White Paper

# *The Possible Pitfalls of Wet Tank Compressed Air Storage*


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Most compressed air systems are specified in SCFM (Standard Cubic Feet per Minute) when they should be specified in a more realistic unit of measure SCFS (Standard Cubic feet per Second). This is because most systems can and will react in seconds not minutes and many system load changes can be overlooked in the averaged time based index of a minute.

When sizing a compressed air system, average requirements generally drive the system feed or compressor horsepower requirements. Storage can solve system issues like compressor band control, or short term flow requirements. Each compressed air system designer has their own method and or reason for specifying compressed air storage volume, and the location or locations of that storage. Compressed air system storage is generally specified as a multiple of the maximum compressor output in SCFM. The multiple generally ranges from 1 to 4 gallons per SCFM of system output with individual or specialized systems using multiples as high as 10 gallons per SCFM.

If the installed storage is wet or before the filtration and dehydration system, great care must be applied when specifying and implementing those items so the storage capacity will not overload or render the equipment ineffective.

To better explain the causes and results of a wet tank storage system in conjunction with a compressed air system experiencing surge conditions, I have specified a generic system to explain the source of the surge air supply and then discuss the effects on each of the critical components.

<u>Sample system specifications:</u>

- 700 HP of compressors creating
    - 2800 SCFM (Standard FT³ / Minute)
    - 46.66 SCFS (Standard FT³ / Second)
    - @ 115 PSIG Discharge
- 3000 Gallons of wet storage
    - = 401.04 FT³ of Storage Area
    - = 3537.17 Compressed FT³ @ 115 PSIG = ((115+14.7)/14.7)*401.04
- 3000 SCFM rated Coalescing Filter
- 3000 SCFM rated Regenerative Air Dryer
- 3000 SCFM rated Particulate Filter
- System Flow Controller

<u>Sample system operation and response</u>

A system load requirement triggers a reaction in the System Flow controller and it opens to fulfill the load requirement. The load is partially supplied by the wet storage tank and it drops 2 PSIG fulfilling the requirement. That 2 PSIG drop translates into the following discharged volume.

3537.17 Compressed FT³ @ 115 PSIG = ((115+14.7)/14.7)*401.04 (In the tank before the requirement)
3485.04 Compressed FT³ @ 113 PSIG = ((113+14.7)/14.7)*401.04 (in the tank after the requirement)

Converting discharged wet tank volume to a time based flow index and % Increase

The following calculations express the flow in SCFM based on various reaction times in the wet tank between 1 to 2 seconds.

| **Tank Volume @ 115 PSIG** | | **Tank Volume @ 113 PSIG** | | **Tank Volume Change** | **Rate of Change** | **Flow converted to SCFM** |
|---|---|---|---|---|---|---|
| 3537.17 $FT^3$ | - | 3485.04 $FT^3$ | = | 52.13 $FT^3$ | 2.0 seconds | 1563.9 SCFM |
| 3537.17 $FT^3$ | - | 3485.04 $FT^3$ | = | 52.13 $FT^3$ | 1.5 seconds | 2085.2 SCFM |
| 3537.17 $FT^3$ | - | 3485.04 $FT^3$ | = | 52.13 $FT^3$ | 1.0 seconds | 3127.8 SCFM |

The following table displays the % flow surge or inrush corrected to SCFM for ease of comparison. The table offers % flow increases when the compressor is operating at 70% and 100% capacity.
It would be common to assume that if the compressors are operating at a 70% load the remaining 30% would supply the increase in system load requirements. If the compressed air storage system is large enough it will supply the load requirement initially until the compressor can react to the new load requirements and replenishment of the storage system.

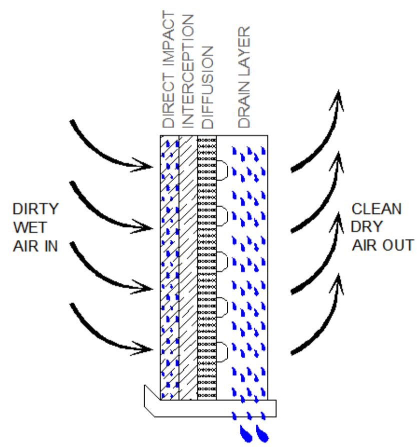
| **Compressor Output** | | | **Storage Supply** | | | **Total Supply** | **Increase** |
|---|---|---|---|---|---|---|---|
| 100% | 2800 SCFM | + | 2.0 Seconds | 1563.9 SCFM | = | 4363.9 SCFM | 156% |
| 100% | 2800 SCFM | + | 1.5 Seconds | 2085.2 SCFM | = | 4885.2 SCFM | 174% |
| 100% | 2800 SCFM | + | 1.0 Seconds | 3127.8 SCFM | = | 5927.8 SCFM | 212% |
| | | | | | | | |
| 70% | 1960 SCFM | + | 2.0 Seconds | 1563.9 SCFM | = | 3523.9 SCFM | 180% |
| 70% | 1960 SCFM | + | 1.5 Seconds | 2085.2 SCFM | = | 4045.2 SCFM | 206% |
| 70% | 1960 SCFM | + | 1.0 Seconds | 3127.8 SCFM | = | 5087.8 SCFM | 259% |

With any of the above examples the system filtration and dehydration equipment is briefly seeing flow rates 30% to 41% over the rated 3000 SCFM. This brief over flow condition is commonly overlooked as a minor blip in the average of equipment operation, however the brief load fluctuations can be just as detrimental as a continuous overload condition. The following sections will discuss the effects of the over flow conditions on each of the components.

COALESCING FILTRATION is a steady state process and depends on a relatively stable compressed air flows with appropriate capacity sizing for inlet conditions.

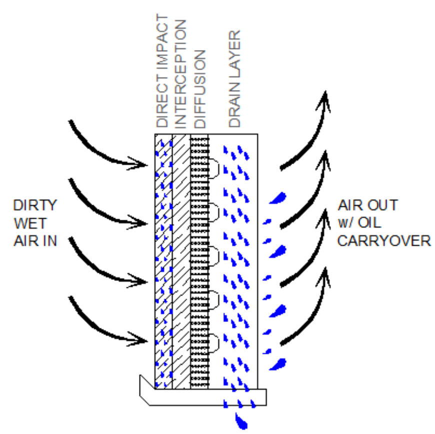
| ***Inlet Condition*** | ***PPM w/w **** | ***Flow Factor*** |
|---|---|---|
| Normal | 0 - 50 | Standard Flow Capacities |
| Severe | 50 - 200 | Standard Flow Capacities x 0.75 |
| Very Severe | Over 200 | Pre Coalesce and Standard Flow Capacities x 0.5 to 0.75 |
| Flooded | Over 2000 | Consult Factory |
| * Incoming air contaminates include oil water and aerosols plus solids | | |

When a Coalescing filter is presented with a steady state compressed air flow the dirty wet (Up to 50 PPM w/w) compressed air permeates the coalescing media and each of the three coalescing mechanisms (direct impact, interception, and diffusion) work in unison to coalesce the oil and water into droplets that are readily separated by gravity. As the coalesced droplets drain to the bottom of the element, they are collected in a quiet zone of the filter for removal via the drain system. Clean dry compressed air then exits the filter housing




STEADY STATE
COLESCING

When a Coalescing filter is presented with a compressed air flow that includes swings in velocity and/or extremely dirty or wet (over to 200 PPM w/w) supply air compressed element bypass is probable.
The wet dirty air permeates the coalescing media and each of the three coalescing mechanisms (direct impact, interception, and diffusion) work in unison to coalesce the oil and water into droplets that are readily separated by gravity. If rapid increases in compressed air velocity occur, the coalesced liquid migrating to the bottom of the drain layer via gravity will be forced off the drain layer and re entrained into the filter discharge stream. If the inlet contaminate level is to high the drain layer will become overloaded forcing moisture off the drain layer into the active zone of the element before it can reach the quiet zone which will cause re entrainment of the contaminates.




SURGE CONDITION
COLESCING

**DEHYDRATION EQUIPMENT**

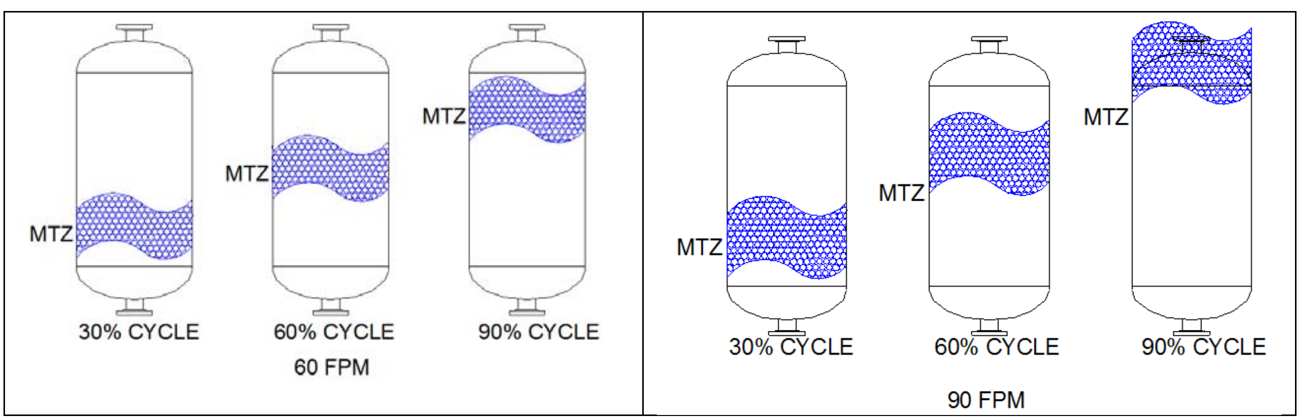
Both refrigerated and desiccant compressed air dryers are designed to operate in a specific and stable volume/velocity range. If volume or velocities increase rapidly the following events can occur.

***Refrigerated Air Dryers*** remove moisture by chilling compressed air, and separating condensed liquids created by the drop in temperature. The compressed air temperature drop is a function of a refrigeration system in conjunction with heat exchangers that actually remove the heat from the compressed air stream. Short term excessive flow may not substantially affect the refrigeration system, however the heat exchangers cannot effectively transfer heat at elevated flow or velocities. This will cause higher compressed air temperatures allowing uncondensed moisture vapor to travel downstream. The moisture separation device in the dryer will also be affected by elevated flow or velocities much like the coalescing filter discussed in the previous section. This inefficiency compounds moisture carry over due to lack of cooling by not efficiently separating what condensed liquids are present at whatever temperature the compressed air is suppressed to.

***Regenerative Air Dryers*** remove moisture by adsorbing moisture onto the surface of an adsorbent such as activated alumina. Adsorbent bed weights are designed primarily by total moisture load over a cycle of operation. Total moisture load is calculated as saturated gas at 100 PSIG and 100°F without liquid present. Liquid present at the inlet of a desiccant dryer will present substantial challenges to efficient operation at a specified dewpoint delivery. A relatively small amount of liquid at the dryer inlet translates to a great deal of moisture vapor which will quickly overload a standard bed design. If large liquid content is present at the dryer inlet it will travel further into the desiccant bed for adsorption. Alumina efficiently adsorbs moisture in the vapor phase.
Velocity changes will generally cause a coalescing filter to carry over liquid to the dryer inlet.

Intermittent elevated flow and velocity conditions will affect two interconnected critical design parameters, gas bed velocity and contact time.

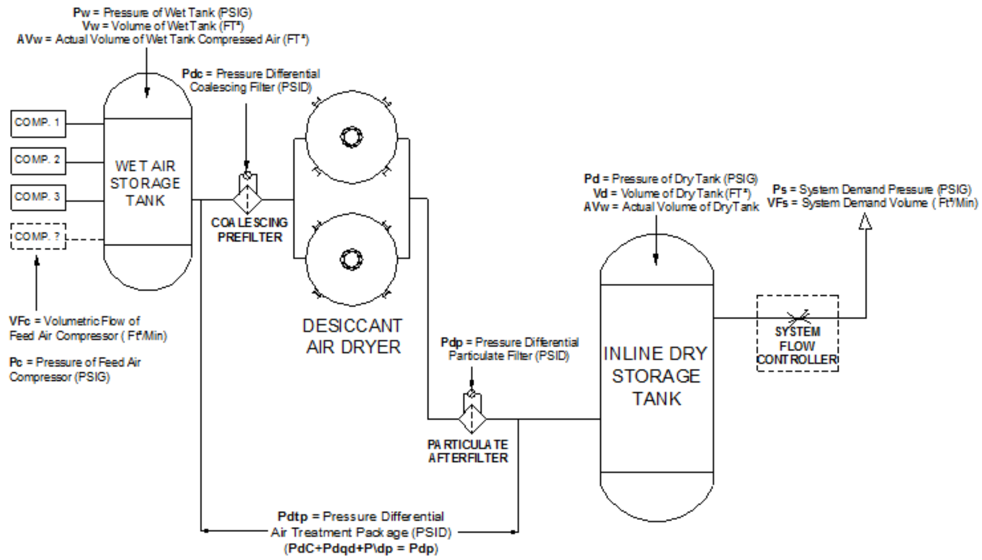
In a stable system with the bed velocities below 60 FPM and contact time in excess of 4.5 seconds the MTZ (mass transfer zone) moves steadily through the adsorbent bed reaching the end of the bed just prior to the end of the complete cycle.




If the velocities increase to 90 FPM the gas contact time reduces and the MTZ expands and moves to quickly through the bed pushing moisture into finer areas of adsorption prior to design loading of the active MTZ. This will cause pre mature breakthrough of the MTZ and dewpoint spikes at dryer discharge.

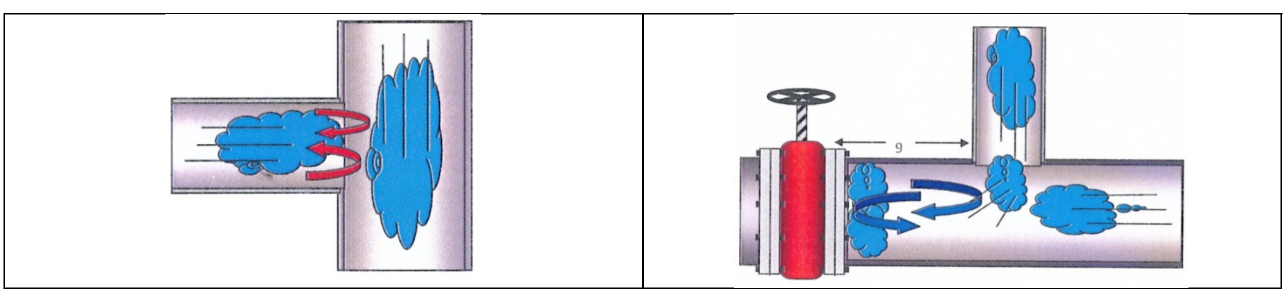
## DRY TANK STORAGE

An Inline dry compressed air storage tank with a 3:1 size ratio to the wet tank will substantially reduce the effects of wet surge demand on system filtration and dehydration components from a wet tank.

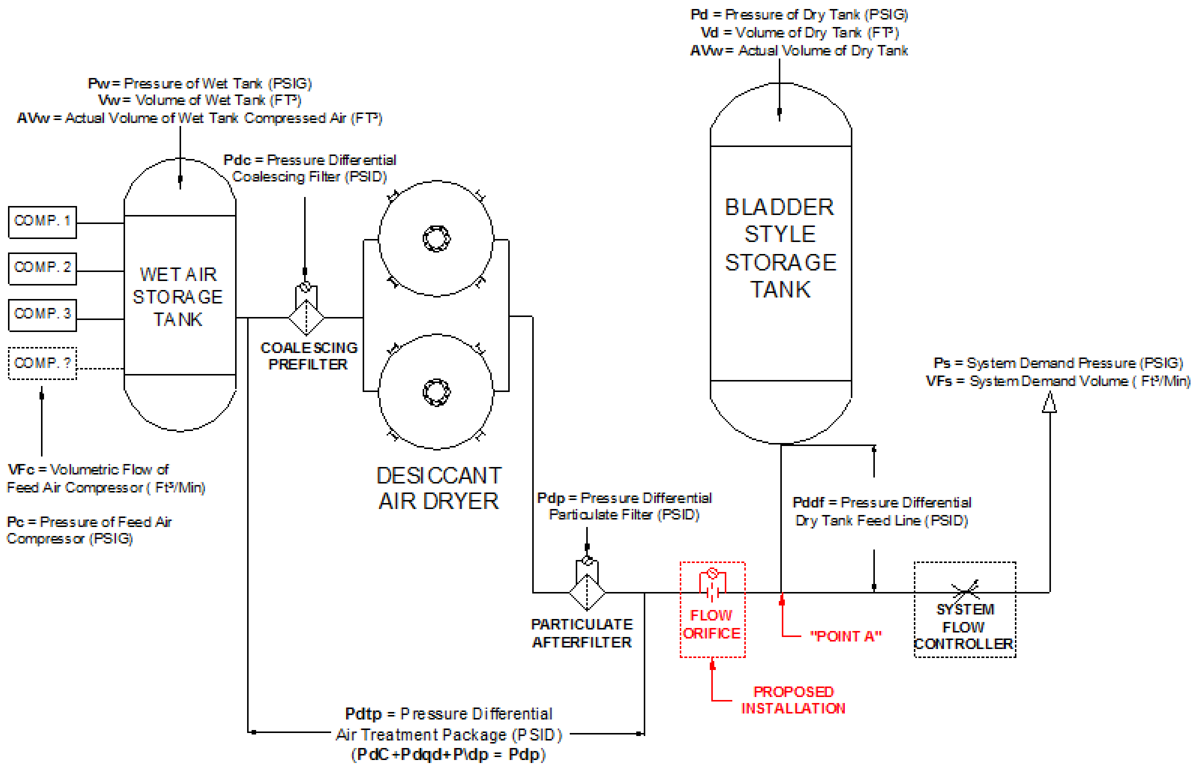



A bladder style tank configuration will not offer the same system protection as an inline. Both systems will provide identical force at (Point A) which equals the wet tank storage pressure less the air treatment package differential. The bladder designs bidirectional connection pipe will have additional resistance created by the following points which gives preferential driving force to the wet tank in supplying system requirements.

1. The longer and more intricate the bidirectional pipe, the higher the resistance.
2. Bidirectional pipe sizing must be designed for surge velocities; inadequacies in this point will exponentially compound resistance in point 1.
3. The bidirectional pipe is generally tied into the supply header through a crossing tee which will cause substantial resistance in both the pressurization and depressurization of the bladder tank.



*Illustrations courtesy of Air Power USA Pickerington, OH   www.airpowerusainc.com




Possible corrective action for bladder style dry tank storage issues

1. Re-pipe the system to an inline configuration.
2. Add an orifice to the system that will create equal to a slightly higher restriction to the wet tank and compressed air treatment package allowing the dry tank to be the higher driving force.
3. Reprogram the system flow controller substantially reducing the PID reaction time of the restriction device. This will limit (not completely remove) surge requirements but has the negative result of large pressure swings downstream of the flow controller.