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Petroleum and related products — Temperature and pressure volume correction factors (petroleum measurement tables) and standard reference conditions

bsi.

National foreword

This British Standard is the UK implementation of ISO 91:2017.
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The UK participation in its preparation was entrusted to Technical Committee PTI/12, Petroleum Measurement and Sampling.

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Petroleum and related products — Temperature and pressure volume correction factors (petroleum measurement tables) and standard reference conditions

Pétrole et produits connexes — Facteurs de correction de volume par rapport à la température et à la pression (tables de mesure du pétrole) et conditions de référence standard

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 2, *Measurement of petroleum and related products*.

This first edition cancels and replaces ISO 91-1:1992, ISO 91-2:1991, ISO 9770:1989, and ISO 5024:1999, which have been technically revised.

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Introduction

Custody transfer of crude petroleum and its products are generally transacted in volumetric quantities. Since crude oils and petroleum products have relatively high coefficients of thermal expansion and compressibility, volumes are corrected to standard conditions of temperature and pressure in order to provide a meaningful and consistent basis for measurement. The definition of standard reference conditions is therefore of fundamental importance in measurement, calculation and accounting of petroleum quantities.

Volume correction factors are used to account for the thermal expansion of liquid hydrocarbons and convert observed volumes to volumes at standard temperature and pressure. Tables of volume correction factors were originally developed by collecting empirical data relating to the volumetric change of hydrocarbons over a range of temperatures and pressures. Cooperative international work on volume correction factors dates from 1932. The temperature volume correction factor tables (petroleum measurement tables) referenced in ISO Recommendation (R) 91:1959[1] were developed during the late 1940s and published jointly by the American Society of Testing Materials (ASTM) in 1952 and the Institute of Petroleum (IP) (metric edition) in 1953[9]. These tables corrected to standard temperatures of 15 °C and 60 °F only, and were based on data for crude petroleum and petroleum fractions published in 1916 by the (United States) National Bureau of Standards (NBS) and some later data on natural gasoline reported in 1942. These 1952 tables were referenced in API/Standard 2540-1966[10] (also designated ASTM D1250-56). A few amendments to ISO/R 91 resulted in the publication of a second edition in 1970[2]. ISO/R 91:1970/Amd 1:1975[3] was published in 1975 for tables based on a reference temperature of 20 °C.

In the early 1970s, it was demonstrated that the previously published tables were not satisfactorily applicable to many crude oils of current economic importance. A revised standard was published in 1980 by the American Petroleum Institute as the API Manual of Petroleum Measurement Standards (*MPMS*) Chapter 11.1 (also designated API/Standard 2540, ASTM D1250-80 and IP 200/80) following the development of a new database by API in cooperation with the US NBS. This study included the examination of 463 samples of crude oil and refined products. The crude oil samples represented 67 % of world production in 1974. The 1980 standard also constituted a major conceptual departure from previous versions in the recognition of the use of computers in the petroleum industry. The actual standard represented by API *MPMS* Chapter 11.1-1980/ASTM D1250-80/IP 200/80 was neither the hardcopy printed tables nor the set of equations used to represent the density data, but was an explicit implementation procedure used to develop computer subroutines. The standardization of an implementation procedure implied the standardization of the set of mathematical expressions, including calculational sequence and round-off procedures, used within the computer code. Adherence to the procedures given in API *MPMS* Chapter 11.1-1980/ASTM D1250-80/IP 200/80 was an attempt to ensure that all computers and computer codes meeting the stated specifications and restrictions would be able to produce identical results. Hence, the published implementation procedures were the primary standard, the distributed subroutines the secondary standard, and the published tables produced for convenience.

API *MPMS* Chapter 11.1-1980/ASTM D1250-80/IP 200/80 was referenced in ISO 91-1:1982[4]. Corrections to the 1980 standard were listed in ISO 91-1:1992[5].

Computer implementation procedures developed by the IP for corrections to 20 °C were published in 1988. These implementation procedures were prepared as standard procedures to enable users to produce their own computer programmes either for the generation of 20 °C tables or for use in calculations without the generation of tables. IP Petroleum Measurement Paper No. 3[8] was referenced in ISO 91-2:1991[6], superseding Addendum 1:1975 to ISO/R 91.

Compressibility factors for hydrocarbons in the 0° to 100° API gravity range were developed in 1945 and published in 1960 as API/Standard 1101[12], Appendix B, Table II. This table was superseded by API *MPMS* Chapters 11.2.1[13] and 11.2.1M[14] published in 1984. API *MPMS* Chapter 11.2.1M-1984 was adopted by ISO/TC 28 and published as ISO 9770:1989[13].

Compressibility factors for hydrocarbons in the 0,500 to 0,611 relative density range and 20 °F to 128 °F were published in 1984 as API *MPMS* Chapter 11.2.2[15]. A second edition of API *MPMS* Chapter 11.2.2

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was published in 1986 with an expanded relative density range of 0,350 to 0,637. A metric version of this standard (350 kg/m^3 to 637 kg/m^3 range) was also published in 1986 as API *MPMS* Chapter 11.2.2M.

Unlike the 1980 temperature correction factor tables (API *MPMS* Chapter 11.1-1980), the compressibility table values given in API *MPMS* Chapters 11.2.1 and 11.2.2 were the standard, not the implementation procedure for the underlying equations.

In 2004, a revision to API *MPMS* Chapter 11.1 (also designated as an adjunct to ASTM D1250-04 and IP 200/04) was published and established procedures for generalized crude oils, liquid refined products, lubricating oils and individual and special applications, by which volume measurements taken at any temperature and pressure (within the range of the standard) can be corrected to an equivalent volume at 15 °C, 60 °F or 20 °C (or other reference temperature) and standard pressure, by use of a correction factor for temperature and pressure of the liquid (CTPL). API *MPMS* Chapter 11.1-2004/Adjunct to ASTM D1250-04/Adjunct to IP 200/04 superseded API *MPMS* Chapters 11.1-1980, 11.2.1-1984 and 11.2.1M-1984.

In 2007, Addendum 1 to API *MPMS* Chapter 11.1-2004/Adjunct to ASTM D1250-04/Adjunct to IP 200/04 was published in order to include some minor updates to the standard.

Previously, most natural gas liquid (NGL) and liquefied petroleum gas (LPG) temperature correction factors were obtained from a variety of sources.

— ASTM-IP Petroleum Measurement Tables, 1952[9], as referenced in ISO/R 91:1970[4]. This publication is limited to a 60 °F relative density range of 0,500 and higher.

— GPA Standard 2142, published in 1957[16].

— GPA Technical Publication TP-16, published in 1988[17]. It is limited to the following products: HD 5 propane with relative densities of 0,501, 0,505, and 0,510; iso-butane at a relative density of 0,565; normal butane at a relative density of 0,585, and natural gasoline (12 psia to 14 psia Reid vapour pressure) at a relative density of 0,664.

— API *MPMS* Chapter 11.1-1980/ASTM D1250-80/IP 200/80 Volume XII, Table 33 "*Specific Gravity Reduction to 60 °F For Liquefied Petroleum Gases and Natural Gasoline*", as referenced in ISO 91-1:1992[5].

— API *MPMS* Chapter 11.1-1980/ASTM D1250-80/IP 200/80 Volume XII, Table 34 "*Reduction of Volume to 60 °F Against Specific Gravity 60/60 °F For Liquefied Petroleum Gases and Natural Gasoline*", as referenced in ISO 91-1:1992[5].

— API/ASTM/GPA Technical Publication TP-25, published in 1988[18].

In 2007, these documents were superseded by API *MPMS* Chapter 11.2.4/GPA Technical Publication TP-27.

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Petroleum and related products — Temperature and pressure volume correction factors (petroleum measurement tables) and standard reference conditions

1 Scope

This document refers to temperature volume correction factors, which allow users to convert volumes, measured at ambient conditions, to those at reference conditions for transactional purposes. This document also refers to compressibility factors required to correct hydrocarbon volumes measured under pressure to the corresponding volumes at the equilibrium pressure for the measured temperature.

Table 1 shows the defining limits and their associated units of correction factors referenced in this document for crude oil, refined products and lubricating oils. These values are shown in ***bold italics***. Also shown in the table are the limits converted to their equivalent units (and, in the case of the densities, other base temperatures). Table 2 shows defining limits of correction factors for light hydrocarbons (natural gas liquids and liquefied petroleum gases).

Table 1 — Defining limits of correction factors for crude oil, refined products and lubricating oils

	Crude oil	Refined products	Lubricating oils
Density, kg/m³ @ 60 °F	***610,6 to 1 163,5***		***800,9 to 1 163,5***
Relative density @ 60 °F	0,611 2 to 1,164 64		0,801 68 to 1,164 6
API gravity @ 60 °F	100 to –10		45 to –10
Density, kg/m³ @ 15 °C	611,16 to 1 163,79	611,16 to 1 163,86	801,25 to 1 163,85
Density, kg/m³ @ 20 °C	606,12 to 1 161,15	606,12 to 1 160,62	798,11 to 1 160,71
Temperature, °C	***–50,00 to 150***		
Temperature, °F	–58,0 to 302		
Pressure, psig	***0 to 1 500***		
Pressure, kPa (gauge)	0 to $1{,}034 \times 10^4$		
Pressure, bar (gauge)	0 to 103,4		
60 °F thermal expansion factor (α60), per °F	$\boldsymbol{230{,}3 \times 10^{-6}}$ ***to*** $\boldsymbol{930{,}0 \times 10^{-6}}$		
α60, Per °C	$414{,}0 \times 10^{-6}$ to $1\,674{,}0 \times 10^{-6}$		

Table 2 — Defining limits of correction factors for light hydrocarbons (natural gas liquids and liquefied petroleum gases)

Density, kg/m³ @ 60 °F	***350,0 to 688,0***
Density, kg/m³ @ 15 °C	351,7 to 687,8
Density, kg/m³ @ 20 °C	331,7 to 683,6
Temperature °C	***–46,0 to 93,0***
Temperature °F	–50,8 to 199,4
Pressure	***Saturation conditions (bubble point or saturation vapour pressure)*** (see Note 2 to 4.1)

This document also specifies standard reference conditions of pressure and temperature for measurements carried out on crude petroleum and its products, including liquefied petroleum gases (see Annex B).

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