Report of the CCM Working Group on Density and Viscosity

Kenichi Fujii

17th CCM meeting, 16 May 2019

Bureau International des Poids et Mesures

Proposed changes to membership

- **Unification of WG Density and WG Viscosity in July 2014**
- **No change in the WGDV membership since last CCM**
- **WGDV meeting held on 13 May 2019 at the BIPM (last Monday)**
  - **27 member institutes (NMIs and BIPM)**
  - **A*STAR, BEV, BIPM, CEM, CENAM, GUM, INMETRO, INRIM, IPQ, KRISS, LNE-CNAM, METAS, NIM, NIS, NIST, NMIA, NMIJ, NMISA, NPL, NPLI, NRC, PTB, SMU, SP, UME, VNIIM, VSL**
  - **Number of participants**
    33 for density
    23 for viscosity

WG Meetings

- **held since last CCM**

  May 13th, 2019, at the BIPM (last Monday)

- **WG Meetings planned**

  In the week of the next CCM meeting at the BIPM

  For WGDV, it is difficult to hold a meeting at a conference nor other occasions because most of the members are working for the mass standard.

Main actions taken and main achievements

- **2001: Establishment of the CIPM formula for the density of water**

  M. Tanaka, G. Girard, R. Davis, A. Peuto and N. Bignell: Recommended table for the density of water between 0 °C and 40 ° C based on recent experimental reports, *Metrologia*, **38**, 301-309 (2001)

- **2003: First KC on the density of a silicon sphere (CCM.D-K1)**

- **2008: Establishment of the CIPM formula for the density of air**

  A. Picard, R. Davis, M. Glaeser and K. Fujii: Revised formula for the density of moist air (CIPM-2007), *Metrologia*, **45**, 149-155 (2008)

- **2009: Density of water: roles of the CIPM and IAPWS standards**

  A. Harvey, R. Span, K. Fujii, M. Tanaka and R. Davis: Density of water: roles of the CIPM and IAPWS standards, *Metrologia*, **46**, 196-198 (2009)

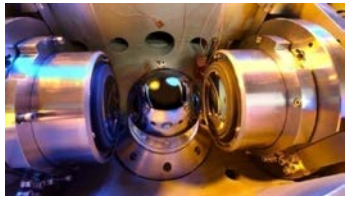
- **2016: Revision of CCM Service Category for density**

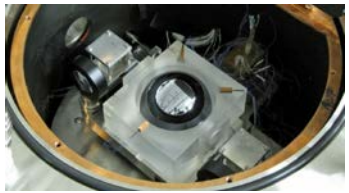
  Standard volume vessel: Density ⇒ Fluid Flow

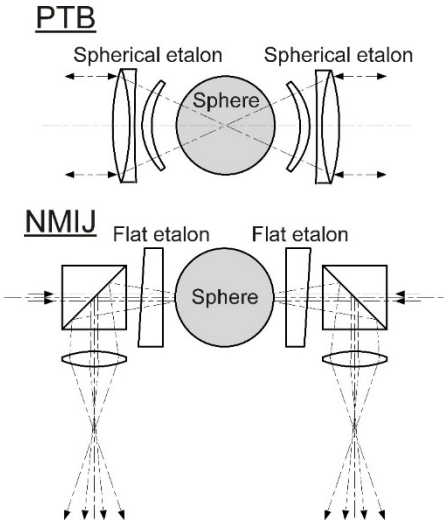
  Refractive index of liquid: new category for Density

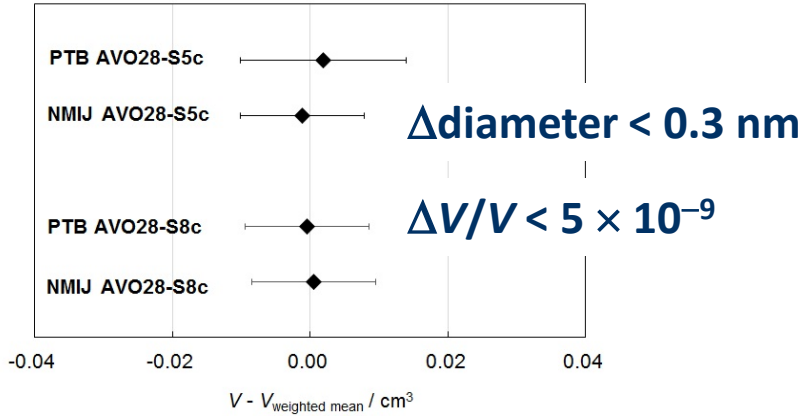
Progressing the state of the art

Fundamental reduction of uncertainty in volume and density measurements









Δdiameter < 0.3 nm

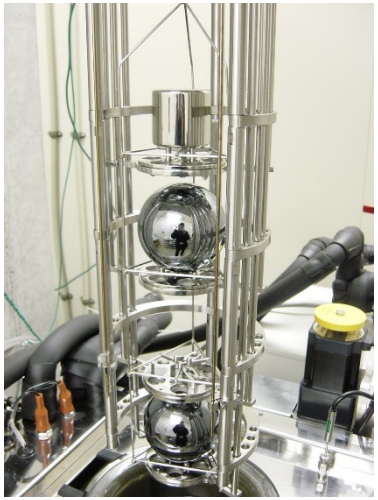
$\Delta V/V < 5 \times 10^{-9}$

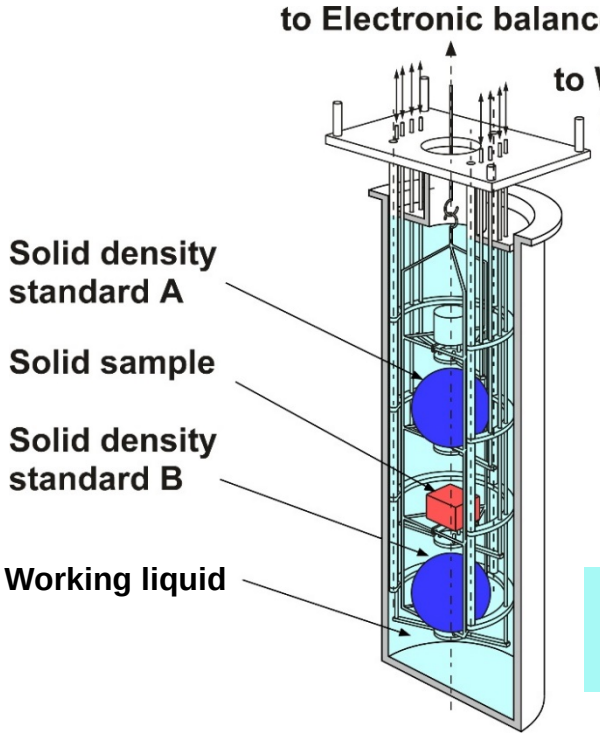
Comparison of the sphere volume measurements at PTB and NMIJ

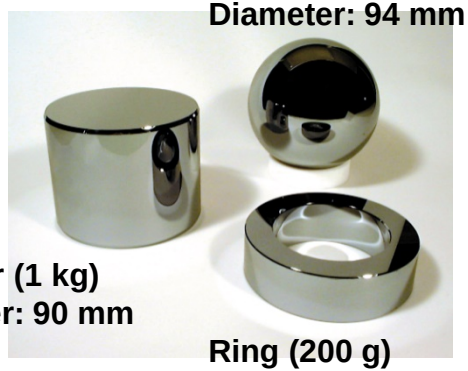
Azuma *et al.*, *Metrologia*, **52**, 360-375 (2015)

Progressing the state of the art

Fundamental reduction of uncertainty in the density measurement by hydrostatic weighing







Hydrostatic weighing: density comparator

$$u(\Delta\rho) / \rho \approx 2 \times 10^{-8}$$

Liaison & stakeholders

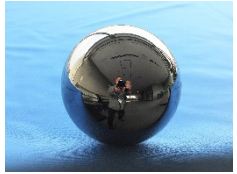
- **Silicon density standards, covered by CCM.D-K1, are now used by most of the NMIs as density standards for calibrating the density of solids, liquids, and even gases.**
- **Traditional users of density standards are the oil, liquor and alcohol industries, where there is still high demand for calibrating hydrometers in legal metrology and taxation (CCM-D-K4).**
- **However, for automatization, there is also increasing demand for using oscillation-type density meter covered by CCM.D-K2 and CCM-D-K5.**
- **In the 200 CMCs for density, about a half of them are for the density and volume of stainless steel weights. This is the reason why CCM.D-K3 is necessary.**
- **In food industry and agriculture, traceable standard for the refractive index of liquids is needed for sugar content measurements.**
- **Supplying the refractive index standard liquids, which is similar to the density standard liquids, is needed (CCM.D-K6). ⇒ Liaison with CCPR**
- **Traceable gas density measurement is needed for energy saving and energy transportation. Such a CMC will be covered by a new KC for *p*-*ρ*-*T* properties of fluids.**

KCs completed (density)

CCM.D-K1 Density measurement of a silicon sphere by hydrostatic weighing (2001-2003)

Pilot NMIJ (JP), Pilot group: METAS (CH), NRC (CA)

Participants NMIJ (JP), PTB (DE), INRIM (IT), KRISS (KR), METAS (CH), NRC (CA), CEM (ES), CENAM (MX)



CCM.D-K2 Comparison of liquid density standards (2004-2005)

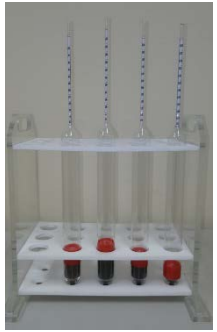
Pilot PTB (DE), Pilot group: NMIJ (JP), NRC (CA)

Participants BEV (AT), NRC (CA), PTB (DE), OMH (HU), NMIJ (JP), KRISS (KR), CENAM (MX), VNIIM (RU)

CCM.D-K4 Hydrometers (2011-2012)

Pilot INRIM (IT), Pilot group: CENAM (MX), PTB (DE)

Participants INRIM (IT), CENAM (MX), PTB (DE), LATU (UY), NMIJ (JP), LNE (FR), NMIA (AU), NIST (US), KRISS (KR)



KCs underway (density)

CCM.D-K3	CCM.D-K3	Density measurements of stainless steel weights (2019-)
	Status	Technical Protocol in progress, Participants identified
	Pilot	NMIJ (JP), Pilot group: BEV (AT), CENAM (MX)
	Participants	BIPM, NIM (CN), NIMT (TH), NMIJ (JP), A*STAR (SG), BEV (AT), INRIM (IT), METAS (CH), PTB (DE), UME (TR), NMISA (ZA), NIS (EG), CENAM (MX), INMETRO (BR), NRC (CA)

CCM.D-K5	Density measurements by oscillation-type density meters (2019-)	
	Status	Technical Protocol in progress, Participants identified
	Pilot	BEV (AT)
	Participants	BEV (AT), A*STAR (SG), NPL (UK), CENAM (MX), NMIA (AU), PTB (DE), IPQ (PT), NRC (CA), UME (TR), NMIJ (JP), SMU (SK), GUM (PL), INMETRO (BR), METAS (CH), HMI (HR), INM (RO), FORCE (DK)

KCs on hydrometer calibrations

- **CCM.D-K4 (pilot: INRIM)**
- **Linking EURAMET.M.D-K4 (pilot: INRIM) and SIM.M.D-K4 (pilot: CENAM) to CCM.D-K4 completed by INRIM and CENAM**
- **APMP.M.D-K4 (Pilot: KRISS): Draft A**
- **Covering degrees of equivalence for 36 NMIs !**

hydrometer calibration

NMI	CCM.D-K4	EURAMET.M.D-K4	SIM.M.D-K4	APMP.M.D-K4
INRiM - Italy	X	X		
MKEH (ex OMH) - Hungary	X	X		
PTB - Germany	X	X		
LNE France	X	X		
IPQ - Portugal	X	X		
VTT - MIKES - Finland		X		
BEV – Austria		X		
UME - Turkey		X		
GUM - Poland	X	X		
SMU - Slovakia		X		
VNIIM - Russia		X		
CENAM - Mexico	X		X	
BSJ - Jamaica			X	
CENAMEP - Panama				
CESMEC - Chile				
IBMETRO - Bolivia				
INDECOPI - Peru				
INEN - Ecuador				
INMETRO - Brazil				
INTI - Argentina				
LACOMET - Costa Rica				
LATU - Uruguay				
NIST - United States of America	X		X	
NRC - Canada			X	
SIC - Colombia			X	
KRISS - Korea (the Republic of)	X			X
NMIJ - Japan	X			X
NMIA - Australia	X			X
NML-SIRIM - Malaysia				X
NIMT - Thailand				X
NMISA - South Africa				X
MSL-IRL - New Zealand				X
NPL - India				X
NIM - China				X
NML-ITDI - Philippines				X
KIM-LIPI - Indonesia				X

Covering CMCs of 36 NMIs

First example of the global evaluation in the field of density

EURAMET

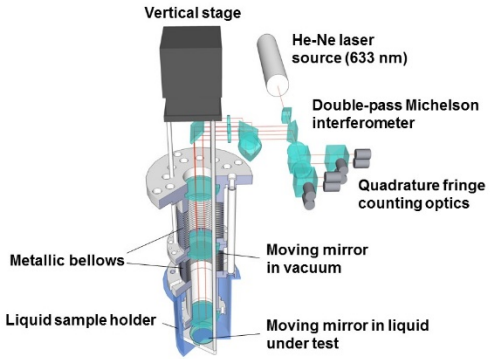
SIM

APMP (new entry)

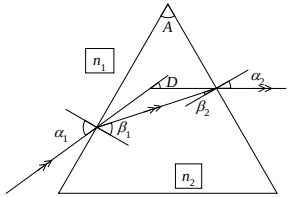
KCs planed (density)

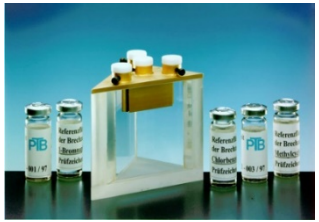
CCM.D-K6 Refractive index of liquids (2021-)

Status	Planned
Pilot	NMIJ (JP)
Comment	This KC is closely related to the samples prepared for the density standard liquids.
	It is being organized as a joint KC with CCPR because CMCs and KCs on other optical properties are in CCPR. A few NMIs in CCPR are also interested in this KC.



Interferometric method



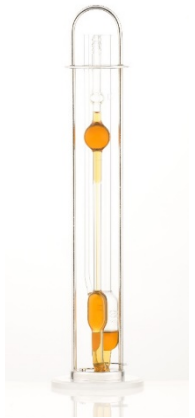


Minimum deviation angle method

KCs completed (viscosity)

CCM.V-K1 Five samples of Newtonian liquids: wide viscosity range (2002)

Status	Approved for equivalence (Final report available)
Pilot	PTB (DE), Pilot group: NMi VSL (NL), IPQ (PT), Cannon (US)
Participants	BNM-LNE (FR), Cannon (US), GUM (PL), CNR-IMGC (IT), NMIJ (JP), NMi VSL (NL), NRCCRM (CN), PTB (DE), SMU (SK), UME (TR), VNIIM (RU), BEV (AT), CENAM (MX), INM (RO), IPQ (PT), NIS (EG), NPLI (IN), SIRIM (MY)



CCM.V-K2 Six samples of Newtonian liquids: wide temperature range (2006)

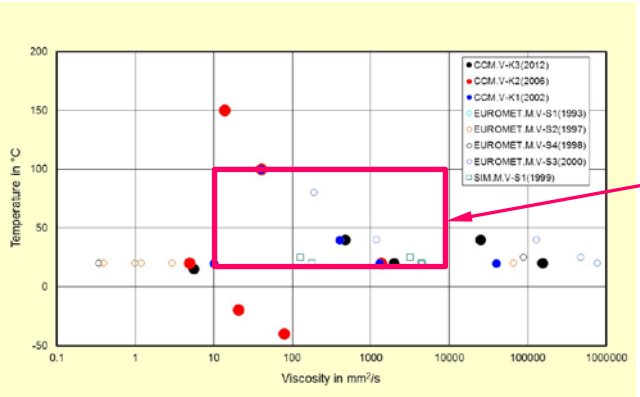
Status	Approved for equivalence (Final report available)
Pilot	Cannon (US), Pilot group: PTB (DE)
Participants	INRIM (IT), IPQ (PT), LNE (FR), NIS (EG), NMi VSL (NL), NMIJ (JP), NIM (CN), PTB (DE), VNIIM (RU), INMETRO (BR), SMU (SK), INM (RO), BEV (AT), Cannon (US)

CCM.V-K3 Three samples of Newtonian liquids: wide viscosity range (2012-2013)

Status	Approved for equivalence (Final report available)
Pilot	NMIJ (JP), Pilot Group: PTB (DE)
Participants	Cannon (US), CENAM (MX), GUM (PL), INMETRO (BR), INRIM (IT), LNE (FR), NIM (CN), NMIJ (JP), PTB (DE), SMU (SK), UME (TK), VSL (NL), BEV (AT), IPQ (PT), KEBS (KE), NIS (EG), NMISA (ZA), NPLI (IN), SIRIM (MY)

KC underway (viscosity)

CCM.V-K4	Two samples of Newtonian liquids: wide temperature range (2018-)
Status	Draft A
Pilot	CENAM (MX)
Participants	CENAM (MX), GUM (PL), INMETRO (BR), NIM (CN), NMIJ (JP), PTB (DE), SMU (SK), VSL (NL), IPQ (PT), NIS (EG), VNIIM (RU), SASO-NMCC (SA)



Range for CCM.V-K4

Program of work for the next 5 years

- **Completion of the KCs underway and planned**

  CCM.D-K3, CCM.D-K5, CCM.D-K6 and CCM.V-K4

- **Consideration on the influence of surface tension for hydrometer calibration (IPQ, Inmetro, PTB)**
- **Linking RMO KCs to the CIPM KCs**
- **Liaison with CCPR for the refractive index evaluation**
- **Consideration for the density measurement under high pressure and temperature**
- **Standards for non-Newtonian liquids**

Chair and Deputy Chair of WGDV

- Deputy Chair, Dr. Henning Wolf, retired PTB in 2018.
- Proposal

  Kenichi Fujii (NMIJ): Chair ⇒ Deputy Chair

  finding the next Deputy Chair in the field of density

  Yoshitaka Fujita (NMIJ): new Chair in the field of viscosity
- Voting completed by WGDV members of 27 institutes
- Result

  Yes: 19

  No: 0

Thank you very much for supporting the activity of WGDV.

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