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Evaluation and improvement of Occupational Health and Safety Management Using HAZOP: A case Study in the Kiln Unit

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Abstract

PT Indocement Tunggal Prakarsa Tbk is a leading cement producer in Indonesia, operating highly sophisticated clinker production facilities. One of the most critical units in the cement manufacturing process is the kiln, where raw meal undergoes pyroprocessing at extremely high temperatures, posing significant occupational health and safety risks. This study aims to assess the process safety risks in the kiln unit using the Hazard and Operability Study (HAZOP) method. The methodology involves identifying process nodes, analyzing potential deviations using guide words, and evaluating risks based on causes, consequences, existing safeguards, and recommended actions. The assessment identified several potential hazards such as temperature deviations, combustion failures, material blockages, and overpressure incidents, which may lead to equipment failure, production loss, or catastrophic events. Risk levels were categorized using a two-dimensional risk matrix based on severity and likelihood. The study concludes with mitigation recommendations including enhanced burner monitoring, installation of redundant safety devices, and improved maintenance programs. These findings are expected to contribute to enhancing the operational safety and reliability of the clinker production process at PT Indocement Tunggal Prakarsa Tbk.

Keywords Risk Matrix, Risk Management, HAZOP

INTRODUCTION

The existence of risks and hazards in the workplace is an unavoidable condition. Hazards may arise from various work activities carried out within the company. These risks can lead to occupational accidents, resulting in losses not only for the workers but also in terms of material damage. According to Law No. 1 of 1970 concerning Occupational Safety, the implementation of safety aspects is mandatory in all workplaces — whether on land, underground, on the water surface, underwater, or in the air — as long as they are within the jurisdiction of the Republic of Indonesia.

PT Indocement Tunggal Prakarsa Tbk., as the largest cement producer in Indonesia, operates several processing units in its production system. These units include: the mining and raw material supply unit (Mining Unit), the raw material drying and grinding unit (Raw Mill Unit), the burning and clinker cooling unit (Burning Unit), the final grinding unit (Finish Mill Unit), the cement packing unit (Packing Unit), and the coal drying and grinding unit (Coal Mill Unit). Although these units are interconnected, the performance evaluation of each unit can be conducted separately.

The burning and clinker cooling unit (Burning Unit), consisting of the Suspension Preheater (SP), Rotary Kiln, and Grate Cooler, is a critical unit because it is where clinker formation occurs. The production process within the kiln unit utilizes modern technology, involving machinery and equipment that carry significant hazard potential, including risks of fire, explosion, environmental pollution, and occupational diseases.

The safety aspect analysis for this unit includes the analysis of hazardous materials and the process hazard analysis. The approaches applied are HIRA (Hazard Identification and Risk Assessment), HAZOP (Hazard and Operability Study), and HAZID (Hazard Identification). A primary purpose of this analysis is to identify and evaluate the potential for accidents, particularly in high-risk areas within the workplace.

Benefits of the Writing

1. Enhances students' ability to record and analyze hazard factors present in the workplace.
2. Increases the writer's knowledge and insights in the field of Occupational Health and Safety, particularly in the cement industry at PT Indocement Tunggal Prakarsa, Tbk.

Company Profile

PT Indocement Tunggal Prakarsa Tbk. ("Indocement" or "the Company") officially commenced operations of its first plant in August 1975. Over a span of 43 years, Indocement has grown to become one of the largest cement producers in Indonesia.

The Company was established on January 16, 1985, through the merger of six cement companies, which at the time operated eight plants. Indocement was founded based on Deed No. 227 dated January 16, 1985, drawn up before Notary Ridwan Suselo, SH. According to its Articles of Association, the Company’s main business activities include the manufacture of cement and building materials, mining, construction, and trading.

Currently, Indocement and its subsidiaries are engaged in several business areas, including the manufacture and sale of cement (as the core business), as well as the production of ready-mix concrete, aggregates, and trass.

Indocement continues to expand its production capacity. On February 22, 2013, the Company began expanding its Citeureup Plant Complex by adding a new production line known as the 14th Plant. Including the 14th Plant, Indocement operates a total of 13 plants, most of which are located on the island of Java—10 plants are situated in Citeureup, Bogor, West Java—making it one of the largest integrated cement plant complexes in the world. The remaining two plants are located in Palimanan, Cirebon, West Java, and one in Tarjun, Kotabaru, South Kalimantan.

Indocement first listed its shares on the Indonesia Stock Exchange (IDX) on December 5, 1989, under the ticker symbol "INTP." Since 2001, the majority of the Company’s shares have been owned by HeidelbergCement Group, based in Germany. HeidelbergCement is a global leader in the aggregates business and a prominent player in cement, ready-mix concrete (RMC), and downstream activities, making it one of the largest building materials producers in the world. The Group employs over 45,000 people across 2,300 locations in more than 40 countries.

Under the "Tiga Roda" brand, Indocement sold approximately 18.7 million tons of cement in 2014, making it the largest single-entity cement seller in Indonesia. The Company's cement products include Portland Composite Cement (PCC), Ordinary Portland Cement (OPC Type I, II, and V), Oil Well Cement (OWC), White Cement, and TR-30 White Finishing Cement. Indocement is the only producer of White Cement in Indonesia.

In addition to cement sales, Indocement, through PT Pionirbeton Industri, which produces ready-mix concrete, sold 3.9 million m^3 of RMC, positioning itself as the market leader in Indonesia's RMC business. In the aggregates sector, PT Tarabatuh Manunggal, a wholly-owned subsidiary of Indocement, commenced production on September 10, 2014. Indocement also owns another aggregate quarry through PT Mandiri Sejahtera Sentra.

As of December 31, 2014, Indocement had an installed cement production capacity of 20.5 million tons, a ready-mix concrete production capacity of 5.0 million m^3 supported by 41 batching plants and 706 mixer trucks, and an aggregate production capacity of 2.8 million tons per year, with total aggregate reserves reaching 80 million tons from two quarries.

In conducting its business, Indocement remains focused on sustainable development with a commitment to reducing carbon dioxide emissions from the cement production process. Indocement was the first company in Southeast Asia to receive Certified Emission Reductions (CERs) under the Clean Development

Mechanism (CDM). Indocement was also the first company in Indonesia to utilize granulated blast furnace slag—a by-product of the steel industry—in cement production, thereby reducing clinker content and lowering CO_2 emissions.

RESEARCH METHODOLOGY

2.4 Stages of HAZOP Execution

Execution of HAZOP considers on units smelling salts converter carried out through the taking after stages :

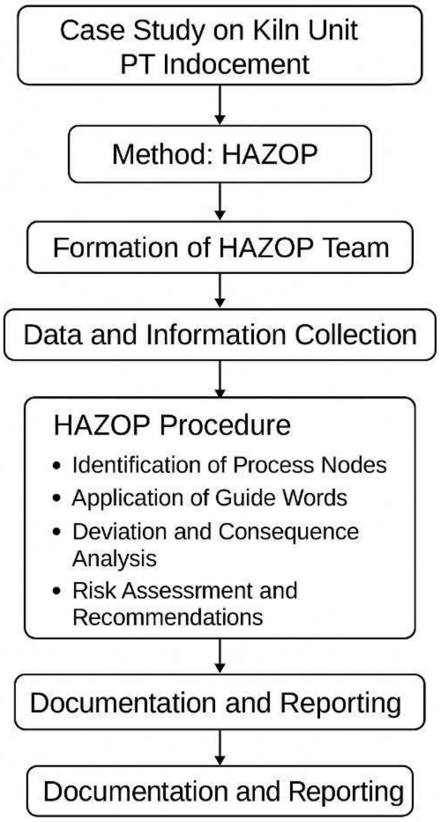

Figure 1. Flowsheet HAZOP in Unit kiln

2.4.1. HAZOP Group Composition

The HAZOP group consists of key personnel who possess relevant experience and expertise in the cement production process at PT Indocement. The team includes:

- Process Engineers

- Field Operators
- Occupational Health and Safety (OHS) Specialists
- Maintenance Engineers
- HAZOP Facilitator (as the mediator)

2.4.2 Information and Data Collection

The data collected for the HAZOP analysis includes:

- Process Flow Diagram (PFD)
- Piping and Instrumentation Diagram (P&ID)
- Operational data for the kiln unit (e.g., pressure, temperature, flow rate)
- Historical incident data and near-miss reports
- Standard Operating Procedures (SOPs) for the kiln operation

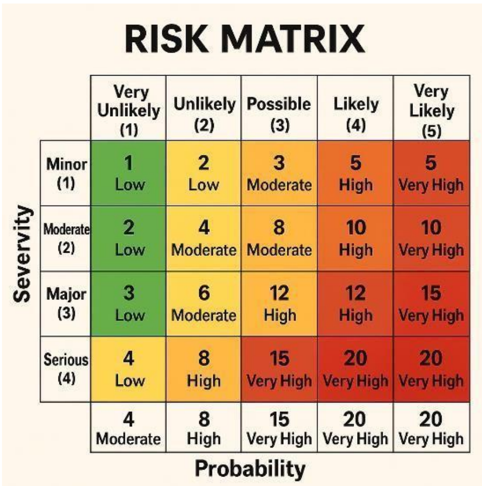

Figure 2. Risk Matrix

2.4.3. Node and Parameter Identification

The system is divided into several nodes based on logical process sections, such as:

- Raw Meal Feed
- Preheater Tower
- Rotary Kiln (Burning Zone)

- Clinker Cooler
- Clinker Storage

For each node, significant parameters such as flow rate, pressure, temperature, composition, and level are identified and assessed.

2.4.4. Application of Guide Words

Guide words like "No," "More," "Less," "As Well As," "Part of," "Reverse," and "Other Than" are applied to assess potential deviations from normal operating conditions. For example:

- **"No Flow"** to identify potential blockages in material or gas flow
- **"High Temperature"** to assess the risk of overheating in the kiln
- **"More Pressure"** to evaluate the risk of pressure build-up in the preheater

2.4.5. Deviation Identification and Consequence Analysis

Each combination of process parameters and guide words is analyzed to identify potential deviations. The analysis includes:

- Possible causes of the deviation
- Potential consequences for safety, environmental impact, and operations
- The need for corrective actions and mitigation measures

2.4.6. Risk Assessment and Recommendations

The identified risks are assessed based on severity (consequence), likelihood of occurrence (probability), and detection capability using a simple risk matrix. Mitigation actions are proposed for risks that are deemed unacceptable. These may include:

- Equipment modifications
- Procedural changes

- Installation of additional safety devices
- Operator training
- Emergency response planning

2.5. Documentation and Reporting

All HAZOP findings are documented in a table format containing the following details:

- **Node**
- **Deviation**
- **Cause**
- **Consequence**
- **Existing Safeguards**
- **Risk Level**
- **Recommended Actions**

PROCESS DESCRIPTION

The cement kiln is a rotary cylindrical vessel operating at an inclined angle and rotated slowly on its axis. Raw materials (primarily limestone, clay, and iron ore) are fed into the kiln through a preheater and pre-calciner, and then subjected to high-temperature pyroprocessing.

1. Preheating and Calcination: Raw meal is preheated in the preheater tower and partially calcined in the pre-calciner before entering the kiln.
2. Kiln Firing: Pulverized coal, natural gas, or alternative fuels are used for combustion in the kiln's firing zone.
3. Clinker Formation: At approximately 1,450°C, materials react to form clinker nodules.

4. Cooling: Clinker exiting the kiln is cooled rapidly in the clinker cooler to recover heat and facilitate handling.

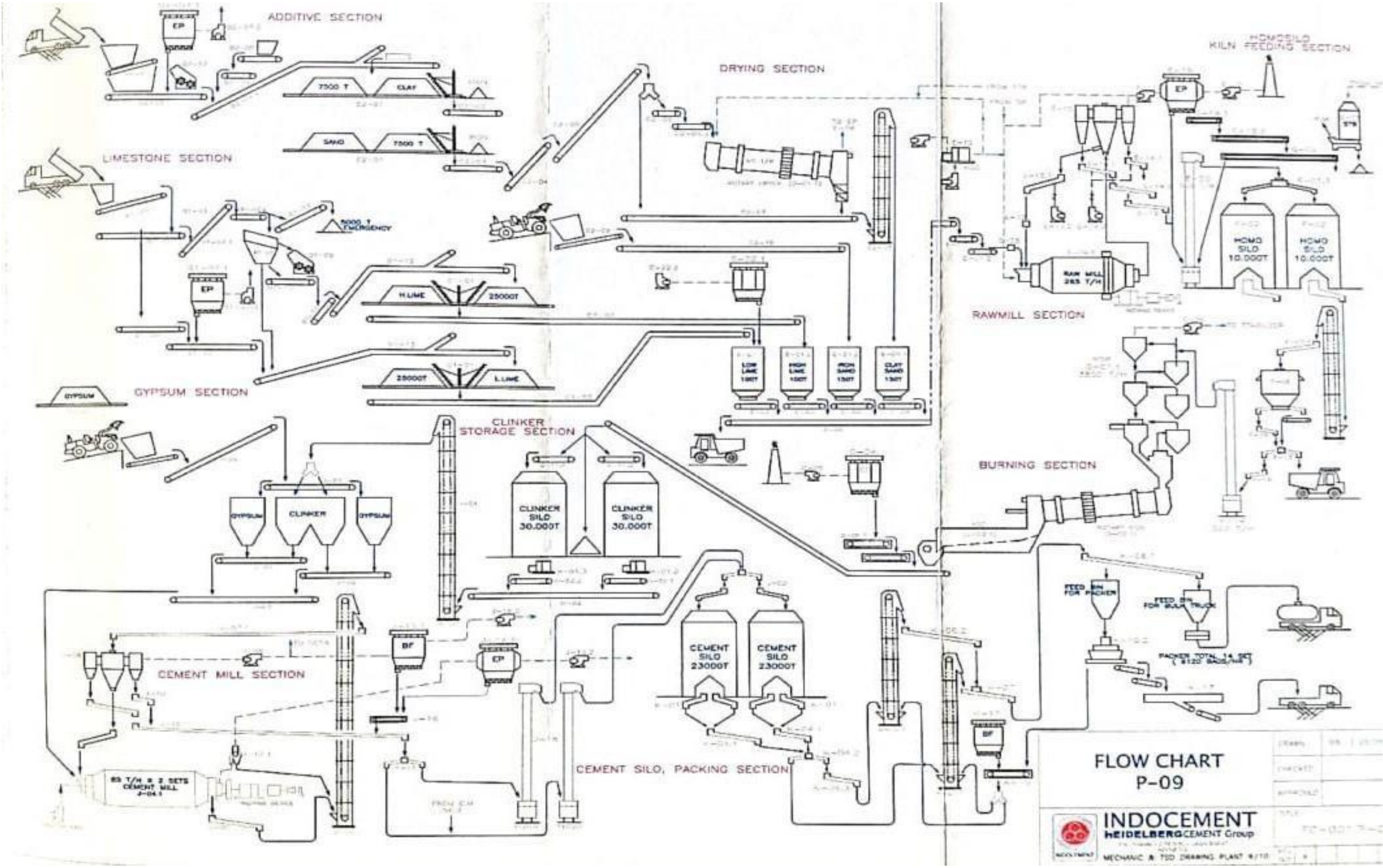

Figure 3. Process Plant 9

Tabel 1. HAZOP

No.	Process Node	Parameter	Deviation	Potential Cause	L	S	R	Consequence	Existing Protection	Recommendation
1	Raw Meal Feed to Kiln	Flow	Low	Plugging, feeder malfunction	1	1	1	Incomplete calcination, poor clinker quality	Flow meter, low flow alarm	Install interlock for low flow; routine maintenance
2	Raw Meal Feed to Kiln	Flow	High	Feeder overspeed, control failure	1	3	3	Overloading kiln, unstable combustion	Flow control loop, DCS control	Fine-tune PID settings
3	Kiln Burner	Fuel Pressure	Low	Pump trip, blockage in fuel line	1	4	4	Flame instability, potential flameout	Pressure indicator, alarm	Add auto cut-off and interlock system
4	Kiln Burner	Temperature	High	Excess fuel or air imbalance	1	3	3	Refractory damage, high NOx emission	Thermocouple, burner control loop	Regular calibration, optimize fuel-air ratio
5	Kiln Inlet	Temperature	Low	Poor preheating, feed interruption	1	2	2	Poor combustion, material fallback	Temperature monitor, DCS trend	Install preheater efficiency monitor
6	Kiln Body	Rotation Speed	Low	Motor or gear failure	1	3	3	Ring formation, production stop	Motor trip protection, RPM sensor	Preventive maintenance schedule

7	Kiln Body	Rotation Speed	High	Speed control malfunction	1	4	4	Lining wear, mechanical damage	Speed monitor, alarm system	Calibrate control system regularly
8	Combustion Air Supply	Pressure	Low	Blower fault, filter blockage	1	4	4	Incomplete combustion, poor fuel efficiency	Pressure switch, trip interlock	Maintain blower and filters; install backup blower
9	Secondary Air from Cooler	Temperature	Low	Cooler malfunction, fan trip	1	3	3	Poor combustion efficiency	Temperature indicator, flow monitor	Add alarm for low temperature
10	Kiln Exit Gas	Temperature	High	Excess fuel, low feed rate	1	4	4	Damage to gas conditioning equipment	Gas analyzer, ESP inlet alarm	Tune burner temp control
11	Kiln Exit Gas	Flow	Low	Blockage in duct, ID fan issue	1	4	4	Backpressure to kiln, system upset	Flow monitor, ID fan interlock	Routine inspection of ducts
12	Clinker Discharge	Temperature	High	Kiln overfire, short residence time	1	4	4	Clinker quality deterioration, cooler overload	Temperature monitor, feed control	Adjust burner profile, tune kiln RPM
13	Kiln Cooler	Cooling Air	Low	Fan failure, duct blockage	1	5	5	Poor cooling → clinker not properly quenched	Fan trip interlock, temperature sensor	Backup cooling fan, maintenance SOP

14	Kiln Cooler	Clinker Flow	Blocked	Clinker jam, grate problem	1	4	4	Overheat in cooler, backflow to kiln	Level indicator, flow sensor	Install chute vibrator or fluidized bed
15	Kiln Dust Handling	Flow	High	Overgrinding, poor ESP setting	1	4	4	Baghouse overload, stack emission increases	Baghouse pressure sensor, dust monitor	ESP tuning, dust valve calibration
16	Kiln Stack	Emission	High	ESP malfunction, duct leak	1	5	5	Exceed emission limits, possible shutdown	Opacity meter, CEMS	ESP inspection routine, duct sealing checks

CONCLUSION

The HAZOP study conducted on the kiln unit of PT Indocement Tunggal Prakarsa Tbk identified critical process deviations that could lead to significant operational and safety risks. These included raw meal feed interruptions, combustion irregularities, mechanical failures in kiln rotation, and cooling inefficiencies. Existing safety measures provide a fundamental level of protection; however, enhancements such as redundant instrumentation, improved maintenance routines, advanced control systems, and automatic response mechanisms are recommended. The implementation of these measures is expected to significantly enhance the operational safety and reliability of the kiln unit.

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