1300 SUMNER AVENUE, CLEVELAND, OHIO 44115 • 216-241-7333

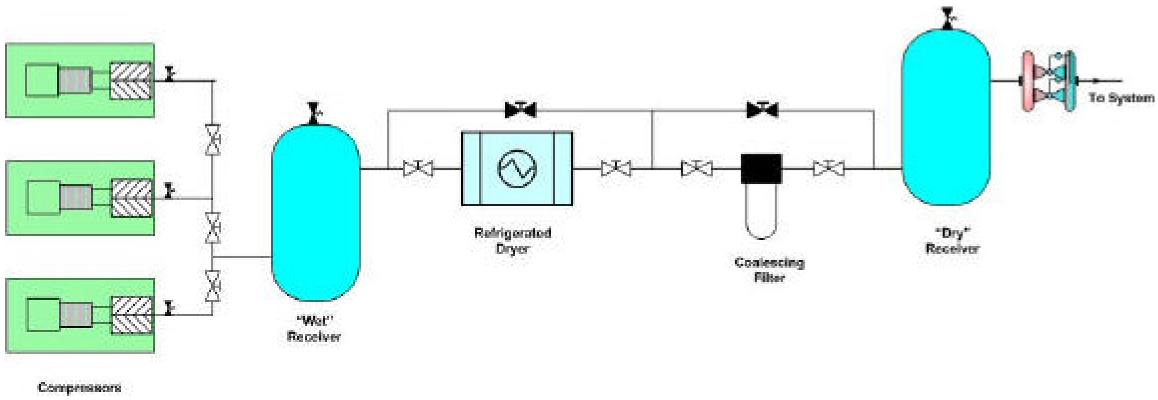
TECHNICAL ARTICLE PROGRAM (TAP)

Compressed Air: The Best Choice

TAP #103

Written by David McCulloch, Mac Consulting

Comparison of a Compressed Air System with a Pressure/Flow Controller and a system with a VSD Compressor and no Pressure/Flow Controller



Let us assume three identical rotary compressors and a dryer and filter sized to match the total output of all three compressors. The "wet" receiver is the "control" receiver, while the "dry" receiver provides storage of dried and filtered air.

The pressure drop through the dryer at full capacity is 3 psi and through the filter is 2 psi, giving a total pressure drop from wet receiver to dry receiver of 5 psi at full capacity.

The pressure from the supply side to the plant system is to be maintained at a minimum of approximately 90 psig.

System with Pressure/Flow Controller

The main function of a PFC is to separate the demand side of the system from the supply side and to allow pressure to the distribution system to be maintained at a steady level (usually +/- 1 psi), sufficient to meet end use requirements. Primary dry receiver volume upstream of the PFC is essential to ensure the required flow to the system.

If the pressure to the distribution system is to be maintained at 90 psig and a minimum PFC inlet pressure of 5 psi above the downstream pressure is required, this gives a minimum dry receiver pressure of 95 psig. With a full capacity pressure drop across the dryer and filter of 5 psi, the minimum wet receiver pressure will be 100 psig.

If the compressors have load/unload capacity control, they will have a range of 100-110 psig (giving an average of 105 psig). Sequencers can determine the number of compressors to be in operation at any given time.

PFC manufacturers' literature suggests a PFC inlet pressure of 5 to10 psi above the downstream pressure and installations often have even more. Any increase in the dry receiver/PFC inlet pressure increases the compressor discharge pressure, and resulting energy costs.

The main advantage is that supply to the distribution system can be maintained at 90 psig +/- 1 psi, providing a constant system pressure and minimizing "artificial demand" from unregulated uses and leaks.

System with One VSD Compressor and no Pressure/Flow Controller

If two of the compressors are constant speed compressors with load/unload capacity control and the third compressor has VSD capacity control, this can be used to maintain a wet receiver pressure within +/- 1 psi, since the discharge pressure is common to all three compressors. The load/unload compressors are base loaded at the set discharge pressure of the VSD.

Given the same requirement of 90 psig to the distribution system, and a 5 psi pressure drop across the dryer and filter at full capacity, the minimum compressor discharge pressure becomes a steady 90 + 5 = 95 psig (+/- 1 psi), with a resulting savings in energy compared with the PFC system load/unload compressors at 100 to 110 psig, or even more savings if a higher dry receiver/PFC inlet pressure is recommended, and the compressors and motors are capable of the higher pressures).

As demand decreases, the VSD compressor will reduce its output and energy consumption to maintain the set discharge pressure. When it's capacity is reduced to about 20 percent, instead of it shutting down, a sequencer can unload, then shut down one of the load/unload compressors and allow the VSD to increase it's capacity to meet the required demand.

However, changes in the delivered output of the compressors will change the pressure drop through the dryer and filter. At full capacity and a wet receiver pressure of 95 psig and a total pressure drop of 5 psi, the dry receiver pressure will be 90 psig.

If one load/unload compressor is unloaded or shut down, the pressure drop becomes $5 \times (2/3)^2 = 2.22$ psi and the dry receiver pressure becomes $95 - 2.22 = 92.78$ psig.

If two load/unload compressors are unloaded or shut down, the pressure drop becomes $5 \times (1/3)^2 = 0.55$ psi and the dry receiver pressure becomes $95 - 0.55 = 94.45$ psig.

This means that while the compressors can operate at a reduced constant discharge pressure and reduced energy level, the pressure from the dry receiver to the distribution system can vary from 90 psig to approximately 95 psig, normally a very acceptable range. This also may result in a marginal increase in air usage by "unregulated" components in the system, including leaks, but this may be more than offset by the energy savings from the compressors operating at a lower discharge pressure.

The sensing point for the discharge pressure of the compressors is effectively buffered from demand side fluctuations by the volume of the wet and dry receivers, reducing the rate of change of pressure at the discharge of the compressors, providing more pressure stability.

If the pressure to the system can be reduced below 90 psig, then the compressor operating pressure range can be reduced even further, saving additional energy.

(In an arrangement as above, it is recommended that the VSD compressor be sized 20 to 25% larger than the base-load compressors, allowing more operating time at a more efficient load point and to overcome the potential gap in output when a load/unload compressor unloads and then shuts down, causing the VSD compressor to go from 20% capacity to full capacity).

Now, if we leave the two load/unload compressors as is, with their control sensing point being at the “wet” receiver, but move the sensing point of the VSD compressor to the dry receiver, we can set and maintain the pressure to the system at the required pressure of 90 psig +/- 1 psi.

At full capacity of all three identically sized compressors, the dry receiver pressure will be 90 psig and the wet receiver pressure will be 95 psig. As the VSD reduces capacity to 20%, while maintaining the dry receiver pressure at 90 psig, the flow and pressure drop through the dryer and filter will be reduced, giving a wet receiver pressure of 90 + 2.69 = 92.69 psig.

If, at this point, one of the load/unload compressors is caused to unload and the VSD goes back to full capacity, the wet receiver pressure will become 90 + 2.22 = 92.22 psig.

If the second load/unload compressor is caused to unload, the wet receiver pressure will become 90 + 0.55 = 90 55 psig.

If the VSD running on its own then reduces its output to 20%, the wet receiver pressure becomes 90 + 0.02 = 90.02 psig.

It becomes obvious with this arrangement that the pressure range at the wet receiver becomes 95.0 to 90.02 psig and the pressure and motor power capability of the load/unload compressors will not be exceeded, while the dry receiver pressure available to the system remains steady at 90 psig +/- 1 psi. The average discharge pressure of the load/unload compressors [(95.0 + 90.02)/2] is only 92.61 psig, providing significant energy savings.

Conclusion

There is more than one approach to any given system. An understanding of system dynamics should allow a total system analysis, including initial and operating costs to be carried out to determine the best solution for the particular plant scenario. In any event, operating at the minimum practical pressure to the plant system, and operating the compressors at the minimum practical discharge pressure, should provide the most energy efficient operation. Adequate primary receiver capacity also is essential.

Using the dry receiver as the control sensing point may require other safeguards in other compressor control scenarios, to ensure that the compressor pressure and motor power capabilities are not exceeded.

In systems where there may be high volume intermittent demands, these should be addressed by the installation of adequate secondary or dedicated storage, close to the specific point of use. A PFC or VSD compressor is not intended to address such occurrences, or an inadequately designed distribution system.