INTRODUCTION

LNG is shaping into a competitive alternative fuel for heavy-duty trucks and ships, thanks to its reduced environmental footprint compared to diesel and heavy fuel oil respectively. However, LNG’s cryogenic nature entails a completely different thermodynamic behavior than traditional oil-based fuels.

ENGIE Lab CRIGEN developed the LNGauge software application to provide crucial data on LNG-fueled trucks and vessels at minimum cost and using only a few sensors. LNGauge evaluates in real time and accurately calculates holding time, energy content and Methane Number inside an LNG storage tank. It can be also adapted to predict LNG composition.

WHAT MAKES THE LNGAUGE THE TOOL YOU HAVE BEEN LOOKING FOR?

1. Holding time, energy content and Methane Number are often not provided during LNG vehicle operations. When they are available, accuracy levels have been judged either unsatisfactory by designers and end-users, or too expensive by owners.

2. LNGauge is based on over 50 years of know-how and expertise of the LNG Lab at ENGIE, combined with corroborative testing at the Moncontour-de-Bretagne LNG terminal.

METHODOLOGY

Provided a set of measured (Temperature $T_m$, pressure $P_m$ and density $p_m$), the composition calculation problem can be formulated as finding composition(s) $x_i$ so that:

$$\rho(x, T_m) = \rho_m$$

$$T_m(x, P_m) = T_m$$

$$\sum x_i = 1$$

$$x_i \leq x_i^{\text{max}}$$

Two approaches have been investigated:

- Calculate one composition value based on a non-linear minimization algorithm
- Calculate a composition space based on random sampling of the space of potential solutions

For holding time simulation, the systems can be described by two layers (gas layer and liquid layer), each layer assumed to be homogeneous and defined by its composition, temperature, pressure and mass.

To accurately describe the evolution of the pressure inside the gaseous phase, several physical phenomena are taken into account:

- Gas compressibility
- Conductive heat flux
- Radiative heat flux
- Evaporations

The following equations define respectively the evolution of mass of the gaseous phase, the energy conservation of the liquid phase, the energy conservation of the gas phases, surface evaporation and radiation heat flux.

**RESULTS**

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Relative average error</th>
<th>Absolute average error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane Number</td>
<td>0.15%</td>
<td>0.02 MW/kg</td>
</tr>
<tr>
<td>Holding time</td>
<td>1.52%</td>
<td>1 day</td>
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</tbody>
</table>

Experimental test campaign. Comparison of simulated and measured data at final pressure.