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Standard Specification for Liquefied Natural Gas Density Calculation Models¹

This standard is issued under the fixed designation D4784; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers Liquefied Natural Gas (LNG) density calculation models for use in the calculation or prediction of the densities of saturated LNG mixtures from 90K to 120K to within 0.1 % of true values given the pressure, temperature, and composition of the mixture.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

D4150 Terminology Relating to Gaseous Fuels

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of general terms used in D03 Gaseous Fuels standards, refer to Terminology **D4150**.

3.2 *Abbreviations:*

3.2.1 **LNG**—Liquefied Natural Gas

¹ This standard is under the jurisdiction of ASTM Committee **D03** on Gaseous Fuels and is the direct responsibility of Subcommittee **D03.08** on Thermophysical Properties.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

4. Summary of the Specification

4.1 The models in this specification can be used to calculate the density of saturated liquid natural gas in the temperature range 90K 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 %
<i>n</i> -Butane	less than 4 %
<i>i</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.

5. Model Used

5.1 *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 course of the study it was necessary to modify the equation of state to give a realistic vapor liquid phase boundary down to a temperature of 43K. This modification was necessary to accommodate the very low reduced temperatures of the heavier hydrocarbons and was accomplished without changing the performance of the equation of state above the triple point of methane. The $f_{ii,o}$ and $h_{ii,o}$ are defined as

$$f_{ii,o} = (T_{ii}^c/T_o^c) \theta_{ii,o}(T_{ri}, V_{ri}) \quad (3)$$

and

$$h_{ii,o} = (V_{ii,o}^c/V_o^c) \phi_{ii,o}(T_{ri}, V_{ri}) \quad (4)$$