# Oil Free Vacuum Pumps for Mass Spectrometry

## Technical Overview

Agilent IDP-15 Dry Scroll Pump

*TriScroll-800 Dry Scroll Vacuum Pumps*

Agilent is seeing additional impetus for the switch to dry pump technology from these departments within end-user customer organizations:

- **Scientific** – desire to eliminate pump oil as a potential sample contaminant
- **Maintenance** – trade increased capital cost for superior cost-of-ownership and longer maintenance interval
- **Environmental** – eliminate cost of disposal of contaminated pump oil, and eliminate slip and fall hazard presented by RVP oil drips and spills

Oil-sealed rotary vane pumps (RVPs) have long been the choice as primary pumps for Mass Spectrometer manufacturers due to their low initial cost. As technology advances, and dry (oil free) pumps become more affordable, more and more customers are opting for these pumps at time of purchase or (more typically) as an upgrade when replacing the RVP. Oil-free pumps eliminate the danger of sample contamination and the inconvenience of oil checks, oil changes or disposal of contaminated oil!

Today's high performance Time of Flight Mass Spectrometers are particularly vulnerable to oil migration, as they typically operate with the TOF region turbos' backing pumps operating near ultimate pressure. The increased resolution of these instruments (long path lengths) also makes them most susceptible to the negative impact of hydrocarbon contamination.

Atmospheric Pressure Ionization (API) Mass Spectrometers typically use a single forepump to evacuate a high pressure (typically 0.5 – 3.0 Torr) transition region and to 'back' the higher vacuum regions' turbo pumps (as shown in Figure 1).

Agilent Technologies

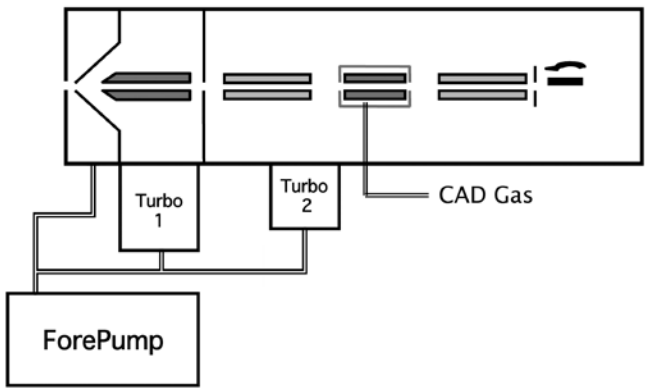


*Figure 1 – Schematic of Typical API Mass Spectrometer*

With typical gas flows at the foreline pump inlet > 100 sccm, the probability of oil migration along the foreline tube is reduced however, discoloration of the foreline tubing on older instruments indicates that oil migration is an ongoing process even under these conditions (as shown in Figure 2).

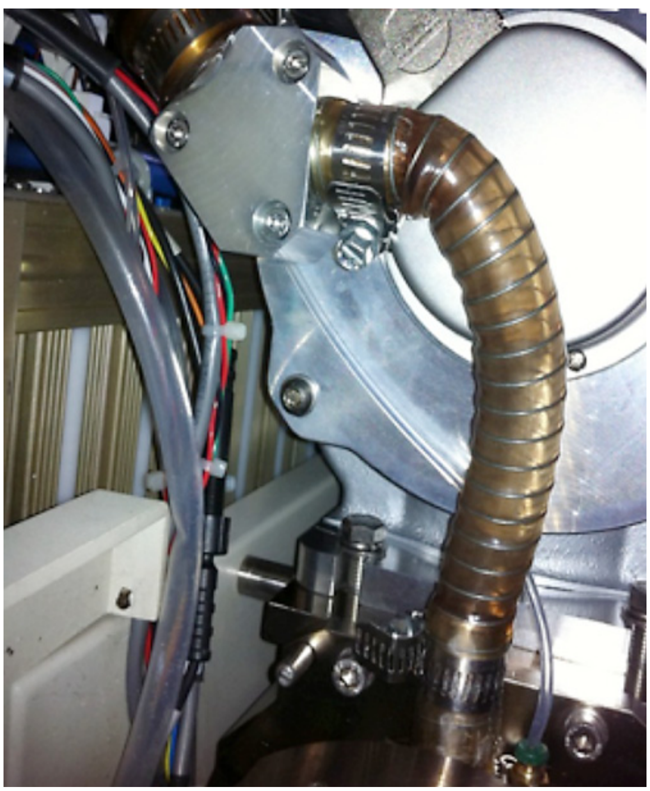

*Figure 2 – Discoloration of Foreline Tubing from RVP*

**The Inverter Advantage**

Frequency Inverters, as used on Agilent's TS-800 Dry Scroll pump have allowed some pump manufactures to exceed the traditional limit of 28 $m^3$/hr pumping speed for pumps operating on Single Phase power. Agilent has optimized design of their Inverter and uses the technology on multiple Dry Pump and Rotary Vane Pump models to:

- eliminate the 28 $m^3$/hr pump speed barrier
- enable speed selection to precisely adjust pump performance
- lower current draw on start-up AND lower steady state power consumption
- provide Universal performance (no difference between 50 Hz and 60 Hz operation)

While modern turbomolecular pumps can operate under a wide range of foreline conditions, the sensitive ion optics of most mass spectrometers have been designed to operate within a finite window of performance for the primary pump. Clearly, a pump whose speed can be 'tuned' to exactly match the OEM pump's performance is ideal, as operation outside a relatively narrow pressure window can result in degradation in performance, as illustrated below:

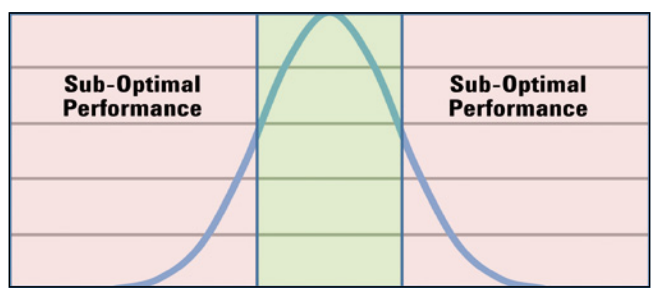


*Figure 3 – Foreline Pressure Impact on Analytical Performance (typ.)*

When customers consider upgrading to dry pumps at time of RVP replacement, they have usually developed a substantial library of analytical methods for the instrument. Being able to precisely duplicate the existing instrument conditions allows the operator to use existing methods without modification.

In addition, when the fore vacuum pump is also used to back a turbo pump, its pumping capacity (as measured by the foreline pressure) can impact the stress on the instrument's turbo pumps as shown in Figure 4.

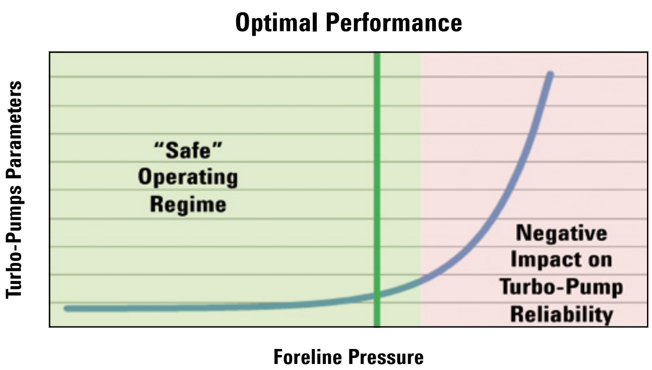


*Figure 4 – Foreline Pressure Potentially Impacts Turbo- Pump Reliability*

Using the instrument diagnostics program (or standalone program) to monitor the turbo pump's power, current & temperature can provide re-assurance that the conversion to dry pumping will not increase the stress on the turbo pump.

## OTHER CONSIDERATIONS

### Up front cost

Although initial cost of dry vacuum pumps is inevitably higher than comparably sized oil-sealed rotary vane pumps (precision machining to tight tolerances drives the cost difference), cost advantages of owning a dry vacuum pump include:

- Interval between tip seal changes of 9,000-12,000 hours vs quarterly or semi-annual oil changes (NOTE: many customers typically exceed the recommended 2-year replacement interval for tip seals)
- Elimination of costs associated with oil changes and disposal: disposal of used (contaminated) RVP oil is becoming increasingly expensive (some estimates are as high as $100/liter)

### Audible Noise

Instrument manufacturers' migration to larger capacity primary pumps has had a direct impact on the increase in audible noise in many analytical labs. Experiments have shown that operating inverter powered pumps such as the TS-800 at even moderately reduced speeds can pay big dividends in noise reduction and in some cases eliminate the need for costly noise enclosures for the primary pumps.

### Power Consumption

Many companies are placing a higher emphasis on the electrical impact of devices installed within a facility. The frequency inverters on the TS-800 and TS-600INV not only minimize the large line current spikes on start-up (measured as high as 50 A with non-inverter pumps), but they also draw lower current at steady state, due to the efficiency of the inverter/motor combination.

## INSTALLATION ON AN EXISTING INSTRUMENT

### Baseline Measurements

A successful conversion of an instrument to dry pumps typically begins by verifying the baseline analytical performance. If the conversion is being done to replace a failed RVP, the most recent optimization data recorded by the customer can be used. If a manufacturer's Instrument Diagnostics Program captures turbo pump performance parameters (Power, Current, Temperature, etc) these should be recorded.

### Installation of Foreline Gauge

If it is necessary to exactly duplicate the OEM pump's performance, a vacuum gauge can be installed (typically at the foreline/instrument bulkhead fitting). By measuring the foreline pressure with the OEM pumps in place, it is a simple process to adjust the TS-800 (or TS-600INV) pump speed to exactly match the OEM pump performance.

### Installation and Speed Selection

After following all manufacturers' recommendations for instrument shutdown, the existing RVP can be removed. Maximum benefit can be obtained by removing all external fittings and tubing, especially on older instruments, where oil-mist saturation has occurred. In some cases, it may be possible to replace foreline tubing inside the instrument, although in many cases, this may require custom fittings and tubing sizes not readily available. Any tubing with visual discoloration should be removed and replaced.

With the dry pump installed, the normal instrument pumpdown sequence should be followed. Inverter driven pumps can be set to maximum RPM during this initial pumpdown, to achieve a low, stable instrument base pressure as quickly as possible. If time permits, an overnight pumpdown is recommended (may be required for TOF systems to reach sufficiently low pressures).

### Additional information

Once a stable (instrument) pressure has been achieved, Agilent's T-PLUS Software can be used to adjust the dry pump's speed to achieve the same foreline pressure as observed with the OEM pumps.

If using turbo pump parameters (via Instrument Diagnostics Program) to confirm performance, be sure to allow the instrument's turbo-pumps to stabilize for at least one hour before recording values.

In some cases, the mass spectrometer may feature operating modes which change the Vacuum conditions inside the instrument: these can be used to further demonstrate the transparency of the dry pump upgrade. For example, some mass spec manufacturer's instruments contain the ability to add a collision or reaction gas to the high vacuum section. Recording the instrument's behavior under different inlet gas conditions can be used to estimate the consistency of the foreline pressure measurements.

### Performance verification

After optimization of the dry pump's speed, confirmation of consistency of turbo pump behavior, and collection of additional vacuum data, analytical measurements on the instrument should be performed, and compared to the baseline values.

The final speed selection will be stored in the pumps firmware, and will be retained even if the power to the pump is disconnected.

### Final Measurements and Customer Sign-Off

After confirming the instrument's performance with the Dry pumps in place, follow the manufacturer's recommendations for instrument shut-down and remove the foreline gauge.

### A pratical example: AB Sciex API-4000

The following measurements (Fig. 5) were recorded during the conversion of an AB Sciex API-4000 from Rotary Vane Forepump (Agilent HS-652) to Dry-Scroll Forepump (Agilent TS-800 with Frequency Inverter).

**VACUUM MEASUREMENTS: BASELINE VS DRY PUMP**

| VACUUM REGION | Baseline | Dry Pump |
|---|---|---|
| **FORELINE Pressure (Torr)** | 0,99 | 0,90 |
| **ANALYZER Pressure (Torr)** | 1,03E-05 | 9,90E-06 |

**TURBO PUMP PARAMETERS: BASELINE VS DRY PUMP**

| TURBO PUMP PARAMETER | Q0 Turbo (V801) | | Analyzer Turbo (V301) | |
|---|---|---|---|---|
| | Baseline | Dry Pump | Baseline | Dry Pump |
| **Power (W)** | 252 | 254 | 34 | 32 |
| **Temp C** | 44 | 44 | 40 | 39 |

*Figure 5 – Vacuum Pressure and Turbo Parameters.*

**ADDITIONAL VACUUM MEASUREMENTS: COLLISION GAS**

| BASELINE | | TS-800 @ 43 Hz | |
|---|---|---|---|
| Collision Gas Setting | Analyzer Chamber Pressure | Collision Gas Setting | Analyzer Chamber Pressure |
| 0 | 1,03E-05 | 0 | 9,90E-06 |
| 2 | 2,38E-05 | 2 | 2,22E-05 |
| 4 | 2,61E-05 | 4 | 2,42E-05 |
| 6 | 2,97E-05 | 6 | 2,74E-05 |
| 8 | 3,07E-05 | 8 | 2,82E-05 |
| 10 | 3,21E-05 | 10 | 2,93E-05 |
| 12 | 3,36E-05 | 12 | 3,06E-05 |
| $R^2$ (2-12) | **0,9583** | $R^2$ (2-12) | **0,9506** |

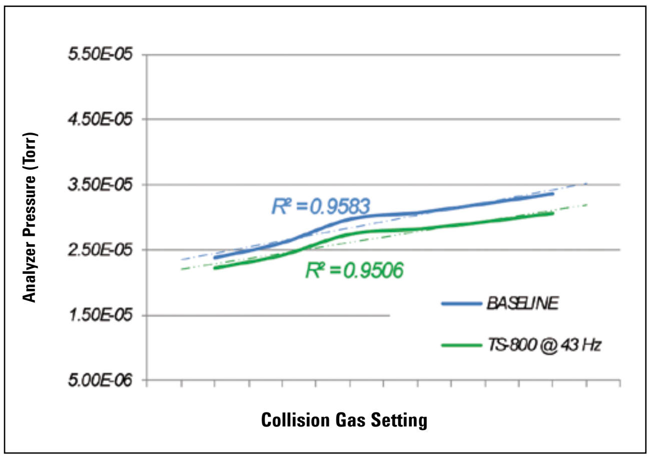


*Figure 6*

Note in Figure 6 that not only do the values and the linearity of the measurements agree, but that the profile of the collision gas response curve matches very closely that recorded with the baseline pumps. This is particularly important for users to be able to re-use existing analytical methods.

## Conclusions

Agilent VPD Dry-Scroll pumps provide a cost-effective upgrade for mass spectrometer systems. Benefits include:

- Elimination of potential sample contamination from rotary vane pump oil (hydrocarbon)
- Reduction in audible noise in the lab*
- Improvement in cost of ownership (improved maintenance interval, eliminate oil disposal costs)
- Replication of OEM Vacuum conditions (consistency with previously developed methods)*

The methodology described above allows the installer to demonstrate with a high degree of confidence the suitability of Agilent's Dry Scroll Pumps for the mass spectrometry application, both during development of new instruments and as a field upgrade.

* with INVERTER driven pumps