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RESEARCH ARTICLE

ANALYSIS OF TPM IMPLEMENTATION BY MEASURING OVERALL EQUIPMENT EFFECTIVENESS (OEE) AND EFFORTS TO IMPROVE FURNACE MACHINE PERFORMANCE AT PT XYZ

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Abstract

PT XYZ is a company operating in the jewelry manufacturing industry. To find out the quality of jewelry before buying and selling it commercially, it is necessary to check the quality of the product. Analysis was carried out in the laboratory using the fire assay method using a furnace machine. This machine operates for 8-10 hours a day at a temperature of 1050 ° C. Using high temperatures can affect the effectiveness of the machine. The implementation of TPM is used to ensure that the equipment and tools used are in good condition. To calculate the machine effectiveness value, the OEE value measurement is used. Data collection was carried out in June 2023 – April 2024 The OEE value was obtained at 58.4%, which is still below the world class standard of >85%. The cause of the low OEE value is due to the low Performance value of 69.8%. The results of the analysis concluded that the causes of the decline in machine performance values were dominated by machine and human factors. The results of proposed improvements were obtained from the 5W 1H interview in the form of replacing the furnace engine chamber every 3 months, cleaning the chamber regularly, calibrating the furnace engine, checking blower traction, adding an automatic timer for the blower, briefing regarding the condition of the machine so that operators are more careful, carrying out cross check and record the estimated grade before carrying out the gold grade analysis.

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Introduction:-

Industrial development is currently increasingly advanced, this can be seen from the increasing market needs and competition that occurs between companies. Every company tries to improve quality by utilizing existing resources. One effort that can be made is to improve the performance of the production process by optimizing the entire process to achieve the goal of a smooth production process from the various aspects involved.

The smooth production process is one of the important factors in the manufacturing industry. If the production process does not experience problems in the use of machines or equipment, the right system to improve performance is through implementing the Total Productive Maintenance (TPM) system. TPM implementation creates increased productivity with considerable cost savings. One method that can be applied is Overall Equipment Effectiveness (OEE) [1].

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PT XYZ is a company operating in the jewelry manufacturing industry. Various types of jewelry are produced ranging from type, color and carat or grade. Analysis of gold content in the laboratory using the fire assay method is not only used to ensure the quality of the product produced meets standards, but is also used to determine the exact content of gold remaining in production before refining and the exact content after refining for reuse in the production process.

In general, the stages in carrying out gold content analysis using the fire assay method are mixing the sample with flux, fusion reaction and cupulation [2] . The difficulty of maintaining the furnace temperature during the cupulation process is an important point in analyzing gold content using the fire assay method .

The furnace must be properly maintained because the machine is used every day. This is because jewelry production is carried out continuously . Damage to one of the furnace components will cause a decrease in performance in producing a product.

One method used to measure the effectiveness of a tool is by using overall equipment effectiveness (OEE). OEE aims to increase the effectiveness of the materials used so that they can be maximized, reduce production costs and provide greater profits to the company. OEE consists of 3 (three) factors, namely: availability factors , quality factors and performance factors [3] .

The problem currently occurring is a decrease in the productivity of the furnace machines used. This machine underwent its last maintenance in April 2022 when the chamber was cracked and sticky, which resulted in the extraction process taking longer. A cupulation process that was previously capable of covering 8 samples in one cycle became 6 samples. So companies need to provide additional working hours from 9 working hours a day to 11 working hours a day.

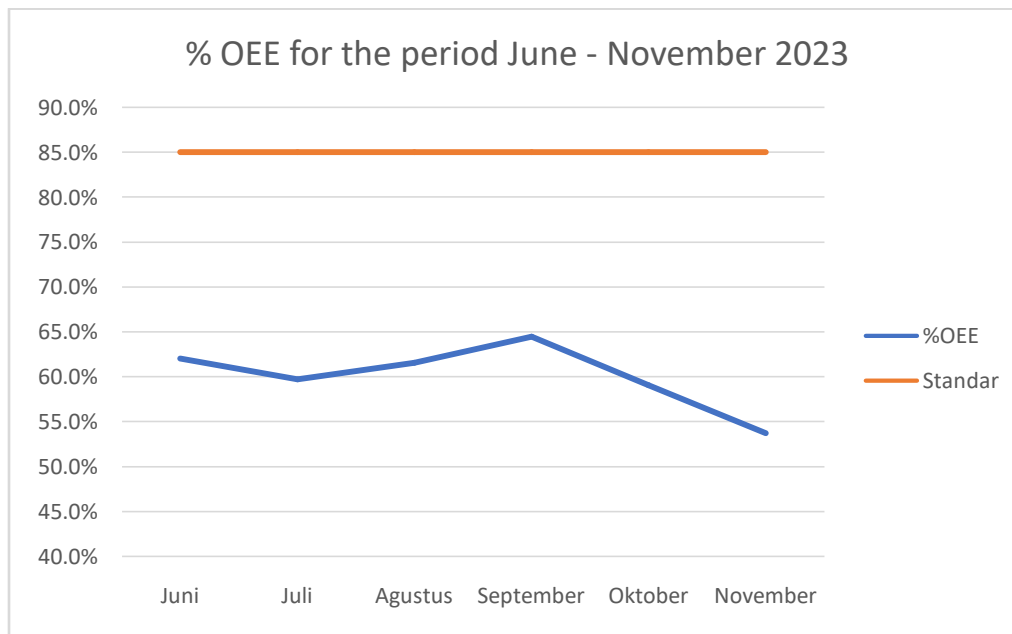


Figure 1:- Graph of OEE values in the period June – November 2023[4]

The decrease in OEE value is of course influenced by three factors, namely availability, performance and quality factors . The following is a detailed calculation of the factors that influence the OEE value.

Table 1 OEE calculation for the period June – November 2023.

Month	Quality	Availability	Performance	OEE
June	97.2 %	85.4%	74.7%	62.0%
July	97.6%	86.2%	70.9%	59.7%
August	97.7%	84.2%	74.8%	61.6%

September	97.7%	83.4%	79.1%	64.5%
October	97.8%	84.7%	71.2%	59.0%
November	99.3%	86.3%	62.7%	53.7%

Based on the OEE calculation results for the period June – November 2023, the smallest performance factor value was obtained. This indicates that the performance value is very influential compared to the other two factors. The value of the performance factor tends to decrease compared to the other two factors which tend to be stable.

Research Methods:-

The flowchart of the analytical research carried out is shown in Figure 2.

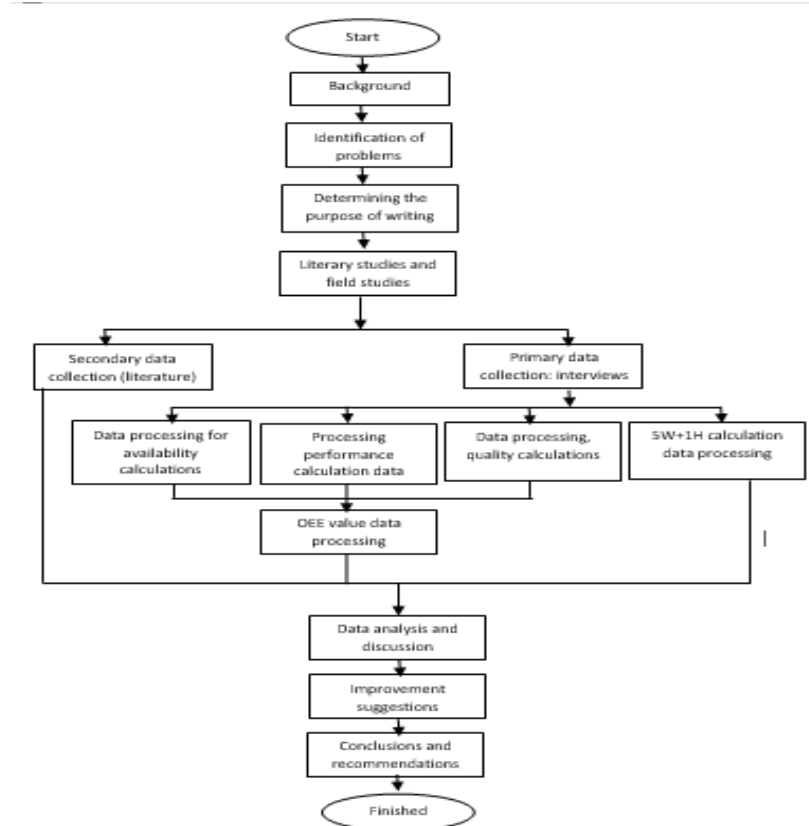


Figure 2:- Research flowchart.

Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a method that can be used to calculate the performance of a machine. Nakarajima (1998) OEE is a method used to measure the level of effectiveness of using a machine or equipment by including several factors. OEE calculates the relationship between these factors. This measurement is comprehensive and very important to know which areas need to increase the productivity of a machine [5] .

The OEE method is carried out to improve machine performance while minimizing losses caused by ineffective use of machines during production. One way to minimize this is to carry out routine maintenance, improve quality control of materials and supervision of the products produced [6] .

$$OEE = \text{Availability} \times \text{Performance} \times \text{Quality} \quad (1)$$

The following is a table of world class standards for each factor:

Table 2 World Class Standard OEE.

Factor	Mark
Availability	≥ 90%
Performance	≥ 95%
Quality	≥ 99.9%
OEE	≥ 85%

The following are factors that influence the size of the OEE value [7] :

Quality factor

Quality factors are factors related to product quality by comparing products that comply with standards with the total number of products produced.

$$\text{Quality} = \frac{\text{Processed amount} - \text{Reject}}{\text{Processed Amount}} \times 100\% \quad (2)$$

Information:

- Quality = Quality factor
- Processed amount = Total number of samples
- Reject = Number of rejected samples

Availability Factor

The availability factor is a measurement of the overall time spent working. Availability is calculated after deducting tool breakdown time or tool preparation time.

$$\text{Availability} = \frac{\text{Loading time} - \text{Downtime}}{\text{Loading Time}} \times 100\% \quad (3)$$

Information:

- Availability = Time availability factor
- Loading time = Total amount of time
- Downtime = Damage time

Factor Per 7 formance

Performance factor is the comparison of actual operating speed with ideal operating speed.

$$\text{Performance} = \frac{\text{Processed amount} \times \text{Cycle Time}}{\text{Operation Time}} \times 100\% \quad (4)$$

Information:

- Performance = Performance factor
- Processed amount = Total number of samples
- Cycle time = Sample cycle time
- Operating time = Available operating time

Fishbone Diagrams

A fishbone diagram is a diagram used to show the cause and effect of a problem. This diagram is included in one of the 7 basic quality tools . Generally there are 6 factors that are the main causes, namely, machines, humans, methods, raw materials, measurements and the environment [8] .

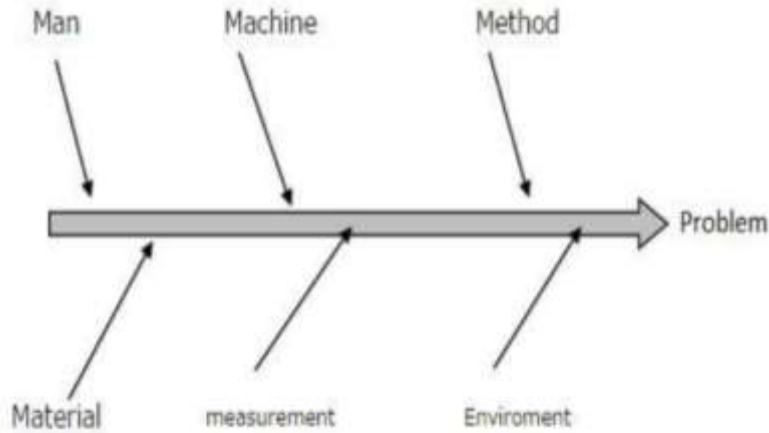


Figure 3:- Fishbone diagram [8].

5W 1H Method Interview

Qualitative descriptive research explains the characteristics of an object, person, group, organization and environment [9] . This research generally uses the 5W 1H method technique. This method is a framework that is used to collect information or data to create a complete picture of an event or incident. 5W 1H is an abbreviation of 5 questions in English, namely: What , Where , When , Who , Why , How [10] .

Results and Discussion:-

The effectiveness value of a machine is obtained from the OEE value, increases and decreases in the OEE value are caused by various factors written in the fishbone diagram and suggestions for improvements are made through interviews using the 5W 1H method.

OEE value

The OEE value is obtained from the multiplication of availability, performance and qualityfactors.

Quality factor

Table 3:- Quality factors.

Month and Year	Total Sample	Reject Samples	% Quality
June 2023	1160	32	97.2
July 2023	1208	29	97.6
August 2023	1197	27	97.7
September 2023	1199	27	99.7
October 2023	1110	24	97.8
November 2023	1082	8	99.3
December 2023	1114	12	98.9
January 2024	1096	4	99.6
February 2024	982	6	99.4
March 2024	1047	3	99.7
April 2024	641	4	98.6
Average			98.6

The following is a graph of quality values for the period June 2023 – April 2024:



Figure 4:-Quality graph.

The quality value tends to increase due to improvements made to the analysis methods used. This is because each gold analyzed has a different color which indicates the use of a different alloy . So it is necessary to adjust the amount of lead used.

Availability factor

Table 4:- Availability factors.

Month and Year	Loading time	Downtime	Operating time	% Availability
June 2023	11880	1740	10140	85.4
July 2023	13200	1820	11380	86.2
August 2023	15180	2400	12780	84.2
September 2023	14520	2410	12100	83.4
October 2023	14520	2220	12300	84.7
November 2023	15840	2170	13670	86.3
December 2023	14520	2230	12290	84.6
January 2024	14520	2200	12320	84.8
February 2024	13200	1970	11230	85.1
March 2024	14520	2100	12420	85.5
April 2024	10560	1290	9270	87.8
Average				85.3

The following is a graph of availability values for the period June 2023 – April 2024:



Figure 5:- Availability graph.

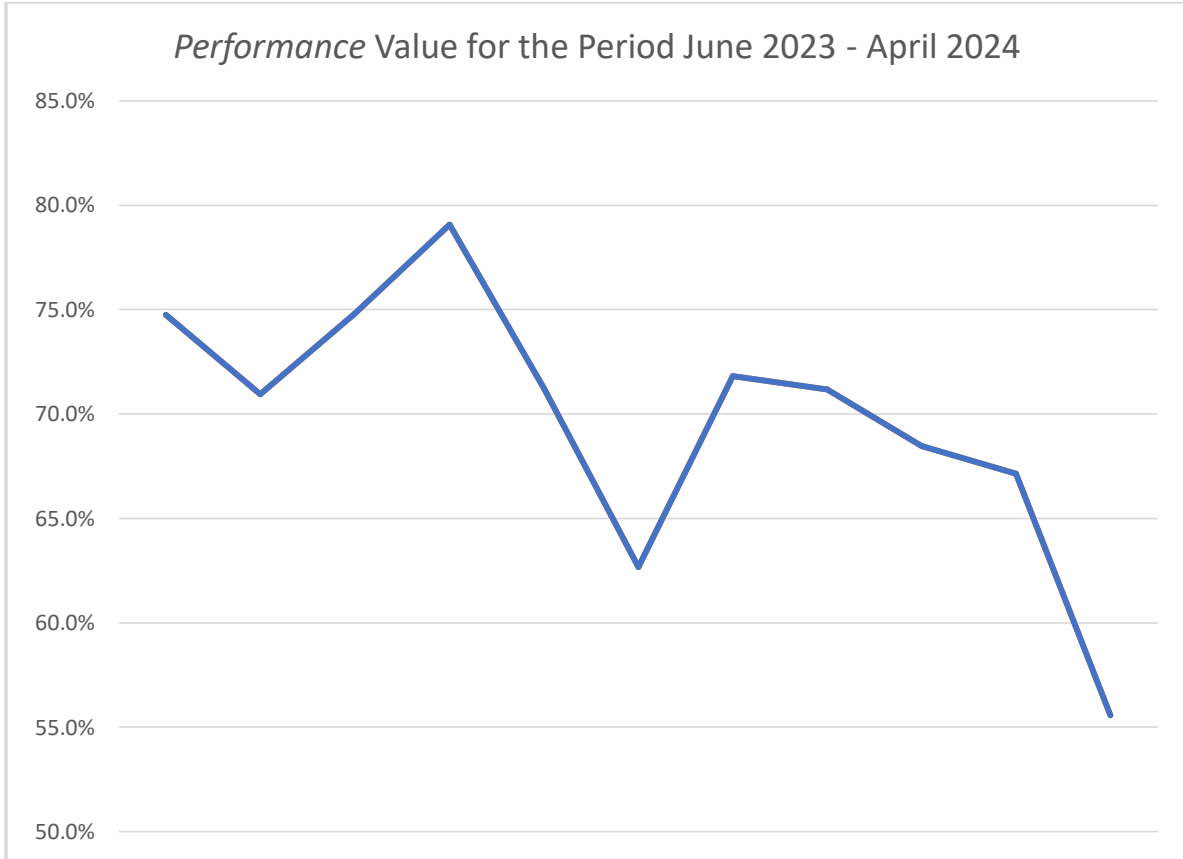
The availability value experiences an erratic increase and decrease due to the time available increasing and decreasing along with the time used in the mining process. This degradation process is also the result of no chamber maintenance .

Performance factors

Table 5 Performance factors.

Month and Year	Cycle	Average time cycle	Operating time	% Performance
June 2023	174	43.56	10140	74.7
July 2023	182	44.36	11380	70.9
August 2023	240	39.83	12780	74.8
September 2023	241	39.73	12100	79.1
October 2023	222	39.46	12300	71.2
November 2023	217	39.48	13670	62.7
December 2023	223	39.58	12290	71.8
January 2024	220	39.86	12320	71.2
February 2024	197	39.03	11230	68.5
March 2024	210	39.7	12420	67.1
April 2024	129	39.93	9270	55.6
Average				69.8

The following is a graph of performance values for the period June 2023 – April 2024:



The performance value tends to decrease due to the need for more cycle time in carrying out the cupulation process due to uneven heating in the machine. In addition, it makes cycle times longer.

OEE

Table 6:- Calculation of OEE value.

Month and Year	% Availability	% Performance	%Quality	OEE
June 2023	85.4	74.7	97.2	62.0
July 2023	86.2	70.9	97.6	59.7
August 2023	84.2	74.8	97.7	61.6
September 2023	83.4	79.1	99.7	64.5
October 2023	84.7	71.2	97.8	59.0
November 2023	86.3	62.7	99.3	53.7
December 2023	84.6	71.8	98.9	60.1
January 2024	84.8	71.2	99.6	60.2
February 2024	85.1	68.5	99.4	57.9
March 2024	85.5	67.1	99.7	57.3
April 2024	87.8	55.6	98.6	48.5
Average				58.6

The following is a graph of OEE values for the period June 2023 – April 2024:

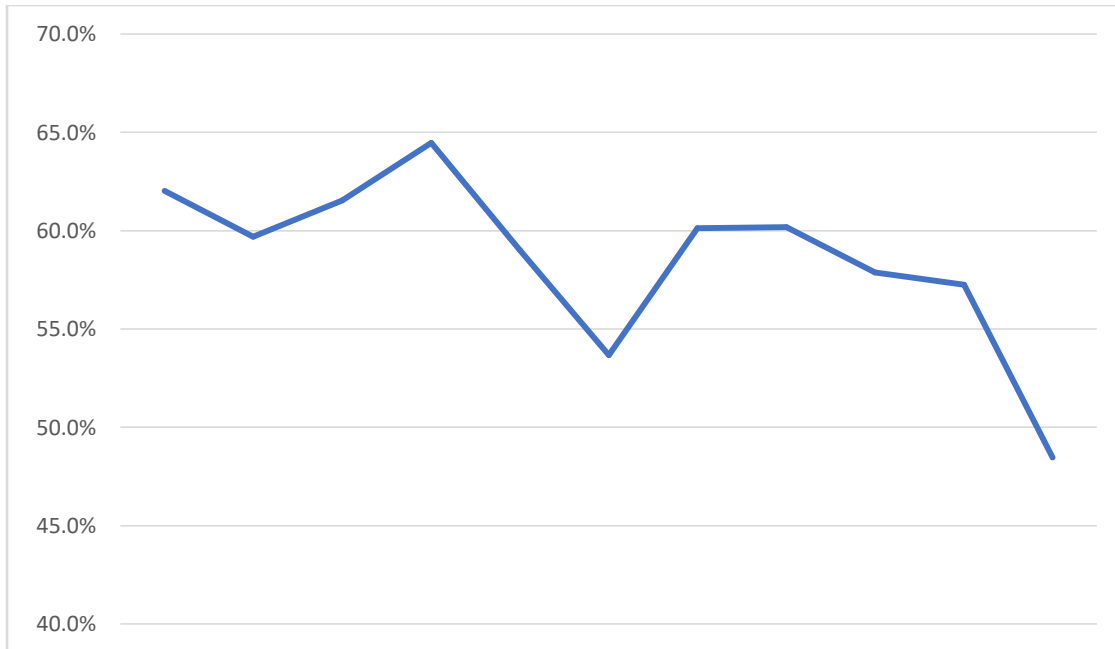
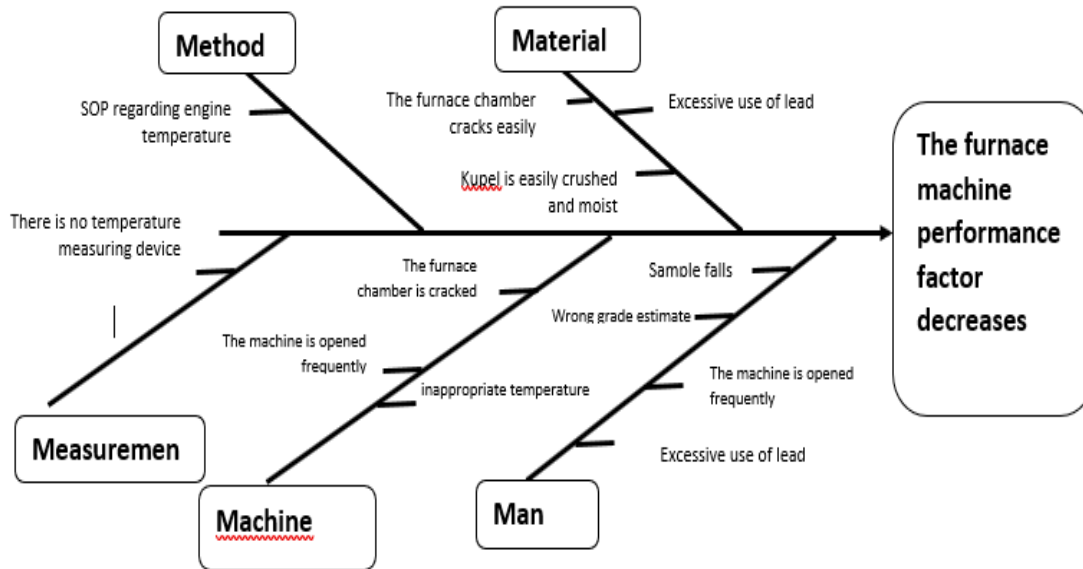


Figure 5:- OEE graph.

Fishbone Diagrams

Furnace engine performance, a fishbone diagram is used.



1. furnace engine chamber easily cracks and sticks due to the nature of the material, the chamber is made from curundum which is easy to crack, easy to heat and absorb.
2. furnace engine chamber can also cause uneven temperature distribution so that the cupulation process cannot run optimally and the time required becomes longer.
3. Inappropriate furnace temperatures are caused by operators opening the furnace lid too often , so that temperature changes occur too quickly.
4. There is no SOP that discusses machine temperature & temperature in the cupulation process, causing operators not to know the limits in opening or closing the furnace .
5. Incorrect grade estimates provided by other divisions can cause failure of the cupulation process and cause the quality value to decrease.
6. Over/under use of lead is a result of incorrect concentration estimation. This can slow down the cupellation process.

7. Samples falling into the furnace chamber can accelerate chamber damage because the material from the chamber is easy to absorb.
8. Coupling media that is damp and not heated can cause an explosion in the furnace or the sample to bounce in all directions. This can also accelerate damage to the furnace engine chamber .
9. A lower room temperature and the blower not turning on optimally can prevent process steam from being wasted optimally and can be absorbed by the furnace engine chamber .
10. The room temperature is lower at night and the blower is not on, which can cause process steam that is not wasted to be condensed again and absorbed by the furnace engine chamber .

Proposed Improvements to the 5W 1H Method

Based on the results of the interviews conducted, the results for each question were:

- a. What
The estimated level is wrong, the cup is not hot, the machine is often opened and closed, the temperature is not reached.
- b. Where (Where)
The furnace chamber is sticky and cracked, the temperature is not appropriate, the heating is uneven, the blower is not optimal.
- c. When (When)
The furnace chamber began to experience damage 3 months after replacement and accelerated when samples fell into it.
- d. Who (Who)
Maintenance staff is responsible for replacement
Fire assay operators are required to report if damage occurs
- e. Why (Why)
The chamber furnace is made from curundum which is easy to heat, easy to crack and absorbs. Because this absorption property can cause accelerated damage. Dropped samples, remaining process vapors, and condensed process vapors will be absorbed into the chamber.
- f. How
Countermeasures that can be taken are: replacing the chamber every 3 months, replacing the chamber with better material, cleaning the chamber regularly, the operator being more careful, making sure the blower is working optimally, and calibrating.

Conclusion:-

Based on the results of data processing and data analysis, the following conclusions can be drawn:

The average OEE value is 58.6%, which is below the world class standard of >85%. The performance factor of 69.8% really influences the OEE value because this value is very small compared to the other two factors. The quality factor value is 98.6% and the availability factor value is 85.3%. Based on interviews using the 5W 1H method, several solutions were obtained to improve furnace machine performance factors through machine factors and human factors. For human factors, the furnace engine chamber is replaced periodically every 3 months, the furnace engine chamber is cleaned regularly and immediately if a sample spill occurs, the furnace engine is calibrated regularly, the blower is checked periodically and the automatic timer is added to turn the blower on and off . Meanwhile, human factors can be carried out by conducting regular briefings regarding the condition of the furnace machine with the operator, carrying out cross checks and recording estimated levels before carrying out gold content analysis.

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