INTERNATIONAL STANDARD

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

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

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

Partie 4: Détermination précise de la hauteur de liquide dans une cuve bilan équipée de cannes de bullage, bullage lent

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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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.

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ISO 18213-4 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 to determine liquid volumes in process tanks for the accountancy of nuclear materials. This part of ISO 18213 is complementary to the other parts, ISO 18213-1 (procedural overview), ISO 18213-2 (data standardization), ISO 18213-3 (statistical methods), ISO 18213-5 (fast bubbling rate) and ISO 18213-6 (in-tank determination of liquid density).

The procedure presented herein for determining liquid height from measurements of induced pressure applies specifically when a very slow bubbling rate is employed. A similar procedure that is appropriate for a fast bubbling rate is given in ISO 18213-5.

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.

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. 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. An algorithm for standardizing tank calibration and volume measurement data to minimize the effects of variability in ambient conditions that prevail during the measurement period is given in ISO 18213-2. The procedure presented in this part of ISO 18213 for determining the height of calibration liquid in the tank from a measurement of the pressure it induces in the tank's measurement system is a vital component of that algorithm.

In some reprocessing plants, the volume of liquid transferred into or out of a tank is determined by the levels of two siphons. The high level corresponds to the nominal volume, and the low level to the heel volume. If the transfer volume cannot be measured directly, then it is necessary to calibrate this volume (as described in the previous paragraph), because the difference between the actual volume and that used for inventory calculations will appear as a systematic error.

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. Steps for using the measurement equation to determine the volume of process liquid in the tank are presented in ISO 18213-1. The procedure presented in this part of ISO 18213 for determining the height of process liquid in a tank from a measurement of the pressure it induces in the tank's measurement system is also a key step in the procedure for determining process liquid volumes.

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

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

1 Scope

This part of ISO 18213 specifies a procedure for making accurate determinations of the liquid height in nuclear-materials-accountancy tanks that are equipped with pneumatic systems for determining the liquid content. With such systems, gas is forced through a probe (dip tube) whose tip is submerged in the tank liquid. The pressure required to induce bubbling is measured with a manometer located at some distance from the tip of the probe. This procedure applies specifically when a very slow bubbling rate is employed.

A series of liquid height determinations made with a liquid of known density is required to estimate a tank's calibration equation (see ISO 18213-1), the function that relates the elevation (height) of a point in the tank to an independent determination of tank volume associated with that point. For accountability purposes, the tank's measurement equation (the inverse of its calibration equation) is used to determine the volume of process liquid in the tank that corresponds to a given determination of the liquid height.

2 Physical principles involved

The methodology in this part of ISO 18213 is based on measurements of the difference in hydrostatic pressure at the base of a column of liquid in a tank and the pressure at its surface, as measured in a bubbler probe inserted into the liquid. Specifically, the pressure, P, expressed in pascals, exerted by a column of liquid at its base is related to the height of the column and the density of the liquid, in accordance with Equation (1) [1]:

$$P = gH_{\mathrm{M}}\rho_{\mathrm{M}} \tag{1}$$

where

H_{M} is the the height of the liquid column (at temperature T_{m}), in m;

ρ_{M} is the average density of the liquid in the column (at temperature T_{m}), in kg/m^3;

g is the local acceleration due to gravity, in m/s^2.

1) The subscript “M” is used to indicate the value of a temperature-dependent quantity at the temperature T_{m}.

For a liquid of known density, ρ, Equation (1) can be used to determine the height, H, of the liquid column above a given point from (a measurement of) the pressure, P, exerted by the liquid at that point. Therefore, process tanks are typically equipped with bubbler probe systems to measure pressure. Components of a typical pressure measurement system (see Figure 1) are discussed in detail in ISO 18213-1, together with a description of the procedural aspects of a typical calibration exercise.

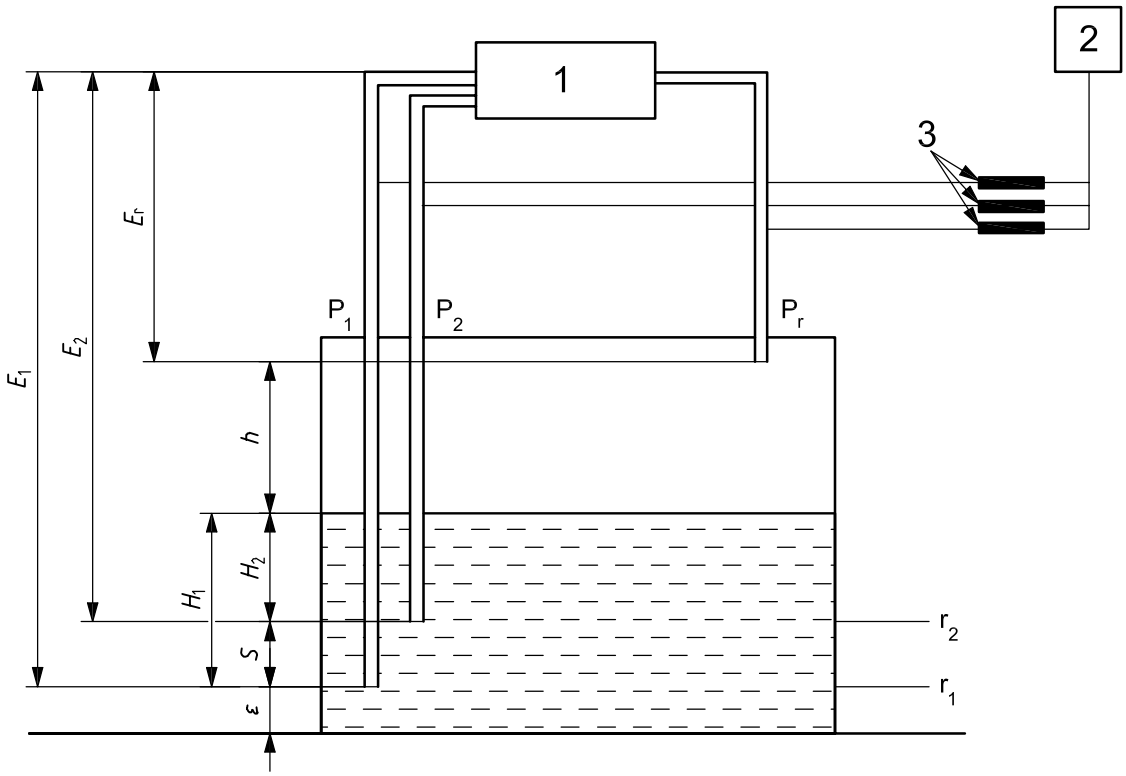
In practice, it is not absolute pressure that is measured, but rather the difference in pressure between the bottom and top of the liquid column. Gas is forced through two probes to measure this differential pressure. The tip of one probe (the long or major probe) is located near the bottom of the tank and immersed in the liquid. The tip of the second probe (reference probe) is located in the tank above the liquid surface.

To measure the pressure, P, exerted by a column of liquid, the pressure of gas in the probe immersed in the liquid should be measured while the gas-liquid interface is at static equilibrium. In practice, it is not possible to measure this pressure directly because it is difficult to maintain a stable and reproducible gas-liquid interface level in the probe. Therefore, a dynamic system is used to make measurements under conditions as close to equilibrium as possible: Gas is forced through the probe at a very low and constant flow rate, and its pressure is measured continuously. The fluctuation with time of these measurements (around some central value) depends on the bubbling frequency.

Provided the gas flow rate is low and constant, the gas pressure at the tip of the major probe first increases with time during the formation of a bubble. The release of a bubble from the tip of the probe causes a sudden increase in the level of the bubble-liquid interface at the tip of the probe and a corresponding decrease in pressure. For a probe with a small diameter (less than 8 mm), the pressure reaches a maximum and then decreases slightly before the sudden drop associated with bubble separation. For probes with larger diameters (greater than 8 mm), the maximum pressure that occurs just before bubble separation may not be accompanied by a decrease, but may instead show a short period of relative stability followed by a sudden drop in response to bubble separation. The dynamics of bubble formation and release, together with their effect on pressure in the probe, are shown in Figures 2 and 3.

Measurements of pressure are made at its maximum in the bubble formation-and-separation cycle because this is the point at which pressure is most stable. Measuring the maximum pressure results in an overpressure (a positive bias), denoted by $(\delta p)_{max}$, relative to the actual pressure at the tip of the probe. A formula for computing the overpressure, $(\delta p)_{max}$, is given in 4.4.

Various factors, in addition to bubbling overpressure, can affect the accuracy of the height determinations that follow from Equation (1). Temperature variations potentially have the greatest effect, especially on the comparability of two or more measurements (such as those taken for calibration), primarily because liquid density changes with temperature. Moreover, differences between actual pressures at the tip of the probes and observed pressures at the manometer can result from the buoyancy effect of air and the mass of gas in the probe lines. A general algorithm for standardizing pressure measurements that compensates for temperature variations and other measurement factors is presented in ISO 18213-2. For the case in which pressure measurements are made with a very slow bubbling rate, details of the pressure-to-height calculation step of this standardization algorithm are presented in Clause 4 of this part of ISO 18213. Analogous calculations that apply for a fast bubbling rate are given in ISO 18213-5. Procedures for estimating the uncertainty of the resulting height determinations are given in ISO 12813-3.



NOTE This configuration is typical but other configurations are possible, see Reference [11] for examples.

Key

1 manometer

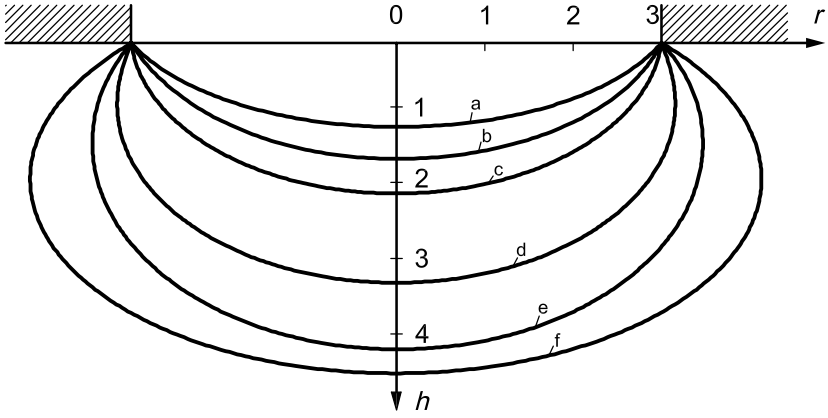
2 gas supply (N_2 or air)

3 flowmeters

	Major probe	Minor probe	Reference probe
Probe designation	P_1	P_2	P_r
Reference point	r_1 (primary)	r_2 (secondary)	—
Height of liquid above reference point	H_1	H_2	—
Elevation of pressure gauge (manometer) above reference point	E_1	E_2	E_r
Elevation of reference probe above liquid surface	$h = E_1 - E_r - H_1$	$h = E_2 - E_r - H_2$	—
Elevation of reference point above bottom of tank	ε	$\varepsilon + S$ [a]	—

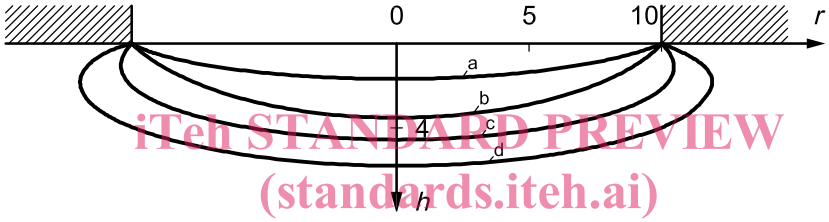
[a] Vertical distance (probe separation): $S = H_1 - H_2$.

Figure 1 — Elements of a typical pressure measurement system for determining liquid content



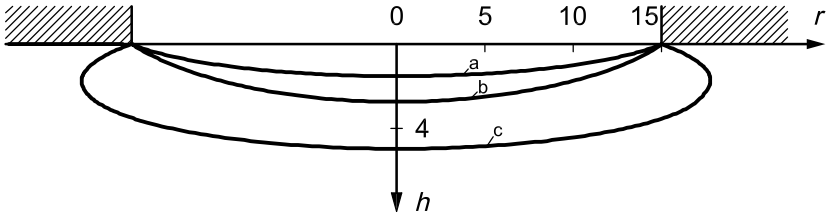
a) Radius of the bubbler probe, r = 3 mm

a ΔP = 3,7
b ΔP = 4,8
c ΔP = 5,7
d ΔP = 7,1
e ΔP = 7,2
f ΔP = 7,4



b) Radius of the bubbler probe, r = 10 mm

a ΔP = 2,0
b ΔP = 4,4
c ΔP = 5,4
d ΔP = 5,9



c) Radius of the bubbler probe, r = 15 mm

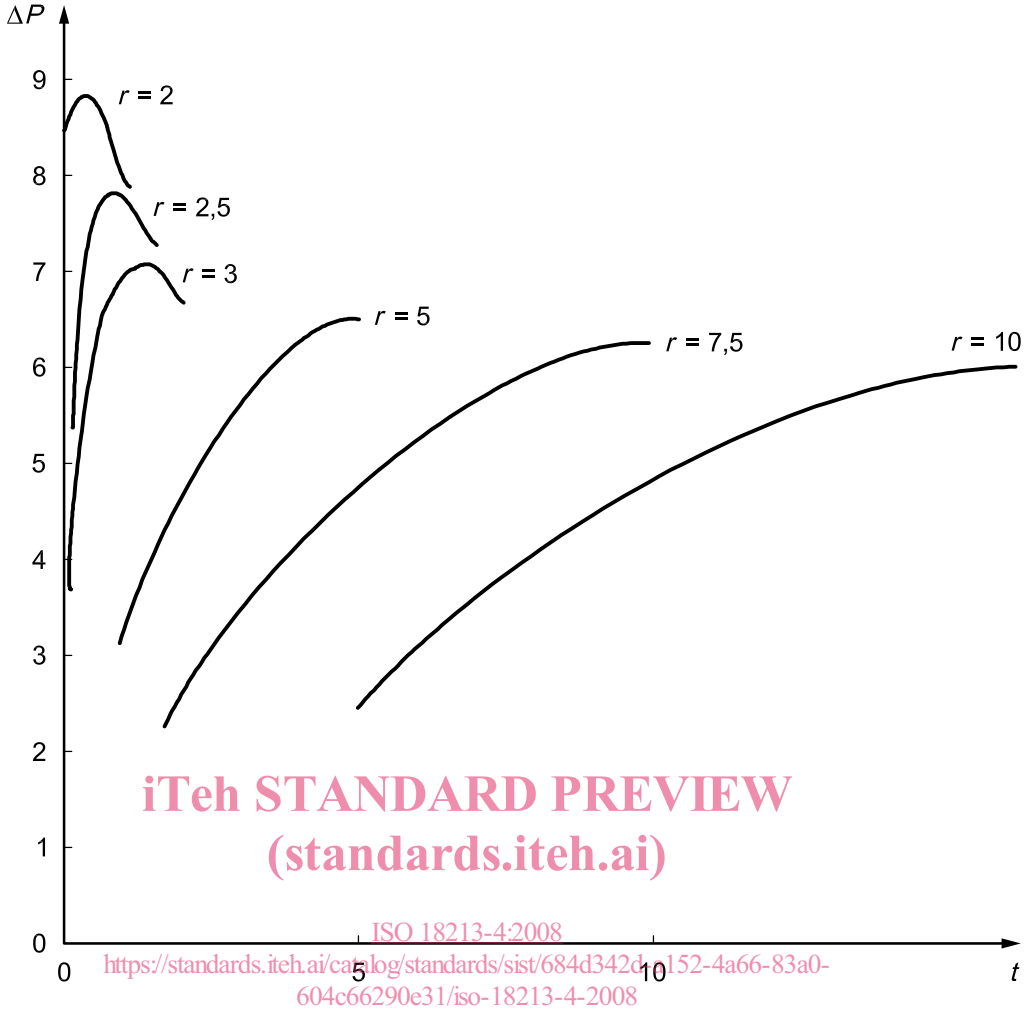
a ΔP = 1,8
b ΔP = 2,8
c ΔP = 5,7

ΔP = mm of H_2O.

Key

r radius of the bubbler probe, mm
h bubble height, mm

Figure 2 — Evolution of a bubble in water



Key

t time, s

ΔP overpressure, mm of H_2O

r radius of the bubbler probe, mm

Figure 3 — Evolution of bubbling overpressure in water