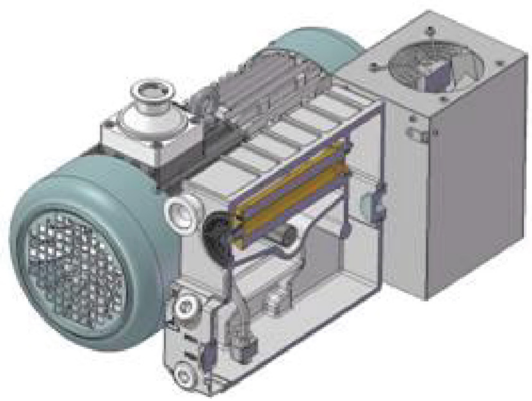
Technical Overview

Using Agilent MS40+ to Replace Multiple RVP Models



Abstract

The Agilent MS40+ single stage rotary vane pump represents the best value medium/large size RVP in the vacuum industry. For a facility operating multiple mass spectrometer models with many types and size of roughing/backing pump, and planning to standardize their instrument fleet on the MS40+, this technical overview describes the process for tuning the MS40+ performance using a combination of inlet restrictors and speed reduction to replace virtually any model of rotary vane pump between 16 and 40 m^3/hr.

Introduction

For customers, supporting multiple models/sizes of rotary vane pumps is costly and inefficient. An ideal solution would be a single, reliable, inexpensive pump whose performance could be tuned to replace multiple pump models.

Since its introduction, the Agilent MS40+ single stage, frequency inverter rotary vane pump has become the pump of choice for many of the world's largest instrument manufacturers. The pump's compact size, light weight, on-board oil mist eliminator, and excellent reliability make it the premium performer in the 40 m^3/hr category.

When Agilent VPD introduced the HS 602/HS 652 rotary vane pumps with built-in frequency inverter, the impact on the vacuum market was significant. The Agilent HS 602/652 pumps could deliver pumping speeds in the range of 32 m^3/hr using a frequency inverter to convert 50 and 60 Hz wall power to spin the pumps at higher speeds. The pumps became lighter (despite the addition of the frequency inverter), delivered universal performance (whether supplied with 50 or 60 Hz wall power) and eliminated the massive current spike on start-up experienced by all fixed frequency pumps. Finally, the ability to communicate with the rotary vane pump allowed instrument manufacturers to access critical pump parameters and include them in instrument diagnostic software, improving field service engineers' ability to diagnose instrument problems.

Since then, Agilent VPD has expanded its line of frequency-inverter pumps to include the TriScroll Inverter driven dry scroll pumps, and the groundbreaking MS40+ rotary vane pump. The MS40+ pump not only surpassed the previous 33 m^3/hr limit, but also introduced an on-board oil mist eliminator and oil return, eliminating the need for costly external accessories.

Working with the Agilent Applications team, MSParts Inc., a Barrie, Ontario mass spectrometer design and support company, performed tests to see if the MS40+ could replace multiple vendors/sizes of rotary vane pumps.

Mass spectrometers often present a difficult challenge for development and support personnel; the differential pumping design drops pressure from atmosphere, to rough vacuum, to high vacuum through multiple stages. The initial stage of this pumping system is typically based on 'free-jet' expansion of gas through a critical orifice. What this means is that the interface will only perform over a finite variation of pressure in this interface region. Over-pumping the interface can produce detrimental effects on performance. Instrument designers such as MSParts face an additional challenge: having to compromise interface performance to compensate for the variation in performance when (traditional fixed-frequency) primary pumps are powered by 50 or 60 Hz mains power.

Experiment description

The initial phase of the experiment involved baselining multiple instruments' performance with the OEM pumps: an Agilent HS 602/652, DS 602, and a competitor's 16 m^3/hr dual stage RVP. A vacuum gauge was mounted on the instrument to monitor the pressure at the backing pump. Turbo-pump operating parameters were recorded, as these can be an indicator of subtle changes in the inlet pressure resulting from minor variations in the performance of the instrument's backing pump. The goal was to exactly duplicate the vacuum conditions present with the OEM pumps.

The MS40+ was installed on the instrument and the speed was reduced to try and achieve the same performance at the appropriate pressure. Since the MS40+ ships with an NW-40 inlet flange, a 40-25 reducer was installed, with the knowledge that this would limit the pumping speed somewhat. With only the NW40-NW25 reducer in place (effectively a 25 mm restricting orifice), speed reduction alone was unable to reduce the pumping speed enough to match the performance of even the largest OEM pump we were trying to replace: the 32 m^3/hr HS 602/652. What was immediately noticeable, however, was the drop in audible noise and operating power drawn when the MS40+ was operated at reduced speed. The goal of MSParts now became to select specific orifices (for each pump model replacement) that would allow them to operate at a frequency near the lower limit of the MS40+, exploiting the noise and power drop, and speculating that the reduced rotation speed could lead to improvements in oil-life, shaft-seal wear, and ultimately pump reliability.

1. A series of restricting orifices were made from NW-25 solid centering ring blanks, in nominal sizes (e.g. 8, 10, and 12 mm).
2. A metering device was installed on each of the target (HS 602/652, DS 602, and 16 m^3/hr competitor) pumps, and the inlet gas load was adjusted to provide an arbitrary pressure of approximately 1 Torr.
3. The metering device/gauge package was then installed on the MS40+ pump, and pressure measurements made with each restrictor, at multiple frequency values.

4. From these measurements, a series of more precise restrictors was made to dimensions (extrapolated from the data) that should allow the MS40+ performance to exactly duplicate the target pumps' pressure at 1 Torr. Since MSParts wanted the MS40+ to operate at 45 Hz in all situations, orifices were made at ±0.2 mm from the calculated value for each pump.
5. Steps 2 and 3 were repeated (after reestablishing the baseline of the target pumps) and the results recorded.
6. For each model mass spectrometer, instrument performance was confirmed with the MS40+ and appropriate restrictor in place.

Results

The results of Step 5 are shown for each pump.

A) MS40+ versus HS 602/HS 652

See Figure 1. The pale green region indicates the speed/orifice 'space' over which the MS-40+ could duplicate the HS 602/652's pumping performance (at 1 Torr nominal) within ±4%. Within the darker green region, target performance within ±2% would be achievable. What this means is that customers wishing to duplicate the performance of the HS 602/652 (at 1 Torr nominal) could install an MS40+ with restricting orifice between 8.8 and 13.0 mm and duplicate the HS 602/652's pressure within ±4% using the MS40+'s speed control. With a restrictor between 9.2 and 12.2 mm, target pressure ±2% could be achieved. For MSParts, the goal is to achieve identical (i.e. 100%) performance at 45 Hz (providing a noticeable drop in Audible Noise and a 40% reduction in the power drawn of the MS40+) so a 12.0 mm will be used.

B) MS40+ versus DS 602

See Figure 2. The DS 602's performance within ±4% could be duplicated with an MS40+ pump and a restricting orifice between approximately 10 and 10.6 mm using the MS40+'s speed control. To achieve ±2%, a restrictor between 10.1 and 10.5 mm must be used. For MSParts, the 10.4 mm will be used to achieve the target pressure (100%) at 45 Hz.

C) MS40+ versus competitor's 16 m³/hr pump

See Figure 3. MSParts' biggest tactical and logistics issue is replacing an Agilent VPD competitor's pump (nominally rated at 16 m³/hr at 60 Hz). The pump's speed is slightly higher than the Agilent DS 402 (at nominal 1 Torr pressure), and an Agilent solution for the OEM customer is proprietary. As can be seen from A and B above, duplicating smaller pump sizes requires more precise orifice sizing. The corollary to this is that the impact of speed reduction is lessened when smaller restrictors are used.

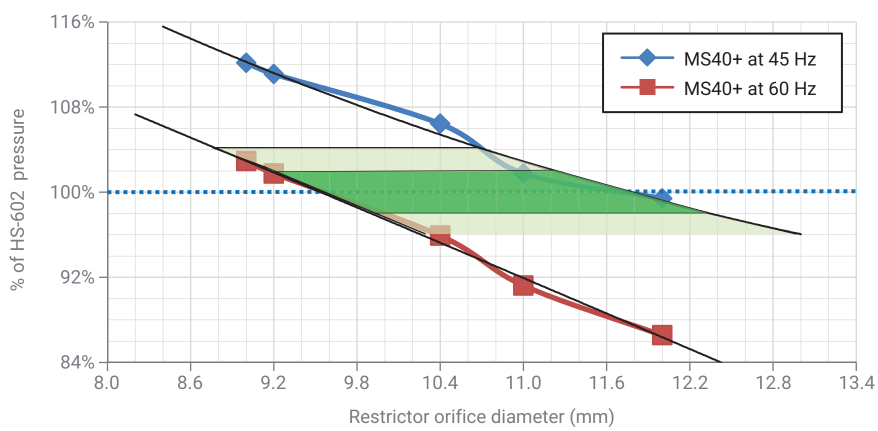


Figure 1. MS40+ versus HS 602 at 0.86 Torr.

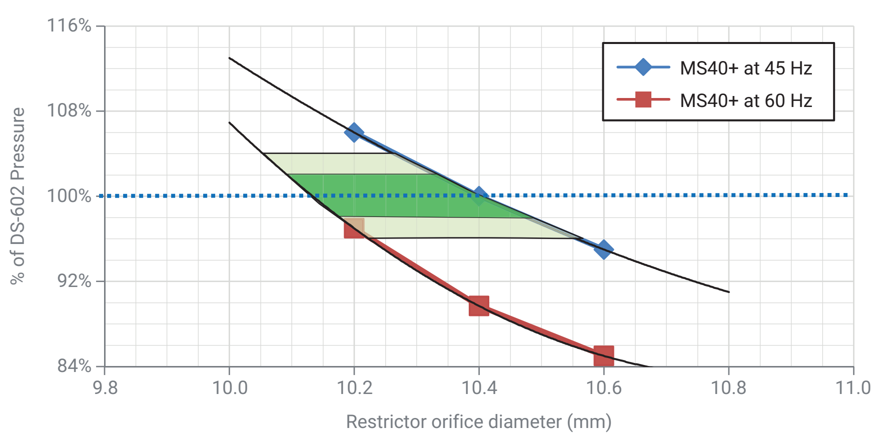


Figure 2. MS40+ versus DS 602 at 0.97 Torr.

The competitor's 16 m³/hr pump performance could be duplicated by the MS40+ within ±4% using a combination of speed control and a restricting orifice between approximately 6.9 and 7.25 mm. To achieve ±2% a restrictor between 6.95 and 7.20 mm must be used. For MSParts, a 7.1 mm restrictor will be procured to achieve the target pressure (100%) at 45 Hz.

D) Confirmation of instrument performance

Using the results of (A), analytical performance of the target instrument (OEM pump: HS 602) was confirmed with the 12.0 mm orifice and the MS40+ set to 45 Hz.

Using the results of (B), analytical performance of the target instrument (OEM pump: DS 602) was confirmed with the 10.4 mm orifice and the MS40+ set to 45 Hz.

MSParts has procured a 7.1 mm orifice restrictor (based on the results of (C)), and is expecting similar analytical results for the instrument with Agilent competitor's 16 m³/hr RVP as the OEM pump.

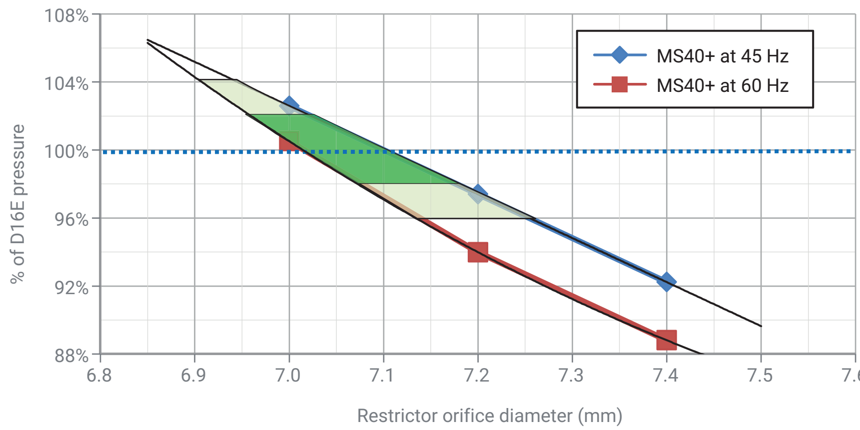


Figure 3. MS40+ versus competitor 16 m³/hr pump at 0.97 Torr.

Conclusion

From the work above we can conclude that with the MS40+ and specific orifice sizes, a wide range of rotary vane pumps can be replaced. Using an inverter driven pump will eliminate performance differences between instruments operating at 50 and 60 Hz mains power. The large current surge of fixed-frequency motor RVP's is also eliminated.

Replacing smaller pumps (in the range of 16 m³/hr) requires a more precise selection of orifice size, while larger pumps (25 to 32 m³/hr) allow more flexibility. Replacing pumps smaller than 16 m³/hr becomes impractical, based on the precision of the small orifice required, and the limited effect of reducing pump speed with a small diameter orifice. Additionally, the economics of replacing, for example, a 10 m³/hr pump with a reduced 40 m³/hr are questionable.

For customers where lowest possible audible noise is the goal, operating the pump at 45 Hz frequency is ideal. Dr. William Stott of MSParts concludes: "The MS40+ combined with selected restrictors will allow us to greatly simply our supported fleet of rotary vane pumps, and our end-user customers will really appreciate the noise reduction in their labs." Operating the MS40+ pump at 45 Hz frequency produced an average power reduction of 40%. Running at 45 Hz can also reduce heat output and hence lower air-conditioning costs and help to create an improved working environment.

Using the above methodology, there is no reason the MS40+ cannot become a suitable replacement for any vacuum competitor's pump in the range of 16 to 40 m³/hr.

www.agilent.com/en/product/vacuum-technologies/oil-sealed-rotary-vane-pumps/single-stage-ms-rotary-vane-pumps-for-labs/ms-40-rotary-vane-pump

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