Evaluate Pressure Drop In Vacuum Systems

A Simple Analysis of Plant Vacuum Systems Can Reduce Utility Expenses

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Organizations typically take great care in the selection of process vacuum pumps. Vacuum pumps are evaluated and selected based on factors such as performance, energy utilization, size, sound level and price. However, the componentry between process vacuum pumps and the production machinery they serve is vitally important to the proper functioning of the system. As it stands, one of the most neglected aspects of vacuum supply is the distribution system. The vacuum distribution system is important because of problems that occur due to pressure loss. Vacuum pumps must operate at an elevated level of vacuum to compensate for excessive pressure drop. This costs energy dollars and magnifies leak problems. Simple and cost effective measures can be taken to alleviate these problems. These measures will raise the operating efficiency of the system.

Pressure Drop

What is pressure drop in a vacuum system? Pressure drop in vacuum systems is similar in concept to pressure drop in plant compressed air systems. It is the difference in operating pressure from the supply point to the use point. In compressed air systems, pressure drop is measured in PSI, which means pounds per square inch. PSI can be used as a measure of pressure drop in vacuum systems as well, but it is much more common to use inches of mercury, or "Hg as it is labeled. Table 1 illustrates some of the common pressure units used in vacuum and how the scales compare with one another. Note that the top of the table represents atmospheric pressure and the bottom of the table represents perfect vacuum. Also, note that there are two common scales that use "Hg.

"HgV	Torr	Millibar	Bar	"Hg Abs.	PSIA
0	760	1,013	1.01	29.92	14.7
2	709	946	0.95	27.92	13.7
5	633	844	0.84	24.92	12.2
10	506	675	0.67	19.92	9.8
15	379	505	0.51	14.92	7.3
18	303	404	0.4	11.92	5.9
20	252	336	0.34	9.92	4.9
22	201	268	0.27	7.92	3.9
25	125	167	0.17	4.92	2.4
28	49	65	0.07	1.92	0.9
29	23	31	0.03	0.92	0.5
29.92	0	0	0	0	0

Table 1: Common Vacuum Units

There is a simple procedure used to find the amount of pressure drop in a vacuum system. First, measure the vacuum level at the inlet of the vacuum pump using a reasonably accurate vacuum gauge. Then, using the same gauge, measure the vacuum level at the point of use or as close to the point of use as possible. It is acceptable to use two separate gauges, but use calibrated gauges or gauges that display similar values for the levels of vacuum found in the system. The difference between the vacuum level at the pump inlet and the vacuum level at the end-use point is the total system pressure drop. Depending on the type of system, the product manufactured and the operating vacuum level, the average system pressure drop will vary from a fraction of an "Hg up to 15" Hg. Higher pressure drop means higher operating costs.

Operating Demand Created By Pressure Drop

To illustrate the artificial demand created by pressure drop in a vacuum system, we will use an example of an average process that requires a volume flow of 100 actual cubic feet per minute (ACFM) at 20" HgV. This example can be scaled up or down to fit any particular application. As system pressure drop increases, there is need for higher vacuum at the pumping system to compensate for the loss. This may not be a problem in moderate levels. A particular vacuum pump may have extra capacity available and some vacuum pump technologies actually use less brake horsepower as vacuum increases. In more severe cases, however, extra capacity will have to be added to the system to account for the greater *volume* of air. The reason additional capacity is required is that, in general, as vacuum level increases, air entering the system expands in proportion to the vacuum level. The higher the vacuum, the greater the expansion. To attain the desired vacuum and overcome this expansion, more volume capacity is needed. At some point, the installed vacuum pump will not be able to keep up with the required expansion of air.

The amount of additional capacity required depends upon the starting vacuum level and the amount of pressure drop. Table 2 illustrates how this phenomenon affects our example system.

ACFM Required By Production Process @ 20" HgV	Pressure Drop In Distribution System	Required Vacuum Level At Vacuum Pump	ACFM Required To Compensate For Pressure Drop
100	1" Hg	21" HgV	111
100	2" Hg	22" HgV	125
100	3" Hg	23" HgV	142
100	4" Hg	24" HgV	166
100	5" Hg	25" HgV	200
100	6" Hg	26" HgV	250
100	7" Hg	27" HgV	333

Table 2: Additional ACFM Required to Overcome System Pressure Drop

This table shows how pressure drop can add significantly to the number of vacuum pumps required to run a production process. A 3" HgV pressure drop adds 42% to the required production ACFM flow. It is not difficult to see how reductions in system pressure drop will lower energy costs by reducing the number of vacuum pumps on line. Operating fewer vacuum pumps not only saves energy dollars, it also lowers plant maintenance costs. Non-tangible benefits to fewer on-line pumps are lower noise level, less mist carryover and lower ambient heat loads. If off-line pumps can be eliminated, a usable floor space increase can be realized.

Leaks

Operation of a vacuum system at higher levels also affects the volume flow of air leaking into the system. Air entering a vacuum system through leaks adds to the production volume demand and must be treated as if it were production demand. As the vacuum level increases, the affect of leaks on the system increases as well. If our example system has 6 ACFM in leak flow rate at 20" HgV, then operation of the same system at 25" HgV will double that number. Even though the percentage of total flow remains the same, it is still an additional load on the vacuum pumps. Also, depending upon the design characteristics of the distribution system, operation at higher vacuum levels may open more leaks due to the increased differential pressure.

Reduce The Pressure Loss

Once total system pressure drop has been measured, it is then prudent to determine which components are adding the most restriction. It is recommended that each component be reviewed individually and then ranked against all other components so a "worst first" repair program can be implemented. To check an individual component, tap into the inlet and discharge of the component and measure the pressure drop. Pressure drops for each component from the vacuum pump to the point of use should be measured and recorded. Some items, like filters with replaceable elements, should have running logbooks established so that element change-out intervals can be determined. The following list contains some areas that should be checked or reviewed for each in-house vacuum system.

Piping: The single biggest problem with vacuum system piping is inadequate diameter. The combination of restrictive pipe diameter and lengthy piping runs can create significant pressure drop. As a rule of thumb on single vacuum pump applications, maintain the diameter of the vacuum pump inlet as far into the process as possible. Smooth interior walled pipe is superior to rough walled. Piping should be as kept short and straight. Elbows should be kept to a minimum and, where they are necessary, large radius is preferable to 90-degree turns. On multiple vacuum pump applications, a full analysis should be completed to determine the optimum pipe diameter.

Valves: Isolation valves and check valves should be inspected to ensure they are full port and match the diameter of the system piping. Typically, standard ball valves have port diameters that are restrictive for vacuum applications. Full port ball, gate or butterfly valves provide excellent flow characteristics and very little restriction. Check valves can also be a source of restriction in vacuum piping systems. When check valves become lodged or fail to completely open immediate repair or replacement is required.

Filters: Many vacuum pump technologies require inlet filtration to remove particulate from the incoming air stream. Filter element loading increases pressure loss and can be easily avoided with proper preventative maintenance. Improperly sized filters with small port diameters can also be a major source of restriction. Check with the filter manufacturer to ensure proper sizing and installation.

Receivers/Separators: At times it is necessary to remove liquids from the vacuum air stream prior to the vacuum pump inlet. It is important to have the correct type, configuration and porting on receivers and separators to ensure adequate liquid separation and low pressure drop. Many separators have minimum and maximum velocity requirements for optimum separation efficiency. It is important to follow these guidelines so that maximum protection is provided for the vacuum pump.

Production Machinery: Production machinery sometimes accounts for the majority of system pressure drop. Conventional thinking, however, does not allow for changes to the internal plumbing of production machinery. Given that the thought process for production machinery design usually does not take into account the energy usage of vacuum supply, it is worthwhile looking into what changes can be made that will improve flow and not sacrifice production efficiency. Sometimes, improvements can be as simple as enlarging the internal diameter of supply tubing.

Vacuum Pump Controls: Some vacuum pump technologies utilize control mechanisms on the pump inlet to automatically regulate the system vacuum level within a preset range. These mechanisms are sometimes set incorrectly or are out of adjustment. Improper functioning of vacuum pump controls can choke off the airflow to the pump and appear to be a plumbing problem even if the rest of the system is functioning optimally. Only qualified service personnel should adjust vacuum pump inlet controls.

Leaks: No vacuum system evaluation is complete without a leak check. Leak checks are important in some facilities because considerable horsepower is used just to overcome the system leak rate. There are several different techniques commonly used for detecting leaks in vacuum systems. Two very common methods are ultrasonic detection and tracer gas detection. Both methods are suitable for production vacuum systems.

Results

In many cases, vacuum distribution problems are solved by adding vacuum pumps to overcome system pressure drop. A program that identifies and corrects the significant causes of pressure drop has the potential to forestall or completely eliminate the need for new vacuum equipment. Of course, it is not practical or economically feasible to eliminate all pressure drop from a vacuum system. However, it is possible to eliminate pressure drop from the worst components so that the tradeoff between operating costs and costs for distribution changes is favorable.

A proactive program can assist in taking vacuum pump horsepower off line. As an example of the amount of savings that can be realized for reducing operating horsepower, one 40 horsepower vacuum pump taken off line can result in a yearly savings of $16,845 at $.06/KWH and 8,750 operating hours. This is a significant sum considering the nominal investment in time and plumbing changes.

The other advantage of a proactive approach is an increase in the quality of vacuum supply to end-use points. Once evaluation and repair programs are completed, vacuum distribution systems that have had increasing demands placed upon them over time or that were marginally sized to begin with will not be as susceptible to fluctuations in production vacuum load. This will result in more production up time, faster cycles, better-formed products and increased holding force. In other words, the system will have greater efficiency.

Resist the tendency to add horsepower to solve vacuum supply problems. Before purchasing additional vacuum equipment or adding on-line horsepower to solve production vacuum problems, evaluate the vacuum distribution system for excessive pressure drop. It is an effective approach for both cost reduction and cost avoidance.

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