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HAZOP Analysis of Air Tank on Dust Collector: Integrating Risk Assessment and Skill Development in Mining

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Abstract

Air tank dust collectors are essential for safeguarding air quality and operational safety in industrial environments. Nevertheless, these systems are highly susceptible to hazards arising from abnormal pressure and temperature conditions. This study employs Hazard and Operability Analysis (HAZOP) to systematically identify and evaluate risks associated with air tanks in dust collection equipment. Conducted within an industrial setting, the analysis highlights that excessive pressure and elevated temperatures can result in severe outcomes, including fires, explosions, and mechanical failure. To mitigate these risks, the study recommends the installation of safety valves, integration of advanced pressure and temperature sensors, and implementation of rigorous maintenance schedules. The findings confirm that HAZOP provides a structured framework for detecting potential hazards and developing preventive measures, thereby enhancing reliability and safety in industrial operations. This research contributes to the broader field of industrial risk management by demonstrating the effectiveness of HAZOP in addressing critical safety challenges related to pressure and temperature control.

INTRODUCTION

Air tank dust collectors are important tools in industries to keep the air clean and ensure safety by filtering dust particles. These systems help prevent air pollution and create a safer environment for workers (Isarinia et al., 2024). However, like other industrial equipment, air tank dust collectors can face problems, especially related to pressure and temperature changes. If not properly managed, these issues can lead to serious accidents like fires, explosions, or equipment breakdowns (Dang et al., 2025).

This study aims to use the Hazard Analysis (HAZOP) method to examine potential dangers in air tanks of dust collection equipment, particularly those related to pressure and temperature changes (Rahmanto & Hamdy, 2022). The goal is to identify these risks and suggest ways to prevent accidents, improving safety in industrial operations (Rahma & Hasanudin, 2023; Suyitno, 2022).

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The importance of this research comes from the growing need to manage risks in industrial settings (Novitrie, 2023). As the demand for clean air and safety increases, it is essential to address the potential problems caused by pressure and temperature changes in air tanks. The results of this study will help develop better safety measures and guidelines for industries using dust collection systems (Sudjimat et al., 2019; Sugianto et al., 2024).

In this study, the HAZOP method is used to analyze the risks of pressure and temperature problems in air tanks. By identifying possible issues, this research aims to provide practical solutions to improve safety and maintain the equipment's reliability (Choi & Byeon, 2020).

METHODS

This study identifies occupational safety and health risks in the sedimentation unit, focusing on temperature and pressure using the HAZOP method. The variables analyzed are pressure and temperature, which can affect the process. The first step is to analyze the P&ID to understand the impact of pressure and temperature, as well as to collect data related to equipment and maintenance steps in the HAZOP flowchart.

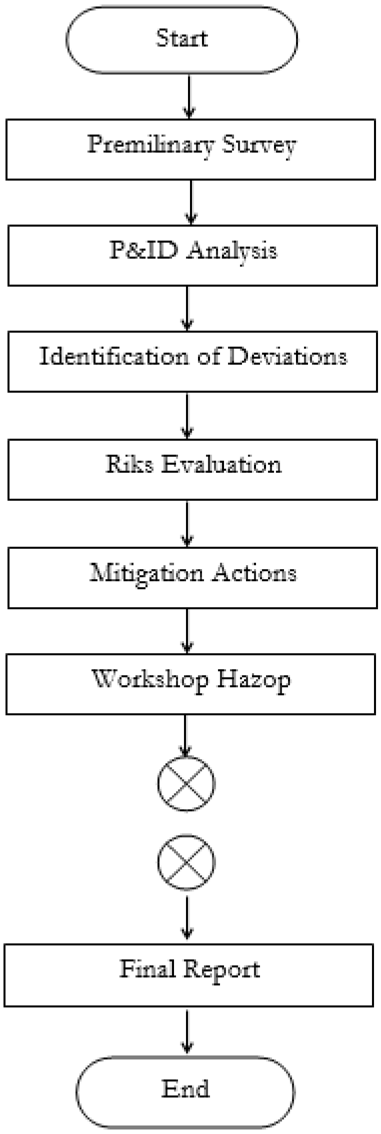

Fig 1. HAZOP flowchart

Preliminary Survey

Collecting equipment data, including item codes, variables, and safe operating limits. Technical specifications of the Air Tank are as follows:
Design Pressure: 0.87 MPa
Trial Pressure: 1.05 MPa
Maximum Working Pressure: 0.8 MPa
Design Temperature: 100°C
Volume: 2.0 m³
Vessel Weight: ~350 kg
Year of Manufacture: 2021
Main Material: GB150 standard

Fig 2. Equipment Data

P&ID Analysis

Analyzing the process and instrumentation diagram to understand the process flow and system operation. The analysis of the Process and Instrumentation Diagram (P&ID) is conducted to obtain a comprehensive understanding of process flow, equipment interactions, and system operation (Sudjimat et al., 2019; Zbaravska et al., 2020). A P&ID represents a graphical depiction of the process system, illustrating the configuration of equipment, piping, instrumentation, and control loops. It is widely recognized as a fundamental tool in process safety and engineering design, as it provides a standardized representation of how process units are interconnected and controlled. From a theoretical perspective, P&ID analysis facilitates the identification of critical control points, safety instrumented functions, and potential failure modes within the system (Choi & Byeon, 2020). Within the context of Hazard and Operability (HAZOP) studies, the P&ID serves as the primary reference document, ensuring that all deviations in process parameters can be systematically traced to specific equipment or instrumentation. Consequently, P&ID analysis is essential not only for risk identification and assessment but also for validating the integrity of safety systems and supporting informed decision-making in industrial process safety management (Engkizar et al., 2024, 2025; Zbaravska et al., 2020).

Identification of Deviations

Detecting deviations based on pressure parameters. Pressure is a critical process parameter that directly influences the integrity, operability, and safety of industrial systems. In HAZOP studies, the identification of deviations in pressure is carried out systematically to determine conditions where the actual operating pressure deviates from the design or safe operating limits (Jalinus et al., 2023; Putri & Yozani, 2019). The primary deviations commonly analyzed include High Pressure, Low Pressure, and No Pressure, each of which may lead to significant operational and safety consequences. From a theoretical perspective, deviations in pressure can be identified by comparing real-time process data with predefined set points or design specifications. This detection is facilitated through instrumentation such as Pressure Indicators (PI), Pressure Transmitters (PT), Pressure Gauges, and Pressure Safety Valves

(PSV) (Susanto et al., 2022).

Upper limit: 1.25 MPa. Exceeding this limit may lead to compressor pump failure, potential explosion, and air blast release.

Lower limit: Vacuum. This condition can cause dust accumulation and clogging, distribution process failure, and malfunction of the pump (Afshari & Fam, 2024).

Risk Evaluation

Risk evaluation in Hazard and Operability (HAZOP) studies is the systematic process of assessing the significance of identified deviations by analyzing their likelihood and consequences (Paper, 2018). While HAZOP primarily focuses on identifying potential hazards and operability issues through deviations in process parameters (e.g., pressure, temperature, flow, level, or composition), risk evaluation provides the framework to prioritize these hazards and determine the adequacy of existing safeguards (Ekinci, 2023).

Table 1. Severity Categories

Severity Category		
Description	**Severity Category**	**Mishap Result Criteria**
Catastrophic	1	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
Critical	2	Could result in one or more of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	3	Could result in one or more of the following: Injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
Negligible	4	Could result in one or more of the following: Injury or occupational illness not resulting in a lost work day, minimal environmental impact, or monetary loss less than $100K.

Table 2. Probability Levels

Probability Levels			
Description	**Level**	**Specific Individual Item**	**Fleet or Inventory**
Frequent	A	Likely to occur often in the life of an item.	Continuously experienced.
Probable	B	Will occur several times in the life of an item.	Will occur frequently.
Occasional	C	Likely to occur sometime in the life of an item.	Will occur several times.
Remote	D	Unlikely, but possible to occur in the life of an item.	Unlikely, but can reasonably be expected to occur.

Improbable	E	So unlikely, it can be assumed occurrence may not be experienced in the life of an item.	Unlikely to occur, but possible.
Eliminated	F	Incapable of occurrence. This level is used when potential hazards are identified and later eliminated.	Incapable of occurrence. This level is used when potential hazards are identified and later eliminated.

RISK ASSESSMENT MATRIX				
SEVERITY / PROBABILITY	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)	High	High	Serious	Medium
Probable (B)	High	High	Serious	Medium
Occasional (C)	High	Serious	Medium	Low
Remote (D)	Serious	Medium	Medium	Low
Improbable (E)	Medium	Medium	Medium	Low
Eliminated (F)	Eliminated			

Fig 3. Risk Assessment Matrix

Mitigation Action

Determining actions to reduce identified risks, such as installing safety valves, using more sensitive pressure sensors, and conducting routine maintenance. Determining actions to reduce identified risks is a critical step in the HAZOP methodology, as it ensures that potential hazards are adequately controlled and the overall system operates within safe limits (Nitter et al., 2025). Mitigation measures may include engineering controls (e.g., installing safety valves, pressure relief devices, and rupture discs to prevent overpressure scenarios), instrumentation enhancements (e.g., deploying more sensitive and reliable pressure and temperature sensors, integrating alarms, and implementing automatic shutdown systems), and preventive maintenance programs (e.g., periodic inspection, calibration, and replacement of critical components) (Rusli et al., 2024). In addition, administrative controls such as developing standard operating procedures (SOPs), operator training, and emergency response plans further strengthen risk reduction. For higher-risk scenarios, inherently safer design principles may be applied, such as reducing operating pressure, modifying process conditions, or using alternative materials. Collectively, these mitigation actions aim to lower the likelihood of hazardous events, minimize the severity of potential consequences, and enhance the resilience of industrial operations (Hicham & Aziz, 2024).

Workshop Hazop

The HAZOP Workshop (Hazard and Operability Study Workshop) is a process risk analysis method carried out collectively, systematically, and in a structured manner through multidisciplinary group discussions. In essence, this workshop serves as an official forum to identify potential hazards and operability issues within a system or process. The scope of this HAZOP workshop is as follows: Multidisciplinary team: involving a process safety engineer, operations, instrumentation, mechanical, HSE, and operator representatives. Facilitator: led by a HAZOP leader. Structured approach: analysis is conducted per node (process section) using guide words. Interactive discussion: all team members contribute, while the facilitator maintains focus and objectivity.

The implementation of the HAZOP workshop is as follows opening: explanation of objectives, scope, and discussion rules. Node Identification: dividing the system into smaller nodes. Application of Guide Words: identifying deviations from normal operation. Team Discussion: assessing causes, consequences, existing safeguards, and additional recommendations. Documentation: the secretary or scribe records all analysis results into the HAZOP worksheet. The outcomes of this HAZOP workshop can be implemented by workers in their respective areas as a concrete step toward effective HAZOP implementation.

Final Report

Preparing a comprehensive report with the analysis results and recommended improvements is the concluding step of the HAZOP study. The final report serves as a formal documentation that consolidates all findings, including identified deviations, their possible causes and consequences, the effectiveness of existing safeguards, and the recommended mitigation measures (Rehail et al., 2024). It typically contains a structured summary of the methodology applied, detailed HAZOP worksheets, risk evaluations, and prioritization of corrective actions (Mocellin et al., 2022).

The collected data is then processed to identify deviations and determine the likelihood and consequences according to standards (Siddiqui et al., 2014). If the risk is acceptable, the HAZOP worksheet is prepared. If the risk is unacceptable, further risk analysis is conducted. The research stages include preliminary surveys, literature studies, and completing the HAZOP worksheet with nodes, deviations, parameters, and risk assessments. The risk assessment is done by multiplying the consequences and likelihood based on expert opinions (Aditya & Nugroho, 2024).

RESULT AND DISCUSSION

The Hazard and Operability (HAZOP) study was conducted on the air tank used in the dust collector system, focusing on two main parameters: pressure and temperature. The analysis included preliminary surveys, data collection, and P&ID evaluation. The technical specifications of the air tank are presented in table 1.

The results identified several potential deviations such as high pressure, low pressure (vacuum), and high temperature. Each of these deviations carries significant consequences, including compressor pump failure, potential explosions, dust accumulation, and equipment malfunction.

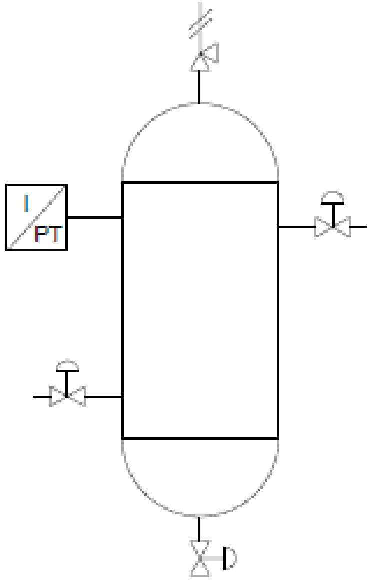

Fig 4. Process Flow and P&ID of Air Tank System

Table 3. Technical Specifications of Air Tank

Variable	Value	Notes
Design Pressure	0.87 MPa	-
Trial Pressure	1.05 MPa	Safety test condition
Maximum Working Pressure	0.80 MPa	Operating limit
Design Temperature	100.00°C	-
Volume	2.00 m³	
Vessel Weight	350.00 kg	Approximate
Material Standard	GB150	-

Table 4. HAZOP Worksheet

Node	Deviation	Possible Causes	Consequences
Air Tank	High Pressure	Compressor overrun, valve failure	Explosion, pump damage
	Low Pressure/Vacuum	Leakage, blocked flow	Dust clogging, pump malfunction
	High Temperature	Poor cooling, external heat	Equipment failure, fire hazard

Table 5. HAZOP Worksheet

Node	Deviation	Probability	Severity	Risk Level	Safeguards/Mitigation
Air Tank	High Pressure	C (Occasional)	1 (Catastropic)	High	Safety valve, pressure relief system, regular maintenance
	Low Pressure/Vacuum	D (Remote)	2 (Critical)	Medium	Check valve, pressure monitoring
	High Temperature	C (Occasional)	1 (Catastropic)	High	Temperature sensor, cooling system

The evaluation using a risk matrix showed that high pressure and high temperature deviations are categorized as high risk, requiring immediate mitigation measures. Meanwhile, vacuum conditions are rated as medium risk, still needing safeguards but with less severe consequences. These findings are in line with previous studies that emphasize the vulnerability of compressed-air systems to overpressure and thermal stress. The comparison highlights similarities with earlier research, but this study provides additional insight by analyzing both pressure and temperature deviations simultaneously, which broadens the understanding of potential hazards. Mitigation strategies proposed include the installation of safety valves, upgrading to sensitive pressure and temperature sensors, and scheduling regular maintenance to ensure system reliability. Implementing these measures will significantly reduce the likelihood of accidents such as explosions, dust clogging, and fire hazards, ensuring safer industrial operations.

CONCLUSION

The HAZOP study on the air tank of dust collector equipment shows that deviations in pressure and temperature are the main hazards. High pressure and high temperature are high-risk conditions with potential for explosion, fire, and equipment failure, while vacuum conditions pose medium risks such as clogging and malfunction. Mitigation through safety valves, sensitive sensors, and regular maintenance is strongly recommended. Integrating HAZOP into routine safety management will improve reliability and reduce accident risks.

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