WATER FLOW CALIBRATION FACILITY IN FRANCE (1 ML/H TO 10 000 ML/H)

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ABSTRACT

Through the world, the tendency to miniaturize all objects is spread widely. Concerning liquid flow metering, several manufacturers are already industrializing instruments specific for small flows. On a metrological point of view, few National Metrological Institutes (NMI) are able to calibrate flowmeters with liquid at flow rate smaller than 1 $l.h^{-1}$ ($2{,}8.10^{-7}$ $m^3.s^{-1}$). During the last five years, LNE-CETIAT (French NMI) was on progress to design and build a new calibration facility to ensure traceability to the international system of units. This paper will present the concepts and the first results obtained during the validation stage of this new standard.

KEYWORDS

Calibration, water, flow, metrology

INTRODUCTION

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

- Type of liquid: water
- Flow range: 8 $l.h^{-1}$ to 36 000 $l.h^{-1}$,
- Liquid temperature: 15°C to 90 °C,
- Pressure of the liquid: 1 bar to 3 bar,
- Uncertainty on volume flow rate: 0.05 % Qv < $U_{k=2}$ < 0.16 % Qv.

As an answer to repeated requests for calibrations at lower flow values than the available range, a study concerning available flowmeters, industrial needs and project feasibility started in 2004 [2]. The aim was 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 were 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,
- Ambient temperature around the flowmeter: 10°C to 50 °C,
- Pressure of the liquid: up to 10 bar,
- Uncertainty on volume flow rate: $U_{k=2}$ ≈ 0.1% Qv.

DESCRIPTION OF THE CALIBRATION FACILITY

Overview

The global architecture of the bench [3] can be described as follow (see Fig.1). 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.

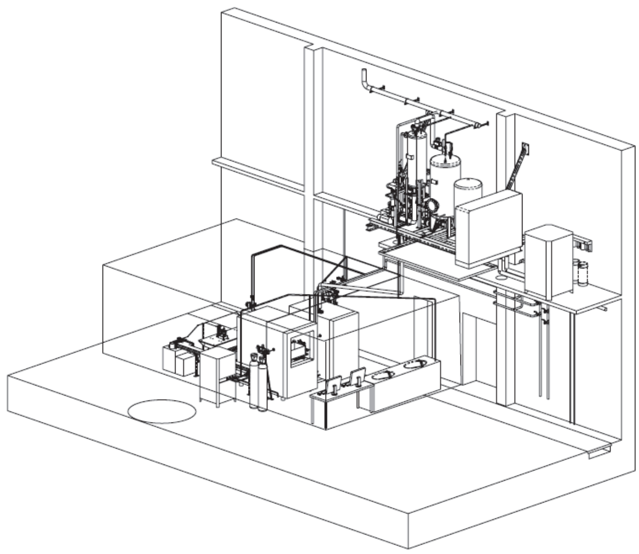

Figure 1: 3D view of the calibration facility

The clean room was tested and its specifications were validated (T = 20°C +/-2°C; 55%RH +/- 5% RH; P = Patm+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

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 capillaries creating a constant pressure loss.

Measurement of the mass flow rate is ensured 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: 1 $ml.h^{-1}$ to 10 $ml.h^{-1}$
- Line 2: 10 $ml.h^{-1}$ to 100 $ml.h^{-1}$
- Line 3: 100 $ml.h^{-1}$ to 1 000 $ml.h^{-1}$
- Line 4: 1 000 $ml.h^{-1}$ to 10 000 $ml.h^{-1}$

Water preparation equipment (Fig. 2)

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

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 filters most of the existing particles. A second filter is situated just before the flow generator and stop 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 small. Specifics measurements have shown that these specificities had no influence on the final uncertainty budget.

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 a second tank using a shower that blow the water in a medium at negative relative pressure.

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 are 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.

Figure 2: Water dispense stage

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 in a bellow. 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). 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 (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.

The second equipment used to control the flow is composed of eight capillaries (see Fig.3) 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 allows the control of the flow and the pressure in the flowmeter. The choice of the inner diameter (from 100 µm to 500 µm) and the length (from 1 to 3 m) of a capillary induce its coefficient of discharge.

Using this set of capillaries, the generation of any flow rate in the complete range is possible for three different upstream pressures. To ensure the stability of the pressure drop, all capillaries have been designed to be used at 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 variation of the viscosity, capillaries are immerged in a thermostatic bath with temperature stability better than 0.01°C.

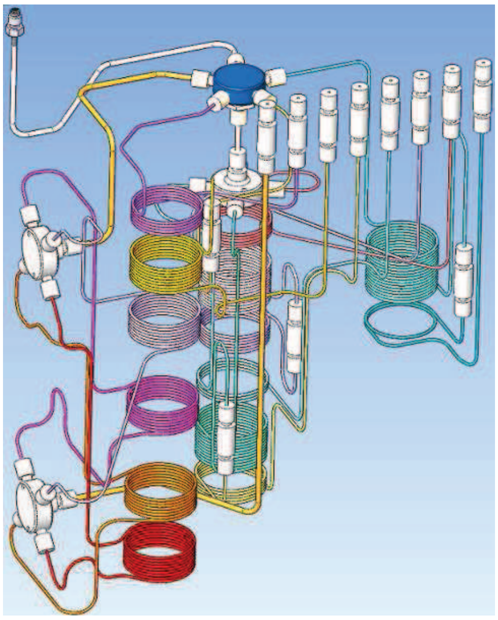

Figure 3: View of the set of 10 capillaries

Flow measurement

The measuring part of the system is separated in four individual lines (see Fig. 4) covering each a decade of the total flow range. The gravimetric method is used to measure the flow (tractability to S.I. units via mass and time measurements). The volume flow rate is deduced from the mass flow rate with the use of water density. The concept of the four lines is identical; the main difference is the maximum load capacity of the weighting cells and the size of the circuits. For each line, water is received in a reservoir covered by a moisture saturator (see Fig.5) in order to avoid evaporating phenomenon.

The four weighting cells are positioned on a marble to reduce vibrations. For each line, the weighted mass of water is independent of the measured flow rate (0,5 g for the line n°1 (range: 1 ml.h^{-1} to 10 ml.h^{-1}); 5g for the line n°2 (range: 10 ml.h^{-1} to 100 ml.h^{-1}) etc… The measure of the filling elapsed time is used to calculate the mass flow rate.

Figure 4: Weighting cells covering the calibration range

The volume of one drop is not enough small in comparison to the quantity of water that is measured. To avoid possible "drop effects", the reservoir always contain water and the fluid is introduced under the free surface. Jet impact in the reservoir is also reduced by the use of a sprinkler.

Figure 5: Weighting cell, reservoir and moisture saturator for the line n°2 (10 ml.h^{-1} to 100 ml.h^{-1}).

Several other technical aspects were taken into account to ensure the stability of the flow. Dead zones and internal volumes were lowered by the use of special fittings and sealing. Variation of density is reduced by the use of a co-current loop with a 0,1°C temperature stability.

Conclusion

This paper presents the new water flow calibration facility in France. The official inauguration of this bench was held in Lyon (FRANCE) on January the 21th of 2012.The concept of this calibration facility is presented in the article. This standard enable calibration for low flow of liquid (1 ml.h^{-1} to 10 000 ml.h^{-1}). The liquid flowing through the device under test is purified water (filtered and degassed) with controlled temperature 10°C to 50°C. The four lines of the laboratory (1 ml.h^{-1} to 10 000 ml.h^{-1}) are already used for customers calibrations at 20°C. Ongoing validations will allow us to perform calibration with water temperature going from 10 to 50°C.

Acknowledgment

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