ISO 27891
Aerosol particle number concentration – Calibration of condensation particle counters

ISO TC 24/SC 4
Particle Characterisation

Please note that all information given in this presentation is preliminary and may change on the way to the final version of ISO 27891.

>>> Only for use within WLTP PMPN <<<

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UNDERSTANDING, ACCELERATED

November 2013

Overview

- Scope
- Actual status of ISO 27891(November 2013)
- General principle
- Primary aerosol & calibration aerosol
- Mixing & flow splitting
- Reference instruments
- Calibration procedure
- Annexes of ISO 27891

Scope of ISO 27801

- Describe methods to determine the detection efficiency of condensation particle counters (CPCs) at particle number concentrations in the range between 1 and 10^5 cm^{-3}, together with the associated measurement uncertainty.
- The particle sizes cover a range from approximately 5 nm to 1000 nm.
- Applicable for inlet flows between approximately 0.1 l/min and 5 l/min.

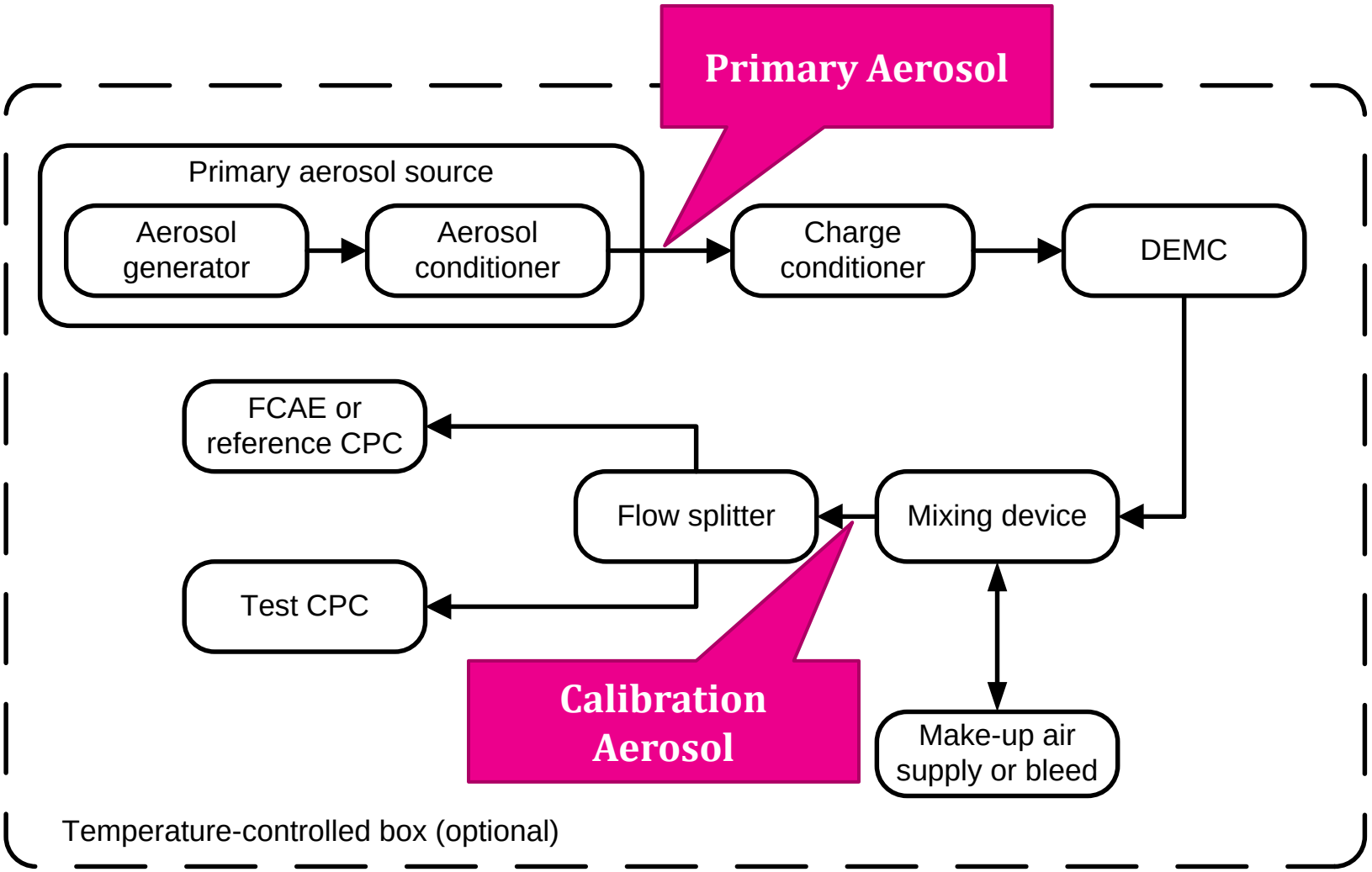
ISO 27891 – Actual Status

- Draft International Standard (DIS) was submitted to ISO secretariat for DIS vote in May 2013. The ballot ended in October 2013.
- Voting result for ISO/DIS 27891: **Approved.**
  - P-Members voting: 10 in favour out of 10 = 100 % (requirement >= 66.66 %)
  - Member bodies voting: 0 negative votes out of 11 = 0% (requirement <= 25 %)

ISO 27891 – Schedule

- Comments on ISO/DIS 27891 have been discussed during the ISO TC 24/SC 4/WG 12 meeting in October in Jacksonville, Florida.
- Final Draft International Standard (FDIS) will be submitted to ISO secretariat before May 8, 2014.
- Publication of ISO 27891 as International Standard is expected in mid-2014.

General Principle – Schematic Setup



Primary Aerosol

- ISO/DIS 27891 does **not** specify aerosol materials and primary aerosol generation methods.
  - Application standards/ guidelines / procedures (like UN-ECE Reg 49 / 83 or PMP) may specify aerosol materials and primary generation methods.
- The stability of flow rate, number concentration and size distribution of the *primary aerosol* shall be such that the requirements for the *calibration aerosol* are fulfilled.

Calibration Aerosol - I

- A CPC calibration certificate is only applicable for the calibration aerosol that is described in the calibration certificate, especially at low particle size.
- Narrow size distribution, so that the size of the particles is well defined (typically GSD < 1,1 for the primary peak in the size distribution) to minimize uncertainty in size and efficiency;
- Stable mode diameter, and stable number concentration in relation to the required time for calibration (typically 10 min for one point), so that the calibration can take place in essentially constant conditions.

Calibration Aerosol - II

- Small fraction of multiply-charged particles (required < 10%, typically < 5 %)
  - these become a significant component of the uncertainty for FCAE calibrations
  - they form extra populations of particles at unwanted larger sizes
- A low vapour content from water, other dispersion media and/or solvents
  - to minimise the growth of particles within the system
- A stable and reproducible gas phase and particle type

Reference Instruments

Table 1 — Calibration aerosol requirements for the FCAE and reference CPC

Reference Instrument	Particle diameter range, nm	Typical particle concentration range, cm^{-3}	Calibration aerosol particle charge requirements	
			Test CPC calibrated at lower detection limit particle diameters	Test CPC calibrated in plateau range of particle diameters
FCAE	5 - 1000	10^3 to > 10^5	$\Phi < 0{,}1$	$\Phi < 0{,}1$
CPC	$d_{min,ref}$ - 1000	~1 to > 10^4	$\Phi < 0{,}1$	no restriction

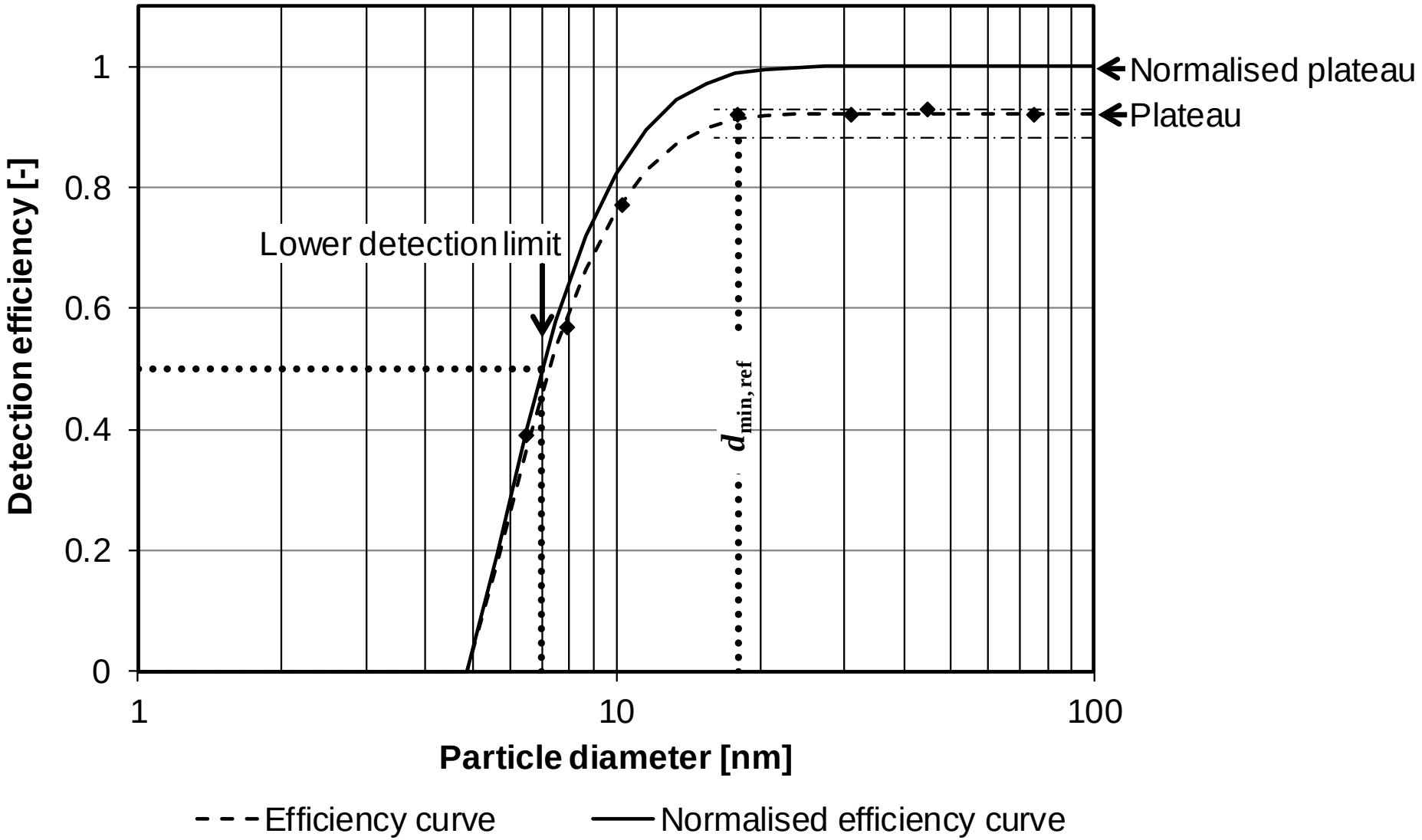
!

The fraction of multiply-charged particles, Φ, is calculated as $\Phi = \sum_{p\geq 2} \phi_p$

$$\phi_p = C_N(d_p) \Big/ \sum_{p\geq 1} C_N(d_p)$$

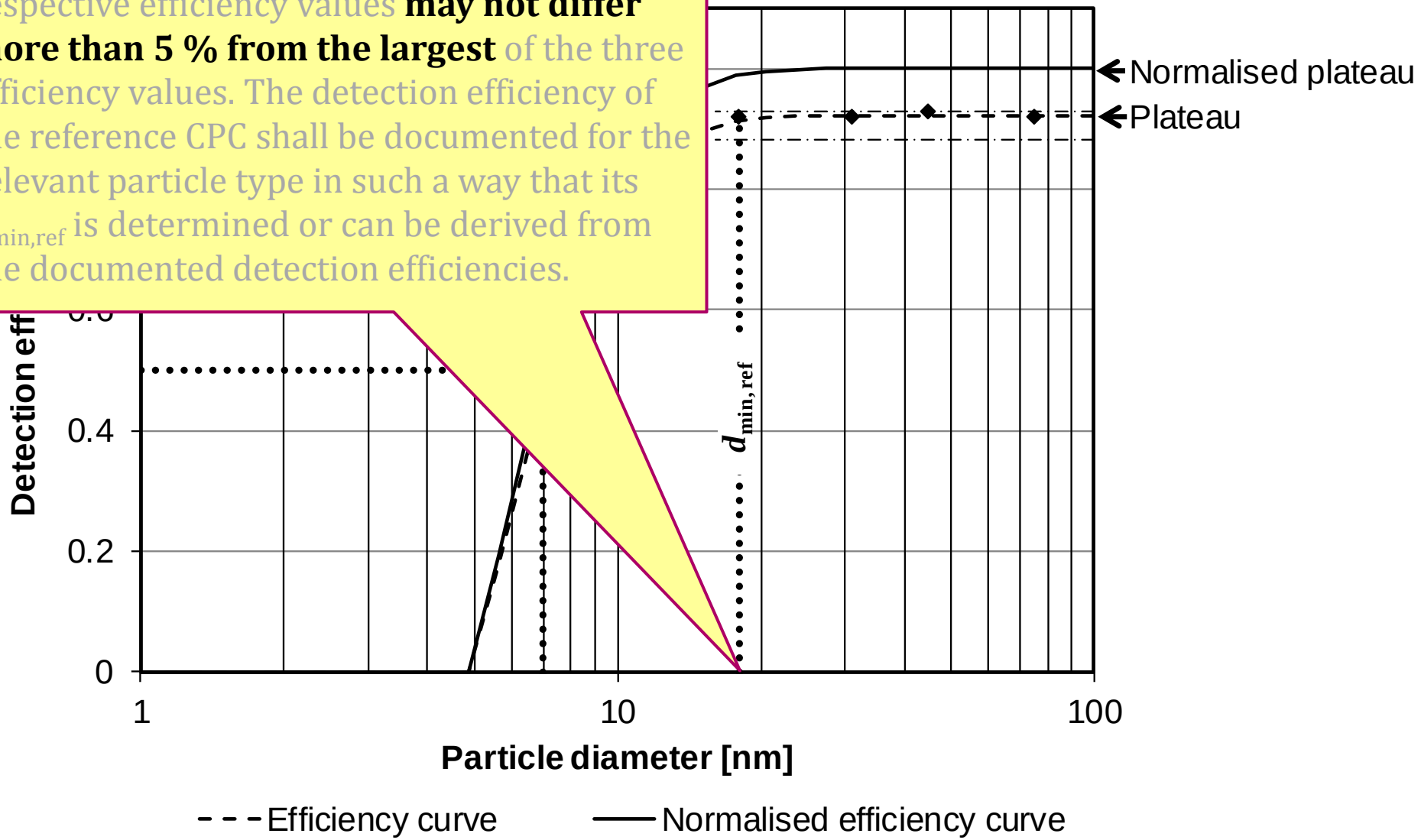
where $C_N(d_p)$ is the concentration of particles with p charges in the calibration aerosol

Reference CPC: $d_{min,ref}$



: $d_{min,ref}$

The lower size limit $d_{min,ref}$ for the application of the reference CPC for calibration of test CPCs is the **smallest value of at least three diameters, the two larger diameters are at least 2 and 3 times $d_{min,ref}$.** The three respective efficiency values **may not differ more than 5 % from the largest** of the three efficiency values. The detection efficiency of the reference CPC shall be documented for the relevant particle type in such a way that its $d_{min,ref}$ is determined or can be derived from the documented detection efficiencies.



The following slides…..

…..present more details for those who are interested.

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Reference Instruments

- Reference instruments (FCAE or CPC) shall have a current, reputable calibration certificate.
  - ISO 27891 also includes procedures to validate an FCAE
- Reference instrument calibration certificates must cover the relevant particle number concentrations, sizes and particle type
- The calibration certificate for the FCAE shall specify the aerosol flow rate measurement (volumetric flow rate, inlet pressure and inlet temperature) and the electrical charge concentration (or electrical current) measurement.

Reference Instruments

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- measurement.

A reputable calibration certificate shall mean either one that has been produced by a laboratory accredited to ISO/IEC 17025 or an equivalent standard, where the type and range of calibration is within the laboratory's accredited scope, or a European Designated Institute or a National Metrology Institute that offers the relevant calibration service and whose measurements fulfil the requirements of ISO 17025.

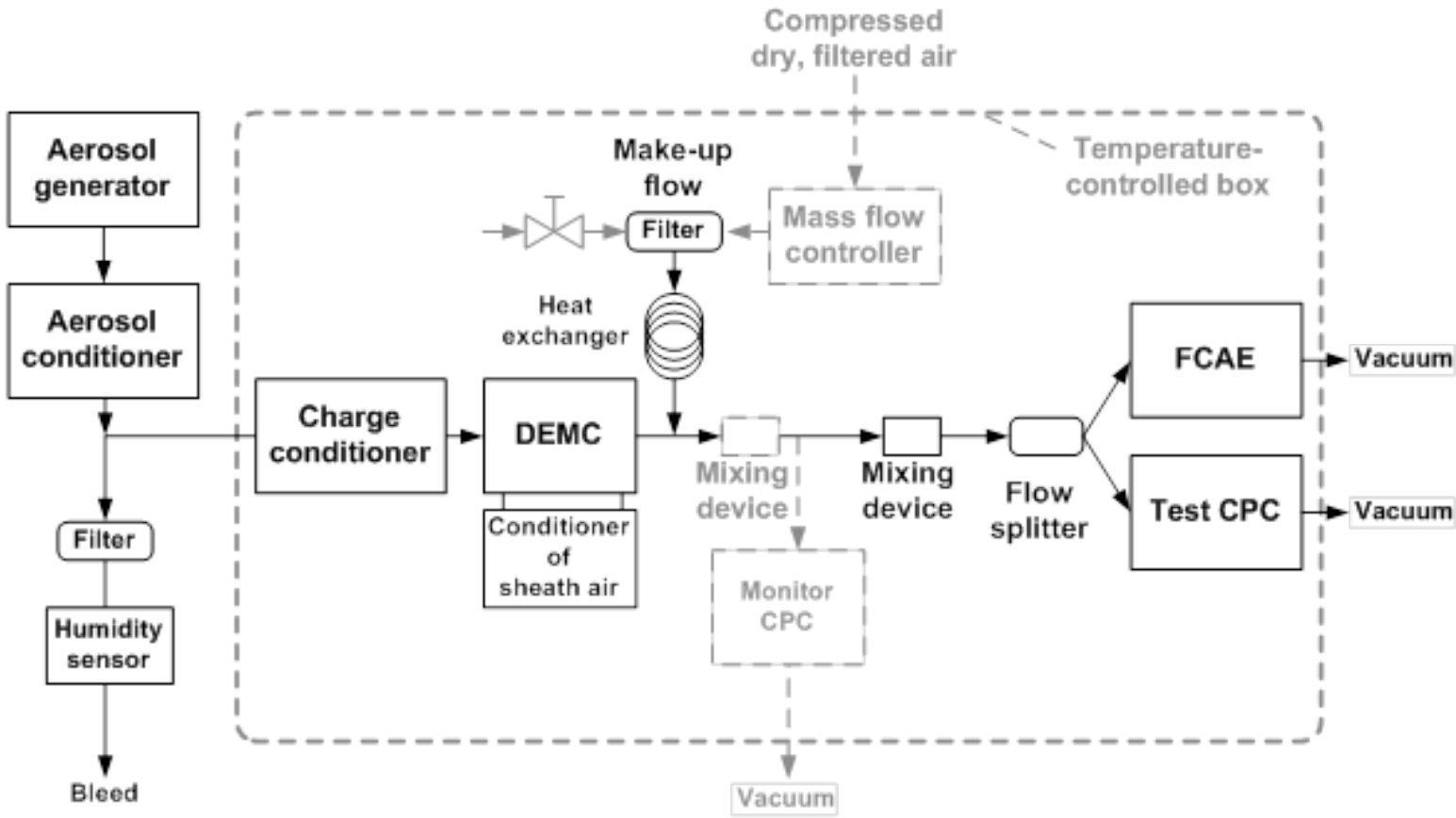
Reference Instruments - CPC

- The reference CPC shall have a design such that the aerosol flow sampled through the inlet shall not be diluted or filtered and the total inlet flow shall be let to the optics.
- It must be operated in single particle counting mode. The reference CPC shall not be used in photometric mode.
- The lower size limit for the application of the reference CPC for calibration of test CPCs is $d_{\mathrm{min,ref}}$

Reference Instruments - CPC

- The calibration certificate for the reference CPC can be the result of either a calibration against a traceably calibrated FCAE, or a calibration with another CPC used as a reference instrument.
- It shall specify
  - particle type, the particle sizes, the particle number concentrations for which the calibration is valid,
  - the maximum concentration of the reference CPC in single counting mode,
  - volumetric inlet flow rate, inlet pressure and inlet temperature at the time of calibration.

Example: FCAE Calibration Setup



The calibration setup with FCAE as reference instrument. Dashed lines in grey show equipment that is not required, but highly recommended.

Mixing & Flow Splitting

- Concentration bias resulting from poor mixing is a major source of error in CPC calibration.
  - Baffle plates, mixing chambers, and mixing orifices are examples for proven devices to avoid this bias.
- A method is provided to eliminate flow splitting bias if reference instrument and test CPC have the same flow rate.
- If both instruments cannot be operated at the same flow rate, the length of the connection tubing shall be used to compensate the difference in the transfer losses.
  - The ratio of the different inlet flow rates shall not be larger than 5 or smaller than 0.2

Calibration Procedure (FCAE) - Preparation

6.2	Preparation
6.2.1	Aerosol generator and conditioner (size distribution)
6.2.2	Other equipment (e.g. mass flow meters etc.)
6.2.3	DEMC (acc. to ISO 15900) and sheath air conditioner
6.2.4	FCAE Flow measurement and stability < 2 % (from 5 measurements in 15 min) Zero value for charge concentration times inlet flow rate < 1 fC/s, standard deviation < 0,5 fC/s (from 30 s averages of 15 min) Overall leak test
6.2.5	Test CPC Flow measurement and stability < 2 % (from 5 measurements in 5 min) Zero arithmetic mean < 1 cm^{-3}, standard deviation < 0,5 cm^{-3} (from 30 s averages of 5 min) High response check
6.2.6	Connect the instruments and the aerosol generator/conditioner to the DEMC DEMC (voltage off), sheath to sample > 7:1 FCAE flow measurement FCAE zero value for charge concentration times inlet flow rate < 1 fC/s, standard deviation < 0,5 fC/s (from 30 s averages of 2 min) Test CPC zero arithmetic mean < 1 cm^{-3}, standard deviation < 0,5 cm^{-3} (from 30 s averages of 2 min) Determine minimum level of FCAE charge concentration times inlet flow rate (zero + 3 x std. dev. + 1,5 fC/s)

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Calibration Procedure (FCAE) – Measurement of Detection Efficiency

6.3	Detection efficiencies
6.3.1	DEMC diameter adjustment
6.3.2	Primary aerosol adjustment The concentration to be within the capability of the charge conditioner Multiply charged particles fraction < 10% Concentration within the range of the FCAE
6.3.3	Splitter bias b measurement
6.3.4	Test CPC efficiency measurement At the specific diameter and concentration: - Record 1 min FCAE, test CPC, use the last 30 s for the calculations - FCAE [CPC] standard deviation < 0,5 fC/s [0,5 cm^{-3}], or CV < 3 % Set DEMC voltage off (or 0) - Record 1 min FCAE, test CPC, use the last 30 s for the calculations - FCAE [CPC] arithmetic mean < 1 fC/s [1 cm^{-3}], standard deviation < 0,5 fC/s [0,5 cm^{-3}], Calculate detection efficiency Repeat another 4 times Calculate the arithmetic mean detection efficiency, arithmetic mean within ± 0,015
6.3.5	Measurement of a different concentration (optionally) Go to 6.3.2 and then 6.3.4
6.3.6	Measurement of a different size (optionally) Go to 6.3.1
6.3.7	Repetition of first measurement If > 3 points have been tested (difference has to be within 0,02)
6.3.8	Fill in the calibration certificate

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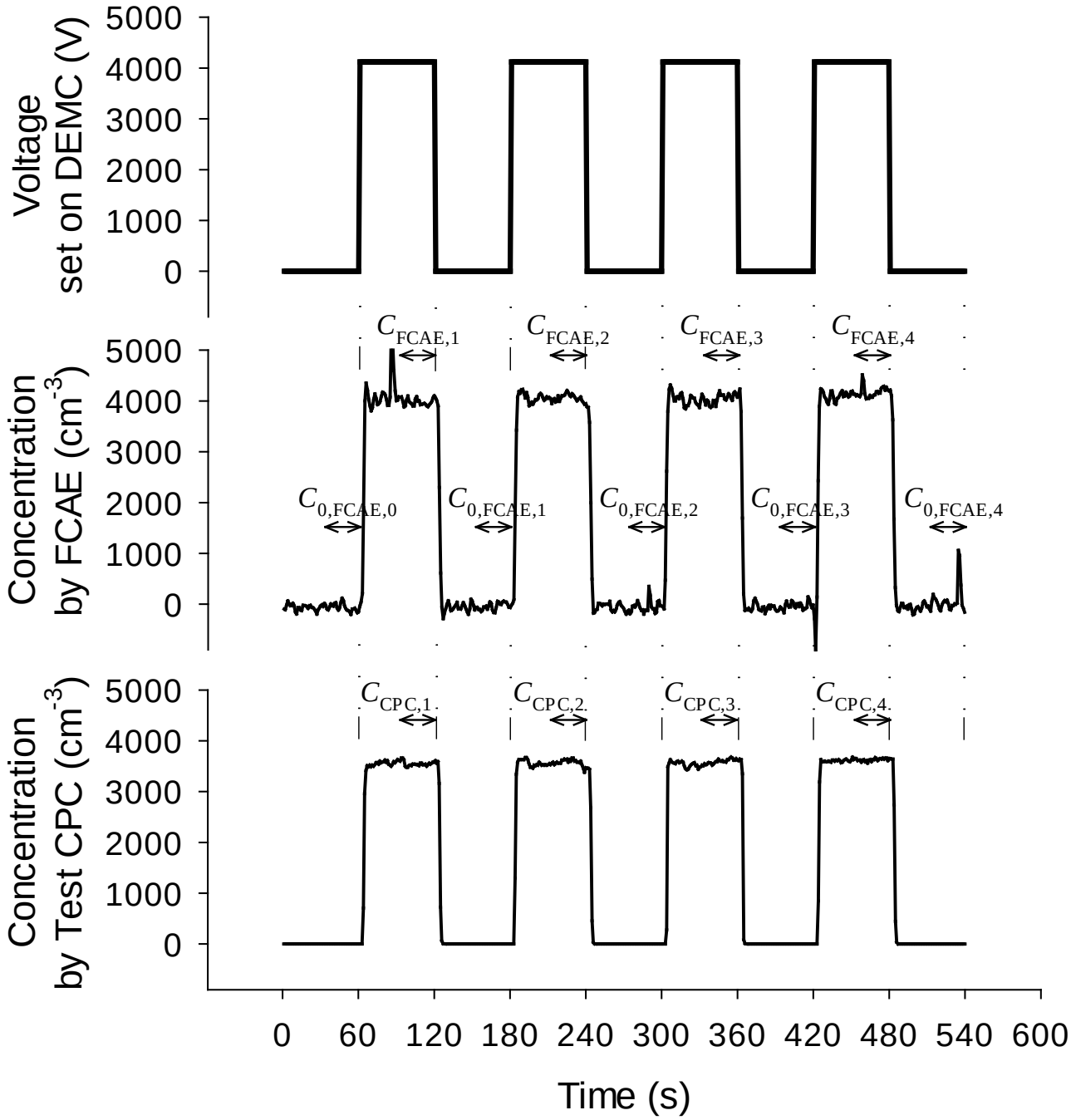
Recommended Data Recording (FCAE)



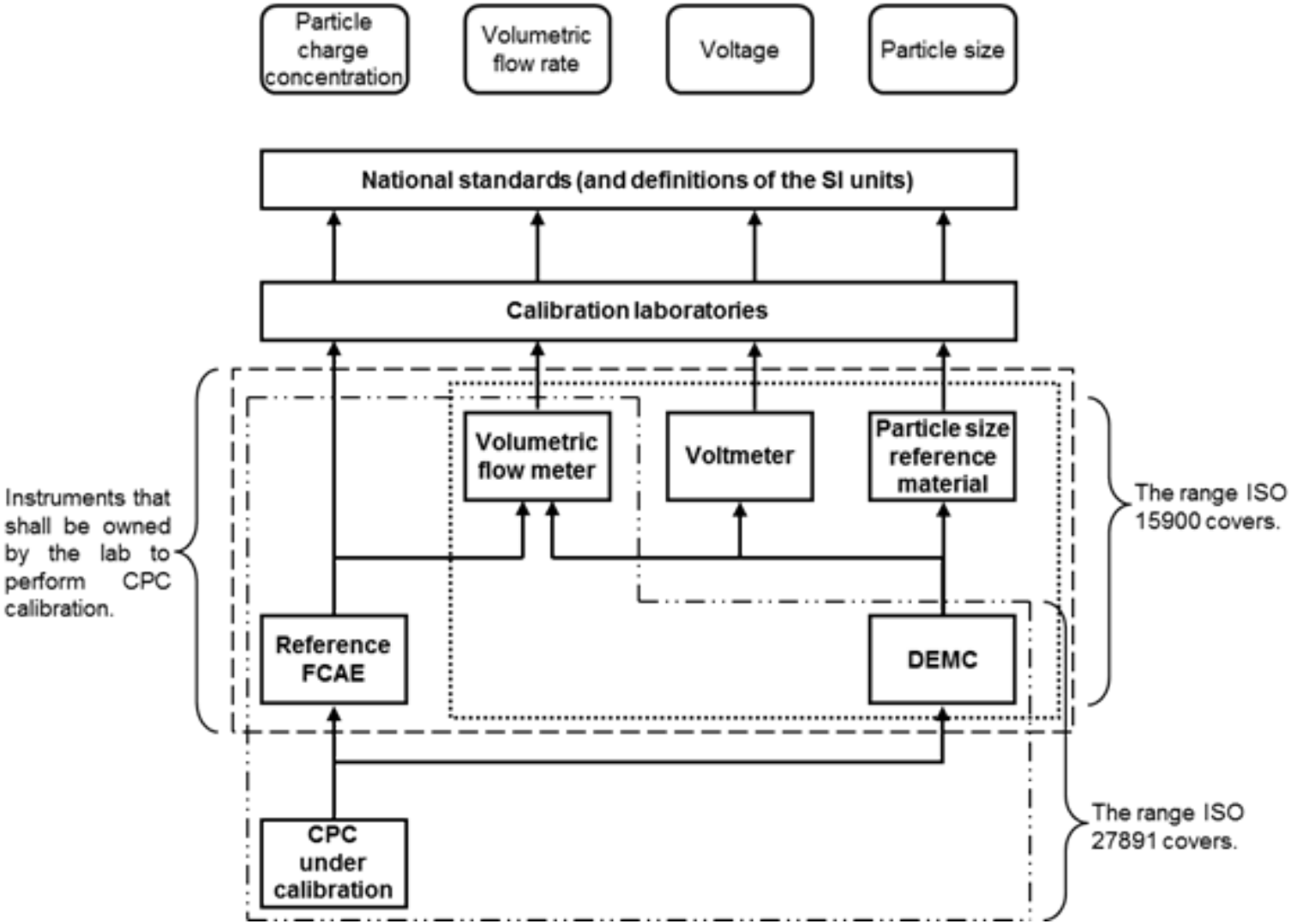
Further Remarks

- Calibration with a reference CPC follows the same principle as reference FCAE (but some equations are different).
- Calibration with a reference CPC is faster (no intermittend zeroing necessary; 4 minutes instead of 9 minutes to determine the detection efficiency).
- For both methods, equations to determine their measurement uncertainty are given.

ISO 27981 - Annexes

A (informative)	CPC performance characterisitics
B (informative)	Effect of particle surface properties on the CPC detection efficiency
C (informative)	Example calibration certificates
D (normative)	**Calculation of the CPC detection efficiency**
E (informative)	Traceability diagram
F (informative)	Diluters
G (normative)	**Evaluation of the concentration bias correction factor between the inlets of the reference instrument and the test CPC**
H (informative)	Extension of calibration range to lower concentrations
I (informative)	Example of a detection efficiency measurement
J (normative)	**Volumetric flow rate calibration**
K (normative)	**Testing the charge conditioner and the DEMC at maximum particle number concentration**
L (informative)	A recommended data recording method
M (informative)	Uncertainty of detection efficiency due to particle size uncertainty
N (informative)	Application of calibration results

ISO 27891 – Traceability (FCAE Example)



The four directly traceable quantities do not completely underpin the quantity measured by the CPC – particle number concentration. **The extra parameter - the mean charge per particle used for the calibration – is determined by the experimental setup, and is controlled by the procedures and checks described in Annex D of ISO 27891.**

Finally….

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Many thanks for your attention!

Questions?

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