

# PERFORMANCE VERIFICATION OF TSI CPCs IN THE FIELD: STANDARD OPERATING PROCEDURE

APPLICATION NOTE CPC-004 (US)

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## Introduction

TSI's Condensation Particle Counters (CPC's) are an important tool for research in numerous fields such as atmospheric science, environmental monitoring, and engine emissions. In all settings where they are used, proper function of the CPC is critical to obtaining high-quality data.

As such, it is common for customers to want to periodically verify the CPC function to not only ensure the collection of high quality data, but to determine if the unit is in need of service or calibration at a given point in time. Since sending a unit in for calibration always translates to downtime, it is advantageous to determine whether or not a CPC truly needs calibration before sending it in.

This application note provides a materials list and instructions for *verifying* the performance of a TSI CPC in the field. While TSI offers many different CPC designs, this application note is concerned only with "full-flow" CPCs; that is, CPCs that pull the entire inlet flow into the optics chamber. Consequently, the procedure described here should be used only for verifying the following models of TSI CPC: 3772, 3772-CEN, 3750, 3750-CEN, 3790, 3790A, 3791, and 3792.

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## Verification ≠ Calibration

While this procedure will confirm if a CPC is working properly, *Verification* is not a substitute for *Calibration*. Table 1 summarizes some of the key differences between this field verification procedure and the calibration performed at TSI.



For engine exhaust CPC users who would like to undertake on-site calibration of their CPCs, refer to TSI Application Note # EECPC-002 (see [References](#)).

For owners of a TSI 3791 or 3792, TSI now offers service for these instruments.

**Table 1: Differences between Field Verification (i.e., procedure described in this document) and Factory Calibration of TSI full-flow CPCs.**

Procedure Feature	Field Verification	Factory (TSI) Calibration	
		3772, 3750, and -CEN versions thereof*	3790, 3790A, 3791, 3792
Aerosol size distribution	Polydisperse	Polydisperse	Monodisperse
Aerosol composition	Sodium chloride (NaCl) or other	Sodium chloride (NaCl)	Emery oil
Counting efficiency at small sizes	Not included	Not included	Included
Official calibration certificate		Included	
Cleaning and alignment			
Firmware updates as needed			

\*The difference between a -CEN version and a “non-CEN” version of either 3772 or 3750 is an additional calibration that is performed outside of TSI, after the product is released from TSI Incorporated.

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## Verification Overview

### Reference Unit

The most suitable way to check the performance of a CPC in the field is to compare it to another CPC with the same specification when the two are challenged with the same aerosol. If the readings of the two instruments compare favorably and neither is exhibiting any errors or warnings, then the CPC being tested may be presumed to be functioning correctly. Maintaining the Reference CPC is, of course, necessary; periodic calibration will keep the Reference CPC in working condition so it can serve as a reliable guide.

### Challenge Aerosol

The verification procedure is intended to be relatively simple to follow while providing a reliable indicator of proper CPC function. As such, it utilizes an aerosol generator to generate polydisperse sodium chloride aerosol. If you prefer a different aerosol composition, such as oil or soot, the generation process may be modified accordingly. Depending on which generator is used, the concentration of the aerosol may be reduced by using a dilution bridge. Once the concentration is stable, the two CPCs are challenged in parallel with the resulting aerosol.

### Data Collection

Models 3772, 3772-CEN, 3750, 3750-CEN, 3790 and 3790A are supported by TSI’s Aerosol Instrument Manager® software, which simplifies the collection of data during the verification process. Models 3791 and 3792; however, are not supported by Aerosol Instrument Manager Software. Reading concentration measurements from these instruments requires the use of a terminal program such as HyperTerminal. Further details are found in the [Instructions](#) section.

## Necessary Materials

The components you need to purchase in order to construct a CPC verification bench may vary a little bit, depending upon two things: A) what aerosol generation process you will use; and B) what model of CPC you will be verifying. But some items (C) are common to all verification setups, regardless of the choices made in (A) and (B). Please use the table below to develop your list of needed materials.

**Table 2: Materials required for assembling a verification bench. For each model of CPC that you want to verify, include one line from section A, one line from section B, and all items from section C.**

<b>A) Aerosol Generation</b>		<b>C) Common items</b>
<b>Choose one of these four:</b>		<b>For all verification benches</b>
1	3073 Portable Test Aerosol Generator, 3062 Diffusion drier, and FLOWBAL1 Flow Balance	3708 Flow splitter
2	3079A Portable aerosol generator, 3062 Diffusion drier, and 1050001 Dilution bridge	3032 Vacuum pump
3	3076 Constant Output Atomizer, 3062 Diffusion drier, and 1050001 Dilution bridge	4148 Flow calibrator
4	Other generator, consider: 1050001 Dilution bridge	3001788 Conductive silicone tubing, 50' roll, ¼"
<b>B) Reference CPC</b>		1601626 Nylon tee fitting for vacuum line, ¼" barb
<b>If you want to verify a...</b>		
<b>...then choose this as your Reference Unit</b>		
3772, 3750, or –CEN versions thereof	3750	
3790, 3790A, 3791, 3792	3790A	

# Instructions

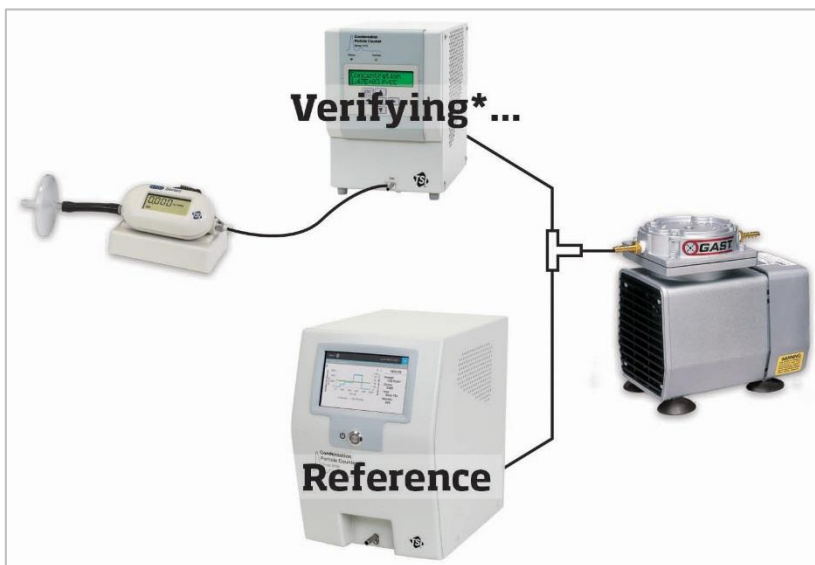
## 1. Warm up Instruments

If your CPC is a part of a solid particle number (PN) sampling system, remove the CPC from the sampling system (Models 3791 and 3792).

Using Figure 1 as a guide, set up both the CPC under test and the Reference CPC to warm up. Provide the CPCs with vacuum in the back and butanol as instructed in the 3790A manual.

Instead of the Flowmeter depicted in Figure 1, attach a filter cartridge to the inlet of each CPC, so the CPCs are sampling filtered air during

warm-up. You may use two filters, or you may use one filter and connect it to both CPCs using the tee fitting. Allow the CPCs 60 minutes to warm up before proceeding.



**Figure 1: Experimental schematic for Step #1-2 of CPC performance verification.**

## 2. Check Inlet Flows

After CPC warm-up, remove the filter(s) from the instrument inlets and connect the flowmeter to the front of the CPC (as shown in Figure 1; be sure the flowmeter is on the volumetric flow setting). Measure and record the volumetric flow rate. Repeat with the Reference CPC.

Inlet volumetric flows for both CPCs should be  $1.0 \pm 0.05$  L/min. If either of the CPCs do not meet this criteria, confirm that the vacuum pump (or house vacuum) is adequately strong. Lower values may indicate that the critical orifice needs cleaning. Contact TSI for guidance in such a circumstance.

While the overall value of the flow is important, so is the trend in the flow over time (i.e., months). It is valuable to keep a record of the CPC flow rates in this regard. If the flow is drifting over time and is outside of this range, or if you have any concerns, please contact TSI.

## 3. Set up the Test

Using Figure 2 as a guide, assemble the verification test bench. If you selected generation option #2 or #3, leave the excess flow valve of the dilution bridge fully opened (in Figure 2, this valve is shown as the lower left valve, closest to the aerosol generator).

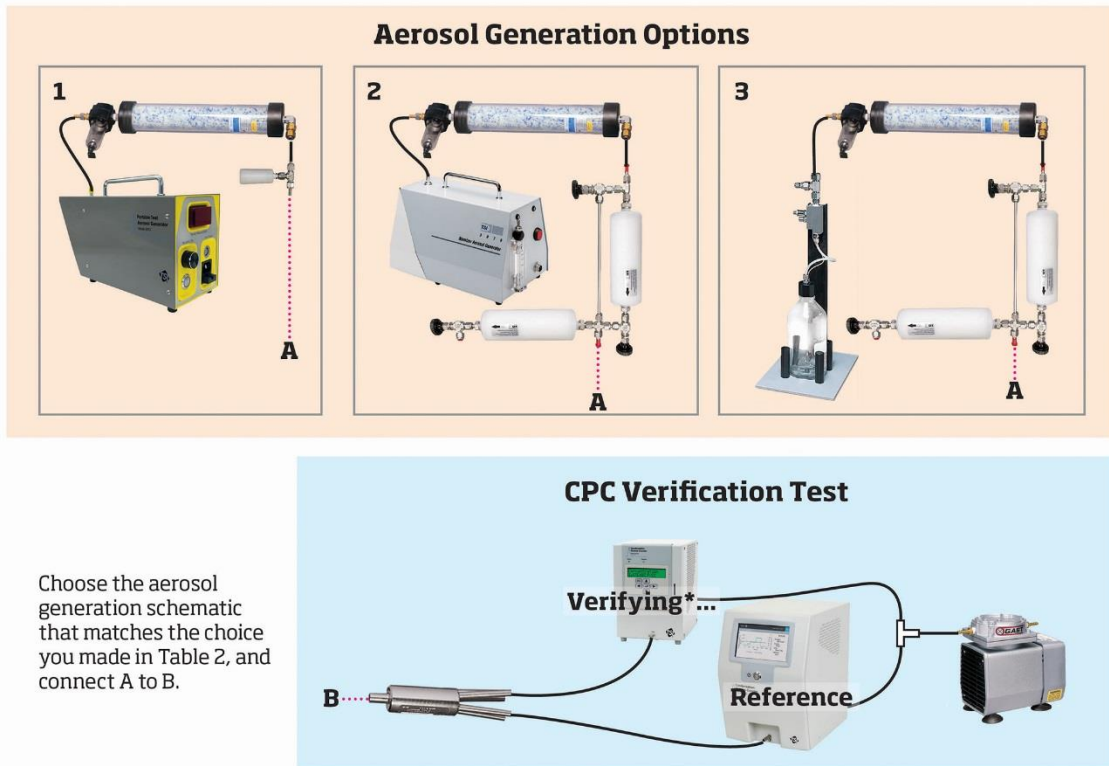


Figure 2: Experimental schematic for Steps #3–6 of the CPC performance verification.

## 4. Establish Data Communication

### Reference CPC

Connect the Reference CPC to TSI's Aerosol Instrument Manager Software (version 11).

### CPC under Test

- **Models 3772, 3772-CEN, 3750, 3750-CEN, 3790 and 3790A**—Connect the CPC under test to Aerosol Instrument Manager Software. If using one computer, open two separate copies of Aerosol Instrument Manager Software.
- **Models 3791 and 3792**—Connect to the CPC under test via a terminal program or using the third party software provided by the engine exhaust system integrator. Follow the HyperTerminal® program instructions in Chapter 7 of the Model 3790A manual.

## 5. Generate Particles

For aerosol generator selections #1 and #2, blend 200-500 milligrams of NaCl in ~50 mL of water in the jar of the 3073 or 3079A. Install the jar, turn on the generator, and adjust its output flow to be >2 L/min. Allow the generator a few minutes to warm up and for its output to stabilize.

For aerosol generator selection #3, blend approximately 500 – 1,000 mg of NaCl in ~250 mL of water in the jar of the 3076. Install the jar, and present compressed air at < 35 psig to the generator. Allow the generator a few minutes to warm up and for its output to stabilize.

If another particle composition is preferred, this generation step may be changed accordingly.

## 6. Conduct the Test

### Adjust the Concentration

#### What concentrations should I use?

The ideal testing range depends upon the model of CPC you are verifying. See Table 3 for recommended test concentrations.

Be sure to include 0 #/cm<sup>3</sup> as one of the test points; this

will serve as a zero-check for the CPC. To do so, attach one filter to the inlets of the instruments using the tee fitting, as discussed in Step #1.

Table 3: Recommended nominal test concentrations by CPC model.

3772, 3772-CEN, 3790A, 3791, 3792	3750, 3750-CEN
0 #/cm <sup>3</sup>	
1 × 10 <sup>3</sup> #/cm <sup>3</sup>	1 × 10 <sup>3</sup> #/cm <sup>3</sup>
5 × 10 <sup>3</sup> #/cm <sup>3</sup>	1 × 10 <sup>4</sup> #/cm <sup>3</sup>
8 × 10 <sup>3</sup> #/cm <sup>3</sup>	8 × 10 <sup>4</sup> #/cm <sup>3</sup>
9 × 10 <sup>3</sup> #/cm <sup>3</sup>	9 × 10 <sup>4</sup> #/cm <sup>3</sup>

#### How do I adjust the concentration?

For aerosol generation option #1 (3073 generator) adjust the concentration with the set point dial.

For aerosol generation option #2 or #3, use the remaining two valves on your dilution bridge to adjust the concentration. Start with both valves as far open as possible. For example, if the concentration is too high and you would like to lower it, leave open the valve that controls access to the straight steel tube (i.e., the upper valve in Figure 2, closest to the 3062 Diffusion drier). Then incrementally close the other (which controls access to the filter, the lower right valve) until the desired concentration is reached.

#### Collecting Data, Reference CPC

Collect data in Aerosol Instrument Manager Software for the Reference CPC for 5 minutes.

#### Collecting Data, CPC Under Test

- **Models 3772, 3772-CEN, 3750, 3750-CEN, 3790 and 3790A** – Collect data in Aerosol Instrument Manager Software for the CPC Under Test for 5 minutes.
- **Models 3791 and 3792**—Use HyperTerminal® program or other terminal program to query the CPC every 20 seconds simultaneously with the Reference CPC's data collection; record this data elsewhere.

#### Repeat

Repeat Step #6 for a total of at least five test concentrations spanning the specified concentration range.

## 7. Analyze the Data

Compare CPC concentrations at each of the test points. The pass/fail criteria vary by CPC model, but the analysis is the same across all models. Use Table 4 to find the correct criteria for your CPC model.

At each test point, the CPC unit that reads a lower concentration must read no lower than the criteria value, as a percentage of the higher concentration, measured by the other unit. If this criteria is met for 100% of the test concentration points, the unit may be regarded as functioning properly.

**Table 4: Pass/fail criteria for various CPC models. The concentration read by the CPC with the lower reading must not be any lower than these values, as a percentage of the higher-concentration CPC. This must be true of all concentrations tested.**

<b>3772, 3772-CEN, 3790A, 3791, 3792</b>	<b>3750, 3750-CEN</b>
81.8%	90.5%

If this criteria is not met, undertake maintenance procedures and troubleshooting steps for the EEPCC under verification. For guidance on these, see the manual for the CPC under verification (for Models 3791 and 3792, use the 3790A manual). Repeat the above test as needed.

If maintenance and troubleshooting efforts do not result in a properly functioning CPC, consider sending in your CPC for factory calibration. Go to the TSI website to begin the RMA process (select Support > Request Repair/Calibration, or follow this link to [https://secure.tsi.com/rma\\_main.aspx](https://secure.tsi.com/rma_main.aspx)), and select the model number of your CPC.

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## References

1. TSI Application Note # EECPC-002: "EEPC Calibration: Order the Right Equipment."  
[http://tsi.com/uploadedFiles/Site Root/Products/Literature/Application Notes/EEPC-002\\_Calibration Equipment Needed for Order.pdf](http://tsi.com/uploadedFiles/Site%20Root/Products/Literature/Application%20Notes/EEPC-002_Calibration_Equipment_Needed_for_Order.pdf)

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**USA** Tel: +1 800 874 2811      **India** Tel: +91 80 67877200  
**UK** Tel: +44 149 4 459200      **China** Tel: +86 10 8219 7688  
**France** Tel: +33 1 41 19 21 99      **Singapore** Tel: +65 6595 6388  
**Germany** Tel: +49 241 523030