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A NORMETEX MODEL 15 m^3/Hr WATER VAPOR PUMPING TEST

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Tests were performed using a Model 15 m^3/hr Normetex vacuum pump to determine if pump performance degraded after pumping a humid gas stream. An air feed stream containing 30% water vapor was introduced into the pump for 365 hours with the outlet pressure of the pump near the condensation conditions of the water. Performance of the pump was tested before and after the water vapor pumping test and indicated no loss in performance of the pump. The pump also appeared to tolerate small amounts of condensed water of short duration without increased noise, vibration, or other adverse indications. The Normetex pump was backed by a dual-head diaphragm pump which was affected by the condensation of water and produced some drift in operating conditions during the test.

I. INTRODUCTION

For tritium processing and many other industrial applications, dry, oil free vacuum pumps are used which do not introduce contaminants into the process and do not produce waste oil which requires proper disposal. Some roots style vacuum pumps claim to be oil-free, but the seals used between the pumping section and the oil reservoir eventually leak or fail resulting in pump oil contamination of the process gas.

The Normetex brand pumps (Ref. 1) are used world-wide in tritium process applications. The most commonly used pump in tritium process applications is the Model 15 pump which is advertised as having a pump speed of 15 m^3 per hour (9 cfm) when operated using 50 Hz electrical power. The only materials exposed to the process gases are stainless steel or nickel plated steel. The pumps are made up of two overlapping scrolls, machined to tight tolerances (50 μm) to produce small operational clearances when pumping gases.

In some tritium process operations, it is necessary to pump gases containing water vapor. Various manufactures of dry scroll pumps utilize a ballast port between various stages of compression to prevent water condensation in the pump (e.g. BOC Edwards Models ESDP12 and GVSP30, and Varian model PTS 300 and PTS 600 pumps).

Condensation of water between the bellows of a metal bellows style pump is known to quickly cause a leak in a pump bellow. It was unknown if pumping gases with water vapor with a Normetex pump would cause condensation in the pump and damage the performance of the pump. The purpose of this paper is to describe a test to examine the effects of pumping a 'wet" gas stream with a Normetex pump and if it altered the pumping performance of a Normetex 15 m^3/hr pump.

II. BACKGROUND

Figure 1 shows the pump speed curve for the Normetex 15 pump reproduced from vendor literature. The pump speed peaks at approximately 12 m^3/hr (3.3 liters/sec) at an inlet pressure of approximately 400 Pa (3 torr). The vendor states the pump curve was created using air with the scroll pump backed by an elastomer diaphragm backing pump.

It was decided for the test to feed 30 volume percent water in air into the pump near the peak of the Normetex pump curve. Typically a metal bellows MB-601 (Ref. 2) pump with the two pump heads connected in series is used to back the Normetex pump. Due to concerns of failing the metal bellows pump from water vapor condensation a bellows, an alternate backing pump was selected (described in the next section).

To determine the exhaust pressure of the Normetex pump for the test, the properties of saturated water vapor were examined. At 30 percent water vapor, condensation will occur around 34.0 kPa (255 torr) if the water temperature is less than approximately 47°C. It was thought the internals of the Normetex pump would be hotter than 47°C and testing with an exhaust pressure near 34 kPa would be near the condensation conditions for the water. A long-term test duration of 2 weeks (336 hours) was chosen to demonstrate the durability of the pump.

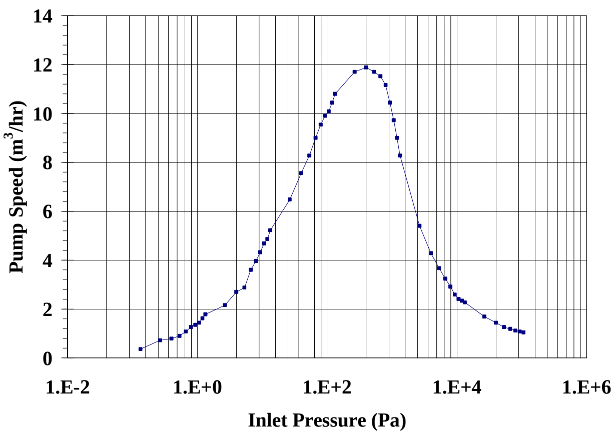

Fig. 1. Normetex 15 Pump Speed Curve (Reproduced From Vendor Literature)

III. EXPERIMENTAL

A schematic of the experimental system is shown in Figure 2. A compressed air supply was dried, reduced in pressure, and fed to the test inlet system. The air inlet system could supply air to rotameters to feed the pump during the test and some air could also bypass the pump to adjust the pressure at the exhaust of the pump. The air inlet system could also fill a vacuum vessel used for pump-down tests (PDTs) to ascertain the Normetex pump performance before and after the water pumping test

The Normetex pump was backed by a Laboport Model N820.3FTP two-stage diaphragm pump with was also used to rough down the system. This pump had an ultimate pressure of 800 Pa (6 torr). The line between the outlet of the Normetex pump and the backing pump was heat-traced to prevent condensation.

The water for the test was contained in a vessel with a heater and was placed on a scale. Water was introduced into the inlet of the pump by varying the opening of the valve connecting the water container to the manifold. The water flow rate was determined by the mass change with time of the water container.

Two tests were used to benchmark the performance of the Normetex pump. PDTs were transient tests where the vacuum chamber was filled with air to roughly 12 kPa (90 torr) and the rate of pressure decrease calculated to determine pump speed/performance. Steady-state flow-through tests (FTTs) were also used to determine pump performance. Various inlet pressures of air were fed to pumping system and the flow rate of air measured. Benchmark pump performance test data were collected before the introduction of water. Comparison of these results to post water vapor test results were used to determine if the pumping performance of the Normetex pump had been altered.

For the water vapor pumping tests, the inlet pressure to the pump was adjusted to give an inlet pressure of 0.4 kPa (3 torr), the water vapor flow controlled by adjusting the valve opening to the connection tee at the inlet of the pump, and the outlet pressure controlled by supplying air to the back side of the pump via a bypass line. Valve positions were adjusted to maintain test conditions. The water feed rate was determined by the mass change of the water container with time. At the end of the test, the water supply was stopped for 30 minutes to dry out the system before the benchmark performance tests.

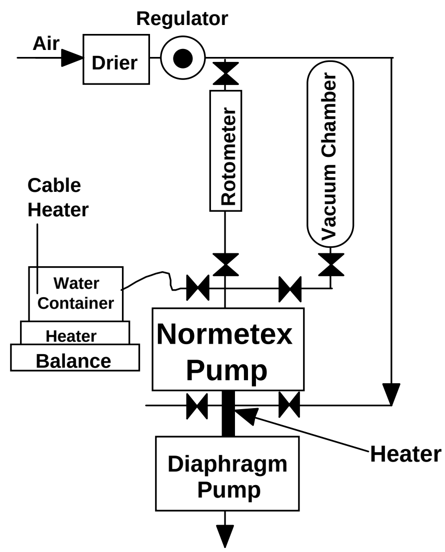

Fig. 2. Experimental Test System Schematic

IV. RESULTS

Five attempts were made before a successful long-term run could be completed. For the first attempt, the water vapor flow rate was unstable which was traced to the design of the water vapor inlet system. Ice crystals formed at the control valve orifice. Attempts to supply sufficient heat to the control valve to prevent ice formation were unsuccessful due to the temperature limit of materials in the valve surrounding the orifice. The total run time was 120 hours with the run not at the desired test conditions of 30% water vapor in air, 0.4 kPa (3 torr) inlet pressure, and a 34 kPa (255 torr) outlet pressure. Baseline pump tests were repeated after this attempt and no effect on pump performance was indicated.

For the second attempt, the water inlet system was modified where water vaporization occurred in the water vessel and not in the control valve. A cable heater in the container provided improved stability of the water supply rate. After establishing the inlet conditions of flow rate and pressure, the outlet condition (pressure) was set which produced unstable operation: the inlet and outlet pressures fluctuated.

For the third attempt, the inlet conditions of 30% water vapor in air at 0.4 kPa (3 torr) inlet pressure were tried with a lower outlet pressure of 26.7 kPa (200 torr). For this test, the inlet pressure and outlet pressures were first set and then the water flow initiated. Flow instabilities were encountered as the water flow rate approached the desired test condition. The flow instability was attributed to significant room temperature variations where the tests were conducted due to the winter season and the constant opening and closing of building doors during the test. Condensation occurred in the water inlet line and then formed ice as it flashed into vapor.

The fourth attempt was similar to the third attempt after the test system was moved to a location with better ambient temperature control. A heat source was also added to the pump inlet line. Even without condensation in the pump inlet line, flow instabilities occurred.

A parametric study where the different parameters were varied from desired test conditions found instabilities occurred when the pump outlet pressure exceeded 18.7 kPa (140 torr) or the water vapor content exceeded 20%, but no instabilities were observed when the pump outlet heat tracing temperature ranged from 20°C to 50°C. Examination of water vapor pressure data found a temperature of 35°C produced saturated vapor for 30% water vapor at 18.7 kPa (140 torr) and also produced saturated vapor for 20% water vapor at 26.7 kPa (200 torr). A thermocouple attached to the Normetex pump housing measured a temperature of 31°C – slightly lower than the 35°C inferred from the test results.

Based on the results from the fourth run, the fifth run was made assuming the internal Normetex pump temperature was 35°C. The outlet pressure for the test was selected as 18.0 kPa (135 torr), slightly below the previous instability pressure of 18.7 kPa (140 torr). The water vapor flow was started after the inlet and outlet conditions were set and took approximately three hours to get near the desired water flow rate. Several additional hours were needed to obtain the desired water flow rate.

The inlet pressures during the test are shown in Figure 3 and varied mostly between 387 and 413 Pa (2.9 and 3.1 torr). The inlet pressure required little adjustment during the test and was usually done by adjusting the air inlet flow rate. The pump outlet pressures during the test are shown in Figure 5.

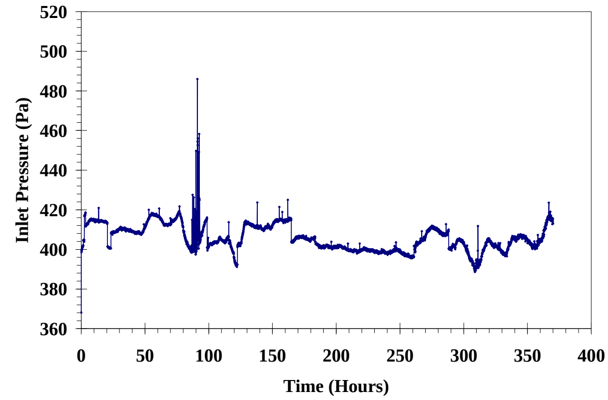

Fig. 3. Normetex Pump Inlet Pressure

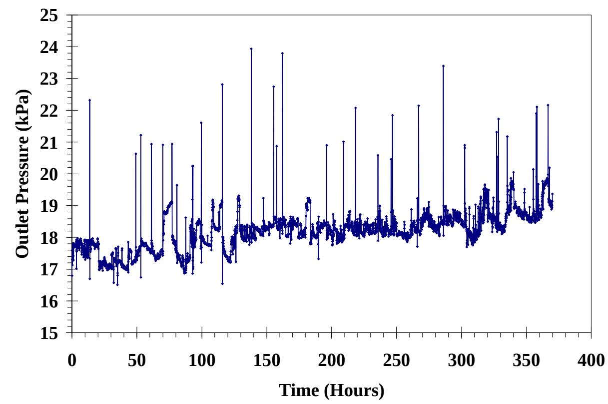

Fig. 4. Normetex Pump Outlet Pressure

V. DISCUSSION

The instabilities in the test inlet and outlet pressures were attributed to variations in room temperature. Figure 5 shows the room temperatures during the test. Around 88 to 95 hours into the test, the inlet pressure experienced its largest fluctuation. Figure 5 shows that preceding and during part of this time, the room temperature was decreasing to almost 22°C and likely causing condensation somewhere in the system producing the inlet pressure fluctuations. As the room temperature returned to it previous, higher values, the inlet pressure returned to its stable pressure range.

The outlet pressure spikes seen in Figure 4 are real and are only shown as a single point due to the sampling frequency of the data collection system. Periodic peaks lasting on the order of two minutes could be seen on the data collection system display screen. These higher discharge pressures were attributed to the way condensation was cleared from the roughing pump, but did not impact pump inlet pressures. Water would collect in the area around the roughing pump and would periodically leave the system as a "slug" of water. Once the water would clear the system, as indicated by its presence in a catch pan, water would slowly accumulate again and the cycle would be repeated. Performance and benchmark tests were repeated and no measurable difference in pump performance could be determined.

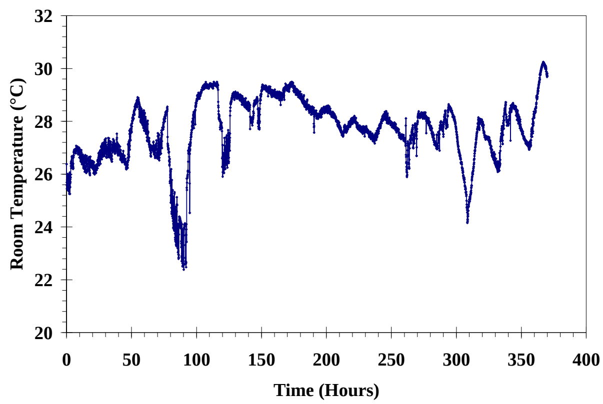

Fig. 5. Room Temperature During Test

VI. CONCLUSIONS

A Normetex Model 15 pump is able to pump water vapor in air for over 370 hours as long as temperatures within the system do not produce condensed water. The apparent temperature of the Normetex pump for these tests was 35°C even though the pump casing temperature was lower and the exhaust piping temperature higher. Even with some condensation in the Normetex pump during unsuccessful pump test trials, the Normetex pump was still functional and its performance not altered during these tests. Water condensation in the backing pump will occur if the water vapor exiting the Normetex pump is near saturation conditions and will likely be the source of pressure fluctuations in the system.

ACKNOWLEDGMENTS

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