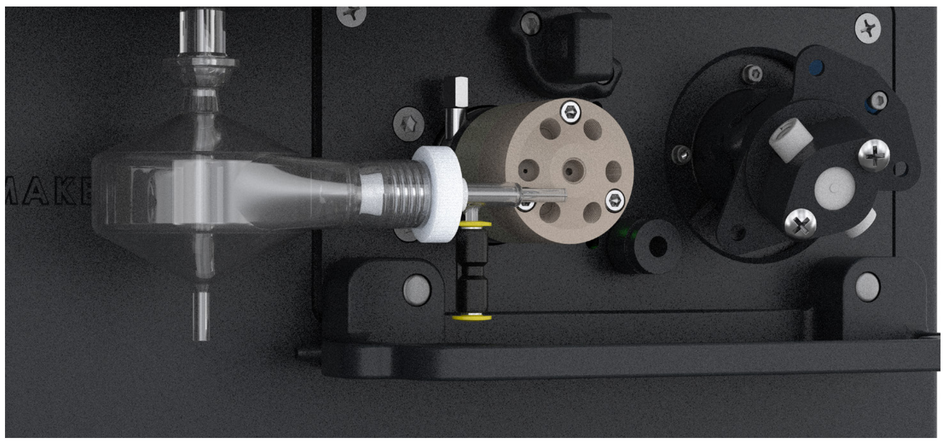
Technical Overview

Reduce Costs and Boost Productivity with the Advanced Valve System (AVS) 6 or 7 Port Switching Valve System



Make the switch to higher productivity

Double your sample throughput and reduce argon consumption by over 50% with The Agilent Advanced Valve System (AVS) 6 or 7 port switching valve accessory.

The AVS is an accessory for the Agilent 5900 and 5800 ICP-OES or 5100/5110 ICP-OES instruments. It features a unique 2 position, 6 or 7 port switching valve (the 7th port is for internal standardization) and a high speed positive displacement pump to rapidly fill the sample loop. Controlled argon bubble injection reduces uptake delay and virtually eliminates rinse times to facilitate high throughput sample analysis.

The Agilent AVS provides:

- **Fast, accurate results**—the AVS rinses the sample introduction system while the next sample is presented to the instrument, virtually eliminating the delay-times of a conventional ICP-OES analysis. Using controlled argon bubble injection between the sample and rinse solution prevents mixing of the sample and rinse reducing uptake and rinse times
- **Reduced operating costs**—Shorter analysis times means argon consumption can be reduced by at least 50% per sample. More efficient analysis minimizes the exposure of torches, nebulizers and pump tubes to aggressive chemicals and harsh samples, increasing the life-time of consumables, further reducing costs
- **Ease of use**—Control of the AVS is simple, as it is fully integrated into the ICP-OES hardware and controlled through the ICP Expert software via the optional Pro Pack software module. This ensures optimal timing (unlike third party switching valve accessories with complicated, stand-alone control software)
- **Easy access**—Optimized positioning of the AVS eliminates physical obstruction to the common sample introduction components like torch, spray chamber/nebulizer and pump tubes, when they need to be removed for cleaning or replaced
- **Reduced carry-over**—With argon bubble injection between the sample and rinse solution, carry-over is reduced in the ICP-OES spray chamber. Using an Ar bubble instead of air means the plasma is more stable and gives better analytical precision
- **Improved precision and stability**—Analytical precision and long term stability is improved by eliminating the fast pumping of the peristaltic pump between samples which destabilizes the plasma
- **Higher productivity**—Combined with the Agilent autosampler, the SPS 4 Sample Preparation System, the AVS can double sample throughput
- **Flexibility**—the AVS is compatible with a wide range of high capacity autosamplers, holding over 700 samples, for overnight unattended operation. It is also compatible with the Agilent Advanced Dilution System
- **Durability**—the AVS is ideal for challenging sample matrices. The constant diameter, metal-free liquid flow path is suitable for samples containing strong acids, HF acid, organic solvents and even high levels of dissolved solids

How does it work?

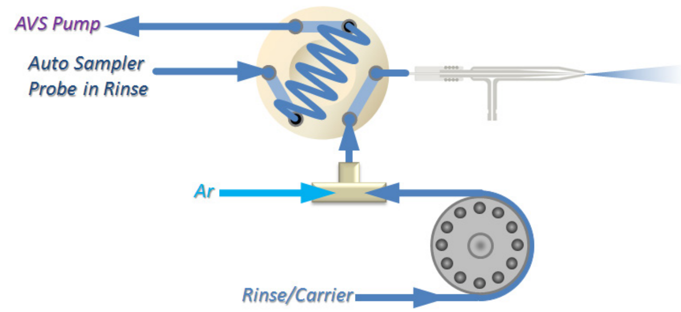


Figure 1a. Stand-by mode.

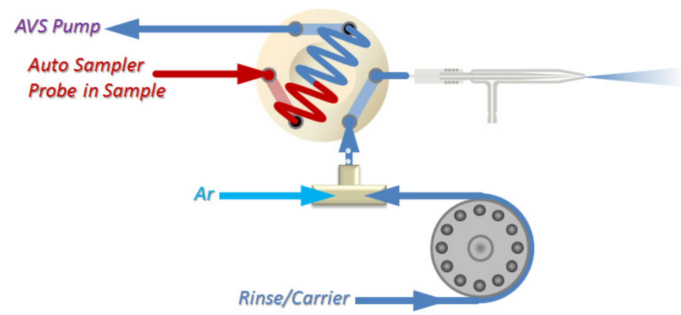


Figure 1b. Sample loading, approximately 5 s.

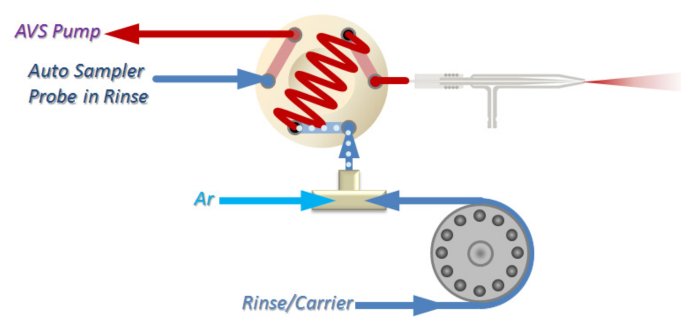


Figure 1c. Stabilization (approx 3 s) and bubble injection.

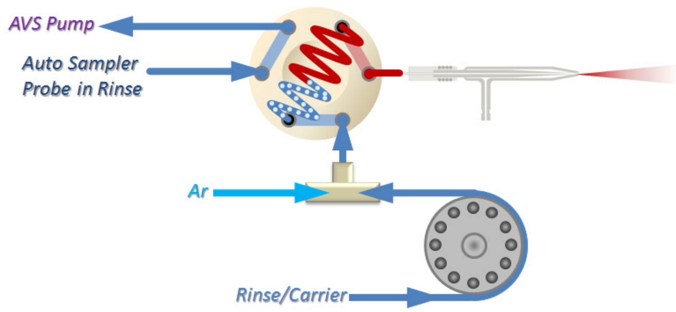


Figure 1d. Analytical measurement.

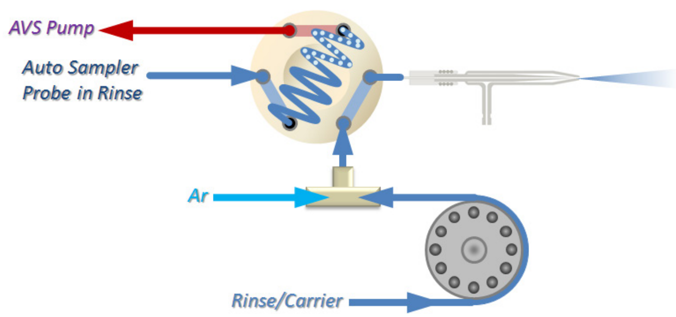


Figure 1e. Return to stand-by mode.

Bubble injection

In the AVS, argon bubbles are injected between the sample and rinse streams to prevent mixing of the two solutions (see Figures 1a-e.) The bubbles separate the two solutions, avoiding mixing and dilution in the loop. This results in longer measurement read times.

For a 1 mL sample loop, bubble injection results in 47 seconds of measurement time versus 20 seconds of stable measurement without bubble injection (Figure 2). Figure 3 displays the effect of bubble injection for a 0.5 mL sample loop. Bubble injection maximizes measurement time and precision for a given sample loop. To increase throughput, a smaller loop can be used which can further reduce uptake delay and reduce rinse times.

Unlike most commercial systems that use air bubble injection, the AVS uses argon to create the segments as argon does not destabilize the plasma like air does, resulting in better analytical precision (see Table 1).

Table 1. Analytical precision of 3 x 5 second replicate measurements of 5 ppm Mn solution, using an AVS 6.

	Analytical precision
5 ppm Mn with Ar injection	0.5% RSD
5 ppm Mn with air injection	1.0% RSD

Analytical throughput

Table 2. Comparison of sample throughput for analysis of wear metals in lubricating oils with and without an AVS 6 accessory.

	With AVS 6	Without AVS 6
Analysis time per sample	22 sec	52 s
Total argon gas consumption per sample	7 L	17.4 L

The AVS improves sample throughput by reducing or eliminating delay and rinse times used in normal ICP-OES analyses. Table 2 shows a comparison of the average sample analysis times and Ar consumption for an analysis of lubricating oil with and without the AVS (*1*). Twenty two elements were measured and the sample to sample time when using the AVS 6 was 22 seconds with an Ar consumption of 7 L per sample. This compares to 52 seconds and 17.4 L Ar consumption without the use of the AVS 6. The differences in throughput and Ar consumption reflect the reductions in uptake delay and rinse times using the AVS 6.

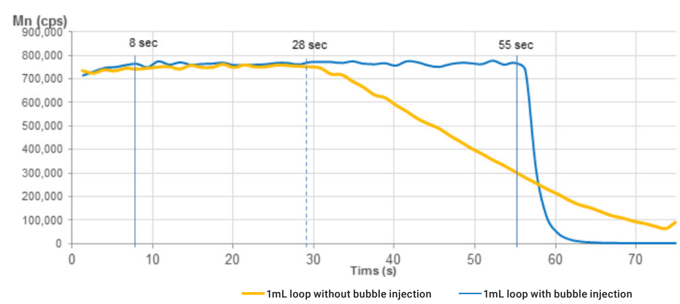


Figure 2. Available measurement time for a 1 mL sample loop with and without bubble injection.

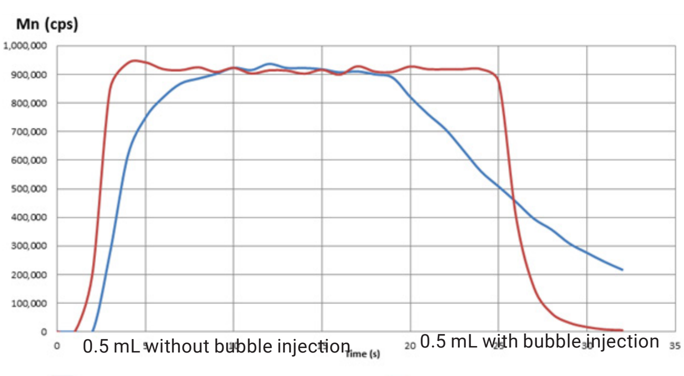


Figure 3. Available measurement time of a 0.5 mL sample loop, showing 19 seconds measurement time versus 9 seconds of measurement time with and without bubble injection, respectively.

Optimization of analytical throughput

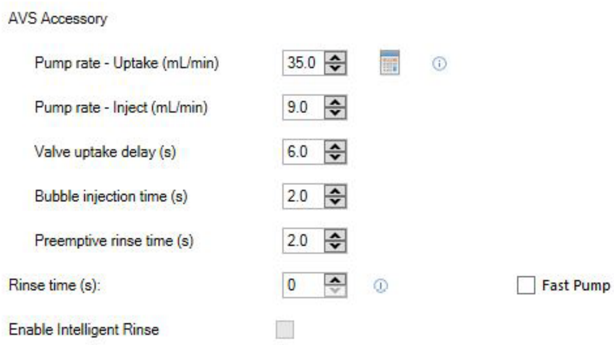


Figure 4. The simple software that controls the AVS accessory.

Ensuring no compromise between analytical speed and precision from the AVS is easy with the simple control software, that is fully integrated with the ICP Expert software (see Figure 4). The software incorporates the AVS parameter calculator to facilitate setup and method development. The main parameters used in the software to optimize performance are:

- Pump rate - Uptake, speed in mL/min (typically set to 35 mL/min)
- Valve uptake delay in seconds (typical value of 5 to 6 seconds)
- Stabilization time (about 3 seconds for the standard nebulizer and capillary)

Example analysis

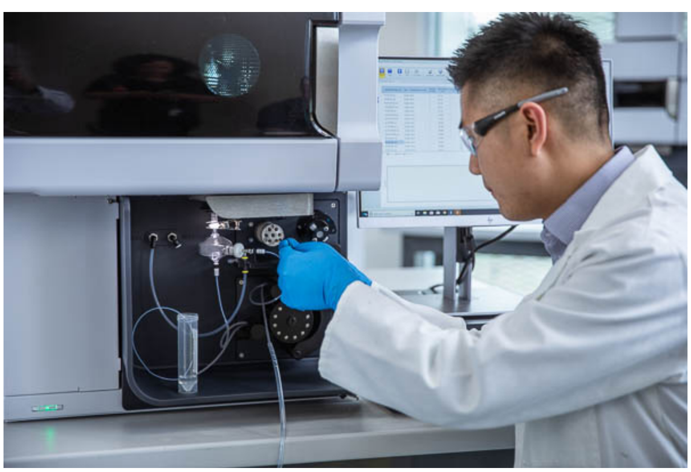


Figure 5. An AVS 7 accessory, integrated with the sample introduction system of an Agilent 5900 ICP-OES.

In an experiment designed to demonstrate the capabilities of the AVS, the following setup was used: An Agilent SPS 4 autosampler with a 1 mm ID probe and a standard SeaSpray concentric glass nebulizer with a (default) 50 mm long capillary connecting it to the valve. All tubing was 1 mm ID, and the peristaltic pump tubing was white/white type used at a constant 12 RPM. All valve fittings were inert and designed to prevent carry over. Clear labels on both the valve fittings and ports simplify installation and maintenance (see Figure 6).

Figure 6. The ports on the AVS are clearly labelled.

With this setup, stabilization delay—the time taken for the sample to exit the switching valve and reach the plasma, is typically 3 seconds regardless of sample loop size. Stabilization delay will increase with a longer capillary between the valve outlet and nebulizer and/or slower peristaltic pump speed or narrower peristaltic pump tubing.

In Figure 7 below, we can see the effect on analytical precision of a 5 ppm Mn solution with various uptake delays using a 0.5 mL sample loop.

The uptake delay must be long enough to allow the sample to be transported from the sample tube on the autosampler through the autosampler probe and transfer tubing, and completely fill the sample loop.

During this uptake phase the AVS pump operates at high speeds—typically 35 mL/min or greater. The uptake delay is affected by the volume between the sample tube and valve inlet which can be minimized by ensuring the length of the transfer tubing between autosampler and valve is as short as is practical. Maintaining a constant 1 mm ID from sample tube to nebulizer ensures that there is minimal mixing of the sample throughout the flow path.

Figure 7 shows that for a 0.5 mL sample loop, an uptake delay greater than 4 seconds will give a typical short term precision better than 0.5% RSD for 5 ppm Mn.

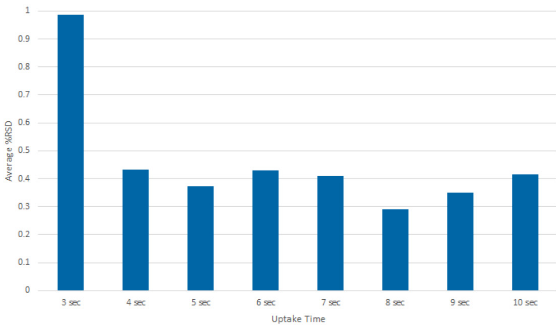


Figure 7. Precision (%RSD) of 5 ppm Mn at various uptake delays using a 0.5 mL sample loop.

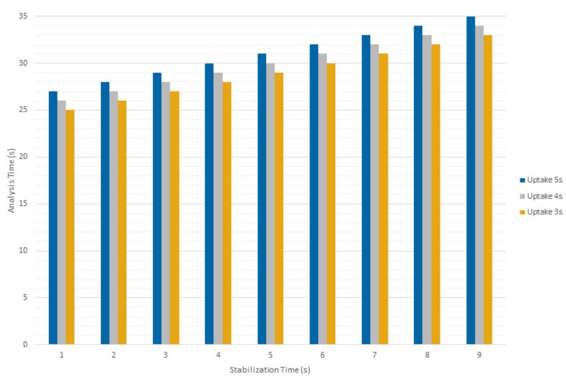


Figure 8. Sample to sample analysis time (in seconds) with various combinations of uptake delay and stabilization delay.

In Figure 8, the sample to sample analysis time is shown for an AVS 6 with a 0.5 mL sample loop at various uptake delays (3, 4 and 5 seconds) and different stabilization times with 3 x 5 second replicates. Optimization for a 0.5 mL loop is achieved with an uptake delay of 4 to 5 seconds and a stabilization delay of 3 seconds, giving an analysis time of about 28 to 29 seconds for an analytical precision typically less than 0.5% RSD for 5 ppm Mn. As expected, sample throughput times increase linearly with increasing stabilization delays.

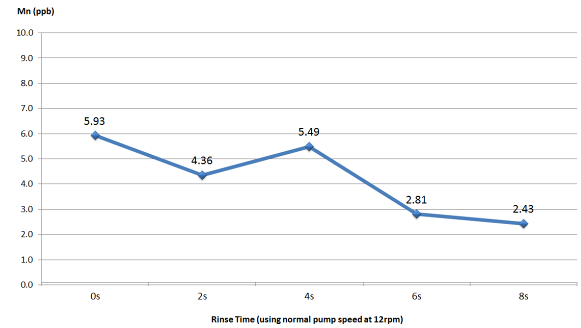


Figure 9. Washout performance of Mn (in ppb) in a blank following a 50,000 ppb Mn solution.

The washout performance of the AVS was investigated by measuring a blank solution after measuring a 50,000 ppb Mn solution. Without any method rinse, the Mn concentration was reduced by close to 4 orders of magnitude from 50,000 ppb to 6 ppb. Using additional method rinse, the measured Mn concentration did not significantly vary from the 0 sec method rinse, as shown in Figure 9. The experimental results demonstrate 4 order magnitude washout and the excellent washout characteristics of the AVS 6.

ICP automation

Figure 10. The ICP automation system comprises the instrument, an autosampler, the AVS switching valve, and the ADS 2 autodilutor.

The AVS switching valve is an integral part of the Agient ICP automation system. The system includes the instrument, autosampler, switching valve, and the new Agilent ADS 2 autodilutor. The autodilutor automates the:

- Preparation of calibration standards
- Pre-measurement dilution of samples
- Reactive dilution and re-measurement of overrange samples or in response to internal standard or QC failure

The ICP automation system combines the high throughput of the AVS with the time-saving benefits of the autodilutor and autosampler.

AVS/ADS timing monitor

The AVS/ADS timing monitor helps optimize and troubleshoot methods by displaying analyte signals with labeled parameter steps. For example, in Figure 10, the Mn signal stabilizes at 12 seconds but the measurement begins at 16 seconds, this shows an opportunity to optimize the method by reducing the stabilization time by 2-4 seconds. The timing monitor also helps identify sample introduction issues, with guidance for trouble shooting available in the Help and Learning Centre.

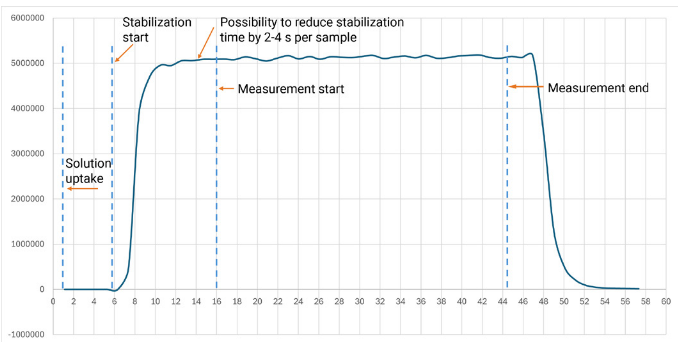


Figure 10. In this timing monitor display, the Mn signal stabilizes at 12 seconds, but the measurement starts at 16 seconds. The measurement could start at 12 seconds, saving up to 4 seconds per sample.

References

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2. Analysis of Waste Samples According to US EPA Method 6010D. Agilent publication no. 5994-2027EN
3. The Fastest and Smartest Way to Analyze Water Samples by ICP-OES. Agilent publication no. 5994-1520EN

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