Application Design Guide

Control Type: Hydro-Pneumatic Tank Controller (HTC)
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PART 1 General

1.01 Hydro-pneumatic tanks are generally used for water supply systems with relatively small demands, especially in cases where the demands are very low during some parts of the day.

1.02 A hydro-pneumatic tank is a vessel in which water is maintained within a desired pressure range above atmospheric. The tank is partially filled with water and the remainder of the volume is compressed air. The installation also includes one or more pumps and usually one or more air compressors.

1.03 Consider the water level and the air pressure in the tank at their desired maximum values and the pump(s) and air compressor(s) quiescent: as water is withdrawn to supply the demand, the air expands which causes its pressure to be reduced. After withdrawal of a predetermined quantity of water, the pump(s) are started (based on tank pressure) and caused to deliver to the tank the same amount of water which had been removed.

1.04 The air in the tank will be compressed as the water volume is increased; when the pump(s) are stopped the air pressure will be close to or at its desired maximum value.

1.05 When the pumps stop, system pressure is monitored and air is either added or removed to optimize the system pressure. For instance, systems that utilize vertical turbine well pumps will typically add a column of air to the system every time they start necessitating removal of air when the tank is finished filling. Systems that utilize closed loop booster pumps to fill the tank may need to have air added when the tank is finished filling to replace air which is absorbed by the water.

PART 2 Typical Operation

2.01 The first pump is started when the air pressure in the tank falls to a preselected value (P_1).

2.02 If the installation includes two pumps, the second pump is started when the air pressure falls to a preselected value (P_2), lower than (P_1).

2.03 At P_3 (less than P_2) the third pump, if provided, would be started…

2.04 All pumps stop when the water level in the tank reaches a preselected elevation.

2.05 When the level sensor stops the pumps, the pressure in the tank is monitored. If the pressure in the tank is below the preselected maximum pressure (P_h), air is added to the tank by a compressor or solenoid valve until the desired pressure is reached. After initial startup the volume of air required to raise the tank pressure is maintained.

2.06 When the source of water is from a vertical pump, which will discharge a volume of air before delivering water on each operation, the air compressor may be omitted. In this case, a solenoid valve should be provided to release air when the water level is at its maximum and when the air pressure is above its desired maximum. In rare cases, the volume of air discharged by the pump will be less than the amount of air absorbed by the water. In these instances installation of both an air compressor and a solenoid valve, with controls to permit either to operate depending upon the conditions, are recommended.

PART 3 Design Data

3.01 Operating Pressures

A. Determine minimum (P_1) and maximum pressures (P_h) at which the tank will be operated.

B. The minimum tank operating pressure (P_n) is that at which the last pump is started. (Slightly higher than the pressure, P_m, this would provide water at the minimum acceptable residual pressure to any point in the distribution system.)

C. The maximum tank pressure (P_h) is determined by the maximum tolerable pressure differential in the distribution system. (The maximum pressure occurs when the volume of water in the tank is maximum {V_h} and is that at which the air compressor is stopped for an add-air system, or that at which the vent solenoid valve is closed for a vent-air system.)

3.02 Precautions

A. The minimum tank operating pressure must be greater than the maximum suction pressure.

B. Provisions should be made to prevent entrance of air into the distribution system.

C. The pumps should not be permitted to operate when the water level in the tank is above a fixed "high level."

3.03 Pumps

A. The nominal pump capacity should be selected at tank pressure P_n with minimum dynamic suction pressure.

B. The pumps should be capable of operation at tank pressure P_n with maximum suction pressure without cavitation.

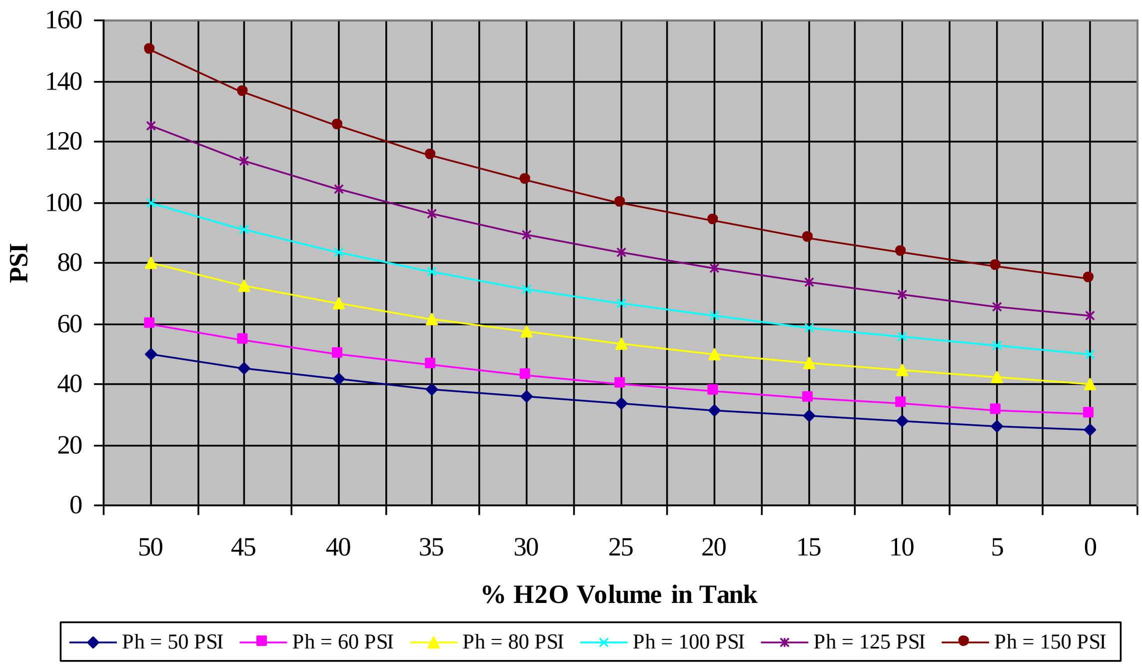
C. Pump curves should be steep enough to permit the pumps to discharge at a reasonable rate at the highest possible tank pressure (P_h for an add-air system).

3.04 Tank

A. Volume

1. From Figure 1 determine the volume of water (V_1), which could be withdrawn from a tank initially 50% full of water at P_h to result in a reduction of pressure to P_1. These calculations are based on the assumption that the vessel temperature remains constant.

Figure 1 PSI vs H20 Volume



2. P_h = High Pressure (Pressure when tank is 50% full of water by volume)
3. P_1 = Low pressure at which first pump is started
4. P_n = Minimum pressure required to serve system

5. For example, if P_h = 100 PSI and P_1 = 80 PSI it is determined from Figure 1 that V1 = 12.5% of the total tank volume. That is, if the tank were 50% full when the air pressure was 100 PSI, withdrawal of a quantity of water equal to 12.5% of the total tank volume (V_T) would reduce the air pressure to 80 PSI.

6. If the maximum volume of water in the tank will not be 50% of the tank volume when the pressure is P_h, the volume can be calculated by using Boyle' Law where

a. $\frac{\text{Initial Pressure}}{\text{Final Pressure}} = \frac{\text{Final Volume}}{\text{Initial Volume}}$

b. The above calculations were made based on the temperature being constant.

B. Determine the minimum tolerable time between successive starts of the pump motor. This will be determined by limitations of the motor, starter, or electrical distribution system. We recommend the minimum cycle time be sufficient to avoid damage to any motor or starter without consideration of the effect of automatic alternation.

C. In small and medium motor ratings, a minimum cycle time of 10 minutes (6 starts per hour) should be adequate. Verify the actual motor start/per hour ratings match or exceed your system requirements. Reduced voltage starters and/or power supply limitations may require longer cycle times.

D. The time between motor starts will occur when the demand is 50% of the capacity of the lead pump. At that demand, the "pump off" time is equal to 50% of the cycle time.

1. V_2, in gallons, should be not less than:
   a. V_2, in gal. = (½ Pump Capacity in gpm) (½ minimum cycle time)
   b. Then the total tank capacity, in gallons, is
      i. V_T in gal. = (100) $\frac{V_2\text{, in gal.}}{}$
      ii. V_2, in % V_T
      iii. Where V_2, in % V_T, is the value determined in (D1b) above.
      iv. V_T, in gal. = 25 (Pump Capacity) (Minimum cycle time)
      v. V_2, in % V_T

Continuing the example used in (a) and (b) above, the total tank volume, in gallons would be:

$$V_T = \frac{25}{8.8} \text{(Pump Capacity) (Minimum cycle time)}$$

If the pump capacity were 100 gpm and the minimum cycle time were 10 minutes, the total tank volume would be:

$$V_T = \frac{25}{5.5} (100)(10) = 4500 \text{ gallons}$$

2. Size

Determine diameter and length from Figure 3 for volume as determined above. (Capacities of elliptical or bulged ends are disregarded for simplicity).

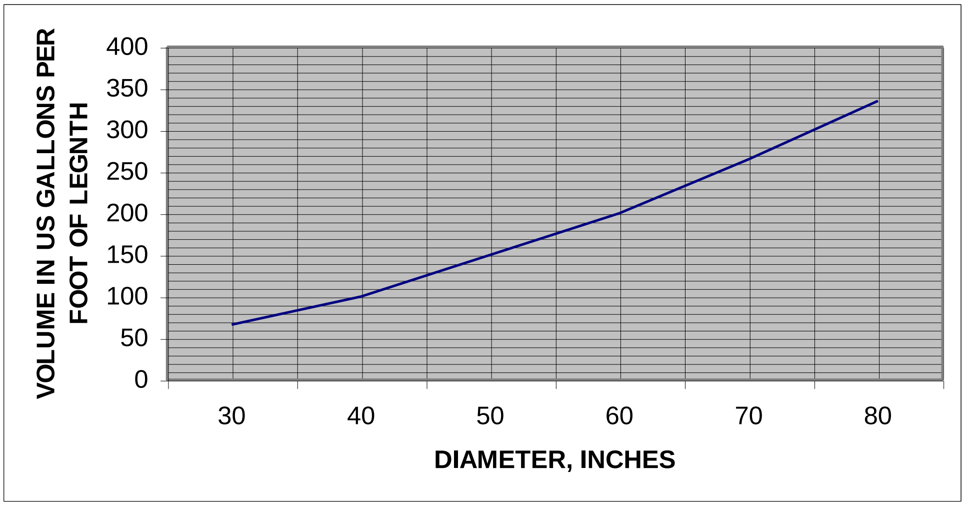


Figure 1

VOLUME OF CYLINDRICAL TANKS, PER FOOT OF LEGNTH

3. Operating Levels

If tank is horizontal, use Figure 4 to determine operating levels, i.e., level at which pump(s) are stopped and level at which the pressure in the tank falls to P_1.

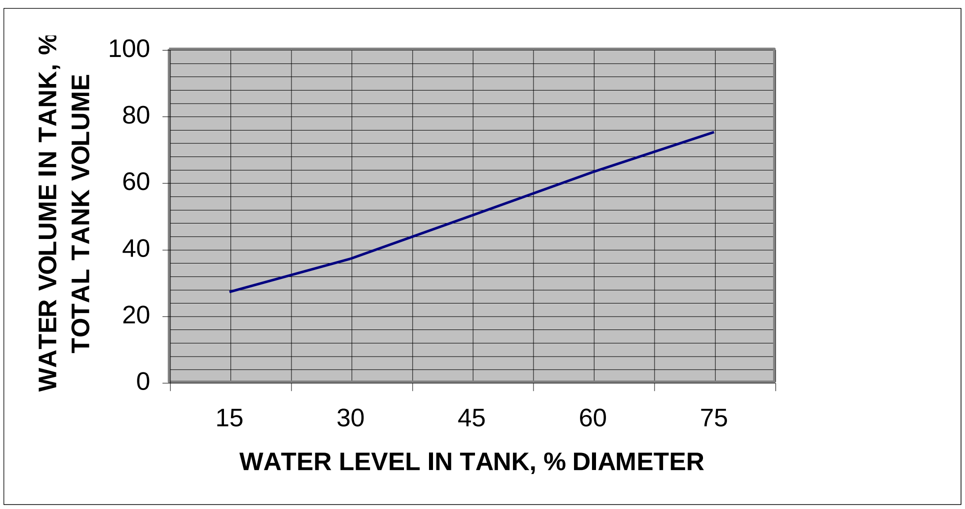


Figure 4

HORIZONTAL, CYLINDRICAL TANKS

4. Maximum useful storage (in event pumps are out of service)

   a. From Figures 1 and 2 determine the volume of water which can be withdrawn from the tank to cause the tank pressure to fall from P_h to P_1 (see A1a above).

   b. See B2 above.

E. AIR COMPRESSOR(S)

The air compressors should be capable of increasing the pressure in the tank from P_1 to P_h in not more than 30 minutes, when the water level in the tank is at its maximum level. (water volume = V_1)

The minimum recommended air compressor CFM = $\frac{(P_1 + 15)}{(P_h + 15)} \cdot \frac{(V_T - V_1)}{225}$

Where V_T and V_1 are in gallons.

Reference:

Water Data				
Q	=	*Flow, in GPM, CFS, etc.*		
H	=	*Head, Feet of Lift of Q*		
1 MGD	=	*1 million gallons per day*	=	*700 GPM*
1 ft³	=	*1 cubic foot*	=	*7.5 gal*
1 cfs	=	*1 cubic foot per second*	=	*450 GPM*
1 gallon H2O	=	*8.33 lbs*		
Pressure				
1 Atmosphere	=	*14.7 PSI*	=	*34 ft H2O*
			=	*29.92 in Hg*
1 PSI		*2.31 feet H2O*	=	*27.72 in H2O*
			=	*2.03 in Hg*
1 foot w.c.	=	*1 foot H2O*	=	*.432 PSI*
1 in w.c.	=	*1 in H2O*	=	*.036 PSI*
Power Data				
1 BTU	=	*1 British Thermal Unit*	=	*Heat Required to Raise Temperature of 1 lb. of water 1º F*
1 HP	=	*33,000 ft-lb/min.*		
	=	*42.5 BTU/min.*		
	=	*2545 BTU/hour*		
	=	*746 Watts*		
Pump HP	=	$\frac{\text{Water Hp}}{\text{Pump Eff}} = \frac{\text{Water Hp}}{\text{ep}}$		
	=	$\frac{(\text{GPM}) \times H}{3{,}960 \times \text{ep}}$		
	=	$\frac{(\text{MGD}) \times H}{5.07 \times \text{ep}}$		
	=	$\frac{(\text{CFS}) \times H}{8.8 \times \text{ep}}$		
Water HP	=	$\frac{\text{GPM (8.33) \#/Gal.} \times \text{feet lift}}{33{,}000 \text{ ft.\#/min.}}$		
	=	$\frac{(\text{GPM}) \times H}{3{,}960}$		
	=	$\frac{(\text{MGD} \times 700 \times 8.33) \times \text{feet lift}}{33{,}000}$		
	=	$\frac{(\text{MGD}) \times H}{5.07}$		
	=	$\frac{(\text{CFS} \times 450 \times 8.33) \times \text{feet lift}}{33{,}000}$		
	=	$\frac{(\text{CFS}) \times H}{8.8}$		