VacAdemics

Issue 5

Applying Vacuum Technology

Lessons From the Field: Vacuum System Performance Surveys

Applying techniques discussed in issue four to solve real world vacuum equipment performance problems

Evaluating the various vacuum equipment options and installing a proper vacuum system are important. However, once in operation, performance shortcomings do occur for a variety of reasons. Evaluating the capabilities of the vacuum equipment vendor is essential. Does the vendor have proven experience with your type of application? Can the vendor adequately support your project with accurate and timely information both before and after an order? And, most importantly, is the vendor able to expediently service the vacuum equipment once it is in operation? These are all questions that must be part of the vendor selection process. This issue presents four case studies of performance problems and how a competent field service engineer solved and corrected the problem.

Nylon Intermediate Production Facility: Nitrogen Gas Bleed For Pressure Control

A U.S. Gulf Coast petrochemical company manufacturing nylon intermediates was operating a vacuum flasher supported by a precondenser and two stage ejector system. Overhead load from the vacuum flasher consisted of 160,000 pounds per hour (pph) of mixed nitriles at a pressure of approximately 35 torr.

The precondenser produced adequate vacuum but the two-stage ejector system that extracted noncondensables from the precondenser was performing in an unstable manner. Suction pressure of the first-stage ejector was cycling between the design 35 torr and as high as 75-80 torr.

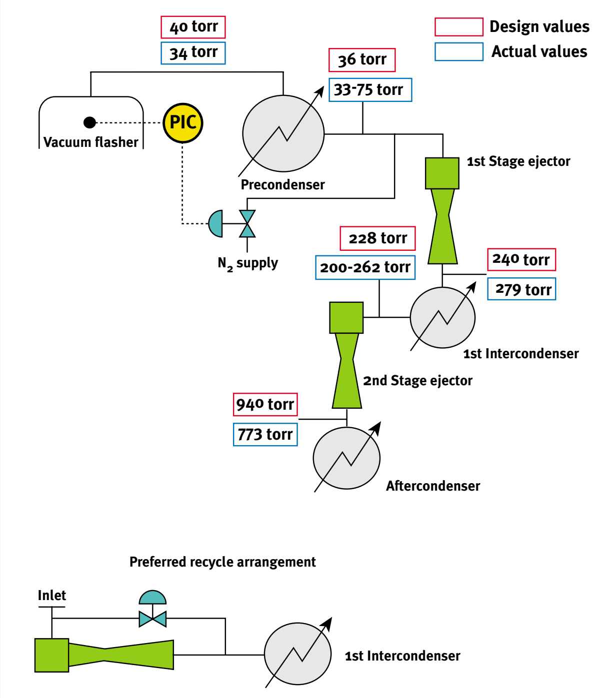
Vacuum flasher pressure was unaffected by the ejector instability, however, plant personnel had concerns that poor ejector performance may at some point have a negative impact on vacuum flasher operating pressure.

The ejector system manufacturer supplied both the precondenser and vacuum system. The manufacturer dispatched a service engineer to the site to survey the equipment and its performance. Figure 1 depicts the pressure profile of the equipment.

The service engineer initially inspected vapor piping and condensate drain legs to ensure equipment layout was satisfactory. Attention then focused on the utilities. Motive steam pressure was measured at the inlet to each ejector. Actual motive steam supply pressure to the ejectors was 140 pounds per square inch gauge (psig); the nozzles were designed to pass the required steam at 125 psig. Although the motive steam pressure was above design and, consequently, the ejectors were consuming more steam, the excessive steam consumption was not enough to cause poor performance.

Cooling water inlet temperature to the condensers was below design, and temperature rise across each condenser was less than the design. Inlet cooling water was designed for 89.6°F and the water flowed in series from the first intercondenser to the aftercondenser.

Figure 1



The actual inlet water was 85°F. The total temperature rise across both condensers at design was 29°F — the actual temperature rise was 13°F. The lower temperature rise would suggest greater cooling water use or lower condensable vapor discharge from the precondenser, neither of which would cause poor ejector system performance.

An ejector system with unstable suction pressure typically is operating in a broken mode. A broken ejector often is caused by low motive steam pressure, a fouled intercondenser, high cooling water temperature or low cooling water flow, or excessive noncondensable loading.

While inspecting the ejector system, the service engineer noticed a periodic audible change in ejector operation. This audible change plus an unstable suction and discharge pressure for the first-stage ejector confirmed this particular ejector was the trouble.

The service engineer noticed plant personnel had installed a pneumatic control valve that bled nitrogen to the suction of the first-stage ejector. Plant personnel installed a nitrogen bleed to control suction pressure so the vacuum flasher would operate at a consistent pressure, even at reduced charge rates. Pressure in the top of the vacuum flasher was sensed and a signal sent to the control valve to bleed nitrogen to the first-stage ejector if the vacuum flasher pressure fell below design.

Noncondensable bleeds should be used with caution

Bleeding nitrogen, which is noncondensable, to the suction of a multistage condensing ejector system will result in unstable performance.

An ejector system is designed to handle noncondensable loading associated with the process. Ejectors downstream of the first intercondenser are designed to handle process-related noncondensables and associated saturation vapors. Bleeding in nitrogen to act as an artificial load for the first-stage ejector and to elevate suction pressure resulted in noncondensable overloading of the downstream ejector.

The service engineer instructed plant personnel to disassemble the nitrogen bleed arrangement and to install recycle control piping around the first-stage ejector or bleed nitrogen to the inlet of the precondenser. For any multistage condensing ejector system the preferred way to maintain performance and suction pressure is to recycle discharge from an ejector immediately preceding the first intercondenser back to the suction of the system. In this way, noncondensable loading is never allowed to increase above design, ensuring broken ejector operation will not occur. Again, vacuum flasher pressure is sensed and a signal sent to the recycle control valve, which will modulate and permit the recycling of vapor flow back to the suction of the first-stage ejector. Once the plant installed this form of recycle control, stable ejector operation was maintained.

A caveat for this correction is that the suggested recycle control arrangement used to correct first-stage ejector instability will not work if a precondenser's operating pressure will permit steam condensation. The composition of recycle flow around an ejector consists of noncondensables plus steam. As the recycle flow is brought around to the suction of the first-stage ejector, the recycled steam will be drawn to the precondenser if the operating pressure will permit steam condensation. When this occurs and recycled flow goes to the precondenser rather than through the first-stage ejector, suction pressure control is not possible.

The most practical method to control operating pressure of a precondenser/ejector system is to control cooling water flowrate, which may be reduced when process charge rate is below design. By lowering water flowrate, the water temperature rise across the precondenser will increase, which has the effect of lowering the logarithmic mean temperature difference (LMTD). Controlling LMTD will control the precondenser operating pressure.

West Coast Petrochemical Plant: Improper Replacement Intercondenser

A West Coast petrochemical plant was operating a fuels vacuum distillation unit that experienced erratic performance after replacing an intercondenser supplied by the original ejector system manufacturer with one designed and built by a local heat exchanger fabrication shop. The system was designed to provide performance as described by Figure 2. The service engineer did not know the user installed a replacement intercondenser.

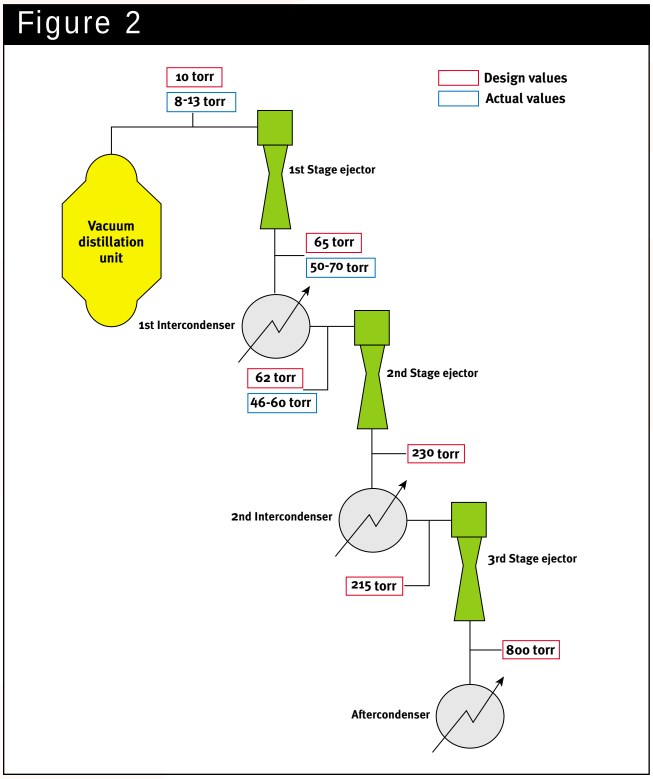
The first-stage ejector was operating in a broken mode, with both suction and discharge pressure remaining unstable. Furthermore, shellside pressure drop across the first intercondenser was almost three times the design pressure drop.

Motive steam supply condition was approximately at the design value, so the service engineer ruled out inadequate steam pressure. High-pressure drop across the first intercondenser would suggest a fouling problem, cooling water flowrate limitation, high inlet water temperature, high noncondensable loading or excessive hydrocarbon loading.

Prior to detailing a method to determine the actual cause, the service engineer discussed general performance characteristics with unit operators. At that time, it was discovered the first intercondenser had been replaced.

Upon visual inspection of the installed unit and its nameplate, the service engineer realized it was the design of another vendor. That vendor did match the original intercondenser's tube count and external dimensions, but after a thorough review of fabrication drawings, it was evident the vendor failed to properly design the shellside baffling to effectively manage hydraulic and thermal requirements. Vacuum condensers have special shellside baffling to ensure minimal pressure drop, noncondensable gas cooling, and separation of

Figure 2



noncondensables and condensate. It is typical to have different baffle spacing at strategic locations within the shell of a vacuum condenser or to incorporate a long air baffle design. The vendor who replaced the intercondenser used conventional software to model the performance. This in turn resulted in a design having fully baffled flow, and consequently, excessive pressure drop on the vapor side.

In this particular instance, high-pressure drop across the shellside caused the system to break performance. The first-stage ejector could not overcome the added pressure drop and reach a discharge pressure where the second-stage ejector would operate. This discontinuity resulted in the first-stage ejector breaking operation, which was characterized by unsteady suction pressure and back streaming of motive steam into the vacuum distillation tower. Both performance conditions were unsatisfactory to the refiner.

Although the plant engineers were reluctant to accept the condenser as the problem, they did agree to install a new condenser designed by the ejector system manufacturer. Once the properly designed condenser was installed and the system restarted, performance was returned to a satisfactory level.

Canadian Ammonia/Urea Fertilizer Complex: Excessive Air Leakage

An ammonia plant SYNGAS compressor provided less than designed horsepower due to high back pressure from a condensing turbine steam surface condenser. The turbine exhaust condenser maintained 113 torr backpressure, but based on the cooling water temperature, the expected backpressure should have been 75 torr. A service engineer was dispatched to the site to evaluate the steam surface condenser and ejector performance to determine the cause of the elevated backpressure.

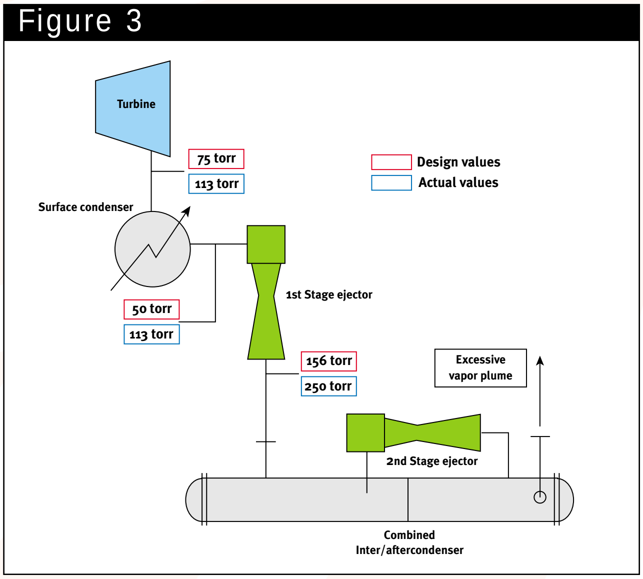
A two-stage ejector system as illustrated by Figure 3 supported the steam surface condenser. The service engineer noticed a substantial exhaust plume from the aftercondenser vent.

Normally, steam surface condenser and ejector systems are vacuum tight, with air leakage less than Heat Exchange Institute design values, with typical air leakage of 5 lbs./hr. or less. An excessive exhaust plume from an aftercondenser suggests high air leakage. There was an air leakage meter installed on the vacuum system and, when activated, the measurement was off the scale.

The service engineer isolated the surface condenser from the ejector system. This made it possible to determine if excessive air leakage was from the surface condenser, upstream piping or within the ejector itself. Once a surface condenser is isolated from a vacuum system and the operating pressure of the condenser does not increase appreciably over time, the air leakage must be downstream of the surface condenser.

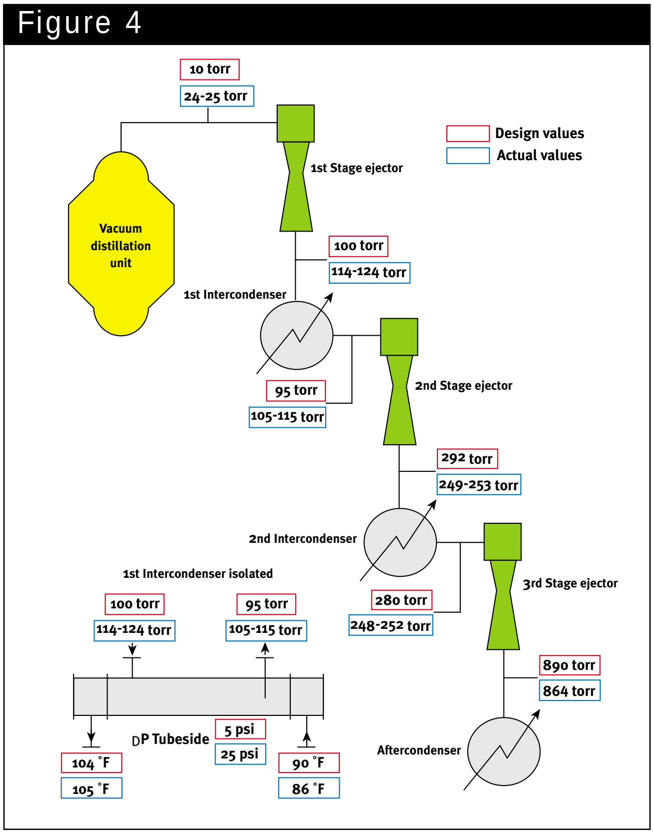
The condenser was isolated from the vacuum system and pressure stayed fairly constant. This confirmed the air leakage was downstream of the condenser and that it was in the ejector system. A closer look at the installation determined that a $^{3}/_{4}$ inch instrument connection was unplugged. The open connection permitted substantial quantities of air to leak into the ejector system and cause poor operation. Once plugged, the entire condenser was then brought on line and after the system was allowed to stabilize, steam surface condenser operating pressure reached the expected 80 torr. The SYNGAS compressor returned to full power once this correction was made.

Figure 3



Gulf Coast Refinery: Fouled Intercondenser

Figure 4



A Gulf Coast refiner was operating a damp crude vacuum distillation tower designed for 10 torr tower top pressure but was maintaining only 24-25 torr. The first-stage ejector was surging and back streaming into the vacuum distillation unit. Figure 4 documents as-sold performance and what was measured in the field.

Broken first-stage ejector performance may be caused by improper motive steam pressure, elevated inlet cooling water temperature, lower than design cooling water flowrate, a fouled first intercondenser, or poor operation of a downstream ejector. The performance survey indicated motive steam supply conditions were satisfactory. Cooling water temperature rise and pressure drop across the first intercondenser indicated a problem.

Design cooling water temperature rise across the first intercondenser was 14°F (7.8°C), however, the actual temperature rise was 20°F (11.1°C). Possible causes for an elevated temperature rise would be lower than designed cooling water flow or an increase in condensable load to the condenser. Pressure drop across the tubeside of the condenser indicated something was wrong. The actual tubeside pressure drop was 25 psi (1.7 bar) while the design was only 5 psi (0.35 bar).

To produce such an elevated pressure drop, tubeside fouling would be severe and actual tube blockage must have occurred.

The first-stage ejector could not overcome the elevated shellside pressure drop and, consequently, broke operation. The broken operation resulted in unstable suction pressure, surging and back-streaming of motive steam into the vacuum distillation unit. The first intercondenser was pulled from the platform and taken down to grade. At grade, the bundle was removed to inspect the shellside for fouling and to rod out the tubes. The shellside did not experience excessive fouling but the tubeside had tubes blocked with solidified calcium carbonate and other soluble salts.

Once the tubeside was cleaned and returned to acceptable condition, the bundle was reinstalled in the condenser, and the condenser reattached to the vacuum unit. Back in service, the system's tower top pressure was maintained at approximately 10 torr and performance was stable.

Summary

Vacuum systems provide extremely reliable performance; however, they do require periodic maintenance. It is recommended that routine surveys be performed to document actual behavior and performance. A vacuum system may be performing at less than optimal conditions for a variety of reasons, such as, improper utilities, fouled condensers, mechanical damage, excessive process load, excessive noncondensable load or improper installation.

A skilled vacuum technician, most often from the vacuum system manufacturer, should conduct the routine surveys and issue performance reports. The performance surveys may be conducted online without affecting the process. The performance reports will document actual performance at a point in time, discuss corrective action where applicable and offer preventative maintenance suggestions.

The reader should note the corrective actions described here were unique to the particular problems discussed. It will not always be possible to apply the same procedure to a comparable performance problem. A review of general corrective techniques is discussed where applicable, however consultation with the vacuum system manufacturer is always recommended. Request the manufacturer visit the plant to conduct a performance survey and evaluate corrective action.

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This is the fifth in a series of six educational newsletters on vacuum equipment. Watch for the next issue of VacAdemics in November.

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