Traceability chains of EuReGa Participants for high-pressure natural gas

EuReGa is the name under which National Metrology Institutes and Designated Institutes cooperate in the field of gas flow measurement in Europe. By combining their traceability chains these countries aim at a more accurate and more stable cubic metre. This document gives a short description of the traceability chains of the participating countries.

EuReGa

The participants are PTB using the pigsar facilities, VSL using the EuroLoop facilities, LNE-LADG operated by CESAME Exadébit, and FORCE Technology. Together these organizations form the EuReGa consortium (European References for Gas). The intercomparison measurements were conducted after re-calibration of the participants' facilities.

Participation in the EuReGa consortium is only possible if the laboratory fulfils the following prerequisites:

- The laboratory has realized the national high-pressure cubic metre entirely independent of other laboratories.
- The traceability chain and the CMC uncertainty analysis are documented in the laboratory's quality system.
- The laboratory has been accredited based on an ISO 17025 compliant quality system.
- The measuring capabilities are listed in appendix C of the BIPM key comparison database.

Table 1: Primary devices for the realization of the national reference values for the high-pressure cubic metre (m³).

Country	Institute	Primary device	Traceable to	Fluid used
The Netherlands	VSL / EuroLoop	24" Gas Oil Piston Prove (GOPP)r	Length	Natural gas
Germany	PTB / pigsar	10" Piston Prover (HPPP)	Length	Natural gas
France	Cesame-Exadebit s.a. / LNE-LADG	Constant volume tank (PVTt)	Mass	Air
Denmark	FORCE Technology	26" Twin Piston Prover	Length	Natural gas

All laboratories meet these requirements. Table 1 gives an overview of the primary devices used by the EuReGa participants to define the high-pressure cubic metre for air or natural gas. The next sections will give a brief description of the different national traceability chains.

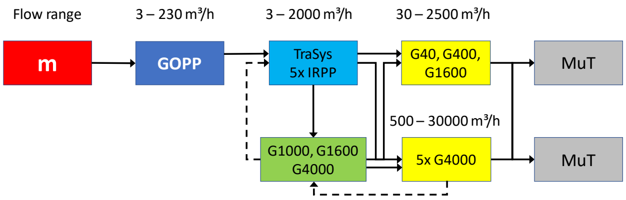

Figure 1: Schematic representation of the Dutch traceability chain for high-pressure gas flow measurement. The reference meters (yellow) are traceable via transfer standards (green) and TraSys (light blue) to the piston prover (blue) and the SI unit metre (red). The meter under test (grey) is calibrated by using a combination of reference meters. The dashed lines indicate the bootstrapping process which is used to calibrate the instrument beyond the range covered by a higher standard.

The Netherlands

The Dutch traceability chain for high-pressure natural gas is schematically depicted in Figure 1. The primary device is the Gas Oil Piston Prover (blue), shortly called GOPP, which was extensively described in [1]. On one side of the free moving piston the tube is filled with oil, the other side contains high-pressure natural gas. The nominal diameter of the honed cylinder is approximately 600 mm. The design was inspired to avoid slip-stick effects of the moving piston. The dimensions of the GOPP are calibrated which makes it traceable to the meter (red). The GOPP is used to calibrate one or more rotary piston gasmeters (IRPPs) that are part of the Traceability System (TraSys for short) secondary reference (light blue). These G250 IRPPs can be calibrated until 230 m³/h. So for the higher flowrates two IRPPs are used in parallel to calibrate a transfer meter (green) up to 400 m³/h. Then the range of 230 – 400 m³/h is copied back to the IRPPs. This process is called bootstrapping and is indicated in Figure 1 by a dashed line. The TraSys reference is used to calibrate the smaller reference meters and also the bigger reference meters (yellow) in their lower operating ranges. For the higher flowrates bootstrapping via transfer standards is performed. The MuTs (grey) are then calibrated using a combination of references (yellow).

Germany

The German traceability chain is schematically depicted in Figure 2. The primary device is a passive piston prover (blue) in which a free moving piston travels through a honed cylinder, which is approximately 250 mm in diameter. The piston can travel at a maximum speed of 3 m/s over a length of 6 m. Due to inertia effects of the piston the effective measurement length is 3 m. The motion of the piston is detected by switches that are mounted in the wall of the prover. The dimensions of the prover are calibrated every 5 years, which makes it traceable to the meter (red). Two G250 reference turbine gasmeters (green) are calibrated simultaneously using the piston prover. With the reference meters four parallel G250 working standards (turbine reference meters, yellow) are calibrated. With the four reference meters a G1000 transfer turbine gasmeter (green) is calibrated, which is used to calibrate four parallel G1000 turbine reference gasmeters. The meters under test (MuT) are calibrated using a combination of reference meters that matches the desired flowrate. The whole facility can operate between 1.6 and 5.1 MPa absolute pressure. For special purposes the piston prover and the two references (Ref) can be operated down to 0.8 MPa.

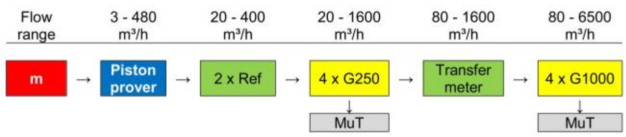

Figure 2: Schematic representation of the German traceability chain for high-pressure gas flow measurement. The reference meters (yellow) are traceable via transfer standards (green) to the piston prover (blue) and the SI unit metre (red). The meter under test (grey) is calibrated by using a combination of reference meters.

France

The French traceability chain is schematically depicted in Figure 3. The primary facility is based on PVTt method, where the mass change in a volume tank with a known volume V is determined based on the change of pressure P and the temperature T in a time interval t, which makes it traceable to mass. The PVTt system is devoted to the determination of the discharge coefficients Cd of sonic nozzles depending on Reynolds numbers and pressure, which will be used as transfer standards on a secondary test bench.

From a 20 MPa storage the PVTt tank is filled with dry air (dew point – 70°C) through a sonic nozzle which is kept under critical flow conditions (i.e. the gas velocity in the throat of the nozzle equals the speed of sound). The mass flow through the nozzle under critical conditions (sonic velocity at throat) is compared with the mass change in the volume tank during a measured time lapse. The Cd coefficient of the nozzle is the ratio of the reference mass flowrate and the mass flowrate calculated from measured quantities at the nozzle, and for each nozzle a Cd law is established depending on the Reynolds number of the flow. The choice for dry air enables low uncertainties, because the real gas factor is not influenced by a varying gas composition. This airflow facility is used to take part in the key comparison. A full description of the facility can be found in [2].

LNE-LADG also provides calibrations with natural gas, using the ENGIE/CRIGEN «PLAT» bench. When a sonic nozzle has already been calibrated using air with the PVTt system, its calibration using natural gas using the PLAT bench delivers the same Cd law depending on Reynolds number (except facilities uncertainties). Afterwards, when Cd laws must be expressed depending on the mass flow instead of the Reynolds number the natural gas properties must be considered (density, viscosity).

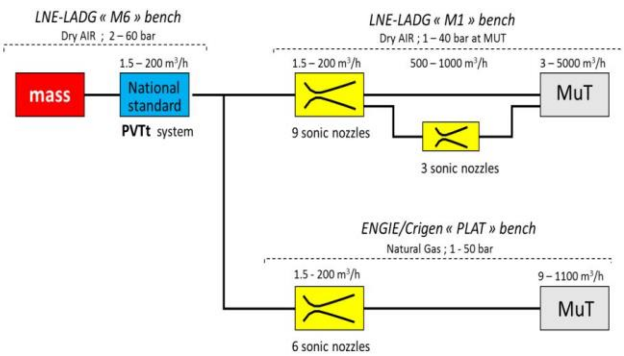

Figure 3: Schematic representation of the French traceability chain for high-pressure gas flow measurement. Sonic nozzles (yellow) are directly traceable PVTt system (blue), which is traceable to mass (red). The meter under test is calibrated by using a combination of sonic nozzles.

Denmark

The Danish traceability chain is schematically depicted in Figure 4. The primary facility (blue) is an active bidirectional piston prover that consists of two parallel cylinders in which the pistons generate flow. It is a gas-gas Piston Prover indicating that there is gas on both sides of the pistons. The pistons actuated simultaneously by external rods, displace gas out of one side of the piston, through connections, spools, a transfer meter and then finally to the other side of the pistons. The position of the pistons is measured using a micropulse linear transducer. The flow through the transfer standard calibrated by the piston prover, is unidirectional by using four valves that work together as a four-way valve. The dimensions of the cylinders are recalibrated every 5 years and a displacement transducer is calibrated every year. This makes the Piston Prover traceable to the meter (red). Three Transfer meters (green) are calibrated on the Piston Prover up to 400 m^3/h. The Working Standards (WSs, yellow) are numbered WS1 to WS7. The calibration of WS1 to WS5 and WS7 is per-formed in a bootstrapping procedure which leads to a step-by-step increase of the calibrated flow range.

All internal calibrations are performed at 0.4, 0.9, 1.7, 3.3, 6.6 MPa absolute pressure. When the internal calibrations have been completed, the Working Standards can then be used individually or in a parallel combination to calibrate a MuT (grey) at pressures between 0.4 and 6.6 MPa absolute pressure at flowrates 8-32000 m^3/h.

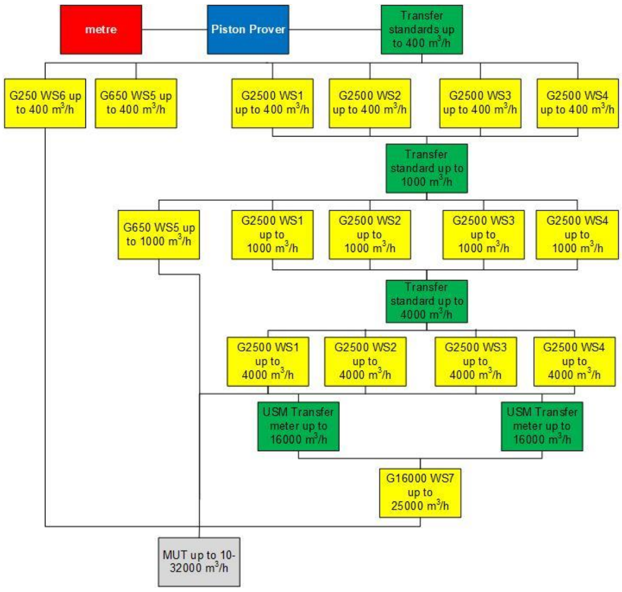

Figure 4: Schematic representation of the Danish traceability chain for high-pressure gas flow measurement. The reference meters (yellow) numbered WS1 .. WS7, are traceable via transfer standards (green) to the piston prover (blue) and the SI unit metre (red). The meter under test is calibrated by using a combination of reference meters.

References

[1] M. P. van der Beek, R. van den Brink, I. J. Landheer (2003): "Gas-Oil Piston Prover", a new concept to realize reference values for High-Pressure Gas-Volume in the Netherlands, Flomeko 2003, Groningen, the Netherlands.

[2] P. Kervevan, P. Manrot, J.-P. Vallet and Ch. Windenberger. The conception and the construction of a new high pressure primary facility for gas. 8th International Symposium on Fluid Flow Measurement, Colorado Springs, USA, June 2012