MODULE 1

CASE STUDY: HYDROGEN LEAK AT THE H2 TRANSSHIPMENT TERMINAL – RESPONSES AND CONCLUSIONS

Introduction to the Context
You are a team of safety specialists at HydroLogistics Sp. z o.o., a premier operator in the hydrogen supply chain across Europe. Your company oversees a contemporary hydrogen transshipment terminal at a seaport, tasked with receiving liquid hydrogen (LH2) from tankers, storing it in cryogenic tanks, and subsequently distributing it as compressed gaseous hydrogen (GH2) to tanker trucks and local refueling stations. The terminal features advanced detection systems, automated safety systems (ESD), and highly trained personnel.

On July 10, 2025, at 11:45 a.m., an incident occurred during the routine procedure of transferring hydrogen from a cryogenic storage tank to a tanker truck.

Comprehensive account of the incident

- **Date and Time:** July 10, 2025, 11:45 AM
- **Location:** HydroLogistics Sp. z o.o. Transshipment Terminal, Compression and Refueling Zone GH2.
- **Facility:** Hydrogen compression module – a three-stage compressor, high-pressure buffer tanks, transmission pipelines, and a tanker truck refueling station.

Course of the event:

- Duty Operators Mr. Kowalski and Ms. Nowak oversaw the refueling process of a 700-bar tanker truck with hydrogen gas. The operation progressed seamlessly for approximately 15 minutes.
- Suddenly, Mr. Kowalski observed an abrupt, nearly instantaneous decline in pressure on the hydrogen supply line to the compressor, accompanied by a simultaneous rise in the readings on the hydrogen detector situated near the expansion valve of the first compression stage.

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- Within 3 to 4 seconds, the hydrogen concentration surpassed the initial alarm threshold (1% by volume) and increased swiftly. The detector's audible alarm activated almost instantaneously, and a visual leak indicator emerged on the control panel.
- Ms. Nowak, proficient in emergency protocols, promptly activated the emergency stop (ESD) button for the compression zone, which automatically closed all valves, halting the hydrogen supply to the compression module and isolating the tanker truck. Additionally, she deactivated the compressor and cryogenic pump.
- At that moment, Mr. Kowalski, adhering to protocol, sprinted toward the nearest manual emergency valve to close it, despite the ESD system already being engaged. As he ran, he heard a loud hissing sound and felt a powerful rush of air, signaling a substantial loss of pressure. A visual inspection disclosed a vigorous jet of gas escaping from the PRV flange situated on the downstream pipeline.
- Water from the sprinkler system atop the compressor building was activated automatically, generating a water curtain to disperse the hydrogen.
- The shift manager, Mr. Adamczyk, present in the command center at the time, promptly contacted emergency services, supplying the precise location and nature of the threat (hydrogen leak, no ignition, ESD system activated). The evacuation of employees from the danger zone (a 50-meter radius from the compressor building) to a designated safe assembly point was also initiated.
- The fire department reached the scene within seven minutes. Upon arrival, the incident commander, after conferring with Mr. Adamczyk, verified that the ESD system had successfully isolated the leak and that no ignition had taken place. Emergency services established water curtains to further disperse the hydrogen and monitored the gas concentration with their portable detectors.
- Approximately 20 minutes following the incident, hydrogen detectors registered concentrations below 0.5% by volume, and the leak was fully contained.

A preliminary investigation carried out by HydroLogistics' internal security team uncovered the following facts:

1. **Pressure Relief Valve (PRV) Failure:** Analysis indicated that the PRV flange, designed to open automatically during an overpressure event, experienced a fatigue fracture in its seal, resulting in an abrupt release of hydrogen. The PRV was last serviced two years prior. A recent visual inspection showed no irregularities.
2. **Overpressure in the Line:** It was established that during the compression process, a brief, transient pressure spike occurred in the line downstream of the compressor, exceeding the nominal pressure but remaining below the PRV actuation threshold (the PRV opening pressure was 800 bar, while the transient spike reached 780 bar). The seal failure resulted from a combination of material fatigue and short-term loading.
3. **ESD Operation:** The Emergency Stop Disconnect (ESD) system functioned accurately and as anticipated within five seconds of the alarm detection. It successfully halted the hydrogen flow, averting any potential long-term leakage.
4. **Water Curtains:** The automatic water curtains (drainers) functioned as intended, effectively dispersing hydrogen and mitigating the risk of creating a potentially explosive environment.
5. **Operator Error (Mr. Smith's Action):** Mr. Smith, acting in good faith and adhering to the "double check" principle, attempted to manually close the emergency valve. This action was unwarranted, as the ESD system had already activated, and entering the hazardous area during an active leak heightened the risk of injury. Fortunately, no ignition took place.
6. **Communication:** Interaction with local emergency services was seamless, facilitated by previous joint exercises and coordinated facility plans.

Security Team Preliminary Conclusions

- The incident underscored the critical significance of effective detection and automatic safety systems (ESD) in mitigating the impacts of hydrogen leaks.
- The incident underscored the necessity for more stringent inspection and replacement protocols for components vulnerable to fatigue, particularly within high-pressure systems (e.g., PRV seals).

- Despite the technology's efficacy, the incident underscored the necessity of enhancing procedures for operators to mitigate unnecessary exposure to risk, even in well-meaning circumstances. Prioritizing evacuation after ESD activation is essential.
- Automatic water curtains have demonstrated efficacy in dispersing hydrogen.
- Ongoing collaboration and coordinated drills with emergency services are highly beneficial.

QUESTIONS FOR PARTICIPANTS (FOR INDIVIDUAL TASKS/GROUP DISCUSSIONS)

1. **Cause Identification:** What were the direct and indirect causes of the PRV failure and hydrogen leak in this instance? Could these incidents have been averted?
2. **The Role of Technology:** In what ways did hydrogen detection systems, electrostatic discharge (ESD) systems, and water curtains aid in managing the situation? Was their performance optimal? What areas could be enhanced?
3. **Operator Action:** Assess Mr. Smith's conduct following the activation of the alarm. Did he adhere to optimal security protocols? Why or why not? What should have been his primary focus?
4. **Emergency procedures:** Which aspects of the current emergency protocols were effective, and which were deemed inadequate or in need of enhancement?
5. **Risk Management:** What insights can be derived from this incident to enhance risk management at the terminal? What modifications should be implemented in the equipment maintenance and inspection plan?
6. **Crisis Communication:** How do you evaluate the effectiveness of communication with Mr. Adamczyk and the emergency services? What aspects could be enhanced in this context?
7. **Training:** What specific deficiencies in operator or supervisor training may have been identified from this case? Which topics should be emphasized in future training sessions?
8. **"Almost" is insufficient:** Although ignition did not occur, the incident approached the threshold of a serious accident. What measures should be implemented to avert a recurrence of such a "near-incident"?
9. **Long-Term Consequences:** What potential long-term repercussions could HydroLogistics face if the hydrogen were to ignite? (Consider financial, reputational, environmental, and legal aspects).

10. **Prevention vs. Response:** This case illustrates that both prevention (maintenance) and response (Emergency Shutdown, procedures) are essential. How can one identify the optimal balance between investing in these two domains?

DISCUSSION STRATEGIES

- Divide into groups of three to four individuals.
- Please review the incident description and preliminary findings with attention.
- Address the questions by engaging in a group discussion for each one. Substantiate your responses by citing the information presented in the case study.
- Remember, there is no singular "perfect" answer to every question. The objective is to foster critical thinking and innovative problem-solving.
- Consider the actions you would undertake if you were part of the security management team.
- Prepare a concise presentation of your key conclusions and recommendations for the entire group.

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