No. 117I

Using the Volume curve for Calculating Air Consumption in Actuation

General Discussion

The volume curve shown on the individual data sheets for air spring products is important in determining some of the dynamic operating characteristics of the part. The data is obtained by measuring the amount of liquid, not air, in the air spring at incremental heights. The test is run with the liquid under pressure (typically 100 or 80 psig as indicated on the data page). So:

1. This curve is a measure of the actual space inside the air spring, not a direct measure of a compressed air volume of air consumption.
2. The only pertinence to the notation “Volume 100 psig” is that the air spring can be assumed fully expanded radially, so this is the maximum that this space inside the air spring will become for a given height in normal operation. Again, this does not indicate that the volume given is the consumed volume of air to get the internal space to 100 psig pressure. Understandably, the diameter will decrease slightly for pressures well below 100 psig, but for pressures from 40 to 100 psig, the air spring can be considered fully expanded, with the internal space closely approximated by the curve.

Important Equations

$$FreeAir_{(in^3)} = \frac{(pressure_{(psig)} + 14.7)}{14.7} \times (Volume_{(chart)})$$

$$AirConsumption_{(in^3)} = FreeAir_{(final\ position)} - FreeAir_{(start\ position)}$$

$$VolumeFlowrate_{(CFM)} = 0.03472 \times \frac{AirConsumption_{(in^3)}}{Time_{(sec)}}$$

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Actuation

In general, estimations of air consumption, flow rates, and supply requirements are the types of actuation related questions that require the volume curve. In each case, it is important to calculate the “Free Air”. This “Free Air” is the actual amount of air (at atmospheric pressure) packed into a given space to get to a given pressure. For example, using the style 22 air spring shown here, if we want to find how much free air is packed into the airspring at an 8 inch height to get the air spring to 65 psig:

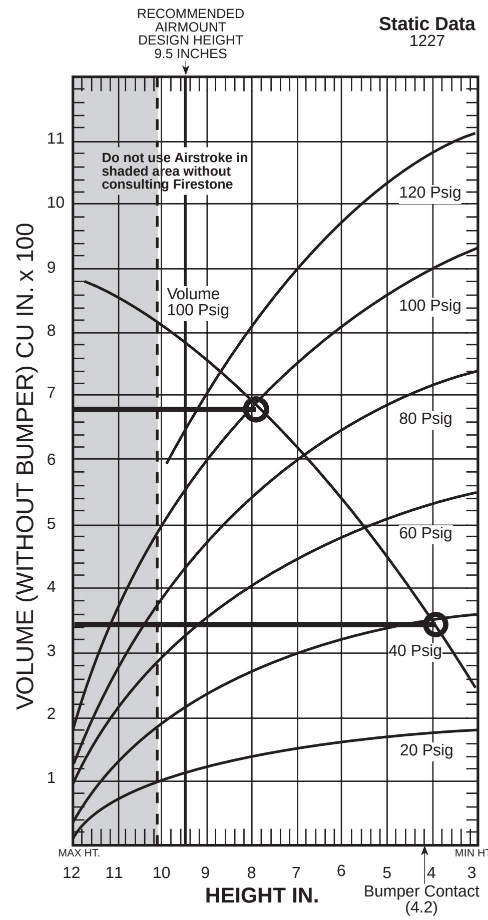
$$FreeAir_{(in^3)} = \frac{(pressure_{(psig)} + 14.7) \times (Volume_{(chart)})}{14.7}$$

From the chart, the volume curve (the actual space inside the air spring to be filled with air) is 685 cubic inches. So, the equation becomes:

$$FreeAir_{(in^3)} = \frac{(65_{(psig)} + 14.7) \times (685)}{14.7}$$

Or, FreeAir = 3,714 cubic inches of air packed into that 685 cubic inch space to get the internal pressure up to 65 psig.

To find out how air must be moved into an air spring during an actuation application, you must do the same type of calculation for the beginning position as well. For example, if you were to use a style 22 going from a 4 inch collapsed height at 10 psig, then extending the part to an 8 inch height by increasing the pressure to 65 psig, the actual amount of free air that you must add to the air spring is the difference between the free air in the air spring at the extended height (8 inch, 65 psig) and the free air in the air spring at the starting position (4 inch, 10 psig):



Force Table (Use for Airstroke® actuator design)						
Assembly Height (in)	Volume @100 PSIG (in³)	Pounds Force				
		@20 PSIG	@40 PSIG	@60 PSIG	@80 PSIG	@100 PSIG
10.0	809	950	1,810	2,830	3,810	4,840
9.0	752	1,170	2,260	3,460	4,670	5,880
8.0	685	1,310	2,590	3,940	5,350	6,700
7.0	610	1,430	2,900	4,390	5,950	7,450
6.0	529	1,540	3,170	4,780	6,470	8,110
5.0	442	1,640	3,380	5,100	6,880	8,630
4.0	349	1,730	3,520	5,340	7,180	9,020

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$$AirConsumption_{(in^3)} = FreeAir_{(final\ position)} - FreeAir_{(start\ position)}$$

Free air at 8 inches, 65 psig = 3,714 cubic inches free air (see earlier calculation).
Free air at 4 inches, 10 psig:

$$FreeAir = \frac{(10psig + 14.7)}{14.7} \times (349)$$

(Note that just like the earlier calculation, the 349 is the actual space inside the air spring taken from the volume curve on the static data chart).

So, the free air inside the air spring at 4 inch and 10 psig is 586 cubic inches. The total air consumption (amount of air that must be moved into the air spring) is then:

3,714 - 586 = 3,128 cubic inches of air.

Note that the only time the free air (or actual volume of air inside the air spring) is equal to the curve shown on the static data chart (actual space inside the air spring) is when the air spring is completely exhausted to atmospheric pressure. For instance, in the earlier example, if the air spring were starting at 4 inch height and completely exhausted (0 psig), the calculation becomes:

$$FreeAir = \frac{(0psig + 14.7)}{14.7} \times (349)$$

Or, FreeAir = 349 cubic inches. In this case the consumption starting at the 4 inch height and 0 psig, going up to 8 inches at 65 psig, would be:

3,714 - 349 = 3,365 cubic inches of free air.

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This information can be used to aid in sizing other air system components. For example, if we use the last instance (going from a 4 inch height at 0 psig to an 8 inch height at 65 psig):

Air Consumption = 3,365 cubic inches of free air

Desired inflation time: 5 seconds

$$VolumeFlowrate_{(in^3/sec)} = \frac{AirConsumption}{Time}$$

$$VolumeFlowrate_{(in^3/sec)} = \frac{3{,}365}{5}$$

Or, Volume Flowrate = 673 cubic inches per second

More commonly,

$$VolumeFlowrate_{(CFM)} = \frac{AirConsumption}{Time_{(sec)}} \times \frac{60_{sec}}{1_{min}} \times \frac{1_{cubic\ foot}}{1728_{cubic\ inches}}$$

Or,

$$\boxed{VolumeFlowrate_{(CFM)} = 0.03472 \times \frac{AirConsumption_{(in^3)}}{Time_{(sec)}}}$$

$$VolumeFlowrate_{(CFM)} = 0.03472 \times \frac{3{,}365}{5}$$

Or, 23.36 cubic feet per minute (CFM) flowrate.