

Summary

The Savillex C-Flow PFA concentric nebulizer range comprises of the general purpose C700d (nominal uptake 700 $\mu\text{L}/\text{min}$), suitable for all non-semiconductor applications of ICP-OES and ICP-MS, plus four low flow rate, "microconcentric" versions: the C200, C100, C50 and C35, with free aspiration uptake rates of 200, 100, 50 and 35 $\mu\text{L}/\text{min}$ respectively. The microconcentric versions are used predominantly for semiconductor analysis and other low sample volume applications (typically in geochemistry), and also with desolvation devices.

The unique two-piece design and construction of the C-Flow allows for very precise manufacturing and more reproducible performance than any other microconcentric nebulizer. This is especially important for 50 $\mu\text{L}/\text{min}$ uptake and 35 $\mu\text{L}/\text{min}$ rate nebulizers, which are the most challenging to manufacture. The design features an inner body that supports the capillary all the way to the nebulizer tip: this also makes the C-Flow rugged enough that it can be backflushed simply and safely using the nebulizer gas.

In addition, Savillex designs, molds and manufactures all its sample introduction products in house using only the highest grade PFA resins: the C-Flow nebulizers have no measureable elemental background contribution. The Savillex C-Flow microconcentric nebulizers are the highest performing, most reproducible and reliable nebulizers available for semiconductor and low volume applications.

C-Flow Design - Body

Unlike all other PFA nebulizers, the C-Flow is unique in that the body assembly is comprised of two parts: an outer body and an inner body (both are molded PFA) that supports the capillary. Savillex's molding expertise allows for the parts to be manufactured to extremely tight tolerances. The photograph to the right shows the two components prior to assembly. Note the quality of the molding and finish. The 4 mm nebulizer gas fitting is shown connected to the outer body. The design allows for precise adjustment and optimization of free aspiration uptake rate during assembly. When the uptake rate is within specification, the two parts are locked together and the uptake rate is fixed, prior to shipment.



C-Flow PFA Microconcentric Nebulizer



*C-Flow Nebulizer Prior to Assembly;
Showing Outer Body and Inner Capillary Support*

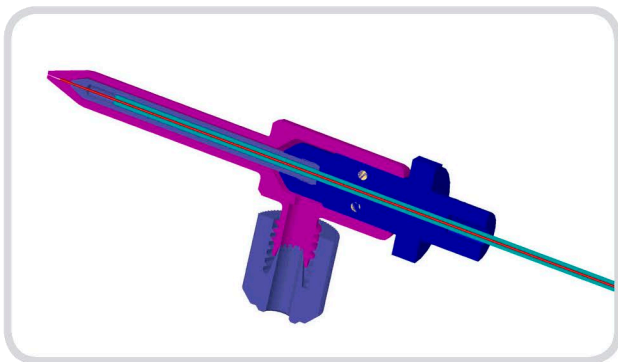
C-Flow Tip Design

The C-Flow is unique among PFA nebulizers in that the capillary is physically supported all the way to the inside of the nebulizer tip. The capillary is positioned centrally within the body, making it the only PFA nebulizer that is a true concentric nebulizer. The design requires highly accurate moldings to ensure the inner support aligns axially with the orifice. Saville's unique molding expertise and design capabilities make this possible. Because the capillary is positioned with very high accuracy and precision, the free aspiration uptake variability is much lower than with other PFA nebulizer designs. The benefits of the unique tip design of the C-Flow become especially apparent at ultra low flow rates (35 $\mu\text{L}/\text{min}$) where reproducibility in performance has been traditionally difficult to achieve.

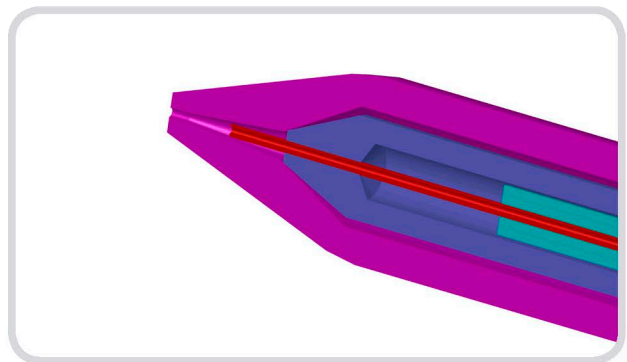
Schematic diagrams of the nebulizer are shown below. Argon carrier gas flows around the inner support, forming an annular gas stream around the end of the capillary. The capillary protrudes into space behind the tip, several mm from the orifice itself. As sample liquid exits the capillary, the annular gas stream shears the liquid, causing prefilming around the entire inner circumference of the tip. Liquid/gas interaction and energy transfer is optimized, resulting in a very fine aerosol with narrow droplet size distribution. The high, annular gas velocity around the end of capillary also prevents salt deposition, a great benefit with difficult semiconductor matrices such as PV (photovoltaic) silicon digests. In addition, for these matrices the C35 is recommended since the low uptake rate prevents plasma overloading.

The tip design provides several key benefits:

- Better reproducibility from nebulizer to nebulizer (free aspiration uptake rate)
- Aerosol direction is co-axial with the nebulizer – typically ± 2 degrees
- High sensitivity due to efficient gas/liquid energy transfer and fine aerosol
- Reliable, reproducible performance even at 35 $\mu\text{L}/\text{min}$ flow rates (C35)
- Longer lifetime than other PFA nebulizers - typically more than two years - because the capillary is physically supported at the tip so its axial position is very stable
- Easy to unclog by backflushing - no wires or flushing tools required



C-Flow - Inner Support Shown in Blue



Nebulizer Tip - Capillary Shown in Red

The C-Flow microconcentric range has become well accepted in semicon labs worldwide. The 200 $\mu\text{L}/\text{min}$ version is the most widely used while the 35 $\mu\text{L}/\text{min}$ version is recognized as the most reliable and reproducible nebulizer available for ultra low flow applications and difficult sample matrices.

Constant ID Uptake Tubing

A limitation of most concentric nebulizers is the potential for blockages due to particulates in the sample. The microconcentric C-Flows have an integrated uptake line and are unique in having constant ID uptake tubing from the sample, all the way to the tip. This is because the uptake tubing itself is actually the capillary at the tip. There are no connectors in the sample flow path, and no constriction near the tip, so the possibility of clogging is greatly reduced. If a blockage did ever occur, the C-Flow can be easily cleared by backflushing with nebulizer gas. With nebulizer gas switched on, a gloved finger is placed over the nebulizer tip which forces gas back down the uptake tube. Because the capillary is supported at the tip, it is not damaged by backflushing. And because there is no ID reduction at any point in the uptake line, any blockage would occur at the end of the tubing connected to the autosampler.



Backflushing a C-Flow Nebulizer

Clearing a blockage by backflushing a C-Flow – no need for tools or wires. Simply place a gloved finger over the tip while Ar nebulizer gas is flowing.

Cleanliness and Chemical Compatibility

The C-Flow range is designed, molded and manufactured in house at Savillex. Savillex uses only the highest grade PFA resins. These grades have the lowest leachable trace metals levels of any molding grade PFA resin. For the analysis of samples containing 1-2% HNO_3 , a new C-Flow can be used immediately without any precleaning. For the analysis of high concentrations of HNO_3 and other mineral acids, it is preferable to aspirate 5% HNO_3 or HNO_3/HF through the nebulizer for 3-4 hours to remove any trace metal contamination from the uptake line. This need only be performed the first time a new nebulizer is used. Savillex offers a convenient system for cleaning new nebulizers with concentrated acids, comprising of a 500 mL Savillex PFA bottle and PFA fittings. Details can be found on the Savillex website.

In addition to concentrated HF, PFA is resistant all other concentrated mineral acids, and to every organic compound except certain halogenated complexes containing fluorine, molten sodium and potassium. The C-Flow is resistant to any sample that can be analyzed by ICP-MS.

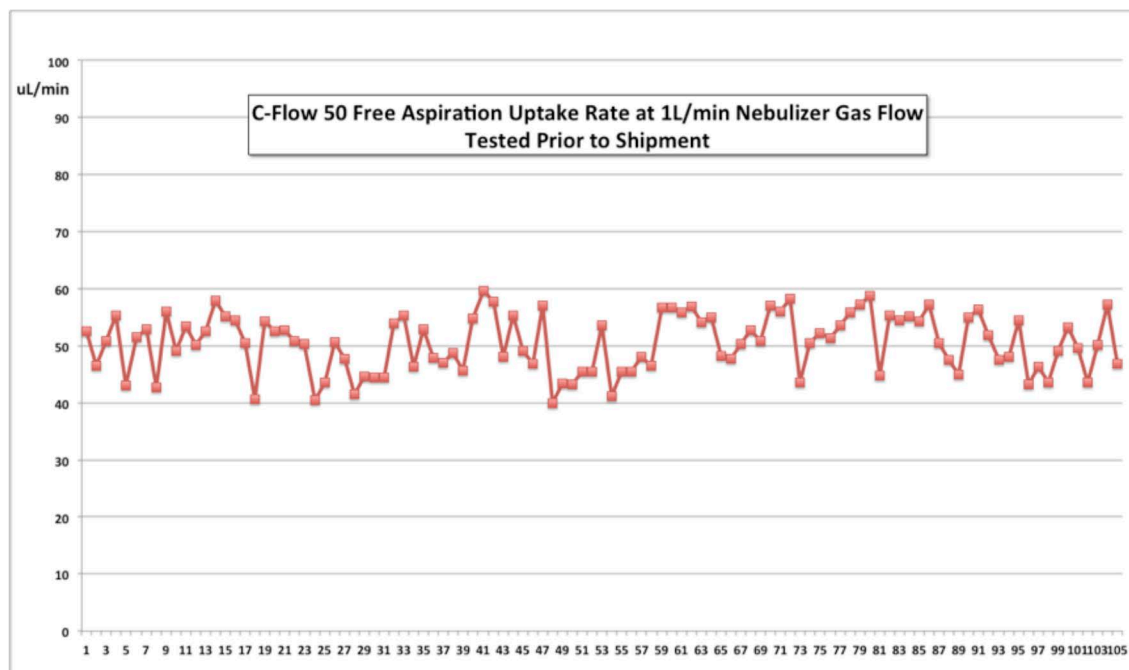
Nebulizer-to-Nebulizer Reproducibility

Because the microconcentric C-Flows are manufactured to very tight tolerances, their free aspiration uptake rate specification range is tighter than any other PFA nebulizer on the market, which means the C-Flows perform reproducibly from nebulizer-to-nebulizer. The uptake rate specifications are as follows:

Nebulizer	Uptake Rate Specification	Uptake Rate Range
C-Flow 200 (C200)	200 uL/min +/- 15%	170-230 uL/min
C-Flow 100 (C100)	100 uL/min +/- 15%	85-115 uL/min
C-Flow 50 (C50)	50 uL/min +/- 20%	40-60 uL/min
C-Flow 35 (C35)	35 uL/min +/- 20%	28-42 uL/min
(all at 1 SLPM nebulizer gas flow)		

Uptake Rate Specifications - Microconcentric C-Flows

The chart below shows the free aspiration uptake rate of 105 C50 nebulizers, tested prior to shipping. As can be seen, all nebulizers are within specification (40-60 uL/min).



C50 – consistency of manufacturing and performance. Plot shows the free aspiration uptake rate (at 1L/min nebulizer gas) of C-Flow 50's prior to shipping. Sample size: 105 nebulizers.

C-Flow - Microconcentric Versions

All microconcentric C-Flows feature an integrated uptake lines and are available with an integrated polyimide autosampler probe encapsulated in PFA. Probes are available to fit all commonly used autosamplers. Custom uptake line lengths and probe lengths are available. Special versions of the C200, C100 and C50 are also available for use with desolvators. These versions are assembled and tested at 110°C to ensure optimum performance at elevated temperature. They are supplied as standard with the CETAC Aridus, and can also be used with the ESI Apex or Nu Instruments DSN-100. For desolvator use, only the C-Flow versions marked “for desolvators” may be used.

Note: C-Flows marked “for desolvators” can not be used in a normal spray chamber - they are only for use with desolvators.

C200

The C200 is the standard version for semiconductor use with ICP-MS. With a larger capillary ID than the other microconcentric C-Flows, the C200 is also surprisingly resistant to salting or clogging due to high TDS samples – when pumped it can tolerate >10% TDS. Beyond semiconductor applications, and where sample volume is limited, the C200 operated in pumped mode is an excellent choice, and it can be operated at uptake rates as low as 100 uL/min.

C100

The C100 is designed for applications that require free aspiration mode and a lower uptake rate. Its free aspiration uptake rate of 100 uL/min makes it an ideal fit for geochemical applications using desolvation devices. It is typically used in free aspiration mode for geological isotope ratio (IR) measurements, since IR precision is degraded slightly by noise due to peri-pump fluctuations. It is slightly less tolerant to high TDS samples than the C200 due to its smaller ID capillary.

C50

The C50 is designed for applications where sample volume is extremely limited. For use with geochemical applications using desolvation devices, where 100 uL/min flow rate is too high for the available sample volume.

C35

The new C35 is designed for semiconductor and geochemical applications where sample volume is extremely limited. In semiconductor it is also the best choice for high Si matrices, since its ultra low uptake rate reduces plasma loading and prevents excessive deposition of SiO₂ on the interface. At such low uptake rates, reproducible nebulizer manufacture is very challenging, but thanks to the unique two piece design of the C-Flow, consistent performance is achieved from nebulizer to nebulizer. This enables the C35 to be manufactured to the tightest free aspiration uptake rate specification (+/-7 uL/min) of any ultra low flow nebulizer.

Custom Versions

For applications where a non-standard uptake rate is required, please contact us. The design of the C-Flow body allows uptake rates as low as 20 uL/min to be reproducibly achieved.