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Controlling Occupational Hazards and Safety Using Job Safety Analysis (JSA) and Hazard Identification, Risk Assessment and Risk Control (HIRARC) Methods

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Abstract

Workplace health and safety is an effort to create a healthy and safe working environment, thus reducing the likelihood of accidents that can cause demotivation and decreased productivity. Issues identified include workers still frequently making mistakes in their work, lack of awareness among workers in adhering to company regulations and Standard Operation Procedures, failure to use personal protective equipment while performing tasks, aging machinery with some parts experiencing unrepaired damage, insufficient insulation installation in pipe lines, hot working environment due to machine heat and sunlight, noise pollution from operating machinery, and oil spills on the production floor. The aim of this research is to reduce workplace accidents in the company by conducting hazard identification, risk assessment, and proposing improvement recommendations. The research utilizes the Job Safety Analysis method to break down activities in each machine operation into work stages, thus obtaining a more detailed identification. The next method used is Hazard Identification, Risk Assessment, and Risk Control, which evaluates job hazards related to machine operation. The results of risk assessment greatly aid in reducing risks and identifying necessary improvements to support production activities. From the research results, 17 activities were identified, resulting in 26 accident hazards stemming from work activities. Based on the results, there are 7 low-risk work hazards, 12 medium-risk work hazards, 5 high-risk work hazards, and 2 extreme- risk work hazards. Risk control measures include administrative controls and the use of personal protective equipment.

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Introduction

Concerned with the increasing incidence of workplace accidents, the government launched the K3 program, which stands for Occupational Safety and Health. Many people still have misconceptions about this program, despite the fact that work accidents do not occur very often. Regarding the OSH program, the government has issued Law No. 1 of 1970 (Dharma et al., 2017). However, despite its significant contribution to worker safety and increased productivity, OHS programs were not well known until 2000. Having good health has the potential to increase productivity in the workplace. High productivity usually comes from workers, but this can only be achieved if the workforce is healthy. Conversely, if workers are sick or have health problems, it will reduce productivity at work (Yusdinata et al., 2018).

PPSDM MIGAS is one of the companies that produces various types of finished materials such as Pertasol CA, Pertasol CB, Pertasol CC, Residue and Solar. Pertasol CA, Pertasol CB, and Pertasol CC products will be distributed to paint, glue, and TBBM (Terminal Bahan Bakar Minyak) Tuban companies. Residual products are sent to Cilacap and neighboring countries such as Singapore, Malaysia. Diesel products are distributed to TBBM (Terminal Bahan Bakar Minyak) Cepu. There are 13 employees working at PPSDM MIGAS in the operator section. In the Crude Oil production process, there are 3 machines that will be operated starting from the Pump, HE (Heat Exchanger) and Furnace machines. Based on

interviews with workers, there are still several work accidents that occur. Work accident data is shown in the Table 1.

Table 1. Work Accidents at PPSDM Migas Cepu

No	Name	Age	Year	Work Accidents
1	Worker 1	54	2018	Slipped
2	Worker 2	53	2018	Exposed to flash back furnace
3	Worker 3	49	2028	Exposed valve
4	Worker 4	54	2019	Slipped
5	Worker 5	54	2019	Slipped
6	Worker 6	28	2020	Exposed to steam pipe heat during residue filling
7	Worker 3	49	2021	Exposed to steam pipes
8	Worker 7	28	2021	Slipped
9	Worker 8	22	2021	Slipped
10	Worker 9	22	2022	Pinched valve
11	Worker 1	54	2022	Sprayed with crude oil
12	Worker 10	43	2022	Sprayed with diesel fuel during pump drain
13	Worker 6	28	2021	Slipped
14	Worker 8	22	2022	Slipped
15	Worker 11	27	2022	Slipped
16	Worker 12	53	2023	Exposed to steam pipes
17	Worker 13	23	2024	Electrocution

Based on interview data revealed many workplace incidents that occurred between 2018-2024. The main reasons behind these incidents within companies are due to hazardous working conditions and risky behaviors exhibited by workers. For example, unsafe environmental factors such as slippery surfaces have caused workers to slip and fall. There are also workplace accidents caused by a lack of understanding and observance of existing regulations.

The three machines area have different problems. The pump area has problems with noise, crude oil spills and leaking pumps. The HE (Heat Exchanger) machine area has problems with lack of insulation installation, gas/smoke from the heating process, hot temperatures from the shell, and slippery floors caused by crude oil spills. And the Furnace engine area has problems with noise from the engine sound, hot temperatures from the cooking process and the startup process of the furnace engine.

Problems arising from the aspects of Man, Machine, Material, Method, and Environment. In the aspect of Man: Workers still often make mistakes at work, lack of awareness from workers in obeying the rules and SOPs in the company, not using PPE in doing work. Machine: Machines that are old and there are still some damaged parts that have not been repaired, lack of insulation installation in the pipe flow. Material: Raw materials in the form of crude oil which are still mixed with sand which can cause failure in the production process. Method: The method used is correct but sometimes workers do not understand the established method. Environment: Hot working environment conditions caused by the heat of the engine and the temperature of the sun, noise coming from operating machines, production floors that have oil splashes.

The urgency of this research is to identify risks and hazards in the workplace, as well as recommendations for improvement proposals to reduce or eliminate these risks. It aims to protect workers' health and safety, preventing injury or even death caused by hazardous working conditions. Help companies understand and comply with applicable OHS regulations and standards. This legal compliance is not only important to maintain the company's reputation, but also to protect workers from potential risks that could lead to legal violations. Improve workers' awareness and skills, and create a safe, healthy and productive work environment.

To prevent continuous work accidents and minimize their impact, risk management is needed in the company. Identification of potential hazards and risks in the work environment is the first stage in conducting risk management. In this study, the Job Safety Analysis (JSA) method was chosen because it divides the activities in each machine operation into work stages, so that a more detailed identification is obtained. The next method is Hazard Identification, Risk Assessment, and Risk Control (HIRARC). Based on the possibility of accidents and the consequences of such accidents, this method can evaluate the occupational hazards associated with machine operations. The results of the risk assessment are helpful in reducing risks and identifying improvements needed to support production activities.

Methods

Occupational Safety and Health (OSH)

Occupational Safety and Health (OSH) is an important aspect that must be present in a company (Noviyanti, 2020). Occupational health refers to efforts to maintain and improve the physical, mental, and social well-being of employees as much as possible (Pamungkas et al., 2018). Ensuring work safety is very important to reduce the occurrence of accidents. Accidents can be characterized as unwanted and unexpected incidents that have the potential to result in catastrophe or loss (Putra et al., 2019).

Work Accidents

Accidents are caused by the lack of attention of the organization or company in the application of OSH itself. So that employees work only according to their duties, without neglecting their safety and health (Saputra & Mahaputra, 2022). In general, work accidents can be attributed to two main factors: human factors, which include unsafe acts, and environmental factors, which involve unsafe conditions. Unsafe acts, or human factors, can be influenced by many factors (Prastawa et al., 2021).

Job Safety Analysis (JSA)

Within the Job Safety Analysis (JSA) framework, each critical step is thoroughly examined to determine possible risks and establish preventive measures. Once potential hazards are identified and the relationship between the workers involved, equipment and tools, work environment and tasks is established, proposals can be made to improve working conditions (Mahaboon et al., 2022).

According to Albrechtsen in the journal (Ghasemi et al., 2023) asserts that JSA has at least six benefits:

1. formalization of work,
2. accountability,
3. employee participation,
4. organizational learning,
5. hazard identification and situation awareness,
6. loss prevention.

Hazard Identification, Risk Assessment, and Risk Control (HIRARC)

Hazard Identification, Risk Assessment, and Risk Control (HIRARC) adalah is a methodical strategy for managing risk, which includes the steps of hazard identification, risk assessment, and risk management. Hazard identification is essential as it allows for the recognition of potential hazards that could harm workers and the public (Wong et al., 2022). HIRARC should conducted in all organizational activities to determine which organizational activities contain potential hazards and have a serious impact on occupational safety and health (Kabul & Yafi, 2022).

1. Hazard Identification

   A hazard is characterized as any event, factor or circumstance that has the potential to cause an adverse outcome, such as harm to health or the environment, or a combination of both. The purpose of hazard control is to implement measures that can reduce the risks associated with hazards (Asari & Leman, 2016).

2. Risk Assessment

   The purpose of a risk assessment is to evaluate the potential safety and health hazards that could arise from unsafe conditions in the work environment. In risk assessment, there are two main factors considered, namely likelihood and severity (Hotma et al., 2020).

Table 2. Scale of probability of occurrence of Risk (Possibility)

Level	Criteria	Explanation
A	Almost Certain	More than once a month
B	Likely	Occurs once per month for up to 1 year
C	Possible	Occurs once every 1 year to 5 years
D	Unlikely	Occurs once every 10 years
E	Rare	Less than 1 time in 10 years

Table 3. Scale of Consequences of Risk Occurrence (Severity)

Level	Criteria	Explanation
1	*Insignification*	No injury, small financial loss.
2	*Minor*	First aid, on-site treatment, and moderate financial loss.
3	*Moderate*	Requires medical treatment, on-site treatment with external assistance, large financial losses.
4	*Major*	Severe injury, loss of production capability, out-of-area handling with no negative effects, major financial loss.
5	*Catastrophic*	Death, poisoning to outside areas with disruptive effects, major financial losses

Table 4. Risk Matrix

Risk Frequency	Risk Impact				
	Insignification 1	*Minor 2*	*Moderate 3*	*Major 4*	*Catastrophic 5*
A (*Almost Certain*)	H	H	E	E	E
B (*Likely*)	M	H	E	E	E
C (*Possible*)	L	M	H	E	E
D (*Unlikely*)	L	L	M	H	E
E (*Rare*)	L	L	M	H	H

(Source: AS/NZS, 2004)

3. Risk Control

The results of risk assessment and analysis will be used in developing control measures that can be applied to a situation. Risk control will prioritize the elimination of risks and control of hazards that occur at the source of risk using engineering principles and control measures (Giovanni et al., 2023). The hierarchy of risk control measures can be seen in Figure 1.

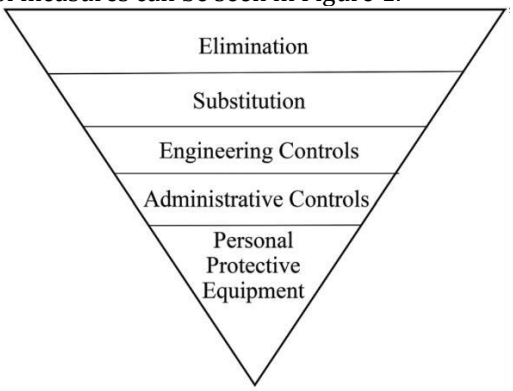

Figure 1. Risk Control Hierarchy

a. Elimination
Elimination is a risk control technique that aims to completely eliminate the source of the hazard.
b. Substitution
Substitution is a hazard control method that involves replacing a hazardous tool, material, system or procedure with a safer alternative.
c. Manipulation Engineering
The source of workplace hazards often comes from technical equipment or systems. Engineering controls involve design improvements and incorporation of safety features to minimize or eliminate these hazards.
d. Administrative control
Administrative control is another approach to risk management, which can be implemented through various means such as organizing work schedules, implementing rest periods, promoting safer work practices, implementing rotations, or conducting health checks.
e. Use of personal protective equipment
The final option for hazard control is the use of personal protective equipment (PPE) Some personal protective equipment against electric shock: gloves, shoes and seat belts. To protect the face and eyes: goggles, protective glasses and combination lenses. For hands, arms, fingers, legs and feet: shoes, long pants and gloves. For the head: head protection and hat. For ears: earplugs. Respiratory: respirator, gas mask and mechanical filter. In case of a fall: seat belt. Skin and body protection: protective clothing (Azuamah et al., 2014). Source according to (Ramli, 2010) in the journal (Ramadhan et al., 2021).

Results

Job Safety Analysis (JSA)

The analysis using Job Safety Analysis (JSA) at three workstations—Pump, Heat Exchanger (HE), and Furnace—identified 17 activities that potentially generate 26 types of hazards. These hazards include fire, oil leakage, slipping accidents, exposure to high temperature equipment, and inhalation of residual gases. The categorization of hazards illustrates that workplace risks arise not only from technical failures of the machines but also from unsafe working practices such as neglecting personal protective equipment (PPE).

1. Job Safety Analysis (JSA) Pump Workstation

Job Safety Analysis (JSA) is a systematic method used to identify potential hazards in each work activity and to determine appropriate preventive measures in order to minimize the risk of accidents.

This analysis is particularly important in work areas involving pressurized or high-temperature equipment, such as pump workstations, where hazards such as leakage, overheating, or fire may occur at any time. Through the implementation of JSA, each stage of work can be mapped in detail, ranging from operator activities, potential hazards that may arise, to the handling strategies that must be applied. The following table presents the results of JSA at the pump workstation, outlining the identified work activities, potential hazards, and handling measures to ensure workplace safety.

Table 5. Job Safety Analysis (JSA) Pump Workstation

No.	Work Activities	Danger	Hazard Handling
1.	Workers open the suction valve in the fully open position.	Pump gets hot	Turn off the power and then turn it off, then check the condition of the pipe that is causing the heat. Use PPE in carrying out the work process. Provide a fire extinguisher near the pump.
		Leakage in the pump	Replace pump parts that are leaking. Use PPE in carrying out the work process.
2.	Workers run the drive unit.	Pump gets hot	Turn off the power and then turn it off, then check the condition of the pipe that is causing the heat. Provide a fire extinguisher near the pump. Use PPE in carrying out the work process.
3.	Workers open the discharge valve slowly until normal operation	Pump gets hot	Turn off the power and then turn it off, then check the condition of the pipe that is causing the heat. Provide a fire extinguisher near the pump. Use PPE in carrying out the work process
4.	Workers observe critical parts.	Pump may catch fire	Provide a fire extinguisher near the pump. Use PPE in carrying out the work process.
		Dirt entering the pump can cause leakage of the mechanical sheal	Cleaning the dirt that enters the pump.
5.	Workers check for anything suspicious (such as abnormal vibration sounds).	Insufficient lubricant so the pump becomes hot	Add or replace lubricant.
		Streaner clogged pump gets hot	Always clean and check the streaner so that dirt can be filtered so that there is no blockage.

2. Job Safety Analysis (JSA) at Heat Exchanger Workstation

Table 6. Job Safety Analysis (JSA) at Heat Exchanger Workstation

No.	Work Activities	Danger	Hazard Handling
1	Workers open cold fluid inlet and outlet valves, hot fluid inlet and outlet valves, cold circulation network valves.	High and greater pressure on the flange/cube	Repair equipment that has malfunctioned.
2	Workers run the cold circulation pump.	HE cube leakage	Repair equipment that has malfunctioned.
3	Workers observe the cold circulation network for possible leaks/clogs.	HE leakage	Repair equipment that has malfunctioned.
		Blockage in HE flow causes high pressure	Clears the blocked flow.
		Flange bolts are not tight, leaking can occur so that oil is scattered	Repair parts that have been damaged. Recheck the condition of existing equipment.

3. Job Safety Analysis (JSA) Furnace Workstation

Table 7. Job Safety Analysis (JSA) Furnace Workstation

No.	Work Activities	Danger	Hazard Handling
1	Workers ensure that around the furnace there are no flammable items / disturbing work.	Fire caused by gases	Extinguish using a fire extinguisher.
2	Workers check and ensure that all fuel valves are in good condition and tightly closed.	Fire from lpg gas	Extinguish using a fire extinguisher.
		Gas may be inhaled by workers	Use personal protective equipment (PPE).
3	Workers purging the combustion chamber.	Residual gas may be inhaled	Use personal protective equipment (PPE).
4	Workers run the cold circulation pump according to procedure using gasoil/diesel.	Cube furnaces can bend due to drastic temperature drops	Replace damaged machine parts.
5	Workers run fuel gas (LPG) as the ignition fuel.	If there is a leak in the network/nuzzle	Repair network/nuzzle that leaks.
		Flashback	Use personal protective equipment (PPE).
6	Workers ignite the fire using plugs.	Can test fire drawing if there are flammable items	Use personal protective equipment (PPE).
7	Workers run the gasoil/diesel fuel oil pump.	Electric motors may catch fire	Place a fire extinguisher near the engine area. Turn off the power to the machine.
8	Workers ignite diesel fuel according to temperature stages.	Cracks in the furnace	Repair parts that have been damaged.
9	Workers check the network for leaks.	Leaks	Repair parts that have been damaged. Use personal protective equipment (PPE).
		Fire	Use personal protective equipment (PPE). Extinguish using a fire extinguisher.
		Oil slick	Use personal protective equipment (PPE).

Hazard Identification, Risk Assessment, and Risk Control (HIRARC)

Hazard Identification

Hazard identification was carried out to determine potential hazards associated with each work activity at the Pump, Heat Exchanger (HE), and Furnace workstations. This process is crucial as it allows researchers to map out possible risks that could affect workers' health, safety, and the environment. The identified hazards include mechanical failures, overheating, oil leaks, gas exposure, and environmental contamination. The details are presented in Tables 8, 9, and 10.

Table 8. *Hazard Identification* for Pump Workstation

No	Work Activities	Potential Hazards	Hazard Risk
1	Workers open the suction valve in the fully open position.	The pump gets hot and then may catch fire	Fire Oil can be splashed on the floor, slipped on
		Leakage in the pump so that oil is splashed on the floor	Slipped Uncomfortable working area conditions
2	Workers run the drive unit.	Pump gets hot	Fire Oil can be splashed on the floor, slipped on
3	Workers open the discharge valve slowly until normal operation	The pump gets hot and then may catch fire	Fire Oil can be splashed on the floor, slipped on
4	Workers observe critical parts.	Pump may catch fire	Fire Oil can be splashed on the floor, slipped on

No	Work Activities	Potential Hazards	Hazard Risk
		Dirt entering the pump can cause leakage of the mechanical sheal	Oil can be splashed on the floor, slipped on
5	Workers check for anything suspicious (such as abnormal vibration sounds).	Insufficient lubricant so that the pump becomes hot	Fire
		Stainer clogged pump gets hot	Fire Oil may splatter on the floor

Table 9. *Hazard Identification* Workstation HE (*Heat Exchanger*)

No	Work Activities	Potential Hazards	Hazard Risk
1	Workers open cold fluid inlet and outlet valves, hot fluid inlet and outlet valves, cold circulation network valves.	High and greater pressure on the flange/cube can cause leaking	- Spilled oil on the floor, slipped - Physical injury and explosion
2	Workers run the cold circulation pump.	HE cube leakage	- Spilled oil on the floor, slipped - Environmental harm, including water and soil pollution
3	Workers observe the cold circulation network for possible leaks/clogs.	HE leakage	- Spilled oil on the floor, slipped - Environmental harm, including water and soil pollution
		Blockage in HE flow leads to high pressure and leaking	- Spilled oil on the floor, slipped - Physical injury and explosion
		Flange bolts are not tight, leaking can occur so that oil is scattered	- Spilled oil on the floor, slipped - Environmental harm, including water and soil pollution

Table 10. *Hazard Identification* Furnace Workstation

No	Work Activities	Potential Hazards	Hazard Risk
1	Workers ensure that around the furnace there are no flammable items / disturbing work.	Fire caused by gases	Fire There was an explosion
2	Workers check and ensure that all fuel valves are in good condition and tightly closed.	Fire from lpg gas	Fires and explosions Gas leak Respiratory distress Environmental pollution
		Gas may be inhaled by workers	- Respiratory distress, respiratory tract irritation
3	Workers purging the combustion chamber.	Residual gas may be inhaled	- Respiratory distress, respiratory tract irritation
4	Workers run the cold circulation pump according to procedure using gasoil/diesel.	Cube furnaces can bend due to drastic temperature drops	- Spilled oil on the floor, slipped
5	Workers run fuel gas (LPG) as the ignition fuel.	If there is a leak in the network/nuzzle	- Spilled oil on the floor, slipped
		Flashback	- Burns from fire jets
6	Workers ignite the fire using plugs.	Can test fire drawing if there are flammable items	- Burns from fire jets
7	Workers run the gasoil/diesel fuel oil pump.	Electric motors may catch fire	Fire Physical injury

No	Work Activities	Potential Hazards	Hazard Risk
8	Workers ignite diesel fuel according to temperature stages.	Cracks in the furnace	- Spilled oil on the floor, slipped
9	Workers check the network for leaks.	Leaks	- Spilled oil on the floor, slipped
		Fire	Fire Physical injury
		Oil slick	- Fire

Risk Assessment

Risk assessment was carried out to evaluate the severity and likelihood of hazards identified at the Pump, Heat Exchanger (HE), and Furnace workstations. This process classifies hazards into four categories—low, medium, high, and extreme—based on their probability of occurrence and potential impact. The assessment provides a clearer understanding of which hazards require immediate technical intervention and which can be managed through routine monitoring and supervision. Tables 11, 12, and 13 present the results of the risk assessment for each workstation.

Tabel 11. *Risk Assessment* of Pump Work Station

No	Work Activities	Potential Hazards	Hazard Risk	Risk Assessment		
				Likelihood	Consequenes	Risk Matrix
1	Workers open the suction valve in the fully open position.	The pump gets hot and then may catch fire	Fire. Oil can be splashed on the floor, slipped on	D (*Unlikely*)	*Insignification*	*Low*
		Leakage in the pump so that oil is splashed on the floor	Slipped. Uncomfortable working area conditions	C (*Possible*)	*Insignification*	*Low*
2	Workers run the drive unit.	Pump gets hot	Fire. Oil can be splashed on the floor, slipped on	C (*Possible*)	*Minor*	*Medium*
3	Workers open the discharge valve slowly until normal operation	The pump gets hot and then may catch fire	Fire. Oil can be splashed on the floor, slipped on	D (*Unlikely*)	*Moderate*	*Medium*
4	Workers observe critical parts.	Pump may catch fire	Fire. Oil can be splashed on the floor, slipped on	D (*Unlikely*)	*Moderate*	*Medium*
		Dirt entering the pump can cause leakage of the mechanical sheal	Oil can be splashed on the floor, slipped on	B (*Likely*)	*Minor*	*High*
5	Workers check for anything suspicious (such as abnormal vibration sounds).	Insufficient lubricant so that the pump becomes hot	Fire	C (*Possible*)	*Insignification*	*Low*
		Stainer clogged pump gets hot	Fire. Oil may splatter on the floor	B (*Likely*)	*Insignification*	*Medium*

The risk assessment for the Pump workstation (Table 11) shows that most hazards fall into the medium-risk category, such as oil leaks that may cause slipping accidents and pump overheating. These risks are primarily linked to operational failures and inadequate preventive maintenance. Although categorized as medium risk, the frequency of occurrence is relatively high, which makes continuous supervision and preventive measures essential. Without strict monitoring and timely technical interventions, these medium risks could escalate into high-risk incidents.

Tabel 12. *Risk Assessment* of HE Work Station *(Heat Exchanger)*

No	Work Activities	Potential Hazards	Hazard Risk	Risk Assessment		
				Likelihood	Consequenes	*Risk Matrix*
1	Workers open cold fluid	High and greater	Spilled oil on the floor,	D	*Insignification*	*Low*

No	Work Activities	Potential Hazards	Hazard Risk	Risk Assessment		
				Likelihood	Consequenes	*Risk Matrix*
	inlet and outlet valves, hot fluid inlet and outlet valves, cold circulation network valves.	pressure on the flange/cube can cause leaking	slipped. Physical injury and explosion	(*Unlikely*)		
2	Workers run the cold circulation pump.	HE cube leakage	Spilled oil on the floor, slipped. Environmental harm, including water and soil pollution	D (*Unlikely*)	*Moderate*	*Medium*
3	Workers observe the cold circulation network for possible leaks/clogs.	HE leakage	Spilled oil on the floor, slipped. Environmental harm, including water and soil pollution	D (*Unlikely*)	*Moderate*	*Medium*
		Blockage in HE flow leads to high pressure and leaking	Spilled oil on the floor, slipped. Physical injury and explosion	E (*Rare*)	*Minor*	*Low*
		Flange bolts are not tight, leaking can occur so that oil is scattered	Spilled oil on the floor, slipped. Environmental harm, including water and soil pollution	D (*Unlikely*)	*Insignification*	*Low*

The Heat Exchanger (HE) workstation (Table 12) demonstrates a mix of medium and high-risk hazards, mainly due to leakages and excessive pressure. Unlike the Pump workstation, the hazards at HE are more related to technical conditions, such as gasket or flange failures, which can lead to environmental pollution and potential injury to workers. The presence of high-risk hazards indicates that engineering controls must be prioritized, especially regular inspection and replacement of defective parts. The medium-risk hazards, although less severe, still require close monitoring since they can contribute to cumulative operational risks.

Tabel 13. *Risk Assessment* of Furnace Work Station

No	Work Activities	Potential Hazards	Hazard Risk	Risk Assessment		
				Likelihood	Consequenes	*Risk Matrik*
1	Workers ensure that around the furnace there are no flammable items / disturbing work.	Fire caused by gases	Fire. There was an explosion	D (*Unlikely*)	*Minor*	*Low*
2	Workers check and ensure that all fuel valves are in good condition and tightly closed.	Fire from lpg gas	Fires and explosions. Gas leak. Respiratory distress. Environmental pollution	D (*Unlikely*)	*Moderate*	*Medium*
		Gas may be inhaled by workers	Respiratory distress, respiratory tract irritation	C (*Possible*)	*Moderate*	*High*
3	Workers purging the combustion chamber.	Residual gas may be inhaled	Respiratory distress, respiratory tract irritation	C (*Possible*)	*Moderate*	*High*
4	Workers run the cold circulation pump according to procedure using gasoil/diesel.	Cube furnaces can bend due to drastic temperature drops	Spilled oil on the floor, slipped	B (*Likely*)	*Major*	*Extreme*

No	Work Activities	Potential Hazards	Hazard Risk	Risk Assessment		
				Likelihood	Consequenes	*Risk Matrik*
5	Workers run fuel gas (LPG) as the ignition fuel.	If there is a leak in the network/nuzzle	Spilled oil on the floor, slipped	D (*Unlikely*)	*Moderate*	*High*
		Flashback	Burns from fire jets	D (*Unlikely*)	*Catastrophic*	*Extreme*
6	Workers ignite the fire using plugs.	Can test fire drawing if there are flammable items	Burns from fire jets	D (*Unlikely*)	*Moderate* (Sedang)	*Medium*
7	Workers run the gasoil/diesel fuel oil pump.	Electric motors may catch fire	Fire. Physical injury	D (*Unlikely*)	*Moderate*	*Medium*
8	Workers ignite diesel fuel according to temperature stages.	Cracks in the furnace	Spilled oil on the floor, slipped	D (*Unlikely*)	*Moderate*	*Medium*
9	Workers check the network for leaks.	Leaks	Spilled oil on the floor, slipped	C (*Possible*)	*Minor*	*Medium*
		Fire	Fire. Physical injury	D (*Unlikely*)	*Catastrophic*	*High*
		Oil slick	Fire. Physical injury	B (*Likely*)	*Insignificatio n*	*Medium*

The Furnace workstation (Table 13) contains the most severe hazards compared to Pump and HE, with several hazards classified as high and even extreme risk. These include gas leaks, flashbacks, and drastic temperature fluctuations that could lead to fire or explosion. The presence of extreme risks signifies that conventional risk controls may not be sufficient; instead, comprehensive safety protocols, emergency preparedness, and advanced monitoring systems are required. This makes the Furnace workstation the most critical area, demanding strict supervision, continuous training for workers, and readiness of emergency response equipment.

Risk Control

Risk control measures were proposed to minimize the identified hazards at the Pump, Heat Exchanger (HE), and Furnace workstations. These measures were developed based on the hierarchy of controls, including administrative actions, engineering improvements, and the use of personal protective equipment (PPE). Table 14 summarize the risk control strategies designed to prevent accidents, reduce the severity of hazards, and ensure a safer working environment.

Table 14. Risk Control Summary

No	Potential Hazards	Risk Control	
		Administrative	Technical
1	Pump overheating and potential fire	Turn off power, inspect pipe condition, direct supervision.	Replace faulty parts, ensure lubrication. PPE: Use fire extinguisher, wear PPE.
2	Pump leakage causing oil spill and slipping	Clean floor regularly, supervision.	Replace leaking parts. PPE: Safety shoes, gloves.
3	HE leakage / high pressure	Regular inspection, warning to workers.	Repair or replace damaged parts, tighten flange bolts. PPE: Use PPE, fire extinguisher nearby.
4	HE blockage in flow channel	Routine cleaning and inspection.	Clear clogged flow. PPE: Safety gear during maintenance.
5	Furnace gas leak / flashback	Shut down system during issues, warnings, supervision.	Repair leaking network or nozzle. PPE: PPE usage, fire extinguisher.
6	Fire from furnace / residual gas inhalation	Ensure area free of flammable items, supervision, warning.	Repair damaged machine parts. PPE: Respirator, goggles, fire extinguisher.
7	Cracks in furnace / oil slick	Shut fuel supply if ignition fails, routine check.	Replace damaged parts, clean working floor. PPE: Full PPE, fire

No	Potential Hazards	Risk Control	
		Administrative	Technical
			extinguisher available.
8	Electric motor fire	Warning, supervision, emergency shutdown.	PPE: Fire extinguisher, protective clothing.

Table 14 shows that most of the proposed controls rely on a combination of administrative supervision and PPE usage, while engineering improvements are mainly required for repairing or replacing faulty machine parts. For the Pump workstation, the main focus is on preventing overheating and leakage through regular inspections and proper lubrication. In the HE workstation, attention is given to leak prevention and pressure management, supported by routine equipment checks. The Furnace workstation presents the most critical hazards, such as gas leaks and flashbacks, requiring strict monitoring, immediate repair of damaged components, and continuous use of PPE. These findings highlight that without consistent supervision and proper safety practices, the effectiveness of technical measures alone would be insufficient to prevent accidents.

Conclusion

This study highlights the importance of systematically addressing occupational hazards through the integration of Job Safety Analysis (JSA) and Hazard Identification, Risk Assessment, and Risk Control (HIRARC). A total of 17 activities and 26 hazards were identified across three workstations, with varying risk levels ranging from low to extreme. The Pump and Heat Exchanger (HE) workstations were primarily exposed to overheating, leakages, and pressure-related hazards, while the Furnace workstation emerged as the most critical due to the potential for gas leaks, flashbacks, and fires. These findings emphasize that occupational risks do not solely originate from machine failures, but are also strongly influenced by unsafe worker behaviors, lack of supervision, and inadequate compliance with safety standards.

The results further demonstrate that effective risk management requires a balanced combination of administrative measures, technical improvements, and consistent use of personal protective equipment (PPE). While technical interventions such as equipment maintenance and insulation upgrades are crucial, they will remain insufficient without behavioral changes, strong safety culture, and continuous supervision. This indicates that occupational safety must be approached not only from a technical perspective but also through organizational and human factors.

For future research, several opportunities remain open. First, quantitative modeling of accident probability using probabilistic risk assessment could provide a more precise prediction of hazard impacts. Second, integration of digital technologies such as IoT-based sensors and predictive analytics could enhance real-time hazard monitoring and prevention. Third, further studies may explore the effectiveness of safety training programs, behavioral interventions, and organizational policies in strengthening compliance and reducing human error. Lastly, expanding research into other industrial sectors would allow broader validation of JSA and HIRARC applications, contributing to the development of more adaptive and sector-specific occupational safety frameworks.

Author Contributions

Conceptualization, M.F.S. and E.M.H.; methodology, M.F.S and F.C.M.; data collection S. and F.C.M.; data analysis, E.M.H; validation, M.F.S; writing—original draft preparation, F.C.M.; writing—review and editing, F.C.M and S. All authors have read and agreed to the published version of the manuscript.

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