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Standard Guide for Use of the Petroleum Measurement Tables¹

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This standard has been approved for use by agencies of the Department of Defense.

INTRODUCTION

This guide discusses the use of temperature and pressure volume correction factors for generalized crude oils, refined products, and lubricating oils, developed jointly by ASTM International, the American Petroleum Institute (API) and the Energy Institute.²

The volume correction factors, in their basic form, are the output of a set of equations derived from, and based on, empirical data relating to the volumetric change of hydrocarbons over a range of temperatures and pressures. Traditionally, the factors have been listed in tabular format called the Petroleum Measurement Tables (hence the appearance of this term in the title), and published as an API Standard/Adjunct to IP 200/Adjunct to ASTM D 1250. However, since the 1980 revision the actual standard has been a set of implementation procedures, not printed tables nor simply a set of equations.

This revised standard, API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD), establishes procedures for crude oils, liquid refined products, and lubricating oils, by which volume measurements taken at any temperature and pressure (within the range of the standard) can be corrected to an equivalent volume at base/standard conditions, normally 15°C, 60°F or 20°C, by use of a volume correction factor (VCF). The standard, API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD), also provides methods for making conversions to alternate conditions from base conditions and to alternate base temperatures. Densities can be corrected by using the inverse of the VCF.

See Section 5 for a list of significant changes from Guide D 1250–80 (provided in its entirety in Annex A1).

USAGE GUIDELINES

The revised standard, API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD), is effective upon the date of publication and supersedes the previous edition of the standard/adjunct(s). However, due to the nature of the changes in the revised standard/adjunct(s), it is recognized that guidance concerning an implementation period may be needed in order to avoid disruptions within the industry and ensure proper application. As a result, it is recommended that the revised standard/adjunct(s) be used on all new applications no later than *two years after the publication date* (May 2004). An application for this purpose is defined as the point where the calculation is applied.

Once the revised standard/adjunct(s) is implemented in a particular application, the previous standard will no longer be used in that application.

If an existing application complies with the previous standard/adjunct(s) (as referenced in Annex A1), then it shall be considered in compliance with the revised standard/adjunct(s).

However, the use of the API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD) remains voluntary, and the decision on when to utilize a standard is an issue that is subject to the negotiations between the parties involved in the transaction.

1. Scope

1.1 The API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD) for temperature and pressure volume correction factors for generalized crude oils, refined products, and lubricating oils, provides the algorithm and implementation procedure for the correction of temperature and pressure effects on density and volume of liquid hydrocarbons. Natural gas liquids (NGLs) and liquefied petroleum gases (LPGs) are excluded from consideration. The combination of density and volume correction factors for both temperature and pressure is collectively referred to in the standard/adjunct(s) as a Volume Correction Factor (VCF). The temperature portion of this correction is termed the Correction for the effect of Temperature on Liquid (CTL). The pressure portion is termed the Correction for the effect of Pressure on Liquid (CPL).

1.2 Including the pressure correction in API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD) represents an important change from the “temperature only” correction factors given in the 1980 Petroleum Measurement Tables. However, if the pressure is one atmosphere (the standard pressure) then there is no pressure correction and the standard/adjunct(s) will give VCF values consistent with the 1980 Petroleum Measurement Tables.

1.3 API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD) covers general procedures for the conversion of input data to a form that is consistent with the computation procedures used to generate VCF values. Two sets of procedures are included 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 Petroleum Measurement 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 metric procedures now incorporate the base temperature of 20°C in addition to 15°C.

1.4 The procedures recognize three distinct commodity groups: crude oil, refined products, and lubricating oils. A procedure is also provided for determining volume correction for special applications where the generalized commodity groups’ parameters may not adequately represent the thermal expansion properties of the liquid and a precise thermal expansion coefficient has been determined by experiment.

2. Referenced Documents

2.1 API Standards:

API Manual of Petroleum Measurement Standards (*MPMS*):
Chapter 11.1–2004 Temperature and Pressure Volume Cor-

rection Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils³

Chapter 11.2.1 Compressibility Factors for Hydrocarbons: 0–90° API Gravity Range

Chapter 11.2.1M Compressibility Factors for Hydrocarbons: 638–1074 Kilograms per Cubic Meter Range

2.2 ISO Standards:

ISO 91–1:1992 Petroleum measurement tables—Part 1:
Tables based on reference temperatures of 15°C and 60°F

ISO 91–2:1991 Petroleum measurement tables—Part 2:
Tables based on a reference temperature of 20°C

2.3 ASTM Adjuncts:

Adjunct to ASTM D 1250: ADJD1250CD—Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils⁴

3. Sponsorship

3.1 The revision of the ASTM/API/IP set of implementation procedures is the result of close cooperation between ASTM International, the American Petroleum Institute (API), and the Energy Institute.²To meet the objective of worldwide standardized measurement practices, it is expected to result in the acceptance of the revised tables by the International Organization for Standardization (ISO), and specifically ISO/TC 28/SC 3, as revisions to International Standards ISO 91–1 and ISO 91–2. API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD) applies to all crude oils, refined products, and lubricants previously covered by Tables 5, 6, 23, 24, 53, 54, 59, and 60. The API designation for the complete set of implementation procedures is the Manual of Petroleum Measurement Standards (*MPMS*) Chapter 11 Section 1. The IP designation for the complete set of implementation procedures is the Adjunct to IP 200.

4. Significance and Use

4.1 The expanded limits of API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD) are defined in a mixture of terms of customary and metric units. Table 1 shows the defining limits and their associated units in ***bold italics***. Also shown in Table 1 are the limits converted to their equivalent units (and, in the case of the densities, other base temperatures).

4.2 Note that only the precision levels of the defining values shown in Table 1 are correct. The other values showing converted units have been rounded to the significant digits shown; as rounded values, they may numerically fall just outside of the actual limits established by the defining values.

4.3 Table 2 provides a cross-reference between the historical table designations and the corresponding section in API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD). Note that procedure paragraphs 11.1.6.3 (U.S. customary units) and 11.1.7.3 (metric

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² The organization that publishes IP test methods and guides.

³ Available on CD-ROM from API. Order Product Number H11013.

⁴ Available on CD-ROM from ASTM International Headquarters. Order Adjunct No. ADJD1250CD.

TABLE 1 Range Limits^A

Physical Units	Crude Oil	Refined Products	Lubricating Oils
<i>Density, kg/m³ @ 60°F</i>	<i>610.6 to 1163.5</i>	<i>610.6 to 1163.5</i>	<i>800.9 to 1163.5</i>
Relative Density @ 60°F	0.61120 to 1.16464	0.61120 to 1.16464	0.80168 to 1.1646
API Gravity @ 60°F	100.0 to -10.0	100.0 to -10.0	45.0 to -10.0
Density, kg/m ³ @ 15°C	611.16 to 1163.79	611.16 to 1163.86	801.25 to 1163.85
Density, kg/m ³ @ 20°C	606.12 to 1161.15	606.12 to 1160.62	798.11 to 1160.71
<i>Temperature, °C</i>	<i>-50.00 to 150.00</i>	<i>-50.00 to 150.00</i>	<i>-50.00 to 150.00</i>
Temperature, °F	-58.0 to 302.0	-58.0 to 302.0	-58.0 to 302.0
<i>Pressure, psig</i>	<i>0 to 1500</i>	<i>0 to 1500</i>	<i>0 to 1500</i>
kPa (gage)	0 to 1.034 × 10 ⁴	0 to 1.034 × 10 ⁴	0 to 1.034 × 10 ⁴
bar (gage)	0 to 103.4	0 to 103.4	0 to 103.4
<i>α₆₀, per °F</i>	<i>230.0 × 10⁻⁶ to 930.0 × 10⁻⁶</i>	<i>230.0 × 10⁻⁶ to 930.0 × 10⁻⁶</i>	<i>230.0 × 10⁻⁶ to 930.0 × 10⁻⁶</i>
α ₆₀ , per °C	414.0 × 10 ⁻⁶ to 1674.0 × 10 ⁻⁶	414.0 × 10 ⁻⁶ to 1674.0 × 10 ⁻⁶	414.0 × 10 ⁻⁶ to 1674.0 × 10 ⁻⁶

^A Defining limits and their associated units appear in ***bold italics***.

TABLE 2 Historical Table Cross-Reference

Historical Table Designation	Procedure Paragraph in Current Standard	Historical Table Designation	Procedure Paragraph in Current Standard
5 A, B & D	11.1.6.2	53 A, B & D	11.1.7.2
23 A, B, & D	11.1.6.2	59 A, B, & D	11.1.7.2
6 A, B, C & D	11.1.6.1	54 A, B, C & D	11.1.7.1
24 A, B, C & D	11.1.6.1	60 A, B, C & D	11.1.7.1

units) provide methods for correcting on-line density measurements from live conditions to base conditions and then to compute VCF factors for continuous volume corrections to base conditions.

4.4 When a glass hydrometer is used to measure the density of a liquid, special corrections must be made to account for the thermal expansion of the glass when the temperature is different from that at which the hydrometer was calibrated. The 1980 CTL Tables had generalized equations to correct glass hydrometer readings, and these corrections were part of the printed odd-numbered tables. However, detailed procedures to correct a glass hydrometer reading are beyond the scope of API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD). The user should refer to the appropriate sections of API *MPMS* Chapter 9 or other appropriate density/hydrometer standards for guidance.

4.5 The set of correlations given in API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD) is intended for use with petroleum fluids comprising either crude oils, refined products, or lubricating oils that are single-phase liquids under normal operating conditions. The liquid classifications listed here are typical terms used in the industry, but local nomenclature may vary. The list is illustrative and is not meant to be all-inclusive.

4.6 *Crude Oils*—A crude oil is considered to conform to the commodity group Generalized Crude Oils if its density falls in the range between approximately –10°API to 100°API. Crude oils that have been stabilized for transportation or storage purposes and whose API gravities lie within that range are considered to be part of the Crude Oil group. Also, aviation jet B (JP-4) is best represented by the Crude Oil correlation.

4.7 *Refined Products*—A refined product is considered to conform to the commodity group of Generalized Refined Products if the fluid falls within one of the refined product groups. Note the product descriptors are generalizations. The

commercial specification ranges of some products may place their densities partly within an adjacent class (for example, a low density diesel may lie in the jet fuel class). In such cases, the product should be allocated to the class appropriate to its density, not its descriptor. The groups are defined as follows:

4.7.1 *Gasoline*—Motor gasoline and unfinished gasoline blending stock with a base density range between approximately 50°API and 85°API. This group includes substances with the commercial identification of: premium gasoline, unleaded gasoline, motor spirit, clear gasoline, low lead gas, motor gasoline, catalyst gas, alkylate, catalytic cracked gasoline, naphtha, reformulated gasoline, and aviation gasoline.

4.7.2 *Jet Fuels*—Jet fuels, kerosene, and Stoddard solvents with a base density range between approximately 37°API and 50°API. This group includes substances with the commercial identification of: aviation kerosene K1 and K2, aviation jet A and A-1, kerosene, Stoddard solvent, JP-5 and JP-8.

4.7.3 *Fuel Oils*—Diesel oils, heating oils, and fuel oils with a base density range between approximately –10°API and 37°API. This group includes substances with the commercial identification of: No. 6 fuel oil, fuel oil PA, low sulfur fuel oil, LT (low temperature) fuel oil, fuel oil, fuel oils LLS (light low sulfur), No. 2 furnace oil, furnace oil, auto diesel, gas oil, No. 2 burner fuel, diesel fuel, heating oil, and premium diesel.

4.8 *Lubricating Oils*—A lubricating oil is considered to conform to the commodity group Generalized Lubricating Oils if it is a base stock derived from crude oil fractions by distillation or asphalt precipitation. For the purpose of API *MPMS* Chapter 11.1–2004/Adjunct to IP 200/04/Adjunct to ASTM D 1250–04 (ADJD1250CD), lubricating oils have initial boiling points greater than 700°F (370°C) and densities in the range between approximately –10°API to 45°API.

4.9 *Special Applications*—Liquids that are assigned the special applications category are generally relatively pure products or homogeneous mixtures with stable (unchanging)