Compressed Air Controls: Simple to State-of-the-Art

General control concepts, part 1 of 3

By R. Scot Foss
President, Plant Air Technology

Key Concepts:

- **Control systems are defined by their application**
- **Many compressor controls protect the compressor**
- **Peak shaving means only operating needed compressors**

When most people think of compressed air controls, they automatically think of compressor controls that govern the results in the system. If the system doesn't work, whatever that means, more sophisticated controls are normally recommended. There is at least a chance that this will work. On the other hand, solutions without problem definitions typically do not succeed.

Compressed Air System Controls:

Control systems can generally be defined by their application.

Point of use **– This typically refers to proportional regulators, which restrict flow and control pressure at a single use point. Regulators are subject to hysteresis or fluctuation when the application changes flow requirements. Sometimes flow controls are applied downstream to limit flow at variable pressure.**

Although 75% of most applications, by point of use count, may have regulators, it is seldom that more than 50% of most systems volumetric demand is actually regulated. This is a result of unregulated usage and regulators that are adjusted to be wide open.

Intermediate or system demand controllers or expanders **- These are typically applied at one location between supply and demand. Sometimes they are applied in various user sectors, when there is sufficient difference in group use pressure to effect a total demand usage reduction. The intent of this type of controller is to limit the pressure or density (pressure and temperature) of the downstream users to a maximum value which is less than that of the minimum supply.**
In 98% of the cases, it is not practical to expect that all production operators will use their point-of-use controls in the best interests of the system.

System demand controls separate demand from supply, allowing each to be managed independently. By doing this, the storage of potential energy on the supply side is used to reduce on-board energy in an operating pressure range, while maintaining the lowest constant demand pressure or pressures simultaneously.

Individual compressor controls **- Because an air compressor is little more than an air pump, air compressor controls limit performance. This is typically performed by:**

- **Throttling or closing the inlet**

- Blowing off a portion or all of the air, usually in conjunction with inlet limiting devices
- Closing the discharge and pumping in and out of the inlet
- Using clearance pockets
- Throttling the driver in response to a pressure input

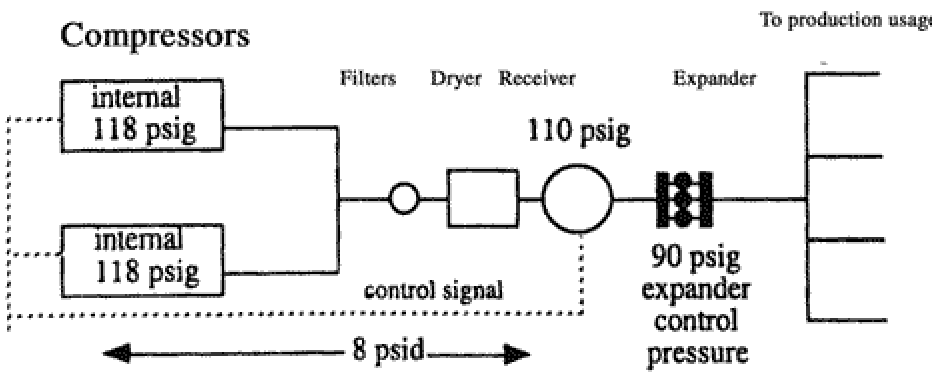

Fig. 1.
Demand expanders control pressure or density of the user's air supply to a value less than that contained in a receiver

These individual control approaches are done in conjunction with either maintaining a specific pressure or keeping the compressor operating between two pressures in an operating dead band. By adjusting individual controls on a limited number of compressors, the loading and unloading of compressors can be organized sequentially. The more compressors there are the wider the required operating pressure ranges.

In most cases, controls are either set at the same value or overlap each other, causing all units to be partially loaded to limit the impact of pressure fluctuation on demand.

Compressor manufacturers use controls to protect or limit the performance of the compressor and protect the units and their prime movers. When the operating parameters of the compressor are out of the boundaries predetermined by the factory, the controls, operation will protect the compressor as a priority over the system's needs.

Most operators have no knowledge of these pre-developed and adjusted boundaries. Because of this, it is often difficult to determine whether one or more than one compressor is operating in a protective mode or working for the system's needs.

Multiple compressor controls **- The intent of this type of control is to coordinate the application of more than one compressor within a range of intended pressures. There are several types of these controls and many operating protocols or approaches.**

- **Pressure-only controls - The approach is to keep those compressors, that are operating, maintaining a pressure or set of pressures. As the demand changes, the pressure-only control system adds, maintains, or deletes compressor capacity using available onboard energy to maintain a pressure or pressures.**

There are a number of subcategories of this type of control. One is sequential pressure-only control, where the addition or deletion of units is based on a preset sequence. Typically, the sequence may be rotated in an orderly manner. This type of control requires an operating pressure range.

- Pressure-only load sharing or shedding - This system utilizes the application of part-loading throttle controls to maintain all compressors that need to be on in the same condition of modulation at a particular pressure. If the pressure changes, capacity controls are used to return to the original pressure. Load shedding has a load and unload element to the approach.

- Pressure and time controls - These are the same as pressure-only controls, but they add the element of adjustable time delay to the operation of the logic. The time delay is typically applied to the end of an unload cycle, restricting reload. This can be tricky to apply because a time delay can effect pressure as an added protocol. Without thoroughly evaluating both capacitance and measured events, it can be easy to make mistakes in adjustment of this type of control system.

- Rate of change, pressure, and time - In this format, the difference between supply and demand is measured in terms of mass or volume. If supply equals demand, the pressure is stable, which is referred to as a "zero" rate of change. When supply exceeds demand, there is a positive rate of change. The reverse would be a negative rate of change. This is by far the most sophisticated approach, because the precise requirement for addition or deletion of air and energy is measured.

Example: If supply is producing a 1000 scfm rate of flow and demand is taking 1200 scfm rate of flow, there is a -200 scfm rate of change. With this information, pressure values can be used to determine how much time is needed to reach a minimum or maximum value.
This format can be operated in a sequence, adding or deleting the next or last compressor respectively. With this improved cueing data, a selective rate of change approach can be used, adding or deleting the most appropriate compressor.

Note: Some multiple-unit control systems actually control the compressors, while others enable the compressors. By enabling, the controls select a compressor and allow it to operate on its independent control and signal relative to the system. Correspondingly, the central supply control can block the compressor’s local controls from functioning.

Another common spin on operating these simple control approaches uses a load and unload set point inside the local compressor control set points. This is an extremely simple approach to multiple-compressor controls. It does not require an integrated interface with the compressor that is controlled by the outer set points on the compressor’s pressure switch.

- Peak shaving control - These are very much like the electrical approach and set up a separate air system off the main system. This peak shaving system typically operates at a much higher pressure with the intent of filling a large storage capacitance over time. It then can be fed into the main system either upstream or downstream of the demand control or expander to act as a compressor, a support system during a base load failure while the backup compressor is being loaded into the system, or as a trim out for high, large events.

An example of this would be a 10-hp compressor/dryer delivering 40 scfm of air into a 20,000-gal. tank (184 scf/psi) until the tank pressure reaches 200 psig. When appropriate, this provides a controlled feed from the peak shaving system, into the main system, down to the demand pressure. If the demand pressure is 100 psig, there are 18,400 scf, which could be displaced from peak shaving. It would be displaced at a rate of 1000 scfm for 18.4 min., 3000 scfm for 6.13 min., or

6000 scfm for 3.06 min. It will take 460 min. to refill the 20,000-gal. tank with this 10-hp peak shaving arrangement.

Peak shaving is not a complex format. The various approaches to getting the higher pressure, higher rate of airflow into the main system without upsetting the host system is the key to this highly applicable systems control approach.

Peak shaving can prevent operating more compressors than are needed all of the time to support a large rate-of-change event that appears once in a while for a limited period of time.

Most systems have at least one more compressor on than is needed all of the time because the last time a base compressor failed, the production system failed.

What was the problem? The pressure dropped quicker than the backup compressor could be loaded to replace the failure. The problem was negative rate of change verses time. The solution was to run only the supply compressors needed to support normal demand and introduce peak shaving instantly to buy time on a base failure.

If supporting a large or coincidental event that occurs once an hour or more, there are 60 min. of recovery time. If covering a once-a-shift event, 480 min. of recovery would be needed.

The idea is that the more recovery time available, the smaller the peak shaving compressor system. Remember that a peak shaving compressor will run continuously. A 10-hp compressor and dryer applied with adequate storage and a control system can act like a 1000-hp compressor for a limited period of time.

These are the various control approaches that can be used in a compressed air system. The system must be known quantitatively in order to apply controls that would include base and trim requirements for each major load condition including, but not limited to, shifts and weekends.

To make this quantitative analysis, obtain the order of events that occur in the system in terms of rate of flow, volume per event, duration of the event, and recovery time available between events. Then measure the capacitance of the system including all vessels and piping that is 2.5-in. and larger.

The reason for not measuring 2-in. pipes and smaller is because there is so little storage it is hardly worth measuring. 1000-ft of 2-in. pipe is equal to 1.61 scf/psi or less than 100 gal. of storage. Without a demand profile and current capacitance, the selection of the size and type of compressors and approach to compressor controls is pure guesswork.

R. Scot Foss is president of Plant Air Technology, P.O. Box 470467, Charlotte, NC 28247. He is the author of "The Compressed Air Systems Solution Series," 1994. A portion of the proceeds from sales of the book is donated to children's charities. The book can be ordered through Southern Corporation.