

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

Section 4—Properties of Reference Materials

**Part 1—Density of Water and Water Volumetric
Correction Factors for Water Calibration of
Volumetric Provers**

FIRST EDITION, DECEMBER 2003

REAFFIRMED, SEPTEMBER 2013



AMERICAN PETROLEUM INSTITUTE

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Measurement Coordination

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Chapter 11—Physical Properties Data
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for Water Calibration of Volumetric Provers

1 Introduction

This Standard specifies the density of water to be used in all applicable API MPMS Standards. It also specifies the volume correction factor equation for water and demonstrates its use for water calibration of volumetric provers (see API MPMS Chapters 12.2.1, 12.2.3).

2 Scope

This standard is applicable to all API Standards that use the density of water or its volume correction factors.

3 References

- H. Wagenbreth and H. Blanke, "The Density of Water in the International System of Units and in the International Practical Temperature Scale of 1968," *Mitteilungen der Physikalisch-Technischen Bundesanstalt (PTB-Mitt)*, 412–415, June 1971.
- G.S. Kell, *Journal of Chemical Engineering Data*, 1967, 12, 66–69; *ibid*, 1975, 20, 97–105.
- N. Bignell, "The Effect of Dissolved Air on the Density of Water," *Metrologia*, 1983, 19, 57–59.
- J.B. Patterson and E.C. Morris, "Measurement of Absolute Water Density," *Metrologia*, 31, 277–288, 1994.
- M. Tanaka, G. Girard, R. Davis, A. Peuto and N. Bignell, "Recommended table for the density of water between 0°C and 40°C based on recent experimental reports," *Metrologia*, 38, 351–359, 2001.

4 Definitions

4.1 density, absolute: The density of a solid or liquid substance at a specified temperature is the mass of the substance occupying a unit of volume at the specified temperature. Density so defined is sometimes referred to as "true density" or "density in vacuo." When reporting density, the units of mass and volume used and the temperature of the determination must be stated (for example, grams per millili-

ter at 15°C). Density is assumed to be for water at atmospheric pressure unless otherwise stated.

4.2 volume correction factor (VCF): The density of a liquid at temperature t divided by its density at a chosen reference temperature. Multiplying a liquid's volume measured at temperature t by the VCF provides the volume of the liquid at the chosen reference temperature. Volume Correction Factors are assumed to be for water at atmospheric pressure unless otherwise stated. Certain API MPMS Chapters call this factor CTDW.

5 Implementation Procedures

The implementation procedures below are the standard. Representative density values are presented in the Appendix A for programming verification purposes only.

5.1 ABSOLUTE DENSITY OF WATER

The previous standard (API MPMS 11.2.3, 1984), which this Standard replaces, was based on the internationally accepted work of Wagenbreth and Blanke, which produced a density of 999.012 kg/m³ at 60°F. In 1994, Patterson and Morris published a paper proposing a new equation based on their laboratory data of VSMOW (see Appendix B), which was accepted by the NIST (National Institute of Standards and Technology). In 2001, a review (Tanaka, *et al.*) proposed a new equation regressed from the data of several researchers (including that of Patterson and Morris). Although they are aware of this paper, the NIST at this writing has chosen to continue to accept the work of Patterson and Morris. This Standard is therefore based on that same work, applicable between 1°C and 40°C (see Appendix C).

The following equation expresses the density of water as a function of temperature in degrees Celsius:

$$\rho_{tC} = \rho_0 [1 - (A\Delta t + B\Delta t^2 + C\Delta t^3 + D\Delta t^4 + E\Delta t^5)] \quad (1)$$