Manual of Petroleum Measurement Standards
Chapter 11—Physical Properties Data

Section 2, Part 4—Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E, and 60E

ASTM Technical Publication [Stock No. PETROLTBL-TP27]
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Chapter 11—Physical Properties Data

Section 2, Part 4—Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E, and 60E

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Measurement Coordination

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Foreword

For custody transfer purposes, natural gas liquid (NGL) and liquefied petroleum gas (LPG) volumes are generally stated at a fixed base temperature and saturation pressure. As most volume transfers occur at temperatures and pressures other than standard conditions, these volumes are adjusted to standard conditions through the use of correction factors.

This document presents a new method to calculate temperature correction factors. With the publication of this document, previous API, ASTM and GPA documents containing NGL and LPG temperature correction factors should no longer be used. The document is specifically titled as being suitable for NGL and LPG liquids. Light hydrocarbon mixtures containing significant quantities of methane, carbon dioxide and nitrogen which have density ranges which overlap those contained in these tables can be encountered. However, the two-fluid correlation which is the basis of these tables was not calibrated for such mixtures.

The actual Standard represented by this report consists of the explicit implementation procedures. Sample tables and other examples created from a computerized version of these implementation procedures are presented within. However, these are for examples only and do not represent the Standard.

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Table of Contents

Nomenclature

A, B, C	parameters in Section 5.1.2 quadratic equation
C_{TL}	temperature correction factor
h_2	scaling factor
k_1, k_2, k_3, k_4	parameters in saturation density equation
T_B	base temperature (60°F, 15°C, or 20°C)
T_{BK}	base temperature (288.15 K, or 293.15 K)
T_c	fluid critical temperature (K)
$T_{c,ref}$	reference fluid critical temperature (K)
T_F	observed measurement temperature (°F or °C)
$T_{r,x}$	reduced observed temperature
T_x	observed temperature (K)
V_{60}/V_{Tx}	ratio of volume at 60°F to volume at temperature T_x. Is the basic definition of C_{TL}
X	interpolating factor
Z_c	critical compressibility factor
α, β, ϕ	parameters in Section 5.1.2 quadratic equation
δ	interpolation variable
τ	parameter in saturation density equation
γ_x	relative density at observed temperature
$\gamma_{x,high}$	relative density at the observed temperature corresponding to the upper bound for the 60° relative density
$\gamma_{x,low}$	relative density at the observed temperature corresponding to the lower bound for the 60° relative density
$\gamma_{x,mid}$	relative density at the observed temperature corresponding to the intermediate 60° relative density used in Section 5.1.2 iteration procedure
$\gamma_{x,trial}$	trial relative density at the observed temperature used in Section 5.1.2 iteration procedure
γ_{TB}	relative density at the base temperature, T_B
γ_{60}	relative density at a base temperature of 60°F
γ_{Tx}	relative density at the observed temperature, T_x
$\gamma_{60,high}$	upper bound for the observed fluid's 60° relative density
$\gamma_{60,low}$	lower bound for the observed fluid's 60° relative density
$\gamma_{60,mid}$	intermediate 60°F relative density value used in Section 5.1.2 iteration procedure
$\gamma_{60,trial}$	trial 60°F relative density value used in Section 5.1.2 iteration procedure
ρ_c	critical molar density (gram-mole/L)
ρ_{60}	density at a base temperature of 60°F (kg/m^3)
ρ_{15}	density at a base temperature of 15°C (kg/m^3)
ρ_{20}	density at a base temperature of 20°C (kg/m^3)
ρ^{sat}	saturation molar density (gram-mole/L)
ρ_{60}^{sat}	saturation molar density at 60°F (gram-mole/L)
ρ_T^{sat}	saturation molar density at observed temperature (gram-mole/L)

Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E, and 60E

0 Implementation Guidelines

This Revised Standard/Technical Publication is effective upon the date of publication and supersedes the ASTM-IP 1952 Petroleum Measurement Tables, GPA 2142, GPA TP-16, Tables 33 and 34 of API MPMS Chapter 11.1-1980 Volumes XI/XI (Adjuncts to ASTM D1250-80 and IP 200/80), API MPMS Chapter 11.2.2/11.2.2M, and API/ASTM/GPA TP-25. However, due to the nature of the changes in this Revised Standard/Technical Publication and the fact that it is or may be incorporated by reference in various regulations, it is recognized that guidance concerning an implementation period may be needed in order to avoid disruptions within the industry and ensure proper application. As a result, it is recommended that this Revised Standard/Technical Publication be utilized on all new and existing applications no later than TWO YEARS after the publication date. An application, for this purpose, is defined as the point where the calculation is applied.

Once the Revised Standard/Technical Publication is implemented in a particular application, the Previous Standard/Technical Publication will no longer be used in that application.

However, the use of API standards and ASTM and GPA technical publications remains voluntary, and the decision on when to utilize a standard/technical publication is an issue that is subject to the negotiations between the parties involved in the transaction.

1 Introduction

For custody transfer purposes, natural gas liquid (NGL) and liquefied petroleum gas (LPG) volumes are generally stated at a fixed base temperature and saturation pressure. As most volume transfers occur at temperatures and pressures other than standard conditions, these volumes are adjusted to standard conditions through the use of correction factors. Separate factors for temperature (C_{TL}) and pressure (C_{PL}) are used to make these corrections. This document presents a new method to calculate temperature correction factors. Pressure correction factors are not within the scope of this document, but can be calculated using American Petroleum Institute *Manual of Petroleum Measurement Standards* (*MPMS*) Chapter 11.1-2004[1] (which superseded Chapter 11.2.1-1984[2] and 11.2.1M-1984[3]), Chapter 11.2.2-1986/GPA 8286-86[4] or Chapter 11.2.2M-1986/GPA 8286-86[5], depending on product type.

Previously, most NGL and LPG temperature correction factors have been obtained from a variety of sources:

- ASTM-IP "Petroleum Measurement Tables"[6], published in 1952. This publication is limited to a 60°F relative density range of 0.500 and higher.

- GPA Standard 2142, "Standard Factors for Volume Correction and Specific Gravity Conversion of Liquefied Petroleum Gases"[7], published in 1957, also contains the same correction factors as the 1982 ASTM-IP document.

- GPA TP-16 "Composite Pressure and Temperature Volume Correction Factor Tables for Liquefied Petroleum Gas (LPG) and Natural Gasoline"[8], published in 1988. It is limited to the following products: HD-5 Propane with a relative densities of 0.501, 0.505, and 0.510; iso-butane at a relative density of 0.565; normal butane at a relative density of 0.585; and natural gasoline (12-14 psia RVP) at a relative density of 0.664.

- API *MPMS* Chapter 11.1-1980/ASTM D1250-80 Volume XII, Table 33 "Specific Gravity Reduction to 60°F For Liquefied Petroleum Gases and Natural Gasoline"[9].

- API *MPMS* Chapter 11.1-1980/ASTM D1250-80 Volume XII, Table 34 "Reduction of Volume to 60°F Against Specific Gravity 60/60°F For Liquefied Petroleum Gases"[9].

- API/ASTM/GPA TP-25 "Temperature Correction for the Volume of Light Hydrocarbons"[10].

With the publication of this document, the above API, ASTM and GPA documents should no longer be used for NGL and LPG temperature correction factors. Text for TP-25 as approved is included without technical change in this present document.

2 Scope

The actual Standard represented by this report consists of the explicit implementation procedures. Sample tables, flow charts, and specific examples created from a computerized version of these implementation procedures are presented within. The examples are to provide guides and check points to those who wish to implement a computerized procedure to represent the Standard, however these are not a part of the actual Standard.

This Standard covers a 60°F relative density range of 0.3500 to 0.6880 which nominally equates to a density at 15°C of 351.7 to 687.8 kg/m^3 and a density at 20°C of 331.7 to 683.6 kg/m^3. The temperature range of this Standard is –50.8 to 199.4°F (–46 to 93°C). At all conditions, the pressure is assumed to be at saturation conditions (also known as bubble point or saturation vapor pressure).

The calculation method was developed from GPA RR-148 "Volume Correction Factors for Natural Gas Liquids – Phase II"[11] and API/ASTM/GPA Technical Publication, TP-25, September, 1998[10]. The implementation procedures for Tables 23 and 24 are entirely consistent with those presented in TP-25. Supporting data can be found in GPA RR-147 "Density Measurements on Natural Gas Liquids"[12]. GPA RR-133 "Volume Correction Factors for Natural Gas Liquids – Phase I"[13] should no longer be used, as GPA RR-148 completely replaced it.

The implementation procedures describe how to:

1) calculate the C_{TL} given an appropriate density factor at the basis temperature and an observed temperature, and

2) calculate the appropriate density factor at basis temperature given a relative density at an observed temperature.

The implementation procedures are presented in pairs by base temperature. First the procedures for Tables 23 and 24 at a 60°F base temperature are given. The procedure for Table 23 makes use of the procedure described in Table 24 thus Table 24 is presented first. These are followed by procedures for Tables 54 and 53 at a base temperature of 15°C which themselves make use of procedures in described in Tables 23 and 24; these in turn are followed by the procedures for Tables 60 and 59 at a base temperature of 20°C which also make use of procedures in described in Tables 23 and 24.

3 Significant Digits

It is intended that all future temperature correction factors be utilized with five decimal digits (e.g., 0.xxxxx or 1.xxxxx). As a result, this document contains C_{TL} values with only five decimal digits. This is a departure from both the 1952 “ASTM-IP Petroleum Measurement Tables” and GPA TP-16, which give either 3 or 4 decimal digits.

4 Comparison to the Previous Standard

As the 1952 ASTM-IP standard is limited to a low-end relative density of 0.50, a comparison can only be made at higher relative densities. The following figures show how the standards compare. The calculations are performed at 10°F and 5°C increments. It can be noted that the deviation plots for the 0.50 to 0.59 relative densities (500 to 590 kg/m^3 densities) are “ragged” in appearance, while the deviation plots for the higher relative densities are “smooth.” This can mostly be attributed to the 1952 ASTM-IP Standard's rounding method: C_{TL} values under relative density 0.60 contain 3 decimal digits while C_{TL} values greater than 0.600 contain 4 decimal digits.

Note: Negative deviations indicate that the new table C_{TL} is lower than the old (1952) ASTM table C_{TL}. Positive deviations indicate that the new table C_{TL} is higher than the old (1952) ASTM table C_{TL}.

Chart 1: C_{TL} Deviations of New Table 24 Values Compared to Old Table 24 Values

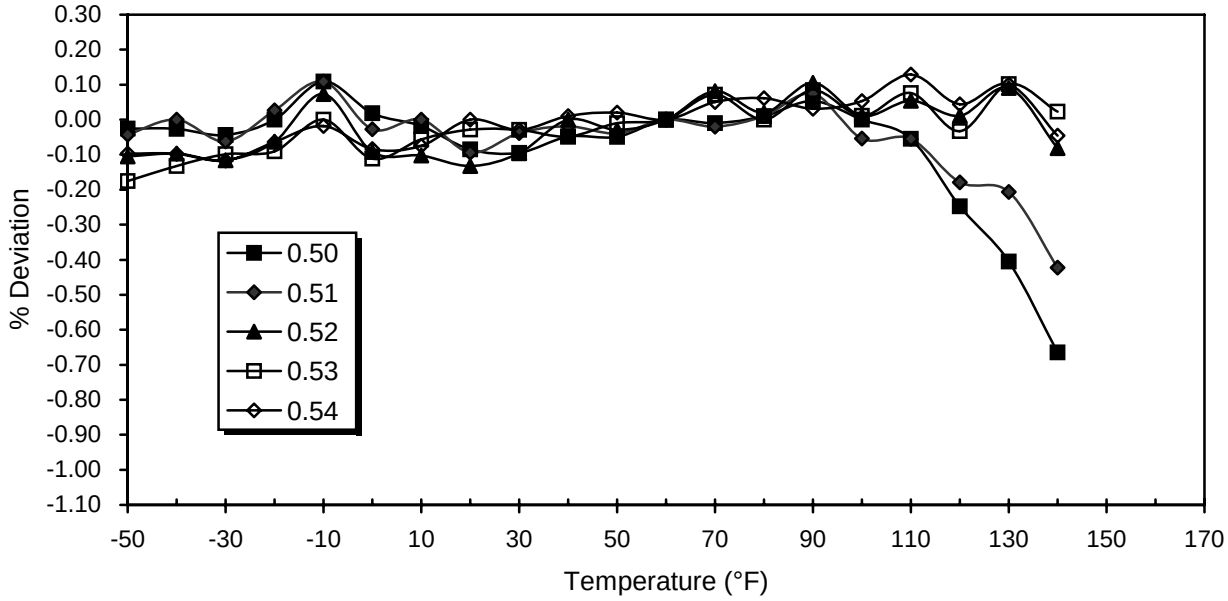


Chart 2: C_{TL} Deviations of New Table 24 Values Compared to Old Table 24 Values

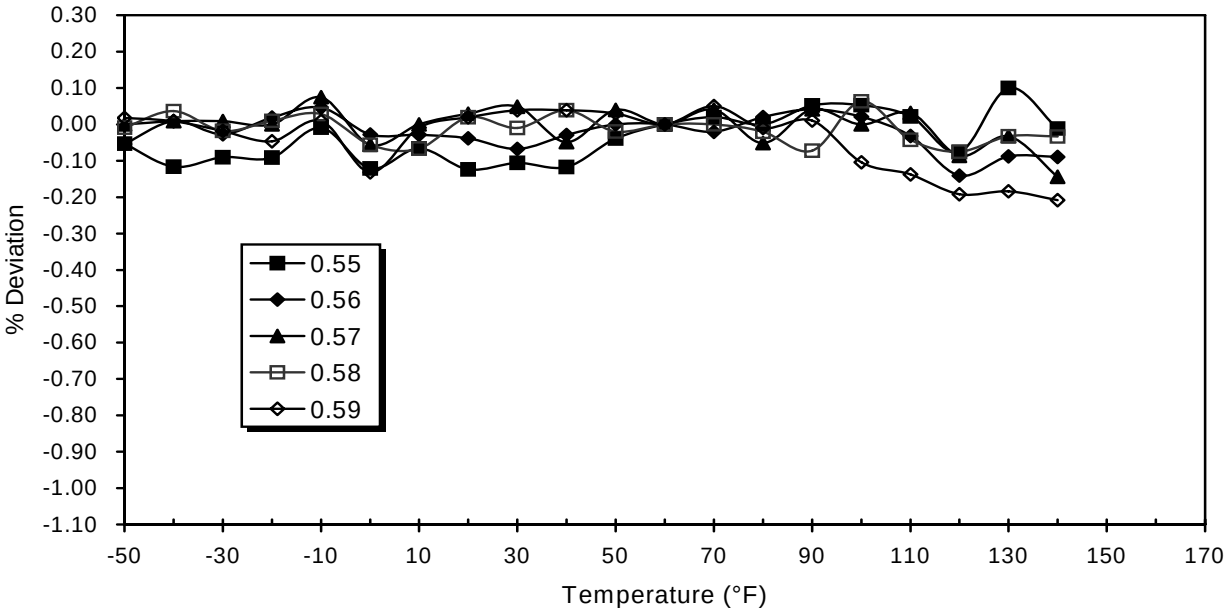


Chart 3: C_{TL} Deviations of New Table 24 Values Compared to Old Table 24 Values

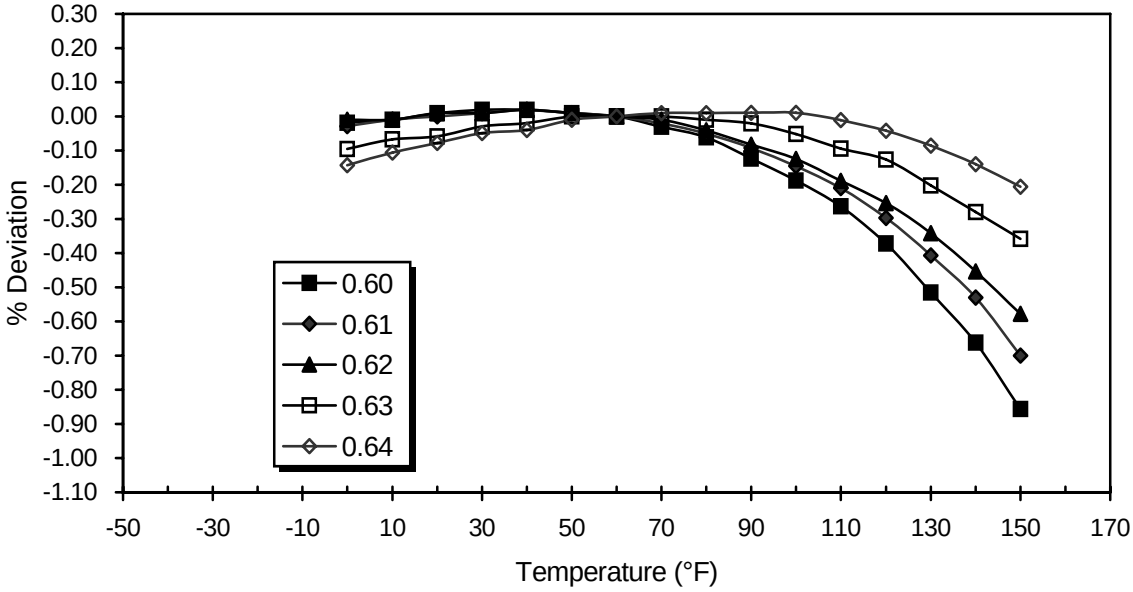


Chart 4: C_{TL} Deviations of New Table 24 Values Compared to Old Table 24 Values

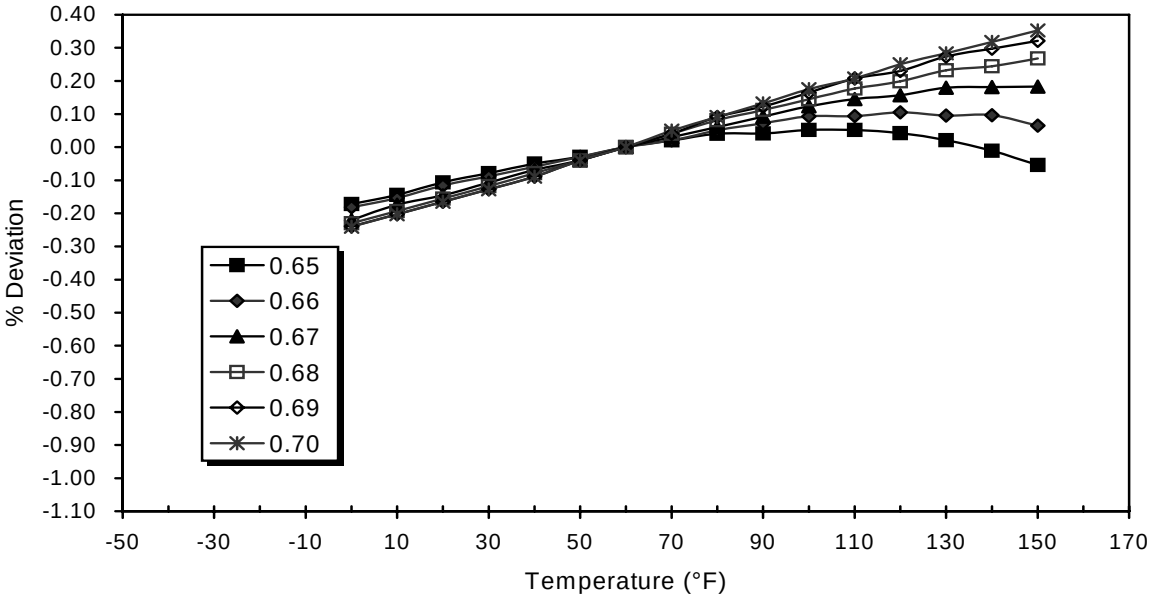


Chart 5: C_{TL} Deviations of New Table 54 Values Compared to Old Table 54 Values

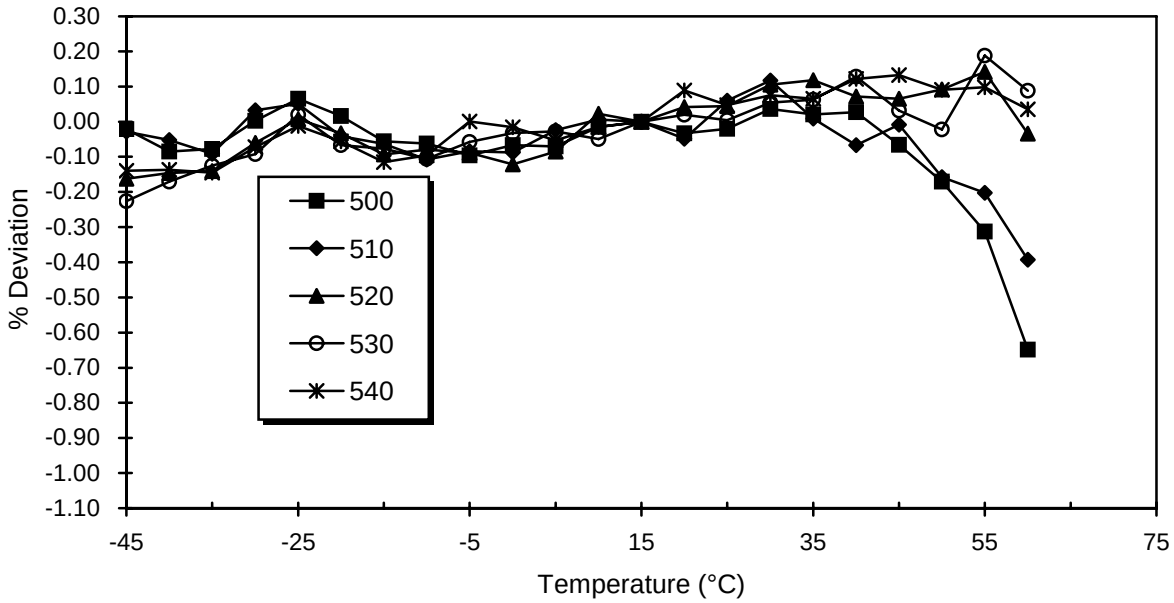


Chart 6: C_{TL} Deviations of New Table 54 Compared to Old Table 54 Values

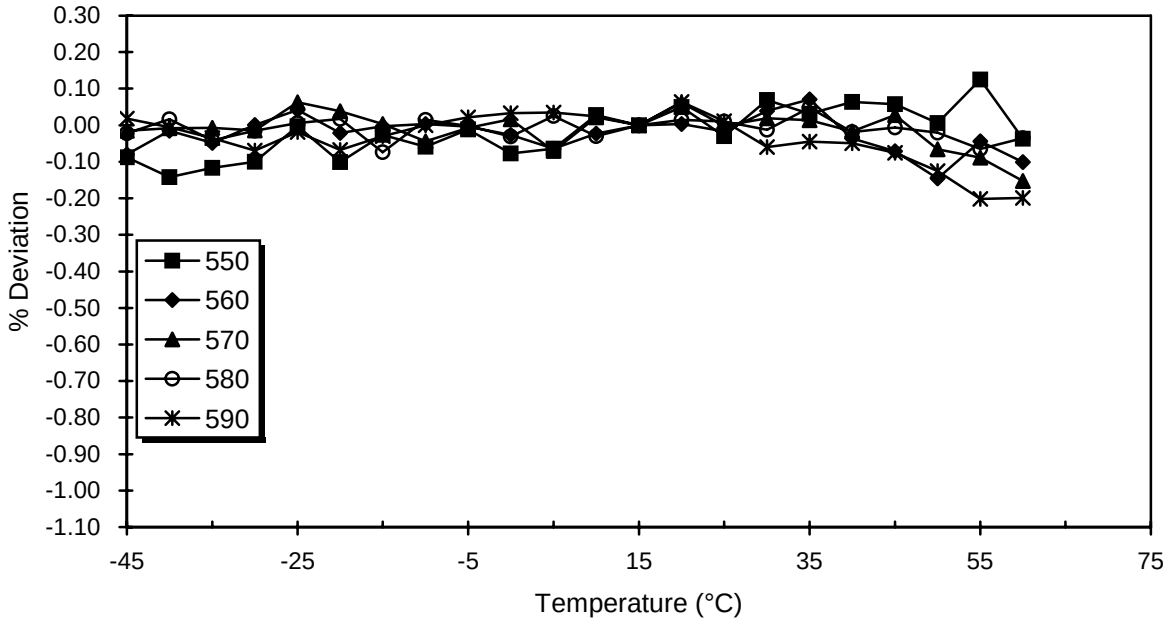


Chart 7: C_{TL} Deviations of New Table 54 Values Compared to Old Table 54 Values

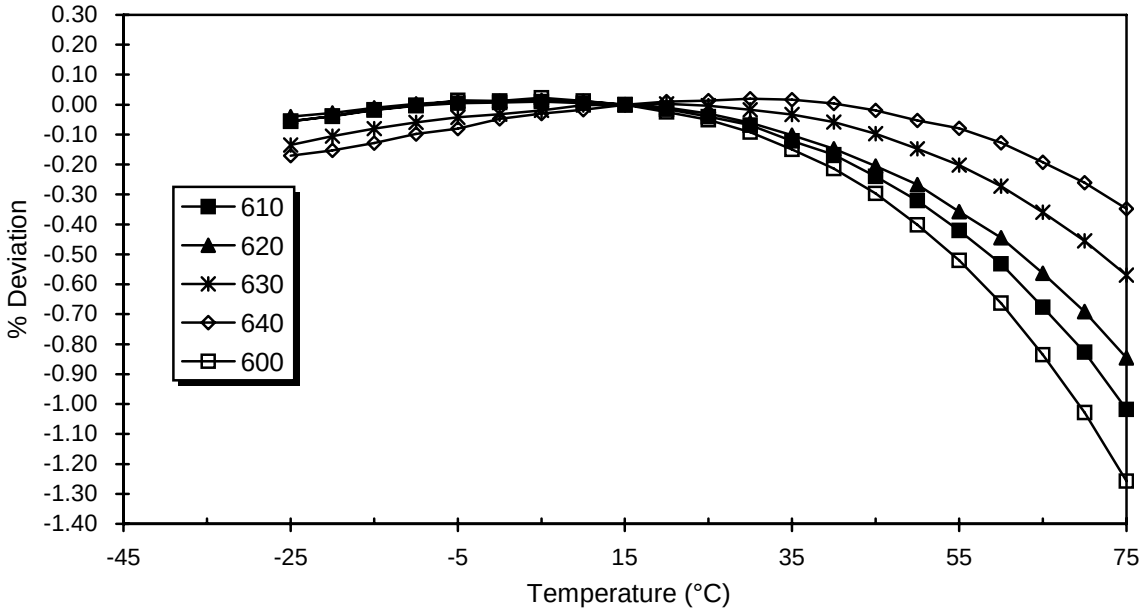
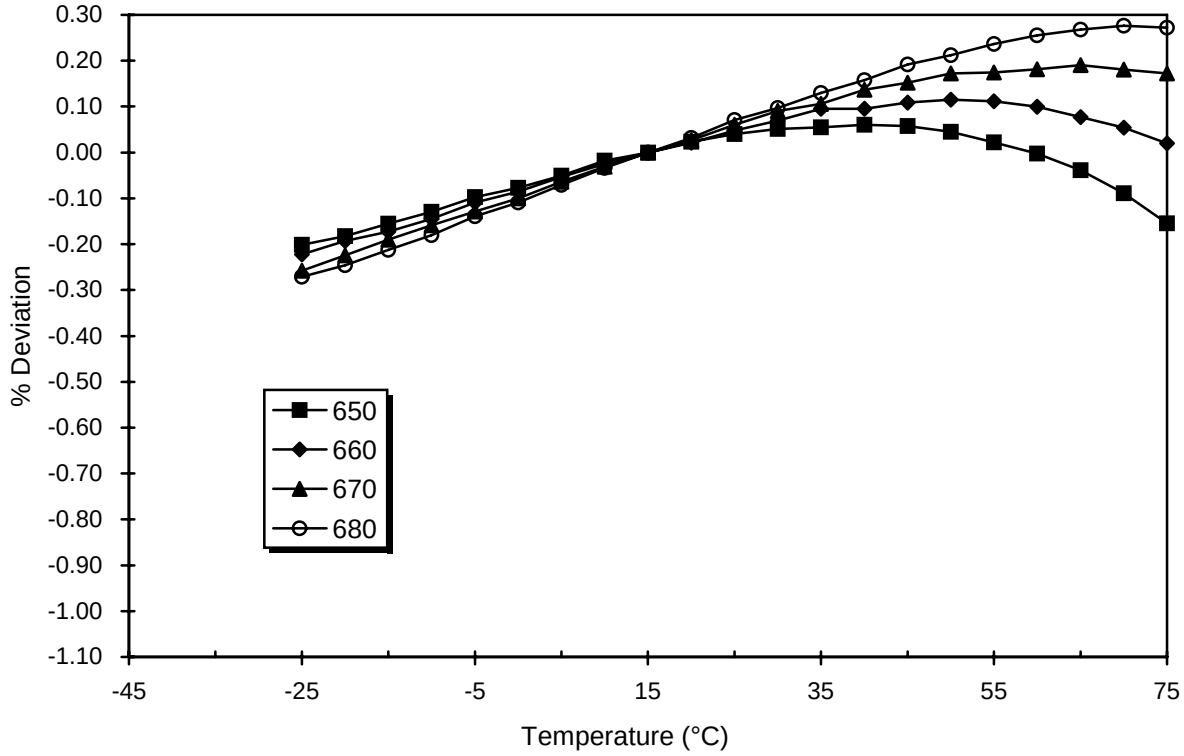


Chart 8: C_{TL} Deviations of New Table 54 Values Compared to Old Table 54 Values



5 Implementation Procedures

The methods to calculate C_{TL} from Tables 24E, 54E, and 60E and relative density at the base temperature from Tables 23E, 53E and 59E follow. These methods are called implementation procedures, which are similar to the methods described and found in American Petroleum Institute *MPMS* Chapter 11.1.

All calculations are to be performed using double precision (i.e., long floating point, eight byte, or 64-bit) arithmetic. This should allow the computer program to recognize the difference between 1.0 and $1.0+\varepsilon$ for absolute values of ε on the order of 10^{-16}. This also means that approximately 16 decimal digits are used for all calculations.

Examples are presented for each of the procedures described, they cover the range of the tables. Even though double precision was used for these example calculations only twelve decimal digits are printed here. If one uses these examples to test their own computer implementation of these procedures, it is suggested that at least eight of the significant digits be matched. The exceptions to this are for the variables α, β, A, B, and C of Table 23 (Section 5.1.2). These may show greater deviation, but the resulting $\gamma_{60,trial}$ and $\gamma_{x,trial}$ values should match within eight significant digits.

5.1 CTL (Table 24) and Relative Density (Table 23) for NGL and LPG using a 60°F Base Temperature

5.1.1 Implementation Procedure for Table 24E (60°F Basis)

This section presents the implementation procedure T24 for the computation of Temperature Correction Factor, C_{TL}. The C_{TL} is used to calculate volumes of fluid at the base temperature from volumes at some known measurement temperature. The fluids are characterized by the specification of relative density at the base temperature, 60°F.

5.1.1.1 Inputs and Outputs

Inputs: Relative density at 60°F, γ_{60}
Observed temperature, T_F (°F)

Output: Temperature Correction Factor, C_{TL} (from T_F to T_B)

5.1.1.2 Outline of Calculations

The calculations are performed using an extended two-fluid corresponding states equation. By comparing densities at 60°F, two reference fluids are selected so that one is slightly more dense and one is slightly less dense than the observed fluid. The densities of these reference fluids are then scaled to the observed reduced temperature (reduced by the critical temperature of the fluid of interest). The Temperature Correction Factor is then computed from the reference fluid densities. See Figure 1 for a general flow chart of the calculation procedure.

5.1.1.3 T24 Implementation Procedure

T24/Step Number Operation/Procedure at that step

T24/1: Round the relative density γ_{60} to the nearest 0.0001 and round the observed temperature T_F to the nearest 0.1°F.

Temperature rounding examples: –0.05 rounds to –0.1; –0.049 rounds to 0.0, –0.051 rounds to –0.1. Density rounding examples follow: 0.35555 rounds to 0.3556, 0.40289 rounds to 0.4029.

T24/2: Convert the rounded observed temperature to units of Kelvin, T_x:

$$T_x = \frac{T_F + 459.67}{1.8}$$

T24/3: The resultant temperature T_x and relative density γ_{60} must fall within the following boundaries:

Temperature between 227.15 and 366.15 K, inclusive (equivalent to –46 to 93°C, or –50.8 to 199.4°F)
Relative density between 0.3500 and 0.6880, inclusive

If these values do not fall in these ranges, then the standard does not apply. Flag this result (possibly by returning a –1 for C_{TL}) and exit this procedure.

T24/4: Determine the two adjacent reference fluids to be used for the calculations. The rounded 60°F relative density γ_{60} will fit between two reference fluids' 60°F relative densities as listed in Table 1. Choose the lowest density reference fluid that has a density value greater than or equal to γ_{60} and refer to this fluid using the subscript "2." Also use the next lowest density reference fluid and refer to this fluid using the subscript "1."

T24/5: Using Table 1, 60°F relative densities, compute the interpolation variable, δ:

$$\delta = \frac{\gamma_{60} - \gamma_{60,1}}{\gamma_{60,2} - \gamma_{60,1}}$$

T24/6: From Table 1 critical temperatures, calculate the fluid critical temperature, T_c:

$$T_c = T_{c,1} + \delta(T_{c,2} - T_{c,1})$$

T24/7: Compute the fluid's reduced observed temperature, $T_{r,x}$:

$$T_{r,x} = \frac{T_x}{T_c}$$

If the reduced temperature $T_{r,x}$ is greater than 1.0, then the fluid is at supercritical conditions and cannot exist as a liquid. Flag this result (possibly by returning a –1 for C_{TL}) and exit this procedure.

T24/8: Compute the reduced temperature at 60°F, $T_{r,60}$:

$$T_{r,60} = \frac{519.67}{1.8T_c}$$

T24/9: From Table 1 critical compressibility factors, Z_c, and critical densities, ρ_c, calculate the scaling factor, h_2:

$$h_2 = \frac{Z_{c,1} \times \rho_{c,1}}{Z_{c,2} \times \rho_{c,2}}$$

T24/10: Calculate the saturation density for both reference fluids at 60°F using the 60° reduced temperature, $T_{r,60}$. For each fluid, the equations to calculate the saturation density at any reduced temperature T_r are:

$$\tau = 1 - T_r$$

$$\rho^{sat} = \rho_c \left(1 + \frac{\left(k_1 \times \tau^{0.35}\right) + \left(k_3 \times \tau^2\right) + \left(k_4 \times \tau^3\right)}{1 + \left(k_2 \times \tau^{0.65}\right)} \right)$$

where the k_1, k_2, k_3, and k_4 parameters are different for each reference fluid and are listed in Table 1. Refer to the calculated density for the first reference fluid as $\rho_{60,1}^{sat}$ and for the second reference fluid as $\rho_{60,2}^{sat}$.

T24/11: Calculate the interpolating factor X:

$$X = \frac{\rho_{60,1}^{sat}}{1 + \delta \left[\left(\frac{\rho_{60,1}^{sat}}{h_2 \times \rho_{60,2}^{sat}} \right) - 1 \right]}$$

T24/12: Obtain the saturation density for both reference fluids at reduced observed temperature $T_{r,x}$ using the procedure in Step T24/10. Refer to the calculated density for the first reference fluid as $\rho_{60,1}^{sat}$ and that for the second reference fluid at $\rho_{60,2}^{sat}$.

T24/13: Calculate the Temperature Correction Factor at the observed temperature, C_{TL}:

$$C_{TL} = \frac{\rho_{x,1}^{sat}}{X\left[1+\delta\left(\frac{\rho_{x,1}^{sat}}{h_2 \times \rho_{x,2}^{sat}}-1\right)\right]}$$

T24/14: Round the Temperature Correction Factor C_{TL} to the nearest 0.00001. Exit this procedure.

Table 1: Reference Fluid Parameters

No.	Fluid Name	γ_{60}	T_c	Z_c	ρ_c	k_1	k_2	k_3	k_4
1	EE (68/32)[1]	0.325022	298.11	0.27998	6.250	2.54616855327	–0.058244177754	0.803398090807	–0.745720314137
2	Ethane	0.355994	305.33	0.28220	6.870	1.89113042610	–0.370305782347	–0.544867288720	0.337876634952
3	EP (65/35)[2]	0.429277	333.67	0.28060	5.615	2.20970078464	–0.294253708172	–0.405754420098	0.319443433421
4	EP (35/65)[3]	0.470381	352.46	0.27930	5.110	2.25341981320	–0.266542138024	–0.372756711655	0.384734185665
5	Propane	0.507025	369.78	0.27626	5.000	1.96568366933	–0.327662435541	–0.417979702538	0.303271602831
6	i-Butane	0.562827	407.85	0.28326	3.860	2.04748034410	–0.289734363425	–0.330345036434	0.291757103132
7	n-Butane	0.584127	425.16	0.27536	3.920	2.03734743118	–0.299059145695	–0.418883095671	0.380367738748
8	i-Pentane	0.624285	460.44	0.27026	3.247	2.06541640707	–0.238366208840	–0.161440492247	0.258681568613
9	n-Pentane	0.631054	469.65	0.27235	3.200	2.11263474494	–0.261269413560	–0.291923445075	0.308344290017
10	i-Hexane	0.657167	498.05	0.26706	2.727	2.02382197871	–0.423550090067	–1.152810982570	0.950139001678
11	n-Hexane	0.664064	507.35	0.26762	2.704	2.17134547773	–0.232997313405	–0.267019794036	0.378629524102
12	n-Heptane	0.688039	540.15	0.26312	2.315	2.19773533433	–0.275056764147	–0.447144095029	0.493770995799

Table Notes:

γ_{60} is the fluid relative density at 60°F and saturation pressure

T_c is the fluid critical temperature in Kelvin

Z_c is the fluid critical compressibility factor

ρ_c is the fluid critical density in gram-moles per liter

k_1, k_2, k_3, and k_4 are saturation density fitting parameters

(1) EE (68/32) denotes a 68 mole % ethane + 32 % ethylene mixture

(2) EP (65/35) denotes a 65 mole % ethane + 35 % propane mixture

(3) EP (35/65) denotes a 35 mole % ethane + 65 % propane mixture

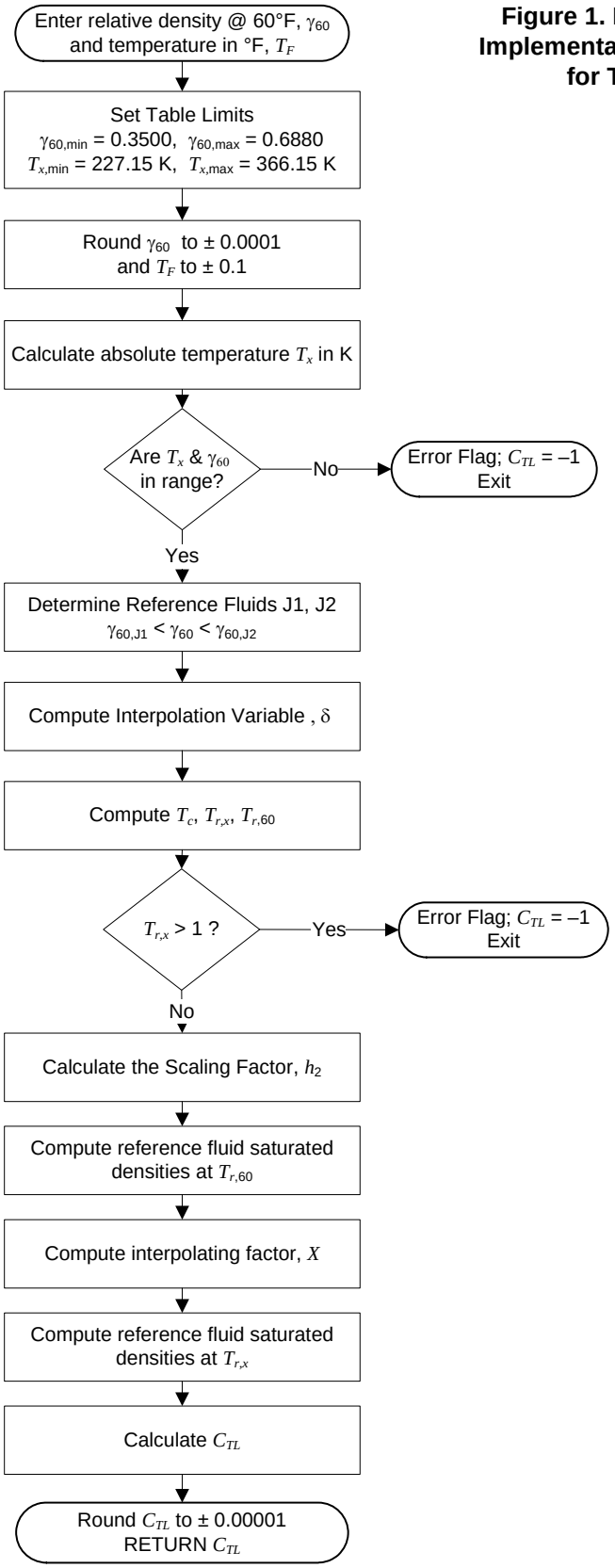


Figure 1. Flow Chart of Implementation Procedure for Table 24

5.1.1.4 Examples for Section 5.1.1 (Table 24E)

(See Table 1 for properties of the Reference Fluids)

Example 24/1 – Utilize EE (68/32) and Ethane

```
    Input Data
Relative density @ 60°F RD60 ...    0.350130
Observed temperature Tf, °F ....  –48.0200
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.3501
Tf, °F, rounded to 0.1 .........  –48.0
  T24/2
Tx, Kelvin .....................  228.705555555556
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
  T24/5
Delta ..........................    0.809699083043
  T24/6
Critical temperature Tc ........  303.956027379569
  T24/7
Reduced observed temp. Tr,x ....    0.752429742971
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.949826716859
  T24/9
Scaling factor h2 ..............    0.902595741301
  T24/10
Tau for fluid at 60°F ..........    0.050173283141
Sat den fluid 1 at 60°F ........   11.892882208216
Sat den fluid 2 at 60°F ........   11.673968376914
  T24/11
Interpolating factor X .........   10.770572039296
  T24/12
Tau for fluid at obs. temp. ....    0.247570257029
Sat den fluid 1 at obs. temp. ..   16.490243357324
Sat den fluid 2 at obs. temp. ..   16.012272020935
  T24/13
CTL ............................    1.374174158511
  T24/14
CTL rounded ....................    1.37417
```

Example 24/2 – Utilize Ethane and EP (65/35)

```
    Input Data
Relative density @ 60°F RD60 ...    0.399950
Observed temperature Tf, °F ....   24.9500
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.4000
Tf, °F, rounded to 0.1 .........   25.0
  T24/2
Tx, Kelvin .....................  269.261111111111
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
  T24/5
Delta ..........................    0.600493975410
  T24/6
Critical temperature Tc ........  322.347999263131
  T24/7
Reduced observed temp. Tr,x ....    0.835311873276
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.895633154899
  T24/9
Scaling factor h2 ..............    1.230484986694
  T24/10
Tau for fluid at 60°F ..........    0.104366845101
Sat den fluid 1 at 60°F ........   13.268022876946
Sat den fluid 2 at 60°F ........   11.625034524899
  T24/11
Interpolating factor X .........   13.871545440974
  T24/12
Tau for fluid at obs. temp. ....    0.164688126724
Sat den fluid 1 at obs. temp. ..   14.572475327916
Sat den fluid 2 at obs. temp. ..   12.816926793350
  T24/13
CTL ............................    1.100764647588
  T24/14
CTL rounded ....................    1.10076
```

Example 24/3 – Utilize EP (65/35) and EP (35/65)

```
    Input Data
Relative density @ 60°F RD60 ...    0.451530
Observed temperature Tf, °F ....   87.4200
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.4515
Tf, °F, rounded to 0.1 .........   87.4
  T24/2
Tx, Kelvin .....................  303.927777777778
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  EP (65/35)
Reference Fluid 2 ..............  EP (35/65)
  T24/5
Delta ..........................    0.540652977812
  T24/6
Critical temperature Tc ........  343.828869453095
  T24/7
Reduced observed temp. Tr,x ....    0.883950723106
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.839678052674
  T24/9
Scaling factor h2 ..............    1.103940309258
  T24/10
Tau for fluid at 60°F ..........    0.160321947326
Sat den fluid 1 at 60°F ........   12.739470807395
Sat den fluid 2 at 60°F ........   11.668538966703
  T24/11
Interpolating factor X .........   12.815798776833
  T24/12
Tau for fluid at obs. temp. ....    0.116049276894
Sat den fluid 1 at obs. temp. ..   11.880371290411
Sat den fluid 2 at obs. temp. ..   10.885682581443
  T24/13
CTL ............................    0.932749411288
  T24/14
CTL rounded ....................    0.93275
```

Example 24/4 – Utilize EP (35/65) and Propane

```
    Input Data
Relative density @ 60°F RD60 ...    0.490400
Observed temperature Tf, °F ....  184.9700
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.4904
Tf, °F, rounded to 0.1 .........  185.0
  T24/2
Tx, Kelvin .....................  358.150000000000
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  EP (35/65)
Reference Fluid 2 ..............  Propane
  T24/5
Delta ..........................    0.546310446458
  T24/6
Critical temperature Tc ........  361.922096932649
  T24/7
Reduced observed temp. Tr,x ....    0.989577599808
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.797700825682
  T24/9
Scaling factor h2 ..............    1.033246217331
  T24/10
Tau for fluid at 60°F ..........    0.202299174318
Sat den fluid 1 at 60°F ........   12.309519597134
Sat den fluid 2 at 60°F ........   11.272394278161
  T24/11
Interpolating factor X .........   11.938610116810
  T24/12
Tau for fluid at obs. temp. ....    0.010422400192
Sat den fluid 1 at obs. temp. ..    7.473276954765
Sat den fluid 2 at obs. temp. ..    7.023541210265
  T24/13
CTL ............................    0.615949186930
  T24/14
CTL rounded ....................    0.61595
```

Example 24/5 – Utilize Propane and i-Butane

```
    Input Data
Relative density @ 60°F RD60 ...    0.540020
Observed temperature Tf, °F ....  155.0400
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.5400
Tf, °F, rounded to 0.1 .........  155.0
  T24/2
Tx, Kelvin .....................  341.483333333333
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  Propane
Reference Fluid 2 ..............  i-Butane
  T24/5
Delta ..........................    0.590928640551
  T24/6
Critical temperature Tc ........  392.276653345758
  T24/7
Reduced observed temp. Tr,x ....    0.870516586753
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.735974351502
  T24/9
Scaling factor h2 ..............    1.263326064155
  T24/10
Tau for fluid at 60°F ..........    0.264025648498
Sat den fluid 1 at 60°F ........   12.016437691588
Sat den fluid 2 at 60°F ........    9.429772887863
  T24/11
Interpolating factor X .........   11.955024717591
  T24/12
Tau for fluid at obs. temp. ....    0.129483413247
Sat den fluid 1 at obs. temp. ..   10.227566043346
Sat den fluid 2 at obs. temp. ..    8.025028872910
  T24/13
CTL ............................    0.851071799690
  T24/14
CTL rounded ....................    0.85107
```

Example 24/6 – Utilize i-Butane and n-Butane

```
    Input Data
Relative density @ 60°F RD60 ...    0.569980
Observed temperature Tf, °F ....    3.0330
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.5700
Tf, °F, rounded to 0.1 .........    3.0
  T24/2
Tx, Kelvin .....................  257.038888888889
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  i-Butane
Reference Fluid 2 ..............  n-Butane
  T24/5
Delta ..........................    0.336760563380
  T24/6
Critical temperature Tc ........  413.679325352113
  T24/7
Reduced observed temp. Tr,x ....    0.621348163025
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.697896988954
  T24/9
Scaling factor h2 ..............    1.012944464538
  T24/10
Tau for fluid at 60°F ..........    0.302103011046
Sat den fluid 1 at 60°F ........    9.757836502218
Sat den fluid 2 at 60°F ........    9.883346486657
  T24/11
Interpolating factor X .........    9.841741258063
  T24/12
Tau for fluid at obs. temp. ....    0.378651836975
Sat den fluid 1 at obs. temp. ..   10.367065629858
Sat den fluid 2 at obs. temp. ..   10.496815949474
  T24/13
CTL ............................    1.062314380669
  T24/14
CTL rounded ....................    1.06231
```

Example 24/7 – Utilize n-Butane and i-Pentane

```
    Input Data
Relative density @ 60°F RD60 ...    0.599970
Observed temperature Tf, °F ....  110.0400
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.6000
Tf, °F, rounded to 0.1 .........  110.0
  T24/2
Tx, Kelvin .....................  316.483333333333
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  n-Butane
Reference Fluid 2 ..............  i-Pentane
  T24/5
Delta ..........................    0.395263708352
  T24/6
Critical temperature Tc ........  439.104903630659
  T24/7
Reduced observed temp. Tr,x ....    0.720746524843
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.657486521258
  T24/9
Scaling factor h2 ..............    1.230050265162
  T24/10
Tau for fluid at 60°F ..........    0.342513478742
Sat den fluid 1 at 60°F ........   10.214309417120
Sat den fluid 2 at 60°F ........    8.446076234558
  T24/11
Interpolating factor X .........   10.282689503192
  T24/12
Tau for fluid at obs. temp. ....    0.279253475157
Sat den fluid 1 at obs. temp. ..    9.687510842155
Sat den fluid 2 at obs. temp. ..    8.011335247961
  T24/13
CTL ............................    0.948465346003
  T24/14
CTL rounded ....................    0.94847
```

Example 24/8 – Utilize i-Pentane and n-Pentane

```
    Input Data
Relative density @ 60°F RD60 ...    0.625020
Observed temperature Tf, °F ....  169.9700
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.6250
Tf, °F, rounded to 0.1 .........  170.0
  T24/2
Tx, Kelvin .....................  349.816666666667
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  i-Pentane
Reference Fluid 2 ..............  n-Pentane
  T24/5
Delta ..........................    0.105628600975
  T24/6
Critical temperature Tc ........  461.412839414980
  T24/7
Reduced observed temp. Tr,x ....    0.758142463288
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.625699007253
  T24/9
Scaling factor h2 ..............    1.006900839912
  T24/10
Tau for fluid at 60°F ..........    0.374300992747
Sat den fluid 1 at 60°F ........    8.652500418110
Sat den fluid 2 at 60°F ........    8.668052899178
  T24/11
Interpolating factor X .........    8.660400031891
  T24/12
Tau for fluid at obs. temp. ....    0.241857536712
Sat den fluid 1 at obs. temp. ..    7.734059015744
Sat den fluid 2 at obs. temp. ..    7.744880148272
  T24/13
CTL ............................    0.893815224960
  T24/14
CTL rounded ....................    0.89382
```

Example 24/9 – Utilize n-Pentane and i-Hexane

```
    Input Data
Relative density @ 60°F RD60 ...    0.640040
Observed temperature Tf, °F ....  –12.0200
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.6400
Tf, °F, rounded to 0.1 .........  –12.0
  T24/2
Tx, Kelvin .....................  248.705555555556
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  n-Pentane
Reference Fluid 2 ..............  i-Hexane
  T24/5
Delta ..........................    0.342587982997
  T24/6
Critical temperature Tc ........  479.379498717114
  T24/7
Reduced observed temp. Tr,x ....    0.518807241906
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.602248440595
  T24/9
Scaling factor h2 ..............    1.196694721271
  T24/10
Tau for fluid at 60°F ..........    0.397751559405
Sat den fluid 1 at 60°F ........    8.816158414827
Sat den fluid 2 at 60°F ........    7.499847998980
  T24/11
Interpolating factor X .........    8.869948165069
  T24/12
Tau for fluid at obs. temp. ....    0.481192758094
Sat den fluid 1 at obs. temp. ..    9.321161815695
Sat den fluid 2 at obs. temp. ..    7.929963121410
  T24/13
CTL ............................    1.057304685863
  T24/14
CTL rounded ....................    1.05730
```

Example 24/10 – Utilize i-Hexane and n-Hexane

```
    Input Data
Relative density @ 60°F RD60 ...    0.660033
Observed temperature Tf, °F ....  177.0450
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.6600
Tf, °F, rounded to 0.1 .........  177.0
  T24/2
Tx, Kelvin .....................  353.705555555556
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  i-Hexane
Reference Fluid 2 ..............  n-Hexane
  T24/5
Delta ..........................    0.410758300710
  T24/6
Critical temperature Tc ........  501.870052196607
  T24/7
Reduced observed temp. Tr,x ....    0.704775178370
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.575259580228
  T24/9
Scaling factor h2 ..............    1.006395599121
  T24/10
Tau for fluid at 60°F ..........    0.424740419772
Sat den fluid 1 at 60°F ........    7.641170665754
Sat den fluid 2 at 60°F ........    7.665708531720
  T24/11
Interpolating factor X .........    7.671217510578
  T24/12
Tau for fluid at obs. temp. ....    0.295224821630
Sat den fluid 1 at obs. temp. ..    6.925133823039
Sat den fluid 2 at obs. temp. ..    6.945363609083
  T24/13
CTL ............................    0.906185214223
  T24/14
CTL rounded ....................    0.90619
```

Example 24/11 – Utilize n-Hexane and n-Heptane

```
    Input Data
Relative density @ 60°F RD60 ...    0.670042
Observed temperature Tf, °F ....  181.0300
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.6700
Tf, °F, rounded to 0.1 .........  181.0
  T24/2
Tx, Kelvin .....................  355.927777777778
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
  T24/5
Delta ..........................    0.247591240876
  T24/6
Critical temperature Tc ........  515.470992700730
  T24/7
Reduced observed temp. Tr,x ....    0.690490411328
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.560081090195
  T24/9
Scaling factor h2 ..............    1.188010824747
  T24/10
Tau for fluid at 60°F ..........    0.439918909805
Sat den fluid 1 at 60°F ........    7.744857153990
Sat den fluid 2 at 60°F ........    6.743069361289
  T24/11
Interpolating factor X .........    7.809053198722
  T24/12
Tau for fluid at obs. temp. ....    0.309509588672
Sat den fluid 1 at obs. temp. ..    7.030188106398
Sat den fluid 2 at obs. temp. ..    6.111938115029
  T24/13
CTL ............................    0.907404360428
  T24/14
CTL rounded ....................    0.90740
```

Example 24/12 – Reduced temperature Tr,x greater than 1

```
    Input Data
Relative density @ 60°F RD60 ...    0.350180
Observed temperature Tf, °F ....  195.0250
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.3502
Tf, °F, rounded to 0.1 .........  195.0
  T24/2
Tx, Kelvin .....................  363.705555555556
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
  T24/5
Delta ..........................    0.812927805760
  T24/6
Critical temperature Tc ........  303.979338757587
  T24/7
Reduced observed temp. Tr,x ....    1.196481172181
Reduced temperature Tr,x greater than 1.0, no solution
```

Example 24/13 – Tf < lower range limit

```
    Input Data
Relative density @ 60°F RD60 ...    0.500000
Observed temperature Tf, °F ....  –50.8500
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.5000
Tf, °F, rounded to 0.1 .........  –50.9
  T24/2
Tx, Kelvin .....................  227.094444444444
  T24/3
Tx less than 227.15, no solution
```

Example 24/14 – RD60 < lower range limit

```
    Input Data
Relative density @ 60°F RD60 ...    0.349940
Observed temperature Tf, °F ....   40.0000
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.3499
Tf, °F, rounded to 0.1 .........   40.0
  T24/2
Tx, Kelvin .....................  277.594444444444
  T24/3
RD60 is less than 0.3500, no solution
```

Example 24/15 – Tf > upper range limit

```
    Input Data
Relative density @ 60°F RD60 ...    0.450000
Observed temperature Tf, °F ....  199.4600
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.4500
Tf, °F, rounded to 0.1 .........  199.5
  T24/2
Tx, Kelvin .....................  366.205555555556
  T24/3
Tx greater than 366.15, no solution
```

Example 24/16 – RD60 > upper range limit

```
    Input Data
Relative density @ 60°F RD60 ...    0.688070
Observed temperature Tf, °F ....    0.0000
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.6881
Tf, °F, rounded to 0.1 .........    0.0
  T24/2
Tx, Kelvin .....................  255.372222222222
  T24/3
RD60 is greater than 0.6880, no solution
```

Example 24/17 – Tf & RD60 = upper range limits

```
    Input Data
Relative density @ 60°F RD60 ...    0.688000
Observed temperature Tf, °F ....  199.4400
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.6880
Tf, °F, rounded to 0.1 .........  199.4
  T24/2
Tx, Kelvin .....................  366.150000000000
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
  T24/5
Delta ..........................    0.998373305527
  T24/6
Critical temperature Tc ........  540.096644421272
  T24/7
Reduced observed temp. Tr,x ....    0.677934224887
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.534544249696
  T24/9
Scaling factor h2 ..............    1.188010824747
  T24/10
Tau for fluid at 60°F ..........    0.465455750304
Sat den fluid 1 at 60°F ........    7.876480858049
Sat den fluid 2 at 60°F ........    6.859355371549
  T24/11
Interpolating factor X .........    8.148529834765
  T24/12
Tau for fluid at obs. temp. ....    0.322065775113
Sat den fluid 1 at obs. temp. ..    7.103375621618
Sat den fluid 2 at obs. temp. ..    6.176601533604
  T24/13
CTL ............................    0.900466171184
  T24/14
CTL rounded ....................    0.90047
```

Example 24/18 – Tf & RD60 = lower range limits

```
    Input Data
Relative density @ 60°F RD60 ...    0.350000
Observed temperature Tf, °F ....  –50.8000
    Computed Data – last digit is rounded
  T24/1
    Input Data – rounded
RD60, rounded to 0.0001 ........    0.3500
Tf, °F, rounded to 0.1 .........  –50.8
  T24/2
Tx, Kelvin .....................  227.150000000000
  T24/3
Input data within range
  T24/4
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
  T24/5
Delta ..........................    0.806470360325
  T24/6
Critical temperature Tc ........  303.932716001550
  T24/7
Reduced observed temp. Tr,x ....    0.747369361839
  T24/8
Reduced temp. at 60°F Tr,60 ....    0.949899567752
  T24/9
Scaling factor h2 ..............    0.902595741301
  T24/10
Tau for fluid at 60°F ..........    0.050100432248
Sat den fluid 1 at 60°F ........   11.889940226938
Sat den fluid 2 at 60°F ........   11.671295077352
  T24/11
Interpolating factor X .........   10.772124448866
  T24/12
Tau for fluid at obs. temp. ....    0.252630638161
Sat den fluid 1 at obs. temp. ..   16.573069193167
Sat den fluid 2 at obs. temp. ..   16.091771523334
  T24/13
CTL ............................    1.381375977418
  T24/14
CTL rounded ....................    1.38138
```

5.1.2 Implementation Procedure for Table 23E (60°F Basis)

This section presents the implementation procedure T23 for calculating the relative densities of NGLs and LPGs at a base conditions of 60°F from known temperatures and densities.

In the past, a hydrometer correction option was allowed so as to be able to correct for the expansion of the glass comprising a hydrometer stem. The hydrometer correction previously took the following form:

Observed densities determined by a glass hydrometer require correction for the effect of temperature on the instrument. Readings from most density meters do not. If the density was determined with a glass hydrometer, then a correction for the expansion or contraction of the glass must be made. Call the rounded observed relative density the uncorrected relative density γ_x^*. Calculate the corrected relative density, γ_x, from:

$$\gamma_x = [1 - 0.00001278(T_F - 60) - 0.0000000062(T_F - 60)^2]\,\gamma_x^*$$

The value of γ_x was not rounded prior to use[10].

Density readings must be corrected for the effect of temperature on the instrument prior to entering the density into the following implementation procedure.

5.1.2.1 Inputs and Outputs

Inputs: Relative density at observed temperature, γ_x
Observed temperature, T_F (°F)

Output: Relative density at 60°F, γ_{60}

5.1.2.2 Outline of Calculations

The calculations are performed using an extended two-fluid corresponding states equation. Two reference fluids are found that are slightly denser and slightly less dense than the observed fluid by comparing their densities at the observed temperature. Iteration must be performed to determine the value of the fluid's relative density at 60°F such that when the Temperature Correction Factor is applied, the observed relative density is obtained. The "guessed" value for the fluid's relative density at 60°F is constrained to lie between the relative densities at 60°F of these two reference fluids (as upper and lower bounds). As the iterations progress, these upper and lower bounds are "brought together" based upon intermediate calculations.

See Figure 2 for a general flow chart of the calculation procedure.

5.1.2.3 T23 Implementation Procedure

T23/Step Number Operation/Procedure at that step

T23/1: Round the relative density γ_x to the nearest 0.0001 and round the observed temperature T_F to the nearest 0.1°F.

Temperature rounding examples follow: –0.05 rounds to –0.1; –0.049 rounds to 0.0, –0.051 rounds to –0.1. Density rounding examples follow: 0.35555 rounds to 0.3556, 0.40289 rounds to 0.4029.

T23/2: Convert the rounded observed temperature to units of Kelvin, T_x:

$$T_x = \frac{T_F + 459.67}{1.8}$$

T23/3: Check the values of temperature and relative density to ensure that they are in the proper range. The observed temperature T_x and relative density γ_x must fall within the following boundaries:

Temperature between 227.15 and 366.15 K, inclusive (equivalent to –46 to 93°C, or –50.8 to 199.4°F)
Relative density between 0.2100 and 0.7400 inclusive.

If these values do not fall in these ranges, then the standard does not apply. Flag this result (possibly by returning a –1 for γ_{60}) and exit this procedure.

T23/4: Reference fluids must be chosen to perform the density calculations. As written here, this is done in two separate steps: T23/4 to compute the density for each reference fluid at the observed temperature and T23/5 to determine which two reference fluids are to be used. However, Steps 4 and 5 could be combined into a single step (e.g., using a binary search technique).

The reference fluids' densities are to be calculated at the observed temperature, T_x. Use the reference fluids' parameter values from Table 1. First, use each reference fluid's critical temperature, $T_{c,ref}$, to compute its reduced observed temperature, $T_{r,x}$:

$$T_{r,x} = \frac{T_x}{T_{c,ref}}$$

If $T_{r,x} \leq 1$, calculate the saturation density for this reference fluid at this reduced temperature $T_{r,x}$. Use the procedure as described in Section 5.1.1.3 Step T24/10. Refer to this calculated density for the reference fluid as $\rho_{x,ref}^{sat}$. Repeat this for 60°F using the reduced temperature $T_{r,60}$:

$$T_{r,60} = \frac{519.67}{1.8T_{c,ref}}$$

Refer to this calculated density as $\rho_{60,ref}^{sat}$. Finally, calculate its relative density at the observation temperature, $\gamma_{x,ref}$, as:

$$\gamma_{x,ref} = \gamma_{60,ref}\left(\frac{\rho_{x,ref}^{sat}}{\rho_{60,ref}^{sat}}\right)$$

where $\gamma_{60,ref}$ is the reference fluid's relative density at 60°F

If $T_{r,x} > 1$, this reference fluid will not be a liquid at this observed temperature and no value of $\gamma_{x,ref}$ can be calculated. It is suggested that this type of "no value" case be flagged by returning a –1 value for $\gamma_{x,ref}$.

T23/5: Determine the two adjacent reference fluids to be used for the calculations. Choose the lowest density reference fluid that has a density value greater than γ_x and refer to this fluid using the subscript "2". Also use the next lowest density reference fluid and refer to this fluid using the subscript "1" (even though this reference fluid may not exist as a liquid at the observation temperature). If γ_x is below that for "EE 68/32" (the least dense reference fluid), then set "EE 68/32" as fluid "1" and "ethane" as fluid "2". If γ_x is above that for "n-heptane" (the most dense reference fluid), then set "n-hexane" as fluid "1" and "n-heptane" as fluid "2".

T23/6: Initialize the bounds on the iteration for the observed fluid's 60°F relative density. For most cases, the observed fluid's 60°F relative density should be between the two reference fluids "1" and "2", $\gamma_{60,1}$ and $\gamma_{60,2}$.

Initialize the upper bound for the observed fluid's 60°F relative density, $\gamma_{60,high}$, as:

$$\gamma_{60,high} = \gamma_{60,2}$$

and the corresponding relative density at the observed temperature, $\gamma_{x,high}$, as:

$$\gamma_{x,high} = \gamma_{x,2}$$

However, if the relative density γ_x is greater than the reference fluid "2" relative density at the observed temperature $\gamma_{x,2}$, then no answer exists. If this is the case, then $\gamma_{x,60}$ should be flagged (perhaps by being set to –1) and exit this procedure.

Initialize the lower bound for the observed fluid's 60°F relative density, $\gamma_{60,low}$, as:

$$\gamma_{60,low} = \gamma_{60,1}$$

and the corresponding relative density at the observed temperature, $\gamma_{x,low}$, as:

$$\gamma_{x,low} = \gamma_{x,1}$$

However, if reference fluid "1" is not a liquid at the observed temperature (i.e., $T_{r,x} > 1$ for the reference fluid), then set the lower boundary convergence 60°F relative density by the following equation:

$$\gamma_{60,low} = \left[\frac{T_x - T_{c,1}}{T_{c,2} - T_{c,1}}\right]\left(\gamma_{60,2} - \gamma_{60,1}\right) + \gamma_{60,1}$$

Note that this equation was derived from equations in Section 5.1 at a reduced temperature of 1.0.

If $\gamma_{60,low}$ is less than 0.3500, then set it equal to 0.3500.

If $\gamma_{60,low}$ has been reset using the preceding technique then recalculate the corresponding $\gamma_{x,low}$ value. Use the procedure in Section 5.1.1.3 Steps T24/4 through T24/13 to calculate its Temperature Correction Factor, CTL. Skip Step 24/14 to avoid rounding the output CTL. The relative density at the observed temperature will be:

$$\gamma_{x,low} = C_{TL} \times \gamma_{60,low}$$

At this point, upper and lower convergence bounds have been set. After one more check, the iterative process to determine a 60°F relative density γ_{60} can begin. If the observed relative density γ_x is less than the lower limit $\gamma_{x,low}$, then no answer exists. If this is the case, then γ_{60} should be flagged (perhaps by being set to –1) and exit this procedure.

T23/7: Calculate an intermediate 60°F relative density value, $\gamma_{60,mid}$ If a value for $\gamma_{60,low}$ exists, then calculate $\gamma_{60,mid}$ from:

$$\delta = \frac{\gamma_x - \gamma_{x,low}}{\gamma_{x,high} - \gamma_{x,low}}$$

If δ is less than 0.001 then set it equal to 0.001; if δ is greater than 0.999 then set it equal to 0.999. Calculate the intermediate 60°F relative density value:

$$\gamma_{60,mid} = \gamma_{60,low} + \delta\left(\gamma_{60,high} - \gamma_{60,low}\right)$$

However, if a value for $\gamma_{x,low}$ does not exist, then calculate $\gamma_{60,mid}$ from:

$$\gamma_{60,mid} = \frac{\gamma_{60,high} + \gamma_{60,low}}{2}$$

Calculate the Temperature Correction Factor, C_{TL}, using this value of $\gamma_{60,mid}$ and T_x, unrounded, and the procedure from Section 5.1.1.3 Steps T24/5 to T24/13. (Do not round this C_{TL} value.) The relative density, $\gamma_{x,mid}$, at observed temperature, T_x, will be:

$$\gamma_{x,mid} = C_{TL} \times \gamma_{60,mid}$$

T23/8: Check for convergence of the 60°F relative density. The calculations will be considered converged if either occurs:

- If γ_x is between $\gamma_{x,low}$ and $\gamma_{x,mid}$ and the difference between $\gamma_{60,low}$ and $\gamma_{60,mid}$ is less than 0.00000001 (10^{-8}).
- If γ_x is between $\gamma_{x,high}$ and $\gamma_{x,mid}$ and the difference between $\gamma_{60,high}$ and $\gamma_{60,mid}$ is less than 0.00000001 (10^{-8}).

If convergence has been achieved, set:

$$\gamma_{60} = \gamma_{60,mid}$$

and skip to Step T23/12.

T23/9: There are three pairs of relative density values: ($\gamma_{x,low}$, $\gamma_{60,low}$), ($\gamma_{x,mid}$, $\gamma_{60,mid}$) and ($\gamma_{x,high}$, $\gamma_{60,high}$). A quadratic equation can be fit through these three points. This quadratic equation should be a good approximation to the actual relationship between γ_x and γ_{60}. Using the value of the observed relative density γ_x in the quadratic equation should give a very good estimate to γ_{60}.

Calculate the parameters for the quadratic equation by:

$$\alpha = (\gamma_{60,high} - \gamma_{60,low})$$

$$\beta = \gamma_{x,high}^2 - \gamma_{x,low}^2$$

$$\phi = \frac{\gamma_{x,high} - \gamma_{x,low}}{\gamma_{x,mid} - \gamma_{x,low}}$$

$$A = \frac{\alpha - \phi(\gamma_{60,mid} - \gamma_{60,low})}{\beta - \phi(\gamma_{x,mid}^2 - \gamma_{x,low}^2)}$$

$$B = \frac{\alpha - A\beta}{\gamma_{x,high} - \gamma_{x,low}}$$

$$C = \gamma_{60,low} - B\gamma_{x,low} - A\gamma_{x,low}^2$$

Using these values of A, B, and C, calculate the associated value $\gamma_{60,trial}$ using:

$$\gamma_{60,trial} = A\gamma_x^2 + B\gamma_x + C$$

This value of $\gamma_{60,trial}$ may have to be adjusted if it goes outside of the range of $\gamma_{60,low}$ or $\gamma_{60,high}$. If $\gamma_{60,trial} < \gamma_{60,low}$, then reset the value as:

$$\gamma_{60,trial} = \gamma_{60,low} + \frac{\left(\gamma_{60,mid} - \gamma_{60,low}\right)\left(\gamma_x - \gamma_{x,low}\right)}{\left(\gamma_{x,mid} - \gamma_{x,low}\right)}$$

If $\gamma_{60,trial} > \gamma_{60,high}$ then reset the value as:

$$\gamma_{60,trial} = \gamma_{60,mid} + \frac{\left(\gamma_{60,high} - \gamma_{60,mid}\right)\left(\gamma_x - \gamma_{x,mid}\right)}{\left(\gamma_{x,high} - \gamma_{x,mid}\right)}$$

Finally, calculate the Temperature Correction Factor, C_{TL}, using the value of $\gamma_{60,trial}$ and the procedure from Section 5.1.1.3 Steps T24/4 to T24/13. Skip Step 24/14 to avoid rounding the output C_{TL}. The relative density at observed temperature, $\gamma_{x,trial}$, will be:

$$\gamma_{x,trial} = C_{TL} \times \gamma_{60,trial}$$

T23/10: Check for convergence of the 60°F relative density. The calculations will be considered converged if the absolute difference between $\gamma_{x,trial}$ and γ_x is less than 0.00000001 (10^{-8}). If converged, set:

$$\gamma_{60} = \gamma_{60,trial}$$

and skip to Step T23/12.

T23/11: The calculation has not yet converged, so the iteration bounds must be updated.

If $\gamma_{x,trial} > \gamma_x$ then reset the upper bounds to:

$$\gamma_{x,high} = \gamma_{x,trial}$$

$$\gamma_{60,high} = \gamma_{60,trial}$$

Also, if $\gamma_{x,mid} < \gamma_x$ then reset the lower bounds to:

$$\gamma_{x,low} = \gamma_{x,mid}$$

$$\gamma_{60,low} = \gamma_{60,mid}$$

Or if $\gamma_{x,trial} < \gamma_x$ then reset the lower bounds to:

$$\gamma_{x,low} = \gamma_{x,trial}$$

$$\gamma_{60,low} = \gamma_{60,trial}$$

Also, if $\gamma_{x,mid} > \gamma_x$ then reset the upper bounds to:

$$\gamma_{x,high} = \gamma_{x,mid}$$

$$\gamma_{60,high} = \gamma_{60,mid}$$

Return to Step T23/7 and continue iterations. Do at most 10 iterations. If 10 iterations are reached, then no solution can be found. Flag this result (possibly by returning a –1 for γ_{60}) and exit this procedure.

Note: At this time, all known cases have been found to require less than 10 iterations.

T23/12: Round the 60°F relative density value γ_{60} to the nearest 0.0001. If the value is less than 0.3500 or greater than 0.6880, then the result is outside the scope of this standard. Flag result (possibly by returning a –1 for γ_{60}). Exit this procedure.

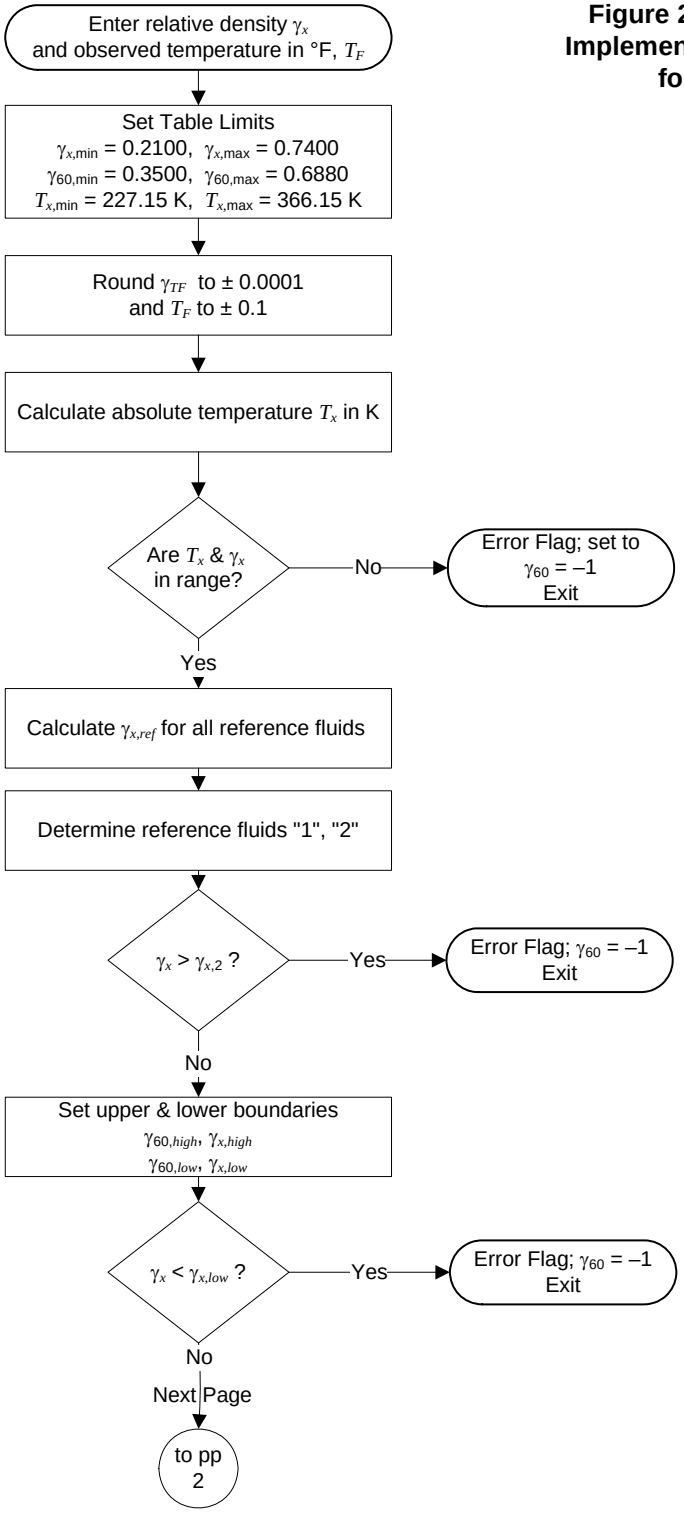
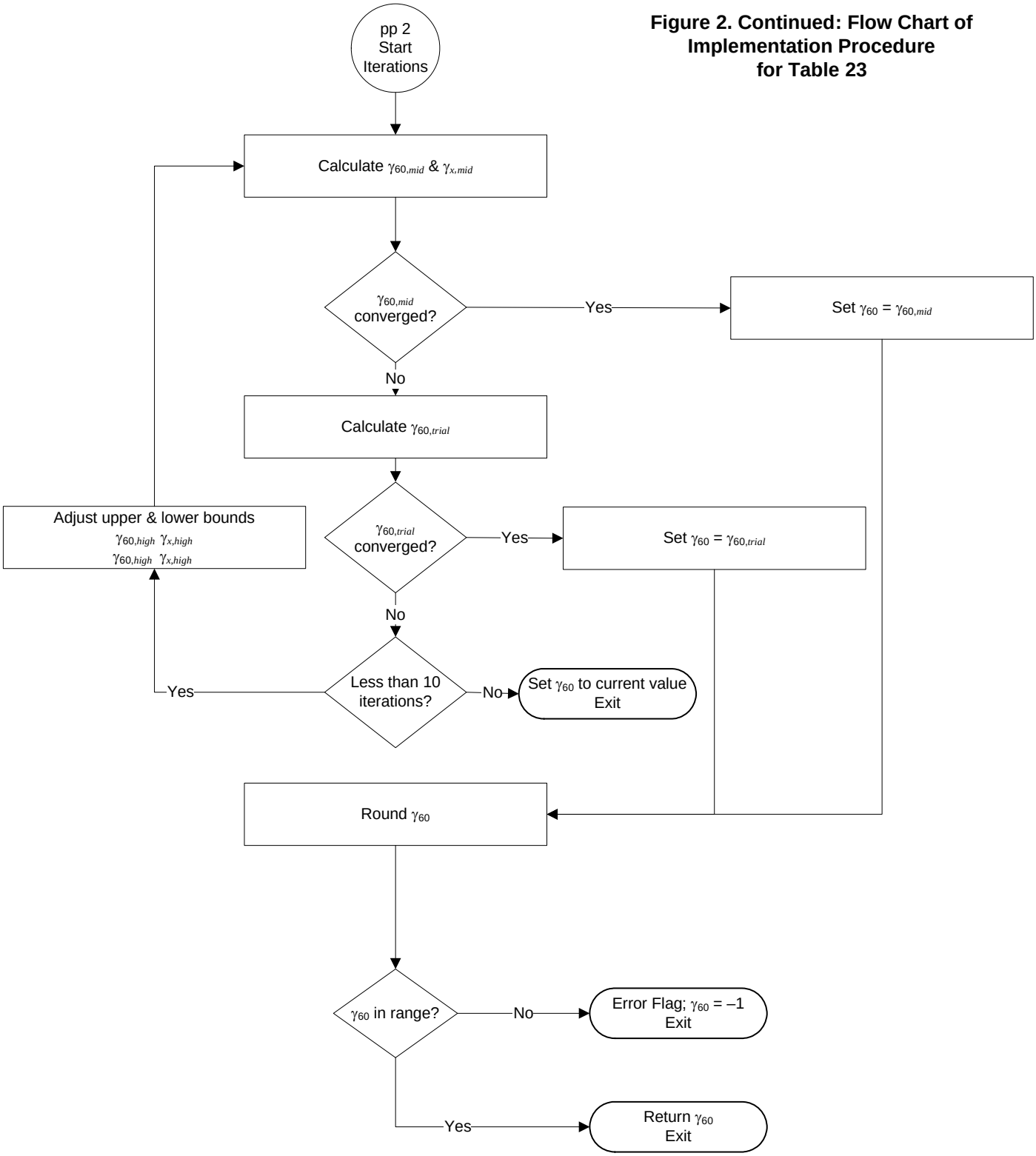


Figure 2. Flow Chart of Implementation Procedure for Table 23

Figure 2. Continued: Flow Chart of Implementation Procedure for Table 23



5.1.2.4 Examples for Section 5.1.2 (Table 23E)

(See Table 1 for properties of the Reference Fluids)

Example 23/1 – Utilize i-Pentane and n-Pentane

```
    Input Data
Relative density @ obs. temp. ..   0.67432
Observed temperature Tf, °F .... –23.33
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.6743
Tf, °F ........................ –23.3
  T23/2
Tx, Kelvin ..................... 242.427777777778
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............   0.668992076725
RDtf for Fluid 2 ...............   0.674300900334
  T23/5
Reference Fluid 1 ..............  i-Pentane
Reference Fluid 2 ..............  n-Pentane
Tr,x for Fluid 1 ...............   0.526513286808
Tr,x for Fluid 2 ...............   0.516188177958
Tr,60 for Fluid 1 ..............   0.627021013716
Tr,60 for Fluid 2 ..............   0.614724913352
  T23/6
Upper boundary RD60,high .......   0.631054000000
Upper boundary RDtf,high .......   0.674300900334
Lower boundary RD60,low ........   0.624285000000
Lower boundary RDtf,low ........   0.668992076725

     Iteration steps                  Pass 1
  T23/7
Delta ..........................   0.999000000000
RD60,mid .......................   0.631047231000
CTL ............................   1.068534241176
RDTf,mid .......................   0.674295574123
  T23/8                              Continue
  T23/9
Alpha ..........................   0.006769000000
Beta ...........................   0.007131305470
Phi ............................   1.001004282842
A ..............................  –0.784857658731
B ..............................   2.329340853270
C ..............................  –0.582762216726
RD60,Trial .....................   0.631052855782
CTL,Trial ......................   1.068531730459
RDTf,Trial .....................   0.674300000000
  T23/10                             Converged
  T23/11 not needed, convergence already achieved
  T23/12
RD60 (RD60,Trial rounded) ......   0.6311
```

Example 23/2 – Steps 9 & 11, Adjust RD60Trial, reset hi+low/hi boundaries

```
    Input Data
Relative density @ obs. temp. ..   0.24573
Observed temperature Tf, °F .... 189.98
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.2457
Tf, °F ........................ 190.0
  T23/2
Tx, Kelvin ..................... 360.927777777778
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ..............  –0.470381000000
RDtf for Fluid 2 ..............   0.341646473673
  T23/5
Reference Fluid 1 ..............  EP (35/65)
Reference Fluid 2 ..............  Propane
Tr,x for Fluid 1 ..............   1.024024790835
Tr,x for Fluid 2 ..............   0.976060840981
Tr,60 for Fluid 1 ..............   0.819115801951
Tr,60 for Fluid 2 ..............   0.780749514726
  T23/6
Upper boundary RD60,high .......   0.507025000000
Upper boundary RDtf,high .......   0.341646473673
Lower boundary RD60,low ........   0.488296314601
Lower boundary RDtf,low ........   0.209990106855
```

Iteration steps	Pass 1	Pass 2	Pass 3	Pass 4
T23/7				
Delta	0.271235596182	0.601796434584	0.126556348248	0.004138210954
RD60,mid	0.493376200751	0.489664201999	0.488882034911	0.488850690456
CTL	0.587375829009	0.529645485907	0.504021249568	0.502607558267
RDTf,mid	0.289797254929	0.259348434199	0.246406934127	0.245700051887
T23/8	Continue	Continue	Continue	Continue
T23/9				
Alpha	0.018728685399	0.002273006817	8.95498051064e–04	3.14747042172e–05
Beta	0.072626467996	0.028442228403	0.007860987453	3.49330713583e–04
Phi	1.649681388134	1.202204934943	5.820815799273	237.456099384553
A	1.515978266954	1.061284960315	1.166129963841	1.088675802961
B	–0.694014759007	–0.470388528249	–0.529337816619	–0.491403133721
C	0.567184205356	0.540274994825	0.548511356689	0.543866723826
RD60,Trial	0.488182097917	0.488768703948	0.488850560207	0.488850688195
RD60,Trial adjusted				
RD60,Trial	0.490569321418	not changed	not changed	not changed
CTL,Trial	0.549012993292	0.498645735699	0.502601576844	0.502607454450
RDTf,Trial	0.269328931569	0.243722429967	0.245697062401	0.245700000000
T23/10	Continue	Continue	Continue	Converged
T23/11				
Reset boundaries				
RDTf,high	0.269328931569	0.259348434199	0.246406934127	
RD60,high	0.490569321418	0.489664201999	0.488882034911	
RDTf,low	not changed	0.243722429967	0.245697062401	
RD60,low	not changed	0.488768703948	0.488850560207	
T23/12				
RD60 (RD60,Trial rounded)				0.4889

Example 23/3 – T23/11, Reset upper boundary only

```
    Input Data
Relative density @ obs. temp. ..   0.50004
Observed temperature Tf, °F .... 190.04
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.5000
Tf, °F ........................ 190.0
  T23/2
Tx, Kelvin ..................... 360.927777777778
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............   0.488812742534
RDtf for Fluid 2 ...............   0.543932948655
  T23/5
Reference Fluid 1 ..............  n-Butane
Reference Fluid 2 ..............  i-Pentane
Tr,x for Fluid 1 ...............   0.848922235812
Tr,x for Fluid 2 ...............   0.783875809612
Tr,60 for Fluid 1 ..............   0.679051546607
Tr,60 for Fluid 2 ..............   0.627021013716
  T23/6
Upper boundary RD60,high .......   0.624285000000
Upper boundary RDtf,high .......   0.543932948655
Lower boundary RD60,low ........   0.584127000000
Lower boundary RDtf,low ........   0.488812742534

     Iteration steps                   Pass 1             Pass 2
  T23/7
Delta ..........................   0.202961096368     0.999000000000
RD60,mid .......................   0.592277511708     0.591700929263
CTL ............................   0.845587965896     0.845005240854
RDTf,mid .......................   0.500822736371     0.499990386246
  T23/8                              Continue           Continue
  T23/9
Alpha ..........................   0.040158000000     0.007581510774
Beta ...........................   0.056925155369     0.011063449627
Phi ............................   4.589528260128     1.000980586162
A ..............................   1.157707890490     1.260826338621
B ..............................  -0.467064681900    -0.569112796362
C ..............................   0.535813879101     0.561057392636
RD60,Trial .....................   0.591708510774     0.591707579111
CTL,Trial ......................   0.845012937594     0.845011991820
RDTf,Trial .....................   0.500001346888     0.500000000000
  T23/10                             Continue           Converged
  T23/11
Reset boundaries
RDTf,high ......................   0.500001346888
RD60,high ......................   0.591708510774
  T23/12
RD60 (RD60,Trial rounded) ........................   0.5917
```

Example 23/4 – Calculated RD60 equals 0.3500, T23/11 lo/hi, T23/8 detects

```
    Input Data
Relative density @ obs. temp. ..   0.22238
Observed temperature Tf, °F ....  87.25
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.2224
Tf, °F .........................  87.3
  T23/2
Tx, Kelvin ..................... 303.872222222222
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ..............  –0.325022000000
RDtf for Fluid 2 ..............   0.267719237662
  T23/5
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
Tr,x for Fluid 1 ..............   1.019329181249
Tr,x for Fluid 2 ..............   0.995225566509
Tr,60 for Fluid 1 ..............   0.968453106422
Tr,60 for Fluid 2 ..............   0.945552535144
  T23/6
Upper boundary RD60,high .......   0.355994000000
Upper boundary RDtf,high .......   0.267719237662
Lower boundary RD60,low ........   0.350000000000
Lower boundary RDtf,low ........   0.222390762498

     Iteration steps                  Pass 1             Pass 2
  T23/7
Delta ..........................   0.001000000000     0.001000000000
RD60,mid .......................   0.350005994000     0.350000328926
CTL ............................   0.635875915052     0.635428359299
RDTf,mid .......................   0.222560381708     0.222400134764
  T23/8                              Continue          Converged
  T23/9
Alpha ..........................   0.005994000000
Beta ...........................   0.022215938970
Phi ............................ 267.236683329960
A ..............................   2.145687234871
B ..............................  –0.919388011785
C ..............................   0.448342750031
RD60,Trial .....................   0.350000323256
CTL,Trial ......................   0.635427908123
RDTf,Trial .....................   0.222399973249
  T23/10                             Continue
  T23/11
Reset boundaries
RDTf,high ......................   0.222560381708
RD60,high ......................   0.350005994000
RDTf,low .......................   0.222399973249
RD60,low .......................   0.350000323256
  T23/12
RD60 (RD60,Trial rounded) ........................   0.3500
```

Example 23/5 – T23/6, RDtf < lower boundary

```
    Input Data
Relative density @ obs. temp. ..   0.34006
Observed temperature Tf, °F ....  64.63
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.3401
Tf, °F .........................  64.6
  T23/2
Tx, Kelvin ..................... 291.261111111111
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............   0.310026832478
RDtf for Fluid 2 ...............   0.346752475914
  T23/5
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
Tr,x for Fluid 1 ...............   0.977025631851
Tr,x for Fluid 2 ...............   0.953922349953
Tr,60 for Fluid 1 ..............   0.968453106422
Tr,60 for Fluid 2 ..............   0.945552535144
  T23/6
Upper boundary RD60,high .......   0.355994000000
Upper boundary RDtf,high .......   0.346752475914
Lower boundary RD60,low ........   0.350000000000
Lower boundary RDtf,low ........   0.340112938057
RDtf observed is less than lower boundary RDtf, no solution
```

Example 23/6 – T23/6, RDtf > upper boundary

```
    Input Data
Relative density @ obs. temp. ..   0.72858
Observed temperature Tf, °F .... –27.53
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.7286
Tf, °F ........................ –27.5
  T23/2
Tx, Kelvin ..................... 240.094444444444
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............   0.706219967989
RDtf for Fluid 2 ...............   0.728360741594
  T23/5
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
Tr,x for Fluid 1 ...............   0.473232373006
Tr,x for Fluid 2 ...............   0.444495870489
Tr,60 for Fluid 1 ..............   0.569046132957
Tr,60 for Fluid 2 ..............   0.534491447849
  T23/6
RDtf observed is greater than Fluid 2 RDtf, no solution
```

Example 23/7 – Test binary search routine at low end

```
    Input Data
Relative density @ obs. temp. ..   0.45572
Observed temperature Tf, °F .... –24.67
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.4557
Tf, °F ........................ –24.7
  T23/2
Tx, Kelvin ..................... 241.650000000000
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............   0.455790716298
RDtf for Fluid 2 ...............   0.462651655172
  T23/5
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
Tr,x for Fluid 1 ...............   0.810606822985
Tr,x for Fluid 2 ...............   0.791438771166
Tr,60 for Fluid 1 ..............   0.968453106422
Tr,60 for Fluid 2 ..............   0.945552535144
  T23/6
Upper boundary RD60,high .......   0.355994000000
Upper boundary RDtf,high .......   0.462651655172
Lower boundary RD60,low ........   0.350000000000
Lower boundary RDtf,low ........   0.459877928850
RDtf observed is less than lower boundary RDtf, no solution
```

Example 23/8 – T23/6 RDtf near RDlowTf, T23/11 reset lower/upper boundaries

```
    Input Data
Relative density @ obs. temp. ..   0.25776
Observed temperature Tf, °F .... 179.28
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.2578
Tf, °F ........................ 179.3
  T23/2
Tx, Kelvin ..................... 354.983333333333
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ..............  –0.470381000000
RDtf for Fluid 2 ..............   0.367118287562
  T23/5
Reference Fluid 1 .............  EP (35/65)
Reference Fluid 2 .............  Propane
Tr,x for Fluid 1 ..............   1.007159204827
Tr,x for Fluid 2 ..............   0.959985216435
Tr,60 for Fluid 1 .............   0.819115801951
Tr,60 for Fluid 2 .............   0.780749514726
  T23/6
Upper boundary RD60,high .......   0.507025000000
Upper boundary RDtf,high .......   0.367118287562
Lower boundary RD60,low ........   0.475719627406
Lower boundary RDtf,low ........   0.203205649078

     Iteration steps                  Pass 1             Pass 2             Pass 3
  T23/7
Delta ..........................   0.333069807351     0.203517533920     0.029802787362
RD60,mid .......................   0.486146501825     0.478475881642     0.477446269344
CTL ............................   0.636706579940     0.560060148072     0.540064021350
RDTf,mid .......................   0.309532676527     0.267975273121     0.257851552201
  T23/8                              Continue           Continue           Continue
  T23/9
Alpha ..........................   0.031305372594     0.009630620270     0.001061240214
Beta ...........................   0.093483301245     0.035990492536     0.005510968782
Phi ............................   1.541589588429     2.776410749513    28.803325550048
A ..............................   1.613666311213     1.551880192561     1.415113489360
B ..............................  –0.729324366880    –0.711644239073    –0.642401682060
C ..............................   0.557290084813     0.557737265084     0.549003291079
RD60,Trial .....................   0.476515881554     0.477414641428     0.477441768642
CTL,Trial ......................   0.513269870440     0.539337110326     0.539961117999
RDTf,Trial .....................   0.244581244788     0.257487433135     0.257799991175
  T23/10                             Continue           Continue           Converged
  T23/11
Reset boundaries
RDTf,high ......................   0.309532676527     0.267975273121
RD60,high ......................   0.486146501825     0.478475881642
RDTf,low .......................   0.244581244788     0.257487433135
RD60,low .......................   0.476515881554     0.477414641428
  T23/12
RD60 (RD60,Trial rounded) ..........................................   0.4774
```

Example 23/9 – T23/11, reset upper/lower using Ethane & EP

```
    Input Data
Relative density @ obs. temp. ..   0.39548
Observed temperature Tf, °F ....  59.78
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.3955
Tf, °F .........................  59.8
  T23/2
Tx, Kelvin ..................... 288.594444444444
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............   0.356376967243
RDtf for Fluid 2 ...............   0.429505267826
  T23/5
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
Tr,x for Fluid 1 ...............   0.945188630152
Tr,x for Fluid 2 ...............   0.864909774461
Tr,60 for Fluid 1 ..............   0.945552535144
Tr,60 for Fluid 2 ..............   0.865242771467
  T23/6
Upper boundary RD60,high .......   0.429277000000
Upper boundary RDtf,high .......   0.429505267826
Lower boundary RD60,low ........   0.355994000000
Lower boundary RDtf,low ........   0.356376967243

     Iteration steps                   Pass 1             Pass 2
  T23/7
Delta ..........................   0.534991685093     0.999000000000
RD60,mid .......................   0.395199795659     0.395230790997
CTL ............................   1.000681275169     1.000681092670
RDTf,mid .......................   0.395469035466     0.395499979792
  T23/8                               Continue           Continue
  T23/9
Alpha ..........................   0.073283000000     3.10263646086e-05
Beta ...........................   0.057470232309     2.45005041712e-05
Phi ............................   1.870668498940     1.001001001559
A ..............................  -0.023321269027    -0.018033364749
B ..............................   1.020443223123     1.015912364749
C ..............................  -0.004706553990    -0.003741745597
RD60,Trial .....................   0.395230822023     0.395230811239
CTL,Trial ......................   1.000681092487     1.000681092551
RDTf,Trial .....................   0.395500010767     0.395500000000
  T23/10                              Continue           Converged
  T23/11
Reset boundaries
RDTf,high ......................   0.395500010767
RD60,high ......................   0.395230822023
RDTf,low .......................   0.395469035466
RD60,low .......................   0.395199795659
  T23/12
RD60 (RD60,Trial rounded) ........................   0.3952
```

Example 23/10 – T23/9 & 11, Adjust RD60Trial, reset hi+low/hi boundaries

```
    Input Data
Relative density @ obs. temp. ..   0.21056
Observed temperature Tf, °F ....  87.46
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.2106
Tf, °F .........................  87.5
  T23/2
Tx, Kelvin ..................... 303.983333333333
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............  –0.325022000000
RDtf for Fluid 2 ...............   0.266017434379
  T23/5
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
Tr,x for Fluid 1 ...............   1.019701899746
Tr,x for Fluid 2 ...............   0.995589471501
Tr,60 for Fluid 1 ..............   0.968453106422
Tr,60 for Fluid 2 ..............   0.945552535144
  T23/6
Upper boundary RD60,high .......   0.355994000000
Upper boundary RDtf,high .......   0.266017434379
Lower boundary RD60,low ........   0.350217135734
Lower boundary RDtf,low ........   0.201957415331
```

Iteration steps	Pass 1	Pass 2	Pass 3	Pass 4
T23/7				
Delta	0.134913863553	0.442156617893	0.285572535939	0.045507746482
RD60,mid	0.350996514811	0.350313978649	0.350250911268	0.350238857349
CTL	0.663001877090	0.618306878199	0.605460325548	0.601336301107
RDTf,mid	0.232711348172	0.216601542528	0.212063030760	0.210611338982
T23/8	Continue	Continue	Continue	Continue
T23/9				
Alpha	0.005776864266	2.19024009057e–04	8.82768152069e–05	1.26286194163e–05
Beta	0.029978477786	0.008277157180	0.003568550978	6.47744349018e–04
Phi	2.082986243708	1.334762574159	2.175177227878	18.901668137223
A	1.946686690732	0.936748950385	0.877145829125	0.793585193044
B	–0.820821476963	–0.385471575544	–0.362105293706	–0.327124761330
C	0.436589003610	0.389858988966	0.387594169917	0.383933874925
RD60,Trial	0.350064149476	0.350225701834	0.350238282649	0.350238776362
RD60,Trial adjusted				
RD60,Trial	0.350436159743	not changed	not changed	not changed
CTL,Trial	0.632080457699	0.594476787322	0.601105752483	0.601304054034
RDTf,Trial	0.221503848245	0.208201050064	0.210530246440	0.210599996106
T23/10	Continue	Continue	Continue	Converged
T23/11				
Reset boundaries				
RDTf,high	0.221503848245	0.216601542528	0.212063030760	
RD60,high	0.350436159743	0.350313978649	0.350250911268	
RDTf,low	not changed	0.208201050064	0.210530246440	
RD60,low	not changed	0.350225701834	0.350238282649	
T23/12				
RD60 (RD60,Trial rounded)				0.3502

Example 23/11 – T23/11, Reset upper boundary only

```
    Input Data
Relative density @ obs. temp. ..   0.45003
Observed temperature Tf, °F .... 199.43
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.4500
Tf, °F ........................ 199.4
  T23/2
Tx, Kelvin ..................... 366.150000000000
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............   0.445396160533
RDtf for Fluid 2 ...............   0.480129616454
  T23/5
Reference Fluid 1 ..............  i-Butane
Reference Fluid 2 ..............  n-Butane
Tr,x for Fluid 1 ...............   0.897756528135
Tr,x for Fluid 2 ...............   0.861205193339
Tr,60 for Fluid 1 ..............   0.707871902797
Tr,60 for Fluid 2 ..............   0.679051546607
  T23/6
Upper boundary RD60,high .......   0.584127000000
Upper boundary RDtf,high .......   0.480129616454
Lower boundary RD60,low ........   0.562827000000
Lower boundary RDtf,low ........   0.445396160533

     Iteration steps                  Pass 1             Pass 2
  T23/7
Delta ..........................   0.132547693417     0.999000000000
RD60,mid .......................   0.565650265870     0.565462936534
CTL ............................   0.796107835259     0.795800434708
RDTf,mid .......................   0.450318608675     0.449995650705
  T23/8                              Continue           Continue
  T23/9
Alpha ..........................   0.021300000000     0.002638575109
Beta ...........................   0.032146708779     0.004122443006
Phi ............................   7.056134451304     1.000989768898
A ..............................   1.331470032321     1.412580442222
B ..............................  -0.619068238574    -0.691719762248
C ..............................   0.574423600922     0.590691810831
RD60,Trial .....................   0.565465575109     0.565465457370
CTL,Trial ......................   0.795804772113     0.795804578573
RDTf,Trial .....................   0.450000203137     0.450000000000
  T23/10                             Continue           Converged
  T23/11
Reset boundaries
RDTf,high ......................   0.450000203137
RD60,high ......................   0.565465575109
  T23/12
RD60 (RD60,Trial rounded) ........................   0.5655
```

Example 23/12 – T23/10 detects solution in one pass, using i-Hexane

```
    Input Data
Relative density @ obs. temp. ..   0.60133
Observed temperature Tf, °F .... 177.17
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.6013
Tf, °F ........................ 177.2
  T23/2
Tx, Kelvin ..................... 353.816666666667
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ..............   0.594442903364
RDtf for Fluid 2 ..............   0.602928497317
  T23/5
Reference Fluid 1 ..............  i-Hexane
Reference Fluid 2 ..............  n-Hexane
Tr,x for Fluid 1 ..............   0.710403908577
Tr,x for Fluid 2 ..............   0.697381820571
Tr,60 for Fluid 1 ..............   0.579671831253
Tr,60 for Fluid 2 ..............   0.569046132957
  T23/6
Upper boundary RD60,high .......   0.664064000000
Upper boundary RDtf,high .......   0.602928497317
Lower boundary RD60,low ........   0.657167000000
Lower boundary RDtf,low ........   0.594442903364

     Iteration steps                  Pass 1
  T23/7
Delta ..........................   0.808086820333
RD60,mid .......................   0.662740374800
CTL ............................   0.907329937112
RDTf,mid .......................   0.601324182589
  T23/8                              Continue
  T23/9
Alpha ..........................   0.006897000000
Beta ...........................   0.010160407517
Phi ............................   1.233141931306
A ..............................   1.780418160509
B ..............................  -1.319032483022
C ..............................   0.812123726312
RD60,Trial .....................   0.662720493291
CTL,Trial ......................   0.907320672201
RDTf,Trial .....................   0.601300003454
  T23/10                             Converged
  T23/11 not needed, convergence already achieved
  T23/12
RD60 (RD60,Trial rounded) ......   0.6627
```

Example 23/13 – Calculated RD60 equals 0.6880

```
    Input Data
Relative density @ obs. temp. ..   0.73592
Observed temperature Tf, °F .... –44.13
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.7359
Tf, °F ........................ –44.1
  T23/2
Tx, Kelvin ..................... 230.872222222222
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ...............   0.714077137643
RDtf for Fluid 2 ...............   0.735959630678
  T23/5
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
Tr,x for Fluid 1 ...............   0.455055133975
Tr,x for Fluid 2 ...............   0.427422423812
Tr,60 for Fluid 1 ..............   0.569046132957
Tr,60 for Fluid 2 ..............   0.534491447849
  T23/6
Upper boundary RD60,high .......   0.688039000000
Upper boundary RDtf,high .......   0.735959630678
Lower boundary RD60,low ........   0.664064000000
Lower boundary RDtf,low ........   0.714077137643

     Iteration steps                  Pass 1
  T23/7
Delta ..........................   0.997274959562
RD60,mid .......................   0.687973667156
CTL ............................   1.069661466437
RDTf,mid .......................   0.735898921680
  T23/8                              Continue
  T23/9
Alpha ..........................   0.023975000000
Beta ...........................   0.031730419484
Phi ............................   1.002782036454
A ..............................  –0.891797542956
B ..............................   2.388763933252
C ..............................  –0.586964652669
RD60,Trial .....................   0.687974827662
CTL,Trial ......................   1.069661229476
RDTf,Trial .....................   0.735900000006
  T23/10                             Converged
  T23/11 not needed, convergence already achieved
  T23/12
RD60 (RD60,Trial rounded) ......   0.6880
```

Example 23/14 – Rd = lower RD limit

```
    Input Data
Relative density @ obs. temp. ..      0.21
Observed temperature Tf, °F ....  189.4
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.2100
Tf, °F ........................ 189.4
  T23/2
Tx, Kelvin ..................... 360.594444444444
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ..............  –0.470381000000
RDtf for Fluid 2 ..............   0.343306875586
  T23/5
Reference Fluid 1 .............  EP (35/65)
Reference Fluid 2 .............  Propane
Tr,x for Fluid 1 ..............   1.023079057040
Tr,x for Fluid 2 ..............   0.975159404090
Tr,60 for Fluid 1 .............   0.819115801951
Tr,60 for Fluid 2 .............   0.780749514726
  T23/6
Upper boundary RD60,high .......   0.507025000000
Upper boundary RDtf,high .......   0.343306875586
Lower boundary RD60,low ........   0.487591079805
Lower boundary RDtf,low ........   0.209600629464

     Iteration steps                  Pass 1             Pass 2             Pass 3
  T23/7
Delta ..........................   0.002986925048     0.090629503273     0.362651574654
RD60,mid .......................   0.487649127468     0.487591210267     0.487591089742
CTL ............................   0.462843318636     0.433769342155     0.431453309175
RDTf,mid .......................   0.225705140487     0.211502118518     0.210372789193
  T23/8                              Continue           Continue           Converged
  T23/9
Alpha ..........................   0.019433920195     1.43950513215e–06
Beta ...........................   0.073927186953     0.001866682512
Phi ............................   8.302409550559     2.317461838814
A ..............................   1.205283669609     0.103011400791
B ..............................  –0.521062500820    –0.043309773699
C ..............................   0.543855074908     0.492143295111
RD60,Trial .....................   0.487584959566     0.487591045409
RD60,Trial adjusted
RD60,Trial .....................   0.487592519310      not changed
CTL,Trial ......................   0.438905949758     0.432128227318
RDTf,Trial .....................   0.214007257783     0.210701880813
  T23/10                             Continue           Continue
  T23/11
Reset boundaries
RDTf,high ......................   0.214007257783     0.210701880813
RD60,high ......................   0.487592519310     0.487591107206
  T23/12
RD60 (RD60,Trial rounded) ..........................................   0.4876
```

Example 23/15 – T23/3, RDtf < lower range limit

```
    Input Data
Relative density @ obs. temp. ..   0.20993
Observed temperature Tf, °F .... 187.94
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.2099
Tf, °F ........................ 187.9
  T23/2
Tx, Kelvin ..................... 359.761111111111
  T23/3
RDTf in is less than 0.2100, no solution
```

Example 23/16 – T23/3, RDtf > upper range limit

```
    Input Data
Relative density @ obs. temp. ..   0.74005
Observed temperature Tf, °F .... –28.48
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.7401
Tf, °F ........................ –28.5
  T23/2
Tx, Kelvin ..................... 239.538888888889
  T23/3
RDTf in is greater than 0.7400, no solution
```

Example 23/17 – RDtf = upper range limit, fails T23/6

```
    Input Data
Relative density @ obs. temp. ..      0.74
Observed temperature Tf, °F ....    –50
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.7400
Tf, °F ........................ –50.0
  T23/2
Tx, Kelvin ..................... 227.594444444444
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ..............   0.716864897522
RDtf for Fluid 2 ..............   0.738661816297
  T23/5
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
Tr,x for Fluid 1 ..............   0.448594549018
Tr,x for Fluid 2 ..............   0.421354150596
Tr,60 for Fluid 1 ..............   0.569046132957
Tr,60 for Fluid 2 ..............   0.534491447849
  T23/6
RDtf observed is greater than Fluid 2 RDtf, no solution
```

Example 23/18 – T23/3, Tf = lower range limit

```
    Input Data
Relative density @ obs. temp. ..       0.5
Observed temperature Tf, °F ....  –50.8
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.5000
Tf, °F ..................... –50.8
  T23/2
Tx, Kelvin ..................... 227.150000000000
  T23/3
RDtf  and Tf are within range, continue
  T23/4
RDtf for Fluid 1 ..............   0.485962637468
RDtf for Fluid 2 ..............   0.528232774666
  T23/5
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
Tr,x for Fluid 1 ..............   0.743949169751
Tr,x for Fluid 2 ..............   0.680762429946
Tr,60 for Fluid 1 ..............   0.945552535144
Tr,60 for Fluid 2 ..............   0.865242771467
  T23/6
Upper boundary RD60,high .......   0.429277000000
Upper boundary RDtf,high .......   0.528232774666
Lower boundary RD60,low ........   0.355994000000
Lower boundary RDtf,low ........   0.485962637468

     Iteration steps                  Pass 1             Pass 2             Pass 3
  T23/7
Delta ..........................   0.332086987697     0.764261437411     0.996676046418
RD60,mid .......................   0.380330330719     0.389044267951     0.389195295035
CTL ............................   1.301530344004     1.284969011460     1.284702066298
RDTf,mid .......................   0.495011466176     0.499909828404     0.499999999725
  T23/8                              Continue           Continue           Continue
  T23/9
Alpha ..........................   0.073283000000     0.011401775368     1.51530764763e–04
Beta ...........................   0.042870179217     0.006504743146     9.04641913088e–05
Phi ............................   4.671337977889     1.332539455216     1.003338101716
A ............................. –28.769572088869   –19.740869990631   –16.984940231986
B ..............................  30.911650589439    21.419561059033    18.658299106732
C ..............................  –7.871700166414    –5.385367233142    –4.693719199874
RD60,Trial .....................   0.391732106088     0.389195798716     0.389195295495
CTL,Trial ......................   1.280310496169     1.284701177082     1.284702065485
RDTf,Trial .....................   0.501538727110     0.500000300726     0.500000000000
  T23/10                             Continue           Continue           Converged
  T23/11
Reset boundaries
RDTf,high ......................   0.501538727110     0.500000300726
RD60,high ......................   0.391732106088     0.389195798716
RDTf,low .......................   0.495011466176     0.499909828404
RD60,low .......................   0.380330330719     0.389044267951
  T23/12
RD60 (RD60,Trial rounded) ..........................................   0.3892
```

Example 23/19 – T23/3, Tf < lower range limit

```
    Input Data
Relative density @ obs. temp. ..       0.5
Observed temperature Tf, °F ....  –50.9
    Computed Data – last digit is rounded
  T23/1
    Input Data – rounded
RDtf, observed rel. density ....   0.5000
Tf, °F ........................ –50.9
  T23/2
Tx, Kelvin ..................... 227.094444444444
  T23/3
Tx less than 227.15, no solution
```

5.2 CTL (Table 54) and Density (Table 53) for NGL and LPG using a 15°C Base Temperature

5.2.1 Implementation Procedure for Table 54E (15°C Basis)

This section presents the implementation procedure T54 for the computation of Temperature Correction Factor, C_{TL}. The C_{TL} is used to calculate volumes of fluid at the base temperature from volumes at some known temperature. The fluids are characterized by the specification of density at the base temperature, 15°C.

5.2.1.1 Inputs and Outputs

Inputs: Density at 15°C, ρ_{15} (kg/m^3)
Observed temperature, T_F (°C)

Output: Temperature Correction Factor, C_{TL} (from T_F to T_B)

5.2.1.2 Outline of Calculations

The calculations are performed using an extended two-fluid corresponding states equation. By comparing densities at 60°F, two reference fluids are selected so that one is slightly more dense and one that is slightly less dense than the observed fluid. The densities of these reference fluids are then scaled to the observed reduced temperature (reduced by the critical temperature of the fluid of interest). The Temperature Correction Factor is then computed from the reference fluid densities. See Figure 3 for a general flow chart of the calculation procedure.

5.2.1.3 T54 Implementation Procedure

T54/Step Number Operation/Procedure at that step

T54/1: Round the density ρ_{15} to the nearest 0.1 and round the observed temperature T_F to the nearest 0.05°C.

T54/2: Convert the rounded observed temperature to units of Kelvin, T_x:

$$T_x = T_F + 273.15$$

T54/3: The resultant temperature T_x and density ρ_{15} must fall within the following boundaries:

Temperature between 227.15 and 366.15 K, inclusive (equivalent to –46 to 93°C, or –50.8 to 199.4°F)
Density between 351.7 and 687.8 kg/m^3 inclusive

If these values do not fall in these ranges, then the standard does not apply. Flag this result (return a –1 for C_{TL}) and exit this procedure.

Note: The density boundaries tested in this step slightly exceed the boundaries used within the T24 implementation procedure (0.3500 to 0.6880 relative density at 60°F) that act as the true limits for this method.

T54/4: Convert the 15°C density to relative density, relative to the density of water at 60°F

$$\gamma_{TB} = \frac{\rho_{15}}{999.016}$$

T54/5: Use the procedure described in Section 5.1.2 for Table 23 to compute a relative density at 60°F from the known relative density at 15°C. Enter the procedure at Step T23/4 so as to avoid additional rounding of the input values. Inputs to implementation procedure T23 are the values of T_{BK} and γ_{TB}, where T_{BK} is the base temperature 15°C in Kelvin (288.15 K) and γ_{TB} is the density at the base temperature 15°C . Implementation procedure T23 is exited after Step T23/11 so as not to round the output values. The converged output from Step T23/11 is γ_{60}.

T54/6: The resultant density $\gamma_{60,}$ if it were rounded to the nearest 0.0001, must fall within 0.3500 and 0.6880 inclusive. Test γ_{60} to ensure it is within the following boundaries:

Relative density greater than or equal to 0.34995 and less than 0.68805

If the relative density does not fall in this range, then the standard does not apply. Flag this result (return a –1 for C_{TL}) and exit this procedure.

T54/7: Use the procedure described in Section 5.1.1 for Table 24 to compute the Temperature Correction Factor (C_{TL1}) from 60°F to the observed temperature, T_x. This step provides the factor used to reduce an observed volume at T_x to a volume at 60°F when the relative density at 60°F, γ_{60}, is known. Enter implementation procedure T24 with T_x and γ_{60} at Step T24/4 to avoid double rounding of the inputs. On exit skip Step T24/14 to avoid rounding the output, C_{TL1}.

By definition:

$$C_{TL1} = \frac{V_{60}}{V_{Tx}} = \frac{\gamma_{Tx}}{\gamma_{60}}$$

T54/8: Use the procedure described in Section 5.1.1 for Table 24 to compute the Temperature Correction Factor (C_{TL2}) from 60°F to the new base temperature 15°C. This step provides the factor used to reduce an observed volume at 15°C to a volume at 60°F if the relative density at 60°F, γ_{60}, is known. Enter implementation procedure T24 at Step T24/4 to avoid double rounding of the inputs. The inputs are T_{BK} and γ_{60}, where T_{BK} is the base temperature 15°C in Kelvin (288.15 K). On exit skip Step T24/14 to avoid rounding of the output C_{TL2}.

By definition:

$$C_{TL2} = \frac{V_{60}}{V_{15}} = \frac{\gamma_{TB}}{\gamma_{60}}$$

T54/9: Compute the desired C_{TL} to reduce volume from the observed temperature, T_F, to the base condition of 15°C. The defining formulas show that the calculation is made by computing the ratio C_{TL1}/C_{TL2}.

$$\frac{C_{TL1}}{C_{TL2}} = \frac{\left(\frac{V_{60}}{V_{Tx}}\right)}{\left(\frac{V_{60}}{V_{15}}\right)} = \frac{V_{15}}{V_{Tx}}$$

$$C_{TL} = \frac{V_{15}}{V_{Tx}} = \frac{\gamma_{Tx}}{\gamma_{15}}$$

T54/10: Perform error check to ascertain that only positive C_{TL} is used. If C_{TL} is less than or equal to 0, set an error flag (such as $C_{TL} = -1$) and quit.

T54/11: Round the Temperature Correction Factor C_{TL} to the nearest 0.00001.

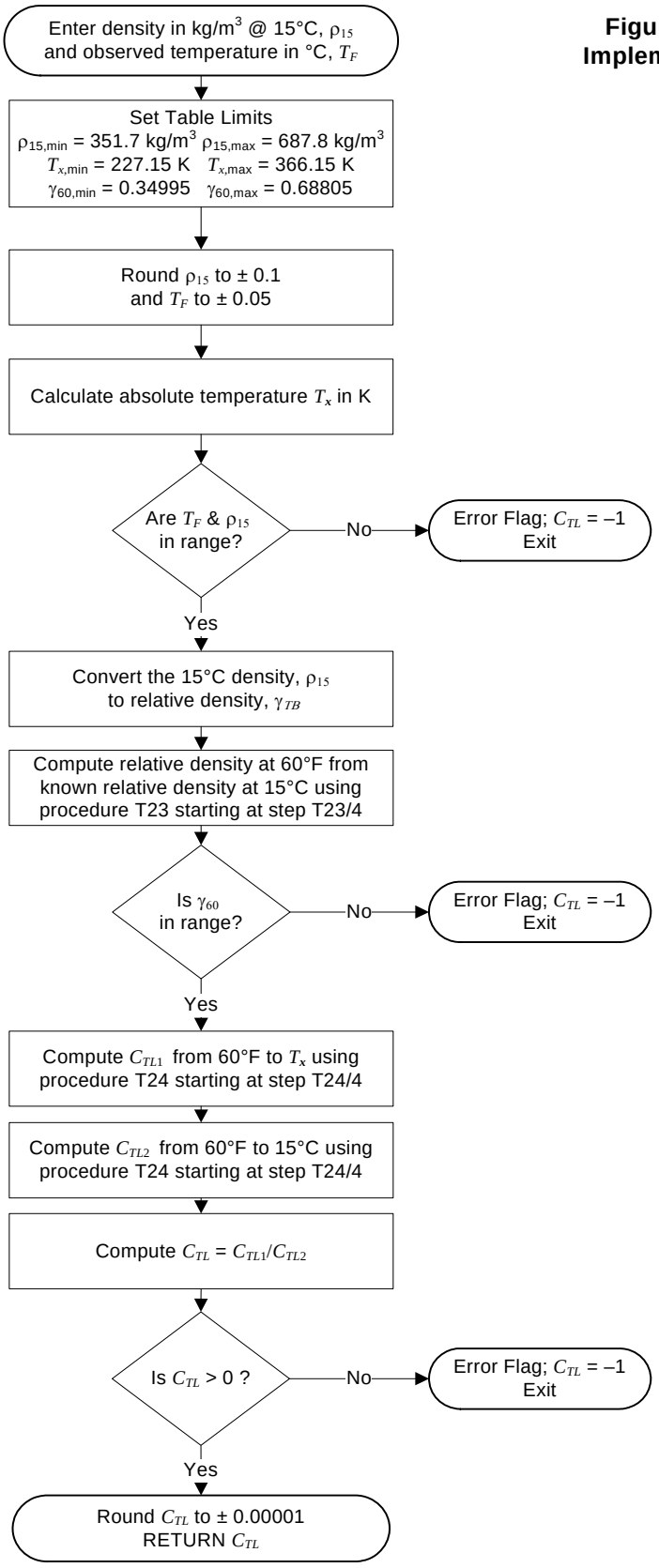


Figure 3. Flow Chart of Implementation Procedure for Table 54

5.2.1.4 Examples for Section 5.2.2 (Table 54E)

(See Table 1 for properties of the Reference Fluids)

Example 54/1 – Utilize EE (68/32) and Ethane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 352.59
Observed temperature Tf, °C .... –45.020
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 .......... 352.6
Tf, °C, rounded to 0.05 ........ –45.00
  T54/2
Tx, Kelvin ..................... 228.15
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.352947300143
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.350947981104
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
CTL1, Tx to 60°F ...............   1.374246650548
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
CTL2, 15°C to 60°F .............   1.005696910034
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   1.366462039245
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   1.36646
```

Example 54/2 – Utilize Ethane and EP (65/35)

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 399.55
Observed temperature Tf, °C ....  –3.920
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 399.6
Tf, °C, rounded to 0.05 ........  –3.90
  T54/2
Tx, Kelvin ..................... 269.25
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.399993593696
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.398679750427
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
CTL1, Tx to 60°F ...............   1.101743247711
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
CTL2, 15°C to 60°F .............   1.003295485330
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   1.098124394877
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   1.09812
```

Example 54/3 – Utilize EP (65/35) and EP (35/65)

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 451.09
Observed temperature Tf, °C ....  30.774
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ......... 451.1
Tf, °C, rounded to 0.05 ........  30.75
  T54/2
Tx, Kelvin ..................... 303.90
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.451544319610
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.450522856945
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  EP (65/35)
Reference Fluid 2 ..............  EP (35/65)
CTL1, Tx to 60°F ...............   0.932384171290
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  EP (65/35)
Reference Fluid 2 ..............  EP (35/65)
CTL2, 15°C to 60°F .............   1.002267286478
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   0.930274971427
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   0.93027
```

Example 54/4 – Utilize EP (35/65) and Propane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 489.92
Observed temperature Tf, °C ....  84.975
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 489.9
Tf, °C, rounded to 0.05 ........  85.00
  T54/2
Tx, Kelvin ..................... 358.15
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.490382536416
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.489511777456
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  EP (35/65)
Reference Fluid 2 ..............  Propane
CTL1, Tx to 60°F ...............   0.608584025858
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  EP (35/65)
Reference Fluid 2 ..............  Propane
CTL2, 15°C to 60°F .............   1.001778832207
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   0.607503379281
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   0.60750
```

Example 54/5 – Utilize Propane and i-Butane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 539.49
Observed temperature Tf, °C ....  68.360
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ......... 539.5
Tf, °C, rounded to 0.05 ........  68.35
  T54/2
Tx, Kelvin ..................... 341.50
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.540031390889
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.539309445177
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  Propane
Reference Fluid 2 ..............  i-Butane
CTL1, Tx to 60°F ...............   0.850308225942
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  Propane
Reference Fluid 2 ..............  i-Butane
CTL2, 15°C to 60°F .............   1.001338650108
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   0.849171482446
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   0.84917
```

Example 54/6 – Utilize i-Butane and n-Butane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 569.42
Observed temperature Tf, °C .... –16.090
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ......... 569.4
Tf, °C, rounded to 0.05 ........ –16.10
  T54/2
Tx, Kelvin ..................... 257.05
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.569960841468
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.569305082960
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  i-Butane
Reference Fluid 2 ..............  n-Butane
CTL1, Tx to 60°F ...............   1.062511014737
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  i-Butane
Reference Fluid 2 ..............  n-Butane
CTL2, 15°C to 60°F .............   1.001151857830
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   1.061288561198
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   1.06129
```

Example 54/7 – Utilize n-Butane and i-Pentane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 599.37
Observed temperature Tf, °C ....  43.360
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 599.4
Tf, °C, rounded to 0.05 ........  43.35
  T54/2
Tx, Kelvin ..................... 316.50
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.599990390544
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.599396660576
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  n-Butane
Reference Fluid 2 ..............  i-Pentane
CTL1, Tx to 60°F ...............   0.948276855780
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  n-Butane
Reference Fluid 2 ..............  i-Pentane
CTL2, 15°C to 60°F .............   1.000990546173
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   0.947338473281
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   0.94734
```

Example 54/8 – Utilize i-Pentane and n-Pentane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 624.42
Observed temperature Tf, °C ....  76.650
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 624.4
Tf, °C, rounded to 0.05 ........  76.65
  T54/2
Tx, Kelvin ..................... 349.80
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.625015014775
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.624458073820
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  i-Pentane
Reference Fluid 2 ..............  n-Pentane
CTL1, Tx to 60°F ...............   0.893460003018
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  i-Pentane
Reference Fluid 2 ..............  n-Pentane
CTL2, 15°C to 60°F .............   1.000891878859
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   0.892663854998
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   0.89266
```

Example 54/9 – Utilize n-Pentane and i-Hexane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 639.41
Observed temperature Tf, °C .... –24.460
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ......... 639.4
Tf, °C, rounded to 0.05 ........ –24.45
  T54/2
Tx, Kelvin ..................... 248.70
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.640029789313
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.639504496457
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  n-Pentane
Reference Fluid 2 ..............  i-Hexane
CTL1, Tx to 60°F ...............   1.057426821739
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  n-Pentane
Reference Fluid 2 ..............  i-Hexane
CTL2, 15°C to 60°F .............   1.000821406041
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   1.056558957827
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   1.05656
```

Example 54/10 – Utilize i-Hexane and n-Hexane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 659.38
Observed temperature Tf, °C ....  80.580
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 659.4
Tf, °C, rounded to 0.05 ........  80.60
  T54/2
Tx, Kelvin ..................... 353.75
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.660049488697
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.659551831579
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  i-Hexane
Reference Fluid 2 ..............  n-Hexane
CTL1, Tx to 60°F ...............   0.905892081483
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  i-Hexane
Reference Fluid 2 ..............  n-Hexane
CTL2, 15°C to 60°F .............   1.000754538301
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   0.905209066572
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   0.90521
```

Example 54/11 – Utilize n-Hexane and n-Heptane

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 669.38
Observed temperature Tf, °C ....  82.790
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 669.4
Tf, °C, rounded to 0.05 ........  82.80
  T54/2
Tx, Kelvin ..................... 355.95
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.670059338389
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.669573371528
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
CTL1, Tx to 60°F ...............   0.907185481500
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
CTL2, 15°C to 60°F .............   1.000725785828
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   0.906527536662
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   0.90653
```

Example 54/12 – Reduced temperature Tr,x greater than 1

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 399.83
Observed temperature Tf, °C ....  90.570
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 399.8
Tf, °C, rounded to 0.05 ........  90.55
  T54/2
Tx, Kelvin ..................... 363.70
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.400193790690
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.398881468881
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
Reduced temperature Tr,x greater than 1.0, no solution
CTL1, Tx to 60°F ...............  –1.0
Value from Table 24 not valid, no solution
```

Example 54/13 – Tf < lower range limit

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 449.56
Observed temperature Tf, °C .... –46.030
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 .......... 449.6
Tf, °C, rounded to 0.05 ........ –46.05
  T54/2
Tx, Kelvin ..................... 227.10
  T54/3
Tx less than 227.15, no solution
```

Example 54/14 – Den15 < lower range limit

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 349.59
Observed temperature Tf, °C ....   4.440
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 349.6
Tf, °C, rounded to 0.05 ........   4.45
  T54/2
Tx, Kelvin ..................... 277.60
  T54/3
Density is less than  351.7, no solution
```

Example 54/15 – Tf > upper range limit

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 449.56
Observed temperature Tf, °C ....  93.030
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 .......... 449.6
Tf, °C, rounded to 0.05 ........  93.05
  T54/2
Tx, Kelvin ..................... 366.20
  T54/3
Tx greater than 366.15, no solution
```

Example 54/16 – Den15 > upper range limit

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 687.85
Observed temperature Tf, °C .... –17.780
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 .......... 687.9
Tf, °C, rounded to 0.05 ........ –17.80
  T54/2
Tx, Kelvin ..................... 255.35
  T54/3
Den15 is greater than  687.8, no solution
```

Example 54/17 – Tf & Den15 = upper range limits

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 687.84
Observed temperature Tf, °C ....  93.020
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ..... 687.8
Tf, °C, rounded to 0.05 ........  93.00
  T54/2
Tx, Kelvin ..................... 366.15
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.688477461822
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.688010661267
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
CTL1, Tx to 60°F ...............   0.900470590102
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
CTL2, 15°C to 60°F .............   1.000678478666
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   0.899860054252
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   0.89986
```

Example 54/18 – Tf & Den15 = lower range limits

```
    Input Data to Implementation Procedure T54
Density (kg/m³) @ 15°C (Den15) . 351.67
Observed temperature Tf, °C .... –46.020
    Computed Data – last digit is rounded
  T54/1
    Input Data – rounded
Den15, rounded to 0.1 ......... 351.7
Tf, °C, rounded to 0.05 ........ –46.00
  T54/2
Tx, Kelvin ..................... 227.15
  T54/3
Tx and Den15 are within range, continue
  T54/4
Den15 relative to 60°F water ...   0.352046413671
  T54/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.350027377993
  T54/6
RD60 is within range, continue
  T54/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
CTL1, Tx to 60°F ...............   1.381296917892
  T54/8, Call Table 24 Procedure with 15°C and RD60
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
CTL2, 15°C to 60°F .............   1.005768222160
  T54/9 CTL = CTL1/CTL2
CTL, Tx to 15°C ................   1.373374985865
  T54/10
CTL is positive, continue
  T54/11 CTL rounded
CTL (rounded) ..................   1.37337
```

5.2.2 Implementation Procedure for Table 53E (15°C Basis)

This section presents the implementation procedure T53 for calculating the densities of NGLs and LPGs at a base conditions of 15°C from known measurement temperatures and densities.

Density readings must be corrected for the effect of temperature on the instrument prior to entering the density into the following implementation procedure.

5.2.2.1 Inputs and Outputs

Inputs: Density at observed temperature, ρ_x (kg/m^3)
Observed temperature, T_F (°C)

Output: Density at 15°C, ρ_{15} (kg/m^3)

5.2.2.2 Outline of Calculations

The calculations are done using an extended two-fluid corresponding states equation. Two reference fluids are found that are slightly denser and slightly less dense than the observed fluid by comparing their densities at the observed temperature. Iteration must be performed to determine the value of the fluid's relative density at 60°F such that when the Temperature Correction Factor is applied, the observed relative density is obtained. The "guessed" value for the fluid's relative density at 60°F is constrained to lie between the relative densities at 60°F of these two reference fluids (as upper and lower bounds). As the iterations progress, these upper and lower bounds are "brought together" based upon intermediate calculations. The relative density at 15°C is then computed from the 60°F relative density by using scaling factors between the properties of the two reference fluids.

See Figure 4 for a general flow chart of the calculation procedure.

5.2.2.3 T53 Implementation Procedure

T53/Step Number Operation/Procedure at that step

T53/1: Round the density ρ_x to the nearest 0.1 and round the observed temperature T_F to the nearest 0.05°C.

T53/2: Convert the rounded observed temperature to units of Kelvin, T_x:

$$T_x = T_F + 273.15$$

T53/3: Convert the density, ρ_x, to relative density, γ_x, relative to the density of water at 60°F:

$$\gamma_x = \frac{\rho_x}{999.016}$$

T53/4: Check the values of temperature and relative density to ensure that they are in the proper range. The observed temperature T_x and relative density γ_x must fall within the following boundaries:

Temperature between 227.15 and 366.15 K, inclusive (equivalent to –46 to 93°C, or –50.8 to 199.4°F)
Relative density, if it were rounded to the nearest 0.0001, must fall within 0.2100 and 0.7400 inclusive. Test γ_x to ensure it is within the following boundaries:

Relative density greater than or equal to 0.20995 and less than 0.74005

If these values do not fall in these ranges, then the standard does not apply. Flag this result (possibly by returning –1 for the density) and exit this procedure.

T53/5: Compute the relative density at 60°F, γ_{60}, from the temperature and the relative density at the measurement condition, γ_x. Use the procedure described in Section 5.2.1 for Table 23 to perform this step. Enter the procedure with γ_x and T_x at Step T23/4 so as to avoid additional rounding of the input values. Exit after Step T23/11 to avoid rounding the result.

T53/6: Compute the relative density at 15°C, γ_{15}, from the relative density at 60°F. This is performed by using the procedure described in Section 5.1.1 for Table 24. Enter implementation procedure T24 with γ_{60} and T_x = 288.15 (e.g. 273.15 + 15.00). Enter at Step T24/4 to avoid double rounding of the inputs. The C_{TL} for the conversion between γ_{60} and γ_{15} will be returned without rounding from Step T24/13. Compute γ_{15}:

$$\gamma_{15} = C_{TL} \times \gamma_{60}$$

T53/7: Insure that only valid values came from Steps T53/5 and T53/6. If the γ_{60} obtained from Section 5.2.1 for Table 23 is greater than –1, then proceed. If not, set the fluid density at 15°C to some flag value such as –1 and quit. If the C_{TL} from Step T53/6 is negative, then set the fluid density at 15°C to the error flag condition and exit this procedure.

T53/8: Calculate the fluid density at 15°C from the relative density at 15°C.

$$\rho_{15} = \gamma_{15} \times 999.016$$

T53/9: Round the fluid density, ρ_{15}, to the nearest 0.1. Exit this procedure.

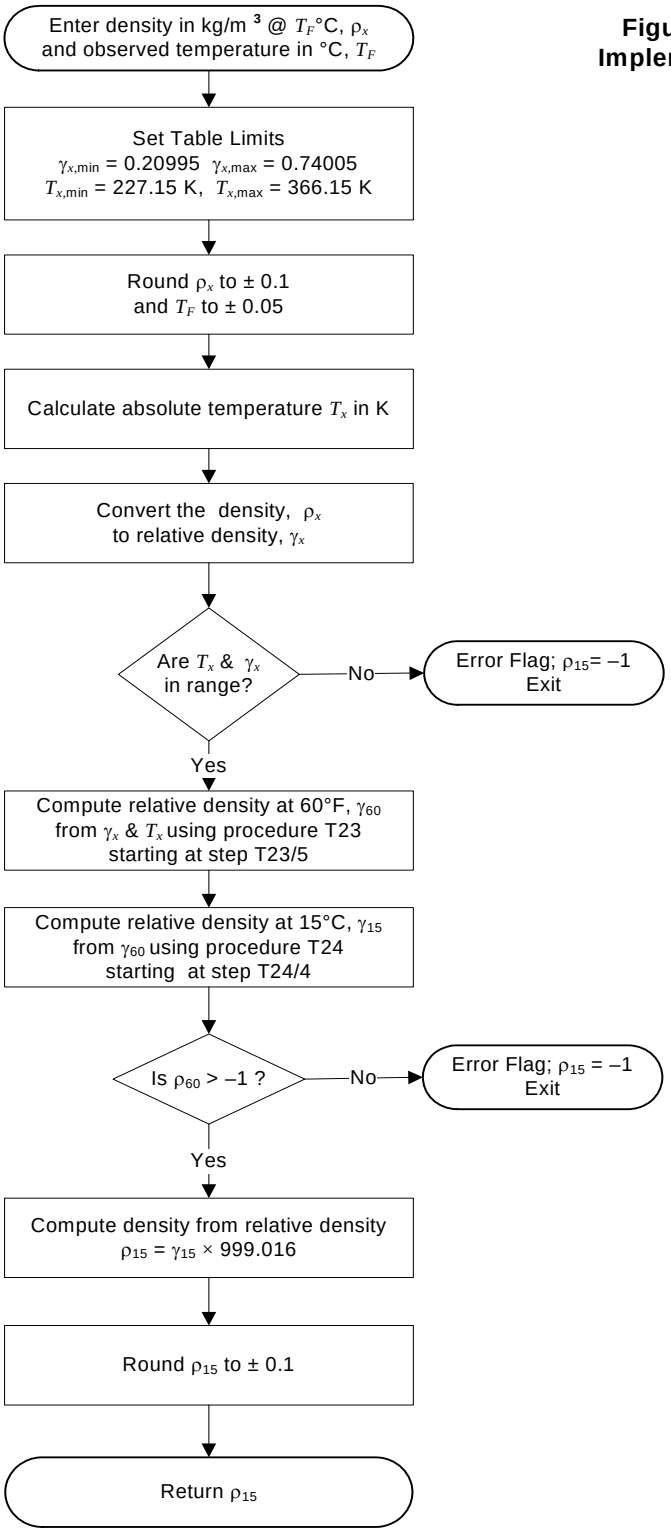


Figure 4. Flow Chart of Implementation Procedure for Table 53

5.2.2.4 Examples for Section 5.2.2 (Table 53E)

(See Table 1 for properties of the Reference Fluids)

Example 53/1 – Utilize EP (65/35) & EP (35/65)

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 532.57
Observed Temperature Tf (°C) ... –44.120
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 532.6
Temperature rounded to 0.05 .... –44.10
  T53/2
Tx, Kelvin ..................... 229.05
  T53/3
Density relative to 60° water ..   0.533124594601
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.440515294609
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.002432483838
Relative density at 15°C .......   0.441586840944
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 441.152319492337
  T53/9
Density at 15°C (rounded) ...... 441.2
```

Example 53/2 – Utilize n-Pentane & i-Hexane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 673.66
Observed Temperature Tf (°C) ... –23.330
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 673.7
Temperature rounded to 0.05 .... –23.35
  T53/2
Tx, Kelvin ..................... 249.80
  T53/3
Density relative to 60° water ..   0.674363573757
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.638538685930
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.000825081981
Relative density at 15°C .......   0.639065532694
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 638.436692209971
  T53/9
Density at 15°C (rounded) ...... 638.4
```

Example 53/3 – Utilize EP (35/65) & Propane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 245.49
Observed Temperature Tf (°C) ...  87.770
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 245.5
Temperature rounded to 0.05 ....  87.75
  T53/2
Tx, Kelvin ..................... 360.90
  T53/3
Density relative to 60° water ..   0.245741809941
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.488795025411
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.001786178364
Relative density at 15°C .......   0.489668100510
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 489.186267098922
  T53/9
Density at 15°C (rounded) ...... 489.2
```

Example 53/4 – Utilize n-Butane & i-Pentane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 499.55
Observed Temperature Tf (°C) ...  87.820
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 499.6
Temperature rounded to 0.05 ....  87.80
  T53/2
Tx, Kelvin ..................... 360.95
  T53/3
Density relative to 60° water ..   0.500092090617
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.591794896225
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.001026475488
Relative density at 15°C .......   0.592402359180
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 591.819435258795
  T53/9

Density at 15°C (rounded) ...... 591.8
```

Example 53/5 – Utilize Ethane & EP (65/35)

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 395.09
Observed Temperature Tf (°C) ...  15.430
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 395.1
Temperature rounded to 0.05 ....  15.45
  T53/2
Tx, Kelvin ..................... 288.60
  T53/3
Density relative to 60° water ..   0.395489161335
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.395233433716
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.003392579214
Relative density at 15°C .......   0.396574294447
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 396.184065341566
  T53/9
Density at 15°C (rounded) ...... 396.2
```

Example 53/6 – Utilize i-Butane & n-Butane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 449.59
Observed Temperature Tf (°C) ...  93.020
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 449.6
Temperature rounded to 0.05 ....  93.00
  T53/2
Tx, Kelvin ..................... 366.15
  T53/3
Density relative to 60° water ..   0.450042842157
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.565490291365
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.001176265550
Relative density at 15°C .......   0.566155458114
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 565.598361142720
  T53/9
Density at 15°C (rounded) ...... 565.6
```

Example 53/7 – Utilize i-Hexane & n-Hexane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 600.74
Observed Temperature Tf (°C) ...  80.650
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 600.7
Temperature rounded to 0.05 ....  80.65
  T53/2
Tx, Kelvin ..................... 353.80
  T53/3
Density relative to 60° water ..   0.601291671004
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.662699711760
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.000745797303
Relative density at 15°C .......   0.663193951418
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 662.541368569934
  T53/9
Density at 15°C (rounded) ...... 662.5
```

Example 53/8 – Calculated RD60 near 0.6880 using n-Hexane & n-Heptane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 736.80
Observed Temperature Tf (°C) ... –44.230
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 736.8
Temperature rounded to 0.05 .... –44.25
  T53/2
Tx, Kelvin ..................... 228.90
  T53/3
Density relative to 60° water ..   0.737525725314
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.687974688885
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.000678561307
Relative density at 15°C .......   0.688441521889
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 687.764095431267
  T53/9
Density at 15°C (rounded) ...... 687.8
```

Example 53/9 – Calculated RD60 near 0.3500 using EE (68/32) & Ethane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 224.56
Observed Temperature Tf (°C) ...  30.680
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 224.6
Temperature rounded to 0.05 ....  30.70
  T53/2
Tx, Kelvin ..................... 303.85
  T53/3
Density relative to 60° water ..   0.224821224084
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.350001829424
  T53/6, Call Table 24 Procedure to obtain CTL from 60°F to 15°C
CTL from Table 24 ..............   1.005770230278
Relative density at 15°C .......   0.352021420577
  T53/7, Values returned from Tables 23 & 24 valid, continue
  T53/8
Density at 15 °C (kg/m³) ....... 351.675031499270
  T53/9
Density at 15°C (rounded) ...... 351.7
```

Example 53/10 – T23/6, RDtf < lower boundary using EE (68/32) & Ethane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 339.63
Observed Temperature Tf (°C) ...  18.130
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 339.6
Temperature rounded to 0.05 ....  18.15
  T53/2
Tx, Kelvin ..................... 291.30
  T53/3
Density relative to 60° water ..   0.339934495544
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............  –1.0
Input data is outside range of Table 23, no solution
```

Example 53/11 – T23/6, RDtf > upper boundary using n-Hexane & n-Heptane

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 727.86
Observed Temperature Tf (°C) ... –33.070
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 727.9
Temperature rounded to 0.05 .... –33.05
  T53/2
Tx, Kelvin ..................... 240.10
  T53/3
Density relative to 60° water ..   0.728616959088
  T53/4
Tx and relative density are within range, continue
  T53/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............  –1.0
Input data is outside range of Table 23, no solution
```

Example 53/12 – Density < input range limit

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 209.74
Observed Temperature Tf (°C) ...  11.530
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 209.7
Temperature rounded to 0.05 ....  11.55
  T53/2
Tx, Kelvin ..................... 284.70
  T53/3
Density relative to 60° water ..   0.209906548043
  T53/4
Relative density is less than 0.2100, no solution
```

Example 53/13 – Input density > input range limit

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 739.32
Observed Temperature Tf (°C) ...  11.530
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 739.3
Temperature rounded to 0.05 ....  11.55
  T53/2
Tx, Kelvin ..................... 284.70
  T53/3
Density relative to 60° water ..   0.740028187737
  T53/4
Relative density is greater than 0.7400, no solution
```

Example 53/14 – Input temperature < input range limit

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 645.62
Observed Temperature Tf (°C) ... –46.030
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 645.6
Temperature rounded to 0.05 .... –46.05
  T53/2
Tx, Kelvin ..................... 227.10
  T53/3
Density relative to 60° water ..   0.646235896122
  T53/4
Tx less than 227.15, no solution
```

Example 53/15 – Input temperature > input range limit

```
    Input Data to Implementation Procedure T53
Density @ obs. temp. (kg/m³) ... 645.62
Observed Temperature Tf (°C) ...  93.070
    Computed Data – last digit is rounded
  T53/1
    Input Data – rounded
Density, rounded to 0.1 ........ 645.6
Temperature rounded to 0.05 ....  93.05
  T53/2
Tx, Kelvin ..................... 366.20
  T53/3
Density relative to 60° water ..   0.646235896122
  T53/4
Tx greater than 366.15, no solution
```

5.3 CTL (Table 60) and Density (Table 59) for NGL and LPG using a 20°C Base Temperature

5.3.1 Implementation Procedure for Table 60E (20°C Basis)

This section presents the implementation procedure T60 for the computation of Temperature Correction Factors, C_{TL}s. The C_{TL}s are used to calculate volumes of fluid at the base temperature from volumes at some known temperature. The fluids are characterized by the specification of density at the base temperature, 20°C.

5.3.1.1 Inputs and Outputs

Inputs: Density at 20°C, ρ_{20} (kg/m^3)
Observed temperature, T_F (°C)

Output: Temperature Correction Factor, C_{TL} (from T_F to T_B)

5.3.1.2 Outline of Calculations

The calculations are performed using an extended two-fluid corresponding states equation. By comparing densities at 60°F, two reference fluids are selected so that one is slightly more dense and one that is slightly less dense than the observed fluid. The densities of these reference fluids are then scaled to the observed reduced temperature (reduced by the critical temperature of the fluid of interest). The Temperature Correction Factor is then computed from the reference fluid densities. See Figure 5 for a general flow chart of the calculation procedure.

5.3.1.3 T60 Implementation Procedure

T60/Step Number Operation/Procedure at that step

T60/1: Round the density ρ_{20} to the nearest 0.1 and round the observed temperature T_F to the nearest 0.05°C.

T60/2: Convert the rounded observed temperature to units of Kelvin, T_x:

$$T_x = T_F + 273.15$$

T60/3: The resultant temperature T_x and ρ_{20} must fall within the following boundaries:

Temperature between 227.15 and 366.15 K, inclusive (equivalent to –46 to 93°C, or –50.8 to 199.4°F)
Density between 331.7 and 683.6 kg/m^3 inclusive

If these values do not fall in these ranges, then the standard does not apply. Flag this result (possibly by returning a –1 for C_{TL}) and exit this procedure.

Note: The density boundaries tested in this step slightly exceed the boundaries used within the T24 implementation procedure (0.3500 to 0.6880 relative density at 60°F) that act as the true limits for this method.

T60/4: Convert the 20°C density to relative density, relative to the density of water at 60°F:

$$\gamma_{TB} = \frac{\rho_{20}}{999.016}$$

T60/5: Use the procedure described in Section 5.1.2 for Table 23 to compute a relative density at 60°F from the known relative density at 20°C. Enter the procedure at Step T23/4 so as to avoid additional rounding of the input values. Inputs to Procedure T23 are the values of T_{BK} and γ_{TB}, where T_{BK} is the base temperature 20°C in Kelvin (293.15 K) and γ_{TB} is the density at the base temperature 20°C. Implementation procedure T23 is exited after Step T23/11 so as not to round the output values. The converged output from Step T23/11 is γ_{60}.

T60/6: The resultant density $\gamma_{60,}$ if it were rounded to the nearest 0.0001, must fall within 0.3500 and 0.6880 inclusive. Test γ_{60} to ensure it is within the following boundaries:

Relative density greater than or equal to 0.34995 and less than 0.68805

If the relative density does not fall in this range, then the standard does not apply. Flag this result (return a –1 for C_{TL}) and exit this procedure.

T60/7: Use the procedure described in Section 5.1.1 for Table 24 to compute the Temperature Correction Factor (C_{TL1}) from 60°F to the observed temperature, T_x. This step provides the factor used to reduce an observed volume at T_x to a volume at 60°F when the relative density at 60°F, γ_{60}, is known. Enter implementation procedure T24 with T_x and γ_{60} at Step T24/4 to avoid double rounding of the inputs. On exit skip Step T24/14 to avoid rounding the output C_{TL1}.

By definition:

$$C_{TL1} = \frac{V_{60}}{V_{Tx}} = \frac{\gamma_{Tx}}{\gamma_{60}}$$

T60/8: Use the procedure described in Section 5.1.1 for Table 24 to compute the Temperature Correction Factor (C_{TL2}) from 60°F to the new base temperature 20°C. This step provides the factor used to reduce an observed volume at 20°C to a volume at 60°F when the relative density at 60°F, γ_{60}, is known. Enter implementation procedure T24 at Step T24/4 to avoid double rounding of the inputs. The inputs are T_{BK} and γ_{60}, where T_{BK} is the base temperature 20°C in Kelvin (293.15 K). On exit skip Step T24/14 to avoid double rounding of the output C_{TL1}.

By definition:

$$C_{TL2} = \frac{V_{60}}{V_{20}} = \frac{\gamma_{TB}}{\gamma_{60}}$$

T60/9: Compute the desired C_{TL} to reduce volume from the observed temperature, T_x, to the base condition of 20°C. The defining formulas show that the calculation is made by computing the ratio C_{TL1}/C_{TL2}.

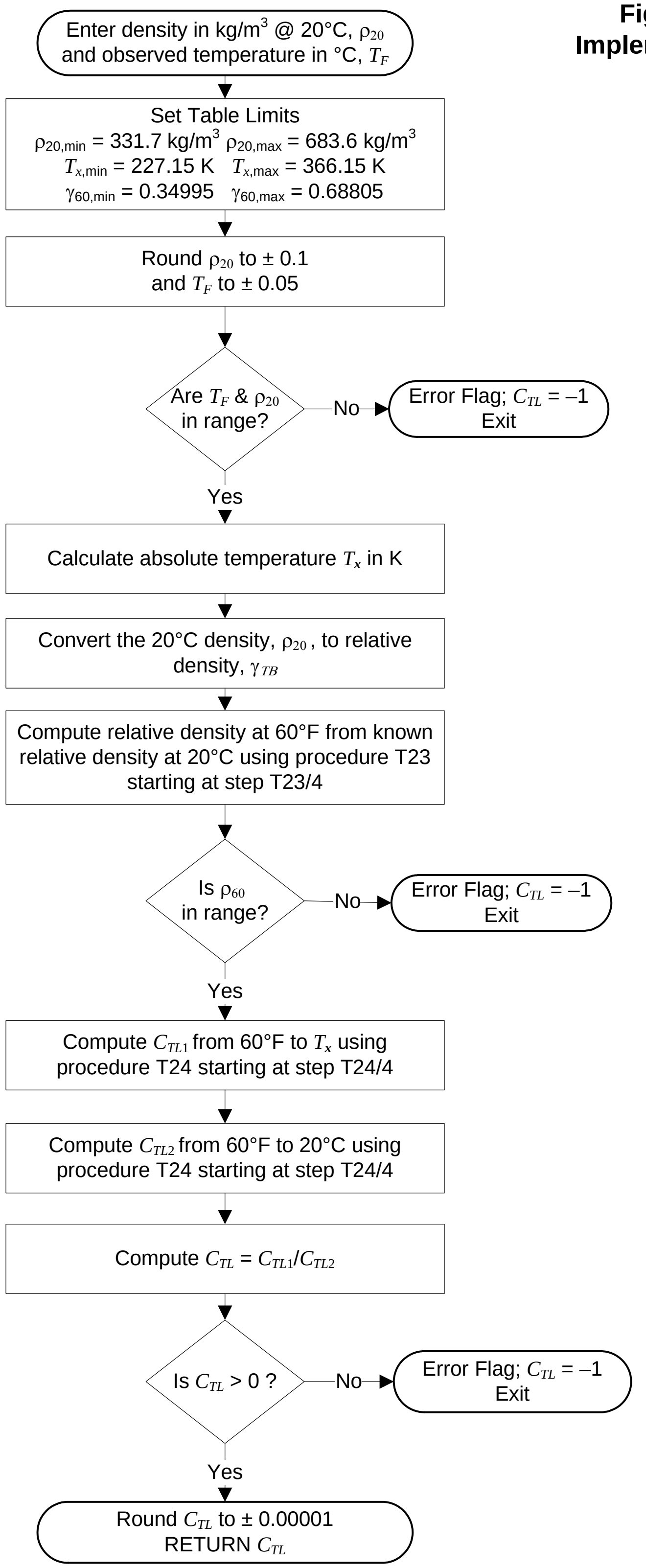
$$\frac{C_{TL1}}{C_{TL2}} = \frac{\left(\frac{V_{60}}{V_{Tx}}\right)}{\left(\frac{V_{60}}{V_{20}}\right)} = \frac{V_{20}}{V_{Tx}}$$

$$C_{TL1} = \frac{V_{20}}{V_{Tx}} = \frac{\rho_{Tx}}{\rho_{20}}$$

T60/10: Perform error check to ascertain that only positive C_{TL} is used. If C_{TL} is less than or equal to 0, set an error flag (such as $C_{TL} = -1$) and exit this procedure.

T60/11: Round the Temperature Correction Factor C_{TL} to the nearest 0.00001. Exit this procedure.

Figure 5. Flow Chart of Implementation Procedure for Table 60



5.3.1.4 Examples for Section 5.3.1 (Table 60)

(See Table 1 for properties of the Reference Fluids)

Example 60/1 – Utilize EE (68/32) and Ethane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 332.69
Observed temperature Tf, °C ....  –5.020
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 .......... 332.7
Tf, °C, rounded to 0.05 ........  –5.00
  T60/2
Tx, Kelvin ..................... 268.15
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.333027699256
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.350810339452
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
CTL1, Tx to 60°F ...............   1.164305432161
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  EE (68/32)
Reference Fluid 2 ..............  Ethane
CTL2, 20°C to 60°F .............   0.949309823927
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   1.226475701416
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   1.22648
```

Example 60/2 – Utilize Ethane and EP (65/35)

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 399.55
Observed temperature Tf, °C ....  –3.920
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 399.6
Tf, °C, rounded to 0.05 ........  –3.90
  T60/2
Tx, Kelvin ..................... 269.25
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.399993593696
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.410257484971
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
CTL1, Tx to 60°F ...............   1.094238548593
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
CTL2, 20°C to 60°F .............   0.974981830112
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   1.122316862527
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   1.12232
```

Example 60/3 – Utilize EP (65/35) and EP (35/65)

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 451.09
Observed temperature Tf, °C ....  30.774
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 451.1
Tf, °C, rounded to 0.05 ........  30.75
  T60/2
Tx, Kelvin ..................... 303.90
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.451544319610
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.459584427423
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  EP (65/35)
Reference Fluid 2 ..............  EP (35/65)
CTL1, Tx to 60°F ...............   0.936730755171
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  EP (65/35)
Reference Fluid 2 ..............  EP (35/65)
CTL2, 20°C to 60°F .............   0.982505700078
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   0.953409995582
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   0.95341
```

Example 60/4 – Utilize EP (35/65) and Propane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 489.92
Observed temperature Tf, °C ....  84.975
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 489.9
Tf, °C, rounded to 0.05 ........  85.00
  T60/2
Tx, Kelvin ..................... 358.15
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.490382536416
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.497272599314
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  EP (35/65)
Reference Fluid 2 ..............  Propane
CTL1, Tx to 60°F ...............   0.659050245916
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  EP (35/65)
Reference Fluid 2 ..............  Propane
CTL2, 20°C to 60°F .............   0.986144294080
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   0.668310154886
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   0.66831
```

Example 60/5 – Utilize Propane and i-Butane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 539.49
Observed temperature Tf, °C ....  68.360
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 539.5
Tf, °C, rounded to 0.05 ........  68.35
  T60/2
Tx, Kelvin ..................... 341.50
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.540031390889
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.545748636061
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  Propane
Reference Fluid 2 ..............  i-Butane
CTL1, Tx to 60°F ...............   0.856605931918
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  Propane
Reference Fluid 2 ..............  i-Butane
CTL2, 20°C to 60°F .............   0.989524032138
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   0.865674712384
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   0.86567
```

Example 60/6 – Utilize i-Butane and n-Butane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 569.42
Observed temperature Tf, °C .... –16.090
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 569.4
Tf, °C, rounded to 0.05 ........ –16.10
  T60/2
Tx, Kelvin ..................... 257.05
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.569960841468
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.575142670956
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  i-Butane
Reference Fluid 2 ..............  n-Butane
CTL1, Tx to 60°F ...............   1.060732897657
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  i-Butane
Reference Fluid 2 ..............  n-Butane
CTL2, 20°C to 60°F .............   0.990990359414
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   1.070376606170
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   1.07038
```

Example 60/7 – Utilize n-Butane and i-Pentane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 599.37
Observed temperature Tf, °C ....  43.360
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 599.4
Tf, °C, rounded to 0.05 ........  43.35
  T60/2
Tx, Kelvin ..................... 316.50
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.599990390544
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.604700215005
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  n-Butane
Reference Fluid 2 ..............  i-Pentane
CTL1, Tx to 60°F ...............   0.949609422686
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  n-Butane
Reference Fluid 2 ..............  i-Pentane
CTL2, 20°C to 60°F .............   0.992211317977
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   0.957063687423
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   0.95706
```

Example 60/8 – Utilize i-Pentane and n-Pentane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 624.42
Observed temperature Tf, °C ....  76.650
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 624.4
Tf, °C, rounded to 0.05 ........  76.65
  T60/2
Tx, Kelvin ..................... 349.80
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.625015014775
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.629388813227
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  i-Pentane
Reference Fluid 2 ..............  n-Pentane
CTL1, Tx to 60°F ...............   0.896907512500
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  i-Pentane
Reference Fluid 2 ..............  n-Pentane
CTL2, 20°C to 60°F .............   0.993050721018
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   0.903183990019
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   0.90318
```

Example 60/9 – Utilize n-Pentane and i-Hexane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 639.41
Observed temperature Tf, °C .... –24.460
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 639.4
Tf, °C, rounded to 0.05 ........ –24.45
  T60/2
Tx, Kelvin ..................... 248.70
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.640029789313
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.644192277735
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  n-Pentane
Reference Fluid 2 ..............  i-Hexane
CTL1, Tx to 60°F ...............   1.056377254246
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  n-Pentane
Reference Fluid 2 ..............  i-Hexane
CTL2, 20°C to 60°F .............   0.993538437998
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   1.063247493850
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   1.06325
```

Example 60/10 – Utilize i-Hexane and n-Hexane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 659.38
Observed temperature Tf, °C ....  80.580
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ..... 659.4
Tf, °C, rounded to 0.05 ........  80.60
  T60/2
Tx, Kelvin ..................... 353.75
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.660049488697
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.664004852143
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  i-Hexane
Reference Fluid 2 ..............  n-Hexane
CTL1, Tx to 60°F ...............   0.908011926489
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  i-Hexane
Reference Fluid 2 ..............  n-Hexane
CTL2, 20°C to 60°F .............   0.994043170870
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   0.913453211186
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   0.91345
```

Example 60/11 – Utilize n-Hexane and n-Heptane

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 669.38
Observed temperature Tf, °C ....  82.790
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 669.4
Tf, °C, rounded to 0.05 ........  82.80
  T60/2
Tx, Kelvin ..................... 355.95
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.670059338389
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.673917506957
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
CTL1, Tx to 60°F ...............   0.909032061079
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
CTL2, 20°C to 60°F .............   0.994275014129
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   0.914266222283
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   0.91427
```

Example 60/12 – Reduced temperature Tr,x greater than 1

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 399.83
Observed temperature Tf, °C ....  90.570
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ..... 399.8
Tf, °C, rounded to 0.05 ........  90.55
  T60/2
Tx, Kelvin ..................... 363.70
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.400193790690
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.410447384415
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  Ethane
Reference Fluid 2 ..............  EP (65/35)
Reduced temperature Tr,x greater than 1.0, no solution
CTL1, Tx to 60°F ...............  –1.0
Value from Table 24 not valid, no solution
```

Example 60/13 – Tf < lower range limit

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 449.56
Observed temperature Tf, °C .... –46.030
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 .......... 449.6
Tf, °C, rounded to 0.05 ........ –46.05
  T60/2
Tx, Kelvin ..................... 227.10
  T60/3
Tx less than 227.15, no solution
```

Example 60/14 – Den20 < lower range limit

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 331.59
Observed temperature Tf, °C ....  64.440
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ..... 331.6
Tf, °C, rounded to 0.05 ........  64.45
  T60/2
Tx, Kelvin ..................... 337.60
  T60/3
Density is less than  331.7, no solution
```

Example 60/15 – Tf > upper range limit

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 449.56
Observed temperature Tf, °C ....  93.030
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 .......... 449.6
Tf, °C, rounded to 0.05 ........  93.05
  T60/2
Tx, Kelvin ..................... 366.20
  T60/3
Tx greater than 366.15, no solution
```

Example 60/16 – Den20 > upper range limit

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 683.65
Observed temperature Tf, °C .... –17.780
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 .......... 683.7
Tf, °C, rounded to 0.05 ........ –17.80
  T60/2
Tx, Kelvin ..................... 255.35
  T60/3
Den20 is greater than  683.6, no solution
```

Example 60/17 – Tf & Den20 = upper range limits

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 683.64
Observed temperature Tf, °C ....  93.020
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 ......... 683.6
Tf, °C, rounded to 0.05 ........  93.00
  T60/2
Tx, Kelvin ..................... 366.15
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.684273324952
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............   0.688015480920
  T60/6
RD60 is within range, continue
  T60/7, Call Table 24 Procedure with Tx and RD60
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
CTL1, Tx to 60°F ...............   0.900472587577
  T60/8, Call Table 24 Procedure with 20°C and RD60
Reference Fluid 1 ..............  n-Hexane
Reference Fluid 2 ..............  n-Heptane
CTL2, 20°C to 60°F .............   0.994560942200
  T60/9 CTL = CTL1/CTL2
CTL, Tx to 20°C ................   0.905397094707
  T60/10
CTL is positive, continue
  T60/11 CTL rounded
CTL (rounded) ..................   0.90540
```

Example 60/18 – Tf & Den20 = lower range limits

```
    Input Data to Implementation Procedure T60
Density (kg/m³) @ 20°C (Den20) . 331.67
Observed temperature Tf, °C .... –46.020
    Computed Data – last digit is rounded
  T60/1
    Input Data – rounded
Den20, rounded to 0.1 .......... 331.7
Tf, °C, rounded to 0.05 ........ –46.00
  T60/2
Tx, Kelvin ..................... 227.15
  T60/3
Tx and Den20 are within range, continue
  T60/4
Den20 relative to 60°F water ...   0.332026714287
  T60/5, Call Table 23 procedure
RD60 from Table 23 .............  –1.0
Input data is outside range of Table 23, no solution
```

5.3.2 Implementation Procedure for Table 59E (20°C Basis)

This section presents the implementation procedure T59 for calculating the densities of NGLs and LPGs at a base conditions of 20°C from known temperatures and densities.

Density readings must be corrected for the effect of temperature on the instrument prior to entering the density into the following implementation procedure.

5.3.2.1 Inputs and Outputs

Inputs: Density at observed temperature, ρ_x (kg/m^3)
Observed temperature, T_F (°C)

Output: Density at 20°C, ρ_{20} (kg/m^3)

5.3.2.2 Outline of Calculations

The calculations are done using an extended two-fluid corresponding states equation. Two reference fluids are found that are slightly denser and slightly less dense than the observed fluid by comparing their densities at the observed temperature. Iteration must be performed to determine the value of the fluid's relative density at 60°F such that when the Temperature Correction Factor is applied, the observed relative density is obtained. The "guessed" value for the fluid's relative density at 60°F is constrained to lie between the relative densities at 60°F of these two reference fluids (as upper and lower bounds). As the iterations progress, these upper and lower bounds are "brought together" based upon intermediate calculations. The relative density at 20°C is then computed from the 60°F relative density by using scaling factors between the properties of the two reference fluids.

See Figure 6 for a general flow chart of the calculation procedure.

5.3.2.3 T59 Implementation Procedure

T59/Step Number Operation/Procedure at that step

T59/1: Round the density ρ_x to the nearest 0.1 and round the observed temperature T_F to the nearest 0.05°C.

T59/2: Convert the rounded observed temperature to units of Kelvin, T_x:

$$T_x = T_F + 273.15$$

T59/3: Convert the density, ρ_x, to relative density, γ_x, relative to the density of water at 60°F.

$$\gamma_x = \frac{\rho_x}{999.016}$$

T59/4: Check the values of temperature and relative density to ensure that they are in the proper range. The observed temperature T_x and relative density γ_x must fall within the following boundaries:

Temperature between 227.15 and 366.15 K, inclusive (equivalent to –46 to 93°C, or –50.8 to 199.4°F)
Relative density, if it were rounded to the nearest 0.0001, must fall within 0.2100 and 0.7400 inclusive. Test γ_x to ensure it is within the following boundaries:

Relative density greater than or equal to 0.20995 and less than 074005

If these values do not fall in these ranges, then the standard does not apply. Flag this result (possibly by returning –1 for the density) and exit this procedure.

T59/5: Compute the relative density at 60°F, γ_{60}, from the temperature and the relative density at the measurement condition, γ_x. Use the procedure described in Section 5.1.2 for Table 23 to perform this step. Enter the implementation procedure with γ_x and T_x at Step T23/4 so as to avoid additional rounding of the input values. Exit after Step T23/11 to avoid rounding the result.

T59/6: Compute the relative density at 20°C, γ_{20}, from the relative density at 60°F. This is performed by using the procedure described in Section 5.1.1 for Table 24. Enter implementation procedure T24 with γ_{60} and T_x = 293.15 (e.g. 273.15 + 20). Enter at Step T24/4 to avoid double rounding of the inputs. The C_{TL} for the conversion between γ_{60} and γ_{20} will be returned without rounding from Step T24/13. Compute γ_{20}:

$$\gamma_{20} = C_{TL} \times \gamma_{60}$$

T59/7: Insure that only valid values came from Steps T59/5 and T59/6. If the γ_{60} obtained from Section 5.2.1 for Table 23 is greater than –1, then proceed. If not, set the fluid density at 20°C to some flag value such as –1 and quit. If the C_{TL} from Step T59/6 is negative, then set the fluid density at 20°C to the error flag condition and exit this procedure.

T59/8: Calculate the fluid density at 20°C from the relative density at 20°C.

$$\rho_{20} = \gamma_{20} \times 999.016$$

T59/9: Round the fluid density, ρ_{20}, to the nearest 0.1. Exit this procedure.

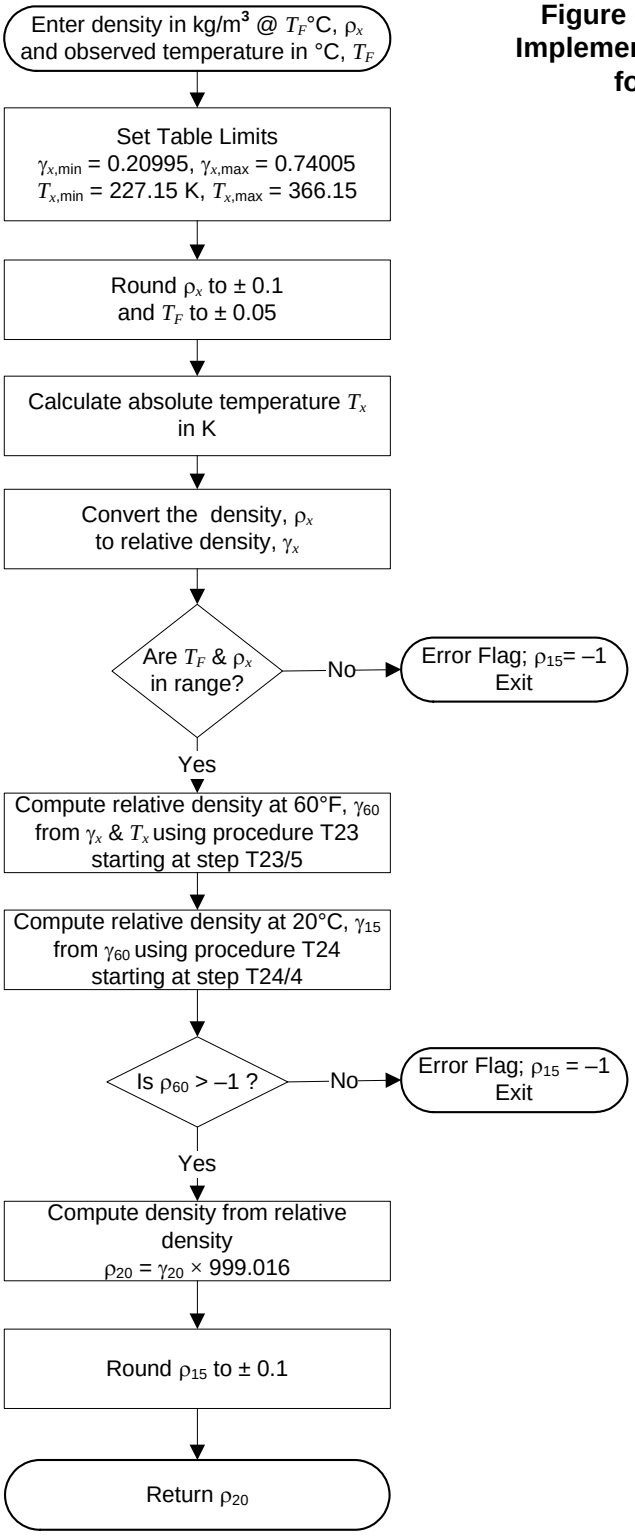


Figure 6. Flow Chart of Implementation Procedure for Table 59

5.3.2.4 Examples for Section 5.3.2 (Table 59E)

(See Table 1 for properties of the Reference Fluids)

Example 59/1 – T23/6, RDtf < lower boundary using EP (35/65) & Propane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 210.00
Observed Temperature Tf (°C) ... –44.500
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 210.0
Temperature rounded to 0.05 .... –44.50
  T59/2
Tx, Kelvin ..................... 228.65
  T59/3
Density relative to 60° water ..   0.210206843534
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............  –1.0
Input data is outside range of Table 23, no solution
```

Example 59/2 – Utilize EP (65/35) & EP (35/65)

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 532.57
Observed Temperature Tf (°C) ... –44.120
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 532.6
Temperature rounded to 0.05 .... –44.10
  T59/2
Tx, Kelvin ..................... 229.05
  T59/3
Density relative to 60° water ..   0.533124594601
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............   0.440515294609
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.979997725752
20 °C relative density .........   0.431703986876
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 431.279190152813
  T59/9
Density at 20°C (rounded) ...... 431.3
```

Example 59/3 – Utilize n-Pentane & i-Hexane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 673.66
Observed Temperature Tf (°C) ... –23.330
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 673.7
Temperature rounded to 0.05 .... –23.35
  T59/2
Tx, Kelvin ..................... 249.80
  T59/3
Density relative to 60° water ..   0.674363573757
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.638538685930
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.993367912870
20 °C relative density .........   0.634303841729
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 633.679686748900
  T59/9
Density at 20°C (rounded) ...... 633.7
```

Example 59/4 – Utilize EP (35/65) & Propane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 245.49
Observed Temperature Tf (°C) ...  87.770
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 245.5
Temperature rounded to 0.05 ....  87.75
  T59/2
Tx, Kelvin ..................... 360.90
  T59/3
Density relative to 60° water ..   0.245741809941
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.488795025411
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.985452958065
20 °C relative density .........   0.481684503679
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 481.210526127346
  T59/9
Density at 20°C (rounded) ...... 481.2
```

Example 59/5 – Utilize n-Butane & i-Pentane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 499.55
Observed Temperature Tf (°C) ...  87.820
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 499.6
Temperature rounded to 0.05 ....  87.80
  T59/2
Tx, Kelvin ..................... 360.95
  T59/3
Density relative to 60° water ..   0.500092090617
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.591794896225
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.991727237885
20 °C relative density .........   0.586899117828
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 586.321609095772
  T59/9
Density at 20°C (rounded) ...... 586.3
```

Example 59/6 – Utilize Ethane & EP (65/35)

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 395.09
Observed Temperature Tf (°C) ...  15.430
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 395.1
Temperature rounded to 0.05 ....  15.45
  T59/2
Tx, Kelvin ..................... 288.60
  T59/3
Density relative to 60° water ..   0.395489161335
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.395233433716
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.971608015812
20 °C relative density .........   0.384011972315
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 383.634104534331
  T59/9
Density at 20°C (rounded) ...... 383.6
```

Example 59/7 – Utilize i-Butane & n-Butane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 449.59
Observed Temperature Tf (°C) ...  93.020
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 449.6
Temperature rounded to 0.05 ....  93.00
  T59/2
Tx, Kelvin ..................... 366.15
  T59/3
Density relative to 60° water ..   0.450042842157
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.565490291365
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.990501113383
20 °C relative density .........   0.560118763204
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 559.567606341195
  T59/9
Density at 20°C (rounded) ...... 559.6
```

Example 59/8 – Utilize i-Hexane & n-Hexane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 600.74
Observed Temperature Tf (°C) ...  80.650
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 600.7
Temperature rounded to 0.05 ....  80.65
  T59/2
Tx, Kelvin ..................... 353.80
  T59/3
Density relative to 60° water ..   0.601291671004
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.662699711760
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.994014419312
20 °C relative density .........   0.658733069163
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 658.084875823243
  T59/9
Density at 20°C (rounded) ...... 658.1
```

Example 59/9 – Calculated RD60 near 0.6880 using n-Hexane & n-Heptane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 736.80
Observed Temperature Tf (°C) ... –44.230
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 736.8
Temperature rounded to 0.05 .... –44.25
  T59/2
Tx, Kelvin ..................... 228.90
  T59/3
Density relative to 60° water ..   0.737525725314
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.687974688885
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.994560181470
20 °C relative density .........   0.684232231424
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 683.558946908054
  T59/9
Density at 20°C (rounded) ...... 683.6
```

Example 59/10 – Calculated RD60 near 0.3500 using EE (68/32) & Ethane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 224.56
Observed Temperature Tf (°C) ...  30.680
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 224.6
Temperature rounded to 0.05 ....  30.70
  T59/2
Tx, Kelvin ..................... 303.85
  T59/3
Density relative to 60° water ..   0.224821224084
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 ..............   0.350001829424
  T59/6, Call Table 24 Procedure to obtain CTL from 60°F to 20°C
CTL from Table 24 ..............   0.948659643284
20 °C relative density .........   0.332032610649
  T59/7, Values returned from Tables 23 & 24 valid, continue
  T59/8
Density at 20°C (kg/m³) ........ 331.705890560614
  T59/9
Density at 20°C (rounded) ...... 331.7
```

Example 59/11 – T23/6, RDtf < lower boundary using EE (68/32) & Ethane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 339.63
Observed Temperature Tf (°C) ...  18.130
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 339.6
Temperature rounded to 0.05 ....  18.15
  T59/2
Tx, Kelvin ..................... 291.30
  T59/3
Density relative to 60° water ..   0.339934495544
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............  –1.0
Input data is outside range of Table 23, no solution
```

Example 59/12 – T23/6, RDtf > upper boundary using n-Hexane & n-Heptane

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 727.86
Observed Temperature Tf (°C) ... –33.070
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 727.9
Temperature rounded to 0.05 .... –33.05
  T59/2
Tx, Kelvin ..................... 240.10
  T59/3
Density relative to 60° water ..   0.728616959088
  T59/4
Tx and relative density are within range, continue
  T59/5, Call Table 23 procedure to obtain relative density at 60°F
RD60 from Table 23 .............  –1.0
Input data is outside range of Table 23, no solution
```

Example 59/13 – Density < input range limit

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 209.74
Observed Temperature Tf (°C) ...  11.530
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 209.7
Temperature rounded to 0.05 ....  11.55
  T59/2
Tx, Kelvin ..................... 284.70
  T59/3
Density relative to 60° water ..   0.209906548043
  T59/4
Relative density is less than 0.2100, no solution
```

Example 59/14 – Input density > input range limit

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 739.32
Observed Temperature Tf (°C) ...  11.530
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 739.3
Temperature rounded to 0.05 ....  11.55
  T59/2
Tx, Kelvin ..................... 284.70
  T59/3
Density relative to 60° water ..   0.740028187737
  T59/4
Relative density is greater than 0.7400, no solution
```

Example 59/15 – Input temperature < input range limit

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 645.62
Observed Temperature Tf (°C) ... –46.030
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 645.6
Temperature rounded to 0.05 .... –46.05
  T59/2
Tx, Kelvin ..................... 227.10
  T59/3
Density relative to 60° water ..   0.646235896122
  T59/4
Tx less than 227.15, no solution
```

Example 59/16 – Input temperature > input range limit

```
    Input Data to Implementation Procedure T59
Density at obs. temp. (kg/m³) .. 645.62
Observed Temperature Tf (°C) ...  93.070
    Computed Data – last digit is rounded
  T59/1
    Input Data – rounded
Density, rounded to 0.1 ........ 645.6
Temperature rounded to 0.05 ....  93.05
  T59/2
Tx, Kelvin ..................... 366.20
  T59/3
Density relative to 60° water ..   0.646235896122
  T59/4
Tx greater than 366.15, no solution
```

6 Sample Sections of Printed Tables

Sample tables based on all the implementation procedures are found on the following pages. These tables are representative of the format and appearance of the printed tables, but complete or partial sets of printed tables may be produced in any reasonable set of variable increments required. Note, these printed tables are not the Standard; the implementation procedures are the Standard.

Even though the implementation procedures are the standard, printed tables can be used. Interpolation should not be used with any printed table since the C_{TL} equations are not necessarily linear.

TABLE 23E – FOR NGL & LPG LIQUIDS
RELATIVE DENSITY REDUCTION TO 60°F

TEMP. (°F)	OBSERVED RELATIVE DENSITY 0.5000	0.5001	0.5002	0.5003	0.5004	0.5005	0.5006	0.5007	0.5008	TEMP. (°F)
	CORRESPONDING RELATIVE DENSITY 60/60°F									
100.0	0.5316	0.5316	0.5317	0.5318	0.5319	0.5320	0.5321	0.5322	0.5323	100.0
100.1	0.5316	0.5317	0.5318	0.5319	0.5320	0.5321	0.5322	0.5323	0.5323	100.1
100.2	0.5317	0.5318	0.5319	0.5320	0.5321	0.5322	0.5322	0.5323	0.5324	100.2
100.3	0.5318	0.5319	0.5320	0.5320	0.5321	0.5322	0.5323	0.5324	0.5325	100.3
100.4	0.5319	0.5319	0.5320	0.5321	0.5322	0.5323	0.5324	0.5325	0.5326	100.4
100.5	0.5319	0.5320	0.5321	0.5322	0.5323	0.5324	0.5325	0.5326	0.5326	100.5
100.6	0.5320	0.5321	0.5322	0.5323	0.5324	0.5324	0.5325	0.5326	0.5327	100.6
100.7	0.5321	0.5322	0.5323	0.5323	0.5324	0.5325	0.5326	0.5327	0.5328	100.7
100.8	0.5322	0.5322	0.5323	0.5324	0.5325	0.5326	0.5327	0.5328	0.5329	100.8
100.9	0.5322	0.5323	0.5324	0.5325	0.5326	0.5327	0.5328	0.5328	0.5329	100.9
101.0	0.5323	0.5324	0.5325	0.5326	0.5327	0.5327	0.5328	0.5329	0.5330	101.0
101.1	0.5324	0.5325	0.5326	0.5326	0.5327	0.5328	0.5329	0.5330	0.5331	101.1
101.2	0.5325	0.5325	0.5326	0.5327	0.5328	0.5329	0.5330	0.5331	0.5332	101.2
101.3	0.5325	0.5326	0.5327	0.5328	0.5329	0.5330	0.5331	0.5331	0.5332	101.3
101.4	0.5326	0.5327	0.5328	0.5329	0.5330	0.5330	0.5331	0.5332	0.5333	101.4
101.5	0.5327	0.5328	0.5329	0.5329	0.5330	0.5331	0.5332	0.5333	0.5334	101.5
101.6	0.5328	0.5328	0.5329	0.5330	0.5331	0.5332	0.5333	0.5334	0.5335	101.6
101.7	0.5328	0.5329	0.5330	0.5331	0.5332	0.5333	0.5334	0.5334	0.5335	101.7
101.8	0.5329	0.5330	0.5331	0.5332	0.5333	0.5333	0.5334	0.5335	0.5336	101.8
101.9	0.5330	0.5331	0.5331	0.5332	0.5333	0.5334	0.5335	0.5336	0.5337	101.9
102.0	0.5330	0.5331	0.5332	0.5333	0.5334	0.5335	0.5336	0.5337	0.5338	102.0
102.1	0.5331	0.5332	0.5333	0.5334	0.5335	0.5336	0.5336	0.5337	0.5338	102.1
102.2	0.5332	0.5333	0.5334	0.5335	0.5335	0.5336	0.5337	0.5338	0.5339	102.2
102.3	0.5333	0.5334	0.5334	0.5335	0.5336	0.5337	0.5338	0.5339	0.5340	102.3
102.4	0.5333	0.5334	0.5335	0.5336	0.5337	0.5338	0.5339	0.5340	0.5340	102.4
102.5	0.5334	0.5335	0.5336	0.5337	0.5338	0.5339	0.5339	0.5340	0.5341	102.5
102.6	0.5335	0.5336	0.5337	0.5338	0.5338	0.5339	0.5340	0.5341	0.5342	102.6
102.7	0.5336	0.5337	0.5337	0.5338	0.5339	0.5340	0.5341	0.5342	0.5343	102.7
102.8	0.5336	0.5337	0.5338	0.5339	0.5340	0.5341	0.5342	0.5343	0.5343	102.8
102.9	0.5337	0.5338	0.5339	0.5340	0.5341	0.5342	0.5342	0.5343	0.5344	102.9
103.0	0.5338	0.5339	0.5340	0.5341	0.5341	0.5342	0.5343	0.5344	0.5345	103.0
103.1	0.5339	0.5339	0.5340	0.5341	0.5342	0.5343	0.5344	0.5345	0.5346	103.1
103.2	0.5339	0.5340	0.5341	0.5342	0.5343	0.5344	0.5345	0.5345	0.5346	103.2
103.3	0.5340	0.5341	0.5342	0.5343	0.5344	0.5344	0.5345	0.5346	0.5347	103.3
103.4	0.5341	0.5342	0.5343	0.5343	0.5344	0.5345	0.5346	0.5347	0.5348	103.4
103.5	0.5342	0.5342	0.5343	0.5344	0.5345	0.5346	0.5347	0.5348	0.5349	103.5
103.6	0.5342	0.5343	0.5344	0.5345	0.5346	0.5347	0.5348	0.5348	0.5349	103.6
103.7	0.5343	0.5344	0.5345	0.5346	0.5347	0.5347	0.5348	0.5349	0.5350	103.7
103.8	0.5344	0.5345	0.5346	0.5346	0.5347	0.5348	0.5349	0.5350	0.5351	103.8
103.9	0.5345	0.5345	0.5346	0.5347	0.5348	0.5349	0.5350	0.5351	0.5352	103.9

TABLE 24E – FOR NGL & LPG LIQUIDS
TEMPERATURE VOLUME CORRECTION TO 60°F

RELATIVE DENSITY 60/60 DEGREES °F

FACTOR FOR CORRECTING VOLUME TO 60°F

TEMP. (°F)	0.4000	0.4001	0.4002	0.4003	0.4004	0.4005	0.4006	0.4007	TEMP. (°F)
50.0	1.03140	1.03137	1.03135	1.03133	1.03130	1.03128	1.03125	1.03123	50.0
50.1	1.03110	1.03107	1.03105	1.03102	1.03100	1.03098	1.03095	1.03093	50.1
50.2	1.03079	1.03077	1.03075	1.03072	1.03070	1.03068	1.03065	1.03063	50.2
50.3	1.03049	1.03047	1.03044	1.03042	1.03040	1.03037	1.03035	1.03033	50.3
50.4	1.03019	1.03017	1.03014	1.03012	1.03010	1.03007	1.03005	1.03003	50.4
50.5	1.02989	1.02986	1.02984	1.02982	1.02979	1.02977	1.02975	1.02973	50.5
50.6	1.02958	1.02956	1.02954	1.02952	1.02949	1.02947	1.02945	1.02942	50.6
50.7	1.02928	1.02926	1.02924	1.02921	1.02919	1.02917	1.02915	1.02912	50.7
50.8	1.02898	1.02896	1.02893	1.02891	1.02889	1.02887	1.02884	1.02882	50.8
50.9	1.02867	1.02865	1.02863	1.02861	1.02859	1.02856	1.02854	1.02852	50.9
51.0	1.02837	1.02835	1.02833	1.02830	1.02828	1.02826	1.02824	1.02822	51.0
51.1	1.02807	1.02804	1.02802	1.02800	1.02798	1.02796	1.02794	1.02791	51.1
51.2	1.02776	1.02774	1.02772	1.02770	1.02768	1.02765	1.02763	1.02761	51.2
51.3	1.02746	1.02744	1.02742	1.02739	1.02737	1.02735	1.02733	1.02731	51.3
51.4	1.02715	1.02713	1.02711	1.02709	1.02707	1.02705	1.02703	1.02701	51.4
51.5	1.02685	1.02683	1.02681	1.02679	1.02676	1.02674	1.02672	1.02670	51.5
51.6	1.02654	1.02652	1.02650	1.02648	1.02646	1.02644	1.02642	1.02640	51.6
51.7	1.02624	1.02622	1.02620	1.02618	1.02616	1.02614	1.02612	1.02610	51.7
51.8	1.02593	1.02591	1.02589	1.02587	1.02585	1.02583	1.02581	1.02579	51.8
51.9	1.02563	1.02561	1.02559	1.02557	1.02555	1.02553	1.02551	1.02549	51.9
52.0	1.02532	1.02530	1.02528	1.02526	1.02524	1.02522	1.02520	1.02518	52.0
52.1	1.02501	1.02499	1.02497	1.02495	1.02494	1.02492	1.02490	1.02488	52.1
52.2	1.02471	1.02469	1.02467	1.02465	1.02463	1.02461	1.02459	1.02457	52.2
52.3	1.02440	1.02438	1.02436	1.02434	1.02432	1.02430	1.02429	1.02427	52.3
52.4	1.02409	1.02407	1.02406	1.02404	1.02402	1.02400	1.02398	1.02396	52.4
52.5	1.02379	1.02377	1.02375	1.02373	1.02371	1.02369	1.02367	1.02366	52.5
52.6	1.02348	1.02346	1.02344	1.02342	1.02340	1.02339	1.02337	1.02335	52.6
52.7	1.02317	1.02315	1.02313	1.02312	1.02310	1.02308	1.02306	1.02304	52.7
52.8	1.02286	1.02284	1.02283	1.02281	1.02279	1.02277	1.02276	1.02274	52.8
52.9	1.02255	1.02254	1.02252	1.02250	1.02248	1.02247	1.02245	1.02243	52.9
53.0	1.02225	1.02223	1.02221	1.02219	1.02218	1.02216	1.02214	1.02212	53.0
53.1	1.02194	1.02192	1.02190	1.02188	1.02187	1.02185	1.02183	1.02182	53.1
53.2	1.02163	1.02161	1.02159	1.02158	1.02156	1.02154	1.02153	1.02151	53.2
53.3	1.02132	1.02130	1.02128	1.02127	1.02125	1.02123	1.02122	1.02120	53.3
53.4	1.02101	1.02099	1.02098	1.02096	1.02094	1.02093	1.02091	1.02089	53.4
53.5	1.02070	1.02068	1.02067	1.02065	1.02063	1.02062	1.02060	1.02059	53.5
53.6	1.02039	1.02037	1.02036	1.02034	1.02032	1.02031	1.02029	1.02028	53.6
53.7	1.02008	1.02006	1.02005	1.02003	1.02002	1.02000	1.01998	1.01997	53.7
53.8	1.01977	1.01975	1.01974	1.01972	1.01971	1.01969	1.01967	1.01966	53.8
53.9	1.01946	1.01944	1.01943	1.01941	1.01940	1.01938	1.01937	1.01935	53.9

TABLE 53E – FOR NGL & LPG LIQUIDS
DENSITY REDUCTION TO 15°C

TEMP. (°C)	OBSERVED DENSITY 210.0	215.0	220.0	225.0	230.0	235.0	240.0	245.0	250.0	TEMP. (°C)
	CORRESPONDING DENSITY AT 15°C									
31.0	352.6	352.6	352.7	352.9	353.2	353.5	353.9	354.5	355.2	31.0
32.0	356.8	356.8	356.9	357.0	357.2	357.5	357.8	358.1	358.5	32.0
33.0	359.6	359.6	359.7	359.7	359.9	360.1	360.3	360.7	361.1	33.0
34.0	362.1	362.2	362.2	362.3	362.4	362.6	362.9	363.3	363.7	34.0
35.0	364.7	364.7	364.7	364.8	365.0	365.2	365.5	365.9	366.3	35.0
36.0	367.2	367.2	367.3	367.4	367.5	367.8	368.1	368.4	368.9	36.0
37.0	369.7	369.8	369.8	369.9	370.1	370.3	370.6	371.0	371.5	37.0
38.0	372.3	372.3	372.4	372.5	372.7	372.9	373.2	373.6	374.1	38.0
39.0	374.8	374.9	374.9	375.1	375.2	375.5	375.8	376.2	376.7	39.0
40.0	377.4	377.4	377.5	377.6	377.8	378.0	378.4	378.8	379.3	40.0
41.0	379.9	380.0	380.1	380.2	380.4	380.6	380.9	381.4	381.9	41.0
42.0	382.5	382.5	382.6	382.7	382.9	383.2	383.5	383.9	384.5	42.0
43.0	385.1	385.1	385.2	385.3	385.5	385.8	386.1	386.5	387.0	43.0
44.0	387.6	387.7	387.7	387.9	388.1	388.3	388.7	389.1	389.6	44.0
45.0	390.2	390.2	390.3	390.4	390.6	390.9	391.2	391.7	392.2	45.0
46.0	392.7	392.8	392.9	393.0	393.2	393.5	393.8	394.3	394.8	46.0
47.0	395.3	395.4	395.4	395.6	395.8	396.0	396.4	396.8	397.4	47.0
48.0	397.9	397.9	398.0	398.1	398.4	398.6	399.0	399.4	399.9	48.0
49.0	400.4	400.5	400.6	400.7	400.9	401.2	401.5	402.0	402.5	49.0
50.0	403.0	403.1	403.1	403.3	403.5	403.8	404.1	404.6	405.1	50.0
51.0	405.6	405.6	405.7	405.9	406.1	406.3	406.7	407.1	407.7	51.0
52.0	408.1	408.2	408.3	408.4	408.6	408.9	409.3	409.7	410.2	52.0
53.0	410.7	410.8	410.9	411.0	411.2	411.5	411.8	412.3	412.8	53.0
54.0	413.3	413.3	413.4	413.6	413.8	414.1	414.4	414.9	415.4	54.0
55.0	415.8	415.9	416.0	416.1	416.4	416.6	417.0	417.4	418.0	55.0
56.0	418.4	418.5	418.6	418.7	418.9	419.2	419.6	420.0	420.5	56.0
57.0	421.0	421.0	421.1	421.3	421.5	421.8	422.1	422.6	423.1	57.0
58.0	423.6	423.6	423.7	423.9	424.1	424.4	424.7	425.1	425.7	58.0
59.0	426.1	426.2	426.3	426.4	426.7	426.9	427.3	427.7	428.2	59.0
60.0	428.7	428.8	428.9	429.0	429.2	429.5	429.9	430.2	430.7	60.0
61.0	431.1	431.1	431.2	431.3	431.5	431.7	432.0	432.4	432.8	61.0
62.0	433.2	433.3	433.4	433.5	433.7	433.9	434.2	434.6	435.0	62.0
63.0	435.4	435.5	435.5	435.7	435.8	436.1	436.4	436.7	437.1	63.0
64.0	437.6	437.6	437.7	437.8	438.0	438.2	438.5	438.9	439.3	64.0
65.0	439.8	439.8	439.9	440.0	440.2	440.4	440.7	441.0	441.4	65.0
66.0	441.9	442.0	442.1	442.2	442.3	442.6	442.8	443.2	443.6	66.0
67.0	444.1	444.1	444.2	444.3	444.5	444.7	445.0	445.3	445.8	67.0
68.0	446.3	446.3	446.4	446.5	446.7	446.9	447.2	447.5	447.9	68.0
69.0	448.4	448.5	448.6	448.7	448.8	449.0	449.3	449.7	450.1	69.0
70.0	450.6	450.7	450.7	450.8	451.0	451.2	451.5	451.8	452.2	70.0

TABLE 54E – FOR NGL & LPG LIQUIDS
TEMPERATURE VOLUME CORRECTION TO 15°C

TEMP. (°C)	DENSITY AT 15 DEGREES °C 400.00	405.00	410.00	415.00	420.00	425.00	430.00	435.00	TEMP. (°C)
	FACTOR FOR CORRECTING VOLUME TO 15°C								
10.0	1.02824	1.02719	1.02623	1.02535	1.02453	1.02377	1.02306	1.02220	10.0
10.5	1.02551	1.02456	1.02368	1.02288	1.02214	1.02145	1.02081	1.02003	10.5
11.0	1.02276	1.02190	1.02112	1.02040	1.01974	1.01912	1.01855	1.01785	11.0
11.5	1.01999	1.01923	1.01854	1.01791	1.01732	1.01678	1.01628	1.01566	11.5
12.0	1.01720	1.01654	1.01595	1.01540	1.01489	1.01443	1.01399	1.01346	12.0
12.5	1.01438	1.01384	1.01333	1.01287	1.01245	1.01206	1.01169	1.01125	12.5
13.0	1.01155	1.01111	1.01070	1.01033	1.00999	1.00967	1.00938	1.00902	13.0
13.5	1.00870	1.00836	1.00806	1.00777	1.00752	1.00728	1.00706	1.00679	13.5
14.0	1.00582	1.00559	1.00539	1.00520	1.00503	1.00487	1.00472	1.00454	14.0
14.5	1.00292	1.00281	1.00270	1.00261	1.00252	1.00244	1.00237	1.00227	14.5
15.0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	15.0
15.5	0.99705	0.99717	0.99728	0.99737	0.99746	0.99754	0.99762	0.99771	15.5
16.0	0.99409	0.99432	0.99453	0.99473	0.99491	0.99507	0.99523	0.99541	16.0
16.5	0.99109	0.99145	0.99177	0.99207	0.99234	0.99259	0.99282	0.99310	16.5
17.0	0.98807	0.98855	0.98899	0.98938	0.98975	0.99008	0.99040	0.99077	17.0
17.5	0.98503	0.98563	0.98618	0.98668	0.98714	0.98757	0.98796	0.98843	17.5
18.0	0.98196	0.98269	0.98335	0.98396	0.98452	0.98503	0.98551	0.98608	18.0
18.5	0.97886	0.97972	0.98050	0.98122	0.98187	0.98248	0.98304	0.98371	18.5
19.0	0.97573	0.97673	0.97763	0.97846	0.97921	0.97991	0.98055	0.98133	19.0
19.5	0.97257	0.97371	0.97474	0.97567	0.97653	0.97732	0.97805	0.97893	19.5
20.0	0.96939	0.97066	0.97182	0.97287	0.97383	0.97472	0.97553	0.97652	20.0
20.5	0.96617	0.96759	0.96887	0.97004	0.97111	0.97209	0.97300	0.97409	20.5
21.0	0.96293	0.96449	0.96590	0.96719	0.96837	0.96945	0.97045	0.97165	21.0
21.5	0.95965	0.96136	0.96291	0.96432	0.96561	0.96679	0.96788	0.96919	21.5
22.0	0.95633	0.95820	0.95989	0.96142	0.96282	0.96411	0.96529	0.96671	22.0
22.5	0.95299	0.95501	0.95684	0.95850	0.96002	0.96141	0.96269	0.96422	22.5
23.0	0.94960	0.95179	0.95376	0.95556	0.95719	0.95868	0.96006	0.96171	23.0
23.5	0.94618	0.94854	0.95066	0.95258	0.95434	0.95594	0.95742	0.95919	23.5
24.0	0.94273	0.94525	0.94753	0.94959	0.95146	0.95318	0.95476	0.95665	24.0
24.5	0.93923	0.94193	0.94436	0.94656	0.94856	0.95039	0.95207	0.95408	24.5
25.0	0.93570	0.93858	0.94117	0.94351	0.94564	0.94758	0.94937	0.95150	25.0
25.5	0.93212	0.93519	0.93794	0.94043	0.94269	0.94475	0.94665	0.94891	25.5
26.0	0.92850	0.93176	0.93468	0.93732	0.93971	0.94190	0.94390	0.94629	26.0
26.5	0.92483	0.92829	0.93138	0.93417	0.93671	0.93902	0.94113	0.94365	26.5
27.0	0.92112	0.92478	0.92805	0.93100	0.93367	0.93611	0.93834	0.94100	27.0
27.5	0.91736	0.92123	0.92469	0.92780	0.93062	0.93318	0.93553	0.93832	27.5
28.0	0.91355	0.91764	0.92128	0.92456	0.92753	0.93022	0.93269	0.93562	28.0
28.5	0.90969	0.91400	0.91784	0.92129	0.92441	0.92724	0.92983	0.93290	28.5
29.0	0.90577	0.91032	0.91436	0.91798	0.92126	0.92423	0.92695	0.93016	29.0
29.5	0.90180	0.90659	0.91084	0.91464	0.91807	0.92119	0.92404	0.92740	29.5

TABLE 59E – FOR NGL & LPG LIQUIDS
DENSITY REDUCTION TO 20°C

TEMP. (°C)	OBSERVED DENSITY 210.0	215.0	220.0	225.0	230.0	235.0	240.0	245.0	250.0	TEMP. (°C)
	CORRESPONDING DENSITY AT 20°C									
31.0	332.9	332.9	333.1	333.3	333.6	334.0	334.5	335.2	336.1	31.0
32.0	338.0	338.1	338.1	338.3	338.5	338.9	339.2	339.7	340.2	32.0
33.0	341.6	341.6	341.7	341.8	341.9	342.2	342.5	343.0	343.5	33.0
34.0	344.8	344.8	344.9	345.0	345.1	345.4	345.7	346.2	346.7	34.0
35.0	347.9	347.9	348.0	348.1	348.3	348.5	348.9	349.3	349.9	35.0
36.0	351.0	351.0	351.1	351.2	351.4	351.6	352.0	352.4	353.0	36.0
37.0	354.0	354.0	354.1	354.2	354.4	354.7	355.0	355.5	356.0	37.0
38.0	357.0	357.0	357.1	357.2	357.4	357.7	358.0	358.5	359.1	38.0
39.0	359.9	359.9	360.0	360.1	360.3	360.6	361.0	361.5	362.0	39.0
40.0	362.8	362.9	362.9	363.1	363.3	363.6	363.9	364.4	365.0	40.0
41.0	365.7	365.8	365.8	366.0	366.2	366.5	366.8	367.3	367.9	41.0
42.0	368.6	368.6	368.7	368.9	369.1	369.3	369.7	370.2	370.8	42.0
43.0	371.4	371.5	371.6	371.7	371.9	372.2	372.6	373.1	373.6	43.0
44.0	374.3	374.3	374.4	374.6	374.8	375.1	375.4	375.9	376.5	44.0
45.0	377.1	377.1	377.2	377.4	377.6	377.9	378.3	378.7	379.3	45.0
46.0	379.9	379.9	380.0	380.2	380.4	380.7	381.1	381.5	382.1	46.0
47.0	382.7	382.7	382.8	383.0	383.2	383.5	383.9	384.3	384.9	47.0
48.0	385.5	385.5	385.6	385.8	386.0	386.3	386.6	387.1	387.7	48.0
49.0	388.2	388.3	388.4	388.5	388.7	389.0	389.4	389.9	390.5	49.0
50.0	391.0	391.0	391.1	391.3	391.5	391.8	392.2	392.6	393.2	50.0
51.0	393.7	393.8	393.9	394.0	394.3	394.6	394.9	395.4	396.0	51.0
52.0	396.5	396.5	396.6	396.8	397.0	397.3	397.7	398.1	398.7	52.0
53.0	399.2	399.2	399.4	399.5	399.7	400.0	400.4	400.9	401.4	53.0
54.0	401.9	402.0	402.1	402.2	402.5	402.7	403.1	403.6	404.1	54.0
55.0	404.6	404.7	404.8	405.0	405.2	405.5	405.8	406.3	406.9	55.0
56.0	407.3	407.4	407.5	407.7	407.9	408.2	408.5	409.0	409.6	56.0
57.0	410.0	410.1	410.2	410.4	410.6	410.9	411.2	411.7	412.3	57.0
58.0	412.7	412.8	412.9	413.1	413.3	413.6	413.9	414.4	414.9	58.0
59.0	415.4	415.5	415.6	415.8	416.0	416.3	416.6	417.1	417.6	59.0
60.0	418.1	418.2	418.3	418.5	418.7	419.0	419.3	419.7	420.2	60.0
61.0	420.6	420.7	420.8	420.9	421.1	421.3	421.6	422.0	422.5	61.0
62.0	422.9	423.0	423.1	423.2	423.4	423.6	423.9	424.3	424.8	62.0
63.0	425.2	425.3	425.4	425.5	425.7	425.9	426.2	426.6	427.0	63.0
64.0	427.5	427.6	427.7	427.8	428.0	428.2	428.5	428.9	429.3	64.0
65.0	429.8	429.9	429.9	430.1	430.2	430.5	430.8	431.1	431.6	65.0
66.0	432.1	432.1	432.2	432.4	432.5	432.8	433.1	433.4	433.9	66.0
67.0	434.4	434.4	434.5	434.6	434.8	435.0	435.3	435.7	436.1	67.0
68.0	436.7	436.7	436.8	436.9	437.1	437.3	437.6	437.9	438.4	68.0
69.0	438.9	439.0	439.1	439.2	439.3	439.6	439.8	440.2	440.6	69.0
70.0	441.2	441.3	441.3	441.4	441.6	441.8	442.1	442.4	442.9	70.0

TABLE 60E – FOR NGL & LPG LIQUIDS
TEMPERATURE VOLUME CORRECTION TO 20°C

TEMP. (°C)	DENSITY AT 20 DEGREES °C 400.00	405.00	410.00	415.00	420.00	425.00	430.00	435.00	TEMP. (°C)
	FACTOR FOR CORRECTING VOLUME TO 20°C								
10.0	1.05537	1.05348	1.05172	1.05009	1.04852	1.04671	1.04502	1.04346	10.0
10.5	1.05278	1.05096	1.04928	1.04772	1.04623	1.04449	1.04288	1.04138	10.5
11.0	1.05017	1.04844	1.04683	1.04534	1.04392	1.04226	1.04073	1.03930	11.0
11.5	1.04754	1.04589	1.04437	1.04295	1.04159	1.04002	1.03856	1.03721	11.5
12.0	1.04490	1.04333	1.04189	1.04055	1.03926	1.03777	1.03639	1.03511	12.0
12.5	1.04224	1.04076	1.03939	1.03813	1.03691	1.03551	1.03420	1.03300	12.5
13.0	1.03956	1.03817	1.03688	1.03569	1.03455	1.03323	1.03201	1.03087	13.0
13.5	1.03686	1.03556	1.03436	1.03324	1.03218	1.03094	1.02980	1.02874	13.5
14.0	1.03415	1.03294	1.03182	1.03078	1.02979	1.02864	1.02758	1.02660	14.0
14.5	1.03142	1.03030	1.02926	1.02830	1.02739	1.02633	1.02535	1.02445	14.5
15.0	1.02866	1.02764	1.02669	1.02581	1.02497	1.02401	1.02311	1.02228	15.0
15.5	1.02589	1.02496	1.02410	1.02331	1.02254	1.02167	1.02086	1.02011	15.5
16.0	1.02310	1.02227	1.02150	1.02078	1.02010	1.01932	1.01859	1.01792	16.0
16.5	1.02029	1.01955	1.01887	1.01824	1.01764	1.01695	1.01631	1.01572	16.5
17.0	1.01746	1.01682	1.01623	1.01569	1.01517	1.01457	1.01402	1.01351	17.0
17.5	1.01460	1.01407	1.01357	1.01312	1.01268	1.01218	1.01172	1.01129	17.5
18.0	1.01173	1.01130	1.01090	1.01053	1.01018	1.00977	1.00940	1.00906	18.0
18.5	1.00883	1.00850	1.00820	1.00792	1.00766	1.00735	1.00707	1.00681	18.5
19.0	1.00591	1.00569	1.00549	1.00530	1.00512	1.00492	1.00473	1.00455	19.0
19.5	1.00297	1.00286	1.00275	1.00266	1.00257	1.00247	1.00237	1.00228	19.5
20.0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	20.0
20.5	0.99701	0.99712	0.99723	0.99732	0.99741	0.99752	0.99761	0.99770	20.5
21.0	0.99399	0.99422	0.99443	0.99463	0.99481	0.99502	0.99522	0.99539	21.0
21.5	0.99095	0.99130	0.99162	0.99191	0.99219	0.99251	0.99280	0.99307	21.5
22.0	0.98788	0.98835	0.98878	0.98917	0.98955	0.98998	0.99037	0.99073	22.0
22.5	0.98478	0.98538	0.98592	0.98642	0.98689	0.98743	0.98793	0.98838	22.5
23.0	0.98166	0.98238	0.98304	0.98364	0.98421	0.98487	0.98547	0.98602	23.0
23.5	0.97851	0.97936	0.98013	0.98084	0.98152	0.98228	0.98299	0.98364	23.5
24.0	0.97533	0.97631	0.97720	0.97802	0.97880	0.97968	0.98050	0.98125	24.0
24.5	0.97212	0.97323	0.97425	0.97518	0.97606	0.97707	0.97799	0.97884	24.5
25.0	0.96887	0.97012	0.97127	0.97231	0.97330	0.97443	0.97546	0.97641	25.0
25.5	0.96560	0.96699	0.96826	0.96942	0.97052	0.97177	0.97292	0.97397	25.5
26.0	0.96229	0.96383	0.96523	0.96651	0.96772	0.96910	0.97036	0.97152	26.0
26.5	0.95895	0.96064	0.96217	0.96357	0.96490	0.96640	0.96778	0.96904	26.5
27.0	0.95558	0.95741	0.95908	0.96061	0.96206	0.96369	0.96518	0.96656	27.0
27.5	0.95217	0.95416	0.95597	0.95762	0.95919	0.96095	0.96257	0.96405	27.5
28.0	0.94872	0.95087	0.95282	0.95461	0.95629	0.95820	0.95993	0.96153	28.0
28.5	0.94523	0.94755	0.94965	0.95157	0.95338	0.95542	0.95728	0.95899	28.5
29.0	0.94170	0.94419	0.94644	0.94850	0.95043	0.95261	0.95460	0.95643	29.0
29.5	0.93814	0.94080	0.94321	0.94540	0.94746	0.94979	0.95191	0.95385	29.5

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