

Calibration and Measurement Capability in Water Density Micro Motion, Inc. – Boulder, CO USA

This report summarizes calibration and measurement capability (CMC) in water density at Micro Motion, Inc. in Boulder, CO USA. All uncertainties discussed include a coverage factor $k=2$.

The density calibration takes place as following:

The average meter density is compared with the average fluid density at stable flowing conditions during the middle of the calibration batch. The average fluid density is calculated based the IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use [1]. The calculation is based on measured temperature, measured pressure, and a pre-determined impurity of the water.

The temperature is measured both up and downstream of the meter using equipment that is calibrated to within ± 0.2 °C. The average of these two measurements is used for the density calculation.

Pressure is measured both up and downstream of the meter using equipment that is calibrated to within ± 0.07 bar. Pressure at the midpoint of the meter is determined from these two measurements. The midpoint pressure is used for the density calculation.

The water impurity is determined monthly, with an Anton Paar density meter (DMA 58). This meter is calibrated at 20 °C with air and a certified water sample from the Dutch national metrological institute (NMI). The density of air and water are entered into the Anton Paar during calibration. Because the Anton Paar provides an extra digit of resolution during calibration, there is no entry error for the density value of the NMI water. Additionally, the density of air entered has a negligible effect on the water density. This was observed by changing the value entered for the density of air +20 % with no change in water density values. Next, a water sample is taken from the calibration facilities and also straight from a water faucet. The density of these water samples are measured using the calibrated Anton Paar. By comparing the values obtained using water from the calibration facilities, to that of the NMI water, the water impurity can be determined.

Long term stability of the water density is determined by calculating the 95% confidence interval of 13 monthly determinations of water impurity from August 2006 to January 2008.

It was determined that density errors due to temperature measurement errors are not constant over all water temperature ranges. Therefore, three CMC values are presented to cover the typical ranges for all Micro Motion water density calibrations. At high temperatures, this becomes the largest contributor to the CMC value. This value can be reduced by using equipment with better calibration specifications.

Density errors due to pressure measurement errors are constant with pressure. All CMC values reported are independent of calibration pressure.

Calibration and Measurement Capability in Water Density

Micro Motion, Inc. – Boulder, CO USA

It should be noted that one of the largest contributors to the reported CMC values is the long term stability for water density. This could be removed by determining the water impurity for each calibration.

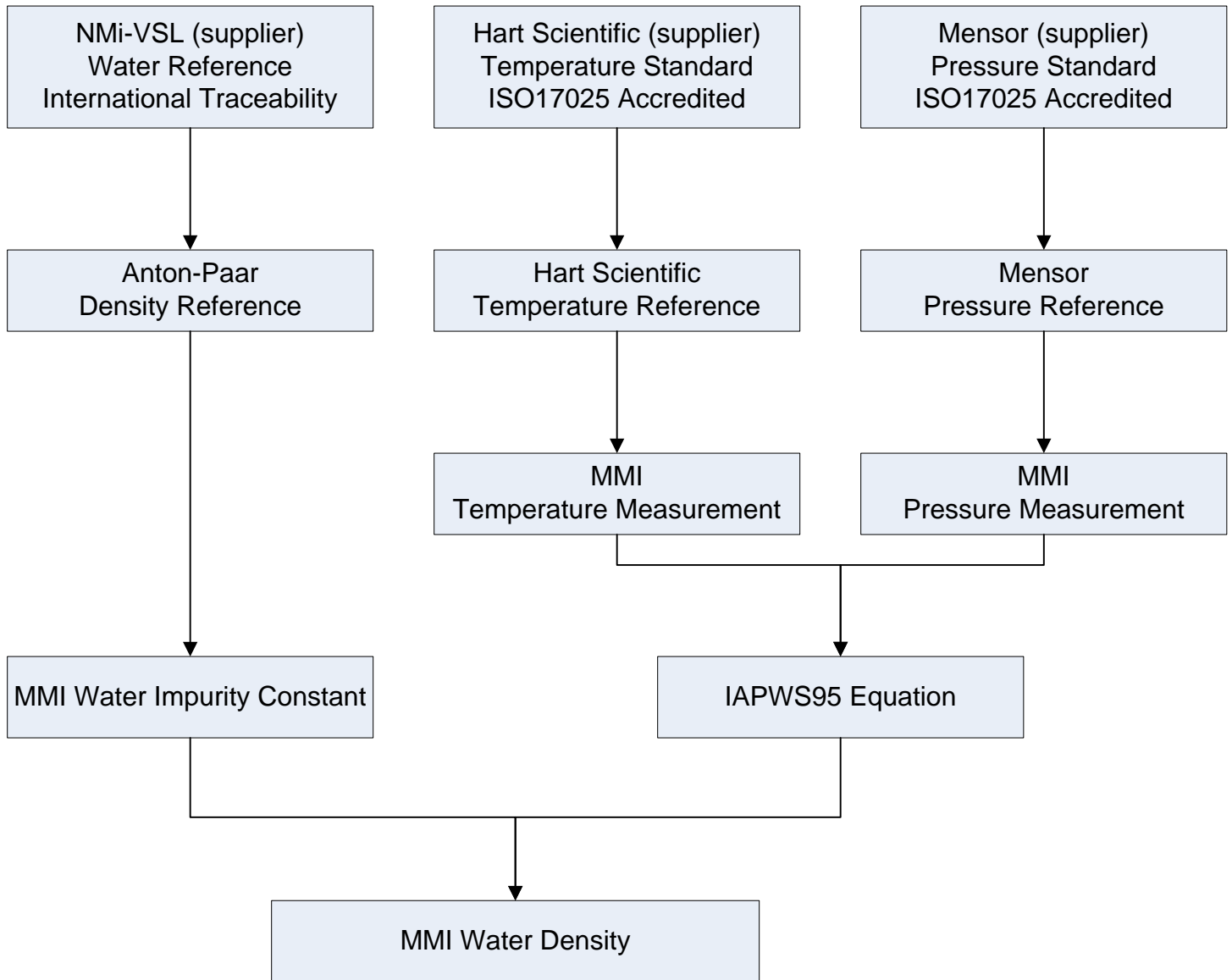
Total uncertainty in the observed density of water, expressed in kg/m³ or % is presented in the table below:

"STANDARD" Calibration and Measurement Capability in water density						
values represent expanded uncertainty with coverage factor $k=2$						
Source	Water 10 °C		Water 20 °C		Water 30 °C	
	kg/m ³	%	kg/m ³	%	kg/m ³	%
Density reference water, NMI	0.010	0.0010	0.010	0.0010	0.010	0.0010
Resolution of DMA 58 during calibration	0.001	0.0001	0.001	0.0001	0.001	0.0001
Temperature (0.01 °C at 20 °C) of DMA 58 during calibration	0.002	0.0002	0.002	0.0002	0.002	0.0002
Resolution of DMA 58 during water density determination	0.010	0.0010	0.010	0.0010	0.010	0.0010
Temperature (0.01 °C at 20 °C) of DMA 58 during water density determination	0.002	0.0002	0.002	0.0002	0.002	0.0002
Pressure of water during tests (0.07 bar)	0.003	0.0003	0.003	0.0003	0.003	0.0003
Temperature of water during tests (0.2 °C)	0.017	0.0017	0.041	0.0041	0.060	0.0060
Long term stability of water density	0.049	0.0049	0.049	0.0049	0.049	0.0049
IAPWS 1995 Equation Uncertainty	0.030	0.0030	0.030	0.0030	0.030	0.0030
CMC Water Density	0.06	0.006	0.07	0.007	0.08	0.008
Micro Motion, Inc. - Boulder, CO USA						

Calibration and Measurement Capability in Water Density

Micro Motion, Inc. – Boulder, CO USA

The following diagram illustrates the traceability chain for water density measurements.



[1] Release on the *IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use* (Fredericia, Denmark September 1996), The International Association for the Properties of Water and Steam