Date of Issue: July 2013
Affected Publication: *MPMS* Chapter 13.1, *Statistical Concepts and Procedures in Measurements,* First Edition, June 1985

ERRATA

On page 11, **Section 13.1.8.4.1, Step 2,** *the second equation under* "Therefore:"*:*

$$= \frac{2.534 \times 7}{\sqrt{2} \times 2.571}$$

Manual of Petroleum Measurement Standards
Chapter 13—Statistical Aspects of Measuring and Sampling

Section 1—Statistical Concepts and Procedures in Measurements

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REAFFIRMED, MARCH 2016

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FOREWORD

This publication covers statistical concepts and procedures used in bulk oil measurement.

Suggested revisions are invited and should be submitted to the director of the Measurement Coordination Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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Chapter 13—Statistical Aspects of Measuring and Sampling

SECTION 1—STATISTICAL CONCEPTS AND PROCEDURES IN MEASUREMENT

13.1.0 Introduction

The nature of physical measurements makes it impossible to measure a physical variable without error. Absolute accuracy is only achievable when it is possible to count the objects or events; even then, when large numbers are involved, it may be necessary to approximate. With the best equipment and directions, the potential for errors in fluid volume measurements involving large amounts of material is large.

Minimizing errors, estimating the remaining errors, and keeping all parties informed of errors is increasingly important to the petroleum industry. Equally important is an understanding of the size and significance of errors. Providing estimates of errors and statements concerning errors in a standard form can help avoid disputes and dispel delusions of accuracy in statements of quantity.

Chapter 13 of the *Manual of Petroleum Measurement Standards* is designed to help those who make measurements of bulk oil quantities improve the value of their result statement by making proper estimates of the uncertainty or probable error involved in measurements. During the development of Chapter 13.1, reference was made to Part XIV, Section 1 (Tentative) of the *Petroleum Measurement Manual* published by the Institute of Petroleum, London, England.

13.1.1 Scope

This chapter covers the basic concepts involved in estimating errors by statistical techniques and ensuring that results are quoted in the most meaningful way. The statistical procedures that should be followed in estimating a true quantity from one or more measurements and in deriving the range of uncertainty of the results are discussed. Sources of error are examined and examples are provided showing how a statement of the overall uncertainty in completed measurements is derived.

The subsequent sections (in preparation at the time this section was published) of Chapter 13 will deal with the application of the concepts discussed in Section 1 to various methods for bulk oil measurement widely used in the petroleum industry. Chapter 13.1 is a reference document explaining theory and the application of statistical procedures whereas subsequent sections will provide statistical equations and typical examples for various types of measurement.

13.1.2 Definitions

The following terms are used throughout Chapter 13.

Accuracy is the ability to indicate values closely approximating the true value of the measured variable.

Bias is any influence on a result that produces an incorrect approximation of the true value of the variable being measured. Bias is the result of a predictable systematic error.

Confidence interval or range of uncertainty, C, is the range or interval within which the true value is expected to lie with a stated degree of confidence.

Confidence level is the degree of confidence that may be placed on an estimated range of uncertainty.

Degrees of freedom is the number of independent results used in estimating the standard deviation.

Direct measurement is a measurement that produces a final result directly from the scale on an instrument.

Error is the difference between true and observed value.

Indirect measurement is a measurement that produces a final result by calculation using results from one or more direct measurements.

Mean, $\bar{x}$, is the average of two or more observed values.

Measurement is a procedure for determining a value for a physical variable.

Normal (Gaussian) distribution (see Appendix A).

The *observed value* is the result obtained from a measurement.

An *outlier* is a result that differs considerably from the main body of results in a set.

Parameters are the values that characterize and summarize the essential features of measurements.

Precision is the degree to which data within a set cluster together.

A *random error* is an error that varies in an unpredictable manner when a large number of measurements of the same variable are made under effectively identical conditions.

Range, w, is the region between the limits within which a quantity is measured.

Repeatability, r, is a measure of the agreement between the results of successive measurements of the same variable carried out by the same method, with the same instrument, at the same location, and within a short period of time.