TECHNICAL ARTICLE PROGRAM (TAP)
Compressed Air: The Best Choice
1300 SUMNER AVENUE, CLEVELAND, OHIO 44115 • 216-241-7333
TAP #101

*Written by David McCulloch, Mac Consulting*

# Mixed Capacity Control Types

## Introduction

Compressed air systems vary from simple, with only one or two compressors, to complex with a variety of compressor and dryer types by different manufacturers, and different capacity controls.

For several years, inlet valve modulation was prescribed as a means of matching compressed air supply with demand, without the need for air receiver capacity. This is not an energy efficient means of capacity control. On the other hand, load/unload capacity control requires a relatively large air receiver capacity to be efficient, and still results in a control range of about 10 psi.

It is recommended that the minimum compressor horsepower in a system be in operation at a given time, and only one compressor be in the "trim" mode, while the others are base loaded.

Some control combinations can result in unexpected results. It is important that each arrangement be analyzed and appropriate controls implemented.

## Scenario # 1

When a compressed air system has two compressors, it may seem logical to set one as the "base load" compressor with Load/Unload capacity control, and the other as the "trim" compressor with Inlet Valve Modulation to accommodate changes in demand. The results may not be as expected. Consider the following installation, Figure 1:

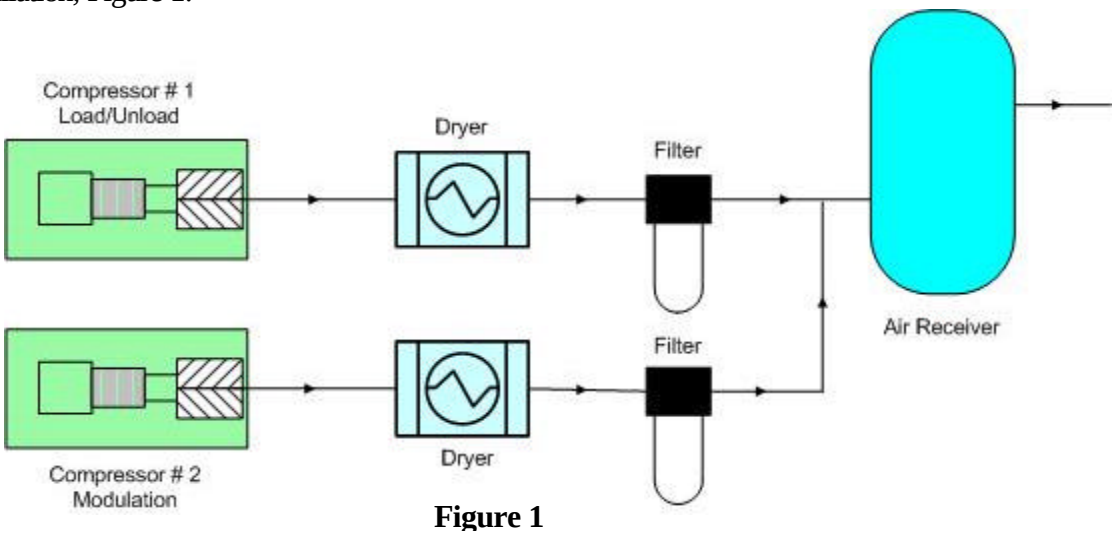


**Figure 1**

The arrangement shown in Figure 1 has the dryers and filters before the air receiver, providing a volume of already dried and filtered compressed air for use in the plant. This is called a "dry" receiver. Let us assume identical compressors, dryers and filters. The following graphs show "dry" air receiver pressure as the base, which generally is lower than the compressor discharge pressure, but is the pressure available to the plant distribution system.

It is important to note that compressor manufacturers set up their capacity controls based upon the discharge pressure of the compressor. This is what we will use unless otherwise stated.

At full compressor capacity, the pressure drop through each dryer is 3 psi and through each filter is 2 psi, giving a total pressure drop of 5 psi (neglecting piping pressure losses). The control pressure range at each compressor discharge is 100 – 110 psig, with Compressor # 1 loading at 100 psig and unloading at 110 psig. Compressor # 2 is modulating from 100% capacity at 100 psig to 40% capacity at 110 psig before unloading.

Compressor # 1 remains at full capacity up to the unload pressure setting of 110 psig, with a constant pressure drop of 5 psi through its dryer and filter. Compressor # 1 discharge pressure is always 5 psi above the dry receiver pressure.

When Compressor # 2 is modulating, the pressure drop through its dryer and filter will decrease as the square of its rate of flow. Since the air receiver pressure must be the same for both, the discharge pressure of each compressor must vary.

For example, if Compressor # 2 has modulated to 70% capacity (half-way between 100% and 40%), the pressure drop through its dryer and filter will have fallen from 5 psi to 2.45 psi (5 * 0.70 * 0.70). If we assume a straight-line relationship between discharge pressure and percent capacity, its discharge pressure would be 105 psig (half-way between 100 & 110 psig). With a 2.45 psi pressure drop through its dryer and filter, the air receiver pressure would be 105 – 2.45 = 102.55 psig.

Compressor # 1 then would have a discharge pressure of 102.55 + 5 = 107.55 psig, or 2.55 psi above that of Compressor # 2.

As modulation of Compressor # 2 continues to 59.4% capacity, the pressure drop decreases to 1.76 psi at a discharge pressure of 106.76 psig and a receiver pressure of 105.00 psig. The discharge pressure of Compressor # 1 then would have reached 105.00 + 5 = 110.00 psig, immediately before it would unload. This is illustrated in Figure 2.

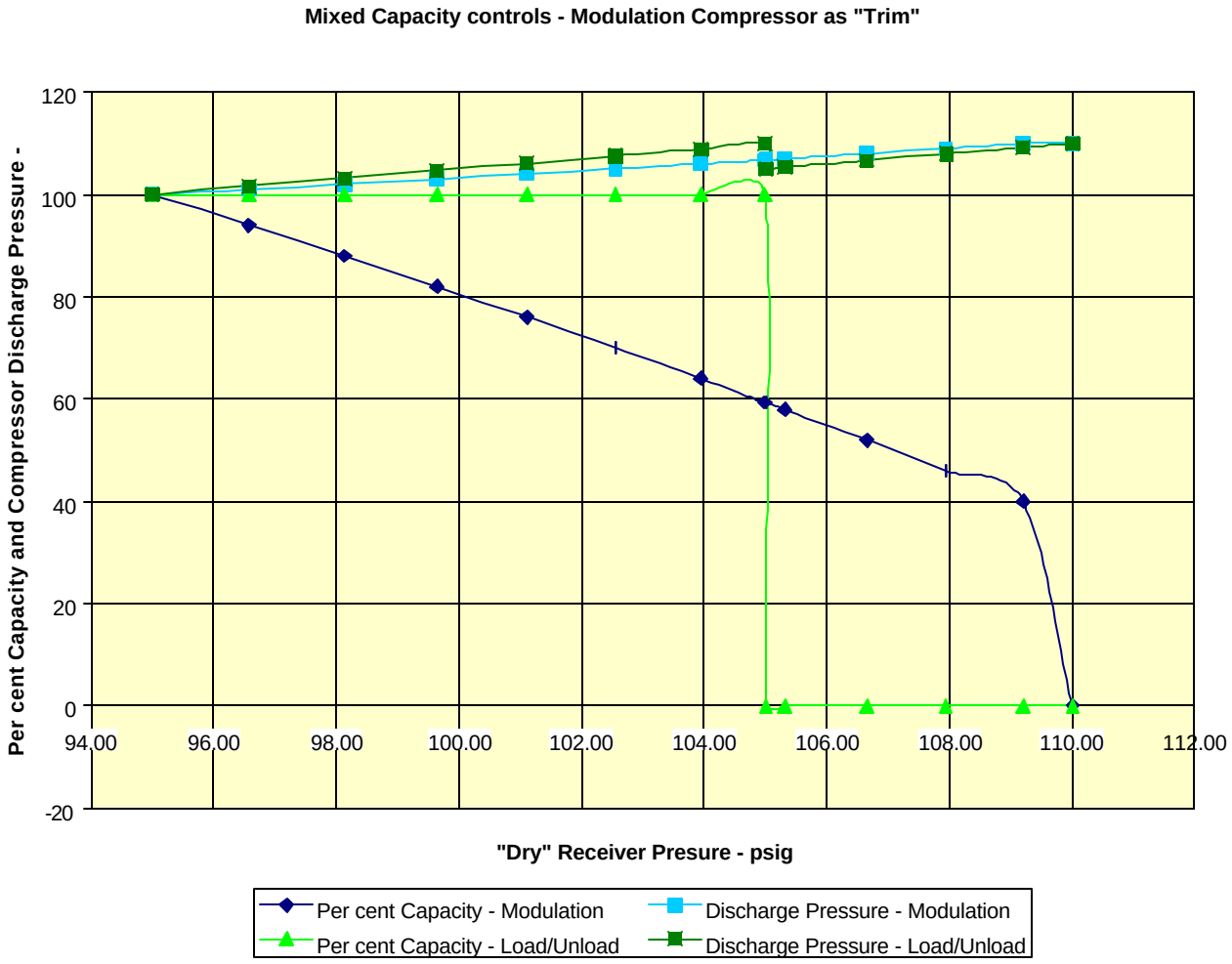


**Figure 2**

Compressor # 1 unloads when Compressor # 2 has modulated to just under 60% of its capacity and is not truly serving as the base load compressor. Total compressor output has dropped from 80% [(100 + 60)/2] to just under 30% [(0 + 60)/2]%. Receiver pressure will fall and Compressor # 2 will attempt to meet demand but, in all probability, Compressor # 1 will soon re-load unless demand has fallen significantly, such as at a shift change or at the end of the normal work day; or if there is sufficiently large receiver capacity.

Some points to note:

- Compressor # 1 unloads sooner than expected. Consider adjusting the control pressure range of each compressor.
- The useful modulation range of Compressor # 2 is only from 100% to 60%, since the Load/Unload Compressor unloads just below this value (see above), probably requiring the Modulating Compressor to cease modulating. Consider adjusting the control pressure range of each compressor.

- If a Modulating Compressor is changed to Load/Unload, be sure that full capacity operation at the upper control band pressure does not exceed the compressor or motor rating.

With a compressor modulation pressure range of 100 – 110 psig, the air receiver pressure range becomes 95 – 110 psig, or 15 psi. This also means that the pressure of the air being delivered to the plant system, from the receiver, is varying by as much as 15 psi. Discuss a reduced control pressure range with your supplier and the resultant need for increased receiver storage capacity.

**Scenario #2**

What would happen if both compressors fed into a common manifold or "wet" (control) receiver and there was only one larger capacity dryer and filter to handle the total flow as shown in Figure 3? (or the filters and dryers from Scenario # 1 were operating in parallel, sharing the total flow):

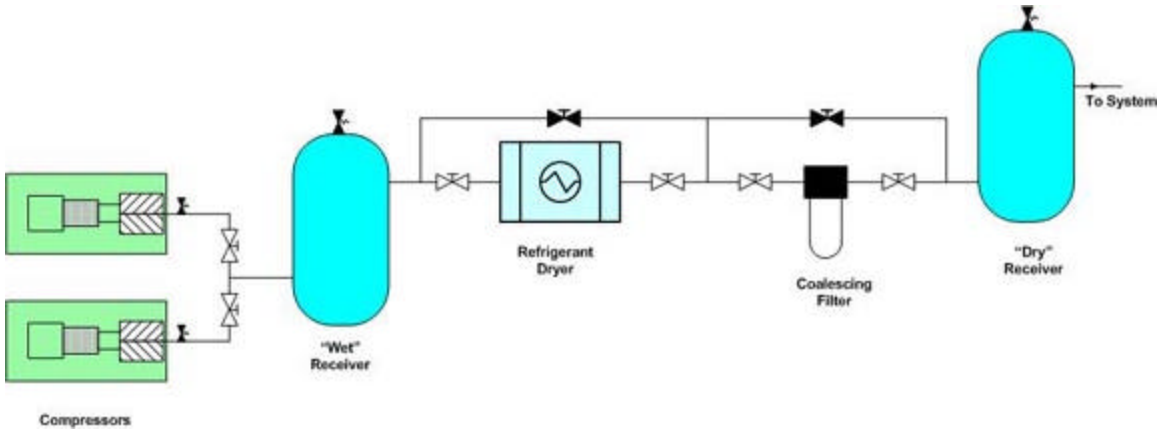


**Figure 3**

The same discharge pressure now must apply to both compressors, regardless of type of capacity control and the pressure drop across the dryer and filter are the same for both. For example, if the Load/Unload compressor is at 100% capacity and the Modulating compressor is at 50% capacity, the flow through the dryer will be 75% of the total capability [(100% + 50%)/2] and the pressure drop will be 0.75 * 0.75 * 5 = 2.81 psi.

Both compressors can operate in the same control pressure band, as shown in Figure 4.

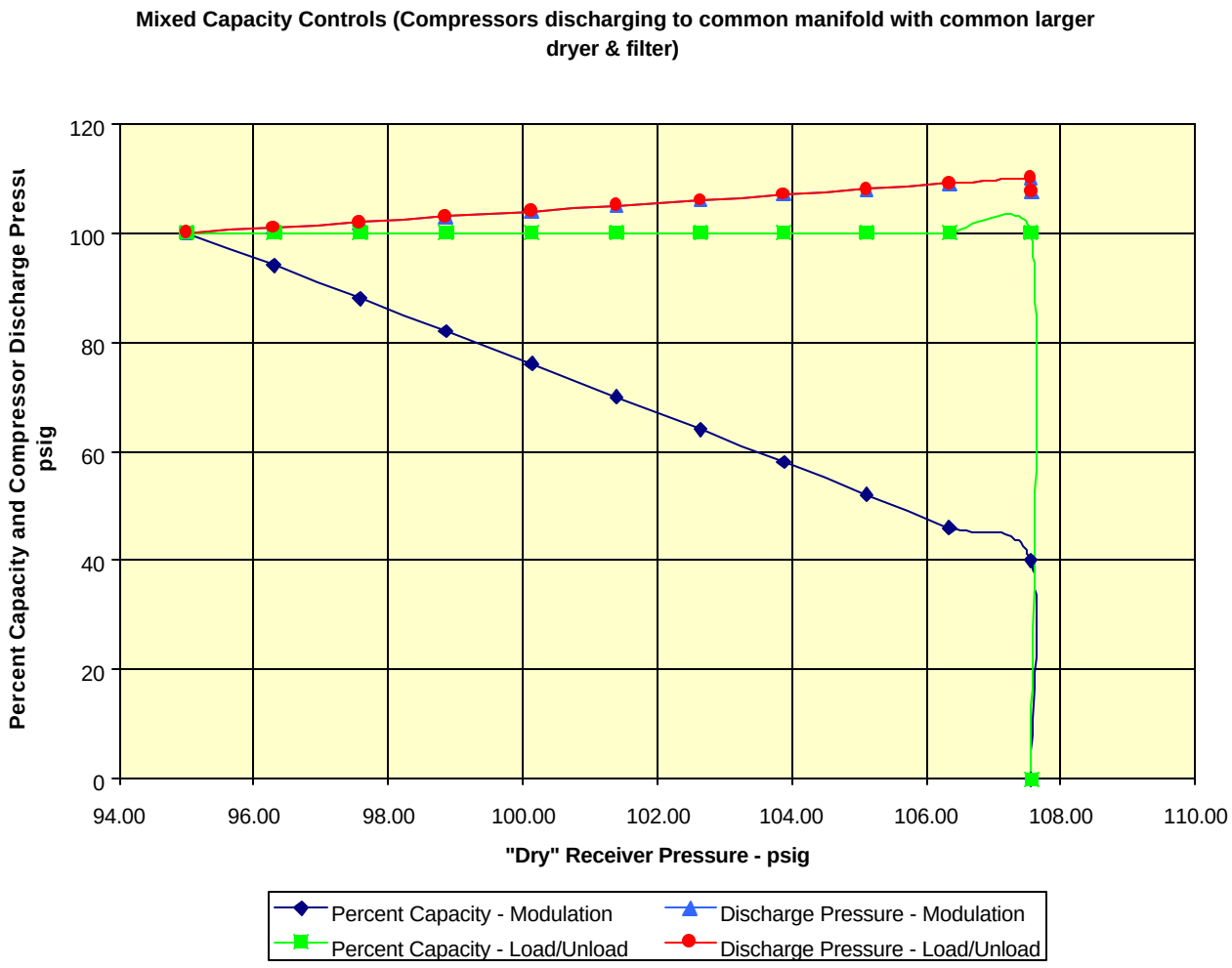


**Figure 4**

Some points to note:

- The Modulating compressor is the "trim" compressor over its full range. When each compressor unloads, its discharge pressure falls from 110 psig to the pressure of the "dry" receiver, since there is no flow through the dryer and filter.
- Multiple dryers can be set up to operate in parallel to share the total capacity, but arrangements must be made to ensure the proper rate of flow through each dryer and that no dryer is overloaded.
- Two compressors, each having 50% capacity, will not provide standby capacity for service needs. A third compressor is needed as standby.
- When considering needed compressed air capacity, three compressors each having 33.3% capacity may allow better control flexibility and energy savings, but without standby capacity. A fourth compressor then would be necessary for standby capacity.

- Dryers and filters also should have stand-by capacity with isolating valves to provide flexibility and serviceability.

**Scenario #3**

One of the main objectives in any control strategy, is to have as few compressors as possible in operation. To accomplish this, Scenario # 2 above can be modified to make the Load/Unload compressor as the "trim" compressor. This requires the pressure band for the Load/Unload compressor to be set lower than the Modulating Compressor.

For this example, we have chosen a Load/Unload compressor discharge pressure control band of 95 – 100 psig, while the Modulation compressor remains at 100 – 110 psig. The result is shown in Figure 5.

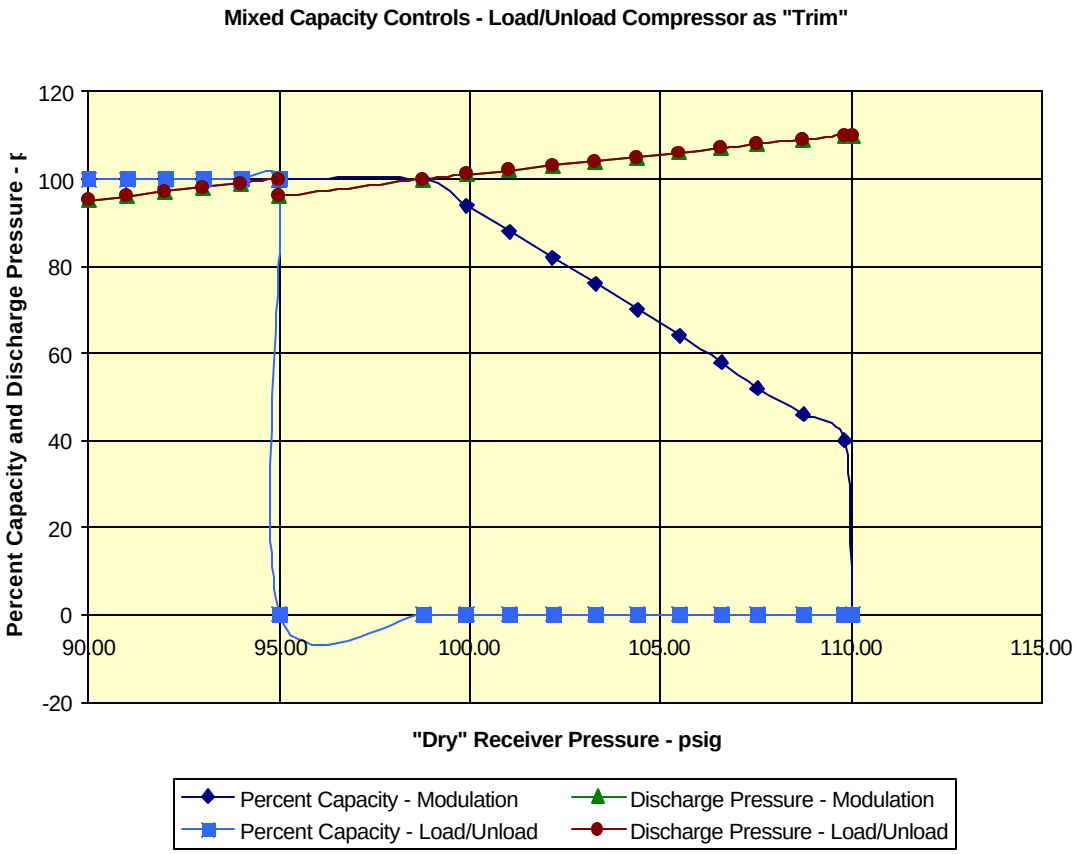


**Figure 5**

Points to note:

- At common compressor discharge pressures from 95 – 100 psig, both compressors are fully loaded and the dry air receiver pressure ranges from 90 – 95 psig.
- As soon as the compressor discharge pressure exceeds 100 psig, the Load/Unload compressor unloads and the volume passing through the dryer and filter is halved. The pressure drop goes from 5 psi to 1.25 psi. The discharge pressure will fall to 1.25 psi above the dry receiver, which is at approximately 95 psig.
- The discharge pressure of the load/unload compressor remains above its re-load set point of 95 psig unless the demand increases and the receiver pressure falls.
- The receiver capacity should be sufficient to extend time between pressure changes and to allow fully unloaded operation for sufficient time to optimize energy savings.
- With an over-run timer, the Load/Unload compressor can be stopped after a pre-set time, saving further energy.
- The Modulating compressor will not modulate until its discharge pressure rises to 100 psig as demand decreases. It will unload at a compressor discharge pressure of 110 psig and a dry receiver pressure of 109.8 psig.

Each system must be analyzed fully to determine the best grouping of components, the amount of storage required and the best control strategy to minimize energy costs.