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Hazard Identification and Risk Management at the Tuban Oil and Gas Production Unit, Indonesia

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***Abstract*— These Ro-Ro vessels are the backbone of inter–island transportation in Indonesia and require an efficient propulsion system to reduce fuel consumption and improve maneuvering performance. This study investigates the influence of ducted propellers on Ro-Ro vessels using Computational Fluid Dynamics (CFD) simulations. Four blades fixed pitch propeller configuration with accelerating duct are examined with different radial gaps at the propeller tip to the inner duct surface (0.1m, 0.3m and 0.5m) at rotational speed of 229 rpm and diameter of 4.202 m. the CFD model validation show average deviation of 4.06 % for KT, 7.63 % for 10*KQ and 3.11 % for efficiency compared with the experimental data. It indicated that the numerical approach is sufficiently reliable for further analysis. The open-water test results suggest that adding a duct does not necessarily improve performance. At a 0.10m gap, thrust, torque, and efficiency decrease by 39.3%, 25.7%, and 20.3%, respectively, whereas the 0.5m gap still results in noticeable performance degradation. Wake-field visualization indicates that smaller gaps produce stronger propeller–duct interaction, with more concentrated energy, sharper velocity gradients, and greater instability near the duct outlet. These findings emphasize that duct geometry and tip clearance must be carefully optimized for the vessel's operating conditions to fully realize the energy benefits of a ducted propeller system on Ro-Ro vessels.**

Keywords— *Oil and Gas Industry, Risk Management, Hazard Identification*

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I. INTRODUCTION

The implementation of Occupational Health and Safety (OHS) practices must align with workforce governance and be directly connected to existing human resources. OHS not only pertains to social security and employee welfare but can also lead to positive results, such as increased production output [1]. Occupational health and safety, commonly known as OHS, is a systematic program designed for industries that includes workers. It serves as a preventive program against work accidents and diseases caused by industrial activities through identifying potential hazards and implementing measures to prevent these issues [2]. OHS holds important strategic value and affects various aspects of human life, business operations, and the progress of quality and sustainable development in human resources, economics, social sectors, and the environment [3].

According to the ILO, nearly three million workers lose their lives each year due to work-related accidents and illnesses. This figure highlights the ongoing challenge of protecting worker health and safety worldwide. Most of these work-related deaths, totaling 2.6 million, are caused by work-related illnesses. Work-related accidents account for an additional 330,000 deaths [4]. Meanwhile, according to data from the Ministry of Manpower of the Republic of Indonesia, in 2024, the number of workplace accidents recorded in Indonesia was 462,241[5].

The high number of work accidents is caused by a lack of occupational safety and health risk management, so efforts to improve occupational safety and health risk management are essential[6]. The risk management process is carried out using a flowchart that connects risk analysis, risk transparency reporting, and then uses the transparency report to inform risk management decisions. Implemented [7]. According to a study on workplace risk control by Tanisri, Karisno, and Denny Siregar (2022), it was shown that for high risk levels, there was a significant reduction, lowering the existing risk level after risk analysis and control measures were taken [8]. that will be used to implement risk management [7]. According to a study discussin workplace risk control conducted by Tanisri, Karisno, and Denny Siregar (2022) showed that, for high risk levels, there was a significant reduction in the risk after analysis and control measures were implemented [8].

The oil and gas industry is a vital and strategic part of the global economy. Besides being a main energy source, it also plays a major role in economic growth both nationally and internationally. However, despite its importance, industrial projects like building and commissioning refineries often cause harm and pose risks to people, as well as safety and environmental hazards, especially during emergencies[9]. Emergency situations in this industry can include fires, explosions,

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oil spills, workplace accidents, and potential H_2S gas leaks, all of which threaten lives, company assets, and the environment[10]. According to the company's Leak Detection Report (LDR), there were 187 leakage incidents recorded in its operations from 2020 to 2024.

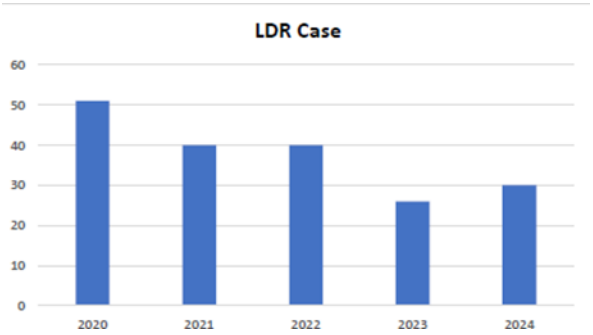

Figure 1. Company Leak Detection Report (LDR) Case Graph

According to Figure 1, out of 187 total leakage incidents, 127 occurred at the Central Processing Area facilities of PT Pertamina EP Sukowati Field. The leaks at the company's production facilities were recorded based on the material involved in the leakage.

Location

Figure 2: Graph of Leakage Incident Locations

Figure 2 indicates that carbon steel is the most commonly leaking material, with 180 reported cases between 2020 and 2024. Based on the company's actual incident data, it is essential for the company to conduct a comprehensive hazard identification process, as most of the fluids released from these leaks come from the production process and contain hazardous gases, especially hydrogen sulfide (H_2S).

Hydrogen sulfide (H_2S), or hydrogen sulfide acid, is a colorless, highly toxic, flammable gas with a characteristic rotten egg odor that can cause physical, psychological, social, and behavioral disorders, including stress in humans[11]. H_2S gas is very dangerous even at low concentrations because it is flammable at a concentration of 4.3–4.6% by volume in the air. The gas is colorless and smells like rotten eggs at low concentrations, but is odorless at high concentrations. Humans can die instantly when exposed to H_2S gas concentrations >2000 ppm[12].

TABLE 1.
H2S EXPOSURE THRESHOLD LIMIT VALUES

Advisory Body	SCOEL	DECOS	ACGIH
Date	**2007**	**2006, 2010**	**2010**
	Conclusions from literature		
animals, no effect level	10 ppm	10 ppm	10 ppm
humans, start of effects			5 ppm
	Uncertainty factors		
species differences		3	unspecified
exposure duration and limited pathological data	2	2	
total	2	6	unspecified
	Recommendations		
8-h exposure limit	5 ppm	1.6 ppm	1 ppm
short term exposure limit (STEL)	10 ppm		5 ppm

The location that will be the object of this research is the oil and gas exploration and production industry of PT Pertamina EP Sukowati Field, Tuban, East Java, Indonesia. In the Central Processing Area of PT Pertamina EP Sukowati Field. In samples taken from the Company's manifold, the concentration of H_2S gas dissolved in oil flowing to the separator is around 1% - 2% which when converted becomes around 10,000 - 20,000 ppm of H_2S gas. According to the company's H2S level measurement and sampling data, the concentration of H2S gas in the Sukowati field work operation in each production area is as follows:

TABLE 2.
GAS CONTENT OF EACH PRODUCTION AREA

Production Area	H_2S Content
Sukowati Well Pad	2 – 3 %
CPA	2-3 %
FSO	5 ppm

The high concentration of H_2S gas in production activities at the PT Pertamina EP Sukowati Field, which can potentially cause leaks at the production facility, poses a hazard that can affect humans and the environment. Exposure to elevated levels can lead to respiratory issues, internal organ damage, increased cancer risk, and even death. Despite existing occupational safety regulations, incidents of exposure to toxic substances still occur frequently. This highlights gaps in workplace risk management, both technically and managerially[14].

Given the high potential hazards involved in operating oil and gas production facilities, a thorough risk assessment is necessary to identify potential risks that could harm the company, the environment, and nearby communities. This is especially important since the production facility's closest distance to residential areas is 168.94 meters.

Source: Oil and Gas Company

Figure 3. Location of the company and surrounding residential areas

II. METHOD

A. Hazard Identification, Risk Assessment, and Determining Control

This discussion will examine the risks associated with the H2S gas hazards resulting from the failure of the separator unit in the Sukowati Field work area, affecting workers and the surrounding environment. This risk assessment will determine the magnitude of the risk and the mitigation options available to reduce it.

Risk analysis and assessment has evolved into an effective and comprehensive method for managing almost all aspects of our lives.[13]HIRADC is one of many approaches that can be used for risk analysis. HIRADC (Hazard Identification, Risk Assessment, and Determining Control) is a key element in an occupational health and safety management system that is directly related to hazard prevention and control efforts (OHSAS 18001, 2019). HIRADC is one of the requirements that must be met in OHSAS 18001:2007 (clause 4.3.1) and ISO 14001:2004. OHSAS 18001:2007 also requires companies to review HIRADC at least once a year. HIRADC can be divided into several parts, such as hazard identification, risk assessment, and determining risk controls[15]. In preparing the risk assessment, it will be carried out by a Risk Assessment Facilitator (RAF) who has an educational background and experience related to upstream oil and gas activities, and who has also been officially appointed by the company through a letter of assignment

Meanwhile, to determine the impact and probability values, use the *Risk Matrix* from the companies listed in the Company Risk Assessment Procedure.

TABLE 3.
PROBABILITY VALUES

Score	Information
1	It's almost impossible to happen
2	Rarely happening
3	It could happen
4	It is very possible that this will happen
5	Almost certainly happening

Source: Oil and Gas Company

In using the probability matrix, the values that already exist in the company are used, where a score of 1 is for events <10-6 per year, a score of 2 is for 10-6-10-4 events per year, a score of 3 is for the possibility of 10-2- 1 events per year, and a score of 5 is for >1 year.

Table 4: Severity level

Score	Information
1	It's almost impossible to happen
2	Rarely happening
3	It could happen
4	It is very possible that this will happen
5	Almost certainly happening

Source: Oil and Gas Company

Table 5:
Risk matrix

Probability	Severity				
	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Source: Oil and Gas Company

Table 6: Risk categories

Risk categories	Risk score
High	15-25
Moderate to high	10-14
Moderate	5-9
Low to moderate	4
Low	1-3

Source: Oil and Gas Company

This risk analysis will use the HIRADC method, involving PT Pertamina EP Sukowati Field's HSSE team as expert judges. The frequency and consequence categories are based on the company's existing risk matrix. In addition, the determination of high-risk production facilities has been carried out through an assessment process conducted by the Risk Assessment Framework team, which was directly appointed by the company

TABLE 7
HAZARD IDENTIFICATION, RISK ASSESSMENT, AND RISK CONTROL IN THE OIL AND GAS INDUSTRY PRODUCTION UNIT IN TUBAN, EAST JAVA.

Equipment	Risk Identification		Risk Analysis							
	Source of Danger	Impact	P	S	R	Control	P	S	R	Determining Control
Valve Operation	- Extreme material temperatur e - Noise - High pressure - Pinch point	- Hands get burned due to the hot valve surface - Hearing loss due to high noise exposure - The explosion was caused by the release of high- pressure fluid. - Hand trapped while operating the valve	3	2	6	- SOP of Valve operation - Basic Safety Training for all workers - Noise Mapping Study - Top 10 Risk campaign - Pinch Point Poster - Special PPE (Earmuff, Hot Gloves)	3	1	3	-Refresh the top ten risks to all workers and contractors
Separator Operation	-Chemical -Pressurize d System -Hydrocarb on Material Fire Potential -Extreme Material Temperatu re -Oil/Other Liquid Spill -Working At High	- CNS Impair, Eye irritation - Exposure to H2S gas to workers and the surrounding environment - Overpressure causes leaks and explosions - Heat stress, skin blisters due to exposure to hot surfaces - Soil and water pollution - Falling from a height can result in broken bones	5	4	20	- Closed system installation - Hydrocarbon fixed gas detection integrated to the shutdown system - SOP of three phase separator - Separator Certificate of Inspection (COI) - Operator certified to H2S Gas handling - Flame Detection integrated to shutdown system - Pressure Safety Valve - Concrete floor & Bundwall around separator - Special PPE (SCBA) - Windsock - Emergency Sign Board - Top 10 risk campaign - Rutine Safety Campaign to operator	5	2	10	- Refresh the top ten risks to all workers and contractors - Emergency Response Plan to evacuate workers and the community - - Emergency drill
Oxidizer Operation	-Overpress ure Oxidizer System -Human error operation -Kebocora n valv e pada suhu operasi tinggi	- Explosion, gas leak, serious injury to operator - Equipment damage, system error - Environmental damage, potential for explosion	3	3	9	- SOP of oxidizer operation - Basic Safety Training all worker - Top 10 Risk campaign	3	2	6	Refresh top ten risk to all worker and contractors

CONTINUED TABLE 7. HAZARD IDENTIFICATION, RISK ASSESSMENT, AND RISK CONTROL IN THE OIL AND GAS INDUSTRY PRODUCTION UNIT IN TUBAN, EAST JAVA.

Equipment	Risk Identification	Risk Analysis								
	Source of Danger	Impact	P	S	R	Control	P	S	R	Determining Control
Absorber Operation	-Ignition Source Potential - Decreased absorption efficiency -H2S Release Potential -Corrosive Exposure -Chemical exposure	- Potential for open flames - Decreasing production volume - Exposure to H2S causes irritation, even death. - Equipment leak - Irritation, respiratory disorders, and environmental pollution	4	3	12	- SOP of Absorber operation - Basic Safety Training all worker - Top 10 Risk campaign	4	2	8	Refresh top ten risk to all worker and contractors
Flare Operation	-Lighting Pollution -Air Emission -Air Quality -Temperatu re Extremes	- 24-hour fire has a psychological effect on the community. - Reduced air quality due to exposure to smoke from flarepits - The temperature increases due to the flame from the flaring - process	4	2	16	- SOP of Flare operation - Flame detection to shutdown system - Basic Safety Training all worker - Top 10 Risk campaign	4	1	8	Refresh top ten risk to all worker and contractors
Tank Operation	-Overfillin g -Flange Open/Clos e Error -Confined Space, Exposure to Toxic Gases -Over/Low Pressure	- Oil spills, environmental pollution - Oil spills, unwanted mixing of fluids - Loss of consciousness, respiratory distress, death Tank deflates/expands until it explodes	4	3	12	- Closed system instalation - Hydrocarbon Fixed gas detection integrated to shutdown system - SOP of Oil Storege tank operation - Oil Tank Certificate of Inspection (COI) - Flame Detection integerated to shutdown system - Pressure Safety Valve - Concrete floor & Bundwall around separator - Special PPE (SCBA) - Windsock - Emergency Sign Board - Top 10 risk campaign - Rutine Safety Campaign to operator	4	2	8	- Refresh terkait panyampaian top 10 risk ke semua pekerja - Emergency Response Plan to evacuate worker and community Emergency drill

CONTINUED TABLE 7. HAZARD IDENTIFICATION, RISK ASSESSMENT, AND RISK CONTROL IN THE OIL AND GAS INDUSTRY PRODUCTION UNIT IN TUBAN, EAST JAVA.

Risk Identification						Risk Analysis				
Equipment	Source of Danger	Impact	P	S	R	Control	P	S	R	Determining Control
Air Compressor Operation	-Mechanic al failure -Rotating Object -Slips, Trips, and Fall Hazard	- Unit failure, Downtime, Plant shutdown - Trapped, to the point of losing limbs - Bruises due to hard impact	3	2	6	- SOP of Compressor operation - Safety Pressure Realese Valve - Basic Safety Training all worker - Top 10 Risk campaign	3	1	3	Refresh top ten risk to all worker and contractors
Heat Exchanger Operation	-Cross Contamin ation -Overheat -Extreme Material Temperatu re	- Toxic emissions, fires and explosions - Plant shutdown, lack of production efficiency Injuries to body parts resulting in blisters on the skin	3	2	6	- SOP of Heat Exchangger operation - Safety Pressure Realese Valve - Basic Safety Training all worker Top 10 Risk campaign	3	1	3	Refresh top ten risk to all worker and contractors
SRU Operation	-Condenser /drain blockage -Corrosion Exposure -H2S Exposure	- H2S and SO2 gas leaks, pollution and death - Damage and leaks in installation - Air po llution, respiratory disorders an d even de ath of personnel	3	3	9	- Closed system instalation - Hydrocarbon Fixed gas detection integrated to shutdown system - SOP of SRU - SRU Certificate of Inspection (COI) - Operator certified to H2S Gas handling - Flame Detection integerated to shutdown system - Pressure Safety Valve - Concrete floor & Bundwall around separator - Special PPE (SCBA) - Windsock - Emergency Sign Board - Top 10 risk campaign - Rutine Safety Campaign to - operator	3	2	6	- Refresh terkait panyampaian top 10 risk ke semua pekerja - Emergency Response Plan to evacuate worker and community Emergency drill

CONTINUED TABLE 7. HAZARD IDENTIFICATION, RISK ASSESSMENT, AND RISK CONTROL IN THE OIL AND GAS INDUSTRY PRODUCTION UNIT IN TUBAN, EAST JAVA.

Risk Identification			Risk Analysis							
Equipment	Source of Danger	Impact	P	S	R	Control	P	S	R	Determining Control
Gas Boot Operation	- Liquid Carryover to Compress or - Hole/Leak /Gas release - Instrument Level Failure	- Damage to the compressor, installation explosion - Pollution, respiratory disorders due to exposure to H2S gas - Damage to downstream installations, - gas/liquid release	3	2	6	- SOP of Heat Exchangger operation - Safety Pressure Realese Valve - Basic Safety Training all worker - Top 10 Risk campaign	3	1	3	Refresh top ten risk to all worker and contractors

III. RESULTS AND DISCUSSION

The risk assessment conducted through the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) framework identified separator operations as the most critical activity within the PT Pertamina EP Sukowati Field. During the hazard identification phase, potential risks were systematically mapped based on process characteristics, material toxicity, historical incident records, and direct field observations. Dominant hazards included potential H_2S release, high-pressure system failures, hydrocarbon fire and explosion potential, and process fluid leakage. These hazards represent significant concern due to the facility's proximity to residential settlements, where operational failures may result in severe human, environmental, and community impacts.

In the subsequent risk assessment phase, each hazard was evaluated using the organization's risk matrix, integrating probability and severity values supported by expert judgment from the HSSE team. The separator unit recorded an initial risk score of 20, placing it in the high-risk category. This high-risk profile is primarily associated with the extreme toxicity of H_2S, combined with the potential for catastrophic failure modes such as uncontrolled gas release, overpressure events, and ignition of hydrocarbon vapors.

The determining control phase evaluated existing engineering and administrative controls, including fixed H_2S gas detectors, pressure safety valves, integrated flame and shutdown systems, certified operators for H_2S handling, and established standard operating procedures (SOPs). These measures were shown to reduce the residual risk to a moderate level, demonstrating effective risk mitigation under normal operating conditions. However, the analysis further indicates that engineering controls alone are insufficient to fully address low-frequency, high-consequence scenarios, particularly large-scale toxic gas releases or shutdown system failures.

Consistent with the HIRADC methodology, which emphasizes both prevention and preparedness, the study highlights the need for enhanced secondary controls. The development and enforcement of a comprehensive Emergency Response Plan (ERP), supported by periodic emergency drills, is essential to ensure effective evacuation, communication, and response coordination. Strengthening organizational preparedness not only reinforces existing safety barriers but also enhances resilience and safety culture, particularly in oil and gas facilities operating in close proximity to populated areas.

IV. CONCLUSION

Based on the hazard identification that has been carried out, it was found that from 10 production units in the Tuban oil and gas industry, there is 1 production unit classified as moderate to high risk, 5 production units classified as moderate risk, and 4 production units included in low operational risk. From the results of this identification, the author focuses on the production unit with the highest risk, namely the operation of the separator unit. Risk controls carried out on the separator unit that have been carried out include the installation of H2S sensor units, Flammable sensors, pressure safety valves, the use of an integrated shutdown system, fulfillment of operator competency, unit feasibility test checks, implementation of operational SOPs, installation of windshoks in the separator area, and renewal of the Certificate of Inspection (COI). Meanwhile, the second control that can be proposed is refresh top ten risks to all workers and contractors, the Emergency Response Plan to evacuate workers and the community, Emergency drill.

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