

# Manual of Petroleum Measurement Standards Chapter 11—Physical Properties Data

## Section 1—Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils

Adjunct to: ASTM D 1250-04 and IP 200/04

MAY 2004  
ADDENDUM 1, SEPTEMBER 2007





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# Addendum 1 to API MPMS Ch. 11.1-2004— Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils

Note: Added text is highlighted yellow. Deleted text is indicated by strikethrough.

## 11.1.2.2 Scope

This Standard provides the algorithm and implementation procedure for the correction of temperature and pressure effects on density and volume of liquid hydrocarbons which fall within the categories of crude oil, refined products, or lubricating oils; NGLs and LPGs are excluded from consideration in this Standard. The combination of density and volume correction factors for both temperature and pressure is collectively referred to in this Standard as a Correction for Temperature and Pressure of a Liquid (CTPL) (~~VCF~~). The temperature portion of this correction is termed the Correction for the effect of Temperature on Liquid (CTL), also historically known as VCF (Volume Correction Factor). The pressure portion is termed the Correction for the effect of Pressure on Liquid (CPL). As this Standard will be applied to a variety of applications the output parameters specified in this Standard (CTL,  $F_p$ , CPL, and CTPL) may be used as specified in other API *Manual of Petroleum Measurement Standards (MPMS) Chapters*.

Including the pressure correction in this Standard represents an important change from the "temperature only" 1980 Tables. However, if the pressure is one atmosphere (the standard pressure) then there is no pressure correction and this Standard will give CTL (~~VCF~~) values consistent with the 1980 Tables.

~~The~~ This Standard provides general procedures for the conversion of input data to generate CTL,  $F_p$ , CPL, and CTPL values at the user specified base temperature and pressure ( $T_b$ ,  $P_b$ ) ~~a form that is consistent with the computation procedures used to generate VCF values~~. This section is then followed by two sets of procedures for computing volume correction factor, one set for data expressed in customary units (temperature in °F, pressure in psig), the other for the metric system of units (temperature in °C, pressure in kPa or bar). In contrast to the 1980 Tables, the metric procedures require the procedure for customary units be used first to compute density at 60°F. This value is then further corrected to give the metric output.

The procedure recognizes three distinct commodity groups: crude oil, refined products, and lubricating oils. A special application category is also provided which provides volume correction based on the input of an experimentally derived coefficient of thermal expansion.

## 11.1.3.3 Calculation of CTL and CPL Factors in This Standard

The specific equation forms for the temperature and pressure correction factors used in this Standard are:

$$\begin{aligned} C_{TL} &= \exp\{-\alpha_T (t-T)[1+0.8\alpha_T (t-T+\delta_T)]\} \\ &= \exp\{-\alpha_T \Delta t [1+0.8\alpha_T (\Delta t+\delta_T)]\} \end{aligned} \quad (14)$$

$$C_{PL} = \frac{1}{1-F_p(P-P_e)} \quad (15)$$

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,  $F_p$  is the compressibility coefficient, and  $\delta_T$  is a small base temperature correction value.

In the 1980 Standard,  $\alpha_T$  was correlated to the density at a 60°F base temperature and 0 psig pressure,  $\rho^*$ , and is denoted as  $\alpha_{60}$ . The CTL equation was developed as a correction to 60°F density, so  $T = 60$  and  $\delta_T = 0$ .  $F_p$  was

correlated to this same base density and the temperature  $t$  at which the compression occurs. The forms for these correlations are:

$$\alpha_{60} = \frac{K_0 + K_1\rho^* + K_2\rho^{*2}}{\rho^{*2}} = \frac{K_0}{\rho^{*2}} + \frac{K_1}{\rho^*} + K_2 \quad (16)$$

$$F_p = \exp\left\{A + Bt + \frac{C + Dt}{\rho^{*2}}\right\} \quad (17)$$

There was one set of coefficients for the  $F_p$  compressibility factor ( $A = -1.99470$ ,  $B = 0.00013427$ ,  $C = 793920$ ,  $D = 2326$ ; based on density in  $\text{kg/m}^3$  at  $60^\circ\text{F}$  the  $A$ ,  $B$ ,  $C$ , and  $D$  values) but several sets of coefficients for the  $\alpha_{60}$  thermal expansion coefficient (the  $K_0$ ,  $K_1$ , and  $K_2$  values) depending upon the liquid's classification and density at  $60^\circ\text{F}$ .

To recognize differences between the current ITS-90 temperature scale and the IPTS-68 temperature scale in effect when the data for this Standard were measured, this Standard makes small corrections to the temperature  $t$  and the base temperature  $T$  and a non-zero base temperature correction factor, denoted as  $\delta_{60}$ , is used. Also, the density used in the correlations,  $\rho^*$ , is slightly different from a  $\rho_{60}$  measured consistent with ITS-90. See 11.1.5.3 for the procedure to convert ITS-90 temperatures to an IPTS-68 basis, Appendix C for the origin of the  $\delta_{60}$  correction factor, and 11.1.6.1 for the calculation of  $\rho^*$  from  $\rho_{60}$ .

Equations (16) and (17) are directly expressed in terms of  $\rho^*$ . However, since  $\rho^*$  can be directly related to  $\rho_{60}$ , then these equations can also be thought of as being a direct function of  $\rho_{60}$ , too.

### 11.1.3.4 Base Pressure in This Standard

For volatile hydrocarbons, the base pressure is the saturation pressure for the liquid (i.e., its “bubble point” pressure). It is generally assumed that if the saturation pressure is less than atmospheric pressure then there is little error in applying the correction at a constant base pressure of 1 atmosphere. For liquids with equilibrium vapor pressure less than atmospheric pressure (0 psig or 14.696 psia) the  $P_e$  value used in Equation 15 shall be atmospheric pressure (0 psig or 14.696 psia). The heavier liquids covered by this Standard are fairly non-volatile—the saturation pressure is less than the atmospheric pressure over the entire temperature range of this Standard. It is only the lightest of the liquids covered by this Standard whose vapor pressures may exceed atmospheric pressure at the higher temperatures.

For simplicity of application, this Standard will neglect any effects of the liquid's saturation pressure exceeding atmospheric pressure. In all equations, this Standard will use  $P_e = 0$  (gauge) and the CPL equation reduces to:

$$C_{PL} = \frac{1}{1 - F_p P} \quad (18)$$

For liquids with an equilibrium vapor pressure greater than atmospheric, the equilibrium vapor pressure ( $P_e$ ) should be subtracted from the pressure input values before entering the calculation sequences given in 11.1.5.1, 11.1.6.1, 11.1.6.2, 11.1.6.3, 11.1.7.1, 11.1.7.2, and 11.1.7.3.

### 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 CTPL is rounded as specified in API MPMS Chapter 12. If there is no guidance for a specific application, round to five decimal places. 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.



### 11.1.5.5 Other Implementation Considerations

- ~~CTPL should be substituted for  $CTL \times CPL$ , where a standard specifies a serial multiplication of correction factors.~~
- Where a calculation within an existing standard makes use of a CTL factor alone, an equivalent value CTPL is calculated with observed gauge pressure set to zero.
- The discrimination rules for the input parameters should comply with the appropriate Standard (Chapters 12.1 and 12.2) prior to implementation of API MPMS Chapter 11.1. Verification data has been completed up to eight decimal places. In this document, the final VCF (CTPL) is rounded to five decimal places. Different rounding precisions may be used to accommodate other standards, however they should not exceed eight decimal places.

11.1.5.1, 11.1.6.1, 11.1.6.2, 11.1.6.3, 11.1.7.1 and 11.1.7.3, *add*:

“Note: For liquids with an equilibrium vapor pressure greater than atmospheric, see 11.1.3.4.”





