Amount of drawdown capacity

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The amount of drawdown capacity is determined by a formula known as Boyle's Law, and February's “Tech Topics” covers this formula and how to apply it to real-life conditions.

Figure 1 - Small captive-air pressure tank.

Last month, we said that the term drawdown refers to the amount of useable water that can be drawn from a hydro-pneumatic tank from the time the pressure switch cuts out, turning the pump off, until the pressure switch cuts back in, turning on the pump. The amount of drawdown capacity is determined by a formula known as Boyle's Law. Simply put, Boyle's Law states that as the volume of the air cushion in a tank decreases, the pressure of that air cushion increases.

Conversely, as the volume of the air cushion increases, the pressure of that air decreases. Therefore, for any given tank, drawdown equals the volume of air at cut-in minus the volume of air at cut-out. Stated as a mathematical formula taking the total volume of a pressure tank into consideration, it looks like this:

Drawdown = P1V / P2 - P1V / P3 where
P1 is the pre-charge pressure.
P2 is the cut-in pressure.
P3 is the cut-out pressure.
V is the total tank volume.

Remember that all pressures must be stated in terms of absolute pressure. At sea level, add 14.7 psi to the gauge pressure to get absolute pressure. To make the calculations easier, Boyle's Law can be restated as:

Drawdown = (P1 / P2 - P1 / P3) x V

Let's try a couple of examples.

Example 1
Consider the following tank conditions, if you will:
A 30/50 pressure switch.
P1 the pre-charge pressure is 28 psi.
P2 the cut-in pressure is 30 psi.
P3 the cut-out pressure is 50 psi.
V the total tank volume is 85 gallons.
Altitude is sea level.

The drawdown formula then looks like this:

Drawdown = (28 + 14.7) divided by (30 + 14.7) minus (28 + 14.7) divided by (50 + 14.7) times 85. Or, (42.7 / 44.7) - (42.7 / 64.7) x 85

Therefore, drawdown = 0.295 x 85 = 25.1 gallons.

Example 2
Using the same tank conditions, put the job up at Lake Tahoe in California at 6,000 feet above sea level.

This time, drawdown = (28 + 11.8) / (30 + 11.8) - (28 + 11.8) / (50 + 11.8) x 85
Now, drawdown = 0.307 x 85 = 26.1 gallons.

Example 3
Use a 30/50 pressure switch, but no pre-charge as could be the case with a conventional tank with no pre-charge.

Drawdown = (0 + 14.7) / (30 + 14.7) - (0 + 14.7) / (50 + 14.7) x 85
Drawdown = 0.102 x 85 = 8.7 gallons, about 10 percent of the total tank capacity. As we will point out later, it is possible, though not always standard practice, to pre-charge conventional tanks.

Example 4
Instead of a 30/50 pressure switch, use a 40/60 pressure switch with a 38 psi pre-charge and the numbers look like this.

Drawdown = (38 + 14.7) / (40 + 14.7) - (38 + 14.7) / (60 + 14.7) x 85.
Therefore, drawdown = 25.8 x 85 = 21.9 gallons.

Example 5
This shows how the drawdown changes if we widened the differential between the cut-in and cut-out pressures from 30/50 to 30/60.

Drawdown = (28 + 14.7) / (30 + 14.7) - (28 + 14.7) / (60 + 14.7) x 85
Drawdown = 38.4 x 85 = 32.6 gallons.

Compare this with the 25.1 gallons from Example 1. A word of caution: Before expanding the cut-in/cut-out differential beyond 20 psi, check with your tank manufacturer to make sure that by doing so, you will not be over-expanding the water chamber.

Another term used in determining drawdown is “acceptance factor.” This simply is the factor by which you multiply the total tank volume to get drawdown. In other words, drawdown = acceptance factor x total tank volume.

If you would rather work with acceptance factors, take the “V” out of the Boyle's Law formula: acceptance factor = P1/ P2 - P1/ P3.

Taking it one step further, if you consider the pre-charge to be the same as the pump cut-in pressure, P1/P2 becomes 1 and the formula then is: acceptance factor = 1 - P1/ P3.

However, as pointed out in earlier articles, the pre-charge must be set a minimum of 2 psi below the pump cut-in pressure to avoid the possibility of having the system pressure drop abruptly to zero before the pump turns on. It is imperative in a captive-air tank to have the pre-charge set at least 2 psi below the pump cut-in pressure. I strongly recommend using the proper version of Boyle's Law, which includes a separate factor for pre-charge in order to accurately represent the drawdown of your system. And always remember to work in terms of absolute pressure in your Boyle's law calculations by adding atmospheric pressure (14.7 at sea level) to the gauge pressure.

Figure 2 - Large conventional pressure tank.

Conventional Tanks: Controlling Drawdown
For a conventional tank to have the same drawdown ratio as a captive-air tank, it is necessary to pre-charge the

conventional tank and to maintain the same air/water ratio that you would have in a captive-air tank (see Figure 1). Logic states that if you have the same amount of air available to push the water out, you will be able to deliver the same amount of water between pump cycles, regardless of whether or not the tank has a diaphragm separating the air from the water. In a captive-air tank, the diaphragm assembly virtually is out of water when the pump turns on. To get the same performance from a conventional tank, the water level can be set such that the pump turns on just before the water level drops to the level of the inlet fitting.

In large conventional tanks (see Figure 2), the easiest method of optimizing the drawdown is to use a small air compressor in conjunction with a water-level probe. The advantage of this set-up is that the probe level can be set anywhere in the tank, from the top to the bottom to optimize the drawdown. Used with a 30/50 pressure switch, the probe should be set at one-third the distance from the water outlet to the top of the tank. For low-pressure switch settings like 20/40, the probe will be set a little higher, and for high-pressure switch settings like 40/60, the probe will be a little lower.

There are two such compressor units commercially available on the market today, The Charge-air 2000 from Maass Midwest (800-323-6259) and the Air Rite by Whitewater Manufacturing (800-966-3110).

Compressor/probe air charging systems typically are used on larger conventional tanks for economic reasons, but often you will see them on smaller tanks where optimizing the drawdown is necessary due to space limitations. Next month, we will talk about other air-charging techniques commonly used with smaller conventional tanks. 'Til then …