Evaluation of a novel nebulizer using an inductively coupled plasma optical emission spectrometer

J Moffett and G. Russell, Agilent Technologies Australia, Pty Ltd, J P Lener Agilent Technologies France

Agilent Technologies

Abstract

Introduction

A novel nebulizer that uses flow blurring technology has been developed for use with an Inductively Coupled Plasma Optical Emission Spectrometer. (ICP-OES) It is designed as a universal nebulizer offering a unique alternative to a variety of nebulizers by providing improved sensitivity, greater tolerance to dissolved salts and strong acids such as HF, resistance to most common organic solvents and efficient operation over a much wider flow rate range than existing nebulizers. In this paper we will compare the performance of the flow blurring nebulizer to the commercially available glass concentric nebulizer (GCN) normally fitted ,using a range of performance criteria such as limits of detection and reproducibility using a range of analytes and liquids.

Description

The flow blurring nebulizer (FBN) shown in Figure 1 is made completely from inert polymeric materials. It is physically robust and can withstand physical shocks that usually damage a GCN.

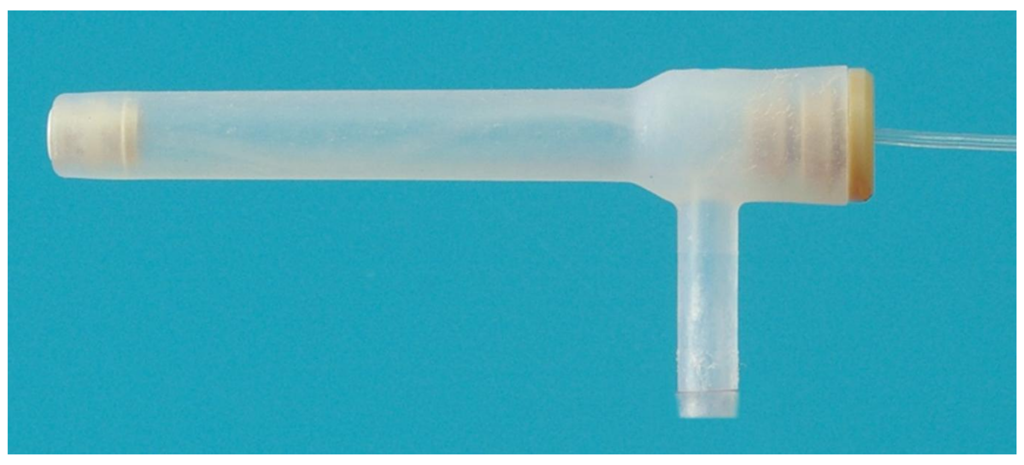

Figure 1 Flow Blurring nebulizer

The capillary tubing extends nearly to the tip. The geometry at the tip, shown in Figure 2, is carefully dimensioned to allow the carrier gas (in this case, argon) to mix with the sample liquid. The result is an aerosol consisting of droplets with a narrow size-distribution range.

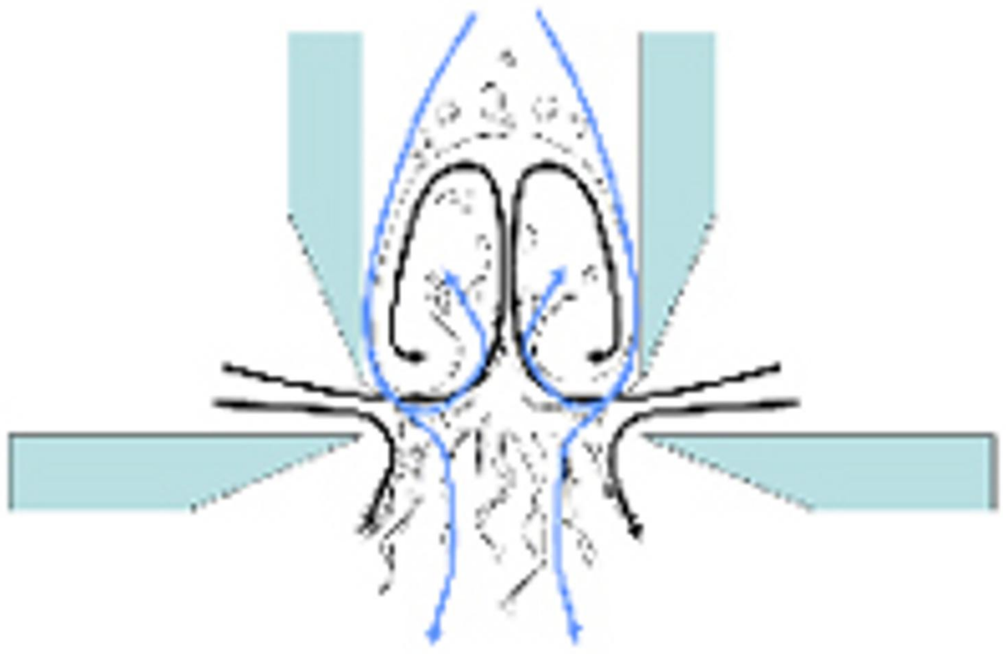

Figure 2 Flow Blurring nebulizer tip showing aerosol creation.

The FBN uses passive nebulization, meaning it has to be pumped. This design ensures there are no low-pressure regions to cause potential crystallization with high total dissolved solids (TDS) or constrictions for blockages to form.

Other Nebulizer Designs

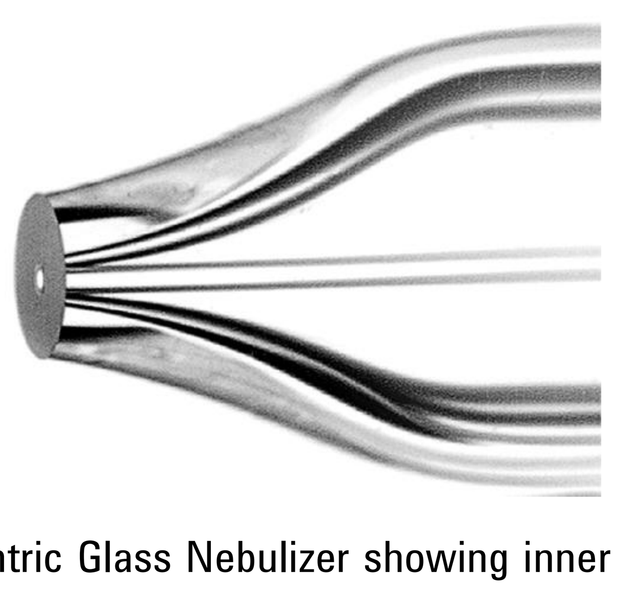

Figure 3 Tip of Concentric Glass Nebulizer showing inner sample capillary and outer tube.

Concentric glass nebulizers (Figure 3) are the most common nebulizer type used in ICP-OES. The design features two concentric glass tubes with liquid pumped through the narrow inner capillary and argon forced through the gap between the inner sample capillary and outer quartz tube. A venturi effect creates an aerosol of relatively narrow droplet distribution resulting in a nebulizer that provides good analytical RSD and detection limits. However the narrow sample capillary is prone to blockages and precipitates forming on the end of the capillary that can effect nebulizer efficiency over time.

Nebulizers designed for samples with high total dissolved solids (TDS) such as the V-Groove nebulizer and cross-flow nebulizer do not rely on the venturi effect of the CGN and are therefore more tolerant to dissolved salts. However, typically these nebulizers generate an aerosol with a wide range of droplet sizes resulting in higher analytycal RSD and poorer detection limits.

Experimental

Instrumentation

An Agilent 725 Series ICP-OES with radially viewed plasma and SPS3 autosampler was used for this work.

The Agilent 725 features a custom designed CCD detector, which provides true simultaneous measurement and full wavelength coverage from 167–785 nm. The CCD detector contains continuous angled arrays that are matched exactly to the two-dimensional image from the echelle optics. The thermally stabilized optical system contains no moving parts, ensuring excellent long-term stability.

Operating Parameters

- 1.3 kW RF Power
- 15 L/min Plasma gas flow
- 2.25 L/min Auxiliary gas flow
- Spray chamber type single-pass and double-pass glass cyclonic
- Torch: standard demountable with 0.38mm quartz injection tube.
- Nebulizer flow = 0.7 L/min
- Replicate read time (for LoD) = 30 s
- Number of replicates (for LoD) = 10
- Stabilization time (for LoD) = 30 s
- Replicate read time (for stability) = 10 s
- Number of replicates (for stability) = 6

Pump tubing

- Two cases of pump tubing were used
- Instrument: orange/green (0.38 mm ID) of materials matched to the solvent being studied
- Waste orange/orange (0.89 mm ID) marprene® for organic solutions
- Instrument: black/black (0.76 mm ID) with aqueous only
- Waste: blue-blue (1.65 mm ID) for aqueous only

Results and Discussion

Table 1. Transport Efficiency at conventional ICP-OES uptake rates

Nebulizer	Solvent type	Spraychamber	TE (%)
GCN	Water	Double-pass	6.1
OneNeb	Water	Double-pass	6.6 (9.0)
OneNeb	Water	Single-pass	3.8–12.8 (15.8)

Table 2. Transport efficiency of OneNeb at very low uptake rates

Solvent	Spraychamber	TE (%)
Water (2–6% HNO_3)	Double-pass	12.5–18.79
Water (2–6% HNO_3)	Single-pass	17.7–31.4
Shellsol®	Single-pass	44.0–48.7
DIBK	Single-pass	49.0

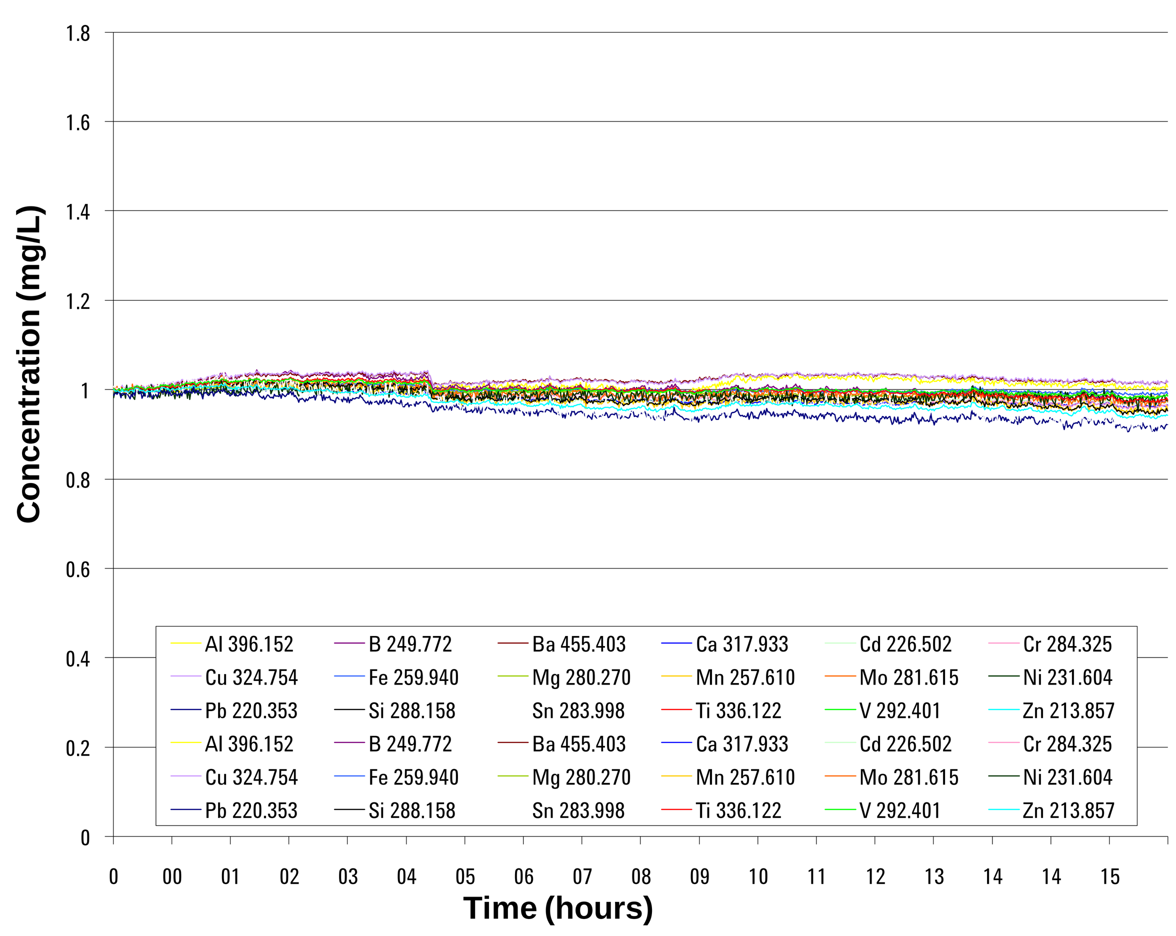

Figure 4 Long term stability of the FBN with DiBK

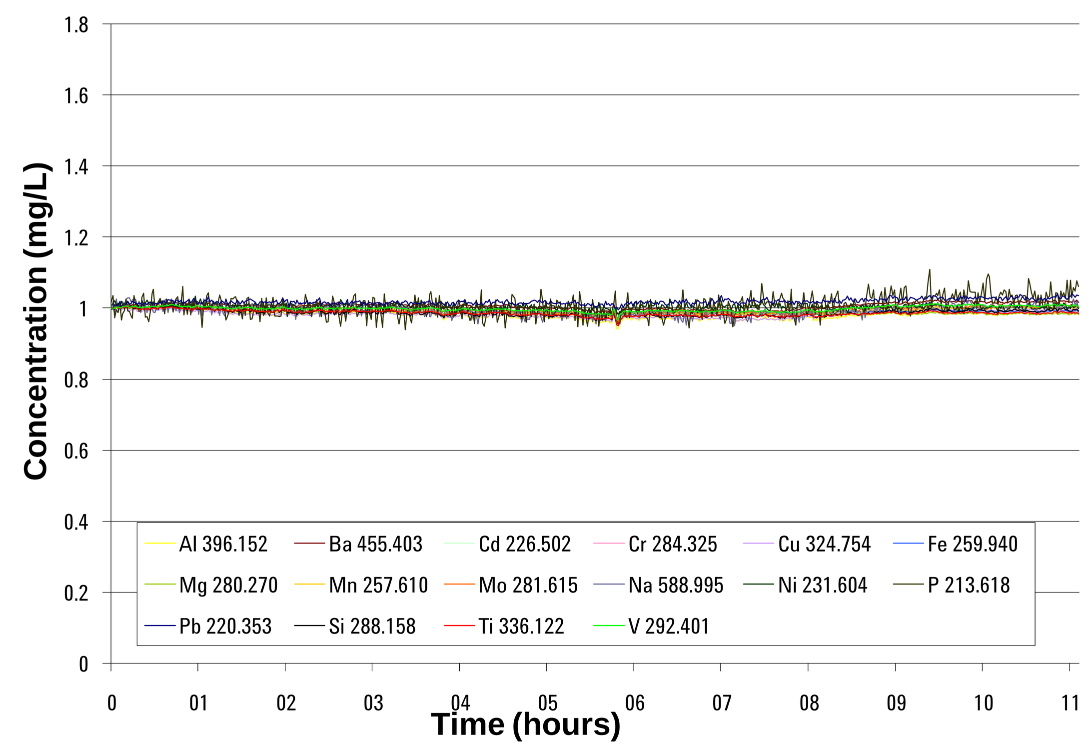

Figure 5 Long term stability of the FBN with ShellSol.

With organic solvents commonly used in ICP-OES analysis such as DiBK and Shellsol, the FBN provided excellent stability over long term runs of 12 hours or greater, demonstrating excellent chemical resistance.

Element	CGN	OneNeb	DL ratio
Ag 328.068	0.61	0.61	99%
Al 167.019	1.94	1.53	127%
As 188.980	12	9.84	122%
Ba 455.403	0.07	0.05	162%
Be 313.042	0.01	0.01	193%
Ca 396.847	0.09	0.07	121%
Cd 214.439	1.27	0.91	139%
Co 238.892	1.9	1.7	110%
Cr 267.716	0.86	0.70	123%
Cu 327.395	1.76	0.96	183%
Fe 238.204	0.90	0.68	132%
K 766.491	59	38	154%
Mg 279.553	0.05	0.05	107%
Mn 257.610	0.19	0.15	131%
Na 589.592	2	1.04	197%
Ni 231.604	5	5	108%
Pb 220.353	12	10	113%
Se 196.026	17	13	133%
Tl 190.794	15	12	129%
V 292.401	1.24	0.96	129%
Zn 213.857	0.50	0.49	101%

Table 3 Comparison of 30 second detection limits between CGN and OneNeb nebulizer

The FBN provided equivalent or superior (>100% ratio) detection limits compared to the high performance concentric glass nebulizer.

Conclusion

The FBN demonstrated excellent tolerance to samples with high TDS. Over weeks of extended testing of these high TDS samples, the FBN proved virtually unblockable. This was in stark contrast to the regular failure of the CGN due to blocking.

In terms of detection limits and tolerance to organic solvents, the FBN proved superior to a high performance CGN. Its resistance to strong acids such as HF proved similar to inert polymeric nebulizers. Tolerance to high TDS samples by the FBN ranked it equal to nebulizers dedicated to handling high TDS such as V-groove nebulizers, without the deterioration in precision or detection limits in aqueous solutions.

The flow blurring nebulizer proved to be a genuine universal nebulizer that is mechanically rugged and durable. It is competitive in price with a high performance concentric glass nebulizer. The FBN is capable of replacing many different types of nebulizers typically required to analyze the wide range of samples an ICP-OES is called upon to measure without compromising performance. A universal nebulizer also simplifies method development and day-to-day operation by eliminating the need to make decisions on which nebulizer is best for which sample and reducing the need for many different nebulizers. It operates with very high nebulization efficiency at sample uptake rates from 40 µL/min, potentially allowing the analysis of volume limited samples.