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TNO report

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Reliability of cryogenic hoses used for dispensers on LNG tank stations – public summary

(“Industrieel onderzoek naar de betrouwbaarheid van cryogene slangen bij LNG dispensers voor LNG tankstations”)

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Rolande and Pitpoint (formerly LNG24) operate LNG tank stations to fuel trucks. Hoses are used to connect the dispenser to the truck. The service life of these hoses is too short. In one to several months of operation they start to leak. This causes safety risks, release of methane, non-planned and immediate interventions, and high operating costs.

The aim of the project is to improve the service life of hoses by reconsidering the hose design and dispenser layout. Multiple dispenser designers and hose suppliers are invited to propose improvements. The hose suppliers Imbema Cleton, Demaco, and Eriks and dispenser designer Cryostar supported the project in-kind with knowledge and test samples.

Due to lack of information on what makes hoses fail, it was decided to assess the causes and to investigate how these causes can be minimized. The effects on improvements on service life have to be tested in service. A selection of proposed improvements has been tested by TNO. In parallel, some hoses were tested in service.

The dispenser of Rolande in Utrecht was selected as baseline, see Figure 1. Six hose designs have been tested for this baseline dispenser lay-out. In addition, tests have been executed on two variations on the baseline layout. Next to the hose stiffness and length, the following parameters affect the loads in the hose:

- how the hose is connected to the dispenser;
- the position of the truck relative to the dispenser. To guide the truck driver, the allowed tank positions are marked on the pavement;
- the ability of the hose to freely rotate under all operating conditions. As international standardisation of the receptacle (the connection of the nozzle to the LNG tank) is underway, it has been decided not to consider improved nozzles in this project.

Figure 1 Rolande’s dispenser lay-out at Utrecht

In designing improved hoses, the requirement was that the internal hose diameter is 1” or larger to keep the fuelling duration limited. To investigate if this requirement can be relaxed, one hose with a ¾” diameter was selected to be tested in the laboratory on loads and in service with respect to flow rates.

The test rig consisted of a simulated dispenser and receptacle of a truck, see Figure 2. The bending and torsion loads in the hose at the connection to the dispenser and at the nozzle has been measured as function of:

- the position of the connection of the hose to the dispenser;
- the position of the truck relative to the dispenser;
- the hose length, weight and stiffness;
- the pressure (0-15 barg) and temperature (ambient-cryogenic) in the hose;
- ice on the outer surface.

Both static and handling loads are determined.

Figure 2 Rolande's dispenser lay-out at Utrecht: hose in parking position (top-left); truck positioned close to the dispenser (top-right); truck parked at the border of the allowed truck positions (bottom).

The test results provide evidence what causes the three known common hose failures:

- Hose failure near the nozzle: This is the location with the highest bending moment for normal operating conditions and thereby the location where fatigue failure can be expected. The bending moment is affected by hose stiffness and weight. The truck position hardly influences these loads except when a truck driver wants to connect the nozzle outside the allowed truck position area and for some positions near the dispenser. To improve service life, a bend restrictor near the nozzle can be used and/or the allowed truck position area can be reduced. The less the hose weight and the less the hose stiffness, the lower the loads at the nozzle.

- Hose failure mid hose: Under normal operating conditions the bending moments are low except when the hose is tangled. This can be avoided by rotating the hose. Within the allowed position area, several truck positions near the dispenser require more nozzle rotation than others. Excluding these areas from the allowed truck position area will reduce these mid-hose failures.

- Hose failure near the dispenser: The bending moments at this location are high when the nozzle is connected outside the allowed truck position area. Reducing the allowed truck position area can help reducing the occurrence of high loads.

The flexible hose length does considerably affect occurrence of high loads:

- For remote truck positions: the less the hose is stretched and the more it is hanging in an easy catenary shape, the lower the loads.

- For truck positions near the dispenser: larger bend radii will be obtained thanks to the longer flexible hose length with reduced local bending moments as a result.

The casing of a dispenser and other equipment near the dispenser can obstruct the hose from having its natural shape with the lowest loads. Several positions near the dispenser are therefore not recommended to be used for fuelling.

All proposed improved hoses had a higher mass and higher stiffness than the hoses used initially, mainly due to means to increase resistance against bending fatigue. However, the need to increase fatigue resistance can likely be relaxed when considering modifications to the dispenser and truck positions. High bending stiffness is not preferred by truck drivers. The hose stiffness of improved hoses in the mid-stiffness range were found acceptable by truck drivers.

From service experience it is known that frozen moisture has a large effect on the hose stiffness. For that reason two of the hoses tested featured vacuum insulation. All hoses, that is with and without vacuum insulation, has been sprayed with water to simulate in-service moisture. In the test however, hardly any effect of ice was observed. The likely reason is that the procedure used to apply ice on the hose surface is not representative for service conditions. As a result, no clear conclusions can be drawn on the benefits of vacuum insulated hoses compared to partially or non-insulated hoses.

The majority of hoses had an internal diameter of 1”. When the fueling duration with a ¾” hose is found acceptable, another parameter can be added to the pallet to optimize the hose performance.

Recommendations for increasing service life of hoses are:

- Mark the sweet spot for truck drivers for parking the truck; reduce the allowed parking area; exclude positions that obstruct the hose from having its natural shape.

- In dispensers design consider: increasing hose length to reduce effects of fueling outside the allowed truck positions; optimizing the nozzle parking positions to reduce bending moments near the nozzle.
- In selecting hoses: less weight and less stiffness reduces loads; consider internal hose diameters less than 1" to allow reducing hose stiffness; evaluated stiffness increase due to frozen water; review options to locally increase the resistance against bending fatigue.

The project results contribute to the transition of diesel to LNG as fuel for trucks:
- It improves the end-user perception on LNG fueling (less failures, higher availability).
- It reduces methane emission due to hose failures.
- It increases the economics of LNG tank stations (less interventions, reduced costs).

The project partners Rolande and Pitpoint, being end-users, invited parties in the supply chain to provide solutions. These parties received in return to their contribution all project results. Rolande and Pitpoint expect that these parties will use the project results to improve their products.

Next to fueling trucks with LNG, also LNG bunkering of vessels is in its development phase. Though there are large differences, they have in common that hoses are used to transfer LNG. As for fueling trucks, there will be a large variation between positions between manifolds. Results of this project can be used to help design bunker facilities.