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IDENTIFICATION OF POTENTIAL HAZARDS AND OPERATIONAL PROBLEMS IN THE COLOUMN COMBINATION V-0301 AT PT PERTAMINA'S CAUSTIC TREATER UNIT USING THE HAZOP METHOD

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Abstract

The presence of harmful gases such as H_2S and mercaptans in the natural gas purification process requires safe handling to avoid the risk of equipment damage and danger to the environment and occupational safety. This study aims to analyze occupational safety risks in the V-0301 Combination Column at the Caustic Treater Unit (CTU) of CPP Gundih, PT Pertamina EP Cepu Asset 4 Zone 11 using the Hazard and Operability Study (HAZOP) method. Observed processes include pre-wash, extraction, and water wash, with NaOH as the primary solvent and demineralized water to remove impurities from natural gas. The analysis is carried out by identifying potential hazards and process deviations based on operating parameters such as pressure, temperature, and flow. The results point to several key risk scenarios, such as the potential for corrosion due to excessive NaOH concentrations and failure of pressure control systems. Risk mitigation recommendations include improved control systems, periodic inspections, and safety training for operators. The study contributed to the improvement of occupational safety and operational reliability of CTU units in natural gas processing facilities.

Keywords: HAZOP, Combination Column V-0301, occupational safety, H_2S, risk mitigation

Introduction

The use of natural gas as one of the main energy sources continues to grow in line with the global need for cleaner and more efficient energy (Ghoniem, 2011). Natural gas, known as a fossil fuel with lower carbon emissions than oil and coal, has become an important component in supporting the global energy transition. However, natural gas processing faces major challenges with the presence of impurities such as hydrogen sulfide (H_2S) and mercaptans (Wiheeb et al., 2013). These compounds are not only harmful to the environment and humans, but can also cause damage to processing equipment and affect the quality of gas products (Haider & Hashmi, 2014).

In this context, the Gundih Central Processing Plant (CPP) managed by PT Pertamina EP Cepu Asset 4 has a strategic role in natural gas refining. One of the technologies used is Coloumn Combination (V-0301) on the Caustic Treater Unit (CTU). The unit consists of three main stages, namely prewash, extraction, and water wash, which are designed to lower H_2S and mercaptan levels to meet safe and standardized natural gas specifications (Raj, Ibrahim, & Jagannath, 2020).

The operational efficiency of these devices depends on the control of process parameters, such as temperature, pressure, and concentration of chemical solutions (Qomariyah, Nuryono, & Kunarti, 2021). In addition, the identification of operational risks through methods such as Hazard and Operability Studies (HAZOP) is an important step to ensure the safety and sustainability of the processing process (Vaughen, Timm, Connolley, & Cowley, 2018). This study aims to analyze the performance of Column Combination in reducing H_2S and mercaptan content, as well as evaluate relevant risks and mitigations to support process optimization.

This research makes an important contribution to the natural gas industry in two main aspects: first, improving the operational efficiency and safety of the V-0301 Combination Column through a deep understanding of the process mechanism and the risks that occur; second, enriching academic literature related to the application of the HAZOP method in occupational safety risk analysis in the energy sector (Aliabadi, Abbassi, Kalatpour, Ahmadi, & Moshiran, 2024). Thus, the results of this research are expected to be the foundation for innovation and development of safer and more sustainable natural gas purification technology.

Research Methods

Literature studies

Literature Study Conducted by Collecting Several Supporting Theories. The literature used comes from several international and national journals as well as from other reference literature.

Data Collection

Data collection is carried out according to related topics, the data is in the form of process flow data, diagrams, P&ID and process data. The main data taken was on the CTU (caustic treater Unit).

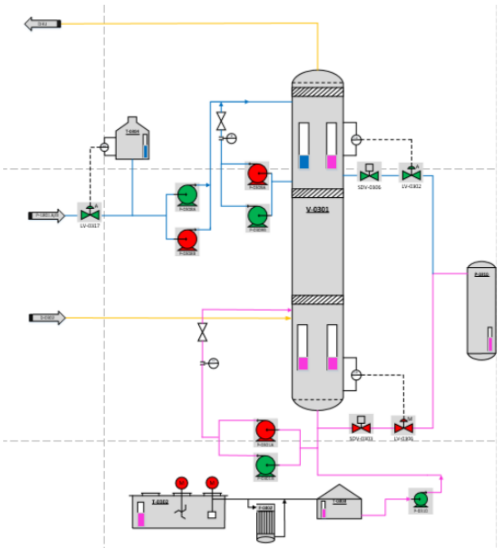

Figure 1 Process Flow Diagram Caustic Treater Unit

Tingkat Keparahan	Konsekuensi Terhadap Objek	Kemungkinan kejadian (Probability)				
		A	B	C	D	E
	Asset	Tidak Pernah Terjadi Di Industri Migas	Pernah Terdengar Di Industri Migas	Pernah Terjadi Di Industri Migas	Terjadi beberapa Kali Di industri Migas	Seringkali Terjadi di beberapa Kegiatan operasional
0	Tanpa Kerusakan	L	L	L	L	L
1	Kerusakan Sangat Kecil	L	L	L	L	L
2	Kerusakan Kecil	L	L	L	M	M
3	Kerusakan Sedang	L	L	M	M	H
4	Kerusakan besar	L	M	M	H	H
5	kerusakan Besar	M	M	H	H	H

Figure 2 Asset Risk Matrix

Tingkat Keparahan	Konsekuensi Terhadap Objek	Kemungkinan kejadian (Probability)				
		A	B	C	D	E
	Manusia	Tidak Pernah Terjadi Di Industri Migas	Pernah Terdengar Di Industri Migas	Pernah Terjadi Di Industri Migas	Terjadi beberapa Kali Di industri Migas	Seringkali Terjadi di beberapa Kegiatan
0	Tanpa cedera	L	L	L	L	L
1	Cedera Ringan	L	L	L	L	L
2	Cedera Sedang	L	L	L	M	M
3	Cedera Berat	L	L	M	M	H
4	fatality	L	M	M	H	H
5	Fatality Ganda	M	M	H	H	H

Figure 3 Matrix of Risks to Humans

Risk Analysis

Risk analysis is carried out to see the risk of hazards that occur at the time of the operation. In this analysis, the main focus is seen from three main parts of the CTU combination column, namely prewash, extraction and waterwash.

Cause and Consequences analysis.

This analysis is used to identify cause-and-effect relationships and consequences that may arise from a particular event or hazard. Some of the main steps include identifying the causes that occurred, and analyzing the resulting impact if the process occurs.

Risk Ranking Analysis

This analysis was carried out to see a systematic method which provides a risk rating based on severity, probability of occurrence, and potential impact. The goal is to prioritize which risks need to be handled first. Some of the main steps are probability assessment, impact assessment and ranking preparation of the scale that must be prioritized.

Hazop analysis

The analysis is carried out by determining the study point of the P&ID data that has been determined. At the selected point, it is determined what components are present in the observed part. It can be seen how the process occurs based on the input to the output. These components can be in the form of combination columns, control valves and processes that occur such as Prewash, Extraction and Waterwash.

Report Preparation

The preparation of this report is prepared in accordance with the results and initial stages carried out which include process flow diagrams, to the value of determining the risk ranking that has been carried out. In this case, it is also a consideration regarding the feasibility of the Caustic treater unit in the safety aspect.

Results and Discussion

Risk Analysis

Before determining the risks that may occur in the process in the Coloumn Combination (V-0301), a thorough understanding of the details of the process, from the input to the output produced, is required. This knowledge is important for identifying potential hazards that may arise during operation. In this analysis, the focus is given on the process in three main sections of the column, namely prewash, extraction, and water wash, which function to purify the gas from the mercaptan content before passing it on to the DHU (Dehydration Unit) unit (Krewall, 2021).

This process involves various supporting equipment, such as pumps and tanks, to ensure smooth operations. Among them, P-0310 and P-0301B pumps are used for injection and circulation of NaOH solution as a solvent to bind H_2S in the prewash section, while P-0308 is used for the injection of demin water in the water wash section. In addition, tanks T-0302 to T-0304 store NaOH solution and demin water, as well as ensure solvent availability in optimal conditions. By understanding the details of the process and the interactions between the equipment, further analysis can be carried out to identify possible hazards using the HAZOP method.

Prewash Section

The main process in the prewash section of Coloumn Combination (V-0301) involves a chemical reaction designed to reduce the H_2S content in the processed gas. The gas from the AGRU is flowed to the bottom of the prewash column, where the NaOH solution is circulated from top to bottom using a P-0301B pump. The NaOH solution serves as a solvent to bind H_2S molecules, resulting in a product with safer gas specifications for subsequent units (Ozekmekci, Salkic, & Fellah, 2015).

The main reaction that occurs involves the interaction between NaOH and H_2S, which form sodium sulfide salts and water. In order for this process to take place efficiently, it is important to maintain an even distribution of the NaOH solution within the column. Flow imbalances or solution concentrations can decrease the absorption efficiency of H_2S. In addition, operating temperatures (110 °F) and operating pressures (385 psig) must be closely monitored to avoid process failures or potential safety risks. This operational control is the key to ensuring that the prewash process runs optimally and safely.

Main Reactions in Prewash:

$H_2S + NaOH \rightarrow NaHS + H_2O$

These reactions, although simple, can be affected by operational variables such as gas flow rate, solution concentration, and temperature stability (Akhtar & Amin, 2012). Risk analysis using the HAZOP method can provide guidance to identify potential deviations, their causes, and possible consequences, so that mitigation can be designed appropriately.

Based on the results of the study of PFD, P&ID data, and Q&A with operators responsible for related processes, potential hazards have been analyzed using HAZOP tables which include the categories of guide words, deviation, cause, consequences and risk ranking, as explained in the literature review section. The analysis of causes and consequences related to the NaOH cycle in the process in the prewash zone is presented in table 1, while the risk ranking value of the analysis is shown in table 2.

Table 1 Cause and Consequences *Analysis* of NaOH Solution Cycle

Guide Words	**Deviation**	**Cause**	**Possible Consequences**
No Flow	No NaOH flow	P-0301B pump malfunction, clogged pipe, empty solution tank	The absorption process of H_2S is stopped, H_2S passes to the next unit, the risk of corrosion and pollution increases
High Flow	Excessive NaOH flow	Flow control malfunction, damage to the regulating valve	Overflooding in the prewash column, decreased absorption efficiency, damage to the internal structure of the column
Low Flow	NaOH flow too low	Pipe leakage, valve clogged, pump capacity decreased	Low H_2S absorption efficiency, increased concentration of H_2S in the outlet gas
Wrong Composition	Wrong NaOH concentration	Mixing error in the T-0302 tank or blending system malfunction	Absorption of H_2S is not optimal, excess NaOH causes corrosion in equipment
High Temperature	The temperature of the solution is too high	Problems with temperature controllers or overheating in pumps or pipelines	Degradation of NaOH solution, decreased absorption efficiency
Low Temperature	The temperature of the solution is too low	Problems with the heating system or the environment is too cold	Absorption slows down, the contact time between NaOH and gas is inadequate

Table 2 Risk Ranking *Analysis* of NaOH Solution Cycle

No.	Possible Consequences	Consequence Classification	Severity (S)	Probability (P)	Risk Ranking (RR)	Risk Categories	Existing Safeguard

1	The absorption process of H_2S is stopped, H_2S passes to the next unit, the risk of corrosion and pollution increases	Asset	4	3	12	High	H_2S gas detector, alarm system, emergency handling procedure
		Injury	4	1	4	Medium	Safety training, use of personal protective equipment (PPE)
2	Overflooding in the prewash column, decreased absorption efficiency, damage to the internal structure of the column	Asset	4	3	12	High	Automatic flow control system, regular column maintenance
		Injury	3	2	6	Medium	Safety training, regular inspection of internal structures
3	Low H_2S absorption efficiency, increased concentration of H_2S in the outlet gas	Asset	5	3	15	High	H_2S gas detection, automatic process control
		Injury	4	1	4	Medium	Use of personal protective equipment, early warning system
4	Absorption of H_2S is not optimal, excess NaOH causes corrosion in equipment	Asset	4	3	12	High	Inspection and maintenance of equipment, NaOH concentration control

		Injury	3	2	6	Medium	NaOH quality control, periodic cleaning of equipment
5	Degradation of NaOH solution, decreased absorption efficiency	Asset	3	3	9	Medium	Temperature and solution quality monitoring, automatic temperature control
		Injury	3	1	3	Low	Temperature alarm, heating maintenance and temperature control
6	Absorption slows down, the contact time between NaOH and gas is inadequate	Asset	3	3	9	Medium	Contact timing and system performance monitoring
		Injury	3	1	3	Low	Installation of protection for contact with hazardous chemicals

Extration Section

The extraction stage in the gas purification process aims to remove the content of mercaptans (organosulfur compounds) remaining in the gas stream after going through the prewash process (De Angelis, 2012). Mercaptans have corrosive properties and undesirable odors, so their separation is essential to improve the quality of the gases produced. In this process, caustic soda (NaOH) solution is used as the main solvent due to its highly alkaline nature and ability to react chemically with mercaptans. This reaction results in a more stable compound, so that the mercaptan content can be effectively removed. This process is carried out in the extraction column, where the NaOH solution circulates and comes into direct contact with the gas stream to ensure that each mercaptan molecule can react optimally.

However, in field practice, the mercaptan content in gas feeds is often very low so that the extraction process becomes less significant. This causes this stage to not always be actively operated, especially to save on operating costs and chemicals. Alternatively, the gas is directly flowed to the next stage, which is a water wash, to remove the NaOH carry-over carried in the gas stream. However, the extraction column is still designed to be usable when the level of mercaptan in the gas increases at any time.

In operation, the extraction column (part of the V-0301 combination column) was operated at a pressure of 384 psig and a temperature of 110 °F. These conditions are designed to support the efficient separation process. Despite its flexible use, the operational design of these columns still plays an important role in ensuring that the gas produced meets the required specifications before being flowed to downstream units such as Dehydration Units (DHUs). This process is an important part of the overall purification system that aims to produce high-quality gases and meet industry standards. The results of HAZOP analysis of the causes and consequences of the extraction section in the coloumn combination (V-0301) are shown in table 3.3 while the risk ranking of the analysis is shown in table 3.

Table 3 Cause and Consequences *Analysis* of NaOH Solution Cycle in *Extraction Section*

No.	Guide Word	Deviation	Cause	Possible Consequences
1	No Flow	No NaOH flow	Pump malfunction P-0301 B	Mercaptan is not bound; Decreased gas quality
2	Low Flow	NaOH flow too low	Blockage in pipelines	The efficiency of the reaction decreases; Merkaptan carry-over
3	High Flow	NaOH flow is too high	Flow control malfunction	Excess NaOH consumption; Operational costs increase
4	Low Concentration	NaOH concentration below specification	Blending error in tank T-0302	Reactions are not optimal; Mercaptan is not completely bound
5	High Concentration	NaOH concentration is too high	Blending error in tank T-0302	Risk of corrosion in the extraction column
6	No Reaction	No mercaptan reaction with NaOH	NaOH is saturated, no regeneration is carried out	Mercaptan remains in the gas stream
7	Temperature High	Operating temperature too high	Temperature control malfunction	NaOH degradation; By-product formation
8	Temperature Low	Operating temperature too low	Overcooling in the heat exchanger	Reaction slows down; Mercaptan is not completely eliminated

9	Pressure Low	Low operating pressure	Leaks in columns	The efficiency of gas contact with NaOH decreases
10	Pressure High	High operating pressure	Pressure control error	Risk of mechanical damage to the column

Table 4 Risk Ranking *Analysis* of NaOH Solution Cycle in *the Extraction Section*

No.	Possible Consequences	Consequence Classification	Severity (S)	Probability (P)	Risk Ranking (RR)	Risk Categories	Existing Safeguard
1	Mercaptan is not bound; Decreased gas quality	Asset	4	3	12	High	Routine maintenance of the P-0301 B pump
		Injury	3	2	6	Medium	PPE for workers around the pump area
2	The efficiency of the reaction decreases; Merkaptan carry-over	Asset	3	3	9	Medium	Periodic inspection of pipelines
		Injury	2	2	4	Low	Safety training and emergency procedures
3	Excess NaOH consumption; Operational costs increase	Asset	3	2	6	Low	NaOH flow control alarm
		Injury	2	1	2	Low	Flow control regulation operational training
4	Reactions are not optimal; Mercaptan is not completely bound	Asset	4	3	12	High	Monitoring of NaOH concentration in T-0302 tank
		Injury	3	2	6	Medium	Protection procedures against direct contact with NaOH
5	Risk of corrosion in the extraction column	Asset	4	3	12	High	Use of corrosion-resistant materials

		Injury	3	1	3	Low	Periodic inspection of the column area
6	Mercaptan remains in the gas stream	Asset	4	3	12	High	NaOH regeneration schedule
		Injury	2	2	4	Low	PPE and worker protection training
7	NaOH degradation; By-product formation	Asset	3	3	9	Medium	Temperature control alarm, heat exchanger inspection
		Injury	2	2	4	Low	Area surveillance for high temperatures
8	Reaction slows down; Mercaptan is not completely eliminated	Asset	3	3	9	Medium	Heat exchanger cooling monitoring
		Injury	2	2	4	Low	Operational training on refrigeration handling
9	The efficiency of gas contact with NaOH decreases	Asset	4	3	12	High	Maintenance of pressure control systems
		Injury	3	2	6	Medium	Area monitoring for leak risk
10	Risk of mechanical damage to the column	Asset	4	3	12	High	Pressure control alarm
		Injury	3	2	6	Medium	Routine pressure inspections

Water Wash Section

The water wash process is the final stage in the Combination Column (V-0301), after going through the pre-wash and extraction stages. This process is carried out by draining the demineralized water in the opposite direction (countercurrent) with the output gas from the extraction part. The main goal of this process is to remove the carryover caustic soda (NaOH) from the gas stream so that it achieves the desired level of purity. This interaction between water and gas ensures that the remaining NaOH carried away can be removed, thus preparing the gas for further processing in the Dehydration Unit (DHU).

Operationally, the water wash section is designed to handle pressures up to 379 psig with an operating temperature of approximately 109°F. The demineralized water stored in the T-0304 tank is injected into this part using the P-0308 pump. This water serves to bind the remaining NaOH in the gas, neutralize it, and prevent contamination of the equipment at the next stage. This process ensures optimal gas quality and reduces the risk of damage or impaired efficiency due to caustic carryover. Critical supporting equipment in this process includes a distributor to distribute the liquid evenly and a baffle to direct the flow of the liquid and minimize turbulence within the column. The water wash process not only ensures the gas meets the required specifications, but also improves the overall efficiency of the gas purification system. The results of HAZOP analysis on the causes and consequences of the water wash section in the coloumn combination (V-0301) are shown in table 5 while the risk ranking of the analysis is shown in table 3.6.

Table 5 *Analysis of Cause and Consequences of* NaOH Carryover in the *Water Wash Process*

No.	Possible Consequences	Consequence Classification	Severity (S)	Probability (P)	Risk Ranking (RR)	Risk Categories	Existing Safeguard
1	NaOH carryover to gas increases, affecting subsequent processes	Asset	4	3	12	High	Monitoring of NaOH levels in gas streams
		Injury	3	2	6	Low	Carryover detection system
2	Washing efficiency decreases, NaOH follows to the next stage	Asset	4	3	12	High	NaOH level alarm in water wash
		Injury	2	2	4	Low	Corrosion-resistant material
3	Gas and liquid contact is not maximum, NaOH carryover remains high	Asset	3	3	9	Medium	Regular inspections of trays and baffles
		Injury	3	2	6	Low	Monitoring of fluid flow direction

4	NaOH dissolution is not optimal, causing carryover to remain high	Asset	4	3	12	High	P-0308 injection pump performance alarm
		Injury	3	2	6	Low	Regular schedule of pump inspections
5	Slower dissolution reactions, causing NaOH carryover	Asset	3	2	6	Low	NaOH concentration automatic control system
		Injury	2	2	4	Low	Visual monitoring of the dissolving process
6	Uneven water flow, decreased water wash efficiency	Asset	4	3	12	High	Optimized fluid distribution system
		Injury	3	3	9	Medium	Periodic inspection of flow distribution
7	NaOH is not washed out, carryover to gas becomes significant	Asset	4	3	12	High	Automatic temperature control system
		Injury	2	3	6	Low	Overtemperature detection alarm
8	Saturated NaOH accumulates, lowers washing efficiency, contaminates the next stage	Asset	4	3	12	High	Solution regeneration system redundancy
		Injury	3	3	9	Medium	NaOH saturation monitoring system

Table 6 Risk Ranking *Analysis of* NaOH Carryover in the *Water Wash Process*

No.	Possible Consequences	Consequence Classification	Severity (S)	Probability (P)	Risk Ranking (RR)	Risk Categories	Existing Safeguard
1	The carryover of NaOH to gas increases, affecting	Asset	4	3	12	High	Monitoring of NaOH levels in gas streams

	subsequent processes. Washing efficiency decreases, NaOH follows to the next stage	Injury	2	1	2	Low	Operational training to mitigate the risk of exposure to NaOH
2	Gas and liquid contact is not maximum, NaOH carryover remains high.	Asset	3	3	9	Medium	NaOH level alarm in water wash
	NaOH dissolution is not optimal, causing carryover to remain high	Injury	3	2	6	Medium	Use of PPE, safety training when handling NaOH
3	The dissolution reaction is slower, causing NaOH carryover.	Asset	4	2	8	Medium	Regular inspections of baffles and liquid distributors
	Uneven water flow, decreased water wash efficiency	Injury	3	2	6	Low	Use of PPE, emergency procedure on NaOH leaks
4	NaOH is not washed out, carryover to gas becomes significant.	Asset	3	2	6	Low	Automatic temperature control system
		Injury	3	1	3	Low	Overtemperature detection alarm, equipment maintenance
5	NaOH carryover to gas increases, affecting subsequent processes	Asset	3	3	9	Medium	Periodic maintenance of the heater
		Injury	2	2	4	Low	Working temperature monitoring,

							safe heater use training
6	The washing efficiency decreases, NaOH follows to the next stage. Gas and liquid contact is not maximum, NaOH carryover remains high	Asset	4	3	12	High	Periodic inspections for leaks in trays and baffles
		Injury	4	2	8	Medium	Corrosion-resistant materials, maintenance and inspection procedures
7	NaOH dissolution is not optimal, causing carryover to remain high. Slower dissolution reactions, causing NaOH carryover	Asset	4	3	12	High	P-0308 injection pump performance alarm
		Injury	3	2	6	Medium	Redundancy of pump systems, safety training
8	The water flow is uneven, the efficiency of water wash decreases.	Asset	4	3	12	High	Automatic drainage system for solution regeneration
	Injury	Injury	3	2	6	Medium	Routine schedule of regeneration or solution replacement

Hazop Analysis

In operational risk analysis, the application of the Hazard and Operability Study (HAZOP) method is the main key to identifying, evaluating, and managing risks that may occur during the process (Zhou & Martirosyan, 2024). HAZOP is a systematic approach designed to evaluate deviations from normal operating conditions in a system, with a focus on the safety and reliability aspects of the process. HAZOP analysis is carried out using guide words such as No Flow, Low Flow, High Flow, Low Concentration, and others to evaluate the possible causes and consequences of the identified deviations.

Risk Distribution of HAZOP Analysis Results

The results of the HAZOP analysis show that the risks identified are spread across three main categories, namely Low Risk, Medium Risk, and High Risk, with a percentage of 29.17% for Low Risk, 41.67% for Medium Risk, and 29.16% for High Risk, respectively.

Low Risk (29.17%)

Risks in this category include deviations that have a small impact on assets or worker injuries, and have a low probability of occurring. For example, deviations such as slightly below the threshold operating temperature can cause the dissolution reaction to slow down without significant consequences to process efficiency or safety. Although this impact is relatively small, mitigation measures are still needed to ensure that there is no escalation of risk in the future. Safeguards applied to this category are usually in the form of routine monitoring and simple warning alarms to detect changes in process parameters.

Medium Risk (41.67%)

The medium risk category is the largest portion in the risk distribution of HAZOP. Deviations that fall into this category, such as slightly out-of-specification NaOH concentrations or low operating pressures due to small leaks, have a more significant impact on process and asset efficiency, although the probability is still moderate. For example, too low a concentration of NaOH can cause the mercaptan reaction to be suboptimal, resulting in the final product not meeting the expected quality specifications. For risks in this category, safeguards such as periodic inspections of pipelines, NaOH level alarms, and automatic pressure control are effective mitigation measures to maintain operational stability.

High Risk (29.16%)

High risks are identified at deviations that can have a major impact on the asset, such as mechanical damage to the column due to high operating pressures or risk of corrosion to equipment due to excessively high NaOH concentrations. This impact not only affects process efficiency but also has the potential to lead to significant financial losses and production downtime. In addition, risks in this category also include potential injuries to workers, such as excessive exposure to NaOH that can pose health risks. Therefore, the safeguards applied to this risk category are more complex, such as the use of corrosion-resistant materials, redundancy of pump systems, and regular pressure inspections to reduce the possibility of risk escalation.

Evaluation and Implications

The dominant proportion of Medium Risk (41.67%) indicates that the operation process requires strict supervision to maintain efficiency and safety. Although Low Risk has the same portion as High Risk (29.16%), high risk has a higher risk of mitigation due to its significant potential impact. A risk-based mitigation approach is applied to determine the priority for handling identified deviations, focusing on preventive and corrective measures that are proportional to the level of risk. To improve operational reliability and safety, the HAZOP results provide the basis for operational procedure updates, improved safeguard design, and ongoing operator training. This combination of steps is expected to reduce the risk distribution in the medium and high risk categories in the future, so that the process can run more efficiently and safely.

HAZOP analysis has provided an in-depth picture of the risk distribution in the NaOH solution cycle in the extraction section. With a risk percentage of Low Risk of 29.17%, Medium Risk of 41.67%, and High Risk of 29.16%, it can be concluded that existing mitigation measures need to be focused on reducing the risk of the medium and high categories through improving the control, monitoring, and periodic inspection system. The analysis also emphasizes the importance of a proactive approach to risk management to ensure safety

Conclusion

Based on the HAZOP analysis on the Coloumn Combination V-0310 in the Caustic Treater at PT Pertamina, it shows that the identified risk levels consist of Low Risk (29.17%), Medium Risk (41.67%), and High Risk (29.16%). The risk of the medium and high categories, which includes 70.84% of the total risk, shows a significant probability of operational deviations, especially in critical parameters such as flow, temperature, pressure, and concentration of NaOH solution. These irregularities can lead to process failures, gas leaks, and occupational safety threats, which require intensive attention. The high Risk Ranking value in several risk scenarios, such as overpressure and wrong composition, confirms that potential hazards to personnel safety and asset damage require stricter management.

With the identified Risk Ranking value, the rate of accidents and safety threats in this cycle is quite high, especially in the risk scenario of the High Risk category. For example, failure to control the pressure or concentration of the solution can lead to the leakage of H_2S gas, which not only threatens the health of workers but can also lead to significant operational losses. Therefore, more systematic mitigation measures are needed to reduce the possibility of accidents.

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