



CASE STUDY

OISD/CS/2025-26/P&E/07

Dt.:26.06.2025

INTRODUCTION

Title: LNG leakage at LCNG Station.

Location: Liquefied to Compressed Natural Gas (LCNG) station.

Loss/ Outcome: Product Loss.

BRIEF OF INCIDENT:

Liquefied Natural Gas leakage occurred at a Liquefied to Compressed Natural Gas (LCNG) station during CNG fixed cascade system filling operations.

Both the high-pressure pumps (discharge pressure 230 kg/cm²) were started after midnight for the filling operation. About an hour later, a dense vapour leak was observed near one of the pumps by a shift operator, during the field round. It was later assessed from the CCTV footage that the leak had occurred less than a minute ago. Although, a shutdown was advised by the operator to the control room, the shutdown was not initiated. Meanwhile the efforts of the operators to identify the leak source went futile due to poor visibility caused by the vapour cloud.

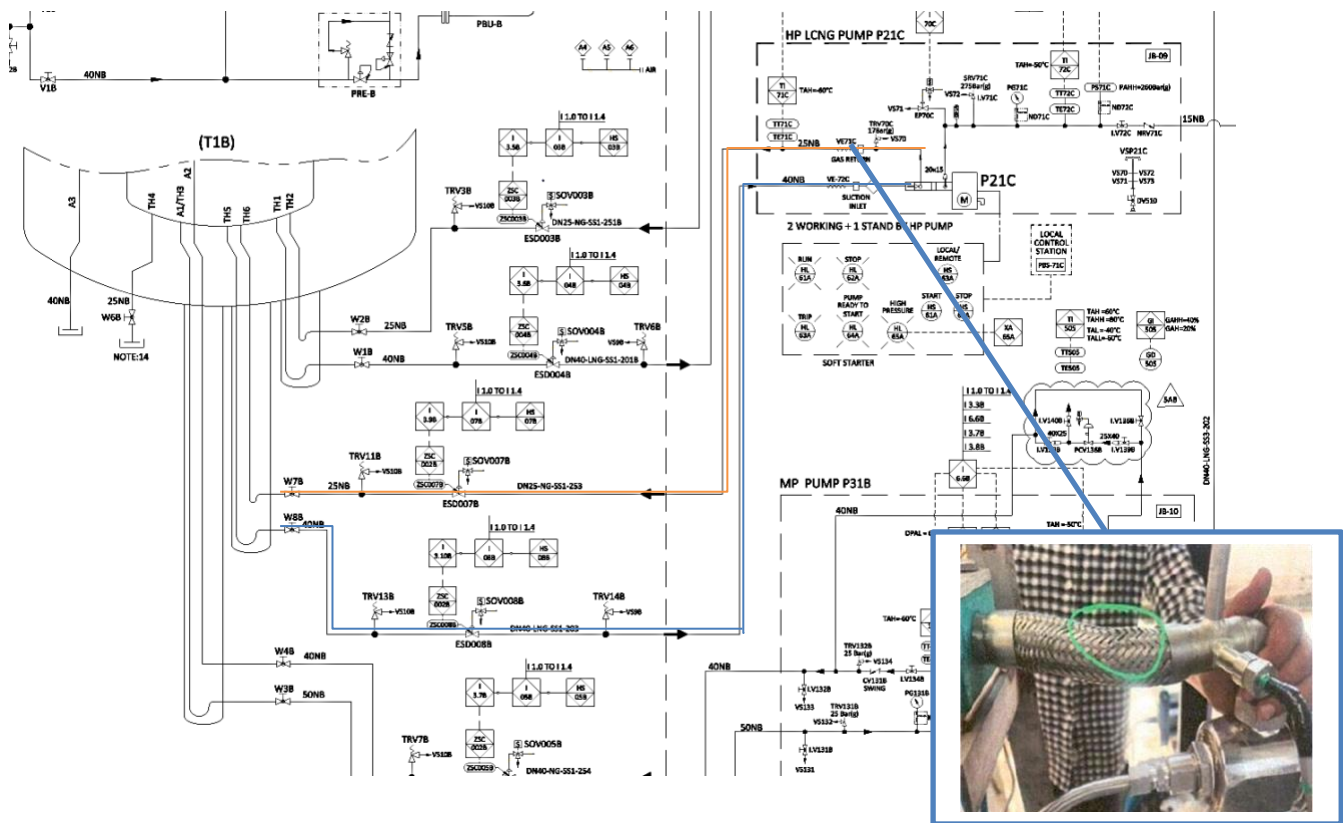
Four minutes after the start of the leak, a hydrocarbon gas detector activated an interlock that initiated closure of both the inlet and return solenoid valves as well as the other associated equipment, including the pump. While the inlet valve closed successfully, the return valve failed to close. The leakage continued for around seven and a half hours subsequently (till around 9:45 hrs), till the connected vessel LNG (around 74KL/ 35MT/ 65% level) nearly emptied out through the leak. Level 3 emergency was declared around 05:00 hrs in the morning to regulate the activity and traffic in the vicinity of the installation.

Following the near-complete venting of the affected LNG tank, the manual isolation valve on the return line was operated to stop the leak. The source of the leak was subsequently identified as a rupture in the stainless-steel braided flexible return hose connected to one of the high-pressure pumps.

OBSERVATIONS / LAPSES

- a. The 2 high-pressure LNG transfer pumps' suction was from the LNG tanks of 114KL each through a 40 NB pipe. The pumps discharged to the high-pressure vaporisers through a 15 NB. The gas from the vaporizers were routed to the fixed cascade system.
- b. To manage vapor generated during start-up and normal operation, each pump was provided with a dedicated 25 NB return line to the storage tank.
- c. The suction and return lines had a manual isolation valve, a solenoid-operated valve (SOV), and a stainless-steel braided flexible connector (hose).

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Sniped from P&ID showing Pump P-21 C suction, return and discharge line

- d. The hydrocarbon gas detector registered the leak approximately four minutes after its actual onset, despite a specified response time of 15 seconds and being in the path of the leak.
- e. The gas detector sensors (catalytic bead type) had not been replaced since initial installation four year ago, exceeding their typical two-year service life.
- f. Prior to the incident, five detectors showed fluctuating LEL readings. At the point of detection by HC gas detectors, seven showed 100% LEL, three showed no response. Within 8–10 minutes, only two still read 100% LEL. Though all detectors were calibrated on about a fortnight ago, the OEM stated they could not vouch for the accuracy as calibration was not done by their authorised vendor.
- g. Temperature sensor near the pump gave a low-temp alarm (-40°C) alarm 10 minutes after the leak started, and a trip at -70°C was triggered after 16 minutes. The sensors were 1.2 metres from the leak point. The sensors had been calibrated recently, with recalibration due the following year.



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- h. The LNG leak occurred in the flexible connector (hose) on the pump return line (25 NB), which was a wire-braided, corrugated stainless-steel hose rated for the intended service. The rupture point was located at approximately the 10 o'clock position.
- i. Third-party failure analysis attributed the hose rupture to prolonged cryogenic exposure and continuous vibration from the reciprocating pump, resulting in fatigue and eventual failure.
- j. Although the Quantitative Risk Assessment had recommended visual inspection checklists for flexible connectors, no inspection records were available. The flexible hose had not undergone hydrostatic testing after commissioning, despite being in service for nearly four years. Similar maintenance deficiencies were observed in other hoses installed at the facility.
- k. The return line solenoid valve failed to close during emergency interlock activation due to complete icing. The failure was likely caused by sealing degradation or internal mechanical issues under cryogenic conditions



- l. No gas dispersion study had been conducted to determine the optimal location and elevation of gas detectors and temperature sensors.
- m. Maintenance records indicated no prior abnormal pump behaviour or leak incidents. Routine servicing had been carried out in accordance with OEM recommendations.
- n. The initial emergency response involved direct water spray to disperse the vapour cloud. A mobile water curtain system was deployed several hours later to contain the vapour dispersion.
- o. Foam was not used to blanket the spilled LNG in the impoundment area, despite the availability of portable high-expansion foam generators on site.
- p. There was a delay of approximately 36 minutes in notifying the site in-charge, contrary to emergency response protocols that require immediate communication with designated emergency controllers.
- q. The facility's risk assessment considered various leak sizes but did not include failure scenarios related to rupture of flexible connectors (hoses), despite their presence in multiple critical circuits.
- r. The quantified risk contours indicated that the 10^{-3} annual fatality risk extended beyond the plant boundary in one direction, posing potential risk to the surrounding public.
- s. The fire protection system comprised two large fire water tanks and five fire pumps (two jockey, two main electric, and one diesel-driven). Two pumps were required to meet demand, with the third maintained as standby.

CONCLUSION / ROOT CAUSE

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The return line flexible connector (hose) of Pump P-21C, which leaked, failed due to cyclic exposure to cryogenic temperatures, intermittent operations, and continuous vibrations. No hydrotesting of the flexible connector (hose) was carried out in past 4 years.

Delayed hydrocarbon detector response probably resulted in icing of the return ESD valve actuator—due to vapor impingement—and its failure to close.

RECOMMENDATIONS

- a. As per Annex-D of EN 12434:2000 (Cryogenic Vessels: Cryogenic Flexible Hoses), all cryogenic flexible connectors (hoses) must undergo routine visual inspections under operating conditions at defined intervals to identify early signs of deterioration. Further, a formal flexible connector (hose) replacement policy should be established for all flexible connectors (hoses) subjected to cryogenic temperatures and mechanical vibrations.
- b. A review of the requirement of hydrotesting the connecting flexible connectors may be carried out, preferably in consultation with OEM. The review may keep in view that for similar application of LNG transfer hoses, it is prescribed in clause 4.10.7(e) of OISD-STD-194 (2025 edition), that LNG transfer hoses shall be tested annually to the maximum pump pressure or relief valve setting.
- c. All ESD valves actuators and mounting kit, which is between actuator and cryogenic stem, should be fitted with protective thermal jackets. So that, in the event of an emergency or a failure of the normal control system, the valves and actuators cannot become inoperative due to icing, mechanical damage, or environmental exposure as per clause 8.3.5 of OISD-STD-194 (2025 edition).
- d. Use of infrared (IR)-type flammable-gas detectors should be considered based on a formal gas - dispersion analysis to ensure optimal coverage in line with clause 6.4.5 of OISD-STD-194 (2025 edition). Any delayed response of detectors shall be analysed and corrected.
- e. As per clause 8.5.5.1 of OISD-STD-194 (2025 edition), portable high-expansion foam generators should be used to effectively manage isolated LNG spills.
- f. As per clause no 8.5.11.2 of OISD-STD-194 (2025 edition), water curtains should be considered to help contain the spread of LNG vapours.
- g. To ensure availability of adequate firefighting pumps, the number of fire water diesel-driven pumps shall be a minimum of 50% of the total number of pumps (including standby pumps) as per clause 8.5.4.4 of OISD-STD-194 (2025 edition).
- h. The Quantitative Risk Assessment (QRA) should be re-evaluated to incorporate flexible connector (hose) rupture as a credible failure scenario. Furthermore, appropriate and adequate mitigation measures must be implemented wherever the 10^{-3} individual risk contour extends beyond the facility boundary.
- i. Regular training sessions and tabletop emergency mock exercises should be carried out for all operating personnel to enhance preparedness and effective emergency response.
