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ANALYSIS OF POTENTIAL HAZARDS AND RISK IN ENGINEERING, PROCUREMENT & CONSTRUCTION SERVICES PROJECT FOR DECONSTRAINT FACILITY CONSTRUCTION USING FAILURE MODE AND EFFECTS ANALYSIS (FMEA) METHOD AT PT. RAGA PERKASA EKAGUNA (RPE) DURI, RIAU

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Abstract:
The Deconstraint facility construction project is a process to install a new Water Injection System with a capacity of 100,000 BWPD, which is distributed through 2 (two) water injection headers at Grand Station and its supporting facilities. The purpose of this study is to assess the risk of potential hazards and risks that will occur if a failure occurs in the EPC process of the Deconstraint Facility Construction using the FMEA (Failure Mode and Effects Analysis) method. This research method uses a descriptive-analytical approach with a qualitative and quantitative approach, with data collection techniques using observation, interviews, and triangulation. The results of this study state the highest Risk Priority Number (RPN) value with a value of 100 (one hundred), which is in the failure of lifting and rigging during the installation of the pump caused by the failure of lifting equipment due to calculation errors while the lowest RPN value with a result value of 6 (six) is in the drawing and design making activities with the potential for failure is in errors in making the design that is made wrong. Controlling potential hazards and risks resulting from lifting equipment failures was explored from human, method, machine, and environmental factors. This study concludes that failures in lifting and rigging during pump installation due to miscalculation of the lifting equipment used have the highest score.

Keywords: Potential Hazards and High Risks, FMEA, RPN, Potential Hazard Control

INTRODUCTION

The oil and gas sector requires special attention and oversight because its work processes are potentially hazardous, utilize advanced technology, and require human resources with specialized skills and competencies. Therefore, every company operating in the oil and gas industry is legally required to implement an HSE Management System within its scope of work. According to data from the Directorate General of Oil and Gas in 2024, over the past six years, accidents have shown a downward trend, but the severity level has actually increased. In 2023, the rate of minor and moderate accidents decreased compared to 2022. However, serious and fatal accidents increased significantly. Fatal accidents in 2022 increased from two to seven in 2023, and serious accidents doubled from two to four in 2022.

The Deconstraint facility construction project, which includes the Engineering, Procurement & Construction (EPC) process, involves installing a new Water Injection System with a capacity of 100,000 BWPD, which will be distributed through two water injection headers at Grand Station and its supporting facilities. According to Soehatman Ramli, in his 2020 book "Risk-Based Process Safety Management (PSM), the Engineering, Procurement, and Construction phase is crucial because it is during this stage that project construction begins, and all materials and equipment are fabricated and installed

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on site. Therefore, the researcher aims to conduct a detailed analysis of potential hazards and risks so that they can be prevented and controlled. Failure mode and effect analysis (FMEA) is a method that can be used to analyze potential hazards and risks in risk management (Ramli, 2018). FMEA can help in selecting stages or corrective steps to reduce the cumulative impact and risk of system failure (Ramli, 2018). Therefore, the reason researchers chose the Failure Mode and Effect Analysis (FMEA) method was to analyze potential hazards and risks in detail so that they can be prevented, as well as increase the opportunity to detect failures, identify the biggest causes of failure and eliminate them, reduce the potential for failure, and build product and process quality (Aprianto, et al., 2021).

Hazard Identification. A hazard is anything that includes an unsafe situation or unsafe act that has the potential to cause a work accident or injury to a person, property damage, or other disruption (Ramli, 2018). Hazard identification is the preparatory or initial stage in Occupational Safety and Health (OHS) risk management. Therefore, hazard identification is crucial for effective risk management in any activity (Ramli, 2010). Hazards can be classified into mechanical, electrical, physical, biological, chemical, physiological, and static hazards. Risk is the effect of uncertainty (ISO 45001:2018).

Risk Assessment. OHS risks are risks directly related to sources of hazards that arise in business activities, including people, equipment, materials, and the work environment. Risk assessment is a systematic method for identifying risks within an activity, planning actions to prevent fatal consequences, and allowing all parties to make decisions regarding appropriate control measures to prevent injuries, damage, and losses in the workplace (Peruzzi et al., 2020).

Failure Mode and Effect Analysis (FMEA). Failure Mode and Effect Analysis (FMEA) is a risk analysis tool that aims to predict system failures so that preventative measures can be taken to prevent losses and workplace accidents (Vecchia Marco et al., 2025). The purpose of FMEA is to assess the potential for failure in a product or process (Ramli, 2018). FMEA focuses on failures and their effects to understand how each failure can be prevented and its impact mitigated (Popov Georgi, Lyon K. Bruce, Holcroft Bruce, 2016). Traditional FMEA assesses the risk level of each component in a system using a Risk Priority Number (RPN). According to Dermott (2009), the impact of a failure is determined by three factors:

a. Severity: The consequences of a failure
b. Occurrence: The potential or frequency of a failure that could occur
c. Detection: The probability of detecting a failure before its impact or effect occurs

Table 1. Form failure mode and effect analysis (FMEA)

Component & Functions	**Potential Failure Mode**	**Potential effect of failure**	**Severity**	**Potential cause of failure**	**Occurance**	**Currents Control**	**Detection**	**RPN**	**Recomme nd ation**	**PIC**
1	2	3	4	5	6	7	8	9	10	

Source: Dermott (2009)

Table 2. Severity Assessment Criteria

Deskripsi	**Rate**
• May cause one or more fatalities • May cause system-wide loss • May cause chemical contamination with long-term impacts on the environment or public health	5 Catastrophic

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• Loss of all facilities and economic damage	
• May cause injury or disabling illness • May cause major property damage and business interruption • May cause chemical contamination with temporary impacts on the environment or public health • Major property damage and significant economic losses	4 Critical
• Medical treatment or work restrictions • Minor loss or damage to subsystems • Chemical contamination that triggers external reporting requirements • Significant property damage and minor economic losses	3 Marginal
• Requiring only first aid or minor medical treatment • Minor damage to equipment or facilities • Chemical contamination that can be handled with routine cleaning without requiring official reporting • Minor property damage	2 Negligible
• No significant impact on injury or illness • Loss or downtime of the system • No chemical contamination to the environment • Repair costs only	1 Insignificant

Source (Povov George, 2016)

Table 3. Occurrence Assessment Criteria

Description	Rate
Likely to occur repeatedly	5 (Frequent)
Likely to occur several times	4 (Likely)
May occur occasionally	3 (Occasional)
Possible, but very unlikely	2 (Seidom)
Unlikely to occur, it can be assumed that the incident or exposure will not occur	1 (Unlikely)

Source (Povov George, 2016)

Table 4. Kriteria Penilaian Tingkat Deteksi *(Detection)*

Description	Rate
Uncertainty becomes absolute	5
Low	4
Medium	3
High	2
Almost certain	1

Source: Shafiee, et al (2019)

Determining the Range Priority Number (RPN) Value. The RPN assessment is generated by multiplying Severity x Occurrence x Detection. The RPN with the highest value should receive top priority in implementing control measures. Similarly, if the severity value is high, then our attention in controlling that risk should receive top priority.

Table 5. Three Classes of Failure, Criticality, and Actions for Controlling Them

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Color	Critically level	Faktor risiko	Risk Mitigation Plan
(green)	Low	1 ≤ RPN ≤ 20	Almost no action is required.
(orange)	Medium	21 ≤ RPN ≤ 45	Existing risk reductions can be maintained throughout the process.
(red)	High	RPN > 45	It is crucial to take steps to eliminate or reduce the risk of failure.

Source: Shafiee, et al (2019)

Tables 2–4 show a 5-point scale for assigning O, S, and D to each failure mode. As shown, each scale varies from 1 to 5, where 1 represents the minimum rating and 5 represents the maximum rating. RPN is a dimensionless parameter in FMEA that indicates the criticality of each failure mode and is calculated by the formula: RPN = O x S x D. Since the ratings of O, S, and D are between 1 and 5, the RPN will range from 1 to 125. The RPN values obtained for each failure mode are then ranked in descending order, and the most critical failure mode is identified.

METHODS

The researcher used a descriptive-analytical type with a qualitative and semi-quantitative approach. Data collection techniques in this study were participant observation, in-depth interviews, and triangulation or a combination of the three (Sugiyono, 2024). The researcher took data sources from primary and secondary data. Primary data was taken from the Project Manager, Construction Manager, Lead Engineer, HSE Coordinator, Field Engineer, Civil Engineer, and Lead Precomm & Comm, while Secondary Data was taken to complete the required data from the primary data. Secondary data in this study came from articles, websites, and documents that had been approved by the user, such as HAZOP, HAZID, HIRADC, and Detail Engineering Design (DED). The time and place of this research were carried out in June - July 2025 on the Deconstraint Facility Construction Project at PT Raga Perkasa Ekaguna Duri Riau.

RESULT AND DISCUSSION

Table 6. Results of Identification of Potential Failures, Potential Effects of Failures and Potential Causes of Failures

No	Component / Function	Potential Failure Mode	Potential effect of failure	Potential cause of failure
Engineering				
1	Design and Drawing Creation	Incorrect Engineering Design	Delays in work progress	Workers do not understand the design requested by the user.
		Incorrect engineering calculations	Material purchasing and the construction process on the ground	The deadline for completion is very short.
Procurement				

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No	Component / Function	Potential Failure Mode	Potential effect of failure	Potential cause of failure
1	Ordering and purchasing materials	The requested material specifications do not match the design	Delay in work progress	Workers do not understand the material specifications according to the engineering design.
		Delay in material arrival	Delay in work progress	Scarcity of required materials
		Changes to engineering design specifications	Delay in work progress	Changes to design and engineering drawings resulting from adjustments to field conditions
2	Journey during the purchase and delivery of materials	The material was damaged when installed	Delay in work progress	Damaged road access to the workshop, or environmental factors such as earthquakes, socio-economic factors (thuggery on the road, etc.)
				Poor packing or packaging of materials
Mechanical Work				
1	Pipe Installation	Failure in lifting and rigging activities / Lifting and Rigging of pipes	Being hit by a material causing injury during medical treatment	Lifting equipment failure due to miscalculation (overload)
		Workers are in an area potentially exposed to falling material	Being hit by material causes a serious work accident, pinching the hand	Failure to secure/close the lifting area, unclear/inappropriate communication between teams
		Unsafe Welding and Pipe Cutting	Fire and Explosion	Welding equipment is damaged or not working properly
			Minor injuries and burns in workers	Workers do not use standard and special Personal Protective Equipment (PPE) for welding, such as Aprons, Safety Gloves, Welding Masks, Safety Shoes, Helmets
2	Hydrotest	The hose is broken or damaged	Personal Injury to cause lost days of work / Lost Time Injury	Absence of inspection of Hydrotest equipment and supplies
		Broken tube connection	Personal Injury to cause lost days of	Hose specifications do not match the gas pressure

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No	Component / Function	Potential Failure Mode	Potential effect of failure	Potential cause of failure
			work / Lost Time Injury	
		No control when high pressure occurs	Personal Injury leading to Medical Treatment Case (MTC)	Pressure Guide malfunction
3	Pump Installation	Workers are in the areaPinch Point	Pinched to cause Medical Treatment Case (MTC)	Poor communication during pipe installation
		Failure in the lifting and fastening activity of the Pump	Property damage resulting in death	Equipment for liftingor the lifting does not match the load to be lifted=
				Equipment for lifting/ liftingdamaged or not functioning properly (Webbing Sling, engine power loss, shackle, etc not working properly)=
		Failure in Pump installation on Skid (Baud size error, Bolt not tight)	Repeating work that causes delays	Related image of incorrect pump skid/mount
4	Pipe Connection Process when Gas and Oil are Active/Tie-in Hot Tap	Failure in welding work	Repeating work / Re-Work which causes time delays	Lack of worker competence
				Welding equipment is damaged or not functioning properly.
		Failure to isolate the welding area from flammable gases	Fire and explosion	No flammable gas checks in the work area
Civil Works / Civil Work				
1	Road access repair	Failure to operate heavy equipment	Heavy equipment overturned, causing serious injury to the operator.	Lack of operator competence
				Uneven ground
				The machine is broken.
				Workers experience fatigue
2	Construction of the MCC room	Failure in Casting	Pollution of residual water from casting into the environment	There is no SOP for controlling water spills from casting residue.
			Exposure to cement chemicals can cause respiratory problems.	Workers do not understand SDS Cement.
				Workers do not use special PPE such as chemical masks and gloves.

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No	Component / Function	Potential Failure Mode	Potential effect of failure	Potential cause of failure
			Exposed to sharp material, causing minor injury	Workers do not use standard PPE
		Pinch Point / pinch point	Injury to the hand or finger	Workers do not use appropriate PPE
3	Making a Water Injection Pump Foundation	Failure in foundation casting activities	Exposure to cement chemicals causes water and soil pollution around the project area.	Exposure to cement chemicals causes water and soil pollution around the project area.
				Workers do not use special PPE such as chemical masks and gloves.
		Exposure to cement chemicals causes water and soil pollution around the project area.	Pump installation fails and causes delays	Workers do not understand drawings or designs
4	Pipe Support Manufacturing	Failure in determining the wrong point	Repeating work can cause time delays	Incorrect determination of the pipe support point
Electrical Work				
1	Cable pulling and installation of accessories	Danger of electrical current from existing facilities	Serious injury resulting in death	There was no prior inspection or survey using cable route drawings from previous facilities.
				There is no electrical insulation when pulling the cable.
		Danger of electric current from cable termination activities (sparks, Electric jump)	Burns causing LTI	There is no electrical insulation when pulling the cable
				Not using adequate PPE when performing termination
2	Connecting new cables to existing cables	Danger of electric current when tie in is done	Electrocuted to death	There is no electrical isolation (LOTO System) when terminating the cable.
3	Connecting new cables to existing cables	Dangers of working at a height of <1.8 meters	Falling resulting in fatality	Workers do not carry out a Full Body Harness 100% Tie in
				Non-standard scaffolding structure
				Lack of worker competence in working at heights (does

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No	Component / Function	Potential Failure Mode	Potential effect of failure	Potential cause of failure
				not have TKBT certification)
Instrument Work				
1	PIC Installation	Failure in lifting and binding activities of the instrument materials	Property damage resulting in a Medical Treatment Case	The equipment used for lifting activities/lifting equipment does not match the load of the material being lifted.
				Failure of lifting operations caused by damaged equipment (rope broken, machine unable to lift, Shackel damaged, etc.)
		Failure when working at a height of more than 1.8 meters	Falling from a height, resulting in broken bones	Workers do not implement a Full Body Harness 100% attached to strong anchors.
				Non-standard scaffolding structure
				Lack of worker competence in working at heights (does not have TKBT certification)
		Failure due to incorrect manual handling	Hit by a material, causing bruising	Workers do not understand the correct manual handling method
2	Field Instrument Transmitter Installation	Failure when working at a height of more than 1.8 meters	Falling from a height, resulting in broken bones	Workers do not carry out a Full Body Harness 100% Tie in
				Non-standard scaffolding structure
				Lack of worker competence in working at heights (does not have TKBT certification)
Precomm – Commissioning				
1	Testing per Equipment	Functional failure of the equipment being tested	Fire and explosion	Error in testing due to miscommunication
				The equipment does not meet the required specifications.
			Repeating work to the point of causing time delays	Error in testing
2	Trial / Commissioning	Failure of the tested equipment function	Fire and explosion	The equipment is not working as it should

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No	Component / Function	Potential Failure Mode	Potential effect of failure	Potential cause of failure
	for 3 times, 24 hours		Errors in operating equipment	Miscommunication between teams

Severity Determination Results. Based on the severity ranking scale, considering the potential effect of failure due to the potential failure mode, it can be concluded that five activities received the highest score, with a score of 5, as follows:

1. Pipe Installation Activity, with the potential for failure during unsafe welding and pipe cutting, which could result in fire and explosion.
2. Pump Installation Activity, with the potential for failure during lifting and rigging, resulting in property damage and even death.
3. Hot Tap Tie-in Activity, with the potential for failure during welding, which could result in fire and explosion. Furthermore, failure to isolate the welding area from flammable gases in this same activity could also lead to fire and explosion.
4. Equipment Testing Activity, with the potential for functional failure of the equipment being tested, which could result in fire and explosion.
5. Commissioning Activity, which involves three commissioning trials. 24 hours, which is the failure of tested equipment, could lead to fires and explosions on this project.

The lowest score is the Ordering and Purchasing of Materials activity, which has the potential to cause failure due to changes in engineering design specifications, with a score of 2 (two). This is because it can cause delays in work progress.

Results of Determining the Occurrence Level. The results of determining the 12 occurrence levels above, taking into account the 12 levels of occurrence frequency of a potential failure (potential effect of failure), conclude that the lifting and rigging activity of the pump installation was caused by the failure of lifting tools that were not strong enough to lift the load, with a score of 5 (five). This could be due to the lifting tools used not being calculated according to the lifting plan, or damaged or improperly designed lifting tools. Meanwhile, the lowest score, with a score of 1 (one), is the Design and Drawing activity, which has the potential for failure due to errors in the design and working drawings in the engineering. This is because Before undertaking the engineering process, the user is very strict in specifying personnel to carry out the Design and Drawing Engineering work. Competent individuals are required to carry out the work.

Detection Score Determination Results. The results of the Detection Score ranking scale above, taking into account the current control currents for potential causes of failure, show that the pump lifting activity using a crane has a score of 4 (four). This is because the only control measures currently available are pre-use inspections and following the lifting and rigging procedures approved by the user. The lowest detection score, 1 (one), indicates that the current controls are very good and can reduce the risk of failure. The smallest risk is in the Design and Drawing Creation activity, where the potential for failure could result in a very short deadline. This is because the controls are effective and quick enough to avoid potential failures due to the design and engineering drawing creation process by conducting direct consultations with the user to discuss the design and drawings.

Determination of the RPN Score

Table 7. Results of the RPN calculation (SxOxD)

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No	Component / Function	Potential Failure Mode	S	O	D	RPN (SxOxD)
Engineering						
1	Design and Drawing Making	Wrong design	3	2	1	6
		Incorrect engineering calculations	4	3	1	12
Procurement						
1	Ordering and purchasing materials	Material specifications that The requested does not match the design.	3	3	2	18
		Late arrival material	3	3	3	27
		Changes to engineering design specifications	3	2	2	12
2	Travel time purchasing and delivery of materials	The material was damaged due to poor packing	3	4	2	24
Construction Mechanical Work						
				2	2	12
		Failure in lifting and tying pipe activities	3			
				3	2	18
1	Pipe Installation		4	4	2	32
		Workers are in the Line on Fire area.				
			4	2	2	18
			5	3	2	30
		Unsafe Welding and Pipe Cutting				
			4	3	2	16
		The hose is broken or damaged	4	2	2	16

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2	Hydrotest	Connection Failure	4	2	2	18
		Uncontrolled High Pressure	3	2	2	12
		Workers are in the Pinch Point area	4	3	3	36
3	Pump Installation			3	2	30
		Failure in the lifting and fastening activity of the Pump				
			5			
				5	4	100
		Failure in Pump installation on Skid (Baud size error, Bolt not tight)	3	2	2	12
			3	3	3	27
4	Tie in Hot Tap	Failure in welding work				
			5	4	2	40
		Failure to isolate the welding area from flammable gases	5	3	2	30
				3	3	36
				2	2	16
				3	2	24
5	Maintenance Access Road	Failure to operate heavy equipment	4	3	3	36
		Failure in carry out work activities at height when carrying out architecture Building	3	4	2	24

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				3	2	18
			3	4	3	36
6	MCC Development					
			3	4	2	24
		Failure in Casting				
				4	3	36
			2	4	3	24
		Pinch Point	3	2	3	18
7	Making a Water Injection Pump Foundation	Failure in foundation casting activities	4	3	3	36
				3	2	24
		Failure to determine the anchor bolt point on the foundation	3	3	2	18
8	Pipe Support Manufacturing	Failure in determining the wrong point	3	3	2	18
				3	2	30
		Electrical hazards originating from existing cable facilities				
			5			
				3	2	30
9	Lying Power Cable and Accessories					

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				3	2	24
		Electrical Hazard during termination (Fire Spark, Electric jump)	4			
				3	2	24
10	Tie in the Power Cable to the Existing Power Cable	Electrical hazard when tie in is performed	4	4	2	32
				3	3	36
	Tie in the Power Cable to the Existing Power Cable			3	3	36
10		Failure to work at a height of >1.8 meters	4	3	3	36
		Failure in lifting and binding activities of materials		3	3	27
		instrument	3	3	3	27
11	PIC Installation		3	4	3	36
		Failure when working at a height of more than 1.8 meters		3	2	18
				3	2	18
		Failure due to incorrect manual handling	3	3	3	18
				3	2	24
	Field Instrument Transmitter Installation	Failure when working at a height of more than 1.8 meters		3	2	24
12			4	3	2	24
				3	2	30
13	Testing per Equipment	Functional failure of the equipment being tested	5	2	2	20
			3	3	2	18
	Trial / Commissioning for 3 times 24 hours		5	3	2	30
14	O'clock	Failure of the tested equipment function	3	4	3	36

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The results of the RPN determination indicate that the highest RPN value is 100 (one hundred) failures of lifting and rigging during pump installation caused by failure of lifting equipment due to calculation errors. This is because in this activity, if a failure occurs due to lifting tools used that do not match the capacity or calculation of the lifting plan, it will have fatal consequences and can result in failure in pump installation activities. According to information obtained from the interview results, pump installation is very critical, and there must be no errors in its installation and operation because this pump is the main equipment or main equipment of this project. While the lowest RPN value with a result value of 6 (six) is in the drawing and design making activities, the potential for failure is in errors in making the wrong design.

CONCLUSION

Based on the calculation results of the Risk Priority Number (RPN) value, failure in the activity of lifting and rigging the pump during the pump installation has a value of 100 (one hundred). While the lowest RPN value with a result value of 6 (six) is in the activity of making drawings and designs, the potential for failure is due to errors in making the design that was made incorrectly.

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