Improving air system efficiency

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Part 5: Understanding the role of compressed air storage.

Storage is one of the most undervalued and misunderstood aspects of the compressed air system. It is best likened to capacitance that you would use in an electric system or the tower reservoir in a water system. The impact of storage on the system is that it determines the rate of change in the system -- pressure drop (or rise) versus time. The more storage capacity, the slower the rate of change in the system in either direction.

Storage plays many essential roles in the efficient operation of the system. Following is a description of some of the uses of storage in the system and how they are applied.

Control storage

Control storage is the volume of air on the supply side of the system that is used to maintain pressure drop or rise relative to the events that occur in the system. Control storage is sized to manage the impact of events relative to the control permissives on the compressors available to the system. The longer it takes to get the compressor to displace its capacity, the more storage is necessary to control how fast and how far the pressure will drop. The larger the events that occur, the more storage is necessary. This type of storage can also be used to match events in the system to the shortcomings of the compressor controls.

Load-shaping storage

Load-shaping storage is a large volume of air that is maintained off-line from the system at considerably higher pressure than that of the system. The air is compressed in the off-line storage by a very small compressor (usually in the 5- to 20-hp range) which operates essentially continuously. This volume is introduced into the system based on event management. When the rate of change exceeds a preset value, or the demand pressure drops below a set point, the volume is metered into the system at a controlled rate of flow. This avoids the need for additional compressors.

The load-shaping volume can be introduced on the supply or demand side of the system. But it is important that the manner of introducing the air to the system does not cause the pressure to rise -- it should only maintain or control the amount of pressure drop. It is not unusual to use a 10,000- to 30,000-gal storage tank for a load-shaping application. Typical load-shaping pressures are 150 to 250 psig and higher.

General storage

General storage is the volume of storage in the overhead piping system from the discharge of the compressor to the point-of-use pipe drops. Its purpose is to support point-of-use events instantly until control storage or compressor capacity can service the event. Because air has a finite speed based on the pressure differential in the piping, general storage supports the user during the

seconds it takes to stop the decay of an event. The amount of useful storage, the transmission time from supply, and the size of the event will determine how much the pressure will drop. The highest critical pressure of any user in the system and the largest volumetric event in the system versus the lowest supply pressure will determine the necessary amount of general storage.

General storage also acts as a buffer between the different users in the system. If general storage is maintained at a level of at least 1 psig above the highest user pressure in the system, no user will ever be affected by another user.

Baffling harmonics

Baffling harmonics, or controlling pulsations, often is accomplished by installing receivers immediately downstream of reciprocating compressors. This is meant to reduce pulsations in the discharge flow from the compressors before the air enters dryers or filters or continues into the system's piping. Receivers are also used to isolate a reciprocating compressor from other types of compressors that would not respond well to discharge pulsations. In general, this is more of a stab-in-the-dark approach than an engineered solution -- not usually the best answer. There are harmonic baffles or snubbers specifically designed for the inlet and discharge of reciprocating compressors which are not only more effective, but use less space. Storage immediately downstream of compressors and upstream of dryers and filters can cause high flows and velocities, which can overload clean-up equipment and degrade the overall cleanliness of the compressed air in the system.

Dedicated point-of-use storage

Dedicated point-of-use storage is storage that is checked to a specific point-of-use application for one of the following purposes:

- **to service an application with added storage so that the rest of the system does not experience the effect of the user. This is normally used to protect another critical high-pressure user.**
- **to provide the needed volume for a high-volume, short-cycle application where the recovery of the storage vessel is metered to a longer time period than the use period. Without this, the necessary power to support the high volume, short-cycle user would need to be supplied constantly, so that when the event occurred, pressure would not drop below the minimally accepted value.**
- **to support a critical pressure user while another larger event is occurring. The volume stored only needs to be enough to control the pressure drop of the user during the time when the other event is occurring.**
- **to increase the ft^3/psig at a location close enough to the operation to increase the speed, thrust, or power of the application with a higher rate of flow. This is normally called a volume, is seldom more than a gallon, and is applied to users of a cycle speed of less than a second.Make sure it's useful.**

Storage in the system is potential energy that can be used at a higher rate of flow than the power necessary to develop it; it is a time and energy management tool in the system. Unfortunately, most people look at the system from the compressors out to the users, instead of in the reverse way. One myth is that storage is required by certain types of compressors and not by others. In reality, all systems need a variety of storage types in order to operate efficiently and accurately.

Useful storage is the capacity to store air multiplied by the useful differential, divided by the atmospheric pressure. Without a useful differential, storage serves no purpose. In most systems, the only way to use storage is to allow the pressure to drop at the production end of the system.

The following is an example of applying useful storage: Let us assume that compression supply pressure is 110 psig. The minimum supply pressure is 100 psig, and the maximum useful differential is 10 psig. There is 100 ft of 6-in. pipe and a 660-gal storage tank, and there is 20.06 ft^3 of capacity at 0 psig for 100 ft of 6-in. schedule 40 pipe. A 660-gal tank has a capacity of 88.235 ft^3 at atmospheric pressure.

Thus, the total storage capacity is 20.06 + 88.235 = 108.295 ft^3 per atmosphere. Dividing the total by the atmospheric pressure gives the storage expressed in cf per psig, or 108.295 / 14.696 psig = 7.369 ft^3 per psig This means that for every 7.369 ft^3 of air that is removed from the system, the pressure will drop 1 psig. The inverse will also occur if a similar amount of air is added to the storage capacity.

Because the maximum differential is 10 psig, the useful storage should be multiplied by 10 psig (10 x 7.369 = 73.69 ft^3). If the largest event in the system calls for 600 ft^3/min, the supply will see it as 600 cfm / 60 sec, or 10 ft^3/sec. If it takes 12 sec to turn on the next compressor, the pressure will drop 10 ft^3/sec for 12 sec, or 120 ft^3. Dividing the actual event of 120 ft^3 by the useful storage capacity of 7.369 ft^3 per psig gives the result that the pressure would drop 16.28 psig, from 110 psig to 93.72 psig -- below the minimum acceptable value of 100 psig.

To control the minimum acceptable pressure, divide the event by the allowable pressure drop, or 120 ft^3 / 10 = 12 ft^3 per psig of useful storage. Because there is already 7.369 ft^3 per psig in the system, the difference, 4.631 ft^3 per psig, needs to be added. Multiplying this figure by the atmospheric pressure gives the required capacity 68.057 ft^3. Multiplying this by the conversion factor 7.48 gal/ft^3 gives 509.07 gal of storage minimum. Because industrial unfired pressure vessels come in nominal sizes, a 660-gal tank would need to be piped into the system.

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