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Adopting the OEE Method in the Air Separation Plant (ASP) Machine to Measure Its Productivity at PT XYZ

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***Abstract**. PT XYZ is a company that produces various gases in the form of Oxygen, Nitrogen, and Argon in gas and liquid form. In the production process, the machine runs 24 hours non-stop and will stop production when maintenance is employed once a year. The Air Separation Plant (ASP) machine performance measurements are needed to determine the effectiveness of its production. The reseacrh aims to analyze the factors that affect machine productivity. The method used is quantitative, using the Overall Equipment Effectiveness (OEE) approach. In addition, this study uses interviews to determine the factors that affect engine performance. The results show that the OEE value of the machine is 75%, which is still below the international standard OEE value of 85%. Therefore, it is necessary to optimize engine performance. Based on the analysis using a fishbone diagram, there are five influencing factors: human factors, machines, work methods, environment, and materials. Based on these five factors, the engine factor most influences the low value of engine performance. The predictive maintenance calculations are conducted, especially on expender and cold box machines, every 95 days of machine should use with work efficiency of around 40 hours.*

***Keywords**: Machine Performance, OEE, Preventive Maintenance, Productivity*

Abstrak. PT XYZ merupakan perusahaan yang memproduksi aneka gas berupa Oksigen, Nitrogen dan Argon dalam bentuk gas dan liquid. Pada proses produksinya mesin berjalan 24 jam nonstop dan akan berhenti berproduksi ketika dilakukan maintenance satu kali dalam setahun. Air Separation Plant (ASP) adalah salah satu mesin utama sehingga perlu pengukuran produktivitas. Penelitian ini bertujuan untuk menghitung produktivitas mesin sehingga perusahaan dapat dilakukan evaluasi ke depan. Metode yang digunakan adalah kuantitatif dengan pendekatan Overall Equipment Effectiveness (OEE). Selain itu, penelitian ini menggunakan wawancara untuk mengetahui faktor yang mempengaruhi performansi mesin. Hasil menunjukkan bahwa nilai OEE mesin adalah 75% dimana nilai tersebut masih dibawah nilai OEE standar internasional yaitu 85%. Oleh karena itu, diperlukan pengoptimalan kinerja mesin. Berdasarkan analisis menggunakan fishbone diagram ada lima faktor yang mempengaruhi yaitu diantaranya faktor manusia, mesin, metode kerja, lingkungan dan material. Berdasarkan kelima faktor tersebut faktor mesin yang paling mempengaruhi rendahnya nilai performansi mesin. Sehingga dilakukan perhitungan predictive maintenance terutama pada mesin expender dan cold box yaitu setiap 95 hari pemakaian mesin dengan efesiensi pengerjaanya sekitar 40 jam.

Kata kunci: Performansi Mesin, OEE, Preventive Maintenance, Produktivitas

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INTRODUCTION

Indonesia is a country that prioritizes the industrial sector, such as the manufacturing industry (Azwina et al., 2023). The manufacturing industry needs production capacity measurement to fulfill consumer demand (Karima et al., 2022). One of the manufacturing industries is the gas industry. One company that produces the most significant gas in Indonesia is PT XYZ. The company runs four types of businesses engaged in industrial gas production, industrial gas sales, sales of industrial gas equipment, and installation of industrial gas equipment, with its primary business being a supplier of industrial gases such as air gas (Oxygen, Nitrogen, and Argon) with the production name *Air Separation Plant* (Samator Gas Indonesia, 2023).

The more rapid development of manufacturing companies will lead to intense competition, which requires companies always to carry out production processes and make continuous machine repairs to ensure the production process runs smoothly (Tsarouhas, 2019). Machine production is an essential factor in improving production line performance, and it is necessary to analyze the effectiveness of machine performance to avoid losses for the company (Cheah et al., 2020). The machines require prime conditions to achieve daily production targets and ensure the best performance. Therefore, to maintain stability, it is necessary to keep the machine periodically, such as routine maintenance, to maximize machine efficiency and minimize production process disruption (Karima & Romadlon, 2021).

The production process is making finished products from raw materials that involve machines, energy, knowledge, technical, and humans (Damayanti, 2020). The production process will run well to maintain product quality (Khalif et al., 2020). Therefore, productivity emerges as a measure of company evaluation in assessing product performance and whether production is running optimally by considering factors of raw materials, machines, and people(Tsarouhas, 2019). The Overall Equipment Effectiveness (OEE) approach is one way to measure productivity.

The Overall Equipment Effectiveness (OEE) is a comprehensive measurement to identify the productivity level of machine or equipment performance in theory (S. Huang, 2017). This measurement is critical to determine which areas need to improve productivity or performance efficiency. OEE is also a measurement tool to evaluate and improve productivity improvements in machine use (Elisatriana & Amrina, 2019).

PT XYZ runs machines non-stop for 24 hours and will stop production when maintenance is carried out once a year. PT XYZ often experiences decreased production productivity caused by production machines that experience leaks and a lack of structured machine maintenance. Various equipment are involved in the production process, including the Air Separation Plant (ASP) machine. Therefore, this study aims to measure the effectiveness of the Air Separation Plant machine and identify maintenance priority factors to avoid downtime. If the downtime occurs, the whole productivity of gas will be a problem. Furthermore, OEE implements a Total Productive Maintenance (TPM) program to reduce unplanned maintenance and prevent emergency repairs (Ariyah, 2022). The resulting OEE value will then be compared with the international standard average OEE value to evaluate the machine's effectiveness level and the aspects that need to be repaired immediately.

METHODS

This study used a quantitative method. The data was collected from company-recorded files. The flowchart of the research method can be seen in Figure 1. The research started with direct observations to map the problems. After making observations, the problem was formulated, and data collection, such as production, production loss, preventive maintenance, downtime, and machine component standards from January to December 2022

Furthermore, this study conducted OEE to measure ASP machines based on the availability, performance, and quality values obtained by direct device observation. After calculation, the company's OEE was compared with the international standard OEE to evaluate the overall engine performance. Then, data were analyzed using a fishbone diagram to determine the causal factors affecting the company's OEE value. After that, a preventive maintenance analysis is conducted to schedule the machine effectively.

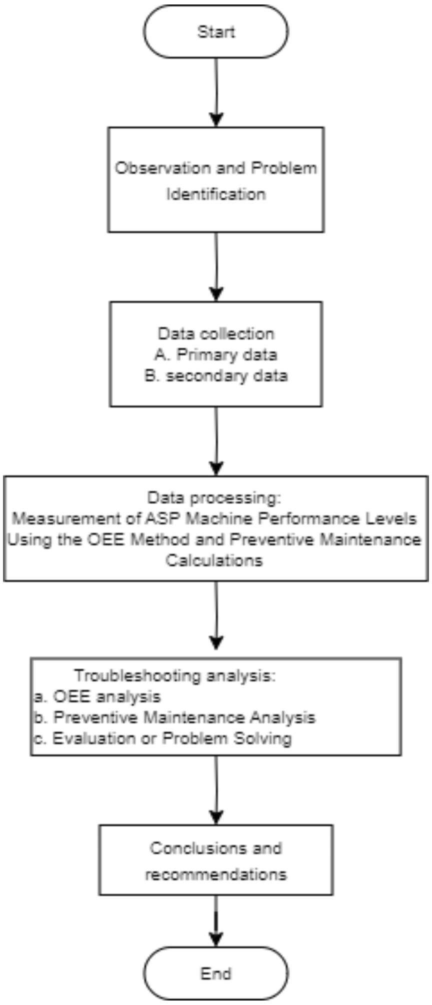

figure 1. flowchart of research methods

OEE values are calculated based on availability, performance, and quality rate. Availability Rate is a ratio that describes the utilization of the time available for machine or equipment operating activities [6] (Kurnia et al., 2022). The following formula used to measure the Availability ratio can be seen in equation (1):

$$\text{Availability} = \frac{operating\ time}{loading\ time} = \frac{loading\ time - downtime}{loading\ time}\ x\ 100\% \quad (1)$$

Loading time is available per day or month minus the planned downtime. Loading time is Total Available Time subtracted from Planned Downtime. Operation time results from reducing loading time with machine downtime (non-operation time). In other words, operation time is the available operating time after machine downtime is excluded from the planned total available time. Performance Rate is a ratio that describes the equipment's ability to produce goods. This ratio results from the operating speed rate and net operating rate. The equipment operating speed rate refers to the difference between the ideal speed (based on the equipment design) and the actual operating speed. Three critical factors are needed to calculate performance efficiency as in equation (2):

$$\text{Performance rate} = \frac{Procesed\ amount\ x\ Ideal\ cycle\ time}{Operating\ time} X\ 100\ \% \quad (2)$$

Quality Rate is a ratio that describes the ability of equipment to produce products according to standards. The formula used for ratio measurement is as in equation (3):

$$\text{Quality Rate} = \frac{Procesed\ amount - Defect\ amount}{Procesed\ amount} x100\% \quad (3)$$

The OEE value is obtained by multiplying the three main ratios. Mathematically the formula for measuring OEE values is based on equation (4).

$$OEE\ (\%) = Availability\ (\%)\ x\ Performance\ Rate\ (\%)\ x\ Quality\ Rate\ (\%) \quad (4)$$

The ideal conditions for OEE after implementing Total Preventive Maintenance (TPM) in a company are the availability rate greater than 90%, the performance efficiency greater than 95%, and the quality rate greater than 99%. Therefore, the ideal condition for achieving OEE shall be greater than 85%. After getting the OEE value, the next step was creating a cause-and-effect diagram using a fishbone diagram. The last step was analyzing the machine, which has more concern about conducting preventive maintenance by Pareto dan *Mean Time to Failure* (MTTF) is the average time between breakdowns (5), and the *Mean Time to Repair* (MTTR) formula is an average repair time (6) (Afiva et al., 2018).

$$MTTF = \frac{Total\ operating\ hours}{Total\ number\ of\ units} \quad (5)$$

$$MTTR = \frac{Total\ repair\ time}{Total\ number\ of\ repairs} \quad (6)$$

RESULT AND DISCUSSION

OEE Results

Measuring production machines at the ASP Plant is to determine the effectiveness of machine performance and analyze the causal factors that affect machine performance using the Overall Equipment Effectiveness method. The data of ASP machine performance can be seen in Table 1.

Table 1. Data Collection in 2022

Month	Loading time (hour)	Downtime (hour)	Operating time (hour)	Processed Amount (m^3)	Ideal Cycle Time (m^3/hour)	Defect Amount (m^3/hour)
January	723.25	16.00	707.25	6,232.287	9,525	186,631
February	576.43	2.00	57443	5,061.877	9,130	132,792
March	698.44	1.25	697.19	6,143.638	9,361	37,275
April	717.12	0.00	717.12	6,319.261	9,414	153,111
May	500.81	0.00	500.81	4,413.138	9,061	226,334
June	744.00	0.00	744.00	6,556.128	9,069	61,995
July	699.12	2.50	696.62	6,138.615	9,447	265,545
August	732.00	0.00	732.00	6,450.384	9,300	205,874
Septembe r	547.12	35.50	511.62	4,508.395	9,118	163,226
October	700.00	167.00	533.00	4,696.796	8,673	388,082
November	608.43	41.00	567.43	5,000.193	8,694	219,861
December	556.50	0.00	556.50	4,903.878	8,945	275,349

Table 2. Availability Rate Result in 2022

Month	Loading time (hour)	Downtime (hour)	Operating time (hour)	Availability Rate (%)
January	723.25	16.00	707.25	97.79
February	576.43	2.00	574.43	99.65
March	698.44	1.25	697.19	99.82
April	717.12	0.00	717.12	100.00
May	500.81	0.00	500.81	100.00
June	744.00	0.00	744.00	100.00
July	699.12	2.50	696.62	99.64
August	732.00	0.00	732.00	100.00
September	547.12	35.50	511.62	93.51
October	700.00	167.00	533.00	76.14
November	608.43	41.00	567.43	93.26
December	556.50	0.00	556.50	100.00
Average availability rate (%)				**96.65**

According to Table 2, the results show that the lowest available rate is in October (76.14%), which is influenced by high downtime. The average value of the availability rate on PT Samator Indo Gas Bekasi ASP production machines is 96.65%. Table 3 shows the highest performance value in January (83.93%). The optimal engine performance speed influenced it, while the lowest value is in October (76.42%) because the quality of the engine performance is lower and there are many production losses. The average performance rate on PT Samator Indo Gas Bekasi's ASP production machines was 80.57% (Table 3).

Table 3. Performance Rate Result in 2022

Month	Operating time (hour)	Processed Amount (m^3)	Ideal Cycle Time (m^3/hour)	Performance Rate (%)
January	707.25	6,232.287	9,525	83.93
February	574.43	5,061.877	9,130	80.45
March	697.19	6,143.638	9,361	82.48
April	717.12	6,319.261	9,414	82.95
May	500.81	4,413.138	9,061	79.84
June	744.00	6,556.128	9,069	79.91
July	696.62	6,138.615	9,447	83.24
August	732.00	6,450.384	9,300	81.95
September	511.62	4,508.395	9,118	80.34
October	533.00	4,696.796	8,673	76.42
November	567.43	5,000.193	8,694	76.61
December	556.50	4,903.878	8,945	78.82
Average performance rate (%)				**80.57**

Table 4. Quality Rate Result in 2022

Month	Processed Amount (m^3)	Defect Amount (m^3)	Rate of Quality (%)
January	6,232.287	186,631	97.00
February	5,061.877	132,792	97.37
March	6,143.638	37,2750	99.39
April	6,319.261	153,111	97.75
May	4,413.138	226,334	94.87
June	6,556.128	61,995	99.05
July	6,138.615	265,545	95.67
August	6,450.384	205,874	96.67
September	4,508.395	163,226	96.37
October	4,696.796	388,082	91.73
November	5,000.193	219,861	95.67
December	4,903.878	275,349	94.43
Average quality rate (%)			**96.33**

Table 4 mentions that the lowest quality rate in October was 91.73%, influenced by the high number of product defects. The average quality rate on PT Samator Indo Gas Bekasi's ASP production machines for the past year was 96.33%. After getting the availability, performance, and quality rates, the next step is calculating the OEE value. The aim is to determine the effectiveness of the ASP production machine. Table 5 employs the calculation results above to show that the average OEE value on the ASP production machine for the last year is 75.0%.

Table 5. OEE Results in 2022

Month	Availability Rate (%)	Performance Rate (%)	Quality Rate (%)	OEE (%)
January	97.79	83.93	97.00	79.61
February	99.65	80.45	97.37	78.05
March	99.82	82.48	99.39	81.82
April	100.00	82.95	97.75	81.08
May	100.00	79.84	94.87	75.74
June	100.00	79.91	99.05	79.15
July	99.64	83.24	95.67	79.34
August	100.00	81.95	96.67	79.22
September	93.51	80.34	96.37	72.39
October	76.14	76.42	91.73	53.37
November	93.26	76.61	95.67	68.35
December	100.00	78.82	94.43	74.42
OEE Average (%)				**75.00**

Table 6. Comparison of OEE Companies with International Standards

OEE Factor	World Class Standard OEE (%)	Our Current OEE (%)
Availability Rate	90.00	96.65
Performance Rate	95.00	80.57
Quality Rate	99.00	96.33
Overall OEE	85.00	75.00

Table 6 mentions that after comparing the international standard OEE value with the OEE value of PT Samator Indo Gas Bekasi, the calculation can be concluded that the average OEE value of production machines in the ASP plan of PT Samator Indo Gas Bekasi is 75%, while the international standard is 85% (Ariyah, 2022), which means that control must be conducted on factors that affect the value of the availability rate, performance rate, and quality rate where the total is still below the international OEE standard. Factors that influence the low OEE value in companies include low-performance rate values. Therefore, further analysis is needed to determine the causal factors using a causal diagram and make suggestions for improvements.

Cause and Effect Diagram

This diagram analyzes the factors that significantly affect the quality of work on the ASP Plant production machine, which causes the low value of the performance rate (Coccia, 2020). Figure 2 shows the causes and effects in the diagrammatic form that cause low OEE values.

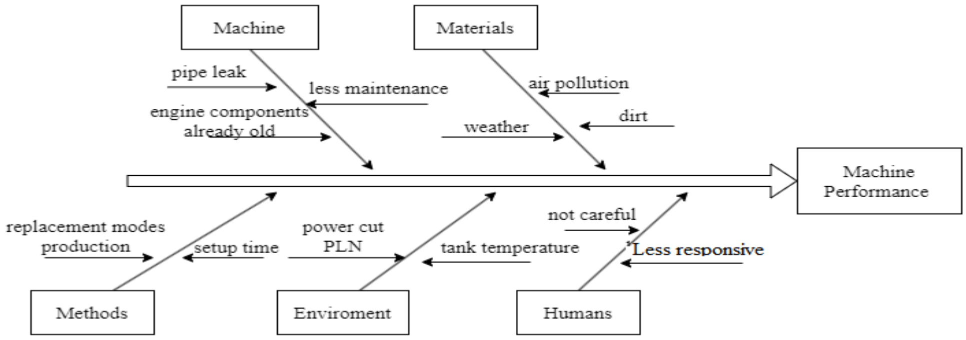

Figure 2. ASP Engine Performance Cause and Effect Diagram

Figure 2 shows five factors, followed by machine, materials, production methods, environment, and man factors (Farmasetika, 2021). First is the machine. Machine factors that are the cause include pipe leaks that often occur on the production floor, causing the machine to rust—old engine components so that machine productivity decreases. Engine component rejuvenation is needed to improve engine performance. Lack of regular maintenance and a detailed record of repair time make it difficult to calculate predictive maintenance. The second is materials. The causative factor of material is air pollution, which causes dirty raw materials. In the production of air separation plants, the main raw material is air, so there are a lot of impurities caused by air pollution, even though filtering has been conducted, which affects product performance. To overcome the issue, regular air filter replacement is required. The weather factor will also affect the level of material quality to be produced and production performance.

The third is methods. Changes in production mode also affect engine performance due to engine speed transitions. Setup time with the evolution of working mode will cause machine setup time to increase, and a particular technique is needed to speed up the mode change to shorten the setup time. Then, the following variable is the environment. The causal factor of the environment is the electricity power cut, which causes the machine to die suddenly and decreases engine performance, and coordination with the electricity is needed to avoid this. The ambient temperature will affect the tank pressure, which causes high production losses. Therefore, a tank temperature stabilizer is needed to stabilize the pressure. The last is man. The causal factor for man is the lack of awareness of operating production machines, which affects their performance. Less responsive to minor damage to the engine, resulting in decreased engine performance.

Preventive Maintenance

The analysis shows that the factors causing the low value of engine performance in the cause and effect diagram are essential factors to improve engine performance to determine a preventive maintenance schedule (Dwi Atmaji & Alhilman, 2018)(J. Huang et al., 2020). The predictive maintenance calculation is used to determine the preventive maintenance schedule based on downtime data. According to Figure 3, a ranking is described in the Pareto diagram, where the highest value will be solved first because it confirms the Pareto Principle concept, which stipulates that 80% of consequences come from 20% of cases, confirming the existence of an unbalanced relationship between inputs and outputs (Raman & Basavaraj, 2020).

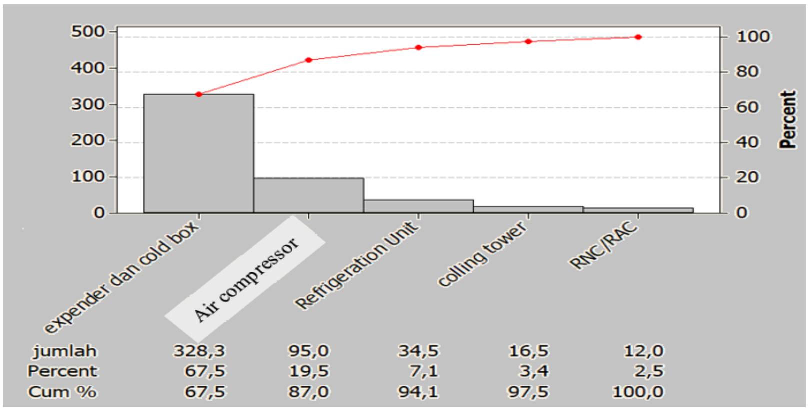

Figure 3. Pareto Chart of Production Machines Downtime for 2021-2022

Figure 3 shows the optimization can be taken first on the expender and cold box machine. It follows the rules of the Pareto diagram, and it shows that it stipulates that 80% of consequences come from 20% of cases, and it should be resolved first (Raman & Basavaraj, 2020). The following is a predictive maintenance calculation for preventive maintenance on the expander cold box machine and air compressor in Table 7. According to Table 7, Expender and Cold Box machines must be maintained after 95 days. Therefore, it shall be maintained on April 4, 2023, according to the last maintenance report, and the work efficiency takes around 40 hours.

Table 7. Expander Cold Box Machines Repair and Damage Time Record

Variable	Downtime data						Total
Frequency	1	2	1	1	2	1	8.00
The time between repairs (hour)	2	167	30	2	119	10.25	320.43

The time between breakdowns (hour)		5,840	730	4,380	3,650	3,600	18,200
MTTF (day)							95.00
MTTR (hour)							40.00

Finding implications

Five factors must be considered to increase the effectiveness of machine performance, including machine, materials, production methods, environment, and man. However, in this study, the engine factor is one factor that significantly affects engine performance. Engine factors often occur on the production floor, which causes a decrease in engine performance. For example, a leaked pipe causes the engine to rust, old engine components, and many parts to be worn out, reducing engine reliability. The lack of regular machine maintenance, the limited availability of machine components that must be repaired, and the lack of detailed repair time recording make it difficult to carry out predictive maintenance, which will later be used as a routine preventive maintenance schedule.

Preventative maintenance is an essential factor in improving machine performance, which impacts the effectiveness of machine performance in production (Nasution et al., 2021). One evaluation of a company's low OEE value is by carrying out predictive maintenance, which will later be scheduled for preventive maintenance to improve machine performance and reliability to increase production effectiveness(Siregar & Munthe, 2019). According to production machine downtime data at the ASP, expander and cold box machines are prioritized to be maintained. The assumption is the longer time between maintenance, the machine's performance is better, and the faster the processing time required, the production process performance is better as well (Siregar & Munthe, 2019). Measuring engine performance is significant for companies with high machine hours so that the effectiveness of machine performance can be known, which can cause indirect losses to the company (Tsarouhas, 2019). The result can be set as a recommendation for companies to continuously improve the performance of production machines by paying attention to the effectiveness of their performance. The company can pay more attention to the machine's condition by calculating the estimated time of machine damage so that the company can determine the steps for machine maintenance and replacement of components before damage occurs. The company is aware of the impact on the effectiveness and productivity of machine performance, which affects the number of quality products produced and, of course, profits or profits. Furthermore, other factors such as man, method, environment, and material shall be considered when conducting preventive maintenance.

CONCLUSION

This study focuses on productivity ASP to measure when preventive maintenance should be conducted. The result shows that the current OEE rate is below the OEE international standard. A root cause diagram is carried out as a fishbone where the engine causes are pipe leaks, lack of maintenance, and old engine components. In materials, the main causes are air pollution, dirt, and weather. In methods, the causes are production replacement mode and setup time. In environments, the causes are power cuts and tank temperature, and for humans, the causes are less responsive and less careful. After focusing on the machine cause, it was found that the expender and cold box machines stipulate that 80% of consequences come from 20% of cases, and it should be resolved first. The machine shall be prioritized for conducting preventive maintenance to avoid low gas production productivity and scheduling regular machine checks.

Further research can be conducted using the OEE approach to other divisions, such as logistics or material handling. Furthermore, the company can pay more attention to other machines' conditions by calculating the estimated time of machine damage to determine the steps for machine maintenance. The company also put on replacing components before damage occurs in some critical areas.

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