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Improving the Quality of Boiler Feed Water Based on the PDCA Cycle by Integrating Seven Tools

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Abstract

A boiler is an equipment that produces steam, which is used as a heater, drives a turbine to produces electricity, and so on. In order to avoid reducing efficiency boilers and save operational costs due to the formation of scale and corrosion on pipes, special treatment is required for boiler water. However, the facts in the field are that many BFW (*Boiler Feed Water*) products are found that do not meet the quality requirements set by the company. PT. Petrokimia Gresik is an industrial chemical company that uses boilers to assist its production process. The method used in this study is quality control analysis with the PDCA approach and Seven Tools in the form of check sheets, histograms, Pareto diagrams, control charts, fishbone diagrams, and FMEA to identify the factors causing the occurrence of defective products and see the corrective actions that must be taken based on the factors causing the occurrence of defective products. Preventive maintenance was carried out to create and schedule socialization of SOPs, collect data on spare part replacements, and check the chemical content in work unit wastewater. Based on the research results, it reveals that the PDCA approach and Seven Tools can minimize defects and succeed in reducing SO_3 and PO_4 parameter defects by 67,5%. The proposed improvement efforts include preventive maintenance, monitoring the consistency of SOP implementation, identifying replacement spare parts, as well as checking chemical content in work unit wastewater.

Keywords: Type your keywords here, between 3 and 6, separated by semicolons (Bahasa Inggris).

1. Introduction

A boiler is equipment that produces steam used as a heater, to drive a turbine that produces electricity, and so on. In order to avoid reducing boiler efficiency and saving operational costs due to the formation of scale and corrosion on pipes, special treatment is required for boiler water (Daeng Polewangi, 2019). The boiler in this production unit utilizes the heat from burning sulfur, which reaches a hot temperature of 1.042°C. Before proceeding the next system, it is necessary to prepare heat reduction to prevent damage the material, hence media in the form of WHB (Waste Heat Boiler) is needed (Huang et al., 2023; Madejski & Żymełka, 2020; Schoeneberger et al., 2022). The SO_2 gas resulting from combustion is directed to the WHB tube while the BFW fluid is flowed to the shell side. This heat exchange converts BFW into steam while the hot gas resulting from combustion experiences a temperature drop of up to 550°C (Pronobis et al., 2023; Rahman et al., 2022; Saidur et al., 2011; Sun et al., 2014).

The BFW used in the steam production process must not contain mineral content in it because it will have an impact on the boiler working system. The impact of deviations in the quality of the water used can result in problems with corrosion, scale, foaming and deposits. In fact, this problem results in losses in the form of reduced boiler efficiency (Hamzah et al., 2021; Klyukin et al., 2023; Setyawan et al., 2021).

Based on production data from October 2022 to March 2023, the BFW production process produced 398028.4 tons where after sampling 168 times, four types of defects occurred, namely PO_4, SO3, pH, and TH analysis defects with a total of 79601.74. tons or 20 %. Due to deviations that are quite large, quality control is needed in order to minimize analytical defects in these parameters so that the performance of the boiler can be maximized, which can indirectly save operational costs. The researchers want to identify the problems above to find out the level of defects that occur in the product and what factors influence it so that they can determine recommendations for improvement and prevention to reduce defects in the product

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2. Research Method

2.1. PDCA and Seven Tools

This research was conducted at the Sulfuric Acid Unit I, PT. Petrokimia Gresik. The initial step taken was observation in the production area, then secondary data were collected through interviews and documentation. Mapping of existing problems was carried out and proposals for improvement were formulated using the PDCA concept and Seven Tools.

PDCA and Seven Tools are methods used to determine the tolerance limits for defects in products that can be accepted by the company. PDCA was developed by American physicist, Dr. W. Edward Deming. This cycle is often also called the Deming cycle (Deming Cycle/Deming Wheel). The PDCA concept is often applied in tests that implement improving the quality of a product, process or work system. The stages in the PDCA concept are as follows (Eriandani, Pudjolaksono, 2018):

a) Plan (Planning)
b) Do (Implementation)
c) Check (Checking results)
d) Action (Adjustment action)

It cannot be denied that the Seven Tools have developed and are known by many people as quality control tools for quality improvement activities and problem solving in the context of improving quality (Dahniar, 2018).

Seven Tools is one of the tools needed to control statistical processes in the form of seven quality control tools. These tools include check sheets**,** histograms, Pareto diagrams, control charts, fishbone (cause and effect) diagrams, scatter diagrams, and process diagrams (Dahniar & Candra, 2021).

2.2. Research Preparation

The problems in this research are related to claims and defects that occur in production. Data were obtained from field observations, interviews, documentation, and literature studies to support research (Hakim et al., 2022; Sugiyono, 2017, 2019). The type of data in this research used primary data obtained from PT. Petrokimia Gresik as the research location. The high number of analytical defects in BFW products is one of the problems currently faced by companies. The first step that needs to be taken to analyze quality control statistically is to create a check sheet table for the number of production and number of defects. Data collection and analysis shows that BFW has more than one type of disability.

From the data above, there was a high level of defects at 23% of the total product sampling from October 2022 to March 2023. Therefore, this research aims to improve product quality and reduce the defects that occur (Isniah et al., 2020).

3. Results and Discussions

3.1. Plans

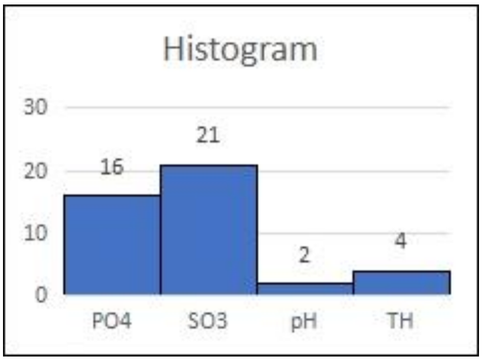
A plan is a step to determine a theme for improving quality problems that often occur. The following is a Pareto diagram of the defects types that often occur in BFW product analysis in the period October 2022 – March 2023.

3.1.1. Check Sheets

The action taken is to collect data on BFW products, both the number of samples and the types of defects that occur (Table 1).

3.1.2. Histograms

A histogram is a tool to determine the distribution of the number of types of defects in a product (Figure 1).



(**Source**: Author's processed data)

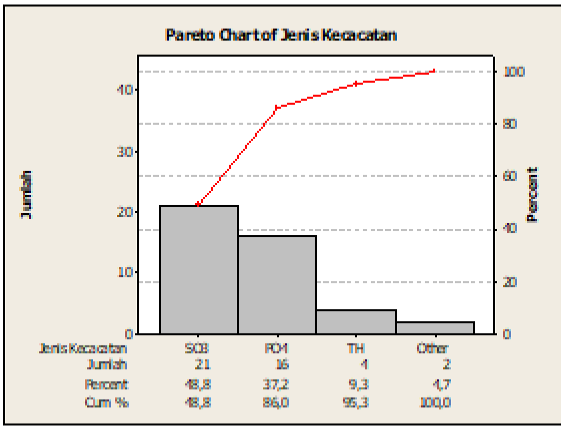
Figure 1. Histogram Data of highest analysis defects

Table 1. BFW product analysis data for the period October 2022 – March 2023

Period	Number of Samples	Types of Disabilities				Total Disability
		PO4	SO3	pH	TH	
Oct	28	3	3	1	1	8
Nov	28	1	3	0	1	5
Dec	28	2	5	1	1	9
Jan	28	5	4	0	0	9
Feb	28	3	3	0	0	6
Mar	28	2	3	0	1	6
Total	168	16	21	2	4	43

(**Source:** PT. Petrokimia Gresik)

3.1.3. Pareto Chart



(**Source**: Author's processed data)

Figure 2. Pareto diagram: Highest analysis disability data for the period October 2022 – March 2023

From the results of the Pareto diagram (Figure 2), the percentage of SO_3 defects is 47,1% and PO_4 defects amounting to 38,8% had the highest rating. This research focuses on this type of disability. Thus, the theme of improvement that will be carried out in this research is to reduce SO_3 and PO_4 analysis defects in BFW products.

3.1.4. Control Chart

Based on the Xbar R-Chart control chart diagram (Figure 3 and 4) that the analysis of the data obtained in October 2022 – March 2023 the upper control and control limits from Table 2 and 3 as well as in Figures 3 and 4 experience fluctuations but are still within the control limits and there is no data out of the control limits.

Table 2. Analysis of SO_3 Control chart calculations of BFW products for the period October 2022 – March 2023

Month	Week	Sample measurement results 1	2	3	4	5	6	7	Xbar	R	CL Xbar	CL R
Oct '22	I	7.1	5.8	5.2	9.0	7.9	5.5	8.2	7.0	3.8	4.9	5.0
	II	6.7	6.1	5.4	7.3	6.5	4.5	7.9	6.4	3.4	4.9	5.0
	III	7.8	6.3	6.8	7.5	3.8	6.9	6.1	6.5	4.0	4.9	5.0
	IV	7.5	4.2	5.4	6.6	6.4	5.8	5.2	5.9	3.3	4.9	5.0
Nov '22	I	3.9	7.4	6.6	6.2	7.1	7.5	4.1	6.1	3.6	4.9	5.0
	II	7.9	7.1	5.2	3.4	6.6	8.0	5.8	6.3	4.6	4.9	5.0
	III	5.8	5.2	5.4	5.4	5.8	6.7	5.2	5.6	1.5	4.9	5.0
	IV	6.1	5.3	5.4	6.1	7.6	5.3	5.5	5.9	2.3	4.9	5.0
Dec '22	I	6.1	3.9	5.7	3.8	6.7	6.9	5.4	5.5	3.1	4.9	5.0
	II	7.2	6.2	3.8	7.3	2.9	0.0	4.5	4.5	7.2	4.9	5.0
	III	3.5	5.9	0.9	6.2	6.3	8.0	0.2	4.4	7.8	4.9	5.0
	IV	4.9	7.2	5.7	2.0	3.3	7.0	7.0	5.3	5.2	4.9	5.0
Jan '23	I	4.6	3.1	2.4	2.2	0.6	7.4	2.4	3.2	6.7	4.9	5.0
	II	4.5	4.1	0.3	5.0	5.5	6.1	5.0	4.3	5.8	4.9	5.0
	III	3.5	3.2	4.9	5.1	3.6	4.0	2.6	3.8	2.5	4.9	5.0
	IV	5.3	0.6	8.0	1.6	3.6	4.0	3.3	3.8	7.4	4.9	5.0
Feb '23	I	7.7	6.1	2.6	3.0	6.4	1.0	3.2	4.3	6.8	4.9	5.0
	II	4.8	2.7	8.0	2.6	2.5	2.9	3.7	3.9	5.5	4.9	5.0
	III	2.8	7.8	3.7	4.7	7.8	2.5	3.9	4.8	5.3	4.9	5.0
	IV	5.9	2.7	4.8	8.0	1.4	1.8	3.1	3.9	6.6	4.9	5.0
March '23	I	3.1	0.8	2.6	0.5	7.9	2.0	3.3	2.9	7.4	4.9	5.0
	II	8.0	0.3	2.4	3.4	1.0	5.5	2.6	3.3	7.7	4.9	5.0
	III	6.4	5.5	2.9	6.7	6.5	7.5	3.7	5.6	4.6	4.9	5.0
	IV	3.7	3.6	6.9	4.2	6.1	5.7	2.4	4.7	4.5	4.9	5.0

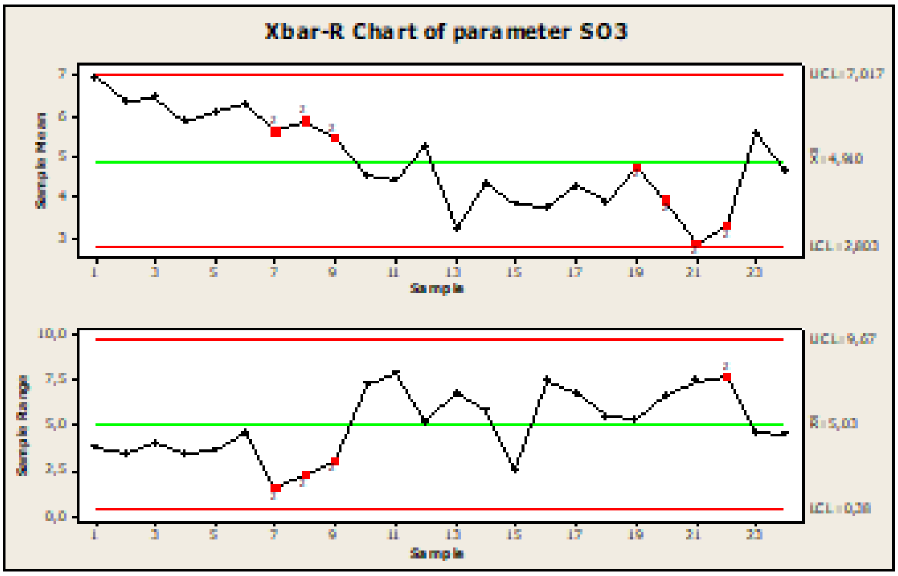


Figure 3. Control Chart SO_3 analysis

Table 3. Control chart calculation of PO_4 parameters for BFW products for the period October 2022 – March 2023

Month	Week	Sample measurement results							Xbar	R	CL Xbar	CL R
		1	2	3	4	5	6	7				
Oct '22	I	8.1	4.9	7.4	8.9	4.7	5.7	5.6	6.5	4.2	6.2	3.3
	II	9.1	9.1	6.4	5.7	7.2	6.9	5.5	7.1	3.6	6.2	3.3
	III	4.9	8.9	3.2	6.4	6.0	5.2	7.2	6.0	5.7	6.2	3.3
	IV	5.5	9.1	6.4	8.3	6.5	6.7	6.5	7.0	3.6	6.2	3.3
Nov '22	I	5.9	6.2	5.5	5.5	5.5	5.5	5.5	5.7	0.7	6.2	3.3
	II	7.8	6.9	4.2	6.3	5.7	8.6	5.6	6.4	4.4	6.2	3.3
	III	6.2	8.8	5.7	5.9	5.1	5.2	6.8	6.2	3.7	6.2	3.3
	IV	5.8	6.4	6.1	5.4	6.3	6.8	5.5	6.0	1.4	6.2	3.3
Dec '22	I	8.4	6.3	7.0	8.4	4.5	5.2	5.0	6.4	3.9	6.2	3.3
	II	6.5	6.9	7.5	4.6	7.1	5.5	5.7	6.3	2.9	6.2	3.3
	III	5.4	5.3	6.1	5.3	4.5	7.0	6.1	5.7	2.5	6.2	3.3
	IV	7.5	3.5	7.7	4.7	5.0	6.3	6.5	5.9	4.2	6.2	3.3
Jan '23	I	6.5	8.7	5.5	6.1	6.3	6.2	7.3	6.7	3.2	6.2	3.3
	II	6.8	7.5	4.4	5.4	6.0	7.2	5.0	6.0	3.1	6.2	3.3
	III	4.5	6.9	4.8	3.6	6.9	6.5	3.9	5.3	3.3	6.2	3.3
	IV	5.6	8.2	5.3	5.9	7.8	8.4	6.2	6.8	3.1	6.2	3.3
Feb '23	I	5.6	9.3	4.2	6.2	5.4	7.5	5.4	6.2	5.1	6.2	3.3
	II	6.7	9.8	6.4	4.6	7.3	5.5	5.4	6.5	5.2	6.2	3.3
	III	6.6	5.1	6.4	6.2	6.4	6.6	6.3	6.2	1.5	6.2	3.3
	IV	4.8	5.1	5.9	5.4	5.1	6.4	4.1	5.3	2.3	6.2	3.3
March '23	I	4.7	4.9	5.5	6.5	6.4	5.7	5.9	5.6	1.8	6.2	3.3
	II	5.5	6.9	6.0	4.3	5.7	6.5	6.5	5.9	2.6	6.2	3.3
	III	5.1	8.2	4.1	7.3	5.9	5.6	7.1	6.2	4.1	6.2	3.3
	IV	6.3	5.7	7.3	6.3	6.7	8.4	5.7	6.6	2.7	6.2	3.3

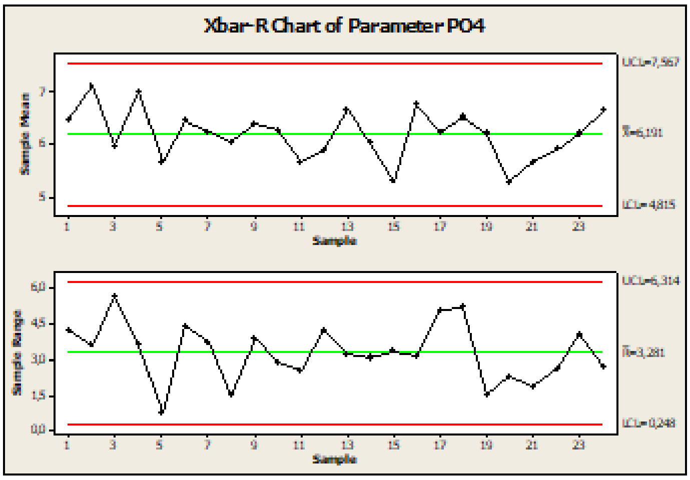


Figure 4. PO_4 analysis control chart

3.1.5. Fishbone Diagram

Fishbone (cause-and-effect) diagram is required to analyze all factors that cause damage to a product. Factors that influence and cause damage to the product need to be followed up to resolve the problem.

3.1.6. Determining dominant factors

From the analysis carried out, it is known that the equipment factor is the most dominant factor or has a big influence on defects in the SO_3 and PO_4 parameters that occur in the production process (Table 5).

Table 5. FMEA Defect parameters SO_3 and PO_4

No	Factor	Problem	Effects of Failure	S	O	D	RPN
1	Machine	There is no preventative maintenance on the pump	Chemical leaks through packing	5	4	4	80
2	Material	Mixing Time is too short	Chemical mixing is less than perfect	3	5	3	45
3	Method	There is no history of replacing the pump packing	Chemical leaks through packing	5	3	2	30
4	Man	Lack of socialization about Standard Operating Procedures (SOP)	Workers are not careful	3	3	3	9
5	Environment	Chemical spills	Environmental pollution	5	3	1	15

Source: Observations and discussions with the company

Table 6. Assessment of the Root Cause of the Problem

Mark	Impact of the Problem (Severity)	Probability of Event (Occurrence)	Seriousness of the Problem (Detection)
5	Influence on the Environment	Very influential	Cannot be avoided
4	Influence on the Company	Somewhat Influential	Often occur
3	Influence on the Factory	Influential	It's likely to happen
2	Influence on Work Units	No Influence	Rarely happen
1	Influence on the Work Area	Very Influential	Occasionally happens

Source: Observations and discussions with the company

3.2. Do

In the previous stage, a plan for the improvement process was determined. At the DO stage, the researchers must immediately carry out an improvement plan from the previous stage. It is expected that these improvements can be carried out optimally so that no time is wasted, which results in company losses (Table 7).

Table 7. Improvement plan

No	What	Why	Who	Where	When	Action
1	There is no preventative maintenance on the pump.	Because maintenance was carried out when the pump is damaged.	Afif Fajar	Production Area	June 2023	Preventive maintenance is carried out every Monday.
2	Mixing Time is too short.	Because chemicals dissolve easily.	Naufal	Production Area	June 2023	Create SOPs regarding the manufacture of chemical solutions.
3	There is no history of replacing the pump packing.	Because the packing is replaced if there is damage.	Boy	Production Area	June 2023	Created packing replacement data.
4	Lack of socialization about SOP (Standard Operating Procedure).	Because there is no need for socialization yet.	Wawan	Production Area	July 2023	Create a socialization schedule regarding SOP.

No	What	Why	Who	Where	When	Action
5	Chemical spills	Due to packaging damage	Taufik	Production Area	July 2023	Checking the SO_3 & PO_4 content in work unit wastewater.

Source: Observations and discussions with the company

3.3. Check

The next step is to evaluate corrective actions at the DO stage. It aims to find out the difference between the actual conditions and the targets to be achieved. Evaluation refers to the viewpoints of Quality, Cost, Delivery, Safety, and Productivity (Idris & Aditya Sari, 2016).

Table 8. Before Research

Types of Disabilities	Amount	%	% Accuracy
SO_3	21	48,8%	48,8%
PO_4	16	37,2%	86%
TH	4	9,3%	95,3%
pH	2	4,7%	100%
TOTAL	43		

Table 9. After Research

Types of Disabilities	Amount	%	% Accuracy
TH	7	41,2%	41,2%
SO_3	5	29,4%	70,6%
PO_4	3	17,6%	88,2%
pH	2	11,8%	100%
TOTAL	17		

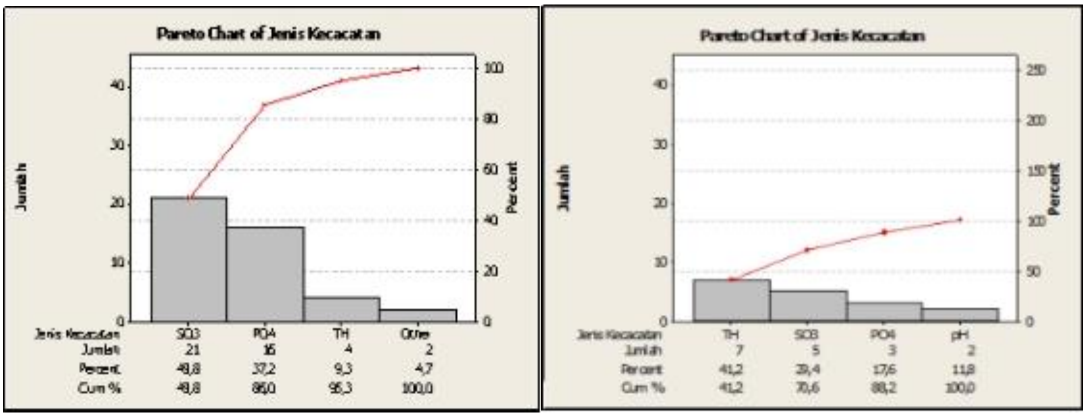


Figure 5. Pareto Chart

Based on the results of applying the Seven Tools method, it succeeded in reducing SO_3 and PO_4 analytical defects by 28.430,2 m^3. This can be seen from the decrease in SO_3 and PO_4 parameter defects from 37 samples to 12 samples or 67,5% compared before using the PDCA and Seven Tools methods. By reducing defects in BFW products, it can also reduce environmental pollution by chemical spills, both SO_3 and PO_4 because the high content of SO_3 and PO_4 can result in increased levels of minerals and nutrients in waters (Sentosa et al., 2017), resulting in DO levels in waters decreased (Zairinayati & Shatriadi, 2019). Referring to Minister of Environment Decree No. 51 of 2004 that if PO_4 pollution levels exceed 0.015 mg/L, it will have an impact on the viability of marine biota in the waters.

3.4. Action

After checking the problems in the BFW product analysis at PT. Petrokimia Gresik can be minimized during the period April – September 2023. The next step is to implement standardization to prevent recurring problems. The following is a standardization table for the BFW production process:

Table 8. Standardization of BFW production processes

No	Factor	Reason	Normal Standard	Company Standards after improvement
1	Machine	There is no preventative maintenance on the pump.	Preventive maintenance is carried out every Monday.	Operators must always check the condition of the pump and carry out preventive maintenance once a week on all equipment.
2	Material	Mixing time is too short.	Create SOPs regarding the manufacture of chemical solutions.	Assess the performance of suppliers and chemical raw materials and complete SDS for each chemical.
3	Method	There is no history of replacing the pump packing.	Created packing replacement data.	Assessing the performance of spare part suppliers.
4	Man	Lack of socialization about Standard Operating Procedures (SOP).	Create a socialization schedule regarding SOP.	The section head must frequently supervise the performance of production operators.
5	Environment	Chemical spills	Checking the SO_3 and PO_4 content in work unit wastewater.	Monitoring waste water in each work unit.

Source: Observations and discussions with the company

4. Conclusion

Based on the results of applying the PDCA method and Seven Tools on BFW products at PT. Petrokimia Gresik so that product quality control can be maintained and even improved so that losses to the company can be minimized due to the large number of defective products. The recommendations for PT. Petrokimia Gresik to carry out all activities routinely and continuously at the Action stage. Other implementations that need to be implemented so that quality control can be maximized, include determining commitment and policies in quality management, establishing a quality control division so that it can carry out monitoring and supervision quickly and precisely in order to minimize defects in, and reviewing the existing management systems.

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