Addendum 2 to API MPMS Ch. 11.1-2004—
Temperature and Pressure Volume Correction Factors
for Generalized Crude Oils, Refined Products,
and Lubricating Oils

11.1.1.5 Changes to Previous Standards

- The term “compressibility coefficient” and symbol “Fp” are used in other standards in a different way. The term and symbol were changed to “scaled compressibility factor” and “Fs,” respectively, to distinguish the difference.
- Section 11.1.2.5.13 was updated to reference API MPMS Chapter 11.3.4 for density and volume corrections of gasohol blends.
- Sections were added for guidance on volume corrections for ethanol, vacuum gas oil (VGO), and naptha.
- Clarification was added to the use of the terms “standard,” “observed,” and “alternate” conditions.
- Clarification was added, and examples were updated, to show final density and volume results should be calculated with unrounded $C_{TL}$ and $C_{PL}$ values or an unrounded $C_{TPL}$ value.
- Wording was added to indicate the examples are provided to guide users in developing computer implementations of the Standard, but are not part of the Standard.
- If other standards call for use of a $C_{TL}$ factor, alone. An equivalent $C_{TPL}$ factor may be calculated by using a gauge pressure of zero.
- Steps in Sections 11.1.8.23 and 11.1.8.24 were updated to use an arbitrary input density as required in the implementation procedures.
- Section C.7 was added to Appendix C to guide users in converting thermal expansion coefficients to temperature units other and °F⁻¹.
- Appendix F was added to show how the equilibrium vapor pressure of liquids affects the calculations.

11.1.2.2 Scope

As this Standard will be applied to a variety of applications the output parameters specified in this Standard ($\rho$, $\rho_{60}$, $\rho_T$, CTL, $E_F E_p$, CPL, and CTPL) may be used as specified in other API Manual of Petroleum Measurement Standards (MPMS) Chapters.

This Standard provides general procedures for the conversion of input data to generate $\rho$, $\rho_{60}$, $\rho_T$, CTL, $E_F E_p$, CPL, and CTPL values at the user specified base temperature and pressure ($T_b$, $P_b$).

11.1.2.5.3 LPG and NGL

LPGs (Liquefied Petroleum Gases) and NGLs (Natural Gas Liquids) are predominantly butane and propane separated from natural gasoline or natural gas or produced during refinery processing. Most LPGs and NGLs are less dense than the liquids covered by this Standard. API MPMS Chapter 11.2.4/GPA 8217 “Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E, 60E” Gas Processors Association (GPA) Technical Publication TP–25 Temperature Correction For The Volume Of Light Hydrocarbons (or its
successor) should be used for the temperature portion of the volume correction factors for liquids with 60°/60°
relative densities of 0.3500 to 0.6880 (272.8 to 74.2°API at 60 °F, or 349.7 to 687.3 kg/m³ at 60 °F). The tables in
this Standard generally apply to products that do not have to be stored in pressurized containers at normal
temperatures.

11.1.2.5.13 Gasohol Blends of Gasoline and Ethanol

Gasohol is a mixture of gasoline and 10 vol% ethanol. Based on data (available at API) obtained at the University
of Missouri—Rolla, gasohol is best represented as a special application with a 60°F thermal expansion factor (\(\beta\))
of \(714.34 \times 10^{-6} \degree F^{-1}\).

There are several defined blend ranges within fuel specifications which are frequently referred to by the upper
limit of the volume percent of ethanol in the blend. For example, E10 refers to a blend which contains up to 10
volume percent of ethanol. Research by the API has shown that when the gasoline blendstock (often referred to as
a blendstock for oxygenate blending, BOB) and ethanol are blended there is an increase in the total volume and
the coefficient of thermal expansion. Based upon this research, API developed methodologies which are
summarized in API MPMS Chapter 11.3.4 to cover density and volume correction factors for blends of denatured
ethanol and gasoline blend components ranging from 0 % up to 95 % denatured ethanol. Refer to API MPMS
Chapter 11.3.4 for volume correction of gasoline and ethanol blends.

11.1.2.5.14 Ethanol

Refer to API MPMS Chapter 11.3.3 for volume correction of fuel grade ethanol.

11.1.2.5.15 Vacuum Gas Oil (VGO)

Vacuum gas oil is a distillation product of crude oil generally with a boiling range between 310°C to 600°C. This
group of materials was included in the data base for Fuel Oils group of the products tables and was best
represented by the products tables.

11.1.2.5.16 Naphtha

Naphtha is a general term for flammable hydrocarbon mixtures. In the refining industry, petroleum naphtha
typically has a boiling range between 35°C and 205°C and consists of hydrocarbons containing between 4 and 11
carbon atoms. Virgin naphtha was included in the data base for the Gasolines group of the product tables and was
best represented by the products tables. Heavy naphtha was significantly better represented by the products tables
for this group.

11.1.3.1 Distinction Between “Standard,” “Base,” “Observed,” and “Alternate” Conditions

- The “alternate” conditions are any other temperature and pressure conditions to which the observed or
standard density can be corrected. Alternate conditions may be flowing conditions at the primary
device or base temperatures other than 60 °F, such as 15 °C, 20 °C, 30 °C, etc.
11.1.3.3 Calculation of CTL and CPL Factors in this Standard

\[
C_{PL} = \frac{1}{1 - F_P F_s (P - P_b)} \tag{15}
\]

…where \( \alpha_T \) is the thermal expansion coefficient at the base temperature \( T \), \( \Delta t \) is the difference between the alternate temperature and the base temperature, \( F_P F_s \) is the scaled compressibility coefficient factor, and \( \delta_T \) is a small base temperature correction value.

\( F_P F_s \) was correlated to this same base density and the temperature \( t \) at which the compression occurs.

\[
F_P F_s = \exp \left\{ A + B t + \frac{C + D t}{\rho^{1/2}} \right\} \tag{17}
\]

There was one set of coefficients for the \( F_P F_s \) scaled compressibility factor (\( A = -1.99470, B = 0.00013427, C = 793920, D = 2326 \); based on density in kg/m\(^3\) at 60 °F the \( A, B, C, \) and \( D \) values) but several sets of coefficients for the \( \alpha_{60} \) thermal expansion coefficient (the \( K0, K1, \) and \( K2 \) values) depending upon the liquid’s classification and density at 60 °F.

11.1.3.5 Iteration Scheme to Determine Base Density from Observed Density

Because \( \alpha_{60} \) and \( F_P F_s \) in Equations (16) and (17) are direct functions of the 60 °F density \( \rho_{60} \), the CTL and CPL equations are also direct functions of \( \rho_{60} \).

2…

• Calculate the \( F_P F_s \) value using Equation (17). Calculate the CPL using Equation (18).

11.1.3.9 Rounding of Values

Previous versions of the Table values required rounding at various stages of the calculation procedures. The Implementation Procedures are now written with no rounding of initial or intermediate values. The final VCF is rounded to five decimal places. Rounding of input values is only to be used when creating tabular representations of the results from these Implementation Procedures. When the tabular representations are calculated, the initial and final values are to be rounded for display, but intermediate values are never to be rounded.

Although previous versions of this standard required values to be rounded at various stages within the calculation procedures, the calculations procedures are now written with no rounding of initial,
intermediate or final values. Other applications may require rounding of inputs prior to using this standard or rounding of results from this standard (e.g. $C_{TL}$, $C_{PL}$, $C_{TPL}$, or density) for their own purposes. However, calculations using the rounded results will differ slightly from results obtained by direct application of this standard.

The procedures within this standard for creating tabular representations that reproduce the format of the historical tables require rounding of the initial and final values be rounded for display as indicated in Section 11.1.5.4, but intermediate values are never to be rounded.

### 11.1.5 Implementation Procedures - General

If these examples are used to test one's own computer implementation of the procedures, it is required that at least eight of the significant digits be matched for all applicable output values.

The actual API MPMS Chapter 11.1 Standard 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.

#### 11.1.5.2 Method to Calculate Thermal Expansion Factor from Density Measurements Calculation Procedure

Step 8: Go to Step 46 and repeat iteration five times.

Step 10: Round the values of $\alpha_{60}$ and $\rho_{60}$ to be consistent with 11.1.5.4.

Step 104: Exit from this procedure.

The resulting coefficient of thermal expansion (to six digits) is $\alpha_{60} = 446.655 \times 10^{-6}$ °F$^{-1}$ and the calculated density at 60°F (to six digits) is $\rho_{60} = 867.756$ kg / m³. When rounded consistent with 11.1.5.4 the results are $\alpha_{60} = 446.7 \times 10^{-6}$ °F and $\rho_{60} = 867.8$ kg/m³.

#### 11.1.5.4 Rounding of Values for Generating Tables

This procedure gives instructions and increments for rounding density, temperature, pressure, thermal expansion coefficient, and volume correction factor values. These rounding rules are needed to generate the final volume correction factor due to temperature and pressure and to generate the tables in printed tabular (historical) format. All input values must be rounded when generating the tables in historical format.

#### 11.1.5.5 Other Implementation Considerations

- Where a calculation within an existing standard makes use of a CTL factor alone, an equivalent value CTPL is calculated with gauge pressure set to zero.
11.1.6.1  Method to Correct a Measured Volume to Base Conditions and Density from Base Conditions to an Alternate Temperature and Pressure

Output Values

\( F_p F_s \)  
Scaled compressibility factor (psi

Calculation Procedure

Step 6: Calculate the scaled compressibility factor \( F_p F_s \). Use the equation:

\[
F_p F_s = e^{(-1.9947 + 0.00013427 \cdot t^* + \frac{793920 + 2326.0 \cdot t^*}{\rho^2})}
\]

Step 8: Calculate the VCF, the combined temperature and pressure correction, \( C_{TPL} \):

\[
C_{TPL} = C_{TL} \cdot C_{PL}
\]

Round this value of CTPL consistent with 11.1.5.4.

Example Calculations

**API MPMS 11.1.6.1 Customary Units, Example 1**

Step 6 - Calculate scaled compressibility factor \( F_p F_s \)

\( F_p F_s \) for psi ...................................... 0.305779891997

Step 9 - Calculate volume at base conditions and density at alternate conditions

Volume at base conditions ................................ 1020.6035499
Density at t & P, kg/cu m ............................. 978.1780343640
°API at t & P ....................................... 13.0143512059

**API MPMS 11.1.6.1 Customary Units, Example 2**

Step 6 - Calculate scaled compressibility factor \( F_p F_s \)

\( F_p F_s \) for psi ...................................... 0.427958509999

Step 9 - Calculate volume at base conditions and density at alternate conditions

Volume at base conditions ................................ 269.543405
Density at t & P, kg/cu m ............................. 1098.4391355882
°API at t & P ....................................... -2.8076041994

**API MPMS 11.1.6.1 Customary Units, Example 3**

Step 6 - Calculate scaled compressibility factor \( F_p F_s \)

\( F_p F_s \) for psi ...................................... 0.384339609206

Step 9 - Calculate volume at base conditions and density at alternate conditions

Volume at base conditions ................................ 12060.32972
Density at t & P, kg/cu m ............................. 941.3353501926
°API at t & P ....................................... 18.6704615375

**API MPMS 11.1.6.1 Customary Units, Example 4**

Step 6 - Calculate scaled compressibility factor \( F_p F_s \)

\( F_p F_s \) for psi ...................................... 0.664706197066

Step 9 - Calculate volume at base conditions and density at alternate conditions
Volume at base conditions .......... 988.46 988.457250925006
Density at t & P, kg/cu m ............ 784.3590249208 784.359024920833

API MPMS 11.1.6.1 Customary Units, Example 5
Step 6 - Calculate scaled compressibility factor $F_p$
$F_p$ for psi ........................................ 0.60811538634
Step 9 - Calculate volume at base conditions
and density at alternate conditions
Volume at base conditions .......... 10043.2 10043.2031139630
Density at t & P, kg/cu m ............ 790.9208921357 790.920892135717
°API at t & P .......................... 47.2293362331 47.22933623094

API MPMS 11.1.6.1 Customary Units, Example 6
Step 6 - Calculate scaled compressibility factor $F_p$
$F_p$ for psi ........................................ 0.993527440282
Step 9 - Calculate volume at base conditions
and density at alternate conditions
Volume at base conditions .......... 15.2973184 15.297347711445
Density at base conditions .......... 683.0806148596 683.080614859578
°API at t & P .......................... 47.2293362331 47.22933623094

API MPMS 11.1.6.1 Customary Units, Example 7
Step 6 - Calculate scaled compressibility factor $F_p$
$F_p$ for psi ........................................ 0.346454796729
Step 9 - Calculate volume at base conditions
and density at alternate conditions
Volume at base conditions .......... 198.374589 198.375152591264
Density at t & P, kg/cu m ............ 1024.3915370787 1024.39153707874
°API at t & P .......................... 47.2293362331 47.22933623094

API MPMS 11.1.6.1 Customary Units, Example 8
Step 6 - Calculate scaled compressibility factor $F_p$
$F_p$ for psi ........................................ 0.732650236105
Step 9 - Calculate volume at base conditions
and density at alternate conditions
Volume at base conditions .......... 97.0745818 97.07544792923
Density at t & P, kg/cu m ............ 786.9754991473 786.975499147299
°API at t & P .......................... 48.1253684558 48.125368455774

API MPMS 11.1.6.1 Customary Units, Example 15
Step 6 - Calculate scaled compressibility factor $F_p$
$F_p$ for psi ........................................ 4.09282097603
Step 9 - Calculate volume at base conditions
and density at alternate conditions
Volume at base conditions .......... 868.29 868.2896906632
Density at t & P, kg/cu m ............ 530.2025789330 530.202578932960
°API at t & P .......................... 135.116515303 135.116515303434

11.1.6.2 Method to Correct Volume and Density from Observed Conditions to Customary Base Conditions

Output Values

$F_p$ Scaled compressibility factor (psi⁻¹)

Intermediate Values

$F_p^{(m)}$ Scaled compressibility factor on the $m$-th iteration (psi⁻¹)
Calculation Procedure

Step 7: After the convergence criterion in Step 4 is met, set the value of $\rho_{60}$ to the last $\rho_{60}^{(m)}$ value and set the value of $C_{TPL}$ to the last $C_{TPL}^{(m)}$ value. Check this $\rho_{60}$ value to determine if it is in the range of this Standard. If $\rho_{60} < \rho_{60,\text{min}}$ or $\rho_{60} > \rho_{60,\text{max}}$ then this $\rho_{60}$ value is out of range. Set an error condition (such as setting all output values to zero) and exit the procedure. Round this value of $C_{TPL}$ consistent with 11.1.5.4.

Example Calculations

Example 1

<table>
<thead>
<tr>
<th>Step 3</th>
<th>(F_p \text{s}(m))</th>
<th>0.583649345323</th>
<th>0.567047025149</th>
<th>0.567045450015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 7</td>
<td>(F_p \text{s} \text{ for } \psi)</td>
<td>0.567045450015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 8</td>
<td>Volume at base conditions</td>
<td>989.97</td>
<td>989.966310837071</td>
<td></td>
</tr>
</tbody>
</table>

Example 2

<table>
<thead>
<tr>
<th>Step 3</th>
<th>(F_p \text{s}(m))</th>
<th>0.476986337657</th>
<th>0.602443036118</th>
<th>0.603436463770</th>
<th>0.603436540820</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 7</td>
<td>(F_p \text{s} \text{ for } \psi)</td>
<td>0.603436540820</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 8</td>
<td>Volume at base conditions</td>
<td>694333.73394</td>
<td>694331.004655808</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example 3

<table>
<thead>
<tr>
<th>Step 3</th>
<th>(F_p \text{s}(m))</th>
<th>0.489197521374</th>
<th>0.484824153195</th>
<th>0.484824263921</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 7</td>
<td>(F_p \text{s} \text{ for } \psi)</td>
<td>0.484824263921</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 8</td>
<td>Volume at base conditions</td>
<td>28.349287</td>
<td>28.349285764593</td>
<td></td>
</tr>
</tbody>
</table>

Example 4

<table>
<thead>
<tr>
<th>Step 3</th>
<th>(F_p \text{s}(m))</th>
<th>0.578821088788</th>
<th>0.572609812544</th>
<th>0.572609969057</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 7</td>
<td>(F_p \text{s} \text{ for } \psi)</td>
<td>0.572609969057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 8</td>
<td>Volume at base conditions</td>
<td>199.74612</td>
<td>199.746592435773</td>
<td></td>
</tr>
</tbody>
</table>

Example 5

<table>
<thead>
<tr>
<th>Step 3</th>
<th>(F_p \text{s}(m))</th>
<th>0.512082157017</th>
<th>0.539941779272</th>
<th>0.539959172137</th>
<th>0.539959363768</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 7</td>
<td>(F_p \text{s} \text{ for } \psi)</td>
<td>0.539959363768</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 8</td>
<td>Volume at base conditions</td>
<td>10197.174195</td>
<td>10197.1874770065</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example 6

<table>
<thead>
<tr>
<th>Step 3</th>
<th>(F_p \text{s}(m))</th>
<th>1.118639209920</th>
<th>0.910912736669</th>
<th>0.910920838482</th>
<th>0.910923457238</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 7</td>
<td>(F_p \text{s} \text{ for } \psi)</td>
<td>0.910923457238</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Step 8
Volume at base conditions .............. 949.54

Example 7

Step 3
Fp(m) ............................................ 0.535641758165
Step 7
Fp for psi ....................................... 0.519616156675
Step 8
Volume at base conditions .............. 4943.8

Example 8

Step 3
Fp(m) ............................................ 0.445753246624
Step 7
Fp for psi ....................................... 0.438941943315
Step 8
Volume at base conditions .............. 2483.575

Example 9

Step 3
Fp(m) ............................................ 1.460680703550
Step 7
Fp for psi ....................................... 1.459310590459
Step 8
Volume at base conditions .............. 902.303118

Example 12

Step 1
Density less than 470.34 kg/cu m - outside limits of table

11.1.6.3 Method to Correct Volume and Density from Observed Conditions to Alternate Conditions

Output Values

FP,oFs,o Scaled compressibility factor at the observed temperature (psi⁻¹)
FPFs Scaled compressibility factor at the alternate temperature (psi⁻¹)

Calculation Procedure

Step 1: Use the observed values ρ_o, t_o, and P_o and determine the density at base conditions, ρ_{60}, using the procedure in 11.1.6.2. If this procedure returns with an error condition, exit this procedure. Retain the values of ρ_{60}, C_{TL,o}, F_{PL,o}, C_{PL,o}, and C_{TPL,o} in the procedure. Round this value of C_{TPL,o}.

Step 2: With the ρ_{60} value found in Step 1, calculate the corresponding ρ density value at alternate conditions t and P using the procedure in 11.1.6.1. If this procedure returns with an error condition, exit this procedure. Retain the values of C_{TL}, F_{PL}, C_{PL}, and C_{TPL} in the procedure. Round this value of C_{TPL}.

Example Calculations
Example 1

Step 1
F_p(s)m ............................................
F_p,s,o .............................................

Step 2
F_p,s,psi ............................................

Step 3
Volume at base conditions ....... 989.99 989.990602512848
Volume at alternate t & P ............ 936.630178718 936.634084363292

Example 2

Step 1
F_p(s)m ............................................
F_p,s,o .............................................

Step 2
F_p,s,psi ............................................

Step 3
Volume at base conditions ....... 10879.492266 10879.5060165477
Volume at alternate t & P ............ 12729.4544055576 12729.4654849

Example 3

Step 1
F_p(s)m ............................................
F_p,s,o .............................................

Step 2
F_p,s,psi ............................................

Step 3
Volume at base conditions ....... 284.4366525 284.436940266107
Volume at alternate t & P ............ 295.586162551 295.586050990898

Example 4

Step 1
F_p(s)m ............................................
F_p,s,o .............................................

Step 2
F_p,s,psi ............................................

Step 3
Volume at base conditions ....... 14.893489 14.893534494788
Volume at alternate t & P ............ 14.0912728374 14.091278574412

Example 5

Step 1
F_p(s)m ............................................
F_p,s,o .............................................

Step 2
F_p,s,psi ............................................

Step 3
Volume at base conditions ....... 101454.97086 101455.297101008
Volume at alternate t & P ............ 105593.062530991 105593.167078

Example 6

Step 1
F_p(s)m ............................................
F_p,s,o .............................................

Step 2
F_p,s,psi ............................................

Step 3
Volume at base conditions ....... 495.107662 495.109922341430
Volume at alternate t & P ............ 451.319834324387 451.316428993

Example 7
### Step 1
- $F_p (m)$
- $F_p, o$

### Step 2
- $F_p, psi$

### Step 3
- Volume at base conditions: 9866.2, 9866.18119471803
- Volume at alternate t & P: 10084.9424007, 10084.9644601740

**Example 8**

### Step 1
- $F_p (m)$
- $F_p, o$

### Step 2
- $F_p, psi$

### Step 3
- Volume at base conditions: 260.1176, 260.117009046524
- Volume at alternate t & P: 259.943437897, 259.942678128494

**Example 9**

### Step 1
- $F_p (m)$
- $F_p, o$

### Step 2
- $F_p, psi$

### Step 3
- Volume at base conditions: 917.103012, 917.103113370660
- Volume at alternate t & P: 928.382863795, 928.381502424912

**Example 12**

### Step 1
- $F_p (m)$
- $F_p, o$

### Step 2
- $F_p, psi$

### Step 3
- Volume at base conditions: 992.66, 992.655673734276
- Volume at alternate t & P: 1001.96828537, 1001.96012648983

**Example 13**

### Step 1
- $F_p (m)$
- $F_p, o$

### Step 2
- $F_p, psi$

### Step 3
- Volume at base conditions: 977.66, 977.659505441647
- Volume at alternate t & P: 1175.02974652, 1175.02276434999

**Example 18**

### Step 1
- $F_p (m)$
- $F_p, o$

### Step 2
- $F_p, psi$

### Step 3
- Volume at base conditions: 1035.5, 1035.49894579718
- Volume at alternate t & P: 1034.8066795, 1034.80349068147

### 11.1.7.1 Method to Correct a Measured Volume to Metric Base Conditions and Density from
Metric Base Conditions to an Alternate Temperature and Pressure

Output Values

\( F \rho F_a \)  Scaled compressibility factor (kPa\(^{-1}\) or bar\(^{-1}\))

Intermediate Values

\( F_{\rho,psi} \)  Scaled compressibility factor (psi\(^{-1}\))

Calculation Procedure

Step 3: Using this value of \( \rho_{60} \), calculate the density value at the alternate conditions \( t \) and \( P \) using the procedure in 11.1.6.1. There are associated factors that must be adjusted to take into account that the reference temperature is not 60°F and the originally input pressure is not in customary units. Call these factors \( C_{TL}^*, C_{TPL}, C_{TPL}, \) and \( F_{\rho,psi} \).

Step 4: Calculate the correction factors for the metric base temperature by combining the correction factors for 60°F. The temperature correction factor is:

\[
C_{TL} = \frac{C_{TL}^*}{C_{TL,60}}
\]

and the combined temperature and pressure correction factor is:

\[
C_{TPL} = C_{TL} \cdot C_{PL}
\]

Round this value of \( C_{TPL} \) consistent with 11.1.5.4.

Example Calculations

API MPMS 11.1.7.1 Metric units. Example 1

Input Data
Volume at observed alternate t & P ......9885

Step 1 – Convert to customary units
P alternate, PSI ...........................................................................................................356.792849987316

Step 3 – Correct 60°F/0 psi density to alternate conditions:
\( F_{\rho,psi} \) ..............................................................................................................

Step 4 - Modify CTL and Ctpl for temperature base of 15°C
\( F_{\rho,bar} \) ..............................................................................................................

Step 5 - Calculate volume at base conditions and density at alternate conditions
Volume at base conditions ........................................40380.73275 10380.7584211291
Density, kg/cu m, at t & P ........................................811.032850646233
API MPMS 11.1.7.1 Metric units. Example 2

Input Data
Volume at \( \text{observed alternate t & P} \)......397498

Step 1 – Convert to customary units
\( P \) alternate, PSI..........................357.518038072 357.518038706803

Step 3 – Correct 60°F/0 psi density to alternate conditions:
\( F_{\rho}, \text{psi} \) .................................

Step 4 - Modify Ctl and Ctpl for temperature base of 15°C
\( F_{\rho}, \text{bar} \) .................................

Step 5 - Calculate volume at base conditions and density at alternate conditions
Volume at base conditions ....................419376.2898 419374.35003641
Density, kg/cu m, at t & P ...................814.807392 814.803593787420

API MPMS 11.1.7.1 Metric units. Example 3

Input Data
Volume at \( \text{observed alternate t & P} \)......48.75

Step 1 – Convert to customary units
\( P \) alternate, PSI..........................10.8778307923 10.877830792296

Step 3 – Correct 60°F/0 psi density to alternate conditions:
\( F_{\rho}, \text{psi} \) .................................

Step 4 - Modify Ctl and Ctpl for temperature base of 15°C
\( F_{\rho}, \text{kPa} \) .................................

Step 5 - Calculate volume at base conditions and density at alternate conditions
Volume at base conditions ....................45.8488875 45.84935043908
Density, kg/cu m, at t & P ...................814.088144 814.088988184753

API MPMS 11.1.7.1 Metric units. Example 4

Input Data
Volume at \( \text{observed alternate t & P} \)......200.2

Step 1 – Convert to customary units
\( P \) alternate, PSI..........................247.289353345 247.28935344868

Step 3 – Correct 60°F/0 psi density to alternate conditions:
\( F_{\rho}, \text{psi} \) .................................

Step 4 - Modify Ctl and Ctpl for temperature base of 15°C
\( F_{\rho}, \text{bar} \) .................................

Step 5 - Calculate volume at base conditions and density at alternate conditions
Volume at base conditions ....................198.173976 198.174129078352
Density, kg/cu m, at t & P ...................785.46978 785.470386731631

API MPMS 11.1.7.1 Metric units. Example 5

Input Data
Volume at \( \text{observed alternate t & P} \)......1502.3

Step 1 – Convert to customary units
\( P \) alternate, PSI..........................124.732459752 124.732459751663
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Example 6</th>
<th>Example 7</th>
<th>Example 8</th>
<th>Example 9</th>
<th>Example 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Correct 60°F/0 psi density to alternate conditions:</td>
<td>179.121613713</td>
<td>984.12</td>
<td>45.789579</td>
<td>1500.12538513</td>
<td>1500.12538512960</td>
</tr>
<tr>
<td>4</td>
<td>Modify Ctl and Ctpl for temperature base of 15°C</td>
<td>179.121613713145</td>
<td>984.119864783435</td>
<td>614.164092</td>
<td>614.163485038521</td>
<td>1500.12538512960</td>
</tr>
<tr>
<td>5</td>
<td>Calculate volume at base conditions and density at alternate conditions</td>
<td>984.12</td>
<td>646.861987122152</td>
<td>45.789579</td>
<td>614.164092</td>
<td>1500.12538512960</td>
</tr>
<tr>
<td></td>
<td>Volume at base conditions</td>
<td>1593.534679</td>
<td>1593.53956665203</td>
<td>45.789579</td>
<td>614.164092</td>
<td>1500.12538512960</td>
</tr>
<tr>
<td></td>
<td>Density, kg/cu m, at t &amp; P</td>
<td>819.201779</td>
<td>819.204291636398</td>
<td>646.862076</td>
<td>646.861987122152</td>
<td>614.164092</td>
</tr>
</tbody>
</table>
11.1.7.2 Method to Correct Volume and Density from Metric Observed Conditions to Metric Base Conditions

Output Values

\( F_p \)  
Scaled compressibility factor (kPa\(^{-1}\) or bar\(^{-1}\))

Intermediate Values

\( F_{\rho, psi} \)  
Scaled compressibility factor (psi\(^{-1}\))

Calculation Procedure

Step 2: Calculate the correction factors for the density at 60°F, \( \rho_{60} \), corresponding to the observed density \( \rho_o \) at conditions \( t_o,^\circ F \) and \( P_o,psi \) using the procedure in 11.1.6.2. If this procedure returns with an error condition, exit this procedure. There are associated factors that must be adjusted to take into account that the reference temperature is not 60°F and the pressure is not in customary units. Call these factors \( C_{TL}, C_{PL}, C_{TPL}, \) and \( F_{\rho, psi} \).

Step 4: Calculate the correction factors for the metric base temperature by combining the correction factors for 60°F. The temperature correction factor is:

\[
C_{TL} = \frac{C_{TL}^*}{C_{TL,60}}
\]

and the combined temperature and pressure correction factor is:

\[
C_{TPL} = C_{TL} \cdot C_{PL}
\]

Round this value of consistent with 11.1.5.4.

Example Calculations

Example 1
Step 1
P observed, pressure, psi ...............1451.10262769 1451.10262769232

Step 2
F \rho_s(m) ............................................
F \rho_s, psi ............................................

Step 3
F \rho_s, psi ............................................

Step 4
F \rho_s, kPa...........................................

Step 5
Volume at base conditions ..............9989.51 9989.507855127724

Example 2

Step 1
P observed, pressure, psi ...............16.6793405482 16.679340548188

Step 2
F \rho_s(m) ............................................
F \rho_s, psi ............................................

Step 3
F \rho_s, psi ............................................

Step 4
F \rho_s, kPa...........................................

Step 5
Volume at base conditions ..............158685.93324 158686.597577785

Example 3

Step 1
P observed, pressure, psi ...............163.167461884 163.167461884443

Step 2
F \rho_s(m) ............................................
F \rho_s, psi ............................................

Step 3
F \rho_s, psi ............................................

Step 4
F \rho_s, bar...........................................
Step 5
Volume at base conditions .......... 99548.41275 99548.0050864555

Example 5

Step 1
P observed, pressure, psi .......... 375.256154785 375.256154785441

Step 2
F_p, psi ............................................

Step 3
F_p, psi ............................................

Step 4
F_p, kPa...........................................

Step 5
Volume at base conditions ...... 398.4413595 398.441894541839

Example 6

Step 1
P observed, pressure, psi .......... 266.144260052 266.144260051514

Step 2
F_p, psi ............................................

Step 3
F_p, psi ............................................

Step 4
F_p, kPa...........................................

Step 5
Volume at base conditions ...... 2026.841696 2026.85124325365

Example 7

Step 1
P observed, pressure, psi .......... 248.014542064 248.014542064354

Step 2
F_p, psi ............................................

Step 3
F_p, psi ............................................

Step 4
F_p, kPa...........................................

Step 5
Volume at base conditions ...... 91112.73737 91113.0086949391

Example 8

Step 1
P observed, pressure, psi .......... 57.2899088394 57.289908839427

Step 2
F_p, psi ............................................

F_p, psi ............................................
Step 3
Fp, psi .................................

Step 4
Fp, kPa...........................................

Step 5
Volume at base conditions .......... 8378.286189 8378.27232014771

Example 9

Step 1
P observed, pressure, psi .......... 451.067383521 451.067383520550

Step 2
Fp(cm) ............................................
Fp, psi ............................................

Step 3
Fp, psi ............................................

Step 4
Fp, bar............................................

Step 5
Volume at base conditions .......... 103.57 103.569988613388

Example 10

Step 1
P observed, pressure, psi .......... 14.5037743897 14.503774389728

Step 2
Fp(cm) ............................................
Fp, psi ............................................

Step 3
Fp, psi ............................................

Step 4
Fp, kPa............................................

Step 5
Volume at base conditions .......... 883.1234754 883.123317595915

Example 11

Density less than 470.45 kg/cu m - outside limits of table

Example 12

Step 1
P observed, pressure, psi .......... 1500.05286626 1500.05286625765

Example 14

Step 1
P observed, pressure, psi .......... 1500.05286626 1500.05286625765

Example 15

Step 1
P observed, pressure, psi .......... 1500.05286626 1500.05286625765

Example 17
11.1.7.3 Method to Correct Volume and Density from Observed Metric Conditions to Alternate Metric Conditions

Output Values

\( F_{ps,o} \) Scaled compressibility factor at the observed temperature (kPa\(^{-1}\) or bar\(^{-1}\))
\( F_{ps} \) Scaled compressibility factor at the alternate temperature (kPa\(^{-1}\) or bar\(^{-1}\))

Intermediate Values

\( F_{ps,o,psi} \) Scaled compressibility factor at observed temperature (psi\(^{-1}\))
\( F_{ps,psi} \) Scaled compressibility factor at alternate temperature (psi\(^{-1}\))

Calculation Procedure

Step 2: Calculate the density at 60°F, \( \rho_{60} \), corresponding to the observed density \( \rho_o \) at conditions \( t_o,°F \) and \( P_o, psi \) using the procedure in 11.1.6.2. If this procedure returns with an error condition, exit this procedure. There are associated factors that must be adjusted to take into account that the reference temperature is not 60°F and the pressure is not in customary units. Call these factors \( C_{T,o}, C_{P,o}, C_{TPL,o}, \) and \( F_{ps,o,psi} \).

Step 3: Using this value of \( \rho_{60} \) from Step 2, calculate the correction factors for the density \( \rho \) at the alternate temperature and pressure \( t_P,°F \) and \( P_{psi} \) using the procedure in 11.1.6.1. If this procedure returns with an error condition, exit this procedure. There are associated factors that must be adjusted to take into account that the reference temperature is not 60°F and the pressure is not in customary units. Call these factors \( C_{T,L}, C_{P,L}, C_{TPL,L}, \) and \( F_{ps,psi} \).

Step 5: Calculate the correction factors for the metric base temperature by combining the correction factors for 60°F. The temperature correction factor is:

\[
C_{TL,o} = \frac{C_{TL,o}}{C_{TL,60}}
\]

\[
C_{T,L} = \frac{C_{TL}}{C_{TL,60}}
\]

and the combined temperature and pressure correction factor is:

\[
C_{TPL,o} = C_{TL,o} \cdot C_{PL,o}
\]

\[
C_{TPL} = C_{T,L} \cdot C_{PL}
\]
Example Calculations

Example 1

Step 2
F_{ps}(m) ............................................
F_{ps, o,psi} ..........................................

Step 3
F_{ps, psi} ............................................

Step 4
F_{ps, psi} ............................................

Step 5
F_{ps, o,kPa} ..........................................
F_{ps, kPa} ............................................

Volume at base conditions .............. 1234.537198500 1234.53727908176
Volume at alternate conditions ........ 1324.085071914 1324.08293887418

Example 2

Step 1
P observed pressure, PSI ............... 34.1831149379 31.183114937916
P alternate pressure, PSI ............... 353.16690639 353.166906389884

Step 2
F_{ps}(m) .............................................
F_{ps, o,psi} ..........................................

Step 3
F_{ps, psi} ............................................

Step 4
F_{ps, psi} ............................................

Step 5
F_{ps, o,bar} ..........................................
F_{ps, bar} ............................................

Volume at base conditions .............. 1065.250000000 1065.25481274655
Volume at alternate conditions ........ 1167.499616405 1167.51092161033

Example 3

Step 2
F_{ps}(m) .............................................
F_{ps, o,psi} ..........................................

Step 3
F_{ps, psi} ............................................

Step 4
F_{ps, psi} ............................................

Step 5

Round this value of consistent with 11.1.5.4.
F_p,s,o,kPa........................................
F_p,s,kPa........................................

Step 6
Volume at base conditions...........242.362515000 242.362757386791
Volume at alternate conditions......253.450996078 253.449951373001

Example 4

Step 1
Convert to customary units
P observed pressure, PSI...............374.922567974 374.922567974477
P alternate pressure, PSI..............508.35729236 508.357292359977

Step 2
F_p,s(m)...........................................
F_p,s,o,psi........................................

Step 3
F_p,s,psi........................................

Step 4
F_p,s,psi........................................

Step 5
F_p,s,o,kPa........................................
F_p,s,kPa........................................

Step 6
Volume at base conditions...........9944.853375000 9944.84454329600
Volume at alternate conditions......10740.162400778 10740.1454288640

Example 5

Step 1
Convert to customary units
P observed pressure, PSI...............266.144260052 266.144260051514
P alternate pressure, PSI..............1499.98034739 1499.980347385700

Step 2
F_p,s(m)...........................................
F_p,s,o,psi........................................

Step 3
F_p,s,psi........................................

Step 4
F_p,s,psi........................................

Step 5
F_p,s,o,kPa........................................
F_p,s,kPa........................................

Step 6
Volume at base conditions...........16.150516000 16.150478106258
Volume at alternate conditions......16.378670885 16.378581579726

Example 6

Step 1
Convert to customary units
P observed pressure, PSI...............247.724466677 247.724466576560
P alternate pressure, PSI..............50.4731348763 50.473134876255
Example 7

Step 1
Convert to customary units
P observed pressure, PSI .......................... 57.2899088394 57.289908839427
P alternate pressure, PSI .......................... 943.470524052 943.470524051827

Step 2
Fps(m) ............................................
Fps,o,psi ........................................

Step 3
Fps,psi ............................................

Step 4
Fps,psi ............................................

Step 5
Fps,o,kPa ........................................
Fps,kPa ........................................

Step 6
Volume at base conditions ..............
204.024795000 204.025679340181
Volume at alternate conditions ........
191.072022589 191.073619112863
Step 6
Volume at base conditions .............. 207.179427600
Volume at alternate conditions ........... 213.151945102

Example 9

Step 1
Convert to customary units
P observed pressure, PSI ............... 20.3052841456
P alternate pressure, PSI .................. 1499.6902719

Example 11

Step 1
Convert to customary units
P observed pressure, PSI ............... 1500.05286626
P alternate pressure, PSI .................. 1500.05286626

Example 12

Step 1
Convert to customary units
P observed pressure, PSI ............... 1500.05286626
P alternate pressure, PSI .................. 1500.05286626

Example 13

Step 1
Convert to customary units
P observed pressure, PSI ............... 1500.05286626
P alternate pressure, PSI .................. 1500.05286626

11.1.8 Use of Implementation Procedures to Generate Correction Factors in Tabular Format

<table>
<thead>
<tr>
<th>Petroleum Measurement Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table Description</strong></td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>...</td>
</tr>
<tr>
<td>Compressibility Factors for Hydrocarbons Related to API Gravity and Metering Temperature</td>
</tr>
<tr>
<td>Compressibility Factors for Hydrocarbons Related to Density and Metering Temperature</td>
</tr>
</tbody>
</table>

11.1.8.23 Instructions to Generate Tables 6C & 24C — Volume Correction Factors for Individual and Special Applications Volume Correction to 60°F Against Thermal Expansion Coefficients at 60°F

Step 1: Hold pressure at 0 psig. Set input \( \rho_{60} \) to 840 kg/m³. Note: This density value is used only for CPL calculations that will not affect the table results.
11.1.8.24 Instructions to Generate Tables 54C & 60C — Volume Correction Factors for Individual and Special Applications Volume Correction to 15°C or 20°C Against Thermal Expansion Coefficients

Step 1: Hold pressure at 0 kPa (gauge). Set input $\rho_{15}$ (Table 54C) or $\rho_{20}$ (Table 60C) to 840 kg/m$^3$. Note: This density value is used only for CPL calculations that will not affect the table results.

11.1.8.25 Instructions to Generate 1984 Chapter 11.2.1 Compressibility Factor Table — Compressibility Factors for Hydrocarbons Related to API Gravity and Metering Temperature

Output Variables: $F_{ps}$ at input temperature.

Step 4: Determine the $F_{ps}$ values using the procedure in 11.1.6.1. Any commodity group can be specified. Round the $F_{ps}$ value consistent with instructions in 11.1.5.4.

(1981) Chapter 11.2.1 Table. Compressibility Factor Against API Gravity at 60°F

Scaled Compressibility Factor ($F_{ps}$), 1/psig

11.1.8.26 Instructions to Generate 1984 Chapter 11.2.1M Compressibility Factor Table — Compressibility Factors for Hydrocarbons Related to Density and Metering Temperature

Output Variables: $F_{ps}$ at input temperature.

Step 4: Determine the $F_{ps}$ values using the procedure in 11.1.7.1. Specify the commodity type “A.” Round the $F_{ps}$ value consistent with instructions in 11.1.5.4.

(1981) Chapter 11.2.1M Table. Compressibility Factor Against 15°C Base Density

Scaled Compressibility Factor ($F_{ps}$), 1/psig
Appendix C

C.7 Conversion of Thermal Expansion Coefficient to Other Temperature Units

As explained in Appendix C, Section C5.2, there is only one value of alpha to be used with this standard, \( \alpha_{60} \), the coefficient of thermal expansion at 60 °F of the fluid as to be used with the specified thermal expansion correlation used within this standard. The value of \( \alpha_{60} \) used for internal calculations has units of °F\(^{-1}\). However, it is acceptable to report the unit in either °C\(^{-1}\) or °F\(^{-1}\). The conversion from \( \alpha_{60} \) in °C\(^{-1}\) to °F\(^{-1}\) is given by

\[
\alpha_{60} \text{ (°C}^{-1}) = \alpha_{60} \text{ (°F}^{-1}) \times 1.8
\]

Values of \( \alpha \) reported using other correlations or at other temperatures such as 15 °C or 20 °C will differ from the \( \alpha_{60} \) required by this standard. The value of \( \alpha_{60} \) must be determined from density data following the procedures in Appendix E.

Values of \( \alpha_{15} \) and \( \alpha_{20} \) in °C\(^{-1}\) can be estimated from the value of \( \alpha_{60} \) in °F\(^{-1}\) by the equation

\[
\alpha_T = 1.8 \alpha_{60} \left(1 + 0.8 \alpha_{60} (2 \gamma + \delta)\right)
\]

Where \( \delta = 0.01374979547 \) and \( \gamma = -1.000254 \) (for 15 °C) or 8.002046 (for 20 °C).
A volume of a specialized liquid is measured at observed conditions of temperature and pressure. The base density at 15°C is known. Calculate the volume at base conditions and correct the base density to an alternate condition.

**Input Data**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Specialized Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha at 60°F per °C</td>
<td>0.0008041662</td>
</tr>
<tr>
<td>T base temperature, °C</td>
<td>15</td>
</tr>
<tr>
<td>P alternate pressure, bar</td>
<td>45.35</td>
</tr>
<tr>
<td>Base density, kg/cu m</td>
<td>641.8</td>
</tr>
<tr>
<td>Volume at alternate t &amp; P</td>
<td>47.85</td>
</tr>
</tbody>
</table>

**Computed Data**

- T alternate temperature, °F: 193.82
- P alternate pressure, psi: 657.75
- Alpha at 60°F per °F: 0.000446759

**Step 1 - Convert to customary units**

<table>
<thead>
<tr>
<th>t alternate temperature, °F</th>
<th>193.820000000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>P alternate, PSI</td>
<td>657.74618574179</td>
</tr>
<tr>
<td>Alpha at 60°F per °F</td>
<td>0.000446759000</td>
</tr>
</tbody>
</table>

**Step 2 - Correct base metric (observed) density to 60 °F & 0 psi reference conditions**

<table>
<thead>
<tr>
<th>Iteration(n)</th>
<th>Rho60(m)</th>
<th>Rho60*(m)</th>
<th>Ctl,60(m)</th>
<th>d_alpha(m)</th>
<th>Rho60(m)xCtl,60(m)</th>
<th>delta Rho60(m)</th>
<th>E(m)</th>
<th>Dt(m)</th>
<th>Dp(m)</th>
<th>delta Rho(m)</th>
<th>Rho60(m+1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>641.800000000000</td>
<td>641.513362513010</td>
<td>1.000446814523</td>
<td>0.000000000000</td>
<td>642.086765560782</td>
<td>-0.286765560782</td>
<td>-0.286637486990</td>
<td>-0.000000000000</td>
<td>-0.000000000000</td>
<td>641.513362513010</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>641.801971246791</td>
<td>641.515332879412</td>
<td>1.000446814523</td>
<td>0.000000000000</td>
<td>642.086765560782</td>
<td>-0.286765560782</td>
<td>-0.286637486990</td>
<td>-0.000000000000</td>
<td>-0.000000000000</td>
<td>641.513362513010</td>
<td></td>
</tr>
</tbody>
</table>

**Step 3 - Correct 60°F/0 psi density to alternate conditions**

<table>
<thead>
<tr>
<th>t, °F</th>
<th>193.861860191643</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rho60*</td>
<td>641.515332879412</td>
</tr>
<tr>
<td>delta t, °F</td>
<td>133.854985291643</td>
</tr>
<tr>
<td>Ctl*</td>
<td>0.939260765097</td>
</tr>
<tr>
<td>Fs, psi</td>
<td>2.875296454594</td>
</tr>
<tr>
<td>P in psi</td>
<td>657.74618574179</td>
</tr>
<tr>
<td>Cpl</td>
<td>1.019276716462</td>
</tr>
<tr>
<td>Ctpl*</td>
<td>0.957366628549</td>
</tr>
</tbody>
</table>

**Step 4 - Modify Ctl and Ctpl for temperature base of 15°C**

<table>
<thead>
<tr>
<th>Ctl</th>
<th>0.938841277179</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctpl</td>
<td>0.956939054283</td>
</tr>
<tr>
<td>Ctpl, rounded</td>
<td>0.95694</td>
</tr>
<tr>
<td>Fs, bar</td>
<td>41.702651081010</td>
</tr>
</tbody>
</table>

**Step 5 - Calculate volume at base conditions and density at alternate conditions**

| Volume at base conditions | 45.789533747419 |
| Density, kg/cu m at t & P | 614.163485038521 |
**API MPMS 11.1.7.2 Metric Units, Example 8**

**Input Data**

Commodity: Specialized Liquid

Base temperature, °C: 15

Alpha at 60°F per °C: 0.00103734

t observed temperature, °C: 29.18

P observed pressure, kPa: 395

Observed density, kg/cu m: 853.7

Volume at observed t & P: 8501.3

**Computed Data - last digit is rounded for display purposes**

**Step 1**

Convert to customary units

| t observed temperature °F | 84.524000000000 |
| T base temperature, °F | 59.000000000000 |
| P observed, pressure, psi | 57.5289908839427 |

**Step 2**

Correcting observed density to 60°F & 0 psi reference conditions

<table>
<thead>
<tr>
<th>Iteration</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rho60(m)</td>
<td>853.700000000000</td>
<td>865.737133188744</td>
<td>865.736878409727</td>
</tr>
<tr>
<td>Rho60*(m)</td>
<td>853.703382379864</td>
<td>865.740563260019</td>
<td>865.740308479993</td>
</tr>
<tr>
<td>Clt</td>
<td>0.985804899058</td>
<td>0.985804899058</td>
<td>0.985804899058</td>
</tr>
<tr>
<td>d alpha(m)</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>Fs(m)</td>
<td>0.53684525741</td>
<td>0.51591854357</td>
<td>0.51591854357</td>
</tr>
<tr>
<td>Cpl(m)</td>
<td>1.00030697389</td>
<td>1.000295675745</td>
<td>1.000295675745</td>
</tr>
<tr>
<td>C tpl(m)</td>
<td>1.000306987389</td>
<td>1.000295675745</td>
<td>1.000295675975</td>
</tr>
<tr>
<td>Rho60(m)xCtpl,60(m)</td>
<td>841.839997277023</td>
<td>853.700251040320</td>
<td>853.700000000000</td>
</tr>
<tr>
<td>Delta Rho60(m)</td>
<td>11.860002722977</td>
<td>-0.000251040320</td>
<td>-0.000000000005</td>
</tr>
<tr>
<td>E(m)</td>
<td>12.027088707301</td>
<td>-0.000254579903</td>
<td></td>
</tr>
<tr>
<td>Dp(m)</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>Delta Rho(m)</td>
<td>12.037133188744</td>
<td>-0.000254779017</td>
<td></td>
</tr>
<tr>
<td>Rho60(m+1)</td>
<td>865.736878409727</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Output values**

| Rho60 | 865.736878409727 |
| Clt | 0.985804899058 |
| Fs, psi | 0.51591854357 |
| Cpl | 1.000295675745 |
| Ctpl | 1.000295675975 |

**Step 3**

Correcting 60°F density to 15°C base conditions:

| t, °F | 59.000000000000 |
| Clt | 1.000576349988 |
| Fs, psi | 0.475019162473 |
| Cpl | 1.000000000000 |
| Ctpl | 1.000576349988 |

Density, kg/cu m at 15°C: 866.235845849433

**Step 4**

Modify Clt* factor and calculate Ctpl factor for base temperature of 15°C

| Clt | 0.985237057692 |
| Ctpl | 0.985528368620 |
| Ctpl, rounded | 0.9853 |
| Fs, kPa | 0.074832551126 |

**Step 5**

Volume at base conditions: 8378.27232014771
**Example 7**

**Input Data**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Specialized Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha at 60°F per °C</td>
<td>0.001037412</td>
</tr>
<tr>
<td>t observed, °C</td>
<td>29.2</td>
</tr>
<tr>
<td>P observed pressure, kPa</td>
<td>395</td>
</tr>
<tr>
<td>Base temperature, °C</td>
<td>15</td>
</tr>
<tr>
<td>t alternate temp, °C</td>
<td>55.05</td>
</tr>
<tr>
<td>P alternate pressure, kPa</td>
<td>6505</td>
</tr>
<tr>
<td>Observed density, kg/cu m</td>
<td>853.7</td>
</tr>
<tr>
<td>Volume at observed t &amp; P</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Computed Data - last digit is rounded for display purposes**

**Step 1**

**Convert to customary units**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>T base</td>
<td>59.0000000000</td>
</tr>
<tr>
<td>t observed</td>
<td>84.5600000000</td>
</tr>
<tr>
<td>t alternate</td>
<td>131.0900000000</td>
</tr>
<tr>
<td>P observed</td>
<td>57.28990839427</td>
</tr>
<tr>
<td>P alternate</td>
<td>943.47052451827</td>
</tr>
<tr>
<td>Alpha at 60°F per °F</td>
<td>0.000576340000</td>
</tr>
</tbody>
</table>

**Step 2**

**Correcting observed density to 60°F & 0 psi reference conditions**

<table>
<thead>
<tr>
<th>Iteration</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rho60(m)</td>
<td>853.700000000000</td>
<td>865.756362250420</td>
<td>865.756106602179</td>
</tr>
<tr>
<td>Rho60*(m)</td>
<td>853.703382614631</td>
<td>865.759726359631</td>
<td>865.759536986708</td>
</tr>
<tr>
<td>d Alpha(m)</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>FS(m)</td>
<td>0.535748682507</td>
<td>0.515981715023</td>
<td>0.515982117769</td>
</tr>
<tr>
<td>Cpl(m)</td>
<td>1.000307024167</td>
<td>1.000295692863</td>
<td>1.000295693093</td>
</tr>
<tr>
<td>Cpl60(m)</td>
<td>1.000307024167</td>
<td>1.000295692863</td>
<td>1.000295693093</td>
</tr>
<tr>
<td>Rho60(m) x Cpl60(m)</td>
<td>841.821316799279</td>
<td>853.700251891176</td>
<td>853.700000000005</td>
</tr>
<tr>
<td>delta Rho60(m)</td>
<td>11.878683200722</td>
<td>-0.000251891176</td>
<td>-0.000000000004</td>
</tr>
<tr>
<td>E(m)</td>
<td>12.046299667265</td>
<td>-0.000255448429</td>
<td></td>
</tr>
<tr>
<td>D(m)</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>Dp(m)</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>delta Rho(m)</td>
<td>12.056362250420</td>
<td>-0.000255648241</td>
<td></td>
</tr>
<tr>
<td>Rho60(m+1)</td>
<td>865.756362250420</td>
<td>865.756106602179</td>
<td></td>
</tr>
</tbody>
</table>

**Output values**

| Rho60       | 865.756106602179 |
| Ctl,o       | 0.985782987747 |
| Fs,psi      | 0.515982117769 |
| Cpl,o       | 1.000295693093 |
| Ctpl,o      | 0.986074476968 |

**Step 3**

**Correcting 60°F and 0 psi density to alternate conditions:**

<table>
<thead>
<tr>
<th>t, °F</th>
<th>131.090000000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>t corrected to IPTS-68 °F</td>
<td>131.115680255004</td>
</tr>
<tr>
<td>Rho60*</td>
<td>865.759536986708</td>
</tr>
<tr>
<td>al pha60</td>
<td>0.000576340000</td>
</tr>
<tr>
<td>delta t, °F</td>
<td>71.08805355004</td>
</tr>
<tr>
<td>Ctl*</td>
<td>0.958556488638</td>
</tr>
<tr>
<td>Fs,psi</td>
<td>0.599894402634</td>
</tr>
<tr>
<td>Pin psi</td>
<td>943.47052451827</td>
</tr>
<tr>
<td>Cpl</td>
<td>1.000295693093</td>
</tr>
<tr>
<td>Ctpl*</td>
<td>0.964012633237</td>
</tr>
<tr>
<td>Density, kg/cu m</td>
<td>834.599824066622</td>
</tr>
</tbody>
</table>

**Step 4**

**Correcting 60°F density to 15°C base conditions:**

<table>
<thead>
<tr>
<th>t, °F</th>
<th>59.000000000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>t corrected to IPTS-68 °F</td>
<td>59.06621316269</td>
</tr>
<tr>
<td>Rho60*</td>
<td>865.759536986708</td>
</tr>
<tr>
<td>al pha60</td>
<td>0.000576340000</td>
</tr>
<tr>
<td>delta t, °F</td>
<td>-1.000253583731</td>
</tr>
<tr>
<td>Ctl</td>
<td>1.000576389985</td>
</tr>
<tr>
<td>Fs,psi</td>
<td>0.474992948912</td>
</tr>
<tr>
<td>Pin psi</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>Cpl</td>
<td>1.000000000000</td>
</tr>
<tr>
<td>Ctpl</td>
<td>1.000576389985</td>
</tr>
<tr>
<td>Density, kg/cu m</td>
<td>866.255119751516</td>
</tr>
<tr>
<td>Ctl,60</td>
<td>1.000576389985</td>
</tr>
</tbody>
</table>

**Step 5**

**Modify Ctl* factor and calculate the Ctpl factor for 15°C base conditions:**

| Ctl,0       | 0.985215119619 |
| Ctl         | 0.958004304551 |
| Ctpl,0      | 0.986074476968 |
Step 6
Volume at base conditions ...... 985.5064925726
Volume at alternate conditions : 1022.88543009788
Appendix F — Examples Calculations including Equilibrium Vapor Pressure

The $P_e$ value used in Equation 15 shall be in the same units and qualifier (absolute or gauge) as the observed or alternate pressure.

Equilibrium pressure varies with the temperature of the liquid. Therefore, different equilibrium pressures may be required for observed or alternate temperatures.

**API MPMS 11.1.6.1 Customary Units, Example 6**

A volume of a refined product is measured at observed conditions of temperature and pressure. The base kg/m³ is known. Calculate the volume at base conditions and correct the base density to an alternate condition.

**Input Data**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Generalized Refined Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t$ alternate temperature, °F</td>
<td>27.3</td>
</tr>
<tr>
<td>$P$ alternate pressure, PSI</td>
<td>1234.5 - 1244.5</td>
</tr>
<tr>
<td>$P_e$ at alternate temperature, PSI</td>
<td>10.0</td>
</tr>
<tr>
<td>Base density, kg/cu m</td>
<td>657.3</td>
</tr>
<tr>
<td>Volume at alternate $t$ &amp; $P$</td>
<td>14.72</td>
</tr>
</tbody>
</table>

**Computation Data - last digit is rounded for display purposes**

**Calculation of Intermediate Results**

1. $P_{alt} - P_{ealt}$, PSI
2. $t$ corrected to IPTS-68 temperature scale
3. Shift $\rho_{60}$ to IPTS-68 temperature scale
4. Determine coefficient of thermal expansion
5. Calculate temperature correction factor $C_t$
6. Calculate scaled compressibility factor $F_p$
7. Calculate pressure correction factor $C_p$
8. Calculate the Volume Correction Factor $C_{tpl}$
9. Calculate volume at base conditions and density at alternate conditions

**Computed Results**

<table>
<thead>
<tr>
<th>Computation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{alt} - P_{ealt}$</td>
<td>1234.5 - 1244.5</td>
</tr>
<tr>
<td>$t$ corrected to IPTS-68 temperature scale</td>
<td>27.29</td>
</tr>
<tr>
<td>$\rho_{60}$ corrected to IPTS-68 temperature scale</td>
<td>657.3</td>
</tr>
<tr>
<td>$\alpha_{60}$</td>
<td>0.0081</td>
</tr>
<tr>
<td>$C_t$</td>
<td>1.0265</td>
</tr>
<tr>
<td>$F_p$</td>
<td>0.9935</td>
</tr>
<tr>
<td>$C_p$</td>
<td>1.0124</td>
</tr>
<tr>
<td>$C_{tpl}$, rounded</td>
<td>1.04</td>
</tr>
<tr>
<td>Volume at base conditions</td>
<td>15.29</td>
</tr>
<tr>
<td>Density at $t$ &amp; $P$, kg/cu m</td>
<td>683.08</td>
</tr>
</tbody>
</table>
API MPMS 11.1.6.2 Customary Units, Example 6

Input Data
Commodity ...................... Generalized Refined Product

<table>
<thead>
<tr>
<th>t observed temperature, °F</th>
<th>P observed pressure, PSI</th>
<th>Pe at observed temperature, PSI</th>
<th>Rel density, observed t &amp; P</th>
<th>Volume at observed t &amp; P</th>
</tr>
</thead>
<tbody>
<tr>
<td>139</td>
<td>1000</td>
<td>8.0</td>
<td>0.7322</td>
<td>1000</td>
</tr>
</tbody>
</table>

Computation of Intermediate Results

Density kg/cu meter ............ 731.479515200000
Pobs - Peobs, PSI ............ 100.000000000000

Step 1
All input data within range of procedure

Step 2
Initial density, kg/cu m ........ 731.479515200000

Iteration(n) ...... 0 1 2 3

Step 3
Commodity .......... gasoline gasoline gasoline gasoline
Rho60(n) .......... 731.479515200000 770.352202009943 770.350382398833 770.349794252060
K0(n) .............. 192.457100000000 1.48906700000e+03 192.457100000000 192.457100000000
K1(n) .............. 0.243800000000 0.000000000000 0.243800000000 0.243800000000
K2(n) .............. 0.000000000000 -0.018684000000 0.000000000000 0.000000000000
A(n) .............. 0.000004764222 0.000004405447 0.000004405346 0.000004405351
B(n) .............. 1.519043562955 7.831444710641 1.506108416142 1.506108606983
Rho60*(n) .......... 731.483000127510 770.355595657728 770.353776055661 770.353187910199
alpha60(n) ........ 0.000692983108 0.000640779647 0.000640782868 0.000640783604
Ctl(n) ............. 0.944443401311 0.948677400428 0.948677139402 0.948677079691
daL(n) ............ 1.500000000000 8.500000000000 1.500000000000 1.500000000000
Fs(n) .............. 1.18639209920 0.91091273669 0.910920838482 0.910923457238
Cpl(n) ............. 1.001119891965 1.000911751372 1.000911753995 1.000911754995
Ctpl(n) ............ 0.945501075887 0.949542350649 0.949542097086 0.949542039808
Rho60(n)xCtpl(n) ... 691.614668611132 731.482040724130 731.480117593762 731.479515000034

Step 4
delta Rho60(n) ...... 39.864846588868 -0.002525524130 -0.000602393762 0.000000199966

Step 5
E(n) .............. 42.162666553771 -0.002659727740 -0.000634404481
Dt(n) ............. 0.089311509196 0.465134152690 0.82082941045
Dp(n) .............. -0.004676769130 -0.003432954458 -0.003433001237
delta Rho(n) ...... 38.872686809943 -0.001819611110 -0.000588146773
Rho60(n+1) .......... 770.352202009943 770.350382398833 770.349794252060

Step 6, iteration(n) ..... 1 2 3

Step 7
Density at 60°F is within range of procedure

Output values
Density at 60°F .......... 770.349794252060
Relative density .......... 0.771108565080
Ctl ............................ 0.948677079691
Fs for psi ................. 0.910923457238
Cpl ............................ 1.000911754995
Ctpl, rounded ............. 0.94954

Step 8
Volume at base conditions ...... 949.542039808338
### API MPMS 11.1.6.3 Customary Units, Example 3

#### Input Data

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Generalized Refined Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>t observed temperature, °F</td>
<td>68.02</td>
</tr>
<tr>
<td>t alternate temperature, °F</td>
<td>150.3</td>
</tr>
<tr>
<td>P observed pressure, PSI</td>
<td>11</td>
</tr>
</tbody>
</table>

**Forcing negative pressure(s) to zero**

<table>
<thead>
<tr>
<th>Pe at observed temperature, PSI</th>
<th>-9.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pe alternate pressure, PSI</td>
<td>534</td>
</tr>
</tbody>
</table>

| P rho, observed rel density    | 0.8665 |
| Volume at observed t & P      | 285.45 |

**Computed Data - last digit is rounded for display purposes**

#### Calculation of Intermediate Results

| Density kg/cu meter           | 865.647364000000 |
| Pobs - Peobs, PSI            | 11.000000000000  |
| Palt - Pealt, PSI            | 534.000000000000 |

#### Step 1

**Correcting observed density to 60 °F & 0 psi reference conditions:**

<table>
<thead>
<tr>
<th>Iteration(n)</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commodity</td>
<td>fuel oil</td>
<td>fuel oil</td>
<td>fuel oil</td>
</tr>
<tr>
<td>Rho60(n)</td>
<td>865.647364000000</td>
<td>865.730560425361</td>
<td>865.730481427765</td>
</tr>
<tr>
<td>K0(n)</td>
<td>103.872000000000</td>
<td>103.872000000000</td>
<td>103.872000000000</td>
</tr>
<tr>
<td>K1(n)</td>
<td>0.270100000000</td>
<td>0.270100000000</td>
<td>0.270100000000</td>
</tr>
<tr>
<td>K2(n)</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>A(n)</td>
<td>0.000030980897</td>
<td>0.000030980897</td>
<td>0.000030980897</td>
</tr>
<tr>
<td>B(n)</td>
<td>1.307601778625</td>
<td>1.306845058542</td>
<td>1.306845077883</td>
</tr>
<tr>
<td>Rho60*(n)</td>
<td>865.650045852404</td>
<td>865.73323949982</td>
<td>865.733160352460</td>
</tr>
<tr>
<td>alpha60(n)</td>
<td>0.000450635987</td>
<td>0.000448546437</td>
<td>0.000448546490</td>
</tr>
<tr>
<td>Ctl(n)</td>
<td>0.996381066426</td>
<td>0.996397864928</td>
<td>0.996397864500</td>
</tr>
<tr>
<td>Fs(n)</td>
<td>0.489229213867</td>
<td>0.484484362415</td>
<td>0.484484473663</td>
</tr>
<tr>
<td>Cpl(n)</td>
<td>1.000053818110</td>
<td>1.000053335724</td>
<td>1.000053335737</td>
</tr>
<tr>
<td>Ctpl(n)</td>
<td>0.996434689772</td>
<td>0.996451008530</td>
<td>0.996451008114</td>
</tr>
<tr>
<td>Rho60*(n)*Ctpl(n)</td>
<td>865.561062599229</td>
<td>865.64743076884</td>
<td>865.6473697953</td>
</tr>
</tbody>
</table>

#### Step 2

**Correcting 60°F and 0 psi density to alternate conditions:**

<table>
<thead>
<tr>
<th>t, °F</th>
<th>150.300000000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>t corrected to IPTS-68 °F</td>
<td>150.330786371419</td>
</tr>
<tr>
<td>A</td>
<td>0.000003083724</td>
</tr>
<tr>
<td>B</td>
<td>1.306845077883</td>
</tr>
<tr>
<td>Rho60*</td>
<td>865.73323949982</td>
</tr>
<tr>
<td>delta t, °F</td>
<td>90.329911471419</td>
</tr>
<tr>
<td>Ctl</td>
<td>0.959034901244</td>
</tr>
<tr>
<td>Fs, psi</td>
<td>0.631776484622</td>
</tr>
<tr>
<td>P in psi</td>
<td>534.000000000000</td>
</tr>
<tr>
<td>Cpl</td>
<td>1.0003385106716</td>
</tr>
<tr>
<td>Ctpl, rounded</td>
<td>0.962281336729</td>
</tr>
</tbody>
</table>

**Density at t & P, kg/cu m**

| Density, kg/cu m | 835.963128925946 |

#### Step 3

**Volume at base conditions**

| Volume | 284.436940266107 |

**Volume at alternate t & P**

| Volume | 295.586050990898 |
**API MPMS 11.1.7.1 Metric Units, Example 7**

A volume of a specialized liquid is measured at observed conditions of temperature and pressure. The base density at 15°C is known. Calculate the volume at base conditions and correct the base density to an alternate condition.

**Input Data**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Specialized Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha at 60°F per °F</td>
<td>0.000446759</td>
</tr>
<tr>
<td>T base temperature, °C</td>
<td>15</td>
</tr>
<tr>
<td>t alternate temperature, °C</td>
<td>89.9</td>
</tr>
<tr>
<td>P alternate pressure, bar</td>
<td>45.35/46.58</td>
</tr>
<tr>
<td>Pe at alternate temperature, bar</td>
<td>1.21</td>
</tr>
<tr>
<td>Base density, kg/cu m</td>
<td>641.8</td>
</tr>
<tr>
<td>Volume at alternate t &amp; P</td>
<td>47.85</td>
</tr>
</tbody>
</table>

**Computed Data - last digit is rounded for display purposes**

**Calculation of Intermediate Results**

Step 1 - Convert to customary units

| t alternate temperature, °F | 193.82 |
| T base, °F | 59 |
| P alternate, PSI | 657.746168574179 |

Step 2 - Correct base metric (observed) density to 60 °F & 0 psi reference conditions:

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Rho60(n)</th>
<th>Rho60*(n)</th>
<th>Ctl,60</th>
<th>d_alpha</th>
<th>Rho60(n)*Ctl,60</th>
<th>delta Rho60</th>
<th>E</th>
<th>Dt</th>
<th>Dp</th>
<th>delta Rho</th>
<th>Rho60(n+1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>641.800000000000</td>
<td>641.800000000000</td>
<td>641.513362513010</td>
<td>1.000446814523</td>
<td>0.000000000000</td>
<td>-0.286637486990</td>
<td>-0.286637486990</td>
<td>-0.000000000000</td>
<td>641.515332879412</td>
<td>641.800000000000</td>
<td></td>
</tr>
</tbody>
</table>

Step 3 - Correct 60°F/0 psi density to alternate conditions:

| t, °F | 193.82 |
| t corrected to IPTS-68 °F | 193.86 |
| Rho60* | 641.515332879412 |
| alpha60 | 0.000446759000 |
| delta t, °F | 133.85 |
| Ctl* | 0.939260765097 |
| Fs,psi | 2.875296454594 |
| Pin psi | 657.746168574179 |
| Cpl | 1.019276716462 |
| Cpl* | 0.957366628549 |

Step 4 - Modify Ctl and Ctpl for temperature base of 15°C

| Ctl | 0.938841277179 |
| Ctpl, rounded | 0.956939054283 |
| Fs,bar | 41.702651081010 |

Step 5 - Calculate volume at base conditions and density at alternate conditions

| Volume at base conditions | 45.789533747419 |
| Density, kg/cu m at t & P | 614.163485038521 |
**API MPMS 11.1.7.2 Metric Units, Example 3**

**Input Data**
- **Commodity**: Generalized Crude Oil
- **Base temperature, °C**: 15
- **t observed temperature, °C**: -50
- **P observed pressure, kPa**: 12.9
- **Pe at observed temperature, kPa**: 12.9
- **Observed density, kg/cu m**: 722.6
- **Volume at observed t & P**: 145902

**Computed Data - last digit is rounded for display purposes**

### Calculation of Intermediate Results

**Steps**

**Step 1**
Convert to customary units
- **t observed temperature °F**: -58
- **T base temperature, °F**: 59
- **P observed, pressure, psi**: 16.679340548188

**Step 2**
Correcting observed density to 60°F & 0 psi reference conditions

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Rho60(m)</th>
<th>K0(m)</th>
<th>K1(m)</th>
<th>K2(m)</th>
<th>A(m)</th>
<th>B(m)</th>
<th>Rho60*(m)</th>
<th>alpha60(m)</th>
<th>Ctl,60(m)</th>
<th>d_alpha(m)</th>
<th>Fs(m)</th>
<th>Cpl(m)</th>
<th>Ctpl(m)</th>
<th>Rho60(m)xCtpl,60(m)</th>
<th>delta Rho60(m)</th>
<th>E(m)</th>
<th>Dt(m)</th>
<th>Dp(m)</th>
<th>delta Rho(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>722.600000000000</td>
<td>341.095700000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.00004491036</td>
<td>2.000000000000</td>
<td>722.603245212681</td>
<td>0.000653245504</td>
<td>1.075025061700</td>
<td>2.000000000000</td>
<td>0.476890642768</td>
<td>1.000079548542</td>
<td>776.874903934710</td>
<td>-54.274903934710</td>
<td>-50.483089857305</td>
<td>-0.135152229527</td>
<td>-0.000200798113</td>
<td>-58.385782256892</td>
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</tr>
<tr>
<td>1</td>
<td>664.214217743108</td>
<td>341.095700000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000005320795</td>
<td>2.000000000000</td>
<td>664.217742145555</td>
<td>0.000773134926</td>
<td>1.088269020951</td>
<td>0.000000000000</td>
<td>0.601186188829</td>
<td>1.000100283948</td>
<td>722.916246070126</td>
<td>0.000316246070126</td>
<td>0.290566351531</td>
<td>-0.155826567176</td>
<td>0.000299597651</td>
<td>-0.344324399478</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>663.86983343631</td>
<td>341.095700000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000005320795</td>
<td>2.000000000000</td>
<td>663.869868377549</td>
<td>0.000773937176</td>
<td>1.088357010727</td>
<td>0.000000000000</td>
<td>0.602118681321</td>
<td>1.000100439501</td>
<td>722.86993343631</td>
<td>0.0000316246070126</td>
<td>0.290566351531</td>
<td>-0.155960587255</td>
<td>0.000303737100</td>
<td>-0.344324399478</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>663.869868377549</td>
<td>341.095700000000</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
<td>0.000005320795</td>
<td>2.000000000000</td>
<td>663.869868377549</td>
<td>0.000773937176</td>
<td>1.088357010727</td>
<td>0.000000000000</td>
<td>0.602118681321</td>
<td>1.000100439501</td>
<td>722.86993343631</td>
<td>0.0000316246070126</td>
<td>0.290566351531</td>
<td>-0.155960587255</td>
<td>0.000303737100</td>
<td>-0.344324399478</td>
<td></td>
</tr>
</tbody>
</table>

**Output values**
- **Rho60**: 663.869868377549
- **Ctl**: 1.088466331160
- **Fs,psi**: 1.134306792464
- **Cpl**: 1.000000000000
- **Ctpl**: 1.000773959950

**Step 3**
Correcting 60°F density to 15°C base conditions:
- **t, °F**: 59
- **t corrected to IPTS-68 °F**: 59.006621316269
- **A**: 0.000005320796
- **B**: 2.000000000000
- **Rho60***: 663.874903934710
- **alpha60**: 0.00077397176
- **delta t, °F**: -1.000253583731
- **Ctl**: 1.087515323806
- **Cpl**: 1.000073959950
- **Density, kg/cu m at 15°C**: 664.383677067826

**Step 4**
Modify Ctl* factor and calculate Ctpl factor for base temperature of 15°C
- **Ctl**: 1.087515323806
- **Cpl**: 1.000073959950
- **Fs, kPa**: 0.087329935201

**Step 5**
Volume at base conditions: 158686.597577785
API MPMS 11.1.7.3 Metric Units, Example 4

Input Data
Commodity: Generalized Refined Product

<table>
<thead>
<tr>
<th>t observed, °C</th>
<th>22.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>P observed pressure, kPa</td>
<td>2585</td>
</tr>
</tbody>
</table>

Pe at observed temperature, kPa: -7.1

Forcing negative pressure(s) to zero
Base temperature, °C: 15

<table>
<thead>
<tr>
<th>t alternate temp, °C</th>
<th>102.35</th>
</tr>
</thead>
<tbody>
<tr>
<td>P alternate pressure, kPa</td>
<td>3505</td>
</tr>
<tr>
<td>Pe at alternate temperature, kPa</td>
<td>329</td>
</tr>
<tr>
<td>Observed density, kg/cu m</td>
<td>817.55</td>
</tr>
<tr>
<td>Volume at observed t &amp; P</td>
<td>9987.5</td>
</tr>
</tbody>
</table>

Computed Data - last digit is rounded for display purposes

Calculation of Intermediate Results
Pobs - Peobs, kPa: 2585.000000000000

Step 1
Convert to customary units
T base, °F: 59.000000000000

<table>
<thead>
<tr>
<th>t observed, °F</th>
<th>72.050000000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>P observed pressure, PSI</td>
<td>374.922567974477</td>
</tr>
<tr>
<td>P alternate pressure, PSI</td>
<td>508.357292359977</td>
</tr>
</tbody>
</table>

Step 2
Correcting observed density to 60°F & 0 psi reference conditions

<table>
<thead>
<tr>
<th>Iteration(m)</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commodity</td>
<td>jet fuel</td>
<td>jet fuel</td>
</tr>
<tr>
<td>Rho60(m)</td>
<td>817.550000000000</td>
<td>820.654189975112</td>
</tr>
<tr>
<td>K0(m)</td>
<td>330.301000000000</td>
<td>330.301000000000</td>
</tr>
<tr>
<td>K1(m)</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>K2(m)</td>
<td>0.000000000000</td>
<td>0.000000000000</td>
</tr>
<tr>
<td>Al(m)</td>
<td>0.000003397406</td>
<td>0.000003371754</td>
</tr>
<tr>
<td>Bl(m)</td>
<td>2.000000000000</td>
<td>2.000000000000</td>
</tr>
<tr>
<td>Rho60*(m)</td>
<td>817.552777542898</td>
<td>820.656957011782</td>
</tr>
<tr>
<td>alpha60(m)</td>
<td>0.000494172179</td>
<td>0.000490440783</td>
</tr>
<tr>
<td>Ctl,m</td>
<td>0.994033154874</td>
<td>0.994078287334</td>
</tr>
<tr>
<td>d,al pha(m)</td>
<td>2.000000000000</td>
<td>2.000000000000</td>
</tr>
<tr>
<td>Fs(m)</td>
<td>0.579000765408</td>
<td>0.572745475182</td>
</tr>
<tr>
<td>Ctpl,m</td>
<td>1.002175527183</td>
<td>1.002151973087</td>
</tr>
<tr>
<td>Ctpl(m)</td>
<td>0.996195701022</td>
<td>0.996217517055</td>
</tr>
<tr>
<td>Rho60(m)x Ctpl,60(m)</td>
<td>814.439795370921</td>
<td>817.550079497508</td>
</tr>
<tr>
<td>del tA Rho60(m)</td>
<td>3.110204629079</td>
<td>-0.000079497508</td>
</tr>
<tr>
<td>E(m)</td>
<td>3.122081962296</td>
<td>-0.000079799347</td>
</tr>
<tr>
<td>Dr(m)</td>
<td>0.012023019412</td>
<td>0.011931385668</td>
</tr>
<tr>
<td>Dp(m)</td>
<td>-0.006259201048</td>
<td>-0.006144683052</td>
</tr>
<tr>
<td>Rho60(m+1)</td>
<td>820.654189975112</td>
<td>820.654110634883</td>
</tr>
</tbody>
</table>

Output values
Rho60: 820.654110634883
Ctl,o: 0.994078286187
Fs,o,psi: 0.996195701022
Cpl,o: 1.002151973683
Ctpl,o: 0.996195701022

Step 3
Correcting 60°F and 0 psi density to alternate conditions:

<table>
<thead>
<tr>
<th>t, °F</th>
<th>216.230000000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>t corrected to IPTS-68 °F</td>
<td>216.277130766009</td>
</tr>
<tr>
<td>A</td>
<td>0.000003371754</td>
</tr>
<tr>
<td>B</td>
<td>2.000000000000</td>
</tr>
<tr>
<td>Rho60*</td>
<td>820.65687761821</td>
</tr>
<tr>
<td>al pha60</td>
<td>0.000490440783</td>
</tr>
<tr>
<td>delta t, °F</td>
<td>156.270255866009</td>
</tr>
<tr>
<td>Ctl*</td>
<td>0.921879416463</td>
</tr>
<tr>
<td>Fs,psi</td>
<td>0.960919556350</td>
</tr>
<tr>
<td>Pin psi</td>
<td>508.357292359977</td>
</tr>
<tr>
<td>Cpl</td>
<td>1.002151973683</td>
</tr>
<tr>
<td>Ctpl*</td>
<td>0.996195701022</td>
</tr>
</tbody>
</table>

Density at t & P, kg/cu m: 760.257920070010

Step 4
Correcting 60°F density to 15°C base conditions:

- $t, ^\circ F$ ........................................... 59.0000000000
- $t$ corrected to IPTS-68 °F .......... 59.006621316269
- $A$ ................................................. 2.0000000000
- $B$ ................................................. 2.0000000000
- $\text{Rho60}^*$ ................................. 820.65677671821
- $\text{alpha60}$ ............................... 0.000490440878
- $\text{delta t, } ^\circ F$ ...................... -1.000253583731
- $\text{Ctl}$ ................................. 1.000490495623
- $\text{Fs, psi}$ ............................... 0.54659446476
- $P \text{ in psi}$ ............................... 0.000000000000
- $\text{Cpl}$ ................................. 1.000000000000
- $\text{Ctpl}$ ................................. 1.000490495623
- $\text{Density, kg/cu m at 15°C/0 kPa}$ 821.056637883991
- $\text{Ctl, 60}$ ................................. 1.000490495623

**Step 5**
Modify Ctl* factor and calculate the Ctpl factor for 15°C base conditions:

- $\text{Ctl, o}$ ............................... 0.993590934183
- $\text{Ctl}$ ................................. 0.921427460327
- $\text{Ctpl, o}$, rounded ................... 0.995729115724
- $\text{Cpl}$ ................................. 0.99573
- $\text{Ctpl}$, rounded ...................... 0.92595
- $\text{Fs, o, kPa}$ ........................... 0.083069734480
- $\text{Fs, kPa}$ .............................. 0.139369604520

**Step 6**

- Volume at base conditions ...... 9944.84454329600
- Volume at alternate conditions . 10740.14542886400