GLASS EXPANSION
Quality By Design

Mastering Trace Metals Analysis:

Understanding the Factors That Limit ICP Performance

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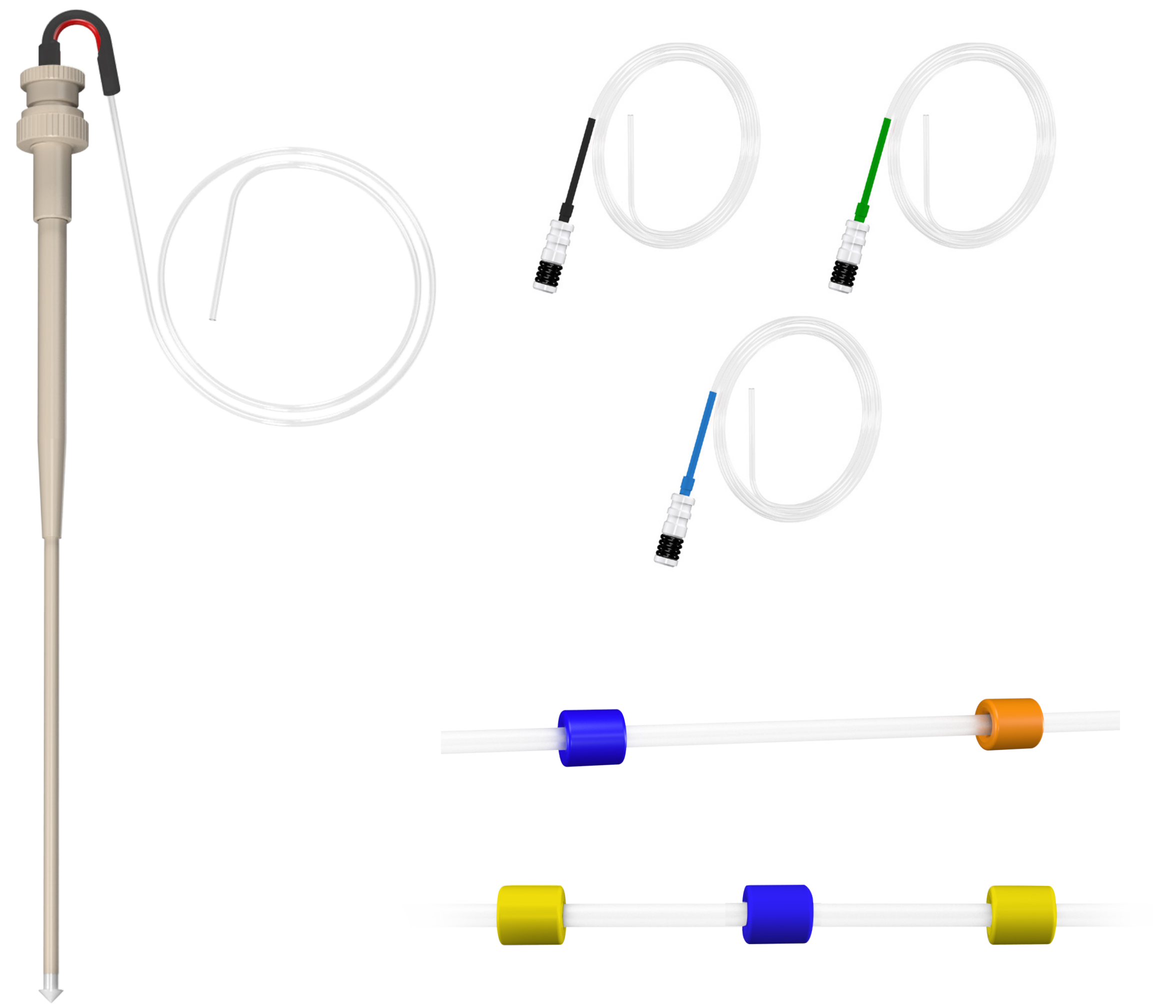
Major Factors Contributing to ICP Variability:

Sample Delivery

Sample Delivery

Sample Probe & Tubing



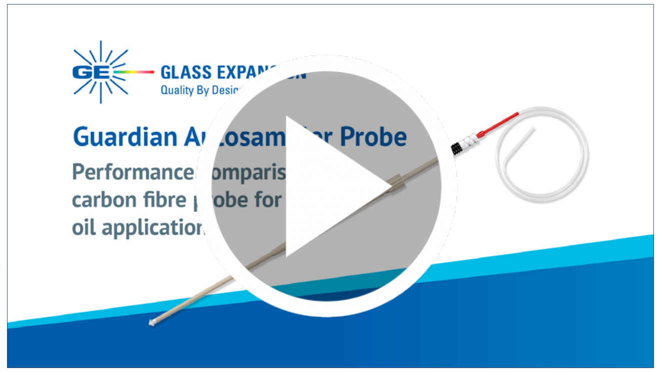
Stable Sample Delivery is the foundation of ICP analysis.

Any instability introduced before aerosol generation directly affects signal quality, precision, robustness, and long-term analytical performance.

Sample Delivery Factor	Effect on ICP Performance	Engineering Considerations
Sample uptake stability	Signal variation and reduced precision	Stable pump flow, leak-free tubing connections, correct probe ID
Particle transport	Blockages, signal drop, drift, increased maintenance	Controlled particle management and flow path design
Carryover & contamination	Memory effects and inaccurate results	Minimized residual sample and droplet retention
Bubble Introduction	Plasma instability, spikes, flickering signal	Tight fittings, smooth flowpath

Example: How Sample Probe Design Can Influence Sample Delivery Performance

Guardian Sample Probe



Guardian Probe Assembly
for ASX-200, 500, 800 Series
P/N 70-803-1787

Environmental Laboratory – Denmark: *"We are absolutely in love with this probe. The filter in the tip works perfect."*

Sample Delivery Challenge	Design Approach	Analytical Benefit
Particle entry into sample line	Ceramic cone tip with a ring of precision formed apertures at the base of the tip	Holds back particulates before they reach the capillary line, helping prevent sample line and nebulizer blockages
Residual droplets on probe surface	Cone-tip design with controlled drainage	Reduced carryover and helps prevent drips from clinging to the tip
Sample transfer between vials	Flared collar skirt	Captures residual sample running down the probe's length, reducing cross contamination as it moves across other sample vials
Probe tip damage or misalignment during handling	Robust cone tip nose	The pointed cone-tip helps guides the probe into vial openings under minor misalignment, reducing the risk of crushed tip or damaged probe

Performance Comparison for Aqueous Applications

Guardian Sample Probe

Aqueous Applications

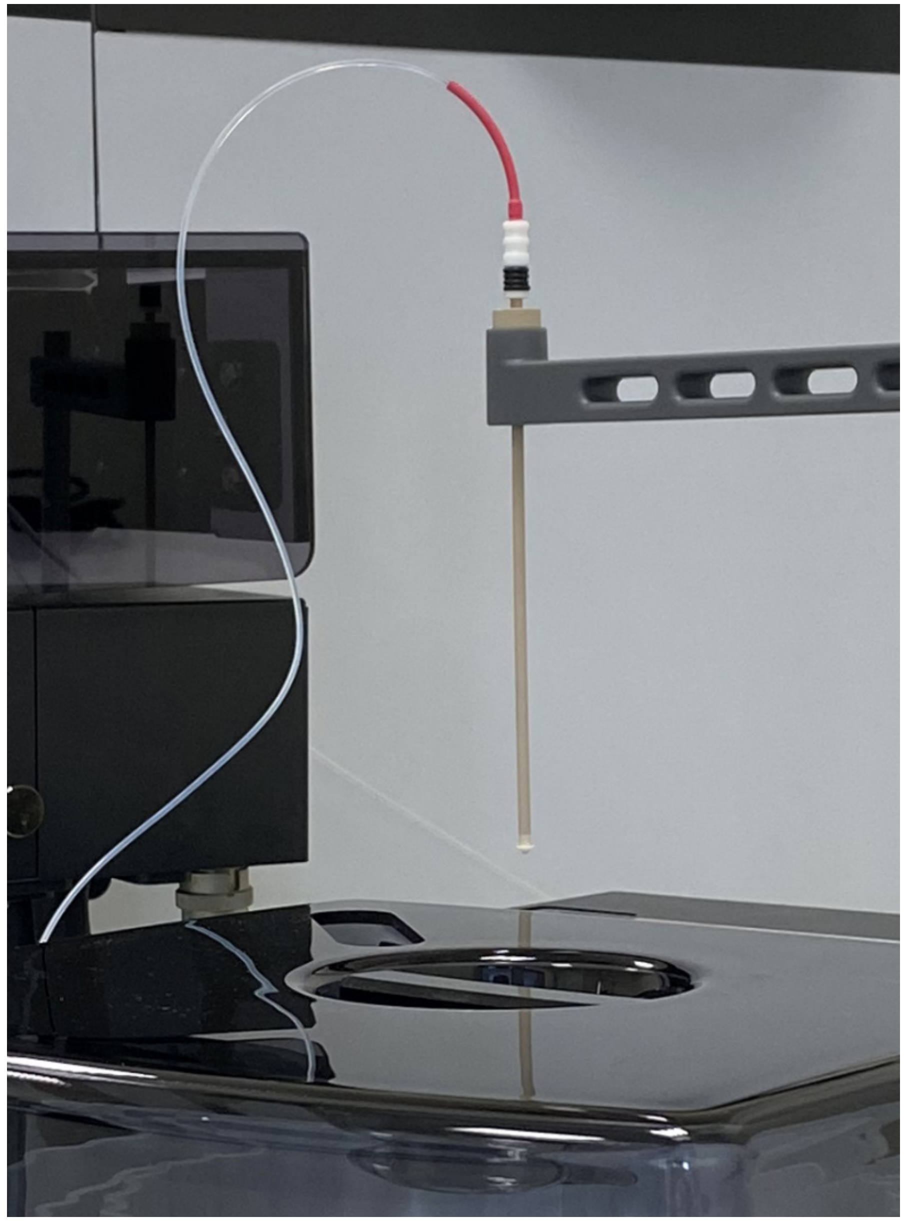
A 2% HNO_3 solution with added dye tracer was used to visualise wetting and drip behaviour. The Guardian Probe demonstrated **minimal beading, uniform wetting,** and **zero dripping** between sample wells.

- No visible droplet formation on the ceramic tip between samples.
- Consistent, repeatable sample uptake with each aspiration cycle.
- Contamination risk reduced to near zero in back to back high/low concentration sequences.

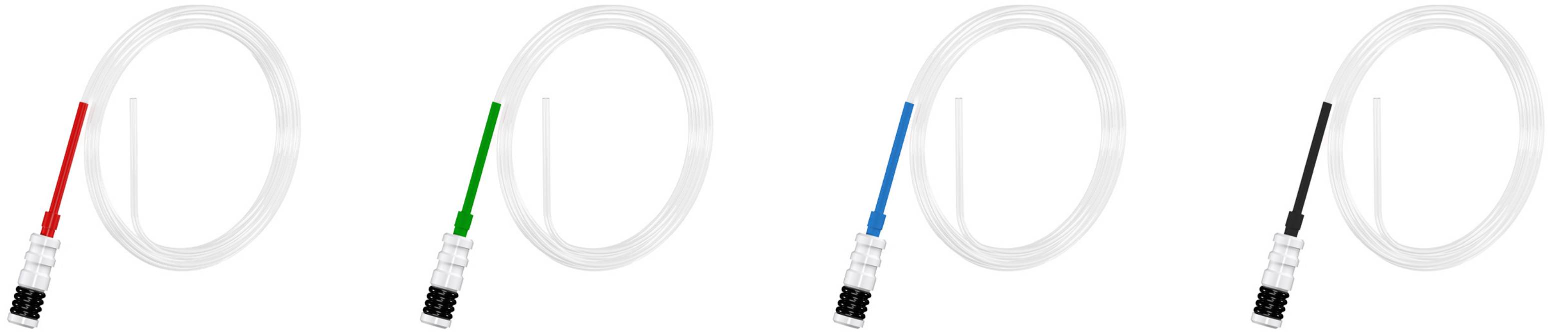
Click to view video demonstration

Different Sample Requirements

Interchangeable UniFit Sample Lines

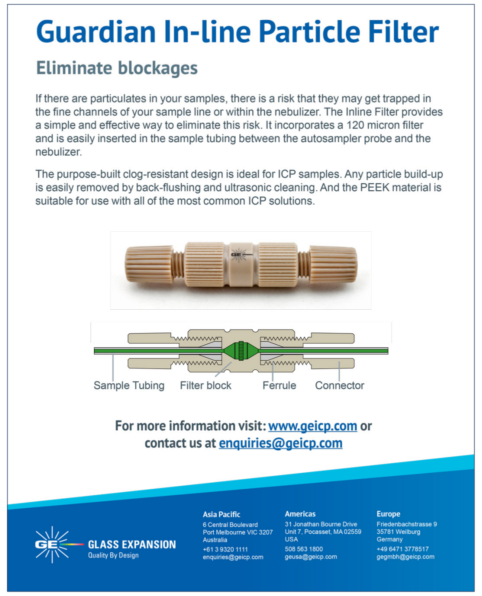


Interchangeable UniFit™ sample lines IDs: 0.3, 0.50, 0.75 and 1.0mm - Easy and low cost to replace and maintain clean sample path.



- For most common ICP-OES applications, choose 0.75mm
- For most common ICP-MS applications, choose 0.5mm
- For sample flow rates of 0.2 mL/min or lower, 0.3mm is ideal

Contract laboratory – Australia: *"The probe has demonstrated robustness and reliability in handling various sample types... As a result of this precaution, it seems we have fewer nebulizer failures compared to previous experiences."*



Guardian In-line Particle Filter

Eliminate blockages

If there are particulates in your samples, there is a risk that they may get trapped in the fine channels of your sample line or within the nebulizer. The Inline Filter provides a simple and effective way to eliminate this risk. It incorporates a 120 micron filter and is easily inserted in the sample tubing between the autosampler probe and the nebulizer.

The purpose-built clog-resistant design is ideal for ICP samples. Any particle build-up is easily removed by back-flushing and ultrasonic cleaning. And the PEEK material is suitable for use with all of the most common ICP solutions.

For more information visit: www.geicp.com or contact us at enquiries@geicp.com

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Pump Tubing ID

Peristaltic Pump Tubing ID:

Ensure optimal ID selection: Directly determines the sample uptake rate to the nebulizer, which affects sensitivity, stability, and washout.

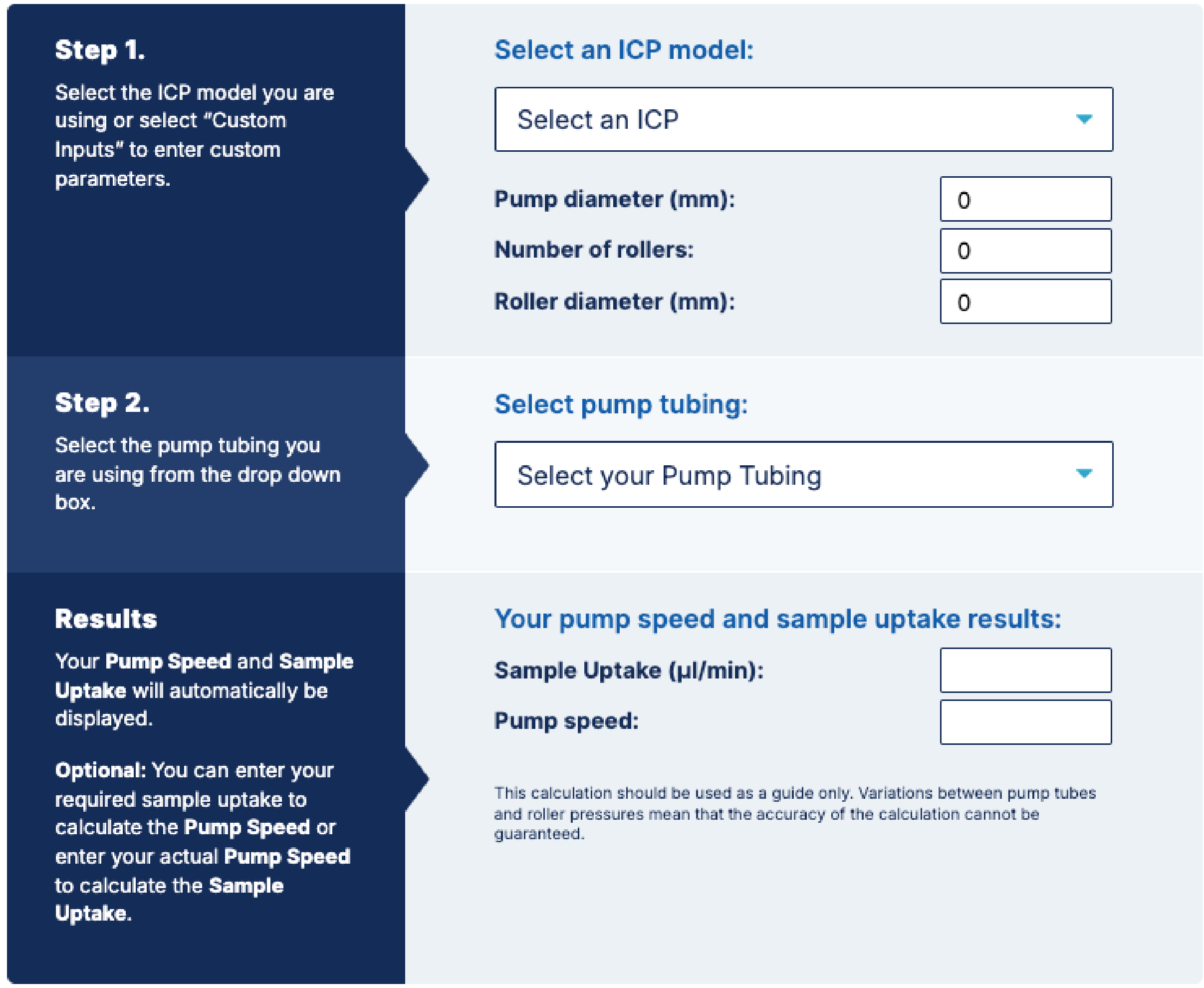
Smaller ID Tubing (0.2 -0.4 mm): Ideal for precise, low-flow applications.

Larger ID Tubing (0.76 -1.02 mm): Suitable for higher flow rates and sample volumes.

Internal standard tubing (0.25 -0.38 mm): Controls Internal Standard flow and dilution.

Waste tubing (1.30 -1.65 mm): Ensure efficient drainage.

Pump Speed and Sample Uptake Calculator



**Use Sample Uptake Calculator (GE website) to estimate flow rate, then verify using clean/new SIS.*

Pump Tubing: Practical Recommendations

Performance Considerations

- Tubing elasticity determines consistent sample flow and signal stability.
- Worn or flattened tubing can cause **flow rate variations and high RSD values.**
- Incorrect tubing size may result in improper nebulizer uptake rates.

Maintenance Guidance

- **Inspect pump tubing regularly** for flattening, cracks, or discoloration.
- Replace tubing periodically depending on system usage and sample matrix.
- **Maintain correct pump tension** and roller alignment.

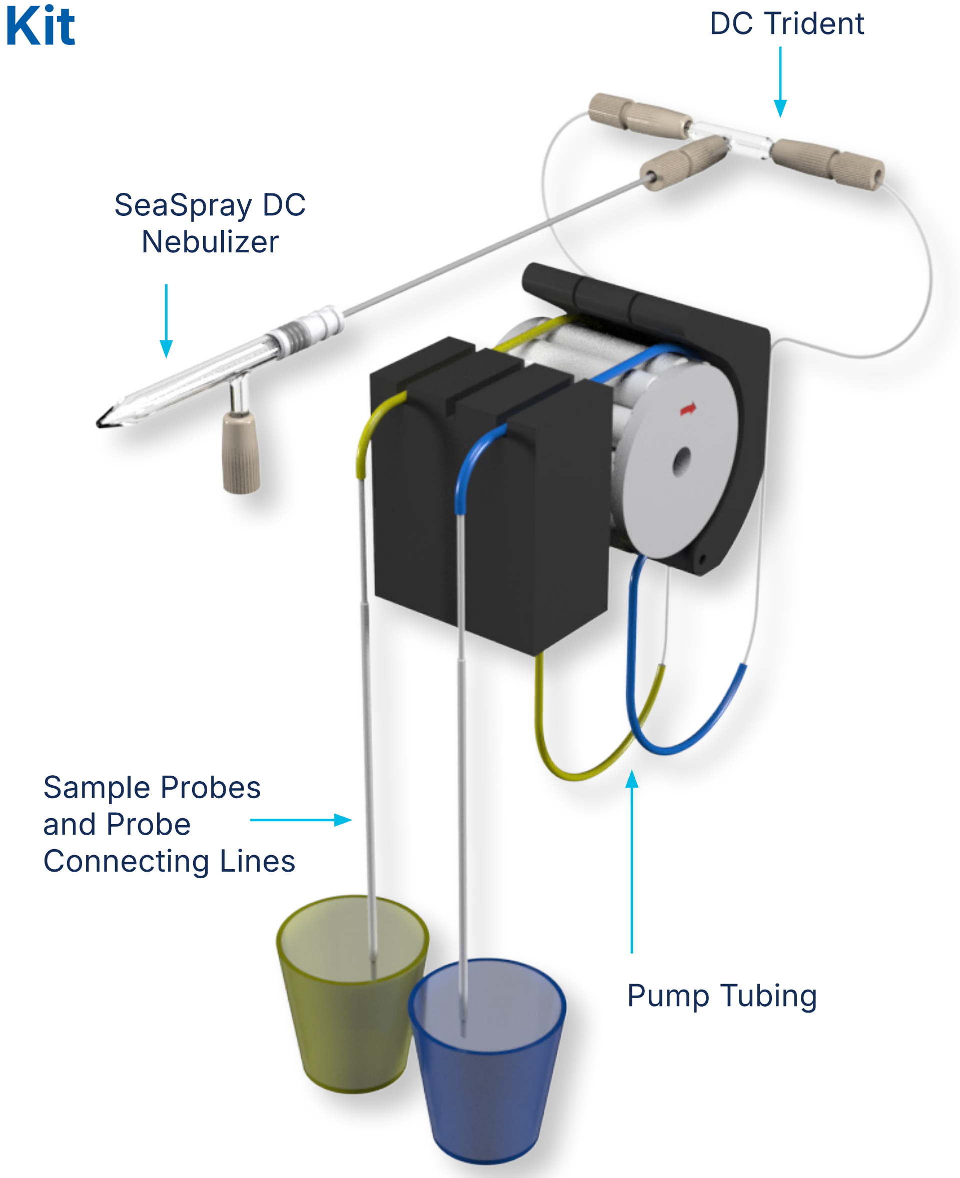
****The EzyGlide Cloth** can be used to lubricate pump rollers. This lubricatior reduces pump tubing wear to increase the service life of pump tubing.*

Tag Colours	ID (mm)
orange/black	0.13
orange/red	0.19
orange/blue	0.25
orange/green	0.38
green/yellow	0.44
orange/yellow	0.51
white/yellow	0.57
orange/white	0.64
black/black	0.76
orange/orange	0.89
white/black	0.95
white/white	1.02
white/red	1.09
red/red	1.14
red/grey	1.22
grey/grey	1.30
yellow/yellow	1.42
yellow/blue	1.52
blue/blue	1.65
blue/green	1.75
green/green	1.85
purple/purple	2.06
purple/black	2.29
purple/orange	2.54
purple/white	2.79
black/white	3.17

Enhancing ISTD Recovery by Minimizing Leaks and Contamination

1. Trident CT™ Internal Standard Addition Kit

- Compact, efficient mixing chamber ensures complete mixing of the sample and reagent.
- **ConstantTorque™ (CT) ratchet fittings** for a durable, leak-free seal on all connections.
- Consistency in torque application helps maintain the reliability and performance of the mixing chamber.



Trident CT™ Internal Standard Kit - P/N 60-703-1179

Select Sample pump tubing:

Sample Pump Tubing

Select Internal standard pump tubing:

Internal Standard Pump Tubing

Sample dilution result:

Sample is diluted by: **80.0%**

ie final concentration of sample is **0.200** times initial concentration

Internal Standard Dilution Result:

Internal standard is diluted by: **20.0%**

ie final concentration of internal standard is **0.800** times initial concentration

or Internal standard is diluted by a factor of **1.3**

This calculation should be used as a guide only. Variations between pump tubes and roller pressures mean that the accuracy of the calculation cannot be guaranteed.

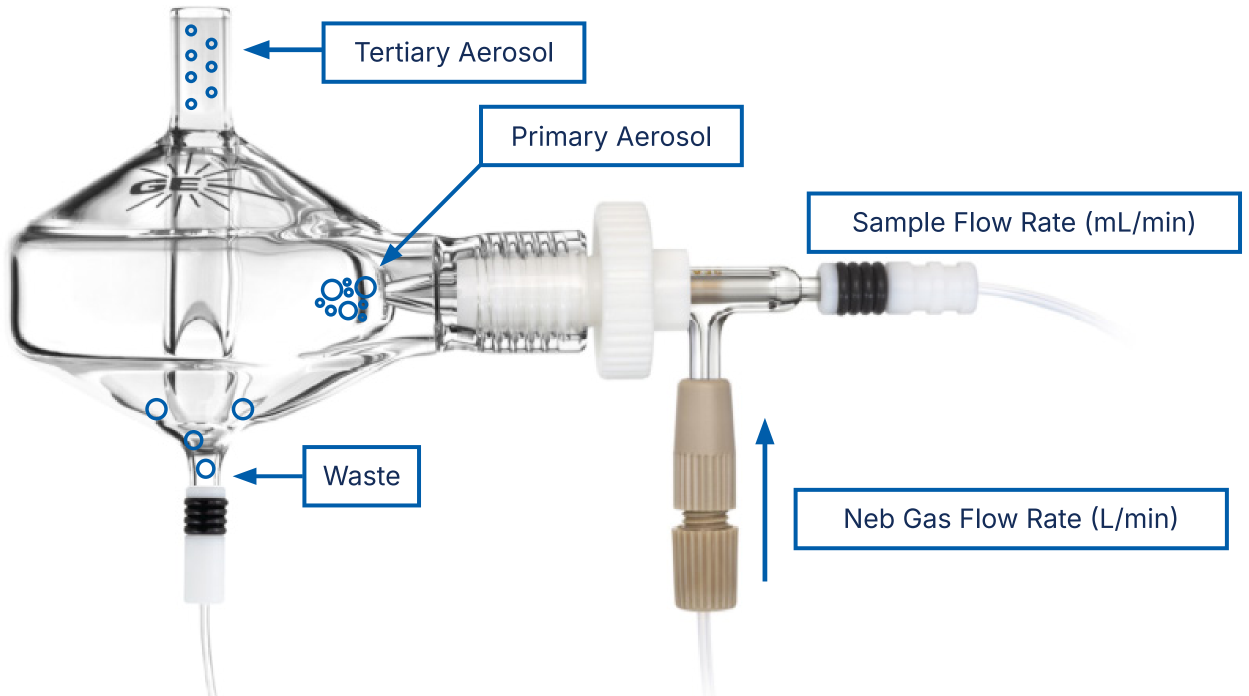
Trident Dilution Factor Calculator

Major Factors Contributing to ICP Variability:
2. Aerosol Generation

Aerosol Generation

Nebulizer & Spray Chamber

Only the smallest droplets (<10 µm) are transmitted to the plasma and around 95- 98% of nebulized sample is drained as waste.

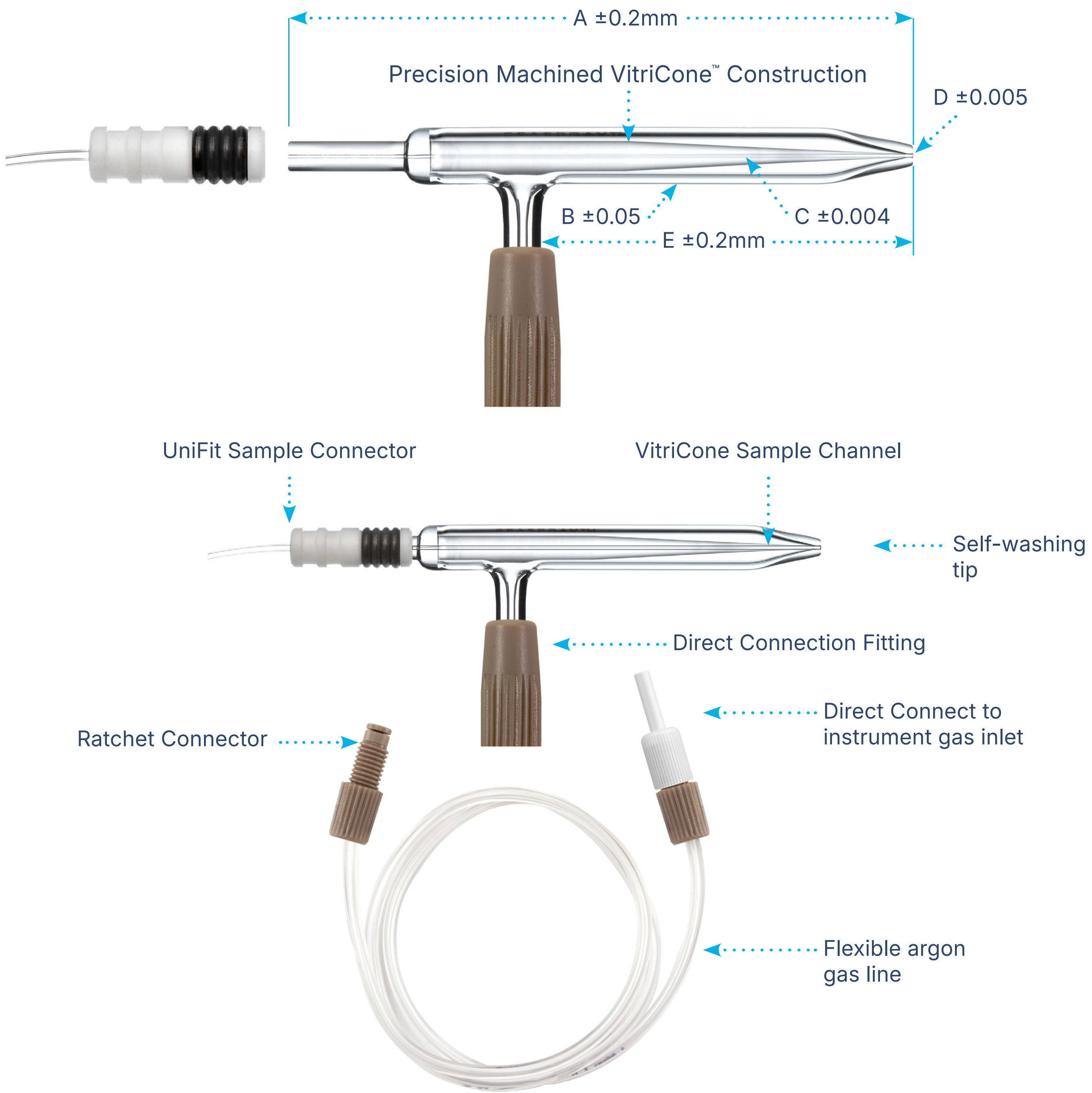


Factor	Effect on ICP Performance	Design/ Operational Considerations
Droplet size distribution	Determines transport efficiency, plasma loading and sensitivity	Nebulizer geometry, gas velocity, liquid flow rate
Aerosol uniformity	Directly affects precision and signal stability	Stable gas/liquid interaction and consistent nebulization
Sample aspiration rate	Changes aerosol production and plasma loading	Pump tubing, uptake rate, nebulizer design
Gas flow conditions	Influences droplet breakup and transport	Optimized nebulizer gas flow and pressure
Matrix properties	Affect atomization and droplet formation	Viscosity, surface tension, dissolved solids

Because only ~1–2% of the sample reaches the plasma, even small disturbances can significantly affect signal stability and sensitivity.

Major Factors Contributing to ICP Variability: Aerosol Generation

1. Nebulizer Design



Engineering Parameter	Influence on Aersol Generation	Potential Analytical Impact
Gas orifice geometry	Controls gas velocity	Sensitivity and transport efficiency
Liquid capillary dimensions	Determines sample uptake	Precision and reproducibility
Gas-liquid interaction	Governs primary droplet formation	Droplet size distribution
Concentricity & manufacturing tolerances	Determines aerosol consistency	Long-term signal stability
Material selection	Chemical compatibility	Robustness and contamination control

More sample ≠ better results

Nebulizer Assessment

Order Summary

1. Check aerosol production
2. Check nebulizer pressure
3. Check gas connection
4. Inspect for blockages
5. Replace component if damaged

Common Symptom	Possible Cause	Practical Recommendation
Poor Sensitivity / High RSDs	Partial nebulizer blockage, gas flow issue, improper installation, or spray chamber seal problem	Verify nebulizer aerosol production. If aerosol is weak, check nebulizer backpressure, gas connectors, and inspect the nebulizer tip for blockages
High nebulizer backpressure	Salt deposits, particulates, or dried residues from high-TDS samples	Clean the nebulizer and inspect the tip using a magnifier. If deposits cannot be removed or damage is observed, replace the nebulizer.
Low nebulizer backpressure (often with sensitivity loss)	Gas leak, damaged nebulizer, or kinked tubing	Inspect argon connectors and tubing for leaks. Replace damaged tubing or the nebulizer if necessary.
No aerosol production	Complete blockage in nebulizer, sample tubing valve, or autosampler probe; damaged nebulizer tip	Identify the blockage location and clean or replace the affected component. If the nebulizer tip is damaged, performance cannot be restored and the nebulizer must be replaced.

Care of Nebulizers: Other Practical Tips

Check Argon Connections

- Increasing RSDs may indicate a small argon leak at the nebulizer connection.
- Polymer gas tubing can harden over time and lose a gas-tight seal.
- Even **~1% argon loss can significantly affect ICP signals**

Quick Sample Uptake Check

- Observe the speed of an air bubble in a 10cm section of uptake tubing.
- Example estimates:
  - 1.0 mm ID tubing: 10cm is 10 s ≈ 470 µL/min uptake
  - 0.5 mm ID tubing: 10cm in 10 s ≈ 118 µL/min uptake

Storage Recommendations

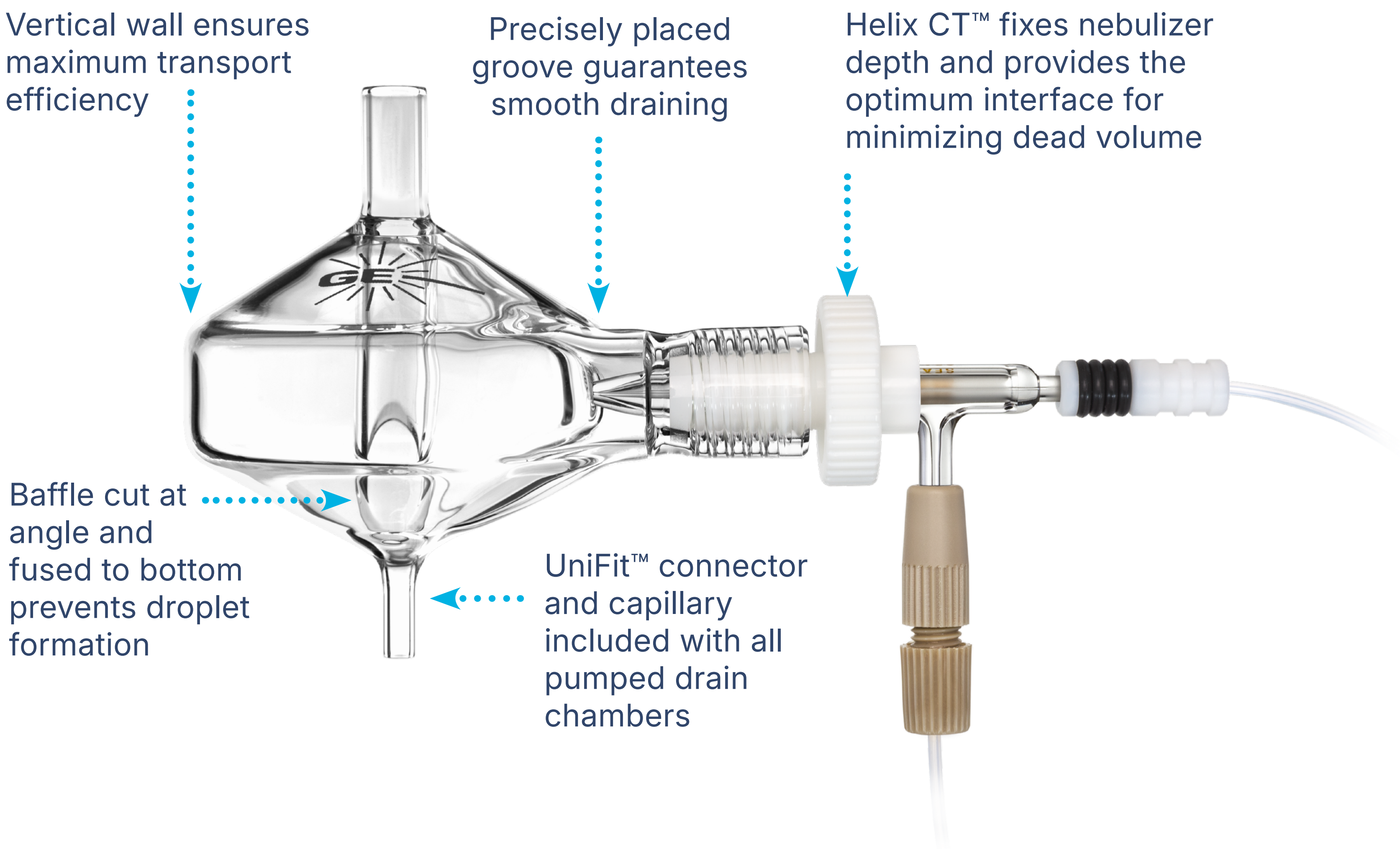
- Always **store nebulizers in their protective storage case.**
- Prevent dust or particles from entering the capillary

Inspect gas connections

All Glass Expansion nebulizers are supplied in specially designed storage boxes

Major Factors Contributing to ICP Variability: Aerosol Generation

2. Spray Chamber Design



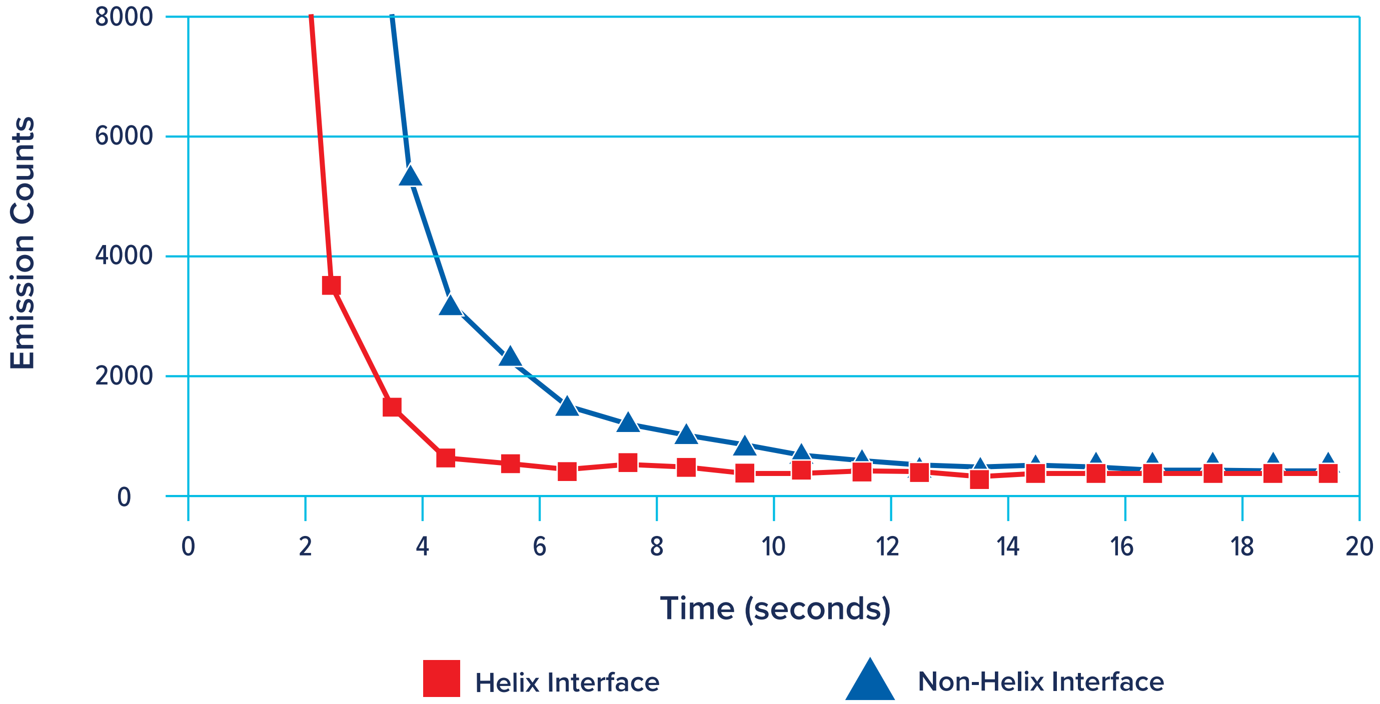
Engineering Parameter	Purpose	Analytical Impact
Droplet seperation efficiency	Removes large droplets	Improved plasma stability
Internal volume	Controls aerosol residence time	Response time and washout
Chamber geometry	Governs aerosol circulation	Precision and transport efficiency
Drainage characteristics	Removes excess liquid	Reduced pulsation and drift

Major Factors Contributing to ICP Variability: Aerosol Generation

2. Spray Chamber Design: Helix CT™

Benefits of the Helix CT™

- Industry-first since 2018
- Sensitivity Gains + Reduced Washout Times
- **ConstantTorque Locking Screw:** Click-to-seal mechanism makes it impossible to overtighten. Consistent inert PTFE seal every time, protecting nebulizers from excessive installation forces.
- **Inert PTFE PressFit Seal:** Chemically inert PTFE ferrule immune to strong acids and organic solvents. Eliminates all drawbacks of traditional O-ring seals, including broken nebulizers.
- **Zero Dead Volume Interface**: Only interface that significantly reduces dead volume around the nebulizer. Minimises washout time, reduces carry-over, and improves sample throughput.
- **Optimum Depth & Torque:** Positive stop ensures correct nebulizer depth every time. Combined with ConstantTorque control, delivers unparalleled day-to-day analytical reproducibility.



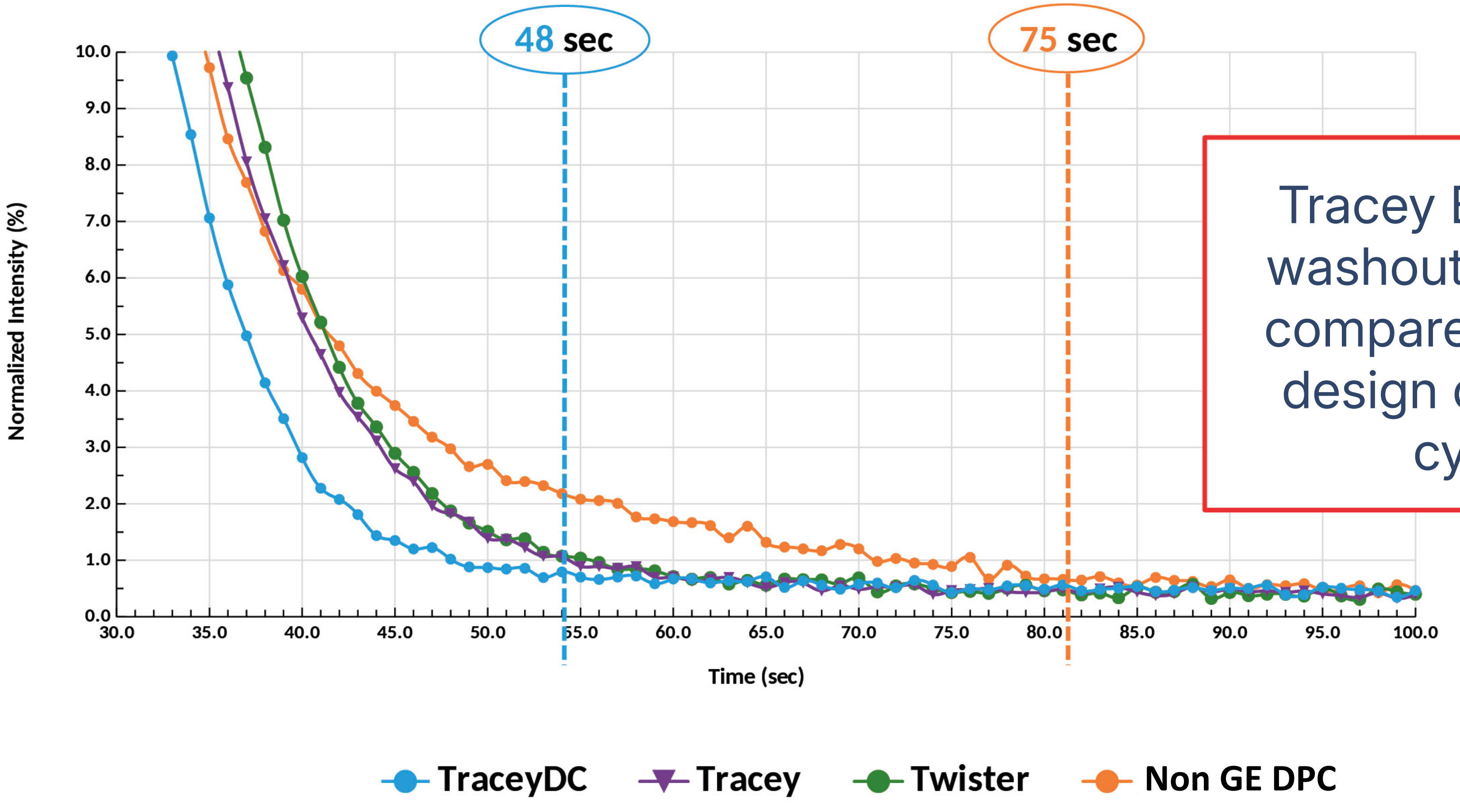
Tracey™ BC Design Concept

Optimized 30 mL low-volume cyclonic design

30 mL BC Spray Chamber → Increase the fraction of useful aerosol delivered while reducing unnecessary sample and solvent load.

- Efficient removal of larger droplets
- Reduced aerosol residence time
- Faster stabilization after sample switching
- Improved sample throughput potential

Washout Profiles for 1 ppm Hg:



Tracey BC achieves washout **64% faster** compared to non-GE design double pass cyclonic

Tracey™ BC PEEK Spray Chamber Design Concept

PEEK Construction

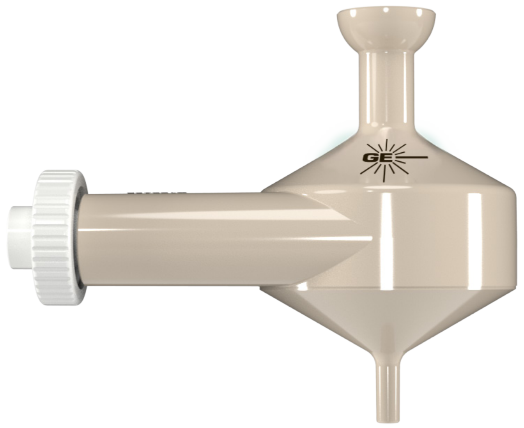
- **PEEK Construction →** Good chemical resistance (up to 5% HF)
- **Superior Wetting:** PEEK material maintains excellent wetting properties with routine laboratory cleaning.
- **No Internal Surface Treatment:** Unlike TFE or PFE, this spray chamber requires no internal surface treatment.

Comparison of Tracey BC PEEK to the PTFE Tracey

Below are the average intensity and RSD results from 41 optimization checks using the PEEK and PTFE spray chambers.

The Optimization Solution contains 2 ppm Pb, As, and Mn in 1% HNO_3.

∗Comparison conducted by Specialty Chemicals Manufacturer - USA



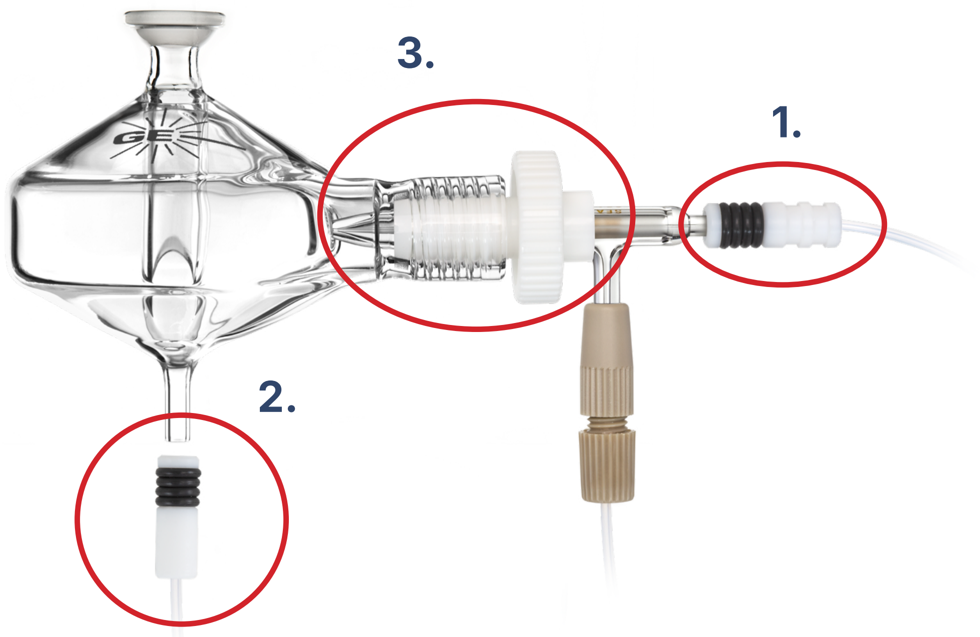
	% Increase in intensity	%RSD
Pb	74%	0.65
As	90%	0.69
Mn	68%	0.68

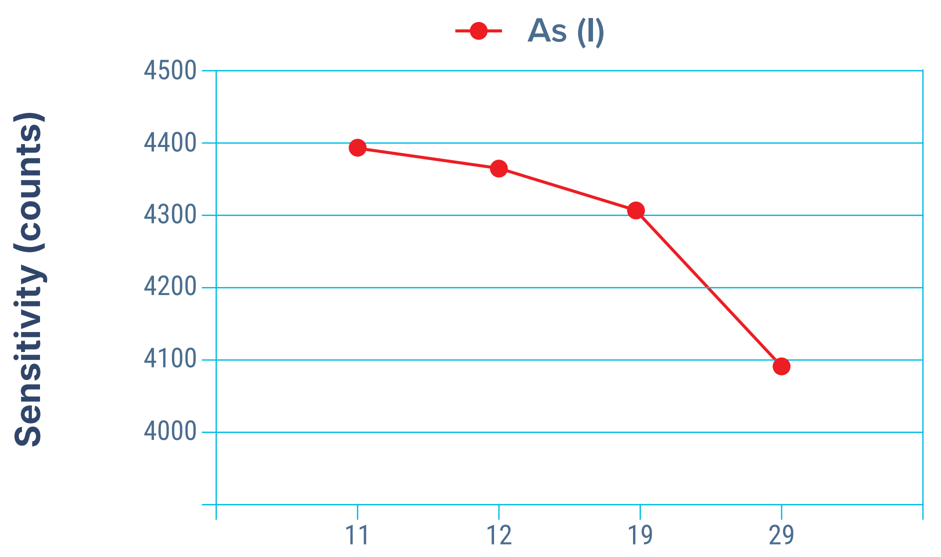
Spray Chamber Assessment

Common Symptom	Possible Cause	Practical Recommendation
Poor sensitivity / signal drift	Inefficient aerosol transport due to deposits contamination inside the spray chamber	Clean spray chamber and verify proper nebulizer intallation
Poor precision / high RSD	Droplet accumulation on internal chamber walls causing unstable aerosol transport	Clean spray chamber to remove deposits and ensure proper draining
Delayed washout / memory effects	Residual sample trapped in spray chamber or drain line	Inspect drain tubing and increase rinse time if necessary
Excess liquid entering plasma	Blocked or poorly draining spray chamber outlet	Inspect and clear drain tubing to ensure proper drainage

Inspect UniFit Drain Connector (Left) and Helix CT Seal (Right)

Hidden Causes of Instability in ICP Systems





Optimum Depth and Torque = Optimum Sensitivity

Connection Issues

- Leaks or **loose fittings**
- Improper waste drain seating → **unstable flow**
- Worn pump tubing → **air ingress**
- Blocked or kinked lines → **restricted flow**

Zero Dead Volume Connections

1. Between Sample line and nebulizer: **UniFit connector**
2. Between Waste tubing and spray chamber: **UniFit connector**
3. Between nebulizer and spray chamber: **Helix CT**

Quick Diagnostic Checks

- **Free-flow test:** steady, fine mist from nebulizer
- **Drain check:** smooth, continuous drainage
- **Visual inspection:** bubbles, wet fittings, leaks

Major Factors Contributing to ICP Variability: Plasma Interface

1. Torch & Injector

Plasma Interface

Torch & Injector

The torch and injector define how efficiently the aerosol is introduced into the plasma and how consistently the plasma can process the sample.

Factor	Influence on ICP Variability	Impact on Performance
Injector diameter and geometry	Controls aerosol transport, plasma penetration, and residence time of analyte	Incorrect sizing can lead to poor atomization, reduced sensitivity, or matrix-dependent effects
Injector material	Affects heat resistance, chemical compatibility, and memory effects	Quartz, alumina, and sapphire injectors behave differently with aggressive matrices
Injector blockage or deposists	Changes aerosol pathway and gas flow dynamics	Causes signal drift, increased background, and poor precision
Torch condition	Wear, cracks, or contamination influence plasma stability	Can result in unstable plasma ignition and increased variability

Torch & Injector Assessment

Torch failure can result from gas leaks, damaged/misalign RF coil, or suboptimal torch selection.

Common Symptom	Possible Cause	Practical Recommendation
Plasma instability Difficulty igniting plasma	Gas leaks from torch connection, worn O-rings, or injector ferrule deformation	**Inspect torch connections,** O-rings, and injector ferrule; replace if worn or damaged.
Poor sensitivity Signal drift	Injector partially blocked by salt deposits from high-TDS samples	Inspect injector tip for salt buildup or blockage; clean or replace if necessary. **Use Elegra™ Argon Humidifier to reduce salt deposition.**
Frequent torch cracking Short torch lifetime	RF coil damage, deformation, or misalignment causing uneven plasma heating	**Inspect RF coil for damage/** discolouration; clean or replace if needed.
Outer tube devitrification	Chemical attack or prolonged exposure to high plasma temperatures	**Inspect torch outer tube for clouding or crystallization;** clean or replace torch if necessary

Devitrification of quartz due to salt deposits (Left), and RF Coil corrosion (Right)

******Even if gas flows are set correctly in the software, poor mechanical connections can cause flow instability and plasma issues.***

Aggressive Sample Matrices

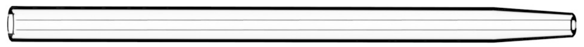
Torch Design

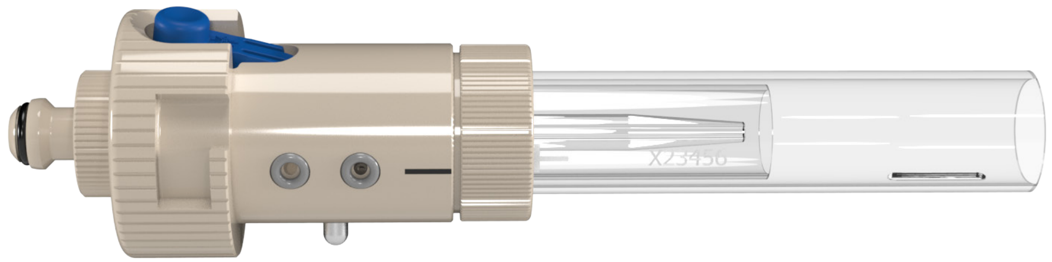
High salt deposits and plasma temperatures shorten quartz torch life

O-ring failures or gas leaks can destabilize plasma or prevent ignition

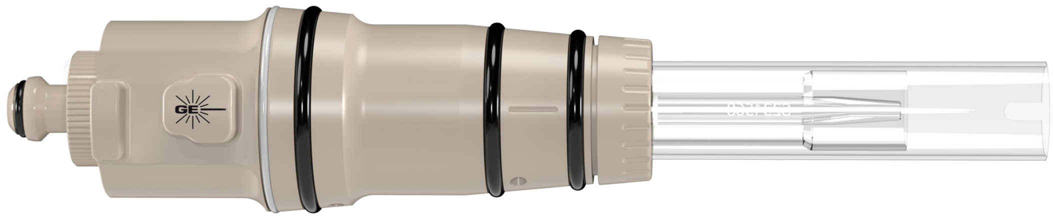
Mitigation:

- Clean torch regularly using appropriate methods for organics, salts, and metals
- **Use a Demountable Torch →** replace only the outer tube, lowering cost of ownership
  - Large bore quartz: 2.0 mm or greater: High TDS
  - Ceramic (alumina): HF-containing samples
  - Platinum/Sapphire Injectors: Inert applications
- **Ferrule-based design:** Secure injector seating, fewer leak points





P/N 30-808-4388
E-Torch for Thermo® PRO Duo



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E-Torch for Agilent® Series SVDV, VDV

Ceramic Outer Tube: Designed for Challenging ICP Applications

Challenge

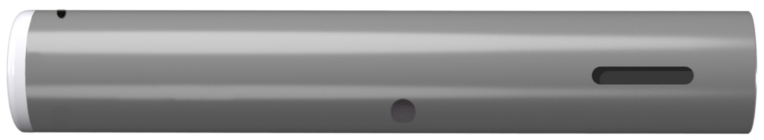
- High thermal stress and aggressive matrices can degrade conventional quartz plasma tubes
- Deposits, devitrification, and cracking can alter plasma conditions over time

Material Solution: Ceramic outer tube design

- Higher thermal stability
- Improved resistance to chemical attack
- More robust plasma conditions

Analytical Impact

- Improved plasma robustness
- Reduced matrix effects
- Improved sensitivity and detection capability
- Longer operating lifetime and reduced maintenance



Ceramic Plasma Tube
for Thermo Scientific® PRO Duo

Quartz Plasma Tube
for Thermo Scientific® PRO Duo

Comparison of Quartz Plasma Tube to Ceramic Plasma Tube

Element	% Increase in intensity	%RSD
Zn (213) λ	17%	0.37
Ni (231) λ	19%	0.57
Mn (257) λ	14%	0.52

Major Factors Contributing to ICP Variability: Plasma Interface

2. RF Coil & Plasma Coupling Effect

Plasma Interface

RF Coil

The RF system provides the energy that sustains the plasma. Any change in energy transfer directly affects ion generation and signal stability.

Factor	Influence on ICP Variability	Impact on Performance
RF power stability	Determines energy transferred into the plasma	Fluctuations affect excitation efficiency and ion production
RF coil position and condition	Controls plasma generation and shape	Poor coupling reduces plasma robustness and signal stability
Matrix loading effects	High solvent or dissolved solids can consume plasma energy	Leads to signal suppression and reduced robustness

RF Coil Assessment

Common Issue: RF Coil Corrosion

Can occur due to heat or chemical oxidation:

- Reduced energy transfer efficiency.
- Increased load on the RF generator / RF power tube.
- Less robust plasma and lower analytical signal intensity.

******Corroded coils may also create hotspots, leading to premature torch failure or melting.***

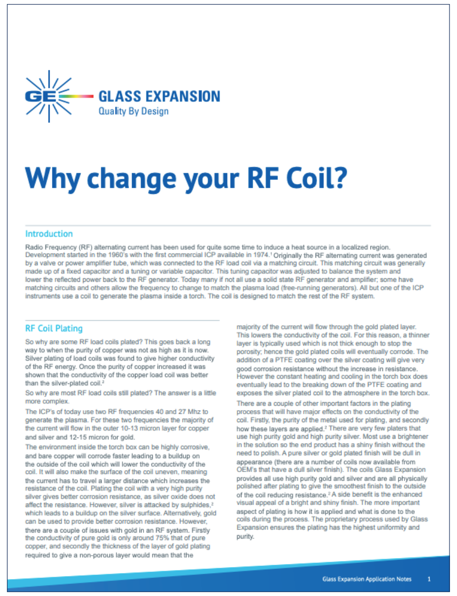
Alignment: Ensures a well-shaped and consistently positioned plasma.

Material & Plating:

- **Copper:** cost-effective but oxidizes quickly
- **Silver-plated:** highest conductivity but prone to tarnish
- **Gold-plated:** best corrosion resistance for harsh environment

Maintenance Recommendations

- Clean periodically to remove deposits and oxidation.
- Replace coils showing copper migration, severe tarnish, or damage.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Why change your RF Coil?

Introduction

RF Coil Plating

RF Coil Application note

Want a FREE review of your Sample Introduction System?

- ✓ Optimize your sample introduction system components
- ✓ Identify other performance enhancing accessories available for your ICP
- ✓ Discuss any sample introduction challenges
- ✓ Explore ways to reduce operating costs
- ✓ Obtain quotes

Contact by email: gegmbh@geicp.com

Thank You

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