Managing Compressed Air Energy

Part II: Usage Effects on Demand

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Defining how air is used helps avoid fixing $100 problems with $50,000 solutions.

The amount of energy required to operate a compressed air system is based not only on how much air is consumed in demand, but how it is used. The relationship between the supply arrangement and demand usage also will determine energy consumed. In examining demand, the first question is: why do we operate the system the way we do? The ability to break down the demand by issue provides information to take the most informed approach to managing the system efficiently. What are some of the key demand issues that influence supply energy?

Minimum Load:

Although this is the condition with the lowest energy requirement, it often represents the most hours of operation per year in most systems. It is usually not evaluated and winds up being the stepchild when evaluating compressor sizes. There is usually a significant amount of part load of a larger-than-necessary compressor or compressors sized for peak demand. The waste and the hours of operation create a major opportunity for savings.

Leaks are usually the predominant user at minimum load, making leak benchmarking an excellent tool. On a regular basis, typically every few weeks, maintenance personnel can bring the demand volume back to the previous benchmark period through selective leak management using a powerful ultrasonic scanner and the system's mass flow metering. If demand is managed properly, pressure could be reduced considerably during low load to reduce operating cost as the percentage of unregulated air consumers usually increases as demand diminishes and the system's pressure rises.

Base Load Demand:

Each of the conditions or shifts will have a base load demand that will not vary. The focus for servicing base load should be on the most efficient compressors.

Trim requirements:

Each of the shift conditions will have a variable portion of the demand above base load. This is called trim. Service trim demand with compressors that is capable of loading and unloading and turning the motor on and off as required. The speed of bringing the motor and compressor to full load can be critical. The focus on trim is smaller, faster compressors with flexible controls. No larger compressor, no matter how inherently efficient part loaded, is as efficient as two smaller compressors with one off.

Profile Of Usage:

Minimum load, base load demand, and trim requirements provide the profile of usage across the conditions, and there can be from one to five conditions in each system. When the anticipated profile is thoroughly developed, a company may find that it will not generate enough hours in trim

to rationalize more expensive and efficient trim units. The base load should be serviced by the most efficient compressors because of the number of hours of service vs the energy consumed.

Do not forget the support of the low load. This probably will be supplied with one or more of the smaller trim compressors. Despite the sensibility of this, normally only the peak is considered. Several large compressors are installed with one extra which is loaded at the first inappropriate distress call from production. Another backup machine is added that gets turned on and left on. When questioned why the last compressor was not turned off, the most popular retort is "they haven't complained since." When waste in demand is corrected, the relative size of the compressors to the total requirement increases significantly. With the system being operated with fewer large compressors, the risk of interruption in the system increases in proportion to the size of the largest unit on line.

With no demand control, no waste management plan, and no information, companies should not be surprised that within the first year virtually all of the systems need what they have and the companies are shopping the next prepackaged solution to a poorly defined system's problem.

The next two demand items are the most pervasive of all demand issues and represent the primary reason why the compressed air system is operated in the manner it is.

Peak Usage From Demand Events

All systems have events. These are typically high volume, short cycle air users, which create the peak in the system. It is important to know not only the rate of flow, volume per cycle, and the duration of the event, but also the recovery time available between events. If this event is ignored, the pressure would drop when it occurred. In most cases, the system is run at a high enough pressure all of the time so that when the event hits the system, it will stay above the minimum acceptable pressure. It requires additional power on-line all of the time in order to operate in this method. This is obviously not the best operating method, but it is the typical approach.

Most plants have no idea what this event is or what its quantitative value is. Evaluating this and other large events in each condition of the system is an essential part of auditing. The highest demand event may be a single high user such as material transfer or dense phase conveying. In most plants the major source of events is the coincidence of several large events hitting the system simultaneously, such as the start up of a shift at a specific time. Typically this highest peak event occurs at first shift start up. Smaller events occur at the return from breaks.

In one case we shut down a 1,500 bhp compressor by disconnecting the shift and break start up horn. Instead of 700 people hitting their equipment at one time, the shift started over a period of 10 minutes. The breaks were split. The power required was significantly reduced. If a company only looked at minimum acceptable pressure and did not trend flow, it probably would miss this opportunity.

Another example of coincidental events would be several solenoids operated or motorized drain valves discharging at the same time. If there are enough of these drains, they are statistically going to overlap each other with some regularity. The more drains, the longer the open duration, and the shorter the intervals between actuation, the larger the event, which will occur. Remember that the system sees events in real time at the rate of flow per event in cubic feet per minute (cfm). A 1/2 in. motorized drain valve may be open for only 5 seconds every 10 minutes. During the open time, it may discharge 40 cubic feet of air at line pressure for 5 seconds, but it occurs at 477 cfm rate of flow. The supply system sees this as a requirement for 110 bhp of compressor for this short duration. How much storage capacity there is in the system and the number of drains that actuate will determine how much the pressure will drop during the event. Imagine four or five of these valves opening at one time. Our experience is that this type of event normally occurs in the

compressor room and will occur sufficiently to prevent any compressor from unloading even when there is not enough demand to support the supply.

It would be unique if someone operating a compressed air system knew what the events were, how they influence the system, or what to do about them other than operating more compressors all of the time to handle the events once in a while. Events are the single most important issue in designing and operating an air system. The amount of storage, controls philosophy, and size and type of compressors are all relative to event management. There are many ways to manage events besides throwing power at them.

Sizing control storage appropriately will help event management (see accompanying section *"Control Storage Application and Calculations"*). Another method of better managing peak events is the development of higher-than-normal-pressure, large-volume storage, which is created off the main air system with typically a very small 150-200 psig, 5-25 hp compressor(s). The air then is reintroduced into the main piping with a valve control system operated by a programmable controller that controls the pressure drop when the rate of change in the system exceeds a preset value normally commensurate with the events, which occur. The size of the storage tank is based on the size of the event and differential pressure between the system's demand pressure and the stored pressure.

The energy required is a function of the required rate of flow times the use time divided by the available recovery time before the event recurs. The idea of load shaping is to support events in the system while preventing the larger main compressors in the supply system from seeing the demand increase on a selective basis.

Critical Or Highest Demand Pressure Required

Most systems operate on an error response basis. If the pressure drops and someone complains, additional compressors are loaded to increase the system's pressure so the complaints will cease. As this is the most common reason for the operating approach, it warrants a little attention. There are always several things that happen:

a. **Both the caller and the powerhouse operator assume the supply is insufficient.**

b. **Neither party defines the problem that provoked the added compressor. There is no trended information.**

c. **Neither party understands the financial consequences of their four- to six-figure decision.**

d. **Half of the time, there is no problem. The caller is a gauge watcher. The other half of the time the problem is local to the caller and adding power has no influence one way or the other. (For years we have encouraged compressor operators to ask the caller to call back in a few moments. They seldom call back because the problem was self-correcting.)**

e. **Neither the caller nor the problem is ever recorded so the real problem can be corrected. The compressor is left on so the operator will never get the call again.**

Is there something wrong with this picture? We find that most high, critical pressure users in the system have some rather common maladies. The most predominant is point of use regulators with high differentials. Differentials on regulators show up on the upstream side of the pilot pressure they are trying to hold. If a company has a 20 psig DP on the point of use regulator, which is not unusual, and it is trying to maintain a pilot pressure of 90 psig on this application, it will have to maintain 110 psig in the overhead system and a higher pressure at the compressors. The operator notices a loss of performance, which he assumes is insufficient supply pressure.

If the philosophy is to keep calls from coming in, imagine the gyrations you will have to go through or the misdiagnoses in order to satisfy this kind of problem. More than half of the audited plants felt that the main piping was undersized. In all of these cases the rational for this diagnosis was that a user in the system could not hold 15-20 psig less pressure at the point of use on a critical pressure application. The real dilemma is the lack of problem definition.

Another problem, which can go hand in hand with the regulator problem is the point of use filter which is loaded with dirt. As the filter gets dirty, the downstream pressure drops. It can run into the differential on the regulator. It will definitely change the way the air user is functioning. Since the user does not know why his air-operated device does not work properly, invariably it is assumed that there is insufficient supply. Nine out of 10 audited plants had never changed the point of use filter cartridges since they had been installed. They also had no replacement cartridges in inventory if they wanted to change the filters. In almost every system, the first two or three highest pressure users had between 15 and 30 psig of differential across the filter, regulator, hose, and disconnects. In most of these plants all point of use installations used the same size installation components regardless of the volume or pressure required by the air-using device. Once the user is installed, if it does not work, companies just increase the regulator until it does. If this does not work, it adds a compressor and elevates the entire system until that one user works. This is how companies typically and mistakenly cope with differential.

Most of the time, the differential at the point of use represents the highest pressure drop in the entire system. Sometimes the problem is another high volume user near the critical pressure application, which causes the branch line or sub header pressure to drop into the critical application.

Silly Solutions:

Make the call. Add more power. Most of the time $100 problems are fixed with $50,000 solutions. It sounds silly, but this is commonplace without investigation, knowledge, or information management tools. Plant engineers and maintenance managers will struggle for months attempting to decide what brand and type of compressor should be used to fix a dirty filter. We hate to think of the tens of thousands of times we re-piped systems to a larger size to fix an undersized regulator. In all cases the retrofit of the piping increased the system's storage capacity although no one thought of storage as a solution. There are much less expensive ways to provide point of use storage than increasing the header size.

Knowing that it will cost more to operate a compressor in the first year than it costs to buy and install one, adding another compressor is a serious decision. Even the most uninformed manager will balk at the capital expenditure if there is not a sound definition of the problem. In most cases, the decision to buy another box of compressed air with all of the required accessories will be sitting on the bottom of the to-do pile. Eventually the problem will be bad enough that production will support the purchase. The purchase, installation, and start up will occur. The pressure will be elevated a few psig and the complaints will cease for a period of time until the process starts all over again.

Conclusions:

The average demand reduction in the audited plants was 43 percent although this is an on-going process. The average demand pressure requirement has been reduced by 12 psig and many plants feel they can reduce this further. The average savings per year including all costs of compressed air has been more than $400,000; the size of the system and the burdened cost of energy, water, and maintenance will influence the potential savings. The average return on investment—adjusted for tax treatment, cost of capital, and adding depreciation for capital—was 16 months.

Control Storage Application and Calculations

Companies need to determine the allowable pressure drop from the signal pressure when they begin to add the next compressor to the terminating pressure when the decay is stopped. The amount of storage will determine how low the pressure will drop.

Consider These Factors:

1. **The largest event in cf/sec that can occur in the system.**

2. **The slowest permissive speed of the compressors in the supply measured in seconds including the cold start of the motor and the internal permissives of the compressor required before it starts to discharge air into the system.**

   - **Single- and two-stage rotary screws range from 6-15 sec with across the line starters.**

   - **Reciprocal compressors range from 12-18 sec with across the line starters.**

   - **Centrifugals range from 28-72 sec with full voltage starters with hot start.**

   - **Two-stage dry screws can range from 12-28 sec on a hot start.**

   Then add the extra time required as the result of adjustment of a reduced voltage starter. This can take as long as 12-18 sec. This assumes the slowest compressor will be able to satisfy the largest event. It does not have to do this in real time. It only needs to stop the decay at an acceptable pressure that could take much longer than the length of time of the largest demand event. Smaller, faster compressors will slow down the event and may outlast the event duration with less horsepower.

3. **The allowable pressure drop. Once the compressors are set up in their local supply pressure profile, the allowable pressure drop is the lowest acceptable pressure drop to neither load the next compressor unnecessarily nor drop below the minimum acceptable pressure of supply to the system. Do not forget the added pressure drop across the cleanup equipment between the lowest P2 pressure and the lowest P3 psig.**

If the largest event is 600 standard cubic foot (scf)/m rate of flow, the scf/sec is 10 cf/sec. Assume the time permissive is 15 sec on the slowest compressor from a cold start. The allowable pressure drop is 3 psig either between the compressors' load pressures or below the last available compressor.

If the permissive is 15 sec, the largest event will remove 15 sec x 10 scf/sec = 150 scf from the system before the slowest compressor will begin to stop the decay.

If the allowable pressure drop is 3 psig, the question is how much storage is needed to support a 3 psig pressure drop with 150 scf of volume reduction: 150 cf times [14.696 psia* divided by 3 psig] times 7.48 gal/scf = 5496 gallons of storage.

Faster compressors could be installed in the trim position. The demand event could be altered by changing the ramp rate of the event or providing dedicated storage at the point of use. The operating pressure of supply could be increased, keeping too much energy on all of the time. This, of course, could involve a great deal more capital and a significant increase in operating cost. Control storage is essential to all systems. Considerable thought should be given to its design and use.

***This assumes that the atmospheric pressure is at sea level.**

R. Scot Foss is president of Plant Air Technology, Charlotte, N.C., a company specializing in system auditing and designing. This series of articles is based on his book, "Compressed Air System Solution Series". A portion of the proceeds from sales of the book is donated to children's charities. The book can be ordered through Southern Corporation.