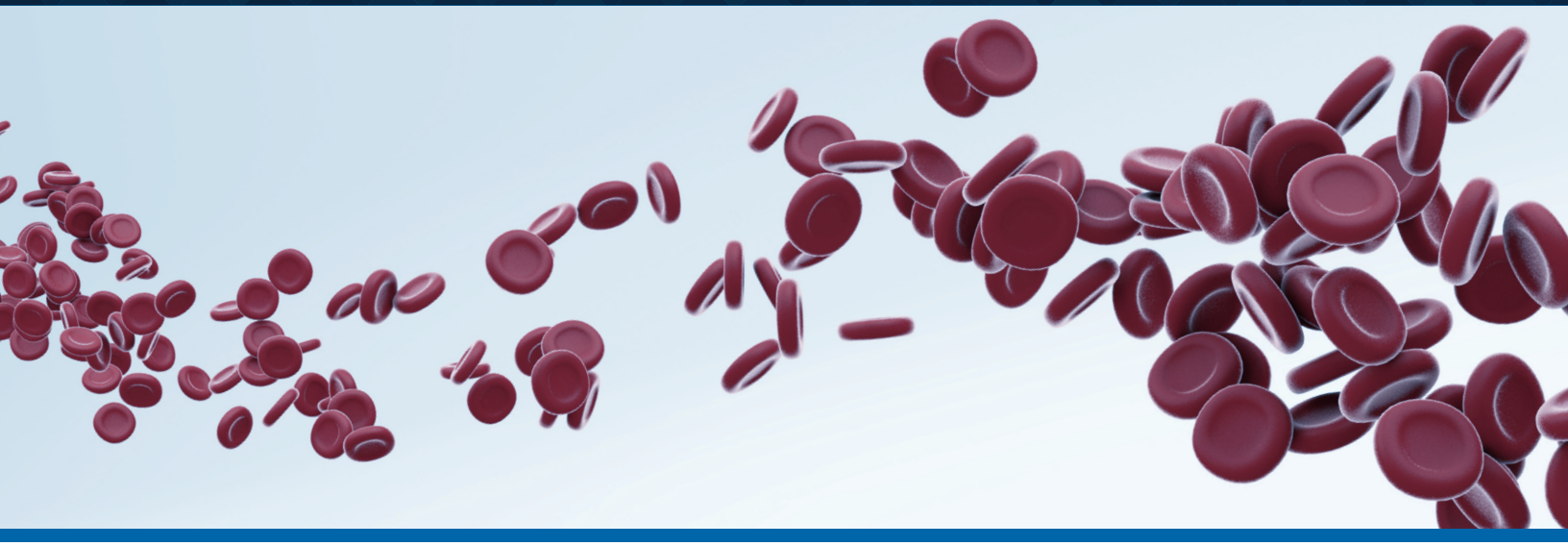


Authors: Kevin Wiederin, Brad Prucha and Kyle Uhlmeyer

SampleSense *FAST* UHT-C – Ultra-high Throughput Sample Introduction System for Micro-volume Clinical Samples – 20 Seconds per Sample

Abstract

Determination of metals in whole blood by ICPMS poses many challenges for high-throughput laboratories. The addition of an automated sample introduction system with sample detection capability ensures analytical integrity by automatically accounting for variable sample viscosities, detecting missed sample events, and minimizing sample consumption. In this application, high-throughput analysis of whole blood is achieved using a novel rinse-trapping valve that is able to quickly and efficiently rinse the sample introduction components. The use of a highly accurate autosampler with microplates maximizes sample throughput, increasing sample capacity by 60-113% (depending on autosampler size). The SampleSense *FAST* UHT-C* system is uniquely optimized for high-throughput micro-sampling, positive confirmation of sample introduction, and stable performance for the analysis of difficult clinical sample matrices such as whole blood. Sample analysis rates of 180 blood lead samples per hour are demonstrated with long-term reproducibility within 1% RSD.

Figure 1. Integrated DXi valve assembly for SampleSense *FAST* UHT-C for NexION 2000.

* *Formerly SampleSense Clinical*

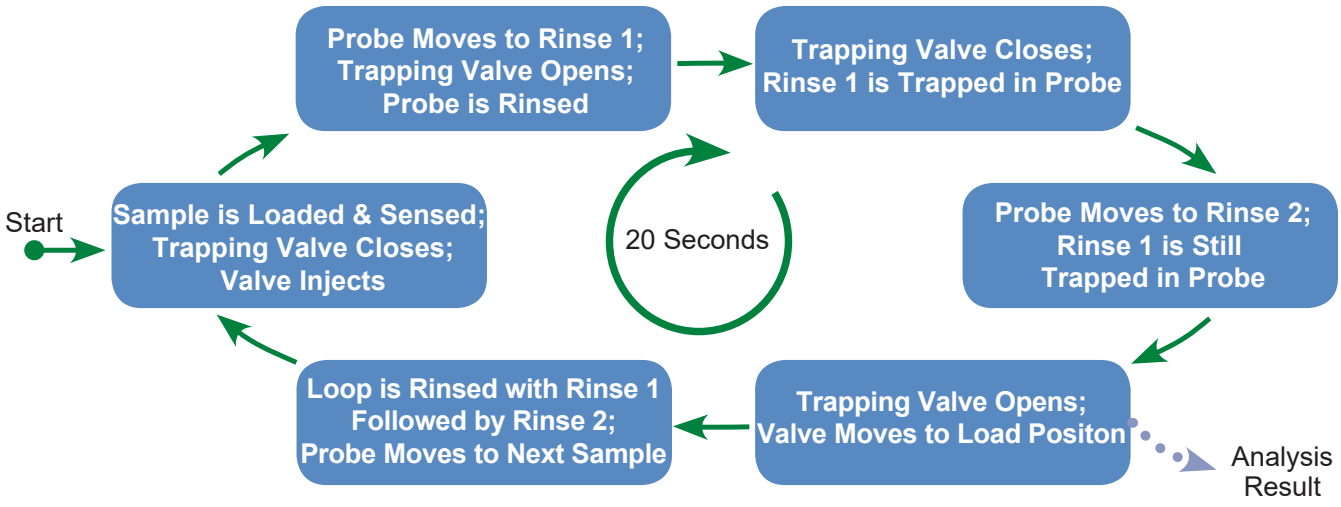
SampleSense *FAST* UHT-C

SampleSense *FAST* combines an autosampler and inert sample valve with integrated optical sensors that automatically detect the presence of a non-segmented liquid sample as it is quickly vacuum loaded onto a sample loop. In a tightly timed analytical sequence, the sensed sample is injected into the ICPMS, which is automatically triggered to acquire data. SampleSense *FAST* UHT-C further builds on the SampleSense *FAST* by incorporating a vacuum control valve (trapping valve) to minimize sample consumption. In addition to automatically sensing and injecting the sample, the SampleSense valve simultaneously switches the position of the trapping valve, shutting off the vacuum. SampleSense also detects and reports sample loading failures. Unsensed samples – for example empty or capped tubes – are identified and logged, saving the operator the time and hassle of deciphering ICPMS data from non-sample events. These features, combined with the highly accurate DXCi autocorrecting autosampler with microplates, greatly improve laboratory productivity and reduce needless sampling errors.

Enhanced Washout

SampleSense *FAST* UHT-C optimizes the dual rinse of the DXCi autocorrecting autosampler by trapping the rinse solution from the first rinse station in the sample probe while the sample is analyzed, eliminating the need to dip into that rinse station after analysis is complete. After analysis, the sample probe moves directly into the second rinse station while the trapping valve is opened, allowing the trapped dual rinse solutions – in series – to wash out the previous sample. Fast and efficient washout is achieved using this rinse-trapping capability, facilitating high throughput of 20 seconds per sample.

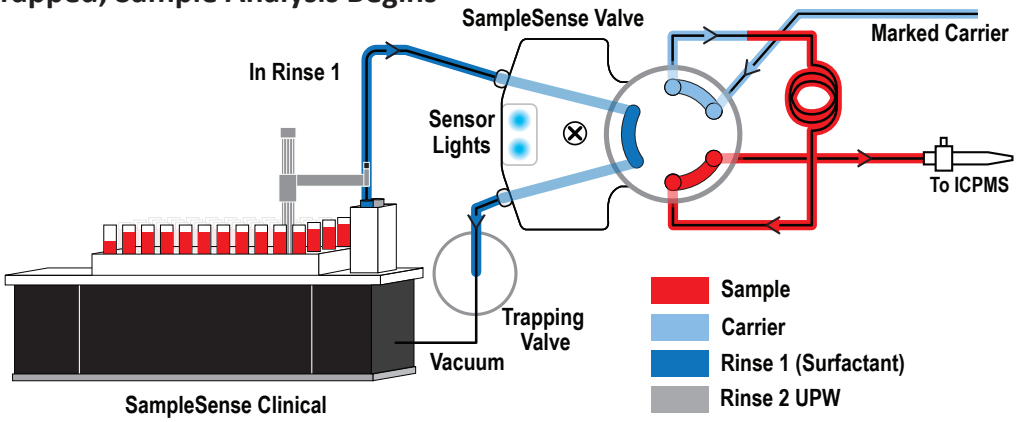
SampleSense *FAST* UHT Analytical Cycle



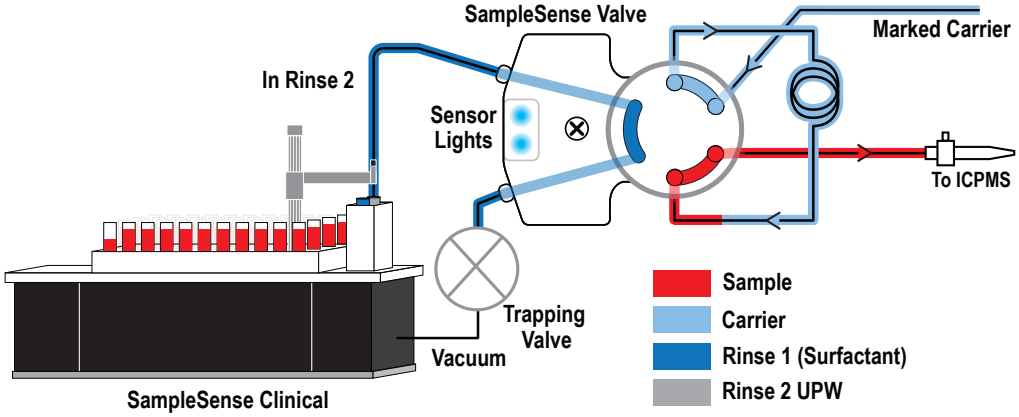
Enhanced Washout *(Continued)*

SampleSense *FAST* UHT-C Dual Rinse Trapping Operation for Clinical Samples

1. Rinse 1 Is Trapped; Sample Analysis Begins



2. Probe Moves into Rinse 2 with Trapped Rinse 1; Sample Analysis Continues



3. Valve Opens, Rinse 1 & 2 Clean Loop and Go to Waste; Analysis Complete, Marked Carrier Follows

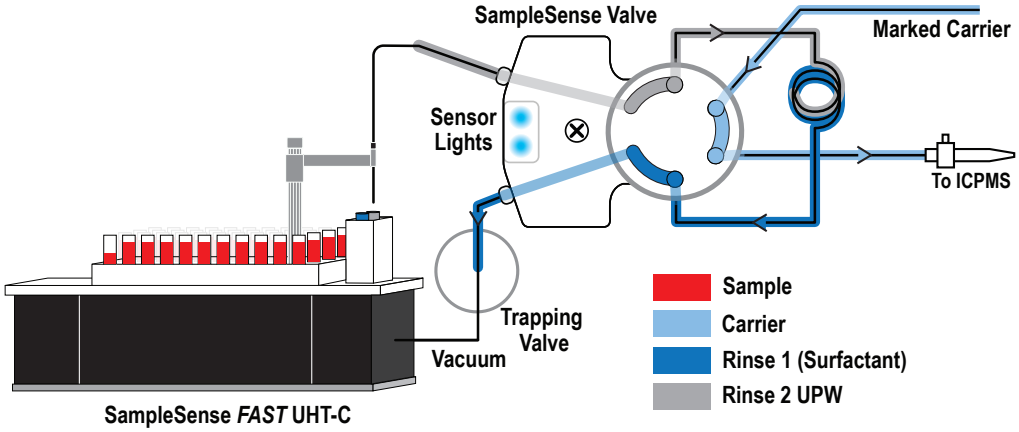


Figure 2. SampleSense *FAST* UHT-C Rinse Diagram: (1) After sample loading and injection, the probe moves to Rinse 1 to begin the rinse sequence. Once the first rinse solution has filled the probe and both sensors are activated, the trapping valve closes, capturing Rinse 1 in the probe. (2) With Rinse 1 trapped, the probe moves into the second rinse station and waits for analysis to complete. (3) Once analysis is complete, the trapping valve opens and both rinses immediately and sequentially clean the loop. The probe moves up and to the next sample for analysis.

Instrumentation and Sample Preparation

All samples were analyzed using SampleSense *FAST* UHT-C in combination with a NexION 2000 ICPMS.

Features

- 3 samples per minute
- Automatic sensing, injection and triggering of the ICPMS analysis
- Detection and reporting of missing or empty sample tubes as “unsensed” samples
- Dual rinse

Bovine whole blood samples were diluted 50x using an aqueous solution of 0.4% v/v TMAH, 1% ethyl alcohol, 0.01% APDC, and 0.05% Triton X-100; the same diluent solution was also used as Rinse 1.

Table 1. Parameters of experiment

Parameter	Standard Mode
ICP RF Power (W)	1500
Nebulizer Gas Flow (L/min)	0.95
Auxilary Gas Flow (L/min)	1.2
Plasma Gas Flow (L/min)	15
Sample Flow Rate (mL/min)	0.65 (Black/Black)
Nebulizer	PFA Integrated Capillary Nebulizer (ICN-64) with *pergo* 2000 AMS humidifier (*pergo* 2000 AMS)
Spray Chamber	Glass AMS (C3X-64)
Torch	Demountable Quartz (DTQ-64)
Injector	2.0 mm Demountable Quartz (IDQ20-64)
Sampler/Skimmer Cones	Nickel (MC-33612/MC-26356)
Peltier Cooler Set Point	2 °C

Experimental Conditions

- SampleSense *FAST* UHT-C
- 4DXCi autocorrecting autosampler with six 96-well microplates
- Dual rinse with rinse trapping:
  - Rinse 1: Surfactant (Triton-X, TMAH, ethanol, APDC)
  - Rinse 2: UPW
- Total run time for 576 samples <3 h 12 min:
  - 20 s/sample
- Analytes:
  - Pb 206 + 207 + 208
  - Bi (IS)
  - Tm (Carrier Marker) – Unsensed samples not injected

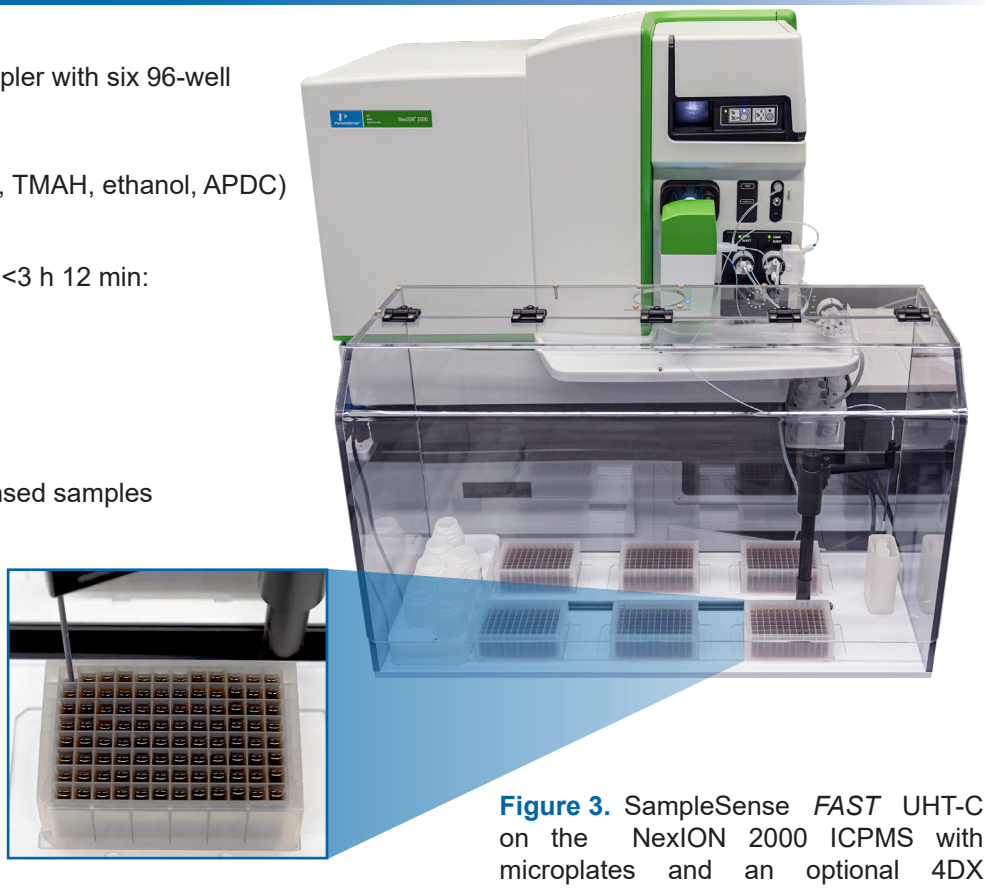


Figure 3. SampleSense *FAST* UHT-C on the NexION 2000 ICPMS with microplates and an optional 4DX enclosure (SC-1410-DX).

Confirmation of Sample Loading with SampleSense

In addition to offering the advantages of automatic sample loading, valve injection, and ICPMS triggering, the optical sensors in the SampleSense valve provide positive confirmation to the laboratory that each sample is properly dispensed into its microplate well and subsequently successfully loaded into the loop for analysis. If a sample container is either underfilled or empty, the SampleSense software logs the unsensed sample event and does not inject the contents of the sample loop. As additional confirmation of a missed sample in the raw ICPMS data, a marker component is added to the carrier solution (Tm in this work). SampleSense automatically responds to any unsuccessful sample-loading event by triggering the ICPMS analysis without injecting the sample loop contents, resulting in the analysis of the marked carrier solution. The presence of this marker, Tm, at a high count rate in the ICPMS data provides additional confirmation to the analyst that a sample was not introduced successfully. An example is shown in Figure 5.

Diagram of Marked Carrier Being Used to Easily Identify a Non-sample Event

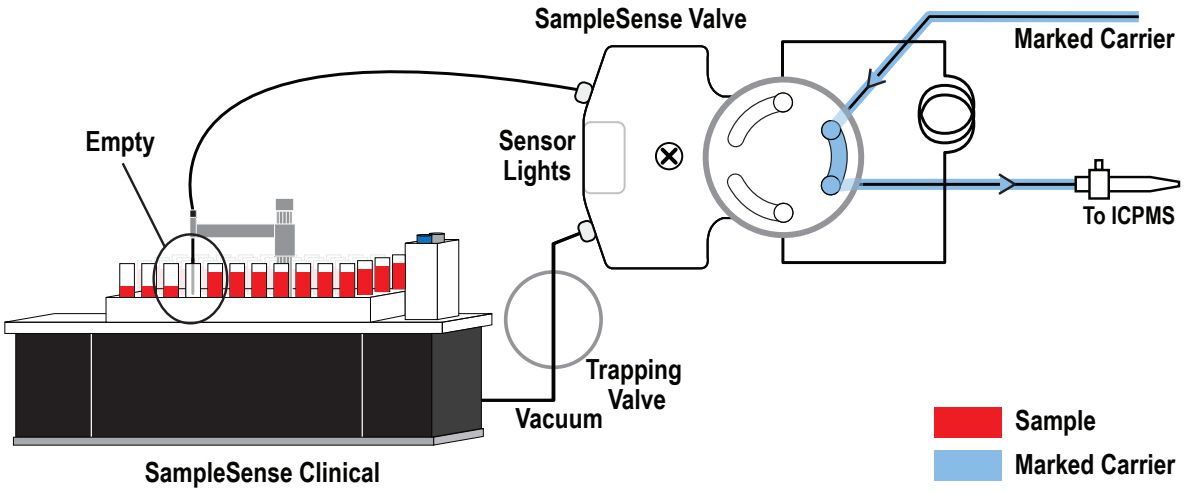


Figure 4. A carrier marker is an element present in the carrier solution that provides verification in the raw data of any non-sample event, such as an empty or underfilled sample. If a sample is not successfully loaded, the SampleSense valve will trigger analysis of the marked carrier solution, providing a noticeably higher count rate for the marker element.

Sample Id	Acquisition Time	QC Status	Pb-1 208 (cps)	Bi 209 (IS) (cps)	Tm 169 (cps)
Blood Pb	10/17/2019 1:53:39 PM	Passed	17489.6	142851.4	93.3
Blood Pb	10/17/2019 1:54:19 PM	Passed	17524.9	141302.9	86.7
Blood Pb	10/17/2019 1:54:39 PM	Passed	17450.2	142313.4	126.7
Blood Pb	10/17/2019 1:55:18 PM	Passed	17426.2	142268.3	93.3
Blood Pb	10/17/2019 1:55:38 PM	Passed	17517.6	142268.3	80.0
Empty Vial	10/17/2019 1:55:57 PM	Failed	479.2	144139.6	321345.9
Capped Sample	10/17/2019 1:56:17 PM	Failed	445.8	143635.2	318745.5
Blood Pb	10/17/2019 1:56:37 PM	Passed	17570.3	142044.8	73.3
Blood Pb	10/17/2019 1:56:56 PM	Passed	17556.9	142044.8	80.0

Figure 5. Screenshot of SampleSense flagging an Empty vial and capped sample using Syngistix™ software. SampleSense *FAST* UHT-C and Syngistix QC technology can be combined to help quickly identify non-sample events based on the presence of elevated signal of the carrier marker. Within the Syngistix method, the QC levels for the carrier marker can be set to create a “Failed” QC status if its count rate is significantly elevated.

Experimental

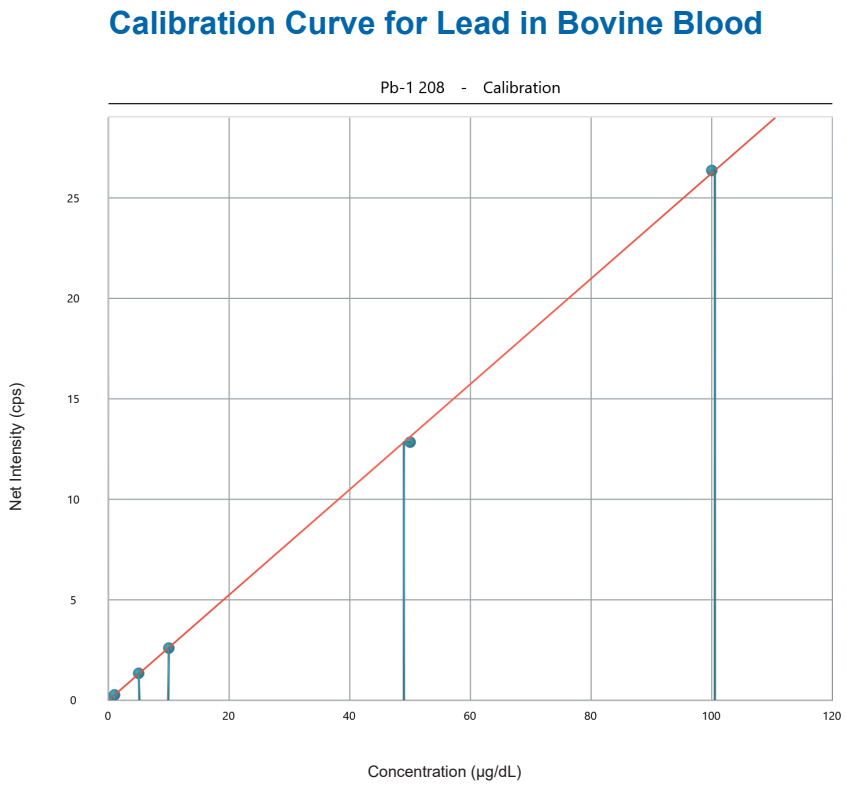


Figure 6. Highly linear calibration of 3 Pb isotopes (206 + 207 + 208).

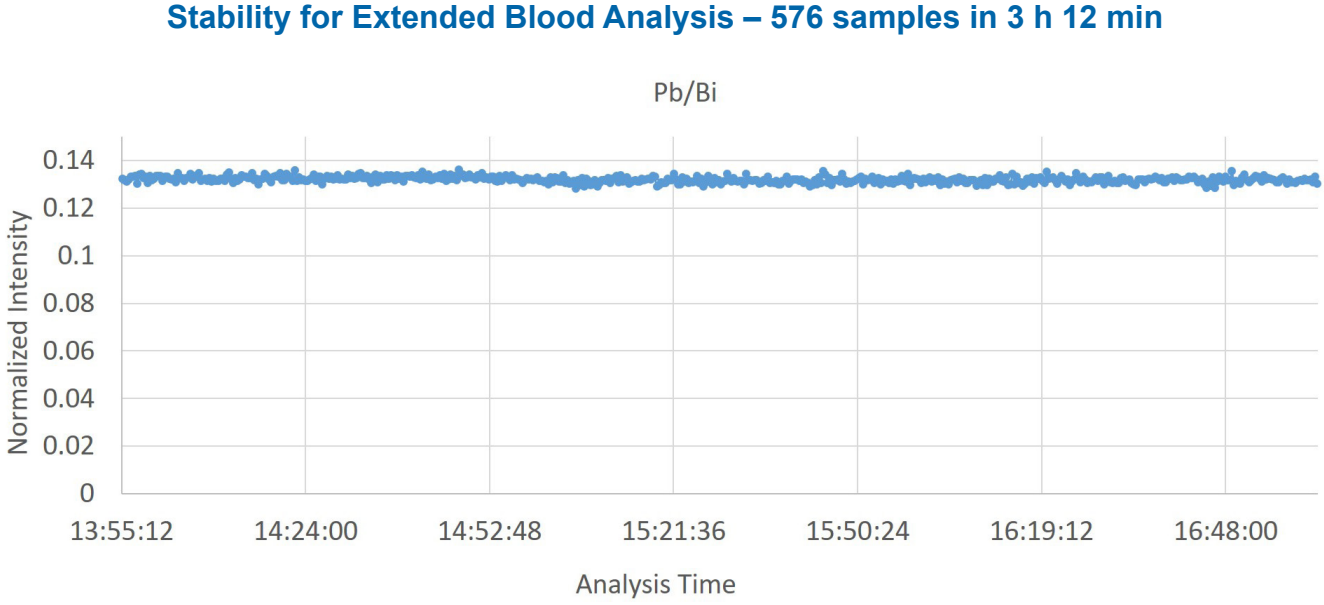


Figure 7. Normalized intensity ratio (Pb [206, 207, 208] / Bi 209) during extended analysis of six 96-well microplates (576 samples). Excellent long-term reproducibility within 1% RSD was observed over the 3 h 12 min analysis for the 50x diluted bovine blood samples.

Experimental *(Continued)*

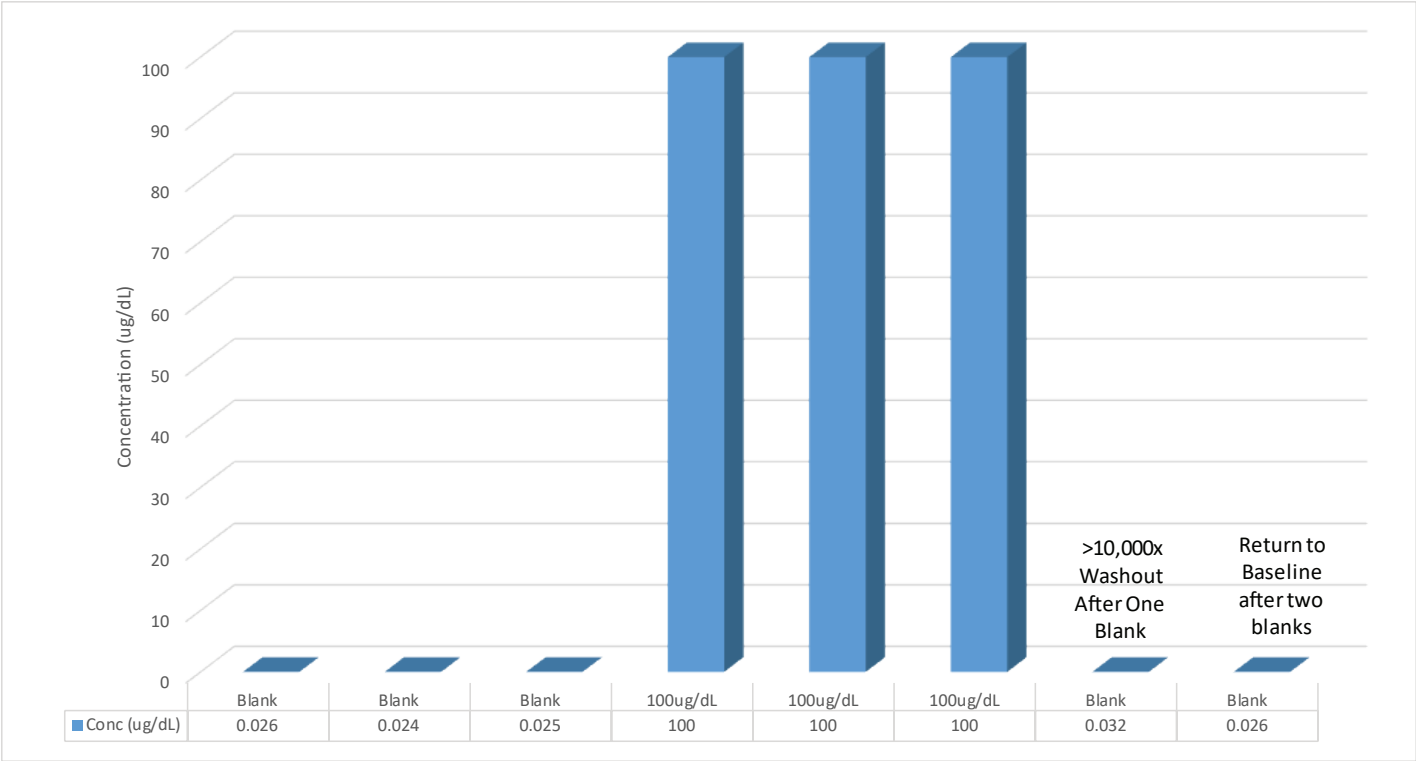


Figure 8. Pb washout after high calibration standard run 3x in a row. With SampleSense *FAST* UHT-C, washout after one blank is >1000x, and Pb returns fully to baseline after two blanks.

Results

The system was calibrated at 0, 5, 10, 50 and 100 µg/dL Pb, a common calibration range for this application. The SampleSense *FAST* UHT-C generated a highly linear calibration curve from the sum of three Pb isotopes (206+207+208) in just over 1.5 min (Figure 6). Following the calibration, 576 samples of 50x diluted bovine blood were analyzed from six 96-well microplates. Each of the 576 sample wells contained 2 mL of diluted bovine blood, and after analysis, sufficient sample remained to complete a second analysis. The rinse-trapping valve on the SampleSense *FAST* UHT-C kept the system clear of the clogging normally associated with extended blood analysis, allowing 576 samples to be analyzed in 3 h 12 min with excellent long-term reproducibility within 1% RSD over the course of the entire analytical sequence (Figure 7). An additional benefit of the rinse-trapping valve is shown by the excellent washout profile of the system. After analysis of three consecutive 100 µg/dL standards, the system achieved >1000x washout in the next blank and completely returned to baseline by the subsequent blank (Figure 8).

Conclusion

SampleSense *FAST* UHT-C optimizes the analysis of whole blood by ICPMS in high throughput clinical laboratories using an advanced, automated valve injection sample introduction system. Built-in optical sensors for sample loading eliminate method customization and the need to adjust timing parameters for variable sample viscosity. Washout of sample introduction components is optimized with a novel rinse-trapping valve. These features, combined with the DXCi autocorrecting autosampler, maximize laboratory productivity and reduce needless sampling errors. The optical sensors in the SampleSense valve also confirm that each sample is properly loaded into the loop for analysis, with capped, underfilled or empty vials being logged by the ESI software and flagged in the raw data by Syngistix QC functions. SampleSense *FAST* UHT-C improves analytical efficiency in a production laboratory environment by maximizing throughput and minimizing and flagging sampling errors, providing a higher level of data authentication and reliability for patient results.

Description	NexION 2000 Part Numbers
SampleSense *FAST* UHT-C 2DX	2F-SS6-UHTC-64
SampleSense *FAST* UHT-C 4DX	4F-SS6-UHTC-64
SampleSense *FAST* UHT-C 8DX	8F-SS6-UHTC-64
SampleSense *FAST* UHT-C 14DX	14F-SS6-UHTC-64