# Report of the CCM Working Group on Pressure and Vacuum

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19th CCM meeting, 25-26 May 2023

CONSULTATIVE COMMITTEE
FOR MASS AND RELATED QUANTITIES

# WG Meetings held since last CCM


70 participants, 23 countries, 34 talks, 10 posters

CCM PV-7, May 18, 2023

# WG Meetings held since last CCM, planned

- 2023-05-16 in presence (UME and NIM, China online), Rockville, Maryland
- To be defined by new chairs: 2026 at the latest

# Main actions taken and main achievements

The WGPV has set clear rules for submitting CMCs in their field:

For the different ranges within the 18 decades of pressure the best units for calibration including their uncertainties were identified.

All submissions must include the uncertainties of these, or if not able to calibrate this, a unit (UUT) with higher uncertainty (now Statement 3).

Statement 2: Input options for CMC columns were defined.

# Main actions taken and main achievements

**Statement 2: Content of CMC entries for pressure, vacuum and molar flow**

| Quantity | Instrument or artifact under study | Instrument or method applied | International standard |
|---|---|---|---|
| Absolut pressure<br>Differential pressure<br>Gauge pressure<br>Molar flow rate | Defined by the WGPV (Statement 3), e.g. non-rotating piston gauge, spinning rotor gauge etc., *if* able to calibrate it. | Hg- Manometer<br>Oil-Manometer<br>Pressure balance<br>Static expansion<br>Continuous expansion<br>Refractometer<br>Atom trap<br>Reference gauge … | ISO 3567<br>ISO 27893<br>ISO 24477<br>etc. |

# Main actions taken and main achievements

- Statement 1
  Choosing participants for KCs
- Statement 2 (updated)
  Content of CMC entries for pressure, vacuum and molar flow rate
- Statement 3 (new)
  Agreement on the uncertainties of the best units under calibration for consideration in CMC entries
- Guideline for reviewers of CMC entries in the field of the CCM WG Pressure and Vacuum: Risk based approach

# Main actions taken and main achievements

From:
WGPV Guideline
for CMC review

Table 1 Supporting evidence for CMC claims dependent upon the associated risk

| Light | Risk | Required documents and items |
|---|---|---|
| 🔴 | High | • Peer reviewed publication or technical peer review for the CMC under review<br>• Written overview[1] of the measurement standard (method, reference standards, traceability, uncertainty budget)<br>• CCM KC or RMO KC[2] if applicable[3] with $E_n < 1$ and transfer standard with suitable uncertainty[4] |
| 🟡 | Medium | • Technical peer review or written overview of the measurement standard (method, reference standards, traceability, uncertainty budget)<br>• RMO KC[5] or hybrid comparison[6] with $E_n < 1$ and transfer standard with suitable uncertainty |
| 🟢 | Low | • SC or hybrid comparison with $E_n < 1$ and transfer standard with suitable uncertainty<br>• Traceability to another CMC entry or fundamental method |

# Main actions taken and main achievements

From:
WGPV Guideline
for CMC review

For **Sector "A" (absolute pressure up to 170 kPa)** the risks are classified as follows (see also graph):

Table 2 Criteria for high and low risk for Sector A (absolute pressure up to 170 kPa[7])

| Light | Risk | Relative uncertainties or pressure range | Applicable in range |
|---|---|---|---|
| 🔴 | High | Independent of uncertainty value: pressure range < $10^{-6}$ Pa | < $10^{-6}$ Pa |
| | | $U^{*}_{\mathrm{rel}} \leq U^{\mathrm{H}}_{\mathrm{rel}}$<br>$U^{H}_{\mathrm{rel}} = 3.5 \cdot 10^{-3} \cdot (p/\mathrm{Pa})^{-0.1618}$ | $10^{-6}$ Pa ≤ $p$ < 1 Pa |
| | | $U^{H}_{\mathrm{rel}} = 3.5 \cdot 10^{-3} \cdot (p/\mathrm{Pa})^{-0.4736}$ | 1 Pa ≤ $p$ < 170 kPa |
| 🟡 | Medium | $U^{\mathrm{H}}_{\mathrm{rel}} < U^{*}_{\mathrm{rel}} \leq U^{\mathrm{L}}_{\mathrm{rel}}$ | |
| 🟢 | Low | $U^{*}_{\mathrm{rel}} > U^{\mathrm{L}}_{\mathrm{rel}}$<br>$U^{\mathrm{L}}_{\mathrm{rel}} = 1.4 \cdot 10^{-2} \cdot (p/\mathrm{Pa})^{-0.147}$ | for $10^{-6}$ Pa ≤ $p$ < 10 Pa |
| | | $U^{\mathrm{L}}_{\mathrm{rel}} = 3.8 \cdot 10^{-2} \cdot (p/\mathrm{Pa})^{-0.575}$ | for 10 Pa ≤ $p$ < 170 kPa |

# Main actions taken and main achievements

From:
WGPV Guideline
for CMC review

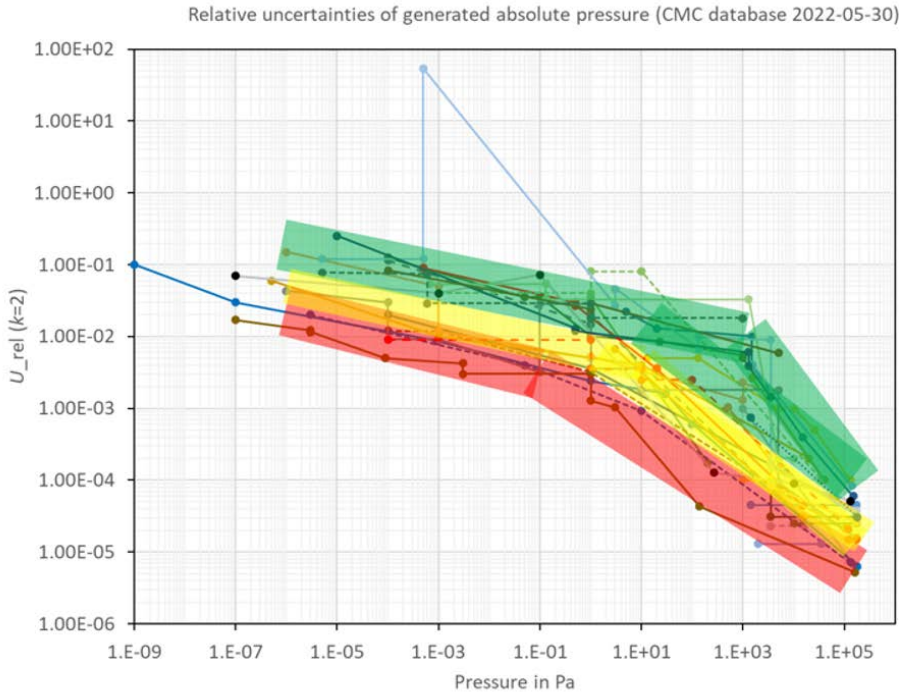
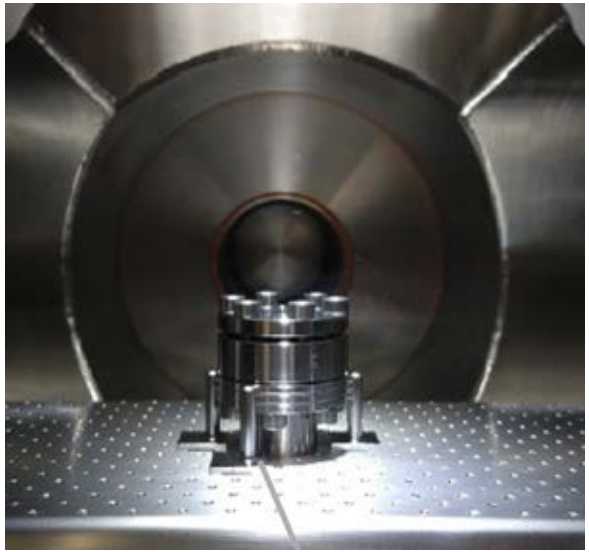



Figure 1 CMC entries in the KCDB as of 2022-05-31 with the colours indicating the associated risks for the CMCs and their dependence on pressure up to 170 kPa. Red: high risk, yellow medium risk, green low risk. Note that the uncertainties are relative and the plot is on a log-log scale.

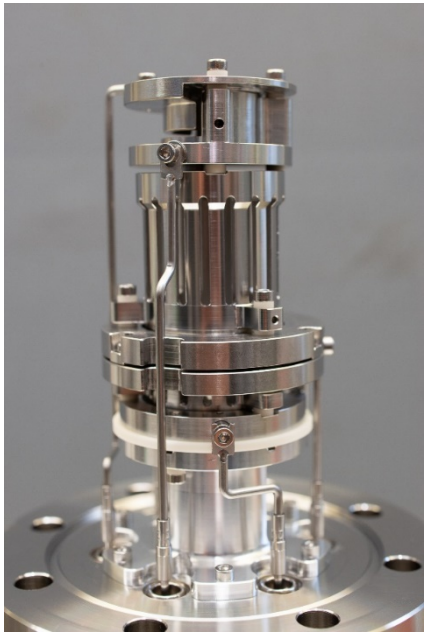
# Progressing the state of the art

## Outgassing standard



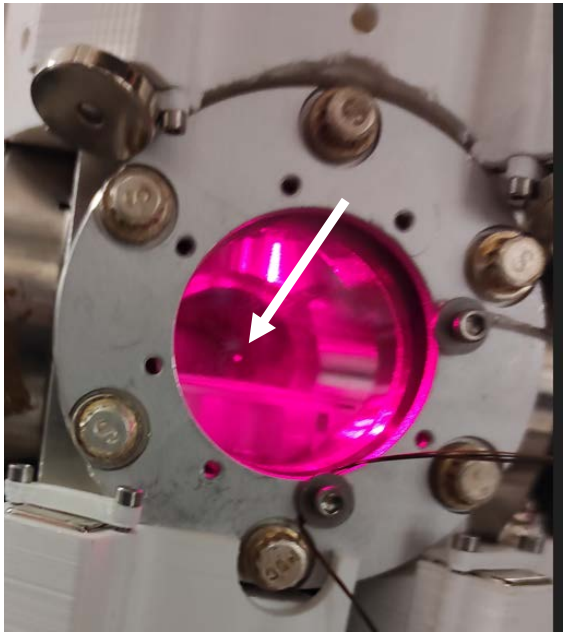
Traceability for
outgassing measurement

## New ionisation gauge



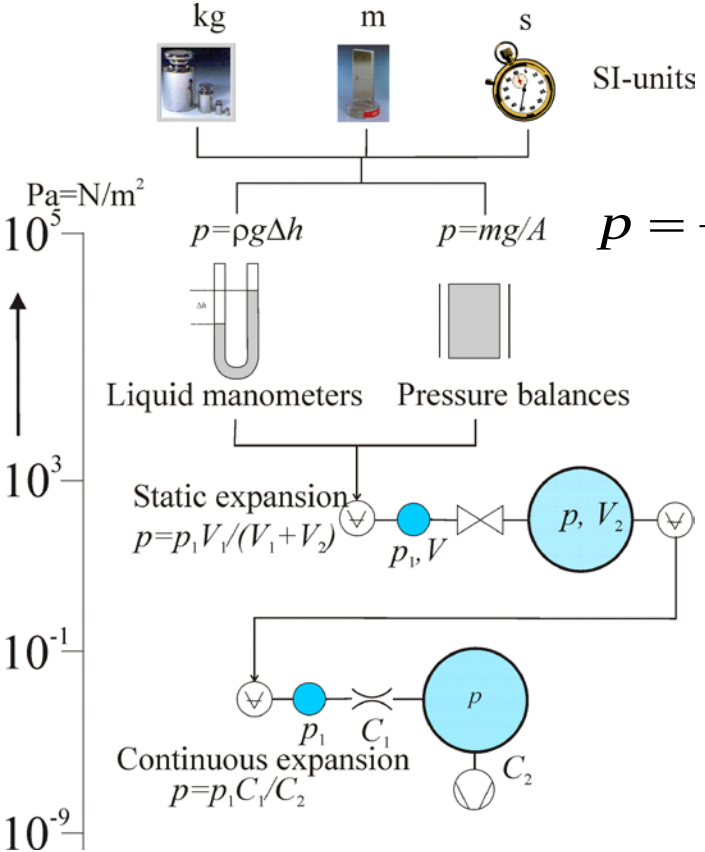
Reference standard
for high vacuum

## Atom traps



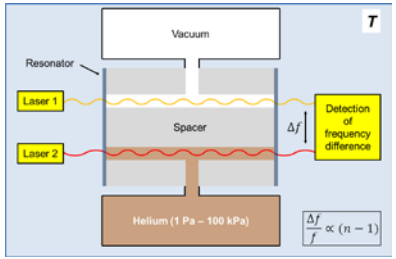
Primary standard
for ultrahigh vacuum

# Progressing the state of the art

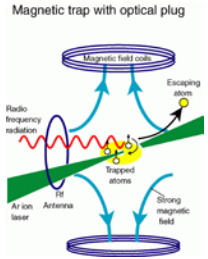



$$p = \frac{F}{A}$$

$$p = \rho_N kT$$




$$\rho_N = \frac{3\varepsilon_0}{\alpha} \cdot \frac{n^2 - 1}{n^2 + 2}$$




$$\rho_N = \frac{\Gamma}{\langle v\sigma \rangle}$$

# Progressing the state of the art

- **Vision to be discussed**:
  Change the quantity for vacuum from pressure (pascal) to gas number density ($m^{-3}$) in molecular regime (< 0.1 Pa)?
- Why?
  Density, not pressure is important in this regime for applications (density/mean free path in accelerators, PVD, CVD, EUV lithography, thermal insulation …). Gas number density (temperature not needed) can be directly realized with much lower uncertainty by new optical methods!

# Liaison & stakeholders

- No formal liaison, but close relationship with ISO TC 112 (Vacuum Technology) and IMEKO TC-16
- Stakeholders: Universities, research institutes (mainly for atom traps, ab initio cross section calculations and refractometers, ab initio calculations of molar polarizability) Accelerator operating institutes, Vacuum and pressure gauge manufacturers, semiconductor industry

# KCs completed and underway

- “Triple KC” CCM.P-K16/17/18, 9 participants: measurements almost completed (K16, 25 to 350 kPa, absolute; K17, 25 to 350 kPa, gauge; K18, 0.7 – 7 MPa, gauge)
- CCM.P-K3 (NIST, PTB), 1 Pa to 10 kPa, start delayed 2018 to 2022, NIST-1 completed, PTB must compensate for the sudden death of engineer

# KCs planned

- P-K3 planned since 2017, NMIJ relinquishes pilot, PTB will take over, NMI co-pilot. Restart 2024.
- ATL (atmospheric leak), LNE relinquishes pilot, CMI or NMIJ will take over, restart 2024
- Liquid pressure, 1 MPa up to 100 Mpa, gauge mode, oil: PTB pilot, NRC, LNE, NPL/I, NMIJ, KRISS, NMI Saudi Arabia, NIST

# Program of work for the next 2 years

Pressure:

- Replacement of primary mercury manometers by alternative standards: special pressure balances, oil manometers and optical standards (new metrology, environment, reduction of traceability chain)
- Low differential pressures with high accuracy and low line pressure – energy saving
- Standards for industrial high pressure technologies (also above 1 GPa) – food preservation, $H_2$ as energy carrier
- Traceable blood and intraocular pressure - health

Vacuum:

- Leak reference standards and transfer standards (hydrogen as carrier gas for energy)
- Standards for outgassing, outgassing reference probes
- Standards for partial pressure measurements (climate change observations)
- Cold atom traps as UHV measurement standard (new metrology)

Pressure and vacuum:

- Optically based standards for pressure (see Metrologia 54, S146 – S161)
- Dynamic pressure measurements
- Digital certificates

# Proposed changes (membership, chairmanship, ToRs)

- No changes in membership (except new representatives)
- New observer status: RISE (Sweden), GUM (Poland)
- New chairperson as of 2023-06-01: Julia Scherschligt, NIST
  New Vice-chair as of 2023-06-01: Hiroaki Kajikawa, NMIJ

Julia Scherschligt,
NIST
Expertise Vacuum

Hiroaki Kajikawa,
NMIJ
Expertise Pressure

In charge as WG chair since 2005.
2005-2014 WG Low Pressures
2014-2023 WG Pressure and Vacuum
**Thank you for your support! Good bye!**

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CCM