Improving Air System Efficiency

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Part 1: Carefully engineered responses to demand will result in more efficient systems and compressed air savings.

The compressed air system is the most misunderstood of all industrial utilities - the best engineering course has little more than a few hours of education regarding air. You can't get the necessary training through vocational technical institutions, colleges, or universities. If you have trouble getting the correct information from the salesmen that call on you, then your only source of information must be experience.

As a result, here are the kinds of things that regularly occur in industrial settings:

- **If there is a complaint about low pressure out in the production area, another compressor is turned on. If that doesn't help, another one is turned on. If maintenance runs out of compressors, they buy more until the pressure rises enough to keep production people from complaining.**

- **If the production people complain about contamination and the compressor appears to be working based on supplier service inspection, maintenance will either replace the equipment with more of the same or deem it as being inappropriate and buy a different kind of clean-up equipment.**

- **If problems persist on a piece of equipment, maintenance will change service companies and never buy that brand or type of equipment again.**

What should be painfully obvious here is that none of the decisions that were made had anything to do with business sense, systems jeopardies, or any kind of problem definition. Keep in mind that many shop mechanics make their operational and maintenance decisions based on the following commandments:

- **Keep it running**
- **Control the maintenance cost**
- **Anticipate and prevent failure**
- **Keep the telephone from ringing**

Real-world example #1

At one of our plants (I was then working for a different company), we were given the opportunity to reconfigure the air system to adapt to an improved manufacturing process. Up to this point, the

role of utilities was so submissive to production that manufacturing didn't even see the point of a briefing. I made the mistake of asking what the rules were for the use of compressed air at the point of use. One of the production managers clarified things quickly. He said, "We take it . . . you make it! If you do a good job, we can keep the costs down." That seems pretty clear, doesn't it?

Everyone wanted to discuss what new supply-side equipment we should put into the budget. I thought that it may make more sense to figure out what we needed. History had shown that no matter how much air was available, in a relatively short period of time, we needed all of it. They were all set to get into the heated subject of how many compressors, what brand, type, and size. I got them to agree that demand should drive the supply. The spokesman for production told us that they were going to need about 4000 cfm more than what they had now. I asked how they determined the 4000 cfm, and at what pressure they needed it at?

The pressure they requested was 90 psig. This number was higher than any previous accepted minimum pressure. Utilities had taken their numbers and inflated them by a 20% "fudge factor" on volume and 5% on pressure. When all this was done, we had arrived at 4800 cfm at 115 psig.

The preliminary guess at the compressor and auxiliary requirements put this expansion at around 1250 bhp. Correcting their fudge factor put it closer to 800 bhp. This was 322 kW less and at $0.08 per kW per hour, meant $25.81 less per hour just for electricity (not including water, maintenance, labor, depreciation, etc.) or $266,074 per year difference in operating cost. The reduction in capital was over $76,000 including installation.

We next refined the loading and determined that we had sized the individual units too large. The sizes were based on the peak of 4800 cfm and convenient to the sizes available from our vendors. We also realized that the base load changed dramatically along with the trim, not only within any shift, but from shift to shift. With this information, we realized that we did not have any trim capability, only blow off capability. This led us to look at two different types of compressors: one was for the base and the other type was for trim.

We, therefore, increased the number of compressors and substantially reduced the size of each. Although we didn't realize it at the time, we had also reduced the risk of interruptions because of the reduced consequences of a unit failure. At the end of this exercise, our capital requirements were reduced further, as well as our annual operating cost. We were entering the reconfiguration process with an $302,074 reduction in first-year capital and operating cost by reducing the fudge factor alone.

Next, I asked what was the minimum acceptable air pressure in production and was it needed. Production said that they needed 90 psig, but it would be nice if they could have more than that. I asked how much more. They said 100 psig. Again, why? They said more would be "nice." This would have required 2008 hp to elevate the pressure 15 psig for the entire system above the current lowest pressure of 85 psig. Doing this would cost $1.14 million. I asked what they would get for the elevated pressure. The spokesman said, "I don't know . . . probably feel a little better about the reliability of the air system, but I didn't consider how much that would cost." You can buy a lot of psychiatric couch time to improve your feelings for $1.3 million!

Real-world example #2

A second example involved an automotive assembly plant that had 73,000 scfm, but over 19,000 cfm of leaks. This plant was a 24-hour-per-day, 7-day-per-week operation; they never shut down unless they absolutely had to. Under these circumstances, no one had noticed how much air was being serviced in the system in a shut-down mode. This would be based on the number of

compressors they had to run to maintain pressure when they did nothing. Everyone agreed that there were many leaks.

No one knew how much the leaks amounted to or the energy required to support them. One person mentioned that they had tried to get management to support a leak-fixing exercise. They learned that management didn't want to spend an unspecified amount of money for an unmeasureable result.

We determined the volume of what we could not shut off and subtracted it from the total supply at our lowest load. That was 19,000 scfm at full line pressure - air that was being used with the plant shut down! (I have seen hundreds of plants with this percentage and a few plants with more leaks by volume). We used over 4800 bhp of compression equipment to maintain the extraordinary waste. That's more than $318 per hour, or $2.79 million per year.

Three concepts to remember

Several years later, I had the opportunity to work in the field for a major pneumatic tool-and-hoist manufacturer. This experience provided me with the next steps in my thinking process. During nine weeks of training, we were taught how to optimize the air tools as they were applied to industrial applications. Three major ideas came from this study.

One was that the efficiency of the equipment was a function of how it was installed. Whenever we demonstrated or tried a tool for a user, we should always try to use our own company-supplied hose and fittings. There was no explanation or technology supplied, other than the fact that the tool would work better. It would achieve more torque, grind more metal, etc. We found that most manufacturers, including my employer, did not go out of their way to specifically state the required volumes or pressures required for proper operation.

The second idea was that you could get applications to work more efficiently at the same pressure or get the same efficiency with more volume at less pressure. As the volume of air required by the tool was a function of the supply pressure, the higher the supply pressure, the more scfm exhausted. You can achieve the same amount of work energy by increasing the mass inversely proportionate to the reduction of the absolute pressure.

The third idea was that sometimes, because of compressed air supply limitations, a different style of tool or size of air motor is necessary.

The Dilbert factor

To further complicate everything, users often break the compressed air decision-making up to two or three different levels of management, based on the capital cost of the components. All too often, compressor decisions are made by an executive who doesn't know an air compressor from a milling machine. When you shake all of this out - depending on the number of required bidders from each group, coupled with the levels of management - there are 20 or 30 different opinions about what should be done. All of these groups have different interests and priorities. It is little wonder that very few air systems work. One of the outcomes is that if the system works - even remotely as well as the designer intended - everyone is delighted. When one begins to look at all of this systematically, you have to change to a new pair of glasses to understand what's going on.

Measuring compressed air

For many years, people have been trying unsuccessfully to measure the performance of compressed air systems. This, of course, has been done with every other utility with no problem. The old "compressed air is free" thinking stems from a lack of knowledge of quantities and cost. You can't determine cost without usage. Then you have to compare demand volume at pressure against supply energy in real time.

Most plants have nothing other than the minimum acceptable gages on the equipment. Most of the few that do anything measure flow from the compressors and not energy. I'm not sure what value this has other than perhaps holding suppliers accountable or noticing change in ambient or maintenance conditions.

Most people who measure flow are interested in demand accountability. They accumulate volume without pressure over a long time, such as a month. This gives a very distorted view of usage and energy because it does not detail peaks, valleys, energy, or efficiencies - which drive cost. The system must be measured in minutes if the information is to be meaningful. The name of the game is usage vs required energy. Until you have information supporting the quantitative problem, it is difficult to get any support for solutions from management or utilities. The air system has a lot of problems, and if we spend a lot of resources on problems, things will get better. Not many managers will invest in that one.

The few systems where I was able to collect data gave me an opportunity to measure constituents of demand - such as leaks and artificial demand. I had always been comfortable with a 10% to 20% value for these two items. What I was realizing was that it was more like 25% to 40% on the average, and that didn't include any supply inefficiencies or inappropriate production usage. Combined with leaks, it is common to see more than 75% of all usage unregulated. Once you know the size of the problem, and you translate that into monetary terms, you can get management's attention. As you dig into the solutions, you need information in order to benchmark progress and build discipline to maintain standards.

As users began including information gathering into retrofits, we were able to see that the estimates of usage when originally designing the system missed the actual usage by a mile. It took a long time to figure this one out. One might begin to believe that the manufacturers of air equipment don't want people to know what the relationship can be between air usage and power required to support it.

It takes 30 scfm at 90 psig or an equivalent weight flow in real time to generate 1 hp of compressed air work energy at the point of use. It takes about 8 to 9 bhp of compressor and auxiliary equipment to generate that power. A typical 1Ú4-in. air drill requires 8.5 scfm or .2 hp of electricity. A 7-in. disc grinder requires 60 scfm or 15 to 18 bhp of electrical support. Rather than judging or guessing why the industry does what they do, I'll show you. They put use factors which supposedly are based on the typical volumes. As an example, they would estimate that the 1Ú4-in. drill would operate for 20% of a minute and the grinder may have a 50% use factor, or 30 seconds per minute. They then estimate the volume per minute from:

8.5 scfm 3 0.20 = 1.7 scfm, or

60 scfm 3 0.50 = 30 scfm

Because all installation components must be sized based on rate of flow - not average flow per time period or cumulative cycle flow over a minute - most systems and components are sized improperly. You cannot take 2 cf per 5 second cycle four times per minute and call it 8 cfm. The rate of flow is 2 scfm 3 (60 sec 4 5 sec), or 24 scfm. The results are high differentials and an

inability to handle peaks. The systems approach to these problems results in high operating pressures and extra compressors that remain on all of the time, to manage large or coincidental demand events.

Storage

Perhaps the most thought-provoking and overlooked issue in the system is storage capacity. For the most part, knowledge about this factor has come in pieces over the past 20-odd years. The supply industry looks at storage only from its own point of view. What I hear most often is that the seller of the compressor specifies the storage based on a "guess-timate" or said that his type of machine did not need a tank. Engineering decisions require more than such stabs in the dark. Whether one compressor requires storage or not, all systems require storage. Storage serves many purposes in a system, such as:

- **isolating events in the system, eliminating the need to keep energy online all of the time for the intermittent appearance of demand**
- **protecting users from seeing the effect of other users**
- **providing the ability to replace air usage over long periods of time and then use it at very high rates of flow. This can eliminate the need for a very large amount of energy, depending on the recovery time available between events served, and**
- **controlling the rate of change in the system based on scf per psid available. Without this being done properly, automation is a waste of time.**

Changing our ways

In the mid '80s, I gave up the battle of point-of-use systems control. It was the exception rather than the rule when you could get operators in a plant to not fiddle with the regulators. An old timer explained it to me. He said that people played with regulators because they could . . . regulators have a handle.

Some things haven't changed at all. Compressed air is still the most expensive in-plant utility by far. It takes more than nine units of electricity (including auxiliary requirements) to generate one unit of air energy. Seldom if ever do we find a system that is achieving much-more than a minimum acceptable result. Somehow, in the development of the industry's thinking, the concept of "more is better" got linked with compressed air. With the exception of storage, nothing could be farther from the truth.

The compressed air world must change with the cost of energy increasing and global competition forcing new priorities. The cry of management today is burden reduction and continuing improvement.

We have learned to keep production complaints to a minimum with whatever resources are available to us . . . all too often more power. The demands on plant engineers, maintenance managers, and production engineering to control cost and improve quality will not allow us to "do what we did, and get what we got."

The merging of all of these topics is the magic of operating a best-in-class system. I invite your open-mindedness, as much of the information will be quite different and occasionally contradictory to what you may believe to be true. It is not the intent of this series of articles to "get the system to work" or "keep the equipment running." It is my intent to provide you with the concepts and information, as they apply to working systems, to improve the quality and quantity of production at a significantly lower compressed air cost. In Part 2 of this series, we will explore the best ways to design a new compressed air system.

What if we treated our electric systems the same way we treat compressed air?

1. We would have to remove all the nameplates from the motors and electrical devices. We normally have no idea what volume or pressure is required of air using devices other than by trial and error.

2. We would buy electrical-using equipment with no regard to voltage, amperage, or the effect that it might have on the system, assuming that the local utility would compensate for whatever the results were on the system.

3. We would remove all the circuit breakers, transformers, capacitors, and starters from the system and use only primary power, regardless of need. If a particular user required control, we would put rheostats on those applications and nothing on the balance of applications.

4. We would use one or two sizes of wire and connection components on all electrical applications, regardless of voltage or amperage, and expect maintenance and the local utility to correct the system to compensate for how the production works. The size and selection of those components would be determined by the stores department and purchased based on price, availability, and minimizing inventory. Example: Use 1Ú4-in. hose and fittings on all applications regardless of flow or pressure. Once the connections are made, if the application doesn't work, you simply increase the pressure supplied to the equipment until it works the way we want it to. Wouldn't that be interesting to do with electricity?

5. Give every operator and supervisor the phone number of the local utility. If the equipment in production isn't working the way that they want it to - regardless of any changes in speeds, feeds, faults, or any other problem - they simply call the local utility, who will alter the way they are supplying electricity to the plant to correct that single problem. If they cannot correct the problem with more whatever, they will simply buy more whatever or build another power plant and try again to solve the problem which was reported over the telephone. After all . . . electricity is free! Well . . . certainly compressed air is free . . . isn't it?

Some of you may think that this example is ridiculous. Actually it would be a relatively close parallel to the way that most compressed air systems are operated. The sad part of this is that there are limited resources available to learn more about compressed air.

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