.

In the feed quality data for one year, pH has 3,333 samples and hardness has 3,338 samples. There are 2,582 off-spec samples for pH (77.23% failure) and 20 for hardness (0.55% failure), placing both in the fourth scale (vulnerable to 61-80%). In operating conditions, specifically combustion air, 259 tests show 99 data outside the quality standard, resulting in a 38% failure, classified as a scale two occurrence. The last risk is from Product Quality, particularly the Chloride parameter, with 7,147 samples and 374 off-spec samples, resulting in a 5.26% failure and classified as a scale one occurrence. Occurrence of Boiler System can sse Table 34.

In the annual condensate quality data, the hardness parameter has 978 samples with zero off-spec data, resulting in a 0% failure and placing it in the first scale. In operating conditions, particularly the level surface condenser, 823 tests show 182 data outside the quality standard, leading to a 22% failure, classified as a scale two occurrence.

Detection defines the likelihood of the detection of a failure mode and it can also be expressed as the ability of a

Table 36.
Detection Assessment

Unit	Potential Cause	Detection Rate				
		1	2	3	4	5
Sea Water Desalination	Condensate Quality	✓				
	Operation Conditions			✓		
	Product Quality	✓				
Softener	Operation Conditions			✓		
	Product Quality	✓				
Deaerator	Operation Conditions			✓		
	Product Quality	✓				
Boiler	Feed Quality	✓				
	Operation Conditions			✓		
	Product Quality (Steam Drum)	✓				
	Product Quality (Blow Down)	✓				
Steam Turbine Generator	Condensate Quality	✓				
	Operation Conditions			✓		

Table 37.
RPN calculation

Unit	Potential Cause	S	O	D	RPN
Sea Water Desalination	Condensate Quality	5	3	1	15
	Operation Conditions	5	4	3	60
	Product Quality	5	1	1	5
Softener	Operation Conditions	2	1	3	6
	Product Quality	3	1	1	3
Deaerator	Operation Conditions	5	2	3	30
	Product Quality	3	1	1	3
Boiler	Feed Quality	5	4	1	20
	Operation Conditions	4	2	3	24
	Product Quality	3	1	1	3
Steam Turbine Generator	Condensate Quality	5	1	1	5
	Operation Conditions	3	2	3	18

person to det ect the potential breakdown mode and its consequence [7]. Occurrence of Boiler System can see Table 34. Based on the failure event data, a detection rating can be given as shown in the following rating table 36.

C. Risk Priority Number

After determining each severity, occurrence, and detection value, the RPN value is obtained. The RPN value is the product of severity, occurrence, and detection. In determining the risk priority number (RPN), the following mathematical formula is used.

$$RPN = Severity\ (S) \times Occurrence\ (O) \times Detection\ (D)$$

After calculating the risk priority number (RPN), the first-ranking potential cause in sea water desalination is identified, particularly in operation conditions, involving recirculation flow and SWD vacuum outlet temperature (max) with an RPN value of 60 (Low) categories. Following the ranking determination, the next step involves mitigation, focusing on addressing the potential failure ranked first, specifically in the operating conditions of the Sea Water Desalination Unit. RPN calculation can see Table 37.

D. Mitigation

1) Mitigation of recirculation flow problems in the Sea Water Desalination Unit

Low recirculation flow below specified standards may decrease desalination product output, elevate blowdown levels, lead to off-spec desal products, cause high brine heater temperatures (scaling risk), and result in unit trips or operational failures. Causes include leaking lines, underperforming pumps, clogged filters, internal pipe scaling or fouling, and low pH levels turning acidic.

So that, to overcome this recirculation flow to less then the

standard is
1. To ensure instrumentation (zero check) or supervisor calibrate the instrumentation before testing
2. To change/repair circulation pump since it has been working below the required standard
3. To make sure there is no leaking pipes
4. Cleaning the evaporator routinely from crust
5. Controlling the pH to reach quality standards
6. Adding anti-scale and anti-foam levels

2) Mitigation of vacuum problems in the Sea Water Desalination Unit

The SWD vacuum temperature parameter consistently exceeds specified standards, potentially leading to elevated blowdown levels and increased scaling in tubes due to excessive temperatures. The cause may be attributed to an acidic pH, contributing to corrosiveness in the pipes. So that, to overcome this high of vacuum pressure problem is by:
1. Controlling the pH to stay within the desired range of between 8.5-9.5.
2. Checking and routine with flushing in the evaporator and adding cooling water

Although the RPN result is 60 which is relatively low, this is still an important concern for the future so as not to worsen the operating conditions of the Sea Water Desalination Unit. Therefore, this mitigation is still needed to maintain the quality of the Sea Water Desalination unit.

IV. CONCLUSION AND SUGGESTIONS

The Utilities Unit is one of the units that has an important role in oil production at PT Kilang Pertamina Internasional RU IV Cilacap. The biggest risk of failure based on the value of the RPN during the study period is in unit 54 (the Sea Water Desalination Unit) where the problem occurs in the category of operating conditions with a lack of recirculation flow of and exceeds the limit on the temperature outlet SWD with RPN points of 60. Mitigation for the highest rating of RPN values, namely carrying out preventive and predictive maintenance where efforts are made to predict damage by carrying out prevention, checking and monitoring chemical injections and cleaning evaporator in unit 54 (the Sea Water Desalination Unit).

Suggestion for this research is that the data collection is better done on a primary basis or as a result of personal analysis so that the data obtained is more precise. Additional follow-up analysis is needed by evaluating the effectiveness of mitigation in reducing each cause of failure risk. Research is conducted with the scope of one process unit in the processing unit so that failure data can be identified in more detail.

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