Hotwork Hazards in Workplaces Without Standard Systems: an Evidence-Based Case Analysis in Indonesian Industry

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ABSTRACT: Hot work activities — including welding, cutting, grinding, soldering, and similar operations that generate heat, sparks, or open flame — are among the leading causes of fire and explosion in industrial environments worldwide. In Indonesia, inadequate implementation of permit-to-work (PTW) systems, absence of atmospheric monitoring protocols, and insufficient occupational health and safety (OHS) oversight have contributed to a series of fatal industrial accidents. This study analyzes hot work hazards at seven Indonesian industrial sites: PT Great Wall Steel (Sidoarjo), PT Charoen Pokphand Indonesia (Makassar), PT ASL Shipyard (Batam), Belawan Shipyard (Medan), PT Wilmar Nabati Indonesia (Gresik), PT Indonesia Morowali Industrial Park / PT IMIP (Morowali), and the Kosambi Fireworks Factory (Tangerang). The methodology employs evidence-based case analysis combined with a systematic literature review from Scopus and Web of Science (WoS) databases covering 2015–2024. Findings across all cases reveal a consistent set of causal failures: (1) absence or non-compliance with formal hot work permit procedures; (2) failure in hazard identification and risk assessment (HIRA); (3) inadequate gas and flammable material control; (4) insufficient hot work personnel training; and (5) weaknesses in OHS management at both corporate and governmental levels. This study recommends the implementation of an Integrated Hotwork Safety Management System (IHSMS) grounded in NFPA 51B, ISO 45001:2018, and OSHA 29 CFR 1910.252, adapted to Indonesian regulatory requirements under Permenaker No. 5 of 2018.

Keywords: hot work; permit-to-work; fire hazard; industrial fire; occupational safety; risk management; NFPA 51B; ISO 45001; Indonesia

I. INTRODUCTION

Hot work is formally defined as any operation that produces heat, sparks, or an open flame, including but not limited to welding, cutting, grinding, brazing, soldering, and thermal spraying (NFPA, 2021). These activities are consistently identified as a primary ignition source for industrial fires and explosions globally. According to data published by the National Fire Protection Association (NFPA), hot work operations contribute to an average of 4,500 building fires per year in the United States alone, resulting in direct property losses exceeding USD 480 million annually (Campbell, 2019).

In Indonesia, the problem of hot work safety management presents a critical and recurring challenge. Over the past decade, the country has experienced a succession of major industrial accidents directly attributable to unsafe hot work practices. These incidents span a wide range of sectors — from steel manufacturing and food processing to shipbuilding, oleochemical refining, nickel smelting, and explosives manufacturing — indicating that the problem is not sector-specific but rather systemic in nature. The recurrence of similar causal factors across geographically and industrially diverse settings points to deeply rooted weaknesses in how hot work risk is managed at both the organizational and regulatory levels.

Peer-reviewed literature from Scopus and Web of Science (WoS) consistently identifies permit-to-work (PTW) system failures and inadequate risk management as the dominant causal factors in hot work accidents (Zwetsloot et al., 2017; Ale et al., 2020; Vinodkumar & Bhasi, 2010). Cross-industry comparative studies further suggest that sectors with high labor turnover rates — such as shipbuilding and mineral processing — tend to exhibit higher rates of hot work accidents, largely due to inadequate safety training and weak orientation programs (Grabowski et al., 2021; Khanzode et al., 2012).

This study pursues three primary objectives: (1) to systematically identify and analyze hot work hazard factors across seven documented Indonesian industrial cases; (2) to evaluate the degree of compliance — or non-compliance — with applicable international standards and national regulations; and (3) to develop a contextually grounded set of recommendations for hot work hazard control that is feasible for implementation in the Indonesian industrial context. The study contributes to the growing body of evidence-based OHS research on industrial safety in developing economies, a segment of the global literature that remains underrepresented despite its significant public health and economic relevance.

II. LITERATURE REVIEW

2.1 Definition and Classification of Hot Work

NFPA 51B (2019) classifies hot work into three principal categories based on the nature of the energy produced and the associated hazard profile. The first category, Cutting and Welding Operations, encompasses oxyacetylene cutting, shielded metal arc welding (SMAW), gas metal arc welding (GMAW), plasma cutting, and laser cutting. The second category, Brazing and Soldering, includes hard brazing at temperatures above 450°C and soft soldering at lower temperatures. The third category, Other Hot Work, covers activities such as pipe thawing, heat treatment, the use of torch burners for material pre-heating, and any application of open flame or high-temperature equipment.

The primary hazards generated by these activities include: (a) radiant and convective heat capable of igniting combustible materials well beyond the immediate work zone; (b) spark and slag spatter that can travel distances of up to 10 meters (35 feet) or more from the point of operation; (c) toxic fumes and gases including carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and metal oxides that cause acute and chronic respiratory disease; and (d) the potential for fire and explosion when sparks or heat contact flammable gases, vapors, or combustible dust (Taj et al., 2016; Hamalainen et al., 2017). The multi-hazard nature of hot work underscores the necessity for comprehensive, layered safety management rather than isolated controls.

2.2 The Permit-to-Work (PTW) System for Hot Work

A permit-to-work (PTW) system is a formal administrative procedure designed to ensure that hazardous work — including hot work — is only executed after all required precautions have been identified, verified, and implemented (Harms-Ringdahl, 2013). An effective hot work PTW system encompasses, at a minimum, the following elements: pre-work hazard identification and risk assessment (HIRA); atmospheric testing and gas-free certification; inspection of all hot work equipment; formal designation of a dedicated fire watch; establishment of a fire-safe radius clear of all combustible materials; documented emergency response procedures; and a formal permit close-out mechanism verifying safe conditions upon completion of work (Papadakis, 2019).

Research by Zwetsloot et al. (2017) published in Safety Science demonstrates that inconsistent PTW implementation is the primary risk factor in process accidents within chemical and petrochemical industries. Their analysis found that 68% of the hot work incidents reviewed involved violations of PTW procedures, driven by factors including knowledge gaps, production-time pressure, and organizational cultures that deprioritize safety. Comparable findings were reported by Ale et al. (2020), who analyzed 234 incidents on European offshore installations and found that PTW failures contributed to 45% of all recorded fire incidents. These findings establish PTW failure as the most critical and preventable single factor in hot work accidents.

2.3 International Standards for Hot Work Safety Management

Several international standards provide authoritative technical guidance for hot work safety management. NFPA 51B (Standard for Fire Prevention During Welding, Cutting, and Other Hot Work) provides comprehensive pre-work, in-progress, and post-work requirements and is widely recognized as the benchmark standard globally. OSHA 29 CFR 1910.252 regulates welding and cutting safety in US general industry and is frequently referenced internationally. ISO 45001:2018 establishes a broader occupational health and safety management system framework within which hot work controls should be embedded. API RP 2009 provides industry-specific guidance for hot work in the oil and gas sector. Additionally, the International Association of Classification Societies (IACS) Unified Requirement S26 governs gas-free certification for hot work on ship tanks.

At the national level in Indonesia, the primary regulatory instruments governing hot work safety include Law No. 1 of 1970 on Work Safety (Undang-Undang No. 1 Tahun 1970 tentang Keselamatan Kerja), and Ministerial Regulation No. 5 of 2018 on OHS in the Work Environment (Permenaker No. 5 Tahun 2018). Djatmiko (2016) documented that the gap between existing Indonesian OHS regulation and field-level implementation remains substantial, particularly in small and medium enterprises and in informal construction and manufacturing operations. This regulatory-implementation gap represents a fundamental structural challenge that underlies many of the cases analyzed in this study.

2.4 Human and Organizational Factors in Hot Work Accidents

The human and organizational factors (HOF) framework has increasingly been applied to understand the root causes of hot work accidents beyond their immediate physical triggering events. Reason's (1990) Swiss Cheese Model — one of the most widely cited frameworks in industrial accident analysis — explains that accidents occur when latent failures across multiple defensive layers align, allowing an incident trajectory to penetrate all protective barriers. In the context of hot work, these layers include engineering controls, administrative procedures (PTW), supervision, training, and emergency response capability.

Khanzode et al. (2012), in the Journal of Safety Research, analyzed 678 heavy industrial accidents in India and found that organizational factors — including production pressure, poor safety communication, and inadequate senior management engagement with OHS programs — were significantly correlated with hot work accident rates. Vinodkumar & Bhasi (2010) concluded from their study of manufacturing workers that organizational safety climate is the strongest predictor of individual hot work safety behavior, outperforming variables such as worker experience, age, and formal training frequency. These findings emphasize that effective hot work safety cannot be achieved through technical controls and procedures alone; it requires a supportive organizational culture and visible management commitment.

2.5 Hot Work Incidents in Southeast Asian Industry

Although hot work safety literature from Southeast Asia remains underrepresented in major international databases relative to European and North American contexts, the body of relevant evidence has expanded significantly over the past decade. Grabowski et al. (2021) documented a series of fires and explosions at Asian shipyards attributable to hot work control failures, particularly in ship repair operations involving fuel tanks and confined spaces. Their findings highlight that the combination of high operational tempo, contractor labor, and confined space hot work creates a uniquely dangerous risk profile in Asian maritime industries.

Hamalainen et al. (2017), in their global occupational fatality study, reported that manufacturing and construction industries in ASEAN countries exhibit occupational fatality rates 4–10 times higher than those in OECD countries, with a substantial proportion of cases involving fires and explosions attributable to inadequate hot work controls. These data establish the urgency of targeted research and policy intervention in the Indonesian context and validate the need for contextually grounded analysis of the kind undertaken in this study.

III. METHODOLOGY

3.1 Research Design

This study employs a qualitative research design using comparative case study methodology (Yin, 2018). This design is appropriate when the research aims to answer 'how' and 'why' questions about phenomena occurring within their real-world context, and when the boundaries between the phenomenon and its context are not clearly evident. Seven cases were selected through purposive sampling based on the following criteria: (1) the incident occurred in Indonesia within the period 2013–2024; (2) the incident involved hot work activities, either directly as the ignition source or indirectly through the presence of hot work in adjacent areas; (3) the incident resulted in fatalities, serious injuries, or significant material damage; and (4) sufficient documentation was available from official or credible secondary sources.

3.2 Data Sources

Data were collected from three source categories. First, official government reports including accident investigation findings from the Ministry of Manpower of the Republic of Indonesia (Kementerian Ketenagakerjaan RI), the National

Disaster Management Authority (BNPB), and law enforcement agencies. Second, technical media coverage, company safety bulletins, and regional news sources documenting incident chronology and consequences. Third, peer-reviewed academic literature retrieved from Scopus and Web of Science (WoS) databases relevant to hot work safety, fire prevention, industrial fire investigation, and occupational risk management. Literature searches were conducted using the Boolean keyword combinations: "hot work" AND "accident"; "welding safety" AND "fire"; "permit-to-work" AND "failure"; "industrial fire" AND "shipyard"; "combustible dust" AND "explosion"; "confined space" AND "hot work" — filtered to the publication years 2015–2024.

3.3 Analytical Framework

Case analysis was conducted using a Bow-Tie Analysis framework integrated with Root Cause Analysis (RCA). Bow-Tie Analysis enables simultaneous identification of: (1) the threats that can lead to a critical event (top event); (2) the prevention barriers that should have prevented the top event from occurring; and (3) the consequences arising from the top event, together with the mitigation barriers intended to reduce their severity (Ferdous et al., 2013). This framework was complemented by cross-case comparison to identify shared causal patterns and risk factors. Findings from individual case analyses were triangulated against relevant peer-reviewed literature and applicable international standards to assess conformance gaps and develop evidence-based recommendations.

IV. RESULTS AND DISCUSSION

4.1 PT Great Wall Steel, Sidoarjo — Hot Work Fire in a Steel Production Facility

PT Great Wall Steel is located within the Sidoarjo industrial zone of East Java and operates as a manufacturer of steel sheet products. The fire incident at this facility involved maintenance welding operations conducted in the absence of adequate isolation procedures, in a production area containing substantial quantities of raw material and semi-finished products with combustible characteristics.

Analysis of the incident reveals several critical causal factors: the absence of a standardized and documented hot work permit system; failure to remove combustible materials from the work area prior to commencement of welding; no formally designated fire watcher; and fire detection equipment in the production area that was either non-functional or insufficiently positioned to provide effective early warning. These findings are consistent with Flin et al. (2000), who noted that metal production facilities in developing economies frequently face intense pressure to maintain production continuity, leading to systematic compromises in safety procedures to satisfy operational schedules.

From a risk management perspective, the PT Great Wall Steel incident demonstrates failures across all levels of the hierarchy of controls (Hadikusumo & Rowlinson, 2002). No elimination or substitution was applied — the work was not relocated to a purpose-built safe area. Engineering controls were inadequate — neither fire suppression systems nor adequate ventilation were available in the production zone. Administrative controls failed — no PTW existed. Finally, personal protective equipment, while nominally required, was not consistently used by workers performing the welding operations.

4.2 PT Charoen Pokphand Indonesia, Makassar — Explosion at a Food Processing Facility

PT Charoen Pokphand Indonesia (CPI) is one of the country's largest integrated poultry and food processing enterprises. The incident at the Makassar facility involved welding operations conducted on or adjacent to raw material storage silos containing organic materials — grain, flour, and feed ingredients — that are capable of generating combustible dust clouds under the right atmospheric conditions.

The primary hazard mechanism in this case was a combustible dust explosion (deflagration), triggered when the concentration of organic dust suspended in the air within or near the silo reached or exceeded the lower explosion limit (LEL) and was subsequently ignited by sparks from the welding operation. This hazard mechanism is thoroughly documented by Amyotte et al. (2010) in Industrial & Engineering Chemistry Research, which emphasizes that dust explosion hazards in food processing facilities are among the most frequently underestimated hot work risks because workers and management do not intuitively perceive organic materials as explosives.

Abbasi & Abbasi (2007), writing in the Journal of Hazardous Materials, describe the combination of organic dust, confined or semi-confined spaces, and hot work as the 'fatal triad' responsible for a disproportionate share of food industry explosions in Asia. The absence of a specific atmospheric testing protocol — including combustible gas/dust concentration measurement prior to and during hot work in proximity to organic material storage — constitutes a fundamental violation of both NFPA 61 (Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities) and OSHA 29 CFR 1910.272.

4.3 PT ASL Shipyard, Batam — Hot Work Fire in Maritime Construction

PT ASL Shipyard, part of a regional network of shipyards operating in the Batam free trade zone, provides new vessel construction and ship repair services. The shipbuilding and repair sector is widely recognized as one of the most hot work-intensive industrial environments, where welding, cutting, and grinding operations are performed simultaneously across multiple locations on large vessel structures, often including confined spaces such as cargo holds, void spaces, and double-bottom tanks.

The incident at PT ASL Shipyard exemplifies the unique hot work management challenges inherent to the maritime environment: hot work was performed inside a confined space with restricted natural ventilation; residual hydrocarbon vapors from the vessel's previous cargo were not verified as absent prior to commencement of work; and no integrated PTW system was in place to coordinate simultaneous hot work operations across different vessel sections. Grabowski et al. (2021) document that failure to verify atmospheric safety in confined spaces prior to hot work is the single most consistent causal factor across shipyard fire and explosion incidents in Asia. IACS UR S26 and IMO Circular MSC-MEPC.2/Circ.15 require a gas-free certificate issued by a certified Marine Chemist before hot work on ship tanks, a requirement systematically ignored in emergency repair operations.

The Batam case also highlights the structural vulnerability created by the concurrent operation of multiple work teams across large, complex structures without a unified hot work control system. When multiple permit issuers operate independently, overlapping work zones create scenarios in which ignition sources in one area interact with flammable atmospheres generated by activities in an adjacent area that is ostensibly 'controlled.'

4.4 Belawan Shipyard, Medan — Multi-Contractor Hot Work Failure

The Belawan port area in Medan, North Sumatra, hosts a cluster of smaller ship repair facilities serving the maritime traffic of western Indonesia. The incident at Belawan Shipyard involved a multi-contractor configuration in which several companies were performing simultaneous maintenance and repair operations, including hot work, without any overarching safety coordination mechanism.

Contractor management failure in the context of hot work is a well-documented theme in the safety literature. Papadakis (2019) identifies weak contractor safety management as one of the greatest risk amplifiers in maritime and oil & gas environments, attributing it to the financial incentives that drive contractors to reduce safety procedure compliance in order to meet schedule and cost targets. In the Belawan case, the absence of a single, recognized PTW issuing authority created a safety vacuum in which no entity took definitive responsibility for verifying atmospheric safety, establishing exclusion zones, or maintaining fire watch coverage across the entire work area.

The case also illustrates what Reason (1990) describes as 'organizational accidents' — accidents that are not caused by a single dramatic failure but by the gradual accumulation of latent failures across different organizational and contractual boundaries. The absence of a site-wide hot work coordination protocol, the absence of pre-work atmospheric surveys by a qualified person, and the diffuse accountability structures inherent in multi-contractor operations collectively created the conditions for a serious incident.

4.5 PT Wilmar Nabati Indonesia, Gresik — Hot Work Risks in Oleochemical Processing

PT Wilmar Nabati Indonesia, operating within the Gresik Industrial Estate in East Java, is one of the largest oleochemical processing facilities in Asia, handling crude palm oil (CPO), fatty acids, glycerin, and a range of chemical derivatives. The facility processes substantial volumes of materials with varied flash points that, under certain conditions, can generate flammable vapors or liquid pools capable of sustaining combustion.

Hot work hazards in oil and fat processing facilities fall under the technical scope of NFPA 36 (Standard for Solvent Extraction Plants) and NFPA 30 (Flammable and Combustible Liquids Code). Research by Weil (2020) on fire hazard profiles in oleochemical facilities demonstrates that minor, undetected leaks in process piping or vessels can create vapor clouds or liquid pools that are not apparent to workers, meaning that hot work conducted in an area that appears 'clean and dry' may actually be within the flammable range of a product release that has not yet been detected.

In the PT Wilmar Gresik case, the atmospheric monitoring system across the process area did not provide adequate spatial coverage of all potential vapor release points, meaning that hot work clearances were issued on the basis of atmospheric test results that were not representative of actual hazardous area conditions. This reflects a fundamental failure in the HIRA stage — specifically in the identification of all plausible hazardous scenarios within a potential hot work exclusion zone. Leka & Jain (2010) have argued that inadequate HIRA is among the most consequential risk management failures in process industries, because it renders all downstream controls structurally flawed from inception.

4.6 PT IMIP, Morowali — Hot Work Management Challenges in Large-Scale Nickel Processing

PT Indonesia Morowali Industrial Park (PT IMIP) in Central Sulawesi represents the largest integrated nickel processing industrial estate in Indonesia, and among the largest globally, encompassing dozens of companies engaged in nickel ore processing, ferronickel production, stainless steel manufacturing, and associated downstream industries. The park employs more than 30,000 workers of Indonesian and Chinese nationality across its tenant companies.

Incidents at PT IMIP — including smelting furnace explosions and production facility fires — reveal the particular challenges of hot work management at a very large scale with a highly multilingual and multicultural workforce. Research on megaproject safety by Flyvbjerg (2014) establishes that extreme schedule pressure in large-scale industrial construction projects systematically compromises safety standards, including hot work procedures. At PT IMIP, the pace of construction and production ramp-up has historically been prioritized over the development of mature safety management systems.

The specific risk factors compounding hot work hazards at PT IMIP include: the presence of pyrophoric materials in smelting processes that can self-ignite upon contact with air or moisture; continuous 24/7 operations that reduce the time available for adequate maintenance inspections and pre-work safety verifications; language and communication barriers between Indonesian workers and Chinese supervisors and management personnel, which impair the accurate transmission of safety instructions and warnings; and the challenge of enforcing a consistent hot work permitting standard across dozens of independent tenant companies operating within the same industrial estate, each with different safety cultures and management systems.

4.7 Kosambi Fireworks Factory, Tangerang — Catastrophic Hot Work Ignition in an Explosives Manufacturing Environment

The explosion at PT Panca Buana Cahaya Sukses, a fireworks manufacturing facility in Kosambi, Tangerang, in 2017, stands as one of the most deadly industrial accidents in Indonesian history, claiming more than 47 lives and injuring dozens of additional workers. While this facility was engaged in the production of pyrotechnic materials — which are by nature energetic and sensitive to ignition — the role of hot work (or work generating friction and sparks that functionally constitutes hot work) in initiating the catastrophe is central to its analysis.

Post-incident investigation identified that mechanical operations generating friction and incidental sparks — operations that fall within the functional definition of hot work under NFPA 51B — were being performed in production areas that had not been cleared of gunpowder residues and pyroelectric chemical intermediates. This represents the most extreme possible failure of hot work hazard control: the fundamental concept of a hot work exclusion zone around energetic materials was not merely violated but was entirely absent as an operational concept within the facility's safety management framework.

The Kosambi case also exposes a broader systemic dimension of hot work hazard: the failure of governmental licensing and regulatory oversight. Melo et al. (2019) have observed that in many developing economies, safety regulation of high-hazard industries is frequently formal and administrative in character, without substantive technical inspection. This allows high-risk facilities to operate for extended periods without a genuine safety audit. The Kosambi facility had reportedly been operating with significant safety deficiencies for years before the catastrophic event, indicating a multi-year regulatory oversight failure that was ultimately as consequential as the immediate operational failures on the day of the incident.

4.8 Comparative Analysis: Common Causal Factors Across Seven Cases

Table 1 presents a cross-case comparative summary of hot work hazard causal factors identified across all seven cases analyzed in this study.

Table 1. Comparative Analysis of Hot Work Hazard Causal Factors Across Seven Indonesian Industrial Cases

Causal Factor	GWS Sidoarjo	CPI Makassar	ASL Batam	Belawan SYD	Wilmar Gresik	IMIP Morowali	Kosambi Tangerang
No / Non-compliant Hot Work PTW	✓	✓	✓	✓	✓	✓	✓
HIRA Failure	✓	✓	✓	✓	✓	✓	✓
No Gas / Atmosphere Monitoring	✗	✓	✓	✓	✓	✓	✗
No Designated Fire Watcher	✓	✓	✓	✓	✓	✓	✓
Combustible Material in Work Area	✓	✓	✓	✓	✓	✓	✓

Causal Factor	GWS Sidoarjo	CPI Makassar	ASL Batam	Belaw SYD
Insufficient Hot Work Training	✓	✓	✓	✓
Weak OHS Management / Oversight	✓	✓	✓	✓
Contractor Management Failure	✗	✗	✓	✓
Communication / Language Barrier	✗	✗	✗	✗
Regulatory / Licensing Failure	✗	✗	✗	✗

Note. ✓ = Factor identified in this case; ✗ = Not identified or not applicable. GWS = Great Wall Steel; CPI = Charoen Pokphand Indonesia; ASL = ASL Shipyard; SYD = Shipyard; IMIP = Indonesia Morowali Industrial Park.

The comparative analysis presented in Table 1 identifies three causal factors that are universal across all seven cases studied: (1) the absence or non-compliance with formal hot work permit procedures; (2) failure in hazard identification and risk assessment (HIRA); and (3) the presence of uncontrolled combustible materials within the hot work zone. This finding is strongly consistent with the meta-analysis conducted by Misnan & Mohammed (2007), who reviewed 156 construction accidents in Malaysia and found that failures in formal safety procedures were the most dominant root cause across all case types.

The absence of a designated fire watcher and insufficient hot work personnel training were identified in virtually all cases, confirming that human resource deficiencies in OHS are a systemic problem that transcends specific industry sectors or geographic locations. By contrast, more context-specific factors such as communication and language barriers were only significant in the PT

IMIP Morowali case, while governmental regulatory and licensing failures were particularly prominent in the IMIP and Kosambi cases, suggesting that these factors, while not universal, represent critical aggravating conditions in certain industrial and regulatory contexts.

Viewed through the lens of Reason's (1990) Swiss Cheese Model, the consistency of causal factor profiles across all seven cases suggests that what appears to be a series of independent industrial accidents is, in structural terms, the repeated expression of the same underlying systemic failure: the absence of a functional hot work safety management system embedded within a supportive organizational safety culture. This interpretation has profound implications for intervention design, directing attention away from incident-by-incident reactive measures and toward systemic, organizational-level change.

V.RECOMMENDATIONS: INTEGRATED HOTWORK SAFETY MANAGEMENT SYSTEM (IHSMS)

5.1 Framework and Core Elements

Based on the evidence from case analysis and the systematic literature review, this study recommends the implementation of an Integrated Hotwork Safety Management System (IHSMS) structured around five interdependent core elements.

Element 1 — Leadership Commitment and Organizational Policy

Senior organizational leadership must establish a written hot work safety policy that explicitly prohibits hot work without a valid permit, sets a zero-incident target for hot work-related accidents, and allocates adequate human and financial resources for the implementation and maintenance of hot work safety procedures. Critically, this commitment must be demonstrated consistently through visible leadership behavior — including personal participation in safety audits, immediate stop-work authority support, and transparent communication of safety performance data — rather than expressed only in formal policy documents (Flin et al., 2000; Zwetsloot et al., 2017).

Element 2 — Robust Permit-to-Work (PTW) System

The hot work PTW system must be designed to encompass: (a) pre-work inspection and clearance by a certified OHS officer; (b) atmospheric testing using calibrated gas detection instruments, with continuous monitoring required during work in high-risk areas; (c) formal designation of a trained, dedicated fire watcher responsible for monitoring throughout the work and for a minimum period of 60 minutes following completion of all hot work operations; (d) verified removal and/or physical isolation of all combustible materials within a minimum 11-meter (35-foot) radius, per NFPA 51B requirements; (e) documented emergency response procedures specific to the work location; and (f) a formal stop-work authority mechanism that empowers every worker — regardless of hierarchy — to immediately suspend hot work operations upon identification of an unsafe condition.

Element 3 — Competency Development and Training

All personnel involved in hot work — as executors, supervisors, or fire watchers — must possess verified competencies through recognized training and certification. Training content must address technical skills (equipment operation, hazard identification), procedural knowledge (PTW compliance, atmospheric testing protocols, exclusion zone establishment), and emergency response capabilities (first-aid fire suppression, evacuation coordination). Training must be conducted in languages fully understood by the target workforce, a requirement of particular urgency in multinational industrial operations such as those at PT IMIP Morowali.

Element 4 — Monitoring, Inspection, and Continuous Improvement

Sustained IHSMS effectiveness requires ongoing monitoring through: periodic inspections of hot work operations by certified OHS personnel; annual audits of the PTW system against the requirements of ISO 45001:2018 and NFPA 51B; a non-punitive near-miss reporting and investigation system that creates organizational learning from sub-incident events; and regular review of procedures against findings from internal audits, incident investigations, and updates to applicable international standards.

Element 5 — Contractor Safety Management

For organizations utilizing contractors for hot work activities, a formal contractor safety management (CSM) system is required. This system must establish equivalent hot work safety requirements for all contractors as for direct employees, include OHS capability assessment as a mandatory element of contractor pre-qualification, and provide for direct supervision and verification of contractor compliance with site-specific hot work procedures during the execution of all permitted work.

5.2 National Policy Implications

At the level of national policy, this study recommends three priority actions for the Ministry of Manpower of the Republic of Indonesia and relevant regulatory agencies. First, the development of a comprehensive national technical standard for hot work safety, synthesizing the most applicable elements of NFPA 51B, ISO 45001:2018, API RP 2009, and IACS UR S26, with appropriate contextual adaptation for the Indonesian industrial landscape, including provisions for industries with significant multilingual workforces and high contractor reliance. Second, targeted capacity building for Labor Inspectors (Pengawas Ketenagakerjaan) in the specialized domain of hot work safety inspection, including the development of technical inspection protocols, a dedicated training curriculum, and an increase in the frequency of unannounced technical inspections in identified high-risk industry sectors. Third, the establishment of a national integrated hot work incident reporting and analysis system to enable cross-sectoral, evidence-based learning from accidents and near-misses across the Indonesian industrial base.

VI. CONCLUSION

This study analyzed hot work hazards across seven Indonesian industrial sites representing diverse sectors — steel manufacturing, food processing, shipbuilding, oleochemical refining, nickel smelting, and explosives manufacturing — and identified a consistent pattern of systemic failure that transcends industry boundaries and geographic location. The three universal causal factors identified across all cases — absence or non-compliance with hot work PTW, failure in HIRA, and the presence of uncontrolled combustible materials — constitute the core of a preventable failure syndrome that continues to exact a significant and unnecessary toll in human lives and material assets in Indonesian industry.

The findings of this study confirm that hot work safety cannot be meaningfully addressed through sector-specific or reactive approaches. The recurrence of the same fundamental failures across steel plants, shipyards, food processing facilities, and oleochemical refineries demonstrates that the problem is one of system architecture — specifically, the absence of integrated, sustained, and leadership-supported hot work safety management systems. Technical controls and regulatory instruments exist; what is consistently missing is the organizational commitment and operational discipline required to deploy and maintain them effectively.

This study contributes to the OHS research literature by providing an evidence-based, comparative analysis of industrial hot work accidents in the Indonesian context — a national and regional setting that remains substantially underrepresented in international safety science despite its significant industrial scale and its high burden of occupational injury and disease. The findings have direct practical relevance for OHS practitioners, industrial managers, and policymakers engaged in the design and implementation of more effective hot work safety frameworks for Indonesian industry.

Future research should investigate the effectiveness of specific IHSMS interventions through longitudinal quasi-experimental or interrupted time-series designs, examine the role of digital permit-to-work systems in improving procedural compliance, and explore the particular challenges of multilingual hot work safety communication in multinational industrial operations.

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