



# Excellence in Fire Safety: Strategies and Innovations for Secure and Sustainable Papermaking Operations



**Durgesh Mishra**  
 Chief Manager  
 – Safety & Environment



**Ravi Prasad**  
 Assistant Manager  
 – Safety



**Dhimant Vijaybhai Vijapara**  
 Sr. Executive  
 – Security & Fire Fighting  
 JK Paper Ltd., Unit- CPM

**Abstract:**

The pulp and paper industry operates under a severe risk profile, demanding fire safety to be a strategic pillar for operational continuity, environmental stewardship, and workforce protection. At JK Paper Ltd., Unit CPM, the management system has evolved to a quantitative, predictive, and technology-driven model, certified under ISO 9001, ISO 14001, ISO 45001, and ISO 14064, alongside FSC accreditation [1].

As demonstrated in fig:1, the core mitigation strategy is rooted in a layered approach for achieving excellence in fire safety: Hazard Identification and Risk Assessment (HIRA), meticulous Fire Load Calculations [2], and the sophisticated Quantitative Risk Assessment (QRA). This QRA models hazards from high-energy utilities and fuels, including Coal, Liquefied Natural Gas (LNG), Propane, Liquid Oxygen, and Liquid CO<sub>2</sub>. Crucially, this technical excellence is reinforced by a robust Apex Safety Structure and a proactive Behavioural Safety Framework, featuring Safety Stewards, Daily Safety Talks, Toolbox Talks, and a Quick Win program. An Online Safety Portal centralizes observation and compliance. By integrating engineering, culture, and sustainability, Unit CPM maintains an exemplary record of zero major fire incidents transforming fire safety into a core, measurable business value “Beyond the Flames.”

**Keywords:** Fire Safety, HIRA, IMS, Environmental Sustainability, Apex Safety Structure & Behavioural Safety.



Fig. 1: Achieving excellence in fire safety

**1. Introduction: The High-Risk Context and Strategic Imperative:**

The pulp and paper manufacturing process presents an elevated, inherent fire risk due to the combination of combustible materials (wood chips, pulp, finished paper), high-temperature operations (drying sections), and complex utilities (Coal, Wood Dust and flammable gases). Fire safety is non-negotiable for Unit CPM, recognizing that a major incident exposes not only human life and property but also environmental integrity and market reputation.

The unit's approach is defined by its compliance with global best practices, evidenced by its compliance with BIS[3] and NFPA standards and its Integrated Management System (IMS) certifications. This paper details the systematic approach, from foundational risk identification to the implementation of state-of-the-art mitigation technologies, with a dual focus on managing high-hazard utility infrastructure and fostering a resilient organizational safety culture.

**2. Foundational Safety Management: HIRA, Fire Load, and QRA:**

The effectiveness of any fire safety program begins with a meticulous understanding of the risks involved. Unit CPM utilizes a progressive, three-tiered risk assessment hierarchy [4]:

**2.1 Hazard Identification and Risk Assessment (HIRA) and Fire Load Calculations:**

HIRA provides the bedrock, systematically identifying critical zones (e.g., raw material storage, electrical substations) and evaluating the probability and severity of hazards. This is complemented by Fire Load Calculations, which quantify the total thermal energy potential of combustible materials per unit area. This calculation dictates:

- ◆ Suppression system sizing: Ensuring the installed automatic systems are correctly sized for maximum potential fire.
- ◆ Structural fire resistance: Guiding engineering requirements for fire-rated walls and segregation.

**2.2 The Shift to Quantitative Risk Assessment (QRA):**

Unit CPM is conducting a comprehensive Quantitative Risk Assessment (QRA) to provide a sophisticated, probabilistic estimate of low-probability, high-consequence events, especially in the utilities block. The QRA process specifically focuses on:

- ◆ Scenario modelling: Using computational fluid dynamics (CFD) to simulate the consequences of Vapor Cloud Explosions (VCE), Pool Fires, and Jet Fires in the highly energetic fuel sections (LNG/Propane).
- ◆ Risk contours: Generating risk contour maps that depict the Individual Risk Per Annum (IRPA) and Societal Risk (F-N curves) around the facility, guiding land use planning and dictating buffer distances for critical infrastructure like control rooms and administrative buildings.
- ◆ Safety integrity level (SIL) determination: Using QRA results to determine the required integrity level for safety-critical systems, ensuring the reliability of automated emergency shutdown (ESD) systems and process interlocks.

**3. Apex Safety Structure and Cultural Framework:**

Beyond technical systems, a strong organizational structure and an engaged safety culture are paramount for sustaining excellence, moving safety Beyond the Flames and into daily operations.

**3.1 Apex Safety Structure:**

As demonstrated in fig. 2, the detailed structure & cultural framework safety governance is formalized through an Apex Safety Structure, ensuring ownership and accountability from the top down:

- ◆ Unit safety committees: Headed by senior management (Unit Head and relevant Functional Heads), these committees meet regularly to review safety performance, audit findings, QRA results, and allocate resources for major fire safety projects.
- ◆ Apex safety team: A cross-functional team of department heads, engineering specialists, and the safety department, responsible for strategy execution, adherence to IMS, and driving compliance.

**3.2 Behavioural Safety Interventions:**

The program moves safety beyond compliance into daily consciousness through active engagement:

- ◆ Safety stewards in each section: A system where trained frontline employees, designated as Safety Stewards, are nominated for a fixed tenure in every major operational section (e.g., Pulp Mill, Utility Block, Process, Maintenance). These stewards act as the eyes and ears of the safety department, conducting informal inspections, coaching colleagues, and leading Toolbox Talks.
- ◆ Daily safety talk: Before the start of every shift, supervisors conduct a mandatory, brief Daily Safety Talk focusing on the critical risks of the day's tasks, seasonal hazards, or recent near misses.
- ◆ Toolbox talks (TBT): These are focused, on-the-job micro-training sessions held immediately before non-routine or high-risk tasks (e.g., Hot Work, Confined Space Entry). TBTs use specific job hazards as a teaching tool, reinforcing the link between procedures and protection.
- ◆ Quick win for every month: An organizational initiative to identify and rectify minor, low-cost safety deficiencies (e.g., damaged guards, missing signage) within a calendar month. The program encourages observation filing through the safety portal and rewards the section with the highest rate of problem identification and closure, driving a culture of continuous minor improvements.



Fig. 2: Apex safety structure and cultural framework

### 3.3 Online Safety Portal for Safety Observations:

A centralized, online safety portal is implemented to foster a proactive reporting culture:

- ♦ **Easy filing:** Employees can quickly and anonymously file safety observations, near-misses, and unsafe conditions via a mobile-accessible platform.
- ♦ **Tracking and closure:** The portal automatically assigns a unique identifier and routes the observation to the relevant department head for action and closure.
- ♦ **Data analytics:** The collected data provides leading indicators for the Apex Safety Structure, enabling trend analysis (e.g., highest observed unsafe act/condition, department with most observations) to proactively target future training and interventions before a major incident occurs.

### 4. Specialized Fuel and Chemical Fire Safety:

The QRA specifically informs the safety measures for the plant’s high-hazard utility systems:

As per the QRA study mitigation & control measures are presented below in table: 1 [4]

Table 1: QRA study mitigation and control measures

Fuel Source	Primary Hazard	Mitigation and Control Measures
Coal	Spontaneous Combustion, Dust Explosion	Continuous Water Sprinkling on stockyards; Routine Infrared Monitoring; Stock rotation/height control.
LNG/Propane	Vapor Cloud Explosion (VCE), Jet Fire	QRA-determined blast walls; Dense network of Flammable Gas Detectors (FGDs); Automated Emergency Shutdown (ESD) systems to isolate fuel supply; High-capacity Dry Chemical Powder (DCP) systems.
Liquid Oxygen (LOX)	Powerful Oxidizer, Material Contamination	Strict segregation from all combustibles; Dedicated concrete platforms; Cryogenic material handling SOPs.
Liquid CO <sub>2</sub> (LCO <sub>2</sub> ) / Chemicals	Asphyxiation, Exothermic reaction, Water contamination	Dedicated pressure relief valve maintenance; Fire-rated cabinets for chemical storage; Containment dykes for run-off; MSDS protocols.



Fig. 3: Comprehensive fire safety strategy

### 5. Integrated Fire Prevention and Engineering Controls:

As demonstrated in fig. 3, the primary strategy remains prevention, executed through meticulous engineering and procedural discipline:

- ♦ **Housekeeping and dust management:** Implementation of daily cleaning schedules in all critical zones and installation of dust extraction and suppression systems at points of maximum dust generation. [4]
- ♦ **Machinery and process safety:** Routine use of thermal imaging and dedicated temperature and vibration sensors on major rotating equipment (e.g., paper machine rollers, pulpers) with real-time alerts. [4]

- ◆ **Electrical safety:** Annual third-party audits of the entire electrical infrastructure; use of CO<sub>2</sub> flooding systems or clean-agent suppression in all critical electrical control rooms and MCC panels.
- ◆ **Advanced suppression:** The system includes automatic water sprinklers, specialized foam-based suppression for chemical/fuel areas, and a redundant fire water network maintained by high-capacity diesel-driven fire pumps.

#### 6. Fire Safety as a Pillar of Environmental Sustainability:

Fire safety is intrinsically linked to environmental management, a commitment formalized by the company's ISO 14001 and ISO 14064 certifications.

- ◆ **Run-off containment:** The Emergency Response Plan (ERP) includes procedures for isolating drains and containing contaminated water and foam run-off to prevent the contamination of natural water bodies.
- ◆ **Emission-conscious drills:** Mock drills are conducted to be emission-conscious, with training emphasizing optimal extinguisher use to minimize the unnecessary discharge of chemical agents, directly supporting the unit's GHG reduction goals and ISO 14064 compliance.
- ◆ **Compliance:** The unit's FSC certification [5] mandates sustainable and responsible sourcing, which is directly linked to fire safety by ensuring materials are handled and stored according to strict, sustainable operational protocols.

#### 7. Emergency Preparedness and Results:

A robust safety culture, underpinned by well-defined procedures and continuous training, is the ultimate line of defence.

- ◆ **Trained teams:** A specialized, round-the-clock shift-wise trained fire team is maintained, supported by a fully equipped on-site fire tender and a dedicated Ambulance.
- ◆ **Training and drills:** Mandatory fire safety training for all personnel is reinforced by a minimum of three comprehensive mock drills per year to ensure coordinated deployment.
- ◆ **Incident record:** A consistent record of zero major fire incidents in the last operational year.

The future vision is focused on AI-driven detection systems and predictive risk analytics, leveraging data from the online safety portal to move beyond corrective action and establish a truly predictive safety environment, reinforcing the unit's commitment to sustainable and resilient operations.

#### 8. Conclusion:

The study highlights that JK Paper Ltd., Unit CPM has achieved excellence in fire safety through a well-structured, multi-layered management approach integrating engineering control, risk-based assessment, and strong safety culture. The implementation of HIRA, Fire Load Calculations, and Quantitative Risk Assessment (QRA) has enabled precise identification, evaluation, and control of high-risk areas, especially involving fuels like LNG, Propane, and Coal. The Apex Safety Structure ensures top-down accountability, while programs like Safety Stewards, Daily Safety Talks, Saturday Safety Talks, and the Online Safety Portal effectively translate safety awareness into daily operational behaviour.

Key practices such as advanced suppression systems, continuous housekeeping and dust management, real-time equipment monitoring, and emission-conscious mock drills reinforce both fire prevention and environmental stewardship under ISO 14001 and ISO 14064 frameworks. The unit's zero major fire incident record exemplifies how technology, human engagement, and sustainability can converge to create a predictive and resilient fire safety ecosystem — a model truly reflecting the spirit of going "Beyond the Flames."

#### References:

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