NOVEL WATER FLOW FACILITY IN FRANCE
Range extension to low flow rates (10 000 ml/h down to 1 ml/h)

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Abstract: In order to extend the French water flow calibration range, LNE-CETIAT is on progress to build a new reference for flow rate measurements ranging from 10 $l.h^{-1}$ down to 1 $ml.h^{-1}$. This new facility based on a gravimetric principle (ISO 4185) will enable calibration with water temperature between 10°C and 50°C. Flow is regulated by the combined use of a tightly regulated "upstream" pressure (0,1 to 10 bar) and the use of capillaries under laminar flow. The expected relative uncertainty for the water flow rate is 0.1% with a coverage factor k = 2 (95% confidence). The paper described the design and the ongoing implementation of this new calibration facility.

Keywords: Micro flowrate, Flow calibration, Gravimetric principle, Water

1. Introduction

LNE-CETIAT is the French designated institute in the field of water flow calibration. The current facility based on the gravimetric method [1] has the following specifications:

- Type of liquid: water
- Flow range: 8 $l.h^{-1}$ to 36 $m^3.h^{-1}$,
- Liquid temperature: 10°C to 90 °C,
- Pressure of the liquid: 1 bar to 3 bar,
- Uncertainty on volume flow rate: 0.05 % $Q_v < U_{k=2} <$ 0.16 % Q_v

As an answer to repeated requests for calibrations at lower flow values than the available range, a study for a project feasibility started in 2004 [2 - 3]. The aim was to detect the interested industries, to define the best flow range coverage and the potential partners for this project.

As a consequence, France decided to develop a new calibration facility to cover lower flow rates in 2006. The objectives in terms of controllable parameters for the project are the following:

- Type of liquid: water (filtered and degassed)
- Flow range: 1 $ml.h^{-1}$ to 10 $l.h^{-1}$,
- Liquid temperature: 10°C to 50 °C,
- Surrounding temperature of the flowmeter: 10°C to 50 °C,
- Pressure of the liquid: 1 bar to 10 bar,
- Uncertainty on volume flow rate: $U_{k=2} \approx$ 0.1% Q_v

2. Description of the calibration facility

2.1. Overview

The global architecture of the bench can be visualized on the following drawing (Fig. 1).

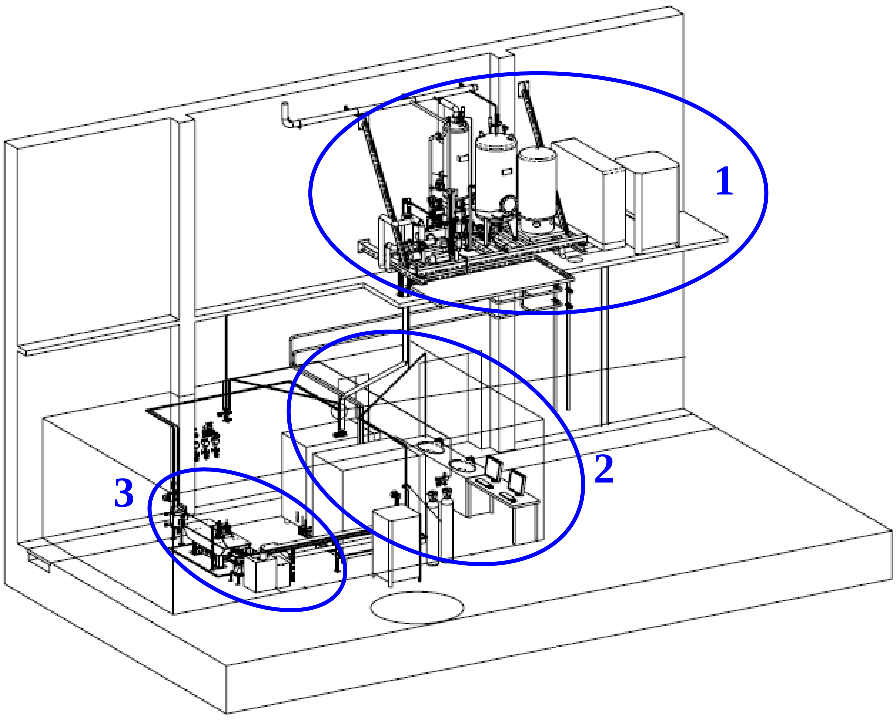

Fig. 1: 3D view of the calibration facility

(1 – Water production, 2 – Supervision and flow generation, 3 – Measuring instruments)

On the first floor, the water is prepared (demineralised, degassed and filtered). At the ground, a clean room with controlled ambient conditions receives the supervision, the flow generation equipments and the measuring instruments. Flow is generated using a pressurized tank (0,1 to 10 bar) and is controlled tightly by the combination of a constant upstream pressure and the selection of a well designed capillary creating a constant pressure loss.

The clean room was tested and its specifications were validated (T = 20°C +/-2°C; 55%RH +/-5% RH; $P = P_{atm}+20$ Pa) The temperature around the weighting cell was recorder during 30 minutes (maximum elapsed time for a measurement) and its stability was better than 0,3°C

Measurement of the flow is ensure by the combination of time and mass measurements. In order to cover the entire range of flow with the expected uncertainty, the measuring process is implemented on 4 separated lines:

- Line 1 for flow range: 1 ml.h^{-1} to 10 ml.h^{-1}
- Line 2 for flow range: 10 ml.h^{-1} to 100 ml.h^{-1}
- Line 3 for flow range: 100 ml.h^{-1} to 1 000 ml.h^{-1}
- Line 4 for flow range: 1 000 ml.h^{-1} to 10 000 ml.h^{-1}

2.2. Water preparation equipment

Water was chosen as the best fluid to be used for this new standard[2 - 3]. The main reasons are the availability, the absence of toxicity, the absence of hazards and finally the compatibility with most of the applications and technologies for flow measurement.

Three characteristics of the liquid has been identified as important in order to be able to perform calibrations with the expected uncertainty. These parameters were translated into specifications to the water preparation equipment (Fig. 2)

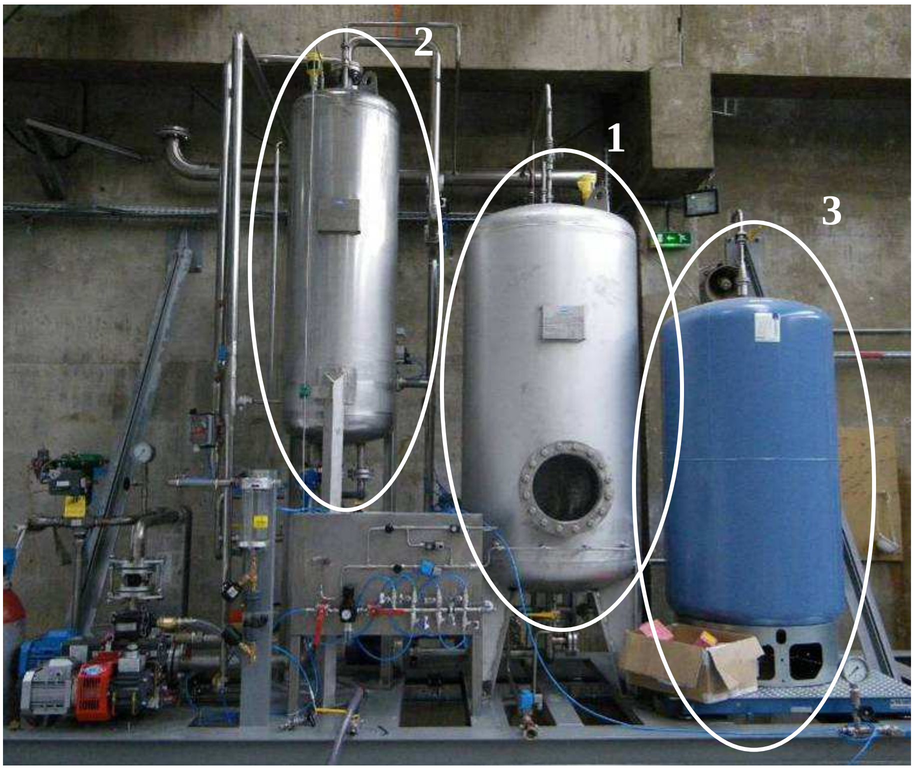

Fig. 2: Water preparation equipment before heat insulation

(1 – Nitrogen bubbling tank, 2 – Heating and degassing tank , 3 – Stock tank)

<u>First parameter</u>

A complete absence of particles with a size larger than 10 µm is necessary to avoid any clogging of the pipes. The inner diameter of some of the capillaries involved in the measuring process can reach 100 µm as a minimum. To cope with this aspect, several filters are positioned along the circuit. The first one is situated near the entry of the water preparation equipment and filter most of the existing particles. A second filter is situated just before the flow generator and stop all the particles created by moving part or specifics equipments (pump, heater,…). Bacteria and algae are a second type of particles that could be encountered To avoid their development, water is saturated with bubbling nitrogen in a first tank and a small amount of fungicide is incorporated.

The influence of this modification of the water composition on its viscosity and density is very small but specifics measurements will be done to qualify the difference and take it into account in the final uncertainty budget.

Second parameter

The presence of bubbles in the circuit could affect the measuring process. The “dead zone” in the circuit could allow bubbles to agglomerate and clog the small capillaries. Due to changes of the local pressure in the pipes, the presence of bubble could induce variation of the flow by compressibility phenomenon. To avoid these specifics issues, water is degassed and most of the dissolved gasses are removed. The degassing process is done in the second tank using a shower that blow the water in a medium at negative relative pressure.

Third parameter

This parameter is the temperature of the fluid. Calibration can be done between 10°C and 50°C. The water preparation equipment is used to maintain the temperature of the fluid before its introduction in the flow generator. All equipments have to be compatible with such temperatures and are isolated to avoid heat exchanges. Temperature is regulated in the second tank with a continuous circulation of the fluid through a heat exchanger.

2.3. Flow generation

The amount of water flowing through the instrument under calibration is maintained and controlled by the combined used of two specifics equipments.

The first equipment is a tank with a capacity of 10 liters where the pressure is tightly regulated with a bellow (Fig.3). Compressed nitrogen allow the control of the pressure in with a stability better than 0,05% of the expected value. This stability is obtained by the selection of an orifice plate (3 available diameters) and the suitable pressure gauges (6 sensors are used to cover the complete range of pressure).

To maintain the water temperature, the tank with its bellow is situated in a thermostatic chamber with a set up value corresponding to the set point imposed in the second tank of the water preparation equipment (in the range of 10°C to 50°C). The temperature regulation was tested in the thermostatic chamber. The homogeneity was better than 0,6°C and the stability was comprised between 0,05°C and 0,1°C.

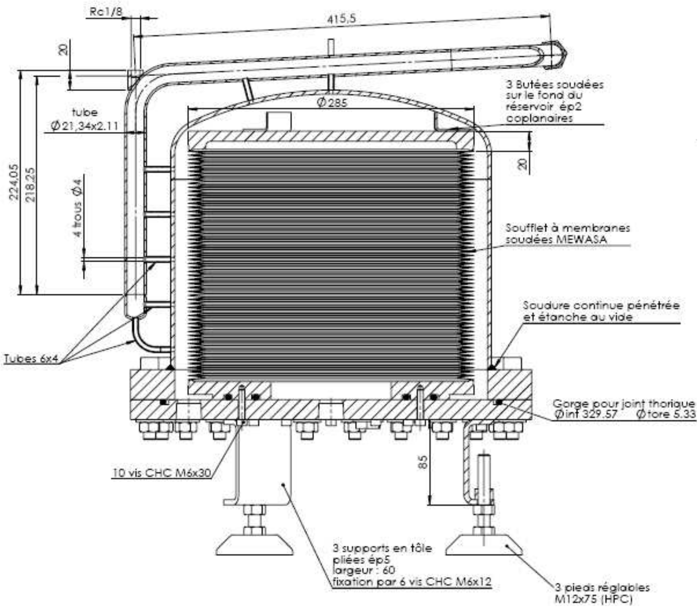

Fig. 3: Flow generator (Pressurized bellow in a tank)

The second equipment used to control the flow is composed of ten capillaries located after the flowmeter under calibration. Thanks to the selection of one of the capillaries, a constant pressure drop is imposed in the circuit. It allow the control of the flow and the pressure in the flowmeter. The choice of the inner diameter (from 100 µm to 325 µm) and the length (from 1 to 4 m) of a capillary induce its coefficient of discharge. Using this set of capillaries, the generation of each flow rate is possible for three different upstream pressure.

To ensure the stability of the pressure drop, all capillaries have been designed to be used with laminar flow. For that regime, the stability of the flow is highly influenced by the viscosity of the fluid which is dependent of the temperature. To avoid the variation of viscosity, capillaries are immerged in a thermostatic bath with a temperature stability better than 0.01°C.

2.4. Flow measurement

The measure equipment is separated in four individual lines covering each a decade of the total flow range (Fig. 4). The gravimetric method is used to measure the flow (tractability to S.I. units via mass and time measurements). The volume flow rate is deduce from the mass flow rate with the use of water density measurement. The concept of the four lines is identical, the main difference is the maximum load capacity of the weighting cells. For each line, water is received in a reservoir covered by a moisture saturator in order to avoid evaporating phenomenon.

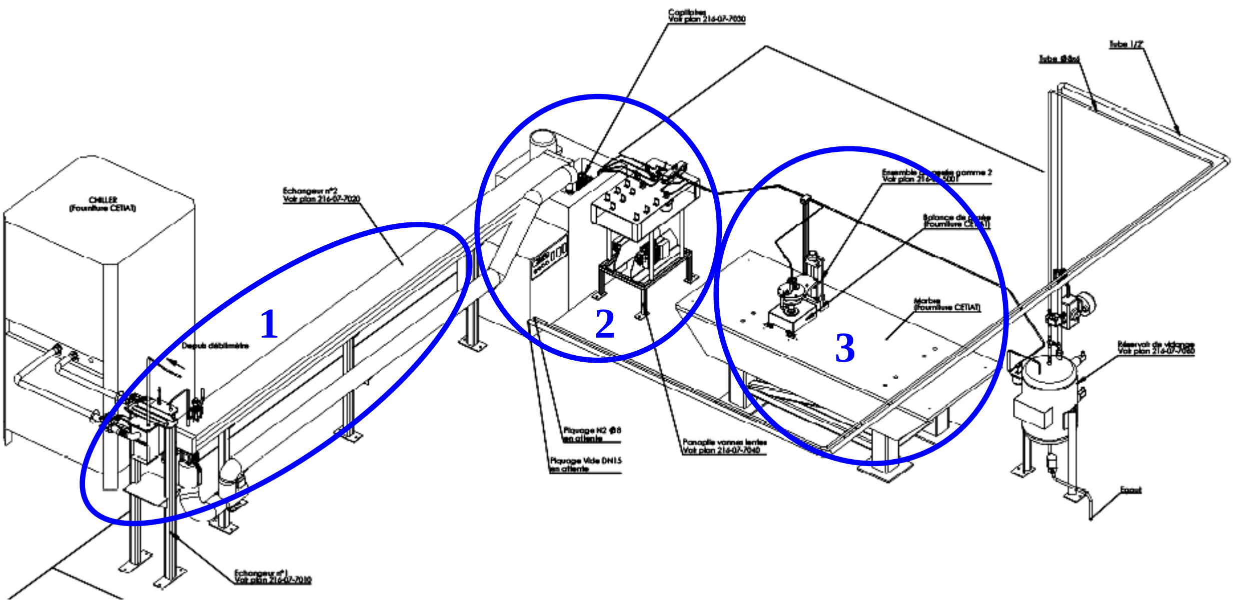

Fig. 4: Schematic view of the measure equipment

(1 – Heat exchangers, 2 – Capillaries in a thermostatic bath and associated valves, 3 – Mass measurement: line n°2)

The four weighting cells are positioned on a marble to reduce vibrations. For the line n°2 (range: 10 ml.h^{-1} to 100 ml.h^{-1}) which is already installed (Fig. 5), a fixed mass of water (5 g) is accumulated in the reservoir and measured with 10 µg resolution. The measure of the filling elapsed time is used to calculate the mass flow rate. To avoid drop effects, the reservoir always contain water and the fluid is introduced under the free surface. Jet impact in the reservoir is also reduce by the use of a sprinkler.

Fig. 5: Weighting equipment

(From bottom to top: weighting cell, weighting reservoir, moisture saturator)

Several other technical aspects were taken into account to ensure the stability of the flow. Dead zones and internal volumes are lowered by the use of special fittings and sealing. Variation of density is reduce by the use of a co-current loop with a 0.1°C temperature stability.

3. Conclusion

This paper presents the ongoing development of a new flow calibration facility in France. The concept of the calibration facility is presented in the article. This standard will enable calibration for low flow of liquid (1 $ml.h^{-1}$ to 10 $l.h^{-1}$). The liquid flowing through the device under test is a purified water (filtered and degassed) with controlled temperature 10°C to 50°C. One of the four lines of the laboratory (10 $ml.h^{-1}$ to 100 $ml.h^{-1}$) is under validation. The extension with the three other lines will be conducted at the end of this year.

Acknowledgment

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