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Data from more than 250 plants show how compressed air energy may be distributed among key usage categories. Use this information to help decide where energy management solutions should be applied first.Although compressed air systems generally are the third highest energy user in an industrial plant, they represent the number one opportunity for both energy and operating cost reductions.

Compressed air systems convert electrical work energy to pneumatic work energy at the point of use. All elements of this process need to be managed efficiently. The optimum process would produce one unit of work energy in the form of expanded mass at the point of use for every 8.5 units of compressor input energy. In industrial plant air systems, which represent more than 7.5 percent of the energy used in U. S. industry, there seems to be little understanding or effort made to achieve any level of efficiency other than the occasional attempt to buy the promise of efficiency with new equipment.

The manner in which compressed air is consumed offers a major opportunity for reduced energy and operating costs. Typically, less than 60 percent of the total compressed air consumed contributes directly to the goods and services for which production was intended. Of this 60 percent, more than a third of it is poorly applied.

The net result is that less than 40 percent of the total consumption of compressed air in industrial plants is essential to process results. The balance negatively influences the cost and quality of goods and services produced. The combination of process efficiency and usage of compressed air makes plant compressed air systems one of the most significant economic opportunities in the industrial sector. Despite this reality, compressed air energy has been increasing while the use of all other forms of energy in industry is diminishing.

Audit results

In the past five years, Plant Air Technology has thoroughly audited plant and process compressed air systems at 551 plants and cumulatively analyzed the audit results of 250 systems. The percentage of total energy used for compressed air in these plants ranged from 6-29 percent, with an average of 9.5 percent. This article will report the findings. It is particularly interesting to note that while most plant managers were aware of potential inefficiencies, the questions of how the system was specifically set up and adjusted and why it was operated the way it was went unasked and unanswered.

Most of the operating personnel in these plants did not know how much compressed air volume they used or needed. They did not know the costs of operating the compressed air system. Only two of these plants monitored both input power and compressed air consumed. There were no standards or operating procedures for the use or supply of compressed air other than maintaining a minimum acceptable result. Generally, success in system operation was determined by the lack of complaints.

The majority of operating personnel acknowledged that their education regarding compressed air systems and their operation was lacking. Most of the audited facilities did not know how their equipment was specifically adjusted and admitted that outside sources maintained the equipment and established equipment operating parameters. In all cases, neither the owner nor the service agency had any records of how or why the equipment was adjusted. The utility costs ranged from a blended rate including demand charges of 0.035 cent-0.117 cent/kW of electricity consumed.

Low load or no load tests were performed at all audit locations in advance of the final audit. All operating conditions were investigated. All parts of the system including supply, storage, distribution, and demand were measured. Problems in the system were evaluated and quantified. Operating costs of the audited systems were determined including all ancillary equipment, maintenance, water, operator costs, and depreciation. Proposed solutions were detailed and costed. Operating cost of the proposed system was determined to establish a return on investment.

Demand side energy
The basics of demand side energy will be covered here. Future articles will discuss usage factors that affect demand and supply side energy issues.

Most systems are evaluated based on perceived supply requirements. If the pressure anywhere in the system is below what is believed to be the minimum, the diagnosis is insufficient supply. Little more is done to determine what is going on in the system. In existing systems, demand is determined by adding up the rated capacity of the compressors that are on regardless of power. An "on" compressor is only an indication of cost, not an indication of need.

Without demand, there is no requirement for supply. Figuring out a reasonable needs profile begins by analyzing demand. All of these systems used air at the pressure it was compressed to with little or no storage and an uncontrolled approach toward expanding the air to the pressure needed. Less than half of the air consumed was regulated. Fifty percent of the regulators were adjusted wide open.

Total unregulated demand is typically 80 percent of the total demand. This creates a unique dynamic not seen in other utilities. As real demand increases, the supply pressure drops and 80 percent of the total use volume diminishes proportional to the reduced density of the supply air. Please keep this in mind as we move forward.

Demand categories for compressed air include:

Appropriate production use—compressed air that is well applied and controlled at the pressure of its intended use. This can include coincidental demand, critical pressure, high rate of flow, and high volume users, which provoke the operating philosophy in the manner that they affect the system and its pressure. A portion of the users necessary to production will be regulated, while the balance will be unregulated.

Inappropriate production use—applications that should use electricity, hydraulics, or mechanical power instead of compressed air. Examples include using plant air for aspiration, agitation, or aeration; using air ejectors in place of a simple vacuum; or using air instead of electric vibrators. These compressed air applications are usually developed with no understanding of cost or the consequences of purchasing alternative equipment to perform the same function.

Open blowing—using plant air for moving product, drying, wiping, cooling, or part and scrap ejection instead of using pressure blowers, knock outs, or specialty nozzles which would have to be purchased and applied.

Drainage—using plant air in conjunction with open valves, notched ball valves, or motorized or solenoid-operated drain valves to dispose of compressed air effluent such as water or lubricant instead of automatic drain traps which do not use compressed air.

Leaks—waste, which is internal to production equipment as well as in the general piping system from the internals of a compressor to the point of use.

Artificial demand—the excess volume of air that is created for unregulated users as a result of supplying higher line pressure than necessary for the application. This includes all previously unregulated consumption including appropriate and inappropriate production use, open blowing, and leaks. As the pressure supplying all uses fluctuates, artificial demand increases and decreases from a minimum to a maximum waste level. As real production demand decreases and the pressure rises, artificial demand increases. As leaks in the system are fixed, the pressure rises and all unregulated demand increases proportionate to the pressure rise including the balance of the leaks. The use of a demand expander can correct this problem when adjusted to the minimum required pressure. It will allow storage to be maintained in the supply system to handle variations in demand.

Attrition—additional air consumption for applications as a result of unmanaged wear. Examples include blast nozzles, textile machinery nozzles, etc. Unattended attrition can increase this consumption by 50 percent volumetrically and frequently provokes the increase in pressure at both the point of use and at the supply. A ½-in. nozzle with 1/16 in. wear that has been elevated from 80 to 90 psig will increase the volume by 50 percent.

Purge air from desiccant dryers— air consumed in the process of stripping air dryers of moisture. This process can range from 3-18.5 percent of the total air system capacity from one dryer type to another. There are specialty categories of air such as CDA 100 that is used in the microelectronics industry where purge can approach 25 percent of total capacity for the system.

Centrifugal compressor blow off—when the demand for air in the system is below the minimum stable mass flow for centrifugal compressors. These compressors will blow off the difference between the minimum stable flow and the actual demand requirement. It is common that all centrifugals installed in an application can be blowing off simultaneously. Depending on the design of the compressor, the current limit low adjustment, and the inlet conditions, the minimum stable flow can range from 60-87 percent of the full load capacity. This is real demand that requires energy whether it is productive or not. The objective in operating a centrifugal compressor should be to keep it fully loaded in base load and operating on its natural curve.

Bleed air or control bypass—a point-of-use consumption where air is bled off the system or bypasses an application to improve the accuracy of pressure and/or flow control. Where pressure accuracy is important and there is considerably more power and/or higher than needed pressure, the pressure will fluctuate erratically or perturbate. This is usually the result of compensating for a controls or storage problem. The most common use of bleed air or bypass is in simulation testing such as in the aerospace industry.

In general, these 10 items represent the constituents of demand that were encountered in the audited systems. The last four categories were represented in only 23 percent of all systems while the others were typical constituents.

Audit conclusions

Demand is the most misunderstood part of the compressed air system. Compressed air mass does the work. Only a few plants used mass to determine the work energy and related supply needed to accomplish their desired results. The majority used volume and pressure in a separate context. There are no standard guidelines for the use of compressed air. Without information or education, none of this is perceived to be a problem because it cannot be defined or quantified.

The audit showed an average cost of $1.66/100 cfm/hr of operation based on an average use pressure of 96 psig that was the same as supply. On a three-shift, five-day-a-week basis, the application of a ¼ in. open blowing device at 90 psig costs $9834/year to operate.

In all of the plants audited, anyone could make this application decision with no discussion or knowledge of the consequences. If this application requires the addition or loading of another compressor, the cost could increase by 10 times.

Most of the audited plants currently have an air committee and have developed standards for the use of compressed air. They also have applied standards for allowable differentials at all applicable points from one end of the system to the other. They view the addition of compressed air users to the system as a business decision (as it should be).

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

The tough question to ask in these plants is how much production revenue must be generated annually in order to do nothing. Because this is bottom-line expense and directly impacts on operating income, the answer is the potential savings times the production revenue divided by the pretax profit. The average plant making 5 percent pretax profit would need $8 million/yr to ignore the $400,000/yr operating cost reduction. This certainly does not make production at any cost a sound reason for having a poorly operated and configured plant air system. **MT**

**Plant Air Technology has audited more than 860 medium to large industrial compressed air systems. The average system of the 250 discussed in this article has 1485 bhp of on-line power. The size of the system and the burdened cost of energy, water, and maintenance will influence the potential savings.*

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