

Valuable Experiences & Learnings from the Rare, Unsafe & Hazardous Fire Incidents in our Power & Utility, NRL

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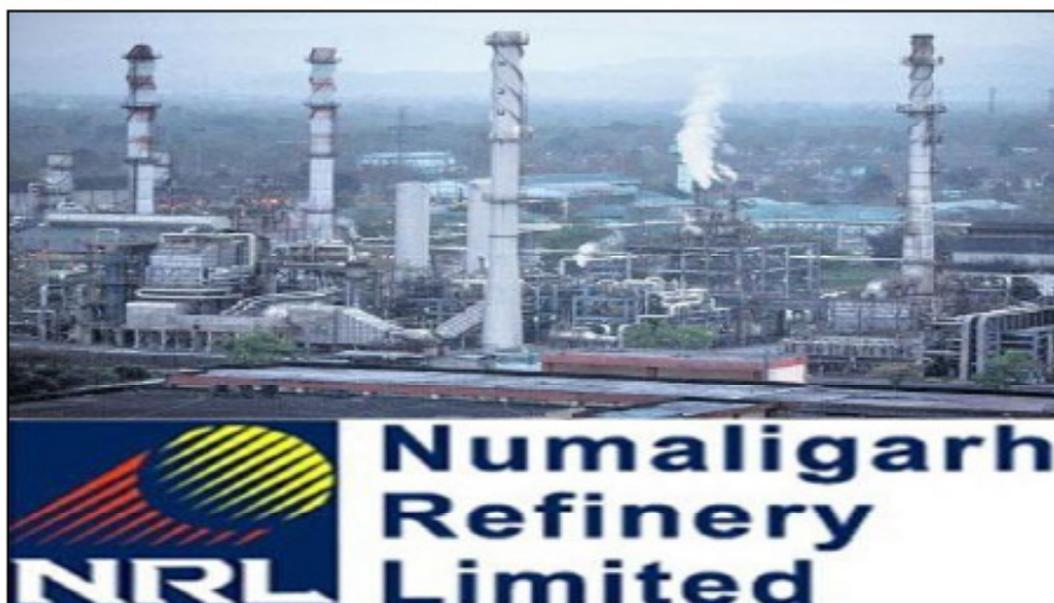
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Abstract

The importance of ethical values within organizations has grown significantly, presenting challenges for leaders. Globalization has increased intercultural interactions, revealing various difficulties and moral dilemmas in navigating diverse ethical standards. Ethics serves as a foundation for moral judgment and a standard for appropriate conduct, providing frameworks for behavior that extend beyond mere regulatory compliance and a clear stance to justify their actions, evaluate their behavior, and promoting accountability and integrity. A critical issue is understanding an organization's ability and responsibility to act ethically within the complex global environment. This qualitative study examines the philosophical and practical aspects of ethical business and its leadership. Based on a thorough analysis and synthesis of 30 primary and secondary literary sources from respected scholars and practitioners. The goal is to develop a comprehensive conceptual framework that captures the essence of business ethics and organizations' understanding that businesses are not isolated entities focused solely on profit but are, in fact, integral components of the larger community. Their roles extend beyond simply providing goods and services; they are also pivotal in fostering social

cohesion and enhancing workplace dynamics. By engaging in ethical practices, businesses contribute to a positive community environment, promote trust among consumers and stakeholders, and enhance overall societal well-being. Business ethics is not merely a moral obligation; it is a strategic imperative that aligns business success with the health and prosperity of the communities in which they operate. Companies can create a positive feedback loop where ethical practices lead to business growth, which in turn benefits society.

Keywords: Fire Safety, Near Miss, Hrsg, Hydrogen Sulphide, Pyrophoric Iron, Lubricating Oil, Power & Utility, Nrl, Incident Learning, Process Safety

1. Introduction

In complex industrial environments such as refineries and power plants, safe and reliable operations are of prime importance. Despite strict adherence to the safety procedures and regular maintenance practices, rare and unforeseen incidents may still occur due to hidden hazards, unexpected reactions, or environmental factors. The Power & Utility (P&U) section of Numaligarh Refinery Limited (NRL) plays a critical role in providing uninterrupted power, steam, and essential utilities to the entire refinery units. Operations in this area involve high-temperature, high-pressure systems, fuel gas handling, lubricating oil circulation, and steam generation through Heat Recovery Steam Generators (HRSGs). Each of these systems carries potential risks that, if not adequately controlled, can lead to fire or safety incidents.

Over the recent years, the NRL P&U team has encountered a few rare, unsafe, and hazardous fire-related events—unusual in nature and not typically covered in standard operating guidelines. These included:

- **Incident-1:** Ignition of dried insect remains concealed within HRSG insulation,
- **Incident-2:** Fire due to hydrogen sulphide (H₂S) release during cooling water system modification,
- **Incident-3:** Spontaneous ignition from pyrophoric iron sulphide deposits in a natural gas fuel header, and
- **Incident-4:** Fire originating from lubricating oil-soaked insulation around turbine casings.

Though each incident was localized and swiftly controlled without any casualties or major damage, they highlighted critical safety blind spots, especially concerning hidden ignition sources, chemical reactivity, and maintenance-related hazards. Detailed analysis and learnings from these events led to the refinement of Standard Operating Procedures (SOPs), reinforcement of inspection and housekeeping practices, and improved awareness among operating personnel.

This paper documents these incidents, analyses their root causes, outlines key learnings, and summarizes the preventive and corrective measures implemented thereafter. The objective is to share these valuable experiences across operational teams, promoting a proactive safety culture and ensuring preparedness for such rare but potentially hazardous events in future operations.

Now let us see all the above mentioned 4 incidents one by one in details:-

2. Incident-1: Ignition of Dried Insect Remains Concealed Within the Hrsg-2 Insulation

2.1 Brief Description

On 30.11.2024 morning, HRSG-2 (Heat Recovery Steam Generator – HRSG) start-up was under progress. After about 3 hours of start-up time, we sensed some burning smell from the Super-heater (SH) & Evaporator (Eva) top duct zone at the Steam Drum floor. When we opened the SH tube headers insulation cladding sheets, we observed some minor smoke was slowly coming. When we further opened the cladding sheets, we saw minor flame coming out from inside the insulation material with burning small. Immediately one DCP was also sprayed on the affected area. The flame disappeared; but the smoke was still coming out. Then we removed the cladding sheets of the whole SH & Eva tube headers. Then another DCP was sprayed. Fire & Safety (F&S) Shift-In-Charge (SIC) was immediately informed. The F&S Crew also reported immediately at site and jointly helped to completely & safely put-off the fire and smoke. Then only slowly & gradually, the smoke got disappeared. The HRSG-2 start-up process was immediately stopped on safety aspects and root cause analysis.

2.2 Root Cause Analysis

It was observed that huge pile of dried (dead) insects which was concealed/hidden inside the insulation cladding gaps & inside the insulation materials. Also, we noticed a long approx. foot (300 mm) crack at the bottom of the SH & Eva Duct Zone surface. Insects are drawn to hot air currents & area lights which glow during the evening & night hours. Overtime, these insect remains dry out, forming a carbon-rich flammable layer. These remains got deposited inside the hot insulation gaps, duct interiors, hot SH & Eva surfaces. Contact with the hot flue gas temperatures > 400 deg C coming out through the crack of the SH/Eva Top Duct Surface ignited the insect matter. This led to the burning of these insects and resulted to the fumes/smokes.

2.3 Corrective Actions Taken/Methodology/Approach

- The crack of the SH/Eva Top Duct Surface was welded and sealed. Now almost no more chances of insects/other organics ingress.
- The Insulation of the whole SH/Eva Top Duct Tube Headers were reassessed and completely sealed by converting the present

insulation into a box-type insulation. Now almost no more chances of insects/other organics ingress.

- The earlier HPML (high-pressure mercury lamps) area bulbs are replaced by more efficient and lesser insects' attraction LED bulbs in phase wise.

2.4 Key Learnings

- Accumulated dead insects near flue gas paths can act as flammable debris. The dried dead insects can also be a source of fire. Do not take it lightly.
- Poor housekeeping in air intakes or ductwork allows insect buildup.
- High flue gas temperatures can ignite dry organic matter.
- Such fires are unexpected, localized, but can escalate if not contained.

- Inspection blind spots (like filters, inside ducts, or dampers) are high-risk areas.
- Perform periodic thermal imaging and gas detection survey to identify hot spots, leaks, or entrapped gases on a regular basis.

2.5 Essential SOPs

- Inspect and clean all the vulnerable zones – Burner, Furnace, SH, Eva, Eco, etc., screens, and ducts regularly.
- Install or maintain insect screens on all air inlets.
- Include insect/debris cleaning in shutdown and startup checklists.
- Use non-combustible materials in areas exposed to flue gas.
- Train personnel to recognize fire risks from organic debris.
- Maintain housekeeping around HRSG in all seasons (especially post-monsoon).
- Keep DCPs and CO2 cylinders always ready.



Figure 1: Dried Insects Accumulation Inside the Hrs-g-2 Sh & Eva Insulation Cladding Sheets



Figure 2: Dried Insects/Organic Accumulation Inside the Hrs-g-2 Sh & Eva Insulation Cladding Sheets



Figure 3: Approx. 300 mm long Crack Inside the HRSG-2 SH & Eva Insulation Cladding sheets through the hot flue gas (temp > 400 deg C) came out and burnt the Dried Insects which are Accumulated inside the Insulation and Cladding sheets



Figure 4: Dried Insects Inside the Earlier Hmpl (High Pressure Mercury Lamp) Area Bulbs In Hrsg-2



Figure 5: Earlier Hpml Now Replaced With More Efficient & Brighter Led Bulbs In Hrsg-2 (Now Much Lesser Chances of Insects or Organic Matters Accumulation)



Figure 6: Box-Type Insulation Installed In Hrsg-2 For Better Sealing & Protection Against The Insects Ingress Inside The Cladding Sheets And Insulation Materials



Figure 7: Box-Type Insulation Installed In Hrsg-2 For Better Sealing & Protection Against The Insects Ingress Inside The Cladding Sheets And Insulation Materials

3. Incident-2: Fire from h₂S During cpp/gtg cws & cwr Underground to Overground Modification/hook-up Jobs

3.1 Brief Description

On 18th April 2023 RTA (Refinery Turn Around – RTA), during the hot jobs (gas cutting) of the CPP GTG cooling water return header (CWR) re-routing job from underground to overground, the smoke was observed with eruption of gases from the CWR header with high pressure with traces of H₂S (also shown in H₂S detector). Hydrogen sulphide (H₂S) – a highly flammable and toxic gas burnt and produced sulphur dioxide (SO₂) and water vapor (H₂O). Mud plugging is effectively & successfully used as a protective layer to cut-off any remains or passing of H₂S and completed the hot jobs safely. DCP was sprayed, the hot jobs were completely stopped immediately and slowly the smoke got disappeared.

3.2 Root Cause Analysis

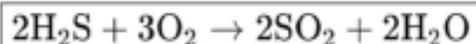
The root cause of smoke & fire was due the presence of unseen & undetected trapped dissolved Hydrogen sulphide (H₂S) present inside the low-lying underground CWR header pipe. During the modification work involving gas cutting, the localized heating released the entrapped dissolved H₂S gas from internal deposits and stagnant pockets. As the pipe was opened, the atmospheric oxygen entered into the header and reacted with the liberated H₂S, leading to a hot exothermic reaction inside the CWR pipe. This reaction resulted in the sudden eruption of hot flue gases

from the cut location, which appeared as smoke-like emissions. The incident occurred despite prior safety precautions including complete nitrogen purging, verification of 0% LEL, and 0 ppm H₂S readings. Immediate actions such as mud plugging and prompt site intervention successfully controlled the situation without escalation.

The likely source of the trapped H₂S was carryover from the Sulphur Recovery Block (SRB) unit, which can remain absorbed in sludge, scale, or stagnant water pockets even after flushing and purging. The CWR header had already been depressurized, and similar hot jobs had been executed earlier at other locations on the same header without any gas detection, indicating that the release was due to localized entrapped gases.

Hydrogen sulphide (H₂S) is a highly flammable and toxic gas. Upon exposure to heat and oxygen, it burns to form sulphur dioxide (SO₂) and water vapour (H₂O), generating heat and hazardous fumes.

Combustion Reaction of H₂S



3.3 Corrective Actions taken/Methodology/Approach

- Re-purging of the CWR circuits carried out with N₂ gas. H₂S checked at different locations. No H₂S found. Only intermittent H₂S was found at the hot job site. Complete purging carried out.
- The idea of Mud plugging inside the CWR header just before the portion of the gas cutting was applied to double ensure that no more unseen trapped H₂S gasses are completely cut-off. This method was very effective, and our hot jobs could be carried out successfully. Later on, the mud inside the CWR header was flushed out safely before charging the CWS & CWR circuits.

3.4 Key Learnings

- We should not take CW lightly and for granted that it cannot catch fire and dangerous. It can also catch fire indirectly which can be hazardous and unexpected. So, do not take it lightly.
- H₂S is highly toxic, flammable, and explosive even at low concentrations.
- Fires involving H₂S produce sulphur dioxide (SO₂), which is also toxic.
- Mud plugging is very effectively used as a protective layer to cut-off any remains or passing of H₂S.

- Release of H₂S gases may also come from the entrapped gases in the CW headers.
- Delayed detection or poor evacuation can lead to fatalities.
- Source isolation and gas detection are critical for control.
- Fire + H₂S = compound hazard (toxicity + combustion risk).
- Share such case studies and lessons learned from these incidents across all refinery departments to enhance collective preparedness.

3.5 Essential SOPs

- Install and maintain H₂S detectors in all risk zones.
- Immediately activate ESD/MCP and isolate the leak source.
- Never enter affected areas without gas clearance and PPE.
- Use dry chemical or foam extinguishers—avoid water unless safe.
- Conduct regular H₂S drills and emergency training for all operations and maintenance personnel.
- Maintain H₂S handling procedures and permit-to-work system.
- Keep DCPs and CO₂ cylinders always ready.
- The idea & counselling of the effectiveness of the Mud-plugging to be carried out among the Employees and all the personnel involved in the jobs.



Figure 8: Cpp Cooling Water Supply & Return (Cws & Cwr) Converted From Earlier Underground To Now Over Ground For Easy Maintenance And Protection Against The Underground Corrosion And Leakage



Figure 9: Cpp Cooling Water Supply & Return (Cws & Cwr) Converted From Earlier Underground To Now Over Ground For Easy Maintenance And Protection Against The Underground Corrosion And Leakage

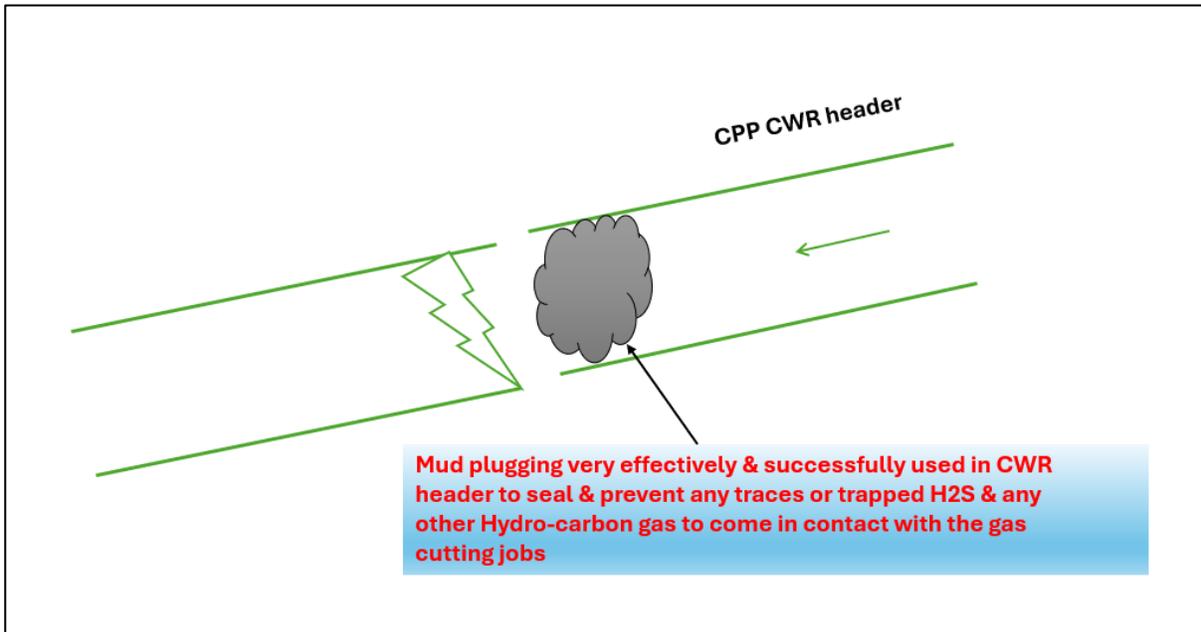


Figure 10: Mud plugging inside the CWR header just before the portion of the gas cutting was applied to double ensure that no more unseen trapped H2S gasses are completely cut-off

4. Incident-3: Spontaneous Ignition from Pyrophoric Iron Sulphide Deposits in a Natural Gas Fuel Header of HRSG-1

4.1 Brief Description

In April 2015 RTA, during the maintenance of HRSG-1 Natural Gas/Fuel Gas (NG/FG fuel) header, slight reddish-orange colour was observed while opening the NG bottommost flange. Immediately the jobs were stopped. The Fire Water (FW) sprayed and wetted the NG header. The reddish-orange colour appearance slowly disappeared.

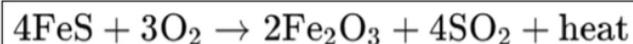
4.2 Root Cause Analysis

The Corrosion or fouling and the eroded iron particles inside the in the HRSG-1 NG/FG fuel header led to the formation of iron sulphide deposits. When the flange was opened, these deposits were exposed to air (oxygen). The reaction between these iron sulphide compounds, and oxygen likely triggered the fire. Oxidation of Iron Sulphide (Spontaneous Ignition) – Exothermic Reaction. The amount of heat can be enough to make the iron deposits glow red. Spontaneous ignition of pyrophoric materials caused a localized minor fire. While the iron itself cannot catch fire, if there is a fuel source present (e.g., residual oils, hydrocarbon gases), the heat created is adequate to ignite the fuel source, and fire must be avoided. When we open equipment (e.g., vessels, fuel gas lines) for maintenance, atmospheric air (oxygen) rushes in. FeS ignites spontaneously due to exothermic oxidation – generating heat, SO₂ gas (toxic) and potentially starting a fire.

• Formation of Iron Sulphide (FeS)



• Oxidation of Iron Sulphide (Spontaneous Ignition) – Exothermic Reaction



4.3 Corrective actions taken/Methodology/Approach

- Immediately the all the jobs were stopped, and FW was sprayed and wetted the iron particles.
- Then slowly the reddish fire like appearance disappeared.
- Then cleaning of the corroded iron particles was carried out with the Non-sparking tools.
- Again, N₂ purging was carried out.

4.4 Key Learnings & Essential SOPs

- Inerting with nitrogen (N₂): Keep oxygen out before opening equipment.
- Wet cleaning / flushing: Wash out FeS deposits to prevent ignition.
- Monitoring for H₂S and SO₂: Both are toxic gases; respiratory protection is often needed.
- Hot work precautions: Ensure FeS has been fully removed or neutralized before welding/grinding.
- Pyrophoric iron (iron sulphide) can spontaneously ignite when exposed to atmospheric air (O₂). Do not take it lightly.
- Corrosion/fouling in NG systems can lead to iron sulphide formation.
- Oxygen ingress during maintenance or leaks is a major ignition risk.
- Proper purging and inerting before opening gas lines is critical.
- Fire can occur even without external ignition—internal risks must be controlled.
- Keep DCPs and CO₂ cylinders always ready.

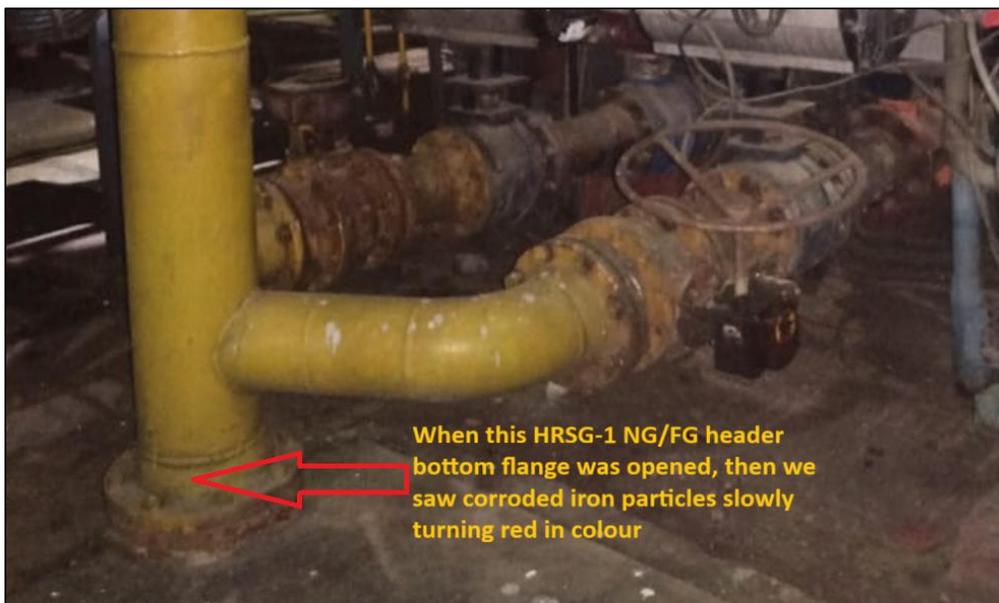


Figure 11: HrsG-1 Ng/Fg Fuel Header Bottom Most Portion Flange When Opened, The Corroded Iron Particles Slowly Turned Red In Colour (Pyrophoric Iron Fire)



Figure 12: Picture Showing Pyrophoric Iron Fire

5. Incident-4: Fire Originating from Lubricating Oil–Soaked Insulation Around Turbine Casings

5.1 Brief Description

On 22 November 2023, at around 9:43 pm, smoke was reported from PCT CW Turbine 25-PT-02E NDE Bearing/Governor insulation area by N2P EA. Immediately informed F&S and RSS. On reaching the site, DCP was sprayed by N2P EA & CPP CR Personnel. F&S crew also reached the site and sprayed DCP/CO₂ to control the smoke. Turbine was also immediately stopped and isolated.

5.2 Root Cause Analysis

Sweating type minor Lube oil (LO) leakage near to the Turbine Governor & NDE Bearing housing, which for longer period of time accumulated inside insulation cover, which generated smoke after accumulation of sufficient oil and getting heated to flash point from the hot surface/body of running turbine.

5.3 Corrective actions taken/Methodology/Approach

- Immediately the stand-by Cooling Water motor driven pump was started and the affected CW Turbine 25-PT-02E was stopped by activating the Emergency Shut-off mechanism.
- DCP was sprayed.
- Informed F&S Team. They immediately reported at site. They also sprayed DCP & one CO₂ cylinder. Slowly the fire and the smoke was contained safely.
- The Turbine thorough healthiness checking was carried out. The LO leakage source was identified and arrested.

5.4 Key Learnings

- Lube oil leakage prone area to be kept open from insulation cover.
- The integrity of the entire oil circuit is to be checked periodically for any deterioration etc.
- The housing area and deflector area to be checked thoroughly during the PM of the turbine.
- Insulation covers over turbine to check periodically for any oil ingress and soaked insulation to be replaced immediately.
- LO-soaked insulation is a hidden fire hazard near hot surfaces. Do not take it lightly.
- Oil leaks can go undetected and saturate insulation over time.
- Castable insulations provided over the hot Turbines Casing for extra protection against the possible fire from the soaked LO insulation.
- Fires can spread rapidly due to oil leaking through insulation.
- Housekeeping and routine inspection is very important.

5.5 Essential SOPs

- Inspect insulation regularly for LO leakages, LO vapour, soaked LO insulation, any burning smells, etc.
- Arrest the minor LO leaks immediately, do not take it lightly.
- Use oil-resistant or fire-retardant insulation where possible.
- Keep insulation clear from flanges, joints, and hot surfaces.
- Maintain LO system pressure, seals, and filters within specified limits.
- Perform thermal imaging to detect abnormal hot spots or leak paths.
- Keep DCPs and CO₂ cylinders always ready.



Figure 13: Lo Leakage From The Turbine Lo Bearing Housing & Governor



Figure 14: Lo Leakage From The Turbine Lo Bearing Housing

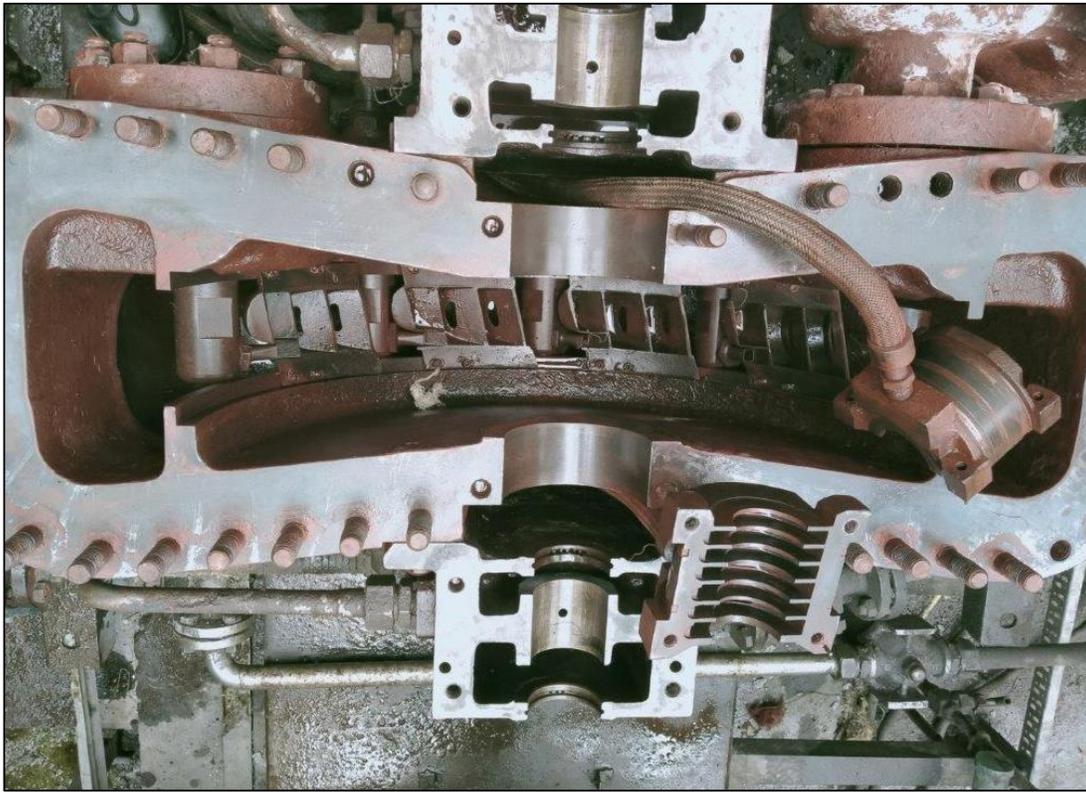


Figure 15: Turbine Internals Thorough Checked, Servicing & Preventive & Thorough Healthiness Checking Done

6. Key Takeaways & Conclusions

6.1 Key Takeaways from All Four Incidents

The four rare and hazardous fire incidents experienced in NRL's Power & Utility (P&U) areas highlight a broad spectrum of hidden

ignition sources, chemical reactivity hazards, and maintenance-related safety challenges. Despite being localized and swiftly controlled, each event provided invaluable operational learning which is tabulated as below:

Incident	Key Learnings	Underlying Themes
Incident-1: Ignition of dried insect remains inside HRSG insulation	Organic debris such as insect remains can ignite when exposed to flue gas temperatures (>400°C). Regular inspection and improved sealing/housekeeping prevent recurrence.	Hidden combustible material & poor sealing of hot zones.
Incident-2: Fire from H ₂ S during cooling water system modification	Entrapped H ₂ S can persist even after purging. Mud plugging proved highly effective. Emphasized toxicity and flammability risks of H ₂ S.	Chemical reactivity, gas entrapment & permit-to-work vigilance.
Incident-3: Spontaneous ignition of pyrophoric iron sulphide (FeS)	Pyrophoric FeS forms through corrosion and ignites spontaneously when exposed to air. Reinforced importance of inerting (N ₂ purging) and wet cleaning.	Pyrophoric materials & oxygen ingress control.
Incident-4: Fire from lubricating oil-soaked turbine insulation	Lube Oil leakage into insulation is a hidden fire hazard. Regular inspection, leak arresting, and use of fire-retardant insulation are critical.	Lube Oil management, maintenance vigilance & insulation healthiness.

Table 1: Key Learnings of the Incidents at A Glance

Collectively, these incidents demonstrate that not all fires originate from typical ignition sources such as sparks or flames - some arise silently from chemical oxidation, decomposition, or concealed heat accumulation.

7. Recommendations for Future Operations

- Conduct thermal imaging and gas-leak detection surveys periodically to detect hidden heat or leakage points.
- Install insect screens and LED lighting in HRSG areas to minimize insects/organic buildup.
- Ensure double-sealing and corrosion-resistant linings in fuel gas headers to minimize FeS formation.
- Include mud-plugging or similar temporary barriers as an approved method in H₂S-related maintenance SOPs.
- N₂ purging and wet cleaning before opening hydrocarbon systems or vessels with known corrosion/fouling.
- Implement routine inspection of insulation for oil ingress, moisture, or degradation.
- Carry out mock drills involving H₂S release, FeS ignition, and turbine insulation fire scenarios to check our readiness.

8. Conclusion

The rare and unusual fire incidents experienced in the Power & Utility (P&U) section of NRL have provided deep insights into the unpredictable nature of industrial hazards and the importance of proactive risk management. Each incident - underscored a common message: even small, often-overlooked factors such as dried insects, minute oil leaks, corrosion deposits, or entrapped gases can escalate into hazardous situations if not identified and addressed timely.

Through prompt action, sound technical judgment, and effective

teamwork, all incidents were successfully contained without any injury or major damage to equipment or infrastructure. Post-incident investigations revealed valuable lessons related to inspection, housekeeping, material compatibility, process monitoring, and safe maintenance practices. The corrective and preventive measures implemented - including enhanced inspection regimes, revised SOPs, use of fire-retardant materials, improved gas detection systems, and continuous personnel training - have significantly strengthened the fire safety preparedness of the P&U area.

These rare fire incidents serve as reminders that safety is not a static condition but a continuous process of learning, improvement, close & minute observations at field. Every near miss or small fire must be viewed as an opportunity - to improve awareness, refine operational discipline, and build resilience against unforeseen risks. By sharing these learnings across teams, NRL fosters a culture of proactive safety, ensuring that both personnel and assets remain protected while maintaining reliable plant performance.

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