JURNAL ILMIAH TEKNIK INDUSTRI
ISSN: 1412-6869 (Print), ISSN: 2460-4038 (Online)
Journal homepage: http://journals.ums.ac.id/index.php/jiti/index
doi: 10.23917/jiti.v22i2.22875

Risk Assessment Analysis in Boiler System with Hazard and Operability Study (HAZOP)

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Abstract. *PT PJB UBJOM and PLTU Pacitan are using steam power to produce electricity called a Steam Power Plan. The process uses a coal-fired boiler to heat water and produces steam (high-temperature water vapor) to turn a turbine. There is always a risk of crushing injuries, electrical shocks and burns, boiler fires, and explosions, and contact with hazardous chemicals in the work environment, which is frequently hot and noisy and involves several large equipment and processes. The objective of this research is to analyze the risk assessment in Boiler systems with Hazard and Operability Study (HAZOP). Additionally, the usual risk matrix was used to quantify and rank the likelihood and severity of each deviation. The five probability and severity categories are divided into four risk assessment levels by the 5x5 risk matrix. This study uses the risk matrix on PT. PJB standard. According to the results of the Hazard and Operability Study (HAZOP) on PT PJB's boiler system, there are two study nodes with extremely high-risk levels: the feed water setting to the steam drum has a damaged feed water pump, and the steam pressure on the steam drum has a damaged safety valve. As a result, the water level is low, and the boiler trips. The controls implemented by PT PJB are pump repair/ replacement, feed water flow sensor, steam drum level sensor, inspection/ safety valve repair, leak check, sensor level, sensor pressure, and safety valve certification.*

Keywords: *risk assessment; boiler system; HAZOP*

I. INTRODUCTION

PT PJB UBJOM and PLTU Pacitan are a subsidiary of the State Electricity Company, which is part of the State-Owned Enterprises and engaged in the operation and maintenance business (Agiyanto & Febriana, 2022). PT PJB is using steam power to produce electricity called a Steam Power Plan. PT PBJ has several generators that supply electricity needs in Java and Bali (Haryanto, 2018).

The Steam Power Plan is one of the power plants produced from the process of heating water into steam to produce electricity. The process uses a coal-fired boiler to heat water and produces steam (high-temperature water vapor) to turn a turbine. Boiler tubes are one of the most important components of power plants where the boiler system produces steam for the processing units to make energy (Tadge et al., 2022). When water is pumped through boiler tubes in water-tube boilers, hot gases from the furnace are utilized to externally heat the water, producing superheated steam (Duarte et al., 2017). Lack of handling and outstanding care for feed water boilers results in several issues, including slag buildup on the boiler walls, corrosion, deposit formation, and steam carryover (Nugraha et al., 2023).

As a company that produces high-capacity electrical energy with advanced technology, PT PJB cannot be separated from the risk of occupational accidents during the operation process. There is always a risk of crushing injuries, electrical shocks and burns, boiler fires, and explosions, and contact with hazardous chemicals in the work environment, which is frequently hot and noisy and involves several large pieces of equipment and processes (Mohd Fahmi Mohd Yusof & Roslina Mohammad, 2023).

A set of procedures are used in risk analysis to quantify and assess risk. Understanding risk characteristics will make it easier to control risk, which is the goal of risk evaluation (Jati Nugroho & Irawan, 2021).

One of the risk analysis tools is Hazard and Operability Study (HAZOP). Hazard and

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Submited: 15-06-2023 Revised: 26-11-2023
Accepted: 20-12-2023

Operability Planning, or HAZOP, is a technique for identifying potential workplace hazards by describing prospective hazards and assessing risks that may arise using a risk assessment matrix (Hadef et al., 2020). The HAZOP approach also examines the machine's operational flow. By speaking with field personnel who use the machine, it is believed that more specific potential dangers can be discovered to reduce and prevent accidents. This technique, which is a component of risk management, can define how occupational safety and health will be used in the business (Susanto et al., 2022).

The purpose of this study was to hazard identification and risk assessment using Hazard and Operability Study (HAZOP) in the Steam Drum Boiler Unit 1 PT PJB UBJ O&M PLTU Pacitan, East Java.

II. RESEARCH METHOD

Hazard identification and risk assessment in Boiler System PT. PJB using the Hazard and Operability Study (HAZOP) methodology. Using the HAZOP technique, all potential deviations

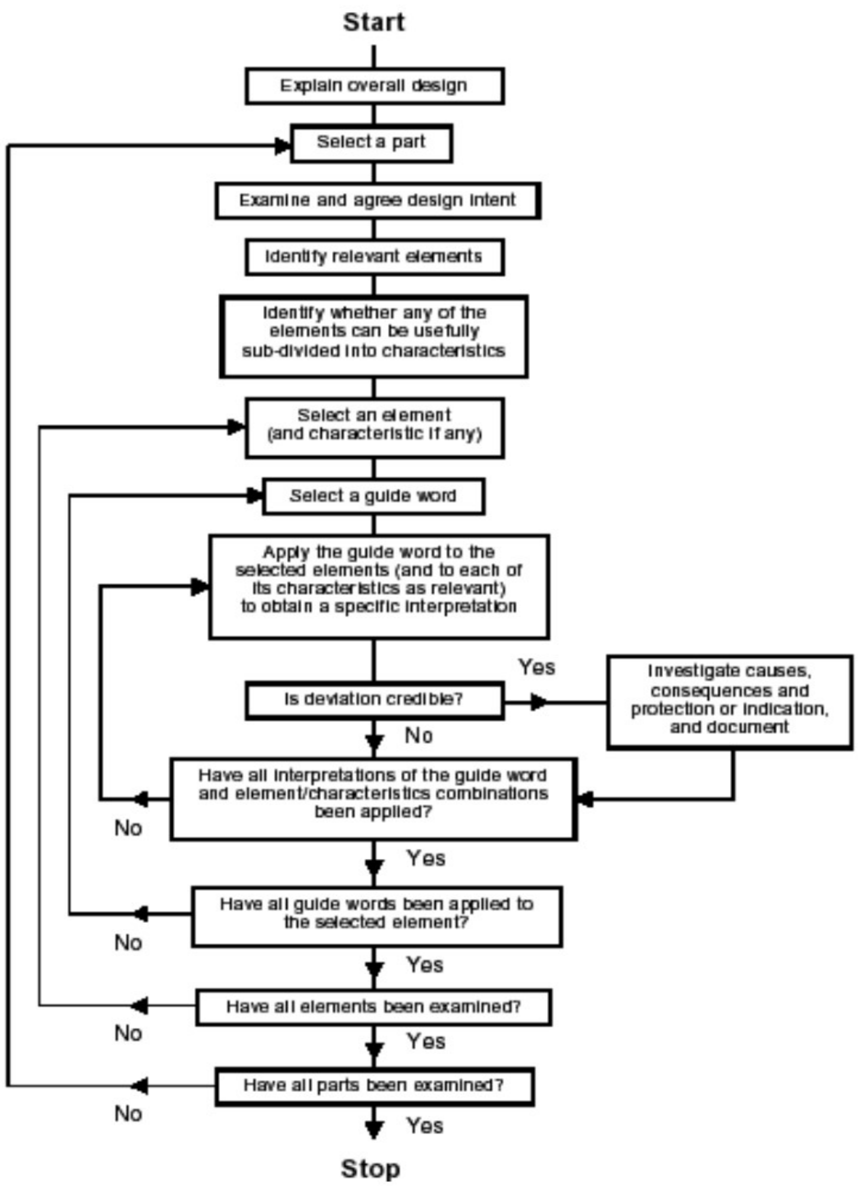

Figure 1. The HAZOP Examination Phase Process Flow (Product Quality Research Institute, 2015)

from the original design goals are identified, and the potential anomalous causes and effects of each departure are determined (Jati Nugroho & Irawan, 2021). It is regarded as a necessary, structured checkup that evaluates the risks that could arise from inappropriate tool and property performance in terms of how those impacts might affect process facilities (Hokmabadi & Karimi, 2023).

The process flow for the HAZOP Examination Phase is shown in the accompanying Figure 1.

Risk has two dimensions, including probability and severity (risk = probability severity), in the risk assessment approach, according to ISO 14971 (Singh & Selvam, 2020). As a result, the experts were asked to assess the likelihood of mishaps and their severity, think about the root causes of deviations, identify existing safety measures, and, if necessary, suggest additional safeguards to bring

Table 1. Severity Level

Severity Level	Description	Indicators	Power Supply	Company Loss
5 – Catastrophe	Risk impact has the potential to fail the company's goals. Special handling is required	a. K-3/Critical Asset: Critical asset damage only requires repair > 6 months or replacement b. K-3/Asset Safety: Assets are heavily damaged, and can no longer be used c. K-3/Safety for the soul: fatalities d. Environment: Location closure, or relocation from KLH	*Downtime* > 1 week	> 5 trillion rupiah
4-Significant	Risk impact has the potential to hinder the company's goals. Mandatory special handling to mitigate it	a. K-3/Critical Asset: Critical asset damage only requires repair in 3-6 months b. K-3/Asset Safety: Assets are heavily damaged, and need improvement. c. K-3/ Safety for the soul: Victims of serious injuries/permanent. d. Environment: Money fine/ operational restrictions from KLH	*Downtime*: 1 day - 1 week	500 billion s.d 5 trillion rupiah
3-Moderate	Risk impact has the potential to lower the company's goals. Treatment/ mitigation required	a. K-3/Critical Asset: Critical asset damage only requires repair for 3 months b. K-3/Asset Safety: Moderate asset damage c. K-3/Safety for the soul: Moderately injured (hospitalized) d. Environment: Warning from KLH	*Downtime*: 12 hours – 1 day.	50 - 500 billion rupiah
2-Minor	Risk impact is acceptable, or can be managed with minimal effort	a. K-3/Critical Asset: Critical asset damage only requires repair 1-month b. K-3/Asset Safety: Minor asset damage c. K-3/Safety for the soul: Minor injuries (outpatient) d. Environment: Warning from KLH. There is environmental pollution but it is still within KLH's threshold and the impact on the environment can be overcome < 1 month	*Downtime*: 3 - 12 hours	500 million s.d 50 billion rupiah
1-Insignificant	Risk impact is acceptable, or mitigated by routine activities	a. K-3/Critical Asset: Critical asset damage only requires minor repairs or a few days b. K-3/Asset Safety: Asset damage can be repaired with FLM and PM c. K-3/Safety for the soul: There were no fatalities d. Environment: There was no warning from KLH. There is environmental pollution but it is still within KLH's threshold and the impact on the environment can be resolved immediately	*Downtime* until 3 hours	< 500 million rupiah

Table 2. Likelihood Level

Level		Qualitative		Quantitative
Category	Description	Frequency	Probability	
1	Very Low	Events are possible only in very extraordinary situations	Less than once in 10 years	<10%
2	Low	Events are possible in special situations	At least once in 10 years	10 – 39%
3	Moderate	Events are possible in most situations	At least once in 5 years	40 - 69%
4	High	Events are possible in various situations	At least once a year	70 – 89%
5	Very High	Events are very possible in various situations	At least once every quarter	>90%

Table 3. Risk Matrix

Probability	Very High	5	Moderate	Moderate	High	Extreme	Extreme
	High	4	Low	Moderate	High	Extreme	Extreme
	Moderate	3	Low	Moderate	High	High	Extreme
	Low	2	Low	Low	Moderate	High	Extreme
	Very Low	1	Low	Low	Moderate	High	Extreme
			1	2	3	4	5
			Insignificant	Minor	Moderate	Significant	Catastrophe
			Impact Scale				

unacceptable risk levels down to an acceptable level (Yousofnejad et al., 2023).

Additionally, the usual risk matrix was used to quantify and rank the likelihood and severity of each deviation. The five probability and severity categories are divided into four risk assessment levels by the 5x5 risk matrix. This study uses the risk matrix on PT. PJB standard.

III. Result and Discussion

The production process of PT PJB UBJ O&M PLTU Pacitan, East Java is generally divided into water and steam cycles, and fuel oil and coal cycles. The water and steam cycles consist of a seawater treatment process until it becomes water that meets the requirements of boiler-fill water. The fuel oil and coal cycles consist of the processing of fuel oil as the initial ignition to the process of handling coal as the main fuel. Production process flow chart of PT PJB UBJ O&M PLTU Pacitan explained in Figure 2.

In the Steam Power Plant (PLTU), the Boiler is a tool used to evaporate filler water, there is a change in the liquid phase to a wet vapor phase in this tool. Wet steam will be evaporated into hot steam. The Boiler system consists of the feed water system, steam system, and fuel system as in

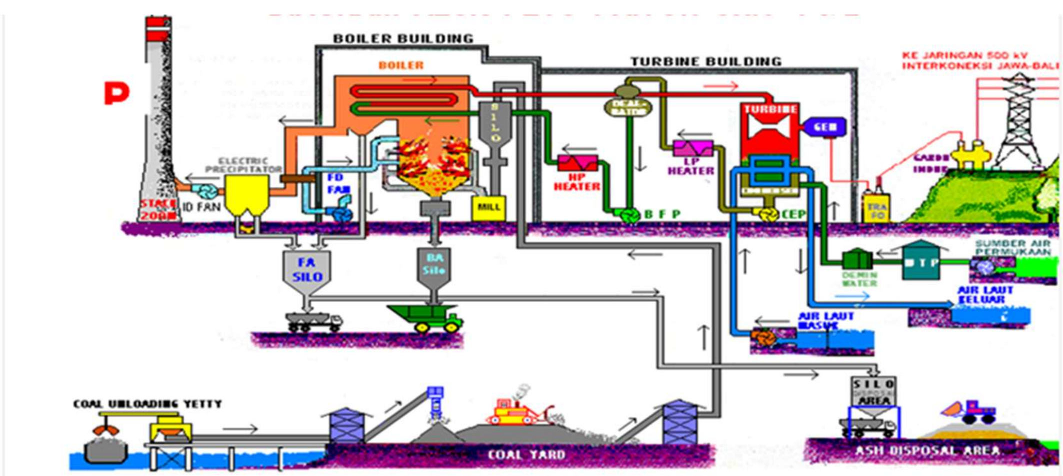

Figure 2. Production Process Flow Chart of PT PJB UBJ O&M PLTU Pacitan

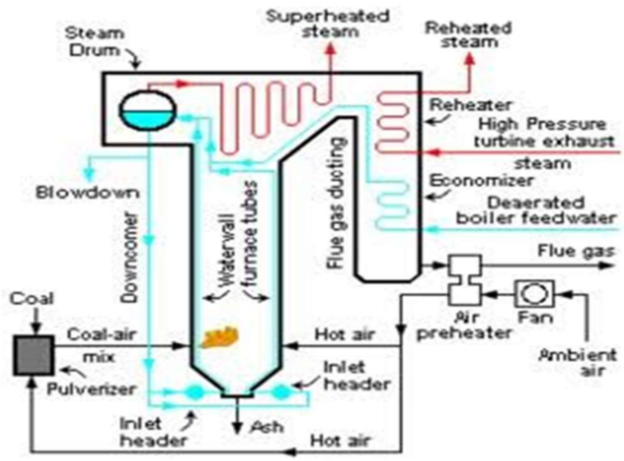

Figure 3. The Boiler System

Figure 3. (Tadge et al., 2022). The feed water system provides water for the boiler automatically according to steam requirements. The steam system collects and controls the steam production in the boiler. In a steam system, the steam pressure is regulated using a faucet and monitored by a pressure monitor. The fuel system is all the equipment used to provide fuel to produce the heat needed by the boiler (Hendrawan & Lusiani, 2022). From the function of the boiler, there are many systems used in the formation of main steam, so it can pose a potential hazard that must be controlled.

Table 4 explains the results of hazard identification and risk assessment using the Hazard and Operability Study (HAZOP) on PT PJB's boiler system which consists of a feed water system (steam drum), steam system (superheater), and fuel system (furnace).

Based on the risk analysis in the steam drum (feed water system) area, there are two study nodes with extreme risk levels. In the Feed water setting to the steam drum there is feed water pump damage that causes the boiler to trip. One of the damages to the feed water pump is the high vibration of the auxiliary boiler steam feed water pump. This damages the impeller and other feed water pump components due to damage to the pump base (Aji, 2022). The amount of power generated and the efficiency of industrial processes will be significantly impacted by any damage to or maintenance required on the boilers (Samantaray & Das, 2020). Boiler-related accidents may cause production loss or property loss. Sometimes innocent bystanders nearby may also perish or suffer damage. The controls implemented by PT PJB are pump repair/ replacement, feed water flow sensor, and steam drum level sensor.

The next extreme risk level, is the steam pressure on the steam drum there is safety valve damage, so the water level is low and causes the

Table 4. Risk Level on Feed Water Setting to Steam Drum

Study Nodes	Guide Word	Parameter	Deviation	Cause	Consequence	L	S	Risk Matrix	Controls
Feed Water Setting to Steam Drum	No	Flow	No Flow	Feed water pump damage	Boiler trip	1	5	Extreme	Pump repair/ replacement, Feedwater Flow Sensor, Steam drum level sensor
	Less	Flow	Less Flow	Piping leak	Temperature Boiler High	2	4	High	Repair/Retubing, Steam drum level sensor, Boiler furnace temperature sensor
	More	Flow	More Flow	Parameters error	Level drum high	1	3	Moderate	Operating settings, steam drum level sensor

Table 5. Risk Level on Steam Pressure Setting in Steam Drum

Study Nodes	Guide Word	Parameter	Deviation	Cause	Consequence	L	S	Risk Matrix	Controls
Steam Pressure Setting in Steam Drum	No	*Pressure*	*No Pressure*	Steam drum manhole leak	There is no steam flow to the Boiler	1	4	High	- Tightening of manhole bolts - Manhole repair - Sensore pressure steam drum - Environment patrol check - Safety valve certification together with OH activity
	Less	Pressure	Less Pressure	Safety valve damage	Steam pressure to the boiler less/none	2	4	High	- Inspection/ safety valve repair - Safety valve resetting - Environment patrol check - Safety valve certification together with OH activity
	More	Pressure	More Pressure	Safety valve damage, low water level	Boiler trip	1	5	Extreme	- Inspection/ safety valve repair - Leak check - Sensor level - Sensore pressure - Safety valve certification together with OH activity

Table 6. Risk Level of Ammonia and Phosphate Chemical Injection

Study Nodes	Guide Word	Parameter	Deviation	Cause	Consequence	L	S	Risk Matrix	Controls
Ammonia and Phosphate Chemical Injection	Less	Addition	Less Addition	Injection line leak	The pH rises and damages the components to form a scale on the pipe	1	4	High	Checking the ammonia and phosphate injection components, and sampling the quality (Ph) of steam drum water is carried out routinely at each start-up unit, and normal operation
	More	Addition	More Addition	Damage to the injection sensor in detecting ammonia and phosphate levels	pH drops and damaged components corrode	1	4	High	

Table 7. Risk Level on Cyclone Separator Steam Drum

Study Nodes	Guide Word	Parameter	Deviation	Cause	Consequence	L	S	Risk Matrix	Controls
Cyclone Separator Steam Drum	Less	Separation	Less Separation	The pH quality of the water is not by operating standards	Cyclone separator steam drum damage	3	4	High	Checking the ammonia and phosphate injection components, and sampling the quality (Ph) of steam drum water is carried out routinely at each start-up unit, and normal operation
	More	Separation	More Separation	The pH quality of the water is not by operating standard	Cyclone separator steam drum damage, Boiler tubing damage	3	4	High	

boiler to trip. A pressure safety valve (PSV) secures the pressure when it is exposed to air, vapor, or pressure excessively. This valve, which is a full set of piping, is crucial to sustaining and supporting an item of equipment or network piping while it is in use. There was a breakdown in the pipeline PA105-10RV-15301- A1A2-02 that carried steam exhaust from the boiler to the Pressure Safety Valve (PSV), where it was released through the umbrella pipe and released into the atmosphere. Failure of the umbrella pipe in line PA105-10RV-15301-A1A2-02 occurs during commissioning. Failure happens as a result of stress that is brought on by incorrectly putting support on the umbrella pipe (Raharjo et al., 2017). The controls implemented by PT PJB are

Table 8. Risk Level on Blowdown Steam Drum

Study Nodes	Guide Word	Parameter	Deviation	Cause	Consequence	L	S	Risk Matrix	Controls
Blowdown Steam Drum	More	Separation	More Separation	The pH quality of the water is not by operating standard	Cyclone separator steam drum damage	3	3	High	- Improve water quality - Steam drum water quality sampling is carried out routinely at each unit start-up and normal operation

Inspection/ safety valve repair, leak check, sensor level, sensor pressure, and safety valve certification.

IV. CONCLUSION

According to the results of the Hazard and Operability Study (HAZOP) on PT PJB's boiler system, there are two study nodes with extremely high-risk levels: the feed water setting to the steam drum has a damaged feed water pump, and the steam pressure on the steam drum has a damaged safety valve. As a result, the water level is low and the boiler trips. The controls implemented by PT PJB are pump repair/replacement, feed water flow sensor, steam drum level sensor, inspection/ safety valve repair, leak check, sensor level, sensor pressure, and safety valve certification.

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