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Nuclear fuel technology — Tank calibration and volume determination for nuclear materials accountancy —

Part 2: Data standardization for tank calibration

Technologie du combustible nucléaire — Étalonnage et détermination du volume de cuve pour la comptabilité des matières nucléaires —

Partie 2: Normalisation des données pour l'étalonnage de cuve

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18213-2 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 5, *Nuclear fuel technology*.

ISO 18213 consists of the following parts, under the general title *Nuclear fuel technology — Tank calibration and volume determination for nuclear materials accountancy*:

— *Part 1: Procedural overview*

— *Part 2: Data standardization for tank calibration*

— *Part 3: Statistical methods*

— *Part 4: Accurate determination of liquid height in accountancy tanks equipped with dip tubes, slow bubbling rate*

— *Part 5: Accurate determination of liquid height in accountancy tanks equipped with dip tubes, fast bubbling rate*

— *Part 6: Accurate in-tank determination of liquid density in accountancy tanks equipped with dip tubes*

Introduction

ISO 18213 deals with the acquisition, standardization, analysis, and use of calibration data to determine liquid volumes in process tanks for accountability purposes. This part of ISO 18213 complements the other parts, which include ISO 18213-1 (procedural overview), ISO 18213-3 (statistical methods), ISO 18213-4 (slow bubbling rate), ISO 18213-5 (fast bubbling rate) and ISO 18213-6 (in-tank determination of liquid density).

Measurements of the volume and height of liquid in a process accountancy tank are often made in order to estimate or verify the tank's calibration or volume measurement equation. The calibration equation relates the response of the tank's measurement system to some independent measure of tank volume. The ultimate purpose of the calibration exercise is to estimate the tank's volume measurement equation (the inverse of the calibration equation), which relates tank volume to measurement system response. In this part of ISO 18213, it is assumed that the primary measurement-system response variable is liquid height and that the primary measure of liquid content is volume.

Beginning with an empty tank, calibration data are typically acquired by introducing a series of carefully measured quantities of some calibration liquid into the tank. The quantity of liquid added, the response of the tank's measurement system and relevant ambient conditions, such as temperature, are measured for each incremental addition. Typically, several calibration runs are made to obtain data for estimating or verifying a tank's calibration or measurement equation. A procedural overview of the tank calibration and volume measurement process is given in ISO 18213-1.

Changes in ambient conditions, (especially variations in temperature, that occur during calibration can adversely affect the quality of the calibration data and, consequently, the reliability of the calibration or volume measurement equation determined from them. Results are also affected by differences in ambient conditions prevailing during calibration and at the time of subsequent measurements made to determine process liquid volumes. The purpose of this part of ISO 18213 is to present an algorithm for standardizing tank calibration and volume measurement data so as to minimize the effects of variability in ambient conditions prevailing at the time of measurement. Data standardization, as the term is used in this part of ISO 18213, refers to the steps taken to adjust raw data to compensate for departures in measurement conditions from a fixed set of reference conditions. The goal is to obtain a set of standardized calibration data, i.e. a series of pairs of height and volume determinations from one or more calibration runs that are standardized to a fixed set of reference conditions. These standardized data can be used to make reliable estimates of the tank's calibration or measurement equation, which is used, in turn, to determine the volume (at reference conditions) of process liquid in the tank.

This part of ISO 18213 pertains to measurements of liquid height and volume obtained during the tank calibration process. For tanks equipped with pressure-measurement systems to determine liquid content, it is necessary to convert pressure measurements to measures of liquid height before the steps of this part of ISO 18213 can be applied. A procedure for determining liquid height from pressure is given in either ISO 18213-4 (slow bubbling rate) or ISO 18213-5 (fast bubbling rate), as appropriate. Other standardization steps presented herein are generally independent of the measurement systems employed. Therefore, with suitable modifications, the methods of this part of ISO 18213 are applicable to a variety of measurement systems.

Nuclear fuel technology — Tank calibration and volume determination for nuclear materials accountancy —

Part 2: Data standardization for tank calibration

1 Scope

This part of ISO 18213 presents procedures for standardizing a set of calibration data to a fixed set of reference conditions so as to minimize the effect of variations in ambient conditions that occur during the measurement process. The procedures presented herein apply generally to measurements of liquid height and volume obtained for the purpose of calibrating a tank (i.e. calibrating a tank's measurement system). When used in connection with other parts of ISO 18213, these procedures apply specifically to tanks equipped with bubbler probe systems for measuring liquid content.

The standardization algorithms presented herein can be profitably applied when only estimates of ambient conditions, such as temperature, are available. However, the most reliable results are obtained when relevant ambient conditions are measured for each measurement of volume and liquid height in a set of calibration data.

2 Physical principles

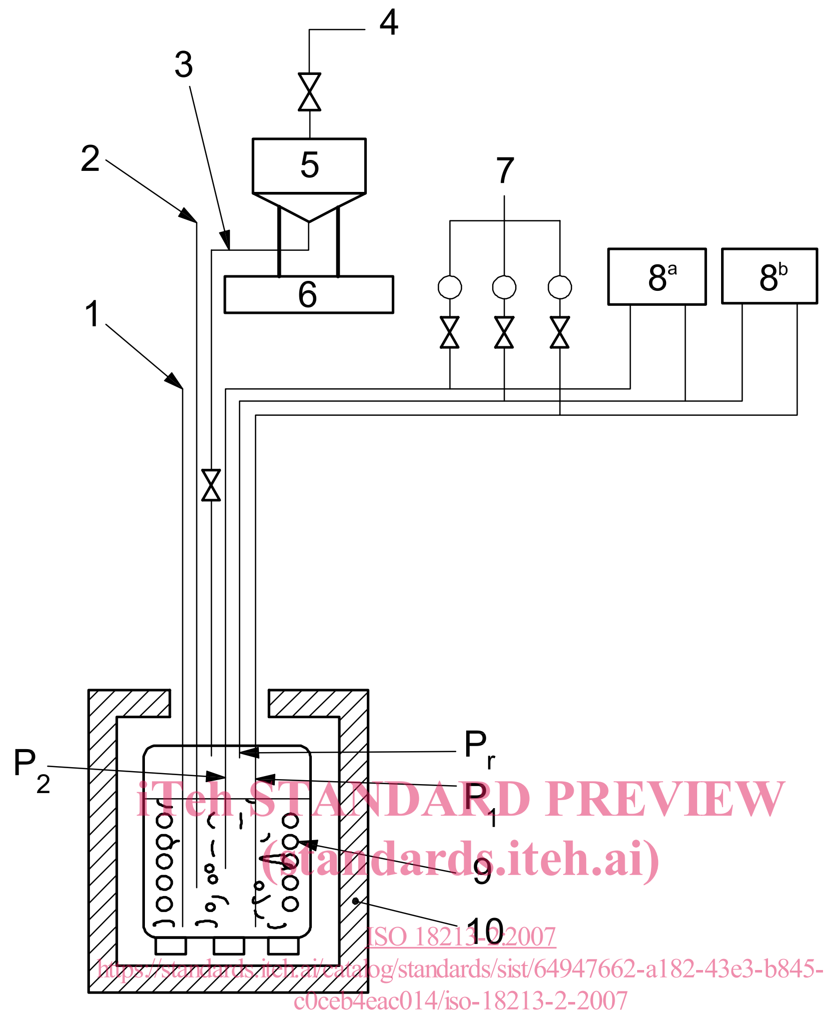
The data standardization procedures in this part of ISO 18213 are based on generally accepted thermodynamic methods. Where appropriate, details are given either in annexes to this part of ISO 18213 or in other parts of ISO 18213.

3 Data required

The basic input data to which the procedures of this part of ISO 18213 apply are pairs of observations that relate the tank's measurement system response (e.g. liquid height) to some independent measure of its liquid capacity (e.g. volume). These data pairs are typically obtained from one or more calibration runs. A typical calibration setup is shown in Figure 1. This setup is described in greater detail in ISO 18213-1[1)].

The density of the calibration liquid is required at all temperatures that are observed during the calibration exercise. Demineralized water is a preferred calibration liquid because its density has been very accurately determined at all temperatures of interest. Moreover, equations have been developed for accurately calculating the density of water from temperature (see Annex A). If some liquid other than water is used for calibration, then it is necessary to determine its density with suitable accuracy to meet calibration requirements at all measurement temperatures.

1) The calibration setup shown in Figure 1 is used for illustrative purposes. Other configurations are possible. See, for example, Reference [1].



Key

1 liquid temperature probe(s)
2 process lines (vent, fill, empty, decontamination, sparge, sample, etc.)
3 supply-line calibration liquid
4 calibration liquid supply
5 prover vessel
6 scale
7 purge gas supply
8 differential pressure manometers
9 tank internals (coils, braces, agitator, etc.)
10 isolation barrier

P_1 major probe
P_2 minor probe
P_r reference probe

[a] Level 2 (“density”).
[b] Level 1 (“level”).

Figure 1 — Elements of a typical tank calibration setup

Measurements of the ambient conditions that prevail at the time of measurement are required for all height and volume measurement pairs. These include the temperature of the liquid in the tank and the prover, the ambient (atmospheric) temperature, barometric pressure and relative humidity. It is also necessary to determine gas flow rates in the bubbler probe lines, as well as certain physical quantities related to the tank's measurement system. The latter include the inner diameter of the bubbler probes and the elevation of the manometer above the tip of each probe; see ISO 18213-1 and either ISO 18213-4 or ISO 18213-5 for details.

The coefficient of linear (thermal) expansion for the material from which the tank and its dip tubes are manufactured is required to perform the calculations indicated in Clause 5. Similarly, if a volumetric prover is used for calibration, the coefficient of linear expansion of the material from which it is fabricated is required to make the thermal adjustments indicated in 4.3.2.

4 Calibration data

4.1 General

The standardization steps that pertain to individual measurements of liquid height and volume are described in 4.2 and 4.3. These steps should be applied to each pair of raw calibration data from one or more calibration runs before these data are used to estimate the tank's calibration or measurement equation (see ISO 18213-1). Likewise, process measurements should also be standardized before they are used in either the calibration or volume measurement equation to determine the volume of liquid in the tank (see ISO 18213-1:2007, Clause 7). The steps in the standardization process are summarized in Figure 2.

The standardization of prover measurements of liquid content (volume) depends naturally on the type of prover employed for measurement. Standardization steps for gravimetric and volumetric provers are given in 4.3.1 and 4.3.2, respectively. The appropriate measure of mass is then used to determine the delivered volume (see 4.3.3).

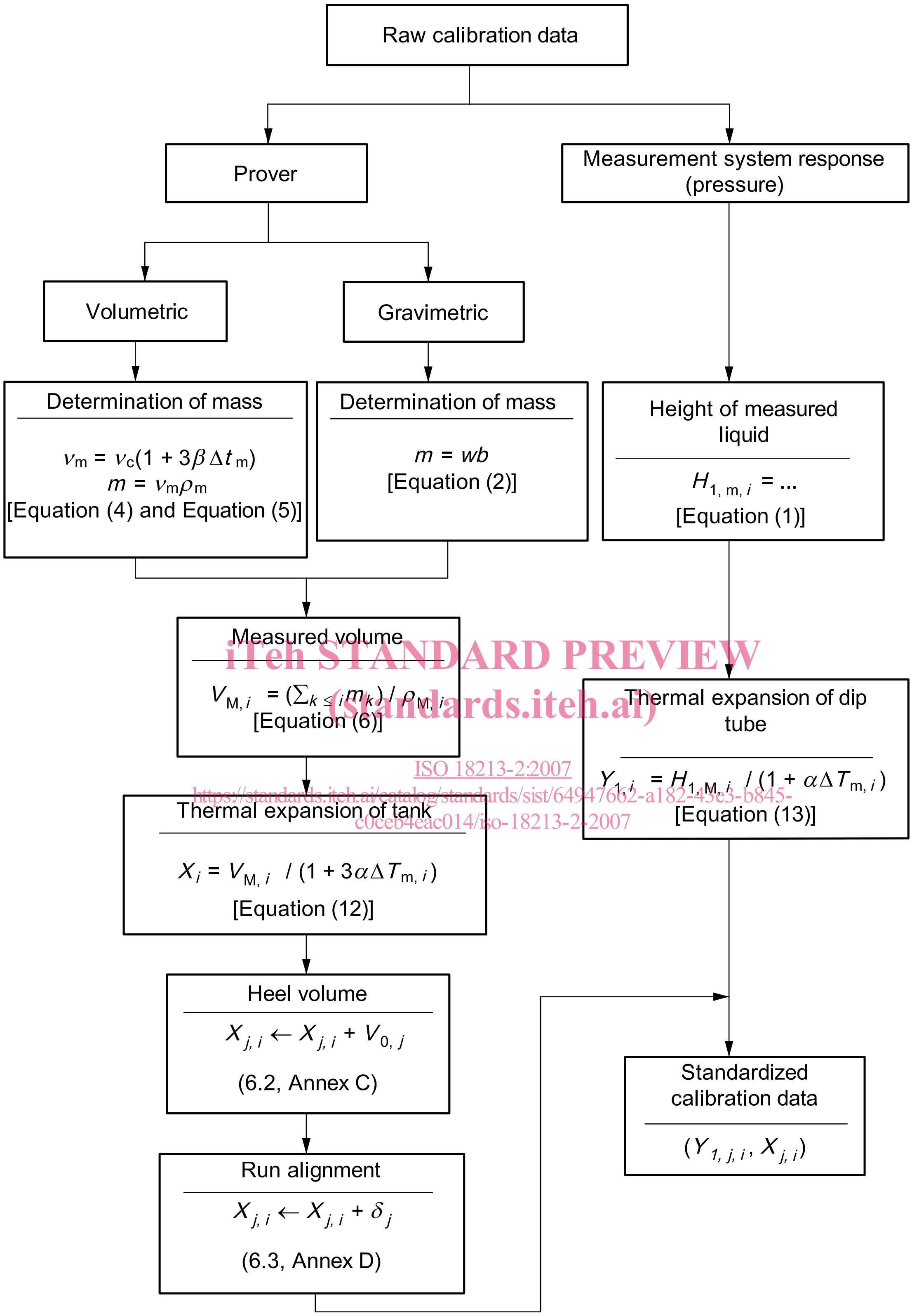


Figure 2 — Summary of steps for standardizing a set of raw calibration data

4.2 Liquid height

Before steps in this document can be applied, the output of the tank's measurement system shall first be converted to determinations of liquid height. For tanks equipped with pressure measurement systems, this should be done with the aid of either ISO 18213-4 (slow bubbling rate) or ISO 18213-5 (fast bubbling rate), as appropriate.

In ISO 18213-5, for example, the height, $H_{1,\mathrm{M}}$, of the column of liquid in the tank above the tip of the bubbling (major) probe at the measurement temperature T_m,[2), 3)] that corresponds to a given pressure measurement is determined from Equation (1):

$$H_{1,\mathrm{M}} = \left[\Delta P_1 + gE_1\left(\rho_{\mathrm{g},1} - \rho_{\mathrm{a,s}}\right) - gE_\mathrm{r}\left(\rho_{\mathrm{g,r}} - \rho_{\mathrm{a,s}}\right) + \left(\delta_\mathrm{r} - \delta_1\right) - g\lambda\left(\rho_\mathrm{M} - \rho_{\mathrm{g},1}\right) - 2\sigma / r_\mathrm{b} \right] \Big/ \left[g\left(\rho_\mathrm{M} - \rho_{\mathrm{a,s}}\right) \right] \quad (1)$$

where

ΔP_1 is the difference in pressure between the bubbling probe and reference probe lines as measured at a gauge located at elevation, E_1, above the tip of the bubbling probe; $\Delta P_1 = P_1(E_1) - P_\mathrm{r}(E_1)$;

g is the local acceleration due to gravity;

ρ_M is the average density of liquid at its measurement temperature, T_M, in the tank;

$\rho_{\mathrm{a,s}}$ is the average density of air in the tank above the liquid surface at the prevailing pressure;

$\rho_{\mathrm{g},1}$ is the average density of gas in the major probe line at the prevailing pressure;

$\rho_{\mathrm{g,r}}$ is the average density of gas in the reference probe line at the prevailing pressure;

E_1 is the elevation of the pressure gage above the primary reference point (the tip of the major probe);

E_r is the elevation of the pressure gauge above the tip of the reference probe;

δ_1 is the pressure drop in the major probe line due to the gas flow resistance;

δ_r is the pressure drop in the reference probe line due to flow resistance;

λ is the distance of the lowest point of the bubble below the tip of the major probe;

σ is the surface tension for the liquid and gas;

r_b is the radius of curvature of the bubble at its lowest point.

If the tank is equipped with some alternative system for determining liquid content, then appropriate modifications to the procedure described in either ISO 18213-4 or ISO 18213-5 can be required to obtain the liquid height measurements to which the subsequent steps in this document are applied.

2) The subscript "1" is used in this part of ISO 18213 to indicate quantities that refer to the major probe. The steps for standardizing data from a second probe are completely analogous.

3) For quantities other than temperature, the letter "m" is used as a subscript to denote temperature dependence. A lower case m (m) refers to the temperature, t_m, of liquid in the prover and an upper case m (M) refers to the temperature, T_m, of liquid in the tank.