LNG Loading Emergency Shutdown

Research Project Assessed in AFT Impulse

UNIVERSITY CASE STUDY

Liquefied Natural Gas Transfer

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Applied Flow Technology

QUESTION

With growing climate concerns, the world looks to natural gas to as a clean way to meet energy demands. Liquefied natural gas (LNG) is liquefied by cooling the gas to -160°C or below (<-256°F), loaded into special tankers for transport, then turned back into gas at its next terminal.

The LNG loading process occurs through loading arms, constructed of expensive low-temperature alloys for cryogenic operation and designed to consider the moving vessel the arm is attached to. An LNG terminal might have two to five loading arms for different purposes. In an emergency shutdown, flow through these arms must be suddenly halted by closing a sequence of valves, opening vent valves, and tripping transfer pumps. **The sudden deceleration of flow results in pressure surge, potentially exceeding pipe design pressures and causing extreme pipe stress, further worsening an emergency.**

ANALYSIS

A research team at Lamar University led by Xinyu Liu evaluated the surge results from an LNG loading emergency shutdown. The system, as constructed in AFT Impulse, is found in Figure 1. In addition to a scenario with the emergency system working as intended, the team considered five cases where the system malfunctioned:

1. **Emergency system working properly**
2. **Pumps fail to trip**
3. **Vent valves fail to open**
4. **Pumps fail to trip and vent valves fail to open**
5. **1 of 4 pumps fail to trip**
6. **1 of 3 vent valves fail to open**

The team also evaluated valve characteristics for the closing and opening valves. These characteristics can drastically impact a surge response, so the team performed sensitivity analysis for comparison.

RESULTS

The maximum surge pressure in each case was compared to the pipe's design pressure of 220 psia (15 bar). Only in the worst-case scenario where both the pumps fail to trip and the vent valves fail to open was this design pressure exceeded (Table 1).

While surge pressure did not exceed the design pressure in most cases, **the resulting transient piping forces created major concerns. The imbalanced force would cause stress, deflection, and vibration as the pressure wave transmitted through the system.** The worst-case with pumps running and vent valves closed saw forces exceed 12,000 lbf (53 kN) near the transfer valves.

The team exported their force results from AFT Impulse into ANSYS for a time history analysis and to assess displacement, vibration, and pipe stress (Figure 2).

ELEMENTS OF SUCCESS

The team emphasized the value of performing system sensitivity analysis with a simulation model, especially with the dangerous consequences of surge during an emergency.

By considering forces in addition to pressures, the team could reveal further pipe stress concerns.

> **"Unaddressed pressure surge and pipe stresses caused by an emergency shutdown could cause a secondary emergency condition"**

FIGURE 1

AFT Impulse workspace highlighting the various closing valves, opening vent valves, and tripping pumps essential to the emergency shutdown procedure.

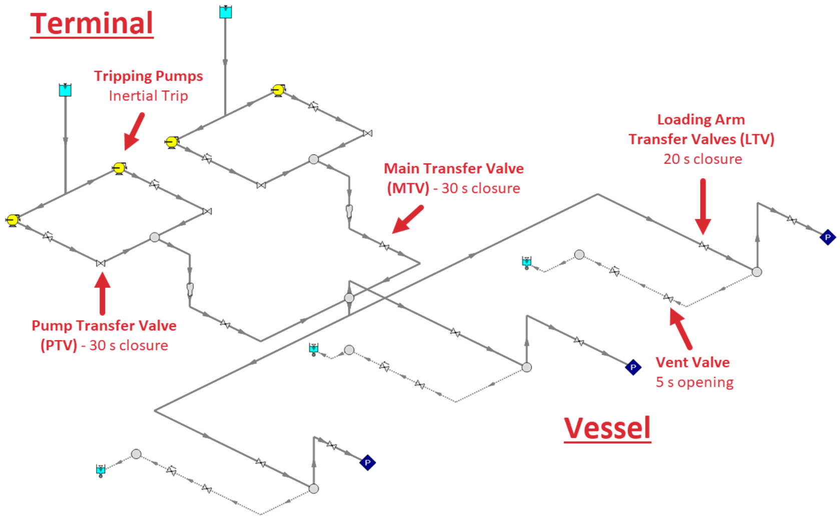

TABLE 1

Table 1: Comparison of maximum surge pressure for each transient case. Only the worst-case with both pump and vent valve failures exceeded the pipe design pressure of 220 psia (15.2 bar)

Case	Max. Surge Pressure psia (bar)	Location of Max. Pressure
1. System working properly	145.3 (10.0	Main Transfer Valve
2. Pumps fail to trip	209 (14.4)	Pump Transfer Valve
3. Vent valves fail to open	207 (14.3)	Loading Arm Transfer Valve
4. Pumps fail to trip and vent valves fail to open	**332 (22.9)**	Pump Transfer Valve
5. 1 of 4 pumps fail to trip	169 (11.6)	Pump Transfer Valve
6. 1 of 3 vent valves fail to open	171 (11.8)	Main Transfer Valve

FIGURE 2

ANSYS stress analysis using forces exported from their AFT Impulse model, graphed below.