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Standard Specification for LNG Density Calculation Models[1]

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INTRODUCTION

This standard is a description of four mathematical models of the equation of state for LNG-like mixtures that were adopted in 1988. The four models include an extended corresponding states model, a cell model, a hard sphere model, and a revised Klosek and McKinley model. Each of the models has been optimized to the same experimental data set which included data for pure nitrogen, methane, ethane, propane, iso and normal butane, iso and normal pentane, and mixtures thereof. For LNG-like mixtures (mixtures of the orthobaric liquid state at temperatures of 120K or less and containing at least 60 % methane, less than 4 % nitrogen, less than 4 % each of iso and normal butane, and less than 2 % total of iso and normal pentane), all of the models are estimated to predict densities to within 0.1 % of the true value. These models were developed by the National Institute of Standards and Technology (formerly the Bureau of Standards) upon culmination of seven years of effort in acquiring physical properties data, performing extensive experimental measurements using specially developed equipment, and in using these data to develop predictive models for use in density calculations.

1. Scope

1.1 This standard covers LNG density calculation models[2] for use in the calculation or prediction of the densities of saturated LNG mixtures from 90 to 120K to within 0.1 % of true values given the pressure, temperature, and composition of the mixture.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Significance and Use

2.1 The models in this standard can be used to calculate the density of saturated liquid natural gas in the temperature range 90 to 120K. The estimated uncertainty for the density calculations is ±0.1 %. The restrictions on composition of the liquefied natural gas are:

methane	60 % or greater
nitrogen	less than 4 %
n-butane	less than 4 %
i-butane	less than 4 %
pentanes	less than 2 %

It is assumed that hydrocarbons with carbon numbers of six or greater are not present in the LNG solution.

3. Models

3.1 *Extended Corresponding States*—The extended corresponding states method is defined by the following equations:

$$Z_i[P,T] = Z_o[P\, h_{ii,o}/f_{ii,o},\, T/f_{ii,o}] \quad (1)$$

$$G_i[P,T] = f_{ii,o}\, G_o[P\, h_{ii,o}/f_{ii,o},\, T/f_{ii,o}] - RT \ln (h_{ii,o}) \quad (2)$$

where:

Z = compressibility factor,
G = Gibbs free energy,
P = pressure,
T = temperature,
o = reference fluid, and
i = fluid for which properties are to be obtained via the equation of state for the reference fluid and the transformation functions $f_{ii,o}$ and $h_{ii,o}$ are introduced to allow extension of the method to mixtures.

The two defining Eq 1 and Eq 2 are necessary since there are two transformation functions. In this case, an equation of state for methane was chosen for the reference fluid. During the

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