

# Design for Lower hp in Air Systems

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*Proper system balance, including storage and pressure differential, keeps hp needs down.*

As long as compressed air systems have existed, there has been a perception that all problems and solutions lie in adequate supply horsepower. A lesser school of thought sees the system as having grown over a period of time and that an inadequate piping system is the reason why the system's pressure cannot be maintained. Neither way of thinking is usually correct. The intent of this article is to explain how the air system really works.

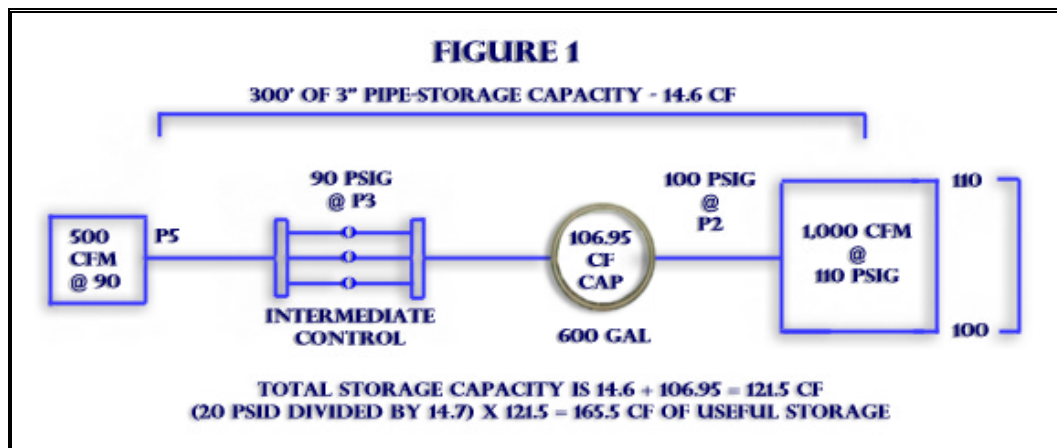
## Basic Operation:

Turning on a compressor in the system without a demand will elevate the pressure in the system to the unloaded pressure set on the compressor. With demand added, stored air in the system will be drawn off until the pressure drops to a preset load pressure in the throttling band of the machine, after which the unit reloads. This assumes that the unit on-line is in the "load/no load" operating mode.

If the compressor is capable of modulating, it will throttle inversely proportionately to the signal pressure in an effort to maintain a preset system pressure. This assumes that the compressor is larger than demand. This method will work, but it requires that the compressor always have excess capacity and be part loaded. Because motor efficiency decreases considerably under part load conditions, this can be a very expensive way to operate. Nevertheless, it is in general use, and I believe this is one of the reasons why most systems have compressors that are larger than they need to be. The amount of time that it takes from "add supply" to "response" to a "stable condition" is a function of the size of the unit on-line, the permissive time on the compressor controls, and the amount of storage capacity in the system.

## Examples:

In the following illustration demonstrating this, Figure 1, a number of items have been omitted regarding time, pressure and volume relationships to simplify the example. We will assume that the system is balanced and that 100% of the demand including leaks to controlled in terms of pressure and temperatures.

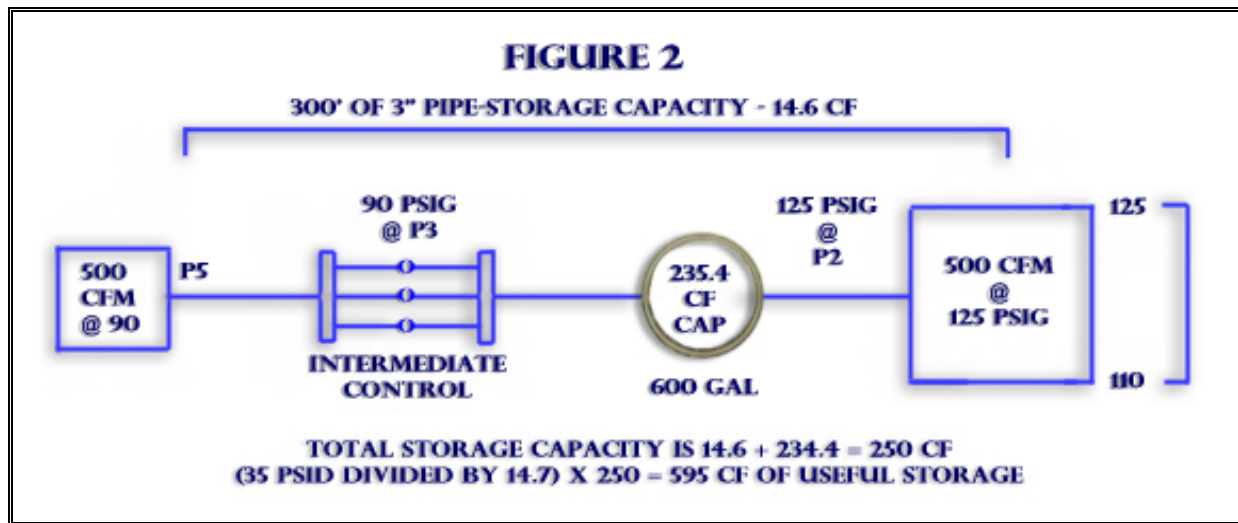


Unfortunately, many systems are supply controlled and therefore unbalanced. The demand volume in the supply controlled system would fluctuate with the supply pressure and keep the compressor loaded despite the real requirement.

In Figure 1, if we assume that the demand is loaded with system's storage at 110 psig, it will be necessary to deplete storage until the pressure in storage upstream of "P3" reaches the load pressure of 100 psig. Table 1 lists the events in terms of demand, storage condition, system pressure and time.

Event item 4 (see Table) required the 1,000 cfm compressor at 110 psig to run for 37.4 seconds to replace the equivalent of 500 cubic feet (cf) at 90 psig or 411.3 cf at 110 psig plus the 124.45 cf at 110 psig that was depleted from storage. The system's cycle time is 14.9 seconds unloaded (9.9 + 5.0) plus 37.4 sec loaded for a total of 52.3 sec.

Let's examine the same event in a system where there is 250 cf of capacity for storage (Figure 2). The demand will be the same, but we will use a 500 cfm compressor rated at full flow at 125 psig. The throttling band for the compressor will be set for 125 psig unloaded and 110 psig load. The formula for useful storage is the capacity times the control pressure differential (psid) divided by the barometric pressure. In this case we have 250 cf of capacity times 35 psid divided by 14.7 psia or 595 cf of useful storage (250 x 2.38 = 595).



<u>EVENT</u>	<u>STORAGE VOLUME</u>	<u>SYSTEM'S PSIG</u>	<u>TIME</u>
1. System stable, no demand	595 cf	125	0 sec
2. Add 500 cfm demand @ 90	340 cf	110	41.6 sec

Total upper storage is at 35 psid. If you divide useful storage by 35, there is 17 cf per psid. You must decay storage 17 cf x 15 = 255 cf @ 125 psig to reduce the storage pressure from 125 to 110.

Remember that you are taking this out at demand, so you convert the 255 at 125 to the equivalent flow @ 90 psig or 347 cfm in order to determine the time for the event. (347 / 500 x 60 = 41.6 sec.)

*(Continued from above)*

<u><b>EVENT</b></u>	<u><b>STORAGE VOLUME</b></u>	<u><b>SYSTEM'S PSIG</b></u>	<u><b>TIME</b></u>
3. Load 500 cfm compressor @ 125 psig 5 sec to full load	305.8 cf	108	5.0 sec

Most compressors have some permissives from signal to full displacement. Depending on the internal and external permissives the time can range from 5 seconds to 30 seconds. If the event is larger than one compressor, then you must plan storage to show down the decay to signal time in order to load the second unit. In this case the five second permissive means that demand, at a rate of 500 cfm, corrected to 110 psig or 411.3 cfm must be multiplied times 5 sec divided by 60 sec or 34.2 cf, in order to get the volume of decay in storage. Since each psid = 17 cf in storage, the storage system has decayed to 108 psig before the compressor that was signaled at 100 psig is fully loaded and recovery has commenced.

4. Compressor is fully loaded Supplying 500 cfm @ 90 demand Plus 296.7 cf depleted from Storage. 500 @ 90 = 367.4 @ 125.	595 cf	125	130.8 sec
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In order to determine the dynamics of the response by the compressor you must find the flow equivalent of 500 cfm @ 90 psig is 367.4 cfm @ 125 psig using pressure ratios (both temperatures are the same). The 500 cfm compressor at 125 psig has an excess capacity of 132.6 cfm @ 125. The storage replacement was 289.2 cf @ 125 psig. The time required to supply the added 500 cfm @ 90 psig plus reach 125 psig by replenishing decay is 289.2 divided by 132.6 or 130.8 seconds.

5. Compressor unloads, cycle repeats	Total cycle time 177.4 sec		
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When the storage pressure reaches 125 psig or the unload setting for the compressor, you will begin to unload the compressor and the cycle begins again. The total unload time was 41.6 seconds to the load pressure + 5 seconds for the permissive on the compressor or 46.6 seconds. The total load time was 130.8 seconds. The total cycle time was 177.4 seconds.

**Table 1**

<u><b>EVENT</b></u>	<u><b>Storage Volume</b></u>	<u><b>SYSTEM'S PSIG</b></u>	<u><b>TIME</b></u>
1. System stable, no demand	165.5 cf	110 psig	0 sec
2. Add 500 cfm of demand at 90 psig	82.75 cf	100 psig	9.9 sec
3. Begin to load compressor which Takes 5 sec to fully load.	41.05 cf	94.95 psig	5.0 sec
4 Compressor fully loaded supply 500 cfm at 90 psig plus 124.45 cf to 110 psig	165.5 cf	110 psig	37.4 sec
5 Compressor unloads and the event repeats.		Total event time	52.3 sec

By using significantly increased storage, 100 % demand control and a wider throttling band for the compressor, we were able to satisfy the same load with half the horsepower and never approach the “P5” control pressure. What was very different was the way that we chose to use time and storage and their effect on energy. It should also be pointed out that the longer cycle time on the smaller compressor will significantly reduce the maintenance potential, as opposed to the shorter cycle time for the larger compressor for the same demand.

You do not have to size storage for the initiation of production, but you will have to put on more than the base load to start in order to recover from the initial depletion of storage. Once the system is recovered, you only need to size storage and compressors (and their throttling band) for the largest single event that could hit the system over any base load at any given time. Remember that an air system is a time machine measured in parts of a minute. You cannot forget the element of time if you wish the system to work properly.

*R. Scot Foss is president of Plant Air Technology, Charlotte, N.C., a company specializing in system auditing and designing. This series of articles is based on his book, “Compressed Air System Solution Series”. A portion of the proceeds from sales of the book is donated to children’s charities. The book can be ordered through Southern Corporation.*