Addendum 1
September 2007

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

SPECIAL NOTES

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

FOREWORD

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API Standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API Standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

Suggested revisions are invited and should be submitted to the Standards and Publications Department, API, 1220 L Street, NW, Washington, D.C. 20005, standards@api.org.

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:

$$C_{TL} = \exp\left\{-\alpha_T (t-T)\left[1+0.8\alpha_T (t-T+\delta_T)\right]\right\} = \exp\left\{-\alpha_T \Delta t\left[1+0.8\alpha_T (\Delta t+\delta_T)\right]\right\} \quad (14)$$

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

where α_T is the thermal expansion coefficient at the base temperature T, Δt is the difference between the alternate temperature and the base temperature, F_P is the compressibility coefficient, and δ_T is a small base temperature correction value.

In the 1980 Standard, α_T was correlated to the density at a 60°F base temperature and 0 psig pressure, ρ^*, and is denoted as α_{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:

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

$$F_P = \exp\left\{A + Bt + \frac{C + Dt}{\rho^{*2}}\right\} \tag{17}$$

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 kg/m^3 at 60°F ~~the *A, B, C,* and *D* values~~) but several sets of coefficients for the α_{60} thermal expansion coefficient (the K_0, K_1, and K_2 values) depending upon the liquid's classification and density at 60°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 δ_{60}, is used. Also, the density used in the correlations, ρ^*, is slightly different from a ρ_{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 δ_{60} correction factor, and 11.1.6.1 for the calculation of ρ^* from ρ_{60}.

Equations (16) and (17) are directly expressed in terms of ρ^*. However, since ρ^* can be directly related to ρ_{60}, then these equations can also be thought of as being a direct function of ρ_{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:~~

~~$$C_{PL} = \frac{1}{1 - F_P P}.$$~~ ~~(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 × 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, 11.1.7.2 and 11.1.7.3, *add*:

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

1220 L Street, NW
Washington, DC 20005-4070
USA

202.682.8000

Additional copies are available through IHS
Phone Orders: 1-800-854-7179 (Toll-free in the U.S. and Canada)
303-397-7956 (Local and International)
Fax Orders: 303-397-2740
Online Orders: global.ihs.com

Information about API Publications, Programs and Services
is available on the web at **www.api.org**