DESIGN CRITERIA AND DEVELOPMENT OF THE NEXT GENERATION OF BUTANOL-CPCs

AAAR:
Raleigh, NC, USA
October 16-20, 2017

Axel Zerrath, Andrea Tiwari, Jacob Scheckman, Brian Osmondson[1]
[1] TSI Inc., 500 Cardigan Road, 55126 Shoreview, MN, USA
Contact: axel.zerrath@tsi.com

Introduction

For over four decades Butanol-based Condensation Particle Counters (CPCs) have contributed significantly to the understanding of nanometer-sized particles and their physical properties. As technology progresses and research moves towards exploring new frontiers, the instrumentation has to keep up pace. The result of research driven innovation is presented here with the next generation of CPCs.

Particle Number Concentration Range

CPCs are operated to monitor nanoparticle concentration in a variety of environments, including

- high concentration, such as mega cities, street canyons or nanoparticle production reactors
- low concentration such as in hospitals or after filters
- environments where technical standards are in place, such as environmental air quality monitoring

Figure 1 compares the improved concentration ranges of the new CPCs to the previous versions.

As can be seen for model 3750 the high accuracy single count mode where each particle is counted as it passes through the CPC's optics was increased 10-fold compared to the widely used model 3772.

In Europe a consensus was reached on requirements for a CPC for atmospheric monitoring and published as CEN/TS 16976. The compliant Model 3750-CEN CPC is calibrated with silver particles by TROPOS. Combined with a compliant sampling system, concentrations now up to 300,000 #/cm³ can be reliably monitored.

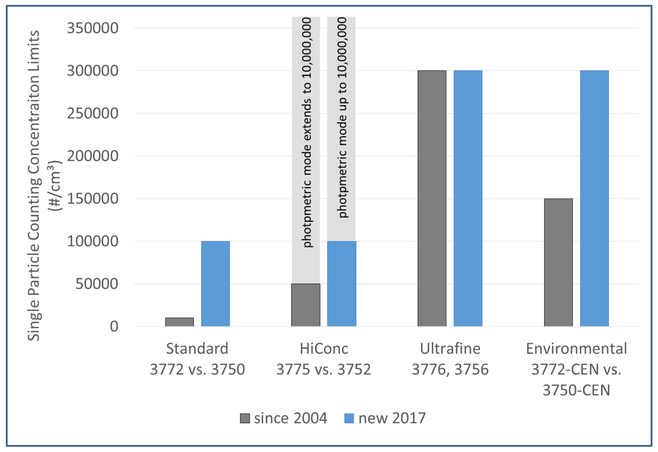

Fig. 1: The dynamic operating range of various CPC solutions. The graph shows maximum particle concentrations, comparing old versus new models.

High upper concentration limits are desirable for some applications, but achieving them while maintaining accuracy is a challenge. Besides the ability to accurately count particles of the specified minimum size (typically between 1 and 10 nm; see "Counting Efficiencies" at right), particle counting accuracy requires the ability to count individual particles as they pass through the CPC's optics.

Response Times

A response time describes the time it takes for a counter to follow a step (significantly steep) change in particle concentration.

Specifications may be published on different basis of measurements, so the user has to pay attention.

The response time is important if the CPC is used stand-alone. In a sizing system (SMPS) the transfer time from a DMA outlet to the CPC inlet is adding to the response time, thus fast scanning of distributions requires a system approach, e.g. like in the SMPS 3938.

New $T_{90\text{-}10\%}$	Low flow	High flow
Standard CPC 3750	n/a	~1 s
High Conc. CPC 3752	~1 s	~1.5 s
Ultrafine CPC 3756	<0.2 s	~1 s

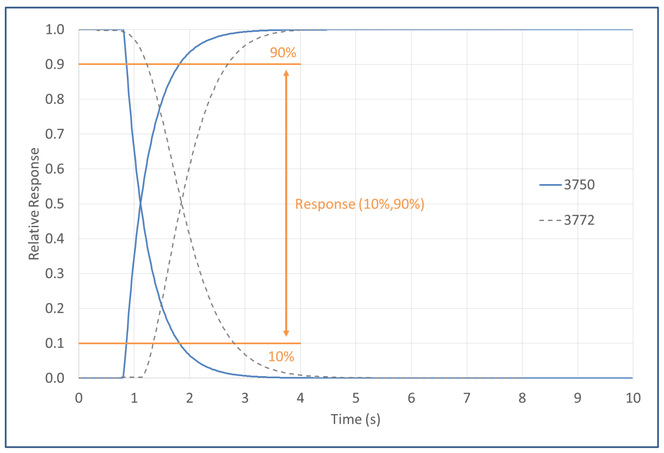

Fig. 2: An example of rise and fall time measurements with a new Standard CPC model 3750 compared to the predecessor 3772.

Counting Efficiencies

Figure 3 shows the counting efficiency curves for the new Butanol-CPCs. Counting efficiency is quantified by comparing the CPC measurement to data from an Aerosol Electrometer (see ISO 27891).

The steepness of the efficiency curve is addresses in technical standards where comparability and traceability are important, such as in engine emissions and air quality monitoring.

Knowing the counting efficiency curve of a CPC model is required for operation of a particle sizer system (SMPS). During SMPS operation, measured particle concentrations that fall within the sub-100% portion of the counting efficiency curve are adjusted upward, in order to provide the most accurate particle number size distribution measurements.

Model 3750 now has a D50% of 7 nm, compared to 10 nm in the previous model 3772. Consequently, 10 nm particles are now measured with >25% greater counting efficiency, as shown in Figure 4.

	New D50%
Standard CPC model 3750	7 nm
High Conc. CPC model 3752	4 nm
Ultrafine CPC model 3756	2.5 nm

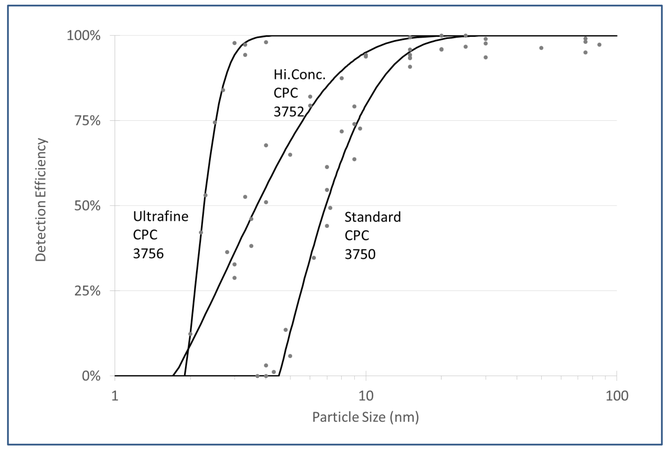

Fig. 3: Counting efficiency curves for various new CPCs.

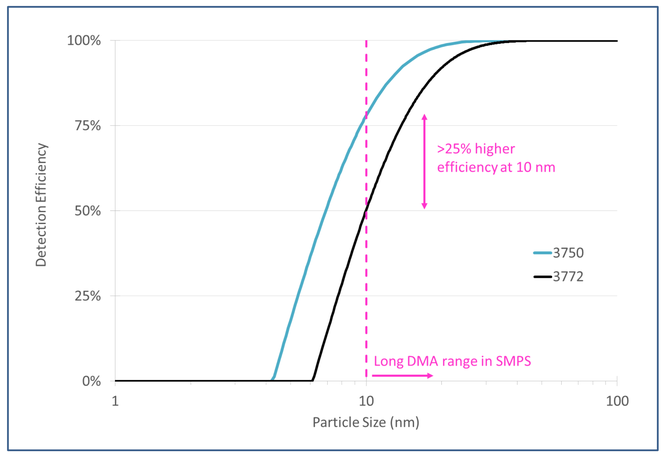

Fig. 4: An example of how an improved counting efficiency curve impacts a particle sizer's counting statistics.

Summary

A new series of Butanol-CPCs has been developed. The above graphs demonstrate improved performance specifications on counting efficiency, concentration range and response time.

- Increased single-count accuracy up to 100,000 #/cm³ resp. 300,000 #/cm³
- Improved counting efficiency down to 7 nm for the standard CPC
- Improved counting efficiency for the standard SMPS
- Fast response times

In addition researchers in measurement campaigns and field studies can now:

- Remotely operate CPCs through Ethernet and Wi-Fi
- Be informed about data quality through new diagnostics such as Pulse Height Monitoring, a measure of the health of the particle to droplet growth process
- Store data locally on the large internal memory with 50 Hz sampling frequency
- Stream data live from multiple CPCs
- Simultaneously work through stored data sets while streaming data
- Measure down to 1nm more reliably with the digital link of ‚Nano Enhancer' with the CPC

References
Fletcher et al. (2009), *Aerosol Science and Technology*, **43**, 425-441.
Hermann et al. (2007), *Aerosol Science*, **38**, 674-682.
Yli-Ojanperä et al. (2012), *Aerosol Science and Technology*, **46**, 1163-1173.