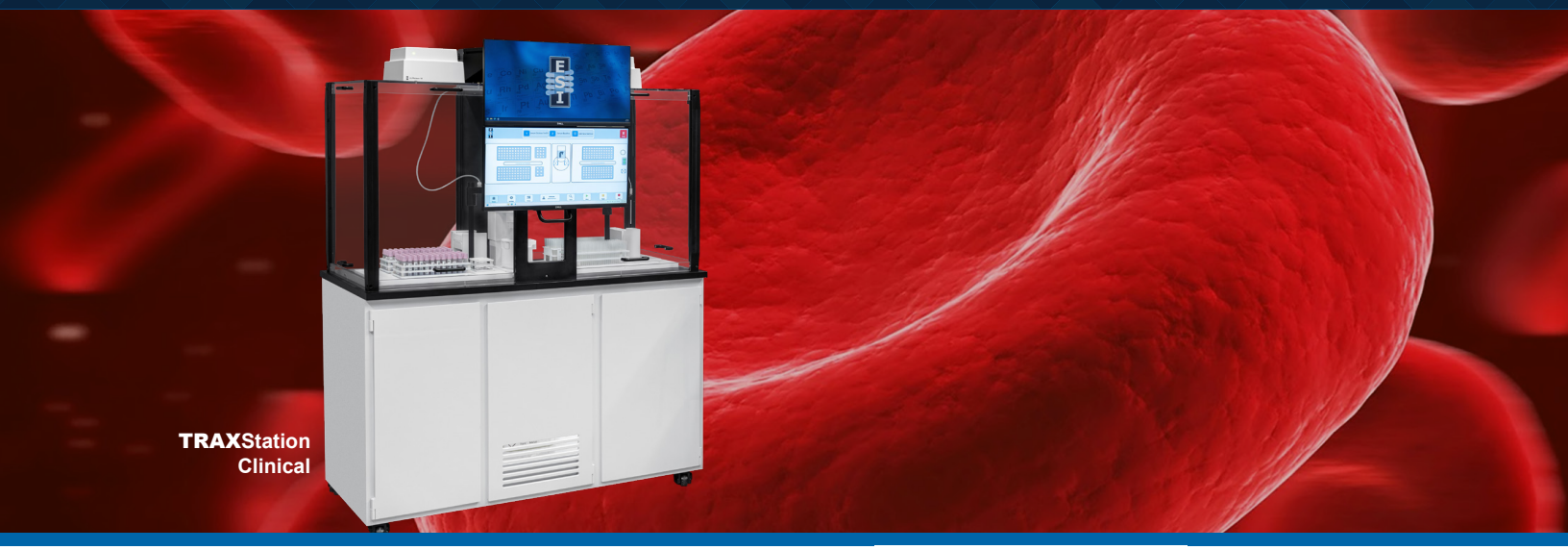

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Automating Capillary Blood Preparation Using SampleConfirm and LinkGauge with **TRAX**Station Clinical

Introduction

Capillary blood collection tubes play a critical role in blood lead (Pb) testing, particularly in pediatric and public health settings, where fingerstick or healstick sampling enables minimally invasive collection from small or vulnerable patient populations. Their use supports broader screening efforts by simplifying collection logistics and improving patient compliance. However, capillary samples introduce both analytical and ergonomic challenges. From an analytical perspective, small and often variable sample volumes, increased risk of clotting, and potential contamination from skin or collection surfaces can impact accuracy and precision of results. In addition, the geometry and low fill volumes of capillary tubes complicate automated aspiration and consistent sample handling. From an ergonomic standpoint, manual manipulation of small tubes – such as uncapping, aligning, and pipetting – can be repetitive, time-consuming, and prone to user fatigue or error, particularly in high-throughput laboratories. Together, these factors make capillary blood samples both essential and challenging for reliable blood lead testing workflows.

Figure 1. Capillary collection tubes on the **TRAX**Station Clinical.

LinkGauge: Automated Liquid Level Detection

Capillary blood collection tubes often contain very limited sample volumes and may exhibit variability due to clotting, air gaps, or inconsistent fill levels. These characteristics can present challenges for automated liquid handling systems where accurate aspiration depends on sufficient volume and consistent sample presentation. Inadequate or irregular sample volumes may lead to incomplete aspiration, increased variability, or failed pipetting events, impacting downstream dilution accuracy and analytical reliability.

Ensuring robust handling of low-volume capillary samples is therefore critical to maintaining precision and confidence in automated clinical workflows. To evaluate the impact of low-volume and variable capillary blood samples on automated pipetting performance, an experiment was designed leveraging the **TRAX**Station Clinical's ultrasonic liquid-level detection in aiding the aspiration process. Capillary tubes at multiple specified volumes and 4 different matrices (blood, serum, urine, and water) were processed to assess the system's ability to detect sample presence.

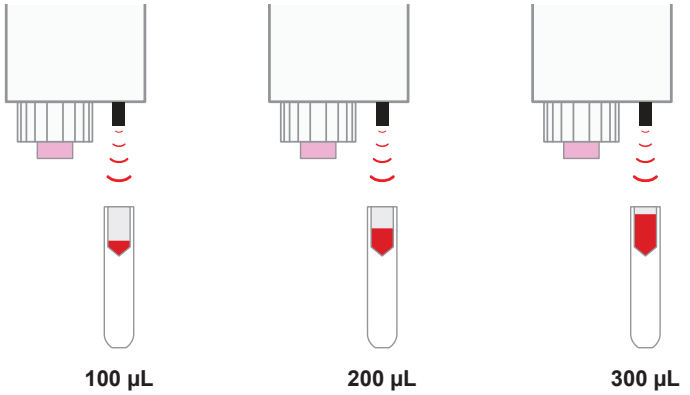

Figure 2. The capillary tube used in this experiment featured a false-bottom design with an internal conical sample well. Tube geometry can significantly influence measured liquid levels; therefore, each tube type must be evaluated to establish appropriate decision thresholds. In addition, sample matrix characteristics can affect meniscus shape due to differences in surface tension and the degree of wetting along the plastic tube walls. The figure above also illustrates the placement of LinkGauge within the workflow and demonstrates how measurements are acquired immediately following cap removal.

Figure 3. LinkGauge detects presence and volume of microsamples automatically.

LinkGauge: Automated Liquid Level Detection *(Continued)*

The graphs below show liquid heights for different matrices in millimeters derived from ADC values that were converted into corresponding height measurements (mm) using the LinkGauge calibration model. The blue data points, from ADC values and converted to millimeters, shown on the graph represent the calibration response of LinkGauge and demonstrate excellent linearity across the evaluated sample volume range. The orange data points represent experimentally measured known sample volumes, which also exhibited excellent linear agreement with the established calibration curve, further validating the accuracy and reproducibility of LinkGauge. At volumes corresponding to ADC values below approximately 100 mcL, the response begins to deviate from linearity. This behavior may be influenced less by LinkGauge's ability to detect extremely small liquid volumes and more by the physical behavior of the liquid itself at very low volumes, where the sample may no longer sit uniformly or flat along the bottom conical shape of the container.

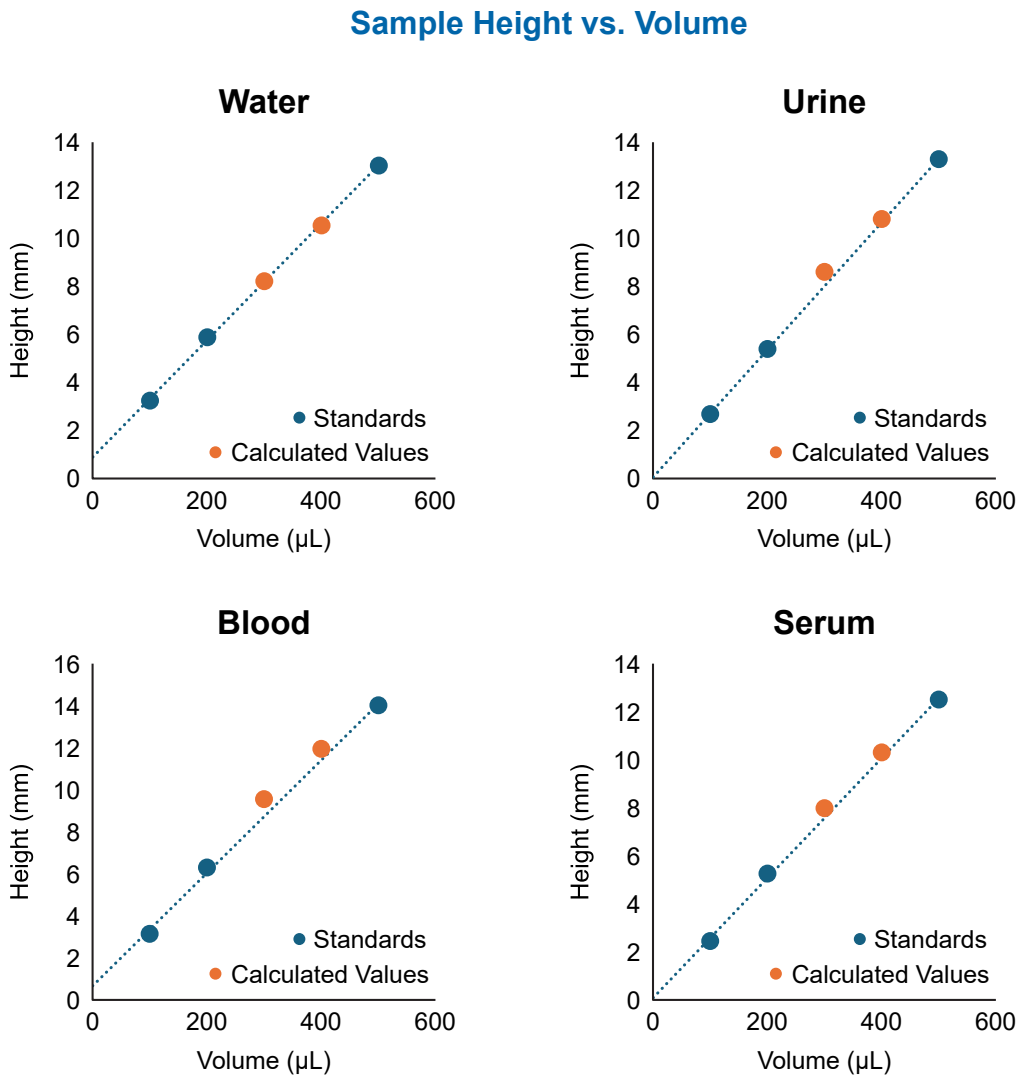

Figure 4. These graphs show liquid heights for different matrices in millimeters derived from ADC values that were converted into corresponding height measurements (mm) using LinkGauge's calibration model.

TRAXStation Clinical Workflow

Barcode Reading & Sample Tracking
Integrated barcode scanning provides complete traceability and seamless connection to instruments and LIMS.

Sample Tube Rocker
Gentle rocking of tubes prior to processing guarantees homogeneous samples for accurate downstream analysis.

Automated Uncapping
Hands-free uncapping reduces manual handling, contamination risk, and biohazard exposure.

Sample Level Detecting
Sound waves are used to detect sample liquid levels. The probe will aspirate from just below the liquid surface.

SampleConfirm™
Sample integrity and verification function designed to confirm sample presence and total sample volume.

Precision Sampling & Dilution
High-accuracy pipetting enables aliquoting into tubes or 96-well plates with programmable dilutions for flexible assay workflows.

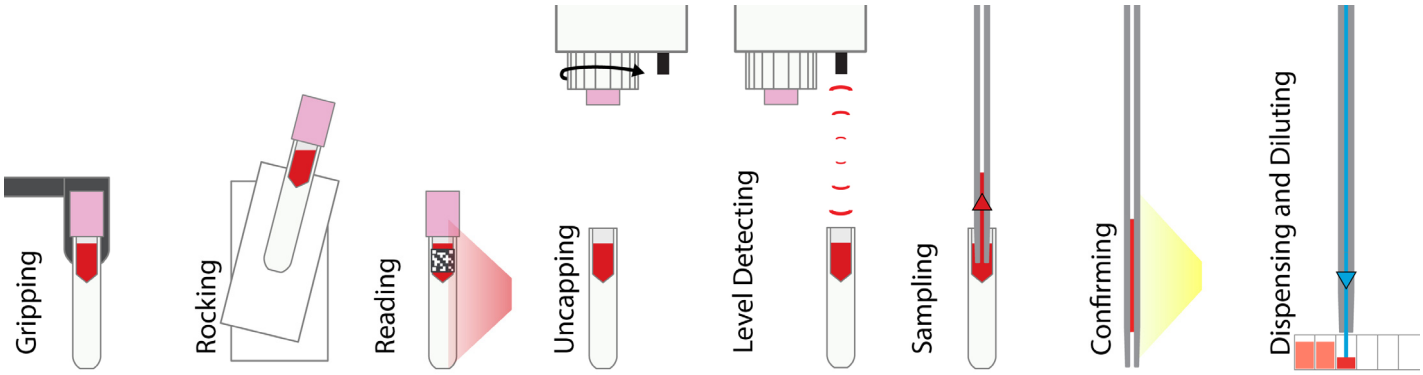

Figure 5. LinkGauge verified that adequate blood volume was present for aspiration. The software used the measured liquid level to position the probe just below the sample surface before initiating aspiration, enabling consistent and reliable sample collection.

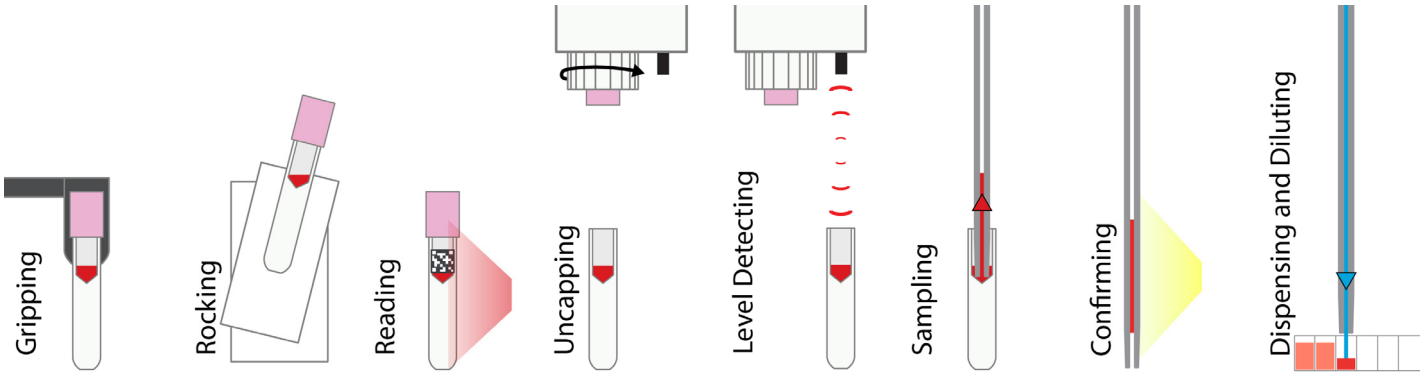

Figure 6. LinkGauge detected a potentially insufficient blood volume for standard surface-based aspiration. In response, the software directed the probe to aspirate from the bottom of the sample tube, with successful sample uptake subsequently verified by the SampleConfirm system during the next step of the automated workflow.

SampleConfirm

When using SampleConfirm, metrics such as aspiration success, detected volume consistency, and frequency of flagged incomplete or failed aspirations were monitored. This approach enables systematic characterization of pipetting reliability under low-volume conditions and determines the effectiveness of built-in sensing technologies in mitigating risks associated with capillary sample variability.

SampleConfirm works by capturing an image of the sample after it has been aspirated into the probe, allowing the system to visually verify that the correct volume has been collected before dispensing. By analyzing the position and length of the liquid column within the probe, it can confirm successful aspiration or detect issues such as air gaps, clots, or insufficient volume. This real-time verification step ensures accuracy and reliability, particularly when working with small or variable clinical samples.

The SampleConfirm probe is constructed from chemically inert CTFE plastic and features a 1.3 mm internal diameter, enabling precise handling of small clinical sample volumes. Its semi-translucent design allows for direct visualization of the aspirated sample within the probe, making it possible to capture an image for verification. With a maximum capacity of approximately 100 µL, the probe supports accurate confirmation of aspirated volume, providing both visual evidence and analytical confidence when working with limited sample volumes.

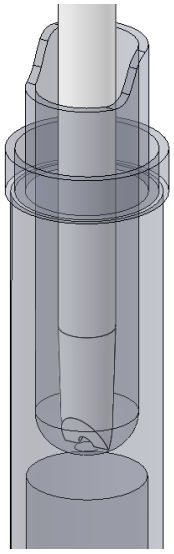

Figure 7. SampleConfirm probe reaches the bottom of the capillary blood tube for accurate microvolume sampling.

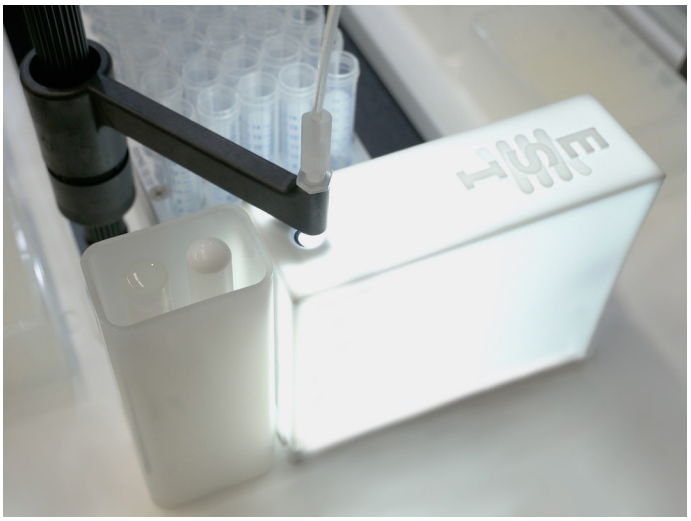

Figure 8. SampleConfirm.

SampleConfirm *(Continued)*

An aspiration performance experiment was conducted to evaluate low-volume sample detection and pipetting accuracy near sample depletion limits. A total starting volume of 200 µL was placed into a sample tube, and sequential 50 µL aspiration attempts were performed using the automated liquid handling system. The first three aspiration events were successfully completed at the target volume, demonstrating accurate and reproducible pipetting performance at low sample volumes. During the fourth aspiration attempt, the system detected insufficient remaining sample volume, resulting in a slightly reduced aspiration of approximately 45 µL. The fifth aspiration attempt correctly resulted in an empty aspiration event, as the available sample volume had been exhausted. These results demonstrate the ability of the SampleConfirm automated system to accurately manage diminishing sample volumes while appropriately identifying and responding to insufficient sample conditions near complete depletion.

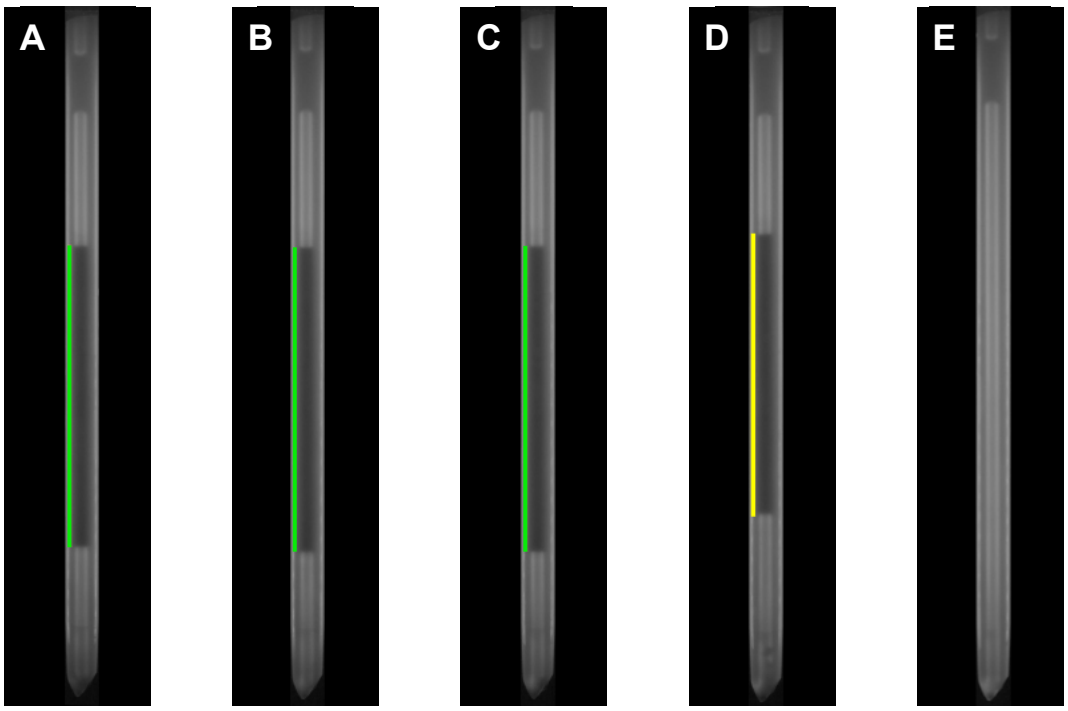

Figure 9. SampleConfirm images demonstrating accuracy and precision of 50 µL aspirations (A-C). As sample volume depletes, sample confirm quantifies the loss of accuracy (D). Upon exhaustion, sample confirm correctly identifies an empty aspiration event (E).

Table 1. Sampling four 50 µL samples from only 200 µL sample. As expected, the fifth attempt shows that no sample remained.

ID	Target Volume of Aliquot (µL)	SampleConfirm Volume (µL)
A	50	49.09
B	50	49.27
C	50	49.51
D	50	45.69
E	50	0

SampleConfirm Data

A low-volume aspiration study was performed using 20 blood samples contained in capillary tubes, each with an initial sample volume of 50 µL, to evaluate aspiration accuracy and SampleConfirm performance under limited-volume clinical conditions. The automated system successfully aspirated 40 µL from all 20 capillary blood samples without aspiration failure, demonstrating reliable and reproducible pipetting performance even at very low sample volumes. Throughout the study, the integrated SampleConfirm technology accurately detected and verified each aspiration level.

Table 2. Sampling of 40 µL from 20 tubes containing 50 µL initial volume of whole blood shows excellent accuracy within <1% of target value.

Sample Number	Volume
1	40.52 µL
2	40.35 µL
3	39.75 µL
4	39.8 µL
5	40.13 µL
6	40.35 µL
7	40.63 µL
8	40.3 µL
9	40.57 µL
10	40.96 µL
11	40.13 µL
12	40.13 µL
13	40.08 µL
14	39.69 µL
15	40.08 µL
16	40.57 µL
17	40.24 µL
18	40.8 µL
19	39.91 µL
20	40.46 µL
Ave.	**40.2465**
SD	**0.322511**
CV	**0.80%**

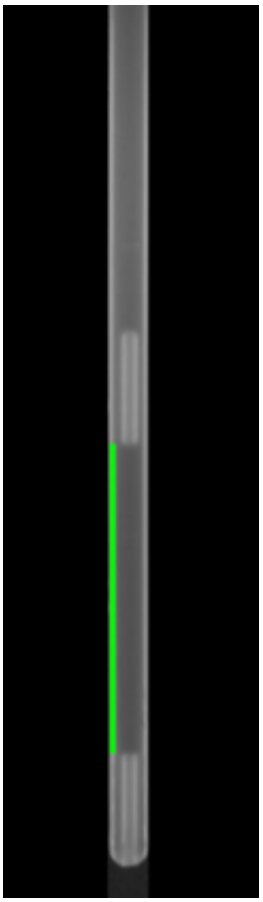

Figure 10. SampleConfirm successful aspiration.

Conclusion

In conclusion, LinkGauge demonstrated the ability to accurately measure sample liquid levels, enabling the automation platform to make critical real-time pipetting decisions, including positioning the probe precisely just below the liquid surface for successful low-volume aspiration. Accurate liquid level determination is particularly important for clinical samples with limited available volume, where improper probe positioning could result in air aspiration, incomplete sample uptake, or loss of valuable specimen material. By continuously monitoring sample levels, the system can dynamically adjust aspiration behavior to maximize sample recovery while minimizing disturbance of the sample matrix.

In combination with SampleConfirm technology, the system was able to accurately verify aspiration events and detect remaining liquid levels, providing additional confidence to the user that the fully automated liquid handling process was functioning properly and consistently throughout the workflow. The ability to identify successful aspirations, partial aspirations, and depleted sample conditions offers an additional layer of process verification that is especially valuable for unattended or high-throughput clinical testing environments. These capabilities help reduce the risk of failed preparations while improving confidence in analytical results generated from low-volume specimens.

Together, these technologies demonstrate that the **TRAX**Station Clinical system is specifically engineered to successfully manage small and often extremely low-volume clinical samples while maintaining reliable aspiration performance, sample integrity, and confidence in automated preparation workflows. The system's ability to reproducibly process difficult blood samples, including capillary tube specimens and high-dilution workflows, highlights its suitability for modern clinical ICPMS laboratories requiring both high throughput and dependable low-volume sample handling performance.