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TNPL's approach to Sustainable Fire Safety & Fire Prevention Practices in Resilient Paper Making Operations

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Abstract:

In current scenario the Paper industries across the globe facing numerous challenges like Environmental issues, structural demographic changes and resource scarcity. Also, Paper industry faces heightened risks of fire hazards due to the extensive use of combustible raw materials, high-energy processes, and continuous production environments. Ensuring robust fire safety measures is therefore vital for protecting employees, safeguarding assets, and promoting operational sustainability. This article describes how TNPL approached these challenges &show cases case studies on comprehensive fire safety strategies tailored for papermaking operations, highlighting the integration of modern tools, advanced detection and suppression systems. Emphasis is laid on the role of new technologies such as smart sensors, automated monitoring platforms, and eco-friendly fire-retardant materials that enhance fire safety, environmental responsibility& avoiding financial losses. Additionally, this article illustrates successful fire prevention and mitigation efforts & discuses on how to encourage a culture of proactive fire safety, where innovation aligns with sustainable manufacturing goals, ensuring resilience and long-term security in papermaking operations

Keywords: *Eco friendly Fire Retardants, Fire prevention & Fire Suppression Systems*

1. Introduction

Fire accidents remain the most appalling human tragedy of modern industry and a serious form of economic waste. A Fire accident is a phenomenon of diverse and multiple etiologies. A Fire accident often is the result of an occurrence, or series of occurrences, chronologically remote from the accident itself. In current scenario industrial fire accidents are responsible for the loss of four or five times as many working days as industrial disputes. The economic burden on the community cannot be expressed in compensation cost alone. It also includes loss of production, disruption of production schedules; damage to productive equipment and in case of large fire accidents, major social dislocation. Fire Safety has been described as everyone's responsibility. As a generalization this is true. It is grossly misleading, however, because most functions in modern society are fulfilled through an organizational hierarchy [1]. Today many paper industries state that their first three concerns are safety, quality, and production respectively. In Paper Industry there are many items which are combustible in nature – starting from Bamboo, Wood chips, Saw dust & Bagasse to the end product Paper. Among that we focused on the area which is highly combustible in nature & which created more economical loss to any organization like Production & storage of products and production & distribution of power through transformers & cables.

2. Fire Safety Strategies for Transformers in TNPL

Transformers are critical components in electrical power systems — used for voltage transformation and power distribution. However, they contain large volumes of flammable insulating oil and operate at high voltages, which make them potential fire hazards if not properly designed, maintained, and protected. Common Causes of Transformer Fires are Electrical Failures due to Short circuits, insulation breakdown, or overloading, Overheating caused by poor cooling, high ambient temperature, or blocked radiators, leakage of oil ignites due to hot surfaces or electrical arcs, high transient voltages can cause dielectric failure & Improper maintenance, loose connections, or failure to monitor warning signals [2]. Fire Hazards Associated with Transformers are Combustible oil serves as insulation and cooling medium, Explosion risk due to sudden arcing inside the tank, spread of fire to nearby equipment, cables, and buildings, Release of toxic gases during burning of oil and insulation materials. The following methods were adopted in TNPL as a fire safety measure for electrical transformers.

a) Automatic Water Sprinkler System

Transformers contain oil that acts as a coolant and insulating medium. In case of an internal fault or oil leak, this oil can catch fire. An automatic water sprinkler system (Figure 1) provides rapid cooling and fire suppression, minimizing equipment damage and preventing fire spread to adjacent units. The system is designed to automatically detect heat or fire and discharge high-pressure water over the transformer surface to cool and extinguish flames (Table 1)

Operation sequence [3]:

1. Heat/Smoke Detected → Sensor activates.
2. Signal sent to control panel → Triggers solenoid valve or deluge valve.
3. Water released through spray nozzles uniformly over transformer.
4. Cooling effect lowers temperature and prevents ignition.

Advantages

- ✓ Provides automatic, fast-acting response to transformer fires.
- ✓ Prevents fire spread to nearby equipment or cable galleries.
- ✓ Reduces downtime and equipment damage

b) Nitrogen Injection Fire Prevention System (NIFPS)

The NIFPS is an automatic fire prevention system that suppresses the fire and prevents explosion by injecting nitrogen gas into the transformer tank (Figure 4) to displace oxygen and stop combustion. The system works on the principle of oxygen displacement and pressure relief when a fire or abnormal temperature rise occurs in the transformer. Sensors detect a sudden rise in temperature or pressure. Control panel sends signal to open the nitrogen cylinder valve. Nitrogen gas is rapidly injected into the transformer oil conservator or main tank. The nitrogen displaces air (oxygen), smothering the fire. The system also opens a drain valve to release part of the hot oil, reducing internal pressure and preventing tank rupture. The fire is extinguished, and the transformer is isolated from the power supply (Table 2).

Figure: 1 Transformer with Automatic Water Sprinkling System

Figure: 2 Thermo-bulb sprinklers

Figure: 3 Fire Hydrant Piping Network with deluge valve

Table :1 System Components & Functions of Automatic water sprinkler System

Component	Function
Thermo-bulb sprinklers (Figure 2)	Detect temperature rise (usually 68°C to 93°C) and trigger water flow.
Deluge valve / Solenoid valve	Opens automatically to release water from pressurized line.
Spray nozzles	Distribute water uniformly over the transformer tank, radiators, and bushings.
Hydrant line (Figure 3)	Provides sufficient water supply for firefighting duration (minimum 30 minutes).
Control panel	Monitors system health and initiates automatic/manual operation.
Piping network	Connects valves and nozzles, designed for corrosion resistance (usually GI or SS).

Operation sequence [3]:

1. Fire or Fault Occurs → Pressure and temperature rise inside transformer.
2. Signal to Control Panel → Trigger received from sensor.
3. Nitrogen Injection Initiated → Solenoid valve opens, nitrogen injected.
4. Oil Discharge → Drain valve opens to relieve internal pressure.
5. Fire Extinguished → Oxygen level inside tank drops below combustion level.

Alarm & Isolation → Transformer trips and power isolated automatically.

Figure: 4
Transformers with NIFPS

Figure: 5
Nitrogen Cylinder with Control Pane

Table :2 System Components & Description of NIFPS

Component	Description
Nitrogen Cylinder (High-pressure) (Figure 5)	Stores nitrogen gas (150–200 bar). Connected via manifold and piping to transformer tank.
Solenoid / Pneumatic Valve	Opens automatically on signal from control panel to release nitrogen.
Pressure Switch / Temperature Sensor	Detects abnormal conditions (pressure surge or high temperature).
Oil Drain Valve Assembly	Opens simultaneously to release a small quantity of hot oil and reduce tank pressure.
Control Panel	Monitors all sensors and controls automatic or manual operation.
Flexible Hose and Piping Network	Connects nitrogen cylinder bank to transformer tank.
Alarm System	Provides audio-visual alerts during system activation.

Advantages

- Automatic operation — Quick response to internal faults or fires.
- Explosion prevention — Reduces pressure and eliminates oxygen.
- No water damage — unlike sprinklers, no risk to electrical components.
- Environment-friendly — Nitrogen is inert and non-toxic.
- Low maintenance — Simple, reliable system with minimal moving parts.

3. Fire Safety Strategies for Motor Control Centre (MCC) Panel Room in TNPL

The MCC (Motor Control Centre) Room houses electrical switchgears, control panels, VFDs, and protection devices that control motors and process equipment. Since these systems handle high electrical loads, the area is prone to electrical fires due to short circuits, overheating, cable faults, or equipment failures. Therefore, ensuring robust fire safety measures is critical to protect equipment, personnel, and continuous operations. Common Fire Hazards in MCC Rooms are loose connections causing arcing or sparking, Overloaded circuits or faulty cable insulation, Accumulation of dust and oil vapors, increasing ignition risk, Improper ventilation leading to overheating of panels & use of combustible materials near electrical panels.

Fire Detection& Alarm annunciation System for MCC Panel rooms

The purpose of a Fire Detection System for MCC (Motor Control Centre) (Figure 6) Panel Rooms is to provide early warning and protection against fire hazards that could damage critical electrical equipment, disrupt power supply, and pose safety risks. Early Detection of Fire or Smoke identifies the presence of smoke, heat, or flames at the earliest stage. It helps to prevent fire from spreading to cables, control panels, and switchgear (Figure 8 & 9). Protection of Critical Electrical Equipment like circuit breakers, relays, and control devices vital for plant operation. A fire alarm control system works by continuously monitoring the environment using sensors such as smoke, heat, and flame detectors, audible warning devices, and a fire alarm control with remote notification capability when a fire hazard is detected.

a)Addressable Point Smoke Detectors (photoelectric) for Low roof MCC Panel Rooms

Figure: 6 Low Roof MCC Panel room equipped with APSD

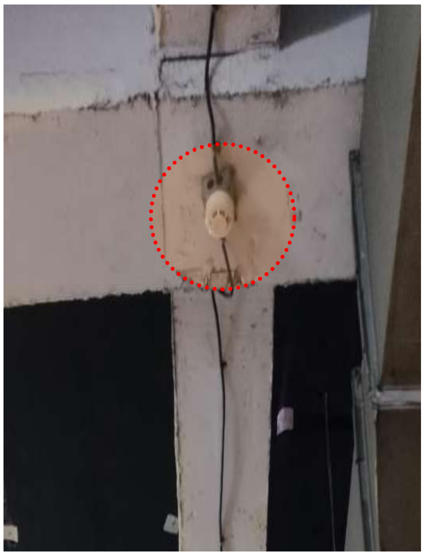

Figure: 7 Photoelectric Smoke Detector

Detection: Detection sensors (Figure 7) constantly check for signs of fire including smoke, heat, or radiant energy. These sensors may use optical, ionization, or thermal detection methods depending on the type. Smoke Detectors that have photo electronic sensing chambers tend to detects moldering fires better than flaming fires, which have little visible smoke. Detectors that have ionizing-type sensing chambers tend to detect fast-flaming fires better than smoldering fires. Because fires develop indifferent ways and are often unpredictable in their growth, neither type of detector is necessarily best nor may a given type of detector not provide adequate warning of a fire. Optical Smoke Detectors: Smoke particles scatter the light, triggering the alarm. Ionization Smoke Detectors: Detect changes in ionized air caused by smoke particles. Heat Detectors: Respond to a temperature increase or when a threshold is exceeded.

Operation sequence [3]:

1. Fire or Fault Occurs → Detection by sensor
2. Signal to Control Panel → Trigger received from sensor
3. Alarm annunciation → Fire alarm both by visual and audible
4. Check for Fire → Physical check for fire based on the addressed zone on which alarm triggers
5. Fire Extinguisher → Using the appropriate fire extinguisher to extinguish fire

Figure: 8
Smoke Sensors in Cable Trench

Figure: 9
Smoke Sensor in Cable Alley Room

b) Beam Detectors for High roof MCC Panel Rooms

Figure: 10
High Roofs MCC with IR Emitter

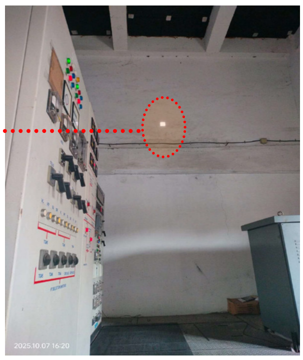

Figure: 11
High Roof MCC with IR Receiver

Detection: A Beam Smoke Detector uses a projected infrared (IR) or visible light beam to detect smoke (Figure 10). It works by sending a beam of light from a transmitter to a receiver (or reflector) (Figure 11) across the room. If smoke particles enter the beam path, they scatter or block part of the light, and the detector triggers an alarm when the reduction in signal exceeds a set threshold. The main purpose of beam smoke detectors is to cover wide or high-ceiling spaces where installing multiple point-type smoke detectors would be impractical or less effective. They provide cost-effective, wide-area smoke detection for taller environments. These environments have large volumes of air, so smoke from a fire takes time to rise and spread, making it difficult for spot-type detectors to detect early. A beam detector can cover up to 100 m of length and wide area coverage, reducing the number of detectors required.

Operation sequence [3]:

1. Transmitter emits an infrared (IR) or visible beam.
2. Receiver continuously monitors the beam's intensity.
3. When smoke enters the beam path → light intensity drops → detector registers alarm.
4. Signal to Control Panel → Alarm Trigger received from sensor
5. Alarm annunciation → Fire alarm both by visual and audible
6. Check for Fire → Physical check for fire based on the addressed zone on which alarm triggers
7. Fire Extinguisher → Using the appropriate fire extinguisher to extinguish fire

Control Panel: The fire alarm control panel (Figure 12) acts as the "brain," receiving signals from the sensors and monitoring the system's state (normal, alarm, trouble). It continuously processes incoming data to determine if an alarm should be triggered.

Alarm Activation: When a sensor detects fire indicators, it sends a signal to the control panel, which activates audible and visual alarms throughout the building and may notify external emergency services or monitoring centers.

Figure: 12 Fire Alarm Control Panel

Audible warning devices: such as bells may not alert people if these devices are located on the other side of closed or partly open doors or are located on another floor of a building.

Zone and Addressing: Conventional systems divide buildings into zones, allowing the panel to indicate which zone the fire is detected in. Addressable systems can pinpoint the exact device and location, providing greater detail for emergency response.

4. Fire Safety Strategies for Paper Machine Dryer Hood in TNPL

The dryer section of a paper machine operates at high temperatures (typically 80–150 °C), and the hood encloses this area to retain heat and recover exhaust air. Because of High temperatures, Presence of dry paper, paper dust, airborne fibers and lint near steam-heated cylinders, the dryer hood becomes a high fire-risk zone. Hence, a water sprinkler system (Figure 13) is installed to rapidly extinguish or suppress fires caused by paper breaks or web fires. The water sprinkler system in paper machine dryer hoods plays a critical fire protection role in the papermaking process, where temperatures are high and combustible vapors, lint, and paper dust can easily ignite. It prevents fire spread to other parts of the machine. It protects critical equipment and personnel. The sprinkler system in the dryer hood (Table 3) is designed to activate automatically when a rise in temperature or presence of flame is detected and to discharge water mist or spray over the affected area to cool, smother, and stop flame spread.

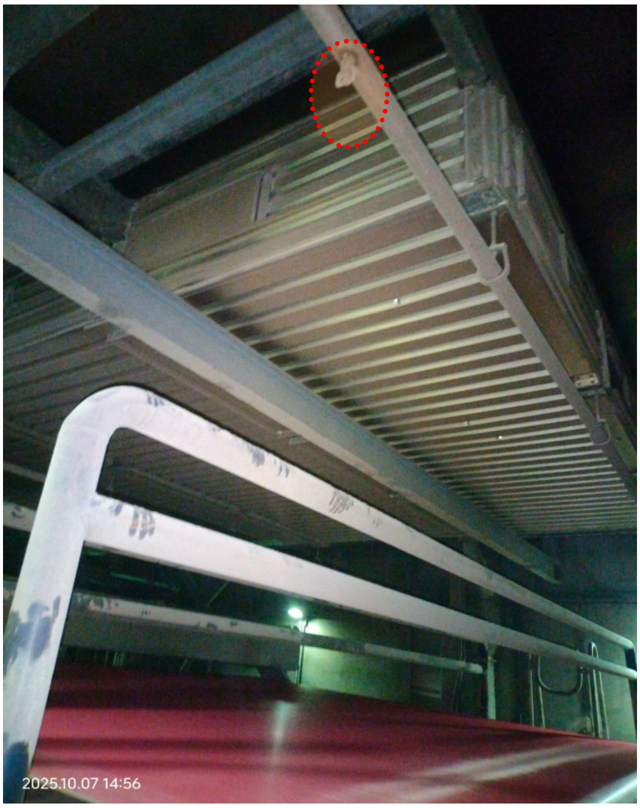

Figure: 13 Water Sprinkler System inside Dryer Hood

Figure: 14 Manual Override Push Button

Figure: 15 Water Sprinkler

Operation sequence [3]:

1. Fire or high temperature detected → signal from heat/flame detector.
2. Deluge valve opens → water floods sprinkler headers.
3. Spray nozzles (Figure 15) discharge water over the dryer hood area.
4. Hood fans shut down automatically to avoid feeding fire with air.
5. Alarm sounds in the control room and local area.
6. Operator performs emergency stop and follows SOP

Table :3 System Components & Description of Water Sprinkler System

Component	Description
Deluge Valve	Controls water flow; activated by heat/flame detectors or manual push button.
Open Sprinkler Nozzles	Special high-temperature-resistant brass or stainless-steel nozzles; spaced uniformly over dryer hood.
Heat / Flame Detectors	Detect temperature rise or flame and trigger the deluge valve.
Water Supply & Piping	Connected to fire main or dedicated high-pressure line (often ≥ 7 kg/cm²).
Manual Override Push Buttons (Figure 14)	Located on both operator and drive sides for manual activation.
Local Alarm / Indicator Panel	Shows activation, valve open, or fault status.

5. Fire Safety Strategies for Turbo Generators (TG) in TNPL

Turbo generator units (steam or gas) contain large volumes of lubricating oil, high temperatures, and electrical equipment in confined areas all of which make them susceptible to oil mist or flash fires. The purpose of the CO_2 system (Figure 16) is to extinguish oil or electrical fires rapidly in the generator (Table 4) and lubrication areas. It prevents explosion or fire spread to adjacent equipment. It protects high-value machinery (generator, bearings, seal oil, lube oil skids). It provides clean and residue-free suppression without damaging electrical insulation or metal parts.

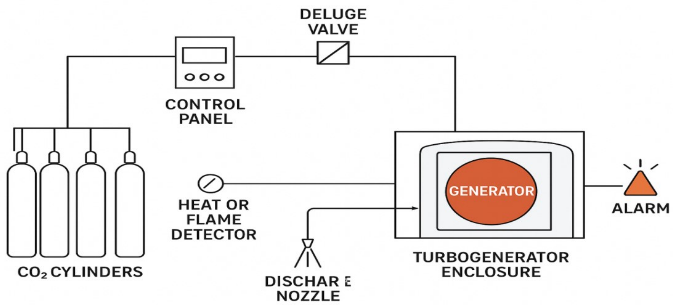

Figure: 16 Schematic view of CO2 Sprinkler System of TG

Figure: 17
CO_2 Cylinders Storage Room at TG

Figure: 18
CO_2 Cylinders Storage Circuit

Operation sequence [3]:

1. Fire detected by heat/flame detector near generator or oil skid.
2. Signal sent to control panel → activates CO_2 release circuit (Figure 17).
3. Pre-discharge alarm sounds (audible + visual) for ~20–30 seconds.
4. Master valve opens → CO_2 released into manifold.
5. CO_2 flows through nozzles → floods the generator housing and bearings.
6. Oxygen concentration drops below 15% → fire extinguishers quickly.
7. System shuts down fuel, lube oil pumps, and ventilation fans

Table :4 System Components & Functions of CO2 Sprinkler System

Component	Function
CO_2 Cylinders (High-pressure or Low-pressure Storage) (Figure 18)	Store CO_2 at 50–60 bar (high-pressure) or in refrigerated tanks (low-pressure).
Master Valve / Manifold	Releases CO_2 into piping system.
Discharge Piping & Nozzles	Direct CO_2 to generator, bearings, and oil systems.
Actuation System	Solenoid, pneumatic, or manual activation.
Flame / Heat Detectors	Automatic detection and signal to release.
Time Delay Device	Allows evacuation before discharge.
Warning Alarms	Horns and strobes to warn personnel.
Manual Release Stations	For emergency manual activation.

6. Fire Safety Strategies for Storage of Final Products in TNPL by Aspirating smoke detection (ASD)

Aspirating smoke detection (ASD) systems (Figure 19), work by actively drawing air from the protected area through a network of pipes and sampling holes into a central detection unit. The central unit (Figure 20) analyzes the sampled air for the presence of smoke, even at very low concentrations, before smoke is visible or a fire has developed significantly.

Figure: 19 ASD in Bundle Storage

Figure: 20 Components in ASD

Figure: 21 Smoke Sensor in Reel Storage

Operation sequence [3]:

A fan inside the detection unit continuously draws air through the red pipe network shown in the image. The drawn air passes through filters inside the central detection boxes to remove dust and contaminants. The filtered air then enters a highly sensitive detection chamber, often using lasers or optical systems, to measure the presence of smoke particles. If the particle concentration surpasses predefined alarm levels, the system triggers a fire alarm, providing early warning.

Advantages:

It provides very early warning of smoldering or incipient-stage fires. Allows facilities (especially those with valuable assets or critical infrastructure) extra time to respond before a fire grows. The system is highly sensitive and effective in areas where conventional smoke detectors (Figure 21) might not give timely alerts, such as storage facilities, server rooms, or places with high ceilings.

7. Way Forward

Fire accident prevention and fire safety measures are crucial component in any area. It is very much essential to Real-time monitor the initial Fire causes and mitigates fire at shortest span of time. Being a Vast area covering with Noise prone zones, it is difficult to continuously monitor the fire alarm and hear the hooters. The existing method of annunciation fire alert system has been planned to connect with DCS operating interface (Figure 22) which triggers alarm & hooter with location of the Fire incident. This allows quick response by DCS operators to fire incident and early fire suppression.

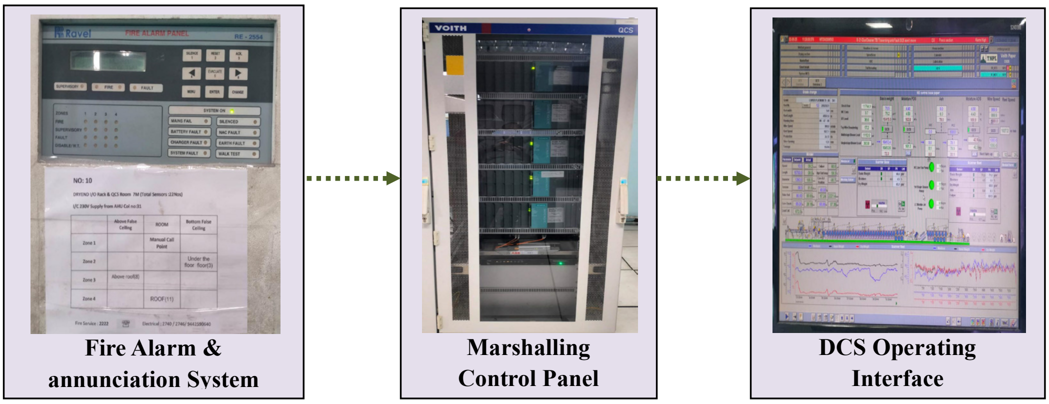

Figure: 22 Fire Alarm system connecting to DCS

8. Conclusion

TNPL's proactive approach to addressing fire safety within the broader sustainability framework exemplifies how innovation and responsibility can coexist in modern papermaking. By integrating advanced detection systems, automated monitoring technologies, and environmentally friendly fire-retardant solutions, the company not only mitigates operational risks but also reinforces its commitment to environmental stewardship and employee well-being. This holistic model demonstrates that a robust fire safety culture—rooted in continuous improvement, technological advancement, and sustainable practices—can significantly enhance resilience, ensure business continuity, and set new benchmarks for safety standards across the global paper industry.

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