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U.S. DEPARTMENT OF ENERGY

In-Plant Trainings

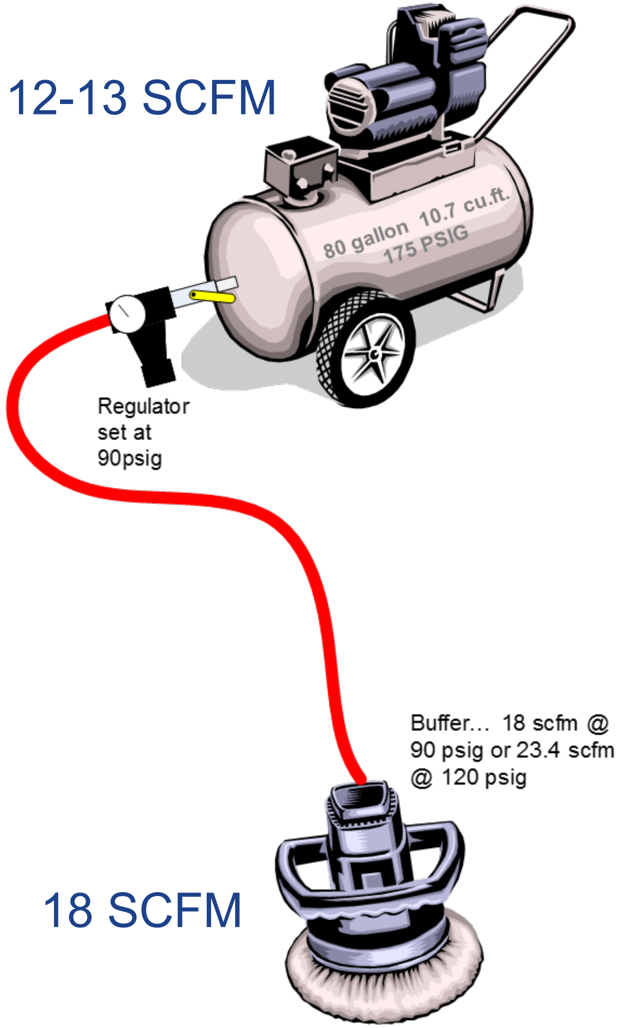
8 – Session Virtual Platform

Session 7

System Volume vs Storage

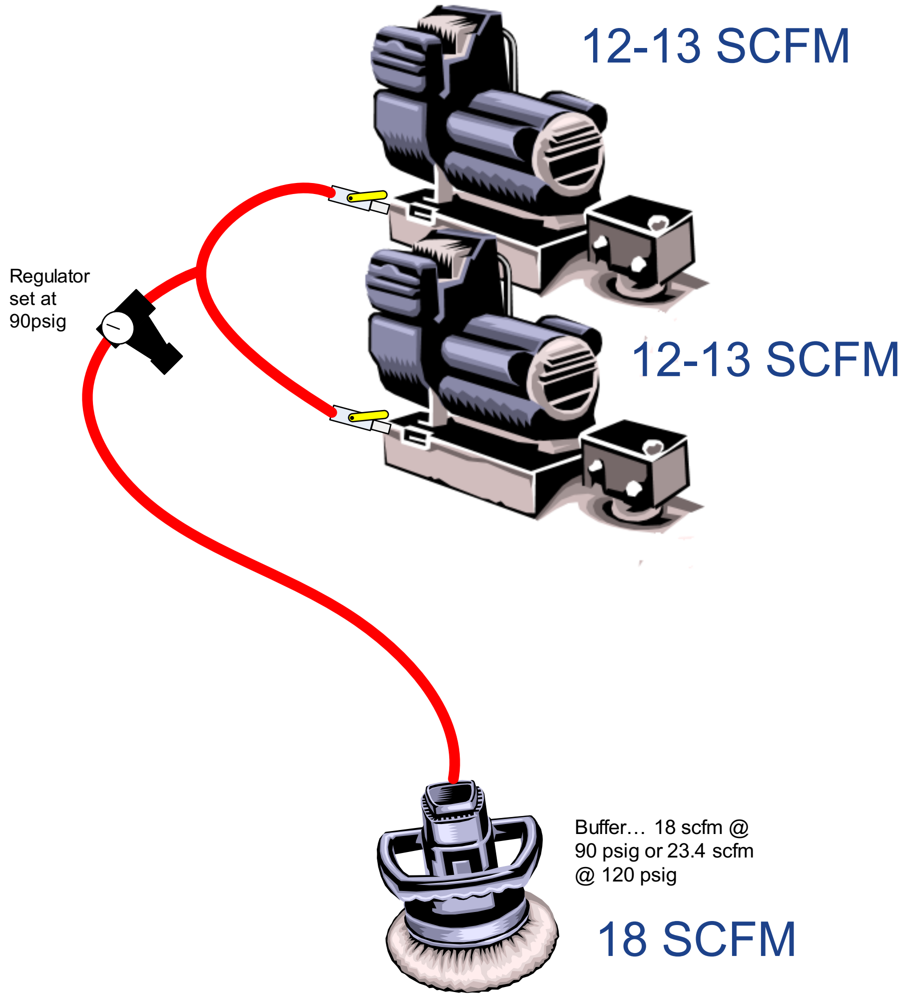
A Simple Example

- A paint area in a body shop has a 5 HP compressor mounted on an 80-gallon air receiver.
- This receiver is pumped up to 175 psig.
- The air flow to the buffer which uses 18 SCFM at 90 PSIG, is regulated to 90 PSIG outflow from the regulator.
- The compressor delivers 12-13 SCFM at 90 psig but yet it runs the 18 SCFM sander OK.
- How can this work???
- The buffer uses more volume(scfm) than the compressor can deliver !!



A Simple Example

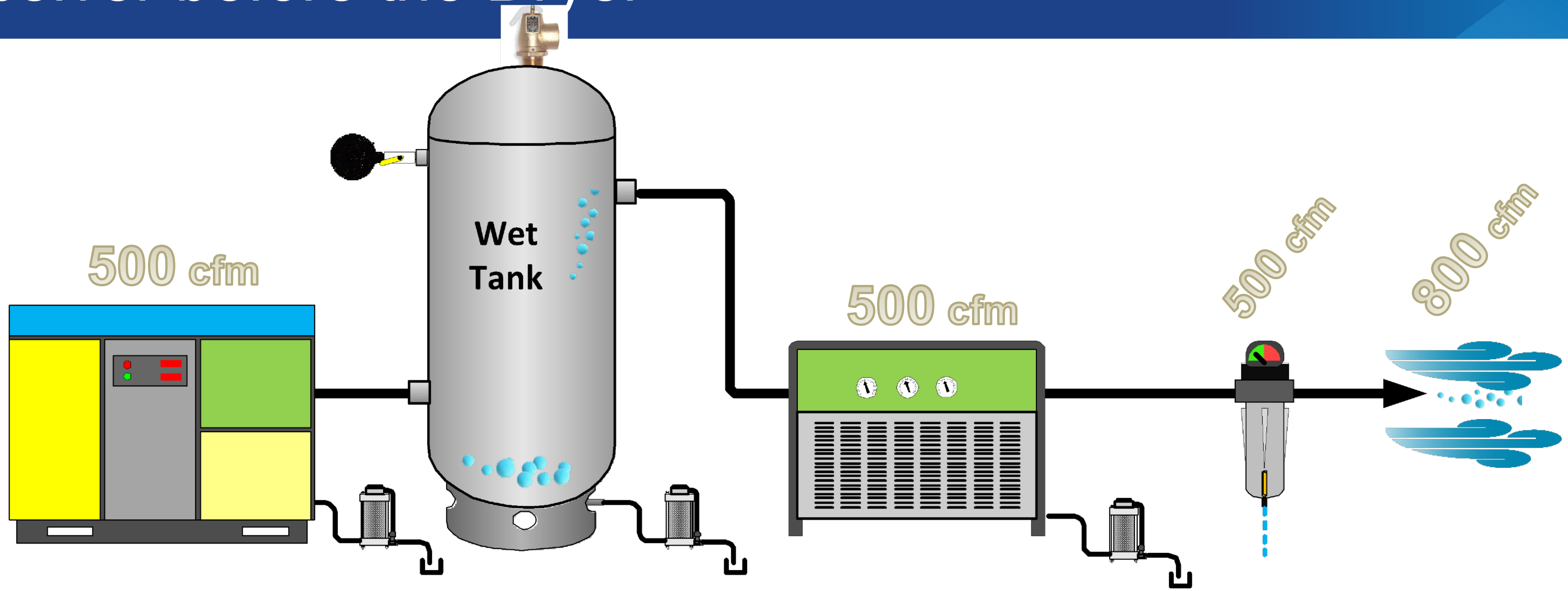
- With no receiver, the painter must install a second 5 hp compressor and therefore use twice the energy as before



Where Does it Go?

- There are wet air receivers and dry air receivers
- Wet Receivers: Wet receivers are located at the discharge of the compressors and provide additional storage capacity and reduce moisture.
- The large surface area of the air receiver acts as a free cooler, which is what removes the moisture.
- Because the moisture is being reduced at this point in the system, the load on filters and dryers will be reduced.
- Wet receivers also act as “Control Storage” which can maximize the effective operation of the compressor control.

Wet Receiver before the Dryer

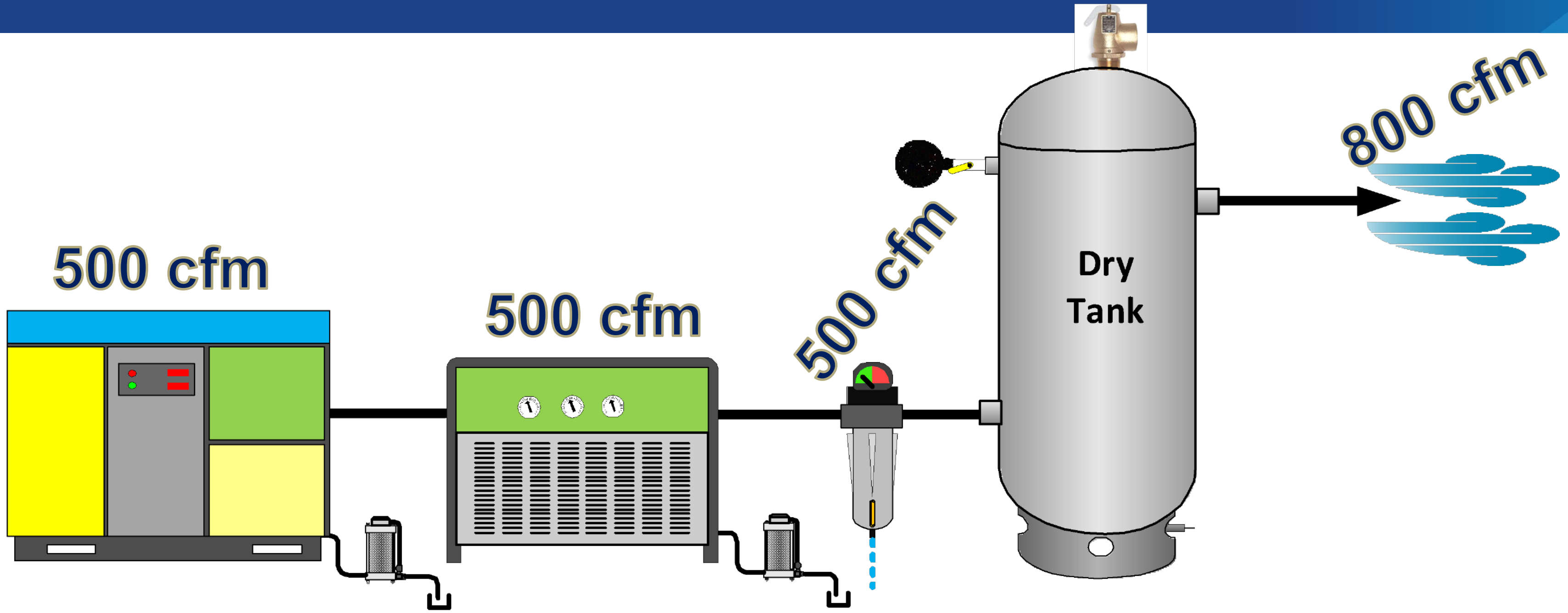


- A Wet Receiver creates radiant cooling and drops out some of the condensate and entrained oil, thus benefiting the dryer.
- However, the receiver will be filled with saturated air, and if there is a sudden demand that exceeds the capacity rating of the compressor and matching dryer, the dryer can be overloaded, resulting in a higher pressure dew point.

Where Does it Go?

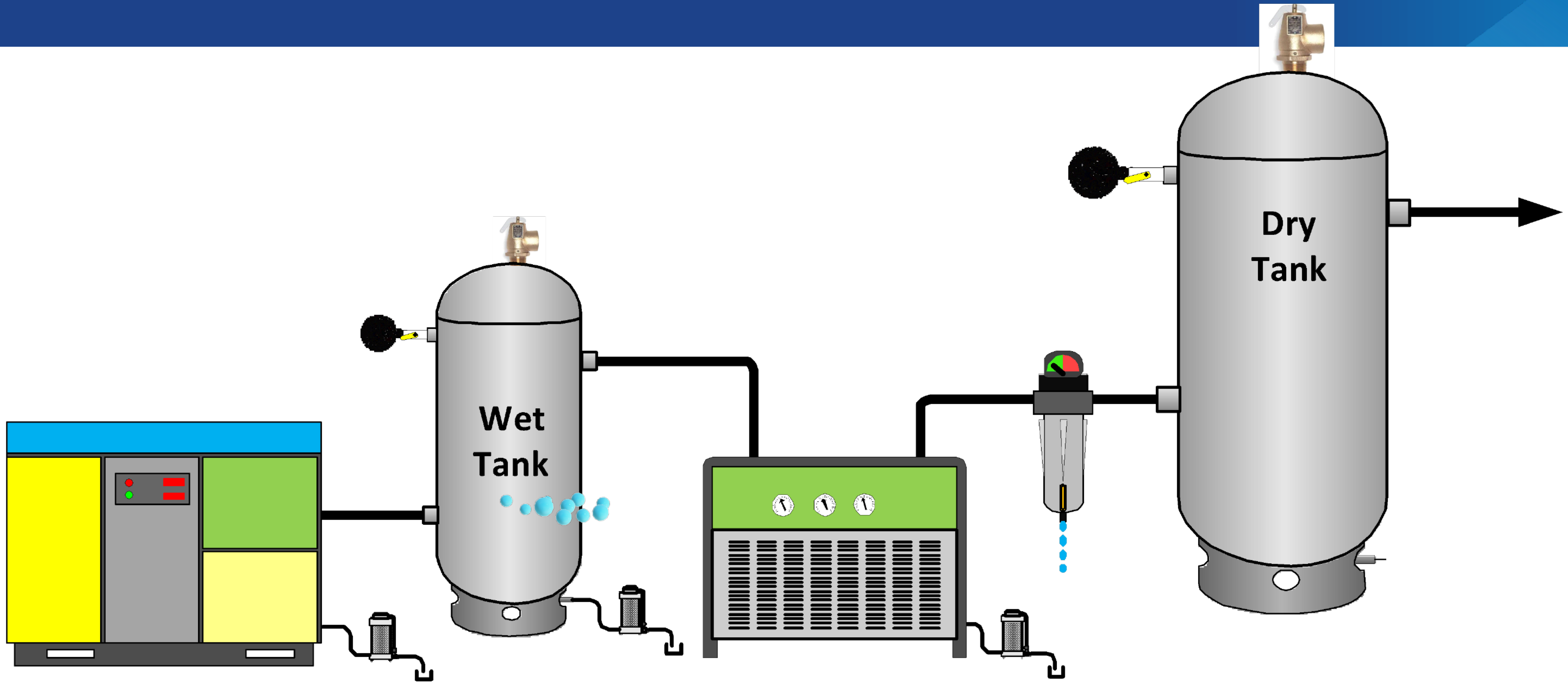
- Dry Receivers: Dry receivers are located immediately downstream of dryers and filters.
- When sudden large air demands occur, dry air receivers should have adequate capacity to minimize a drop in system air pressure.

Dry Receiver after the Dryer



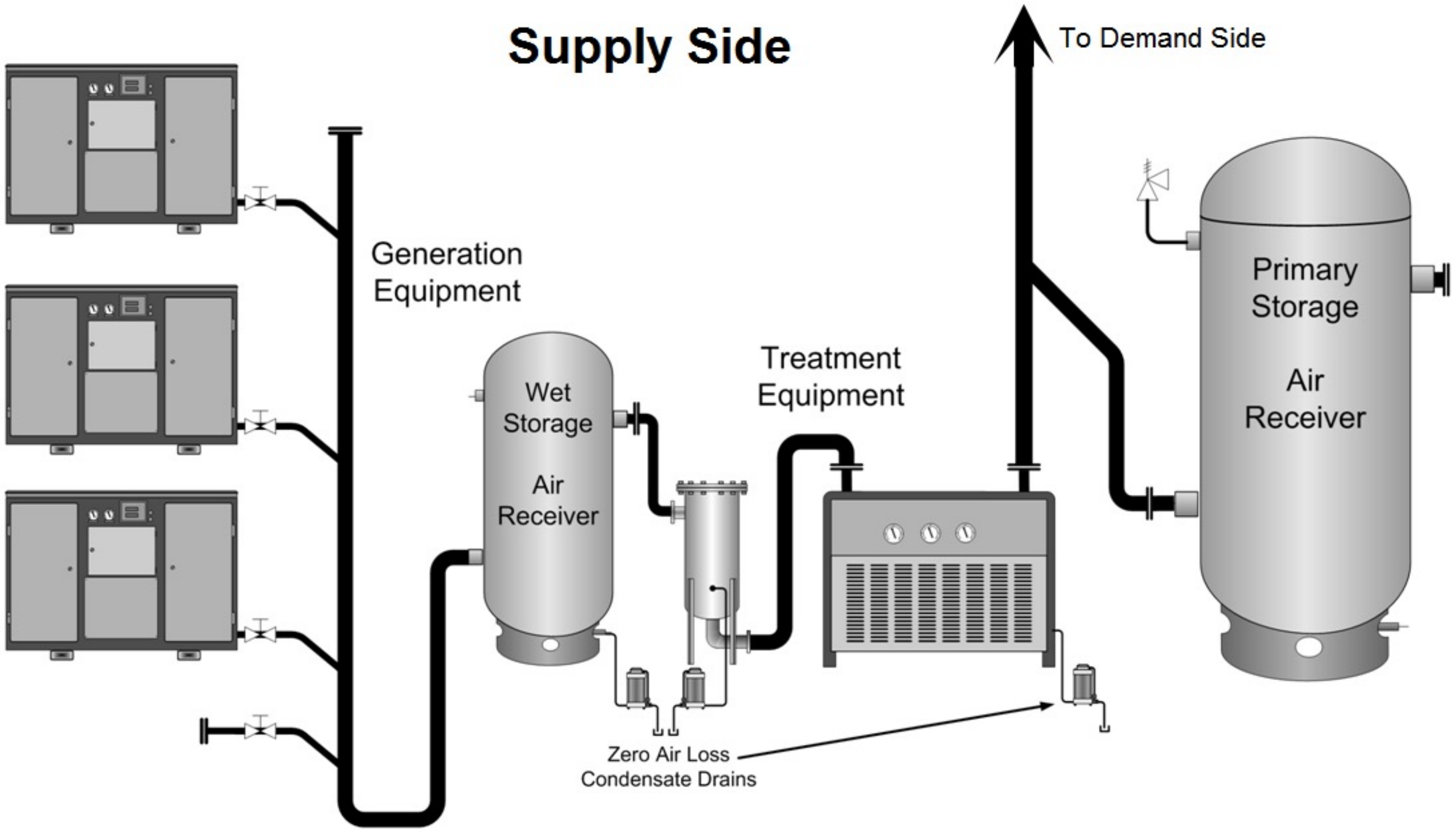
- The receiver is filled with compressed air which has been cleaned and dried.
- A sudden demand in excess of the compressor and dryer capacity rating will be met with dried air.

Best Practice



- A best practice is often to have two receivers at the supply side.
- One "wet" air receiver before the dryer to provide control storage and condensate drop out.
- And a second "dry" air receiver to meet sudden demands.
- Typical size ratio is 25% -30% wet and 70% - 75% dry.

Best Practice



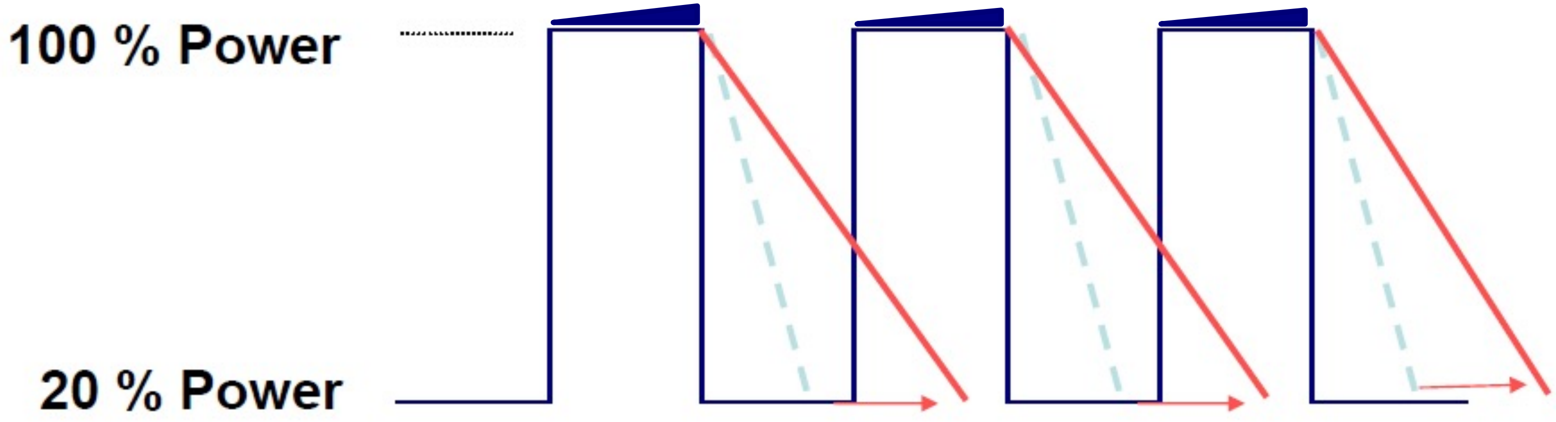
What Size?

- In the past, mainly with reciprocating compressors, rules of thumb for sizing a primary air receiver, have been from 1 gallon per cfm to 3 gallons per cfm of compressor capacity.
- This is no longer regarded as good practice and the recommended primary receiver size will vary with the type of compressor capacity control used.

What Size?

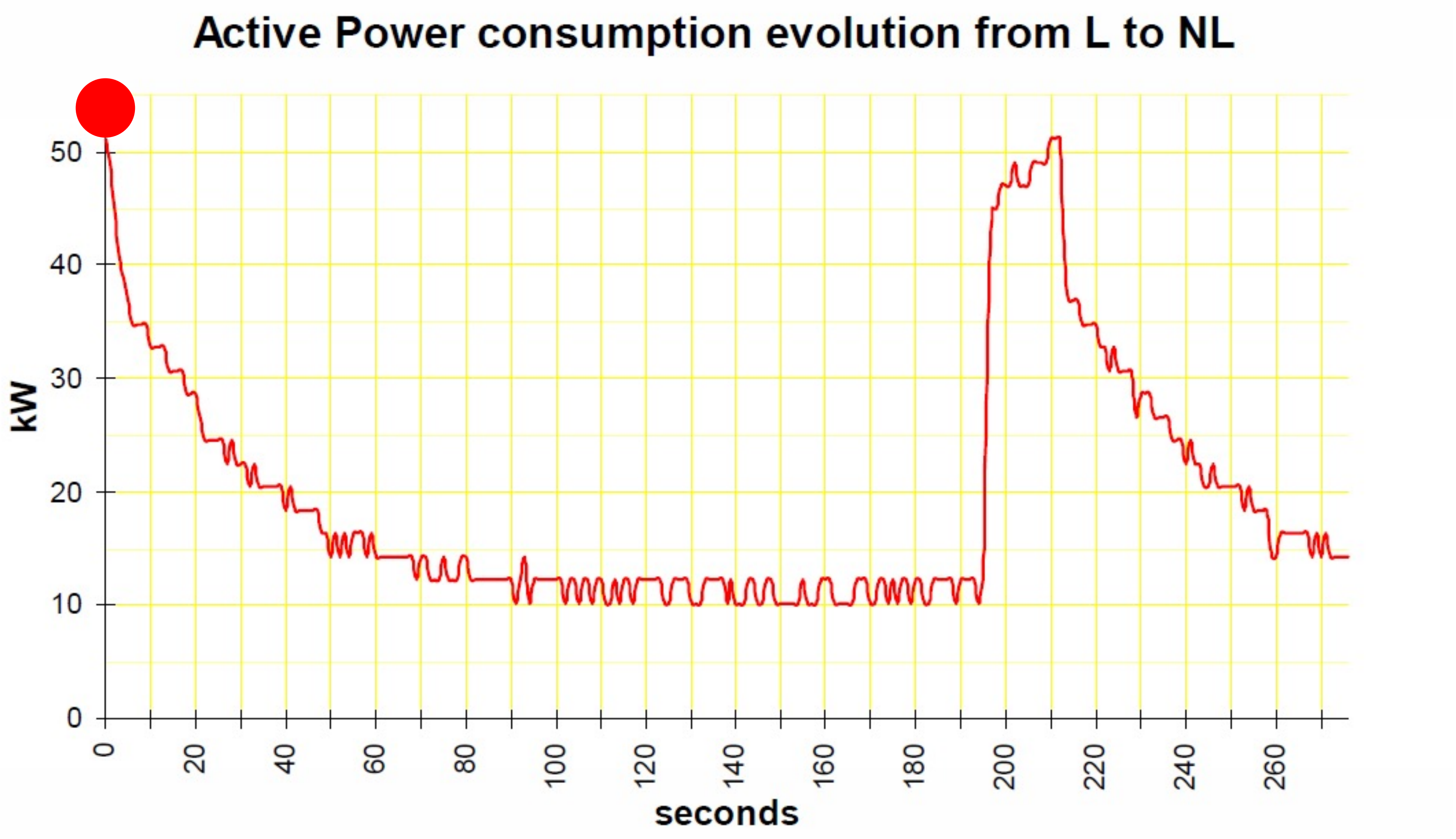
- Some oil injected rotary screw compressors are sold with load/unload capacity control, which is claimed to be the most efficient.
- This also can be misleading, since an adequate receiver volume is essential to obtain any real savings in energy.
- Some rules of thumb established many years ago for reciprocating air compressors, are not adequate for an oil injected rotary screw compressor.

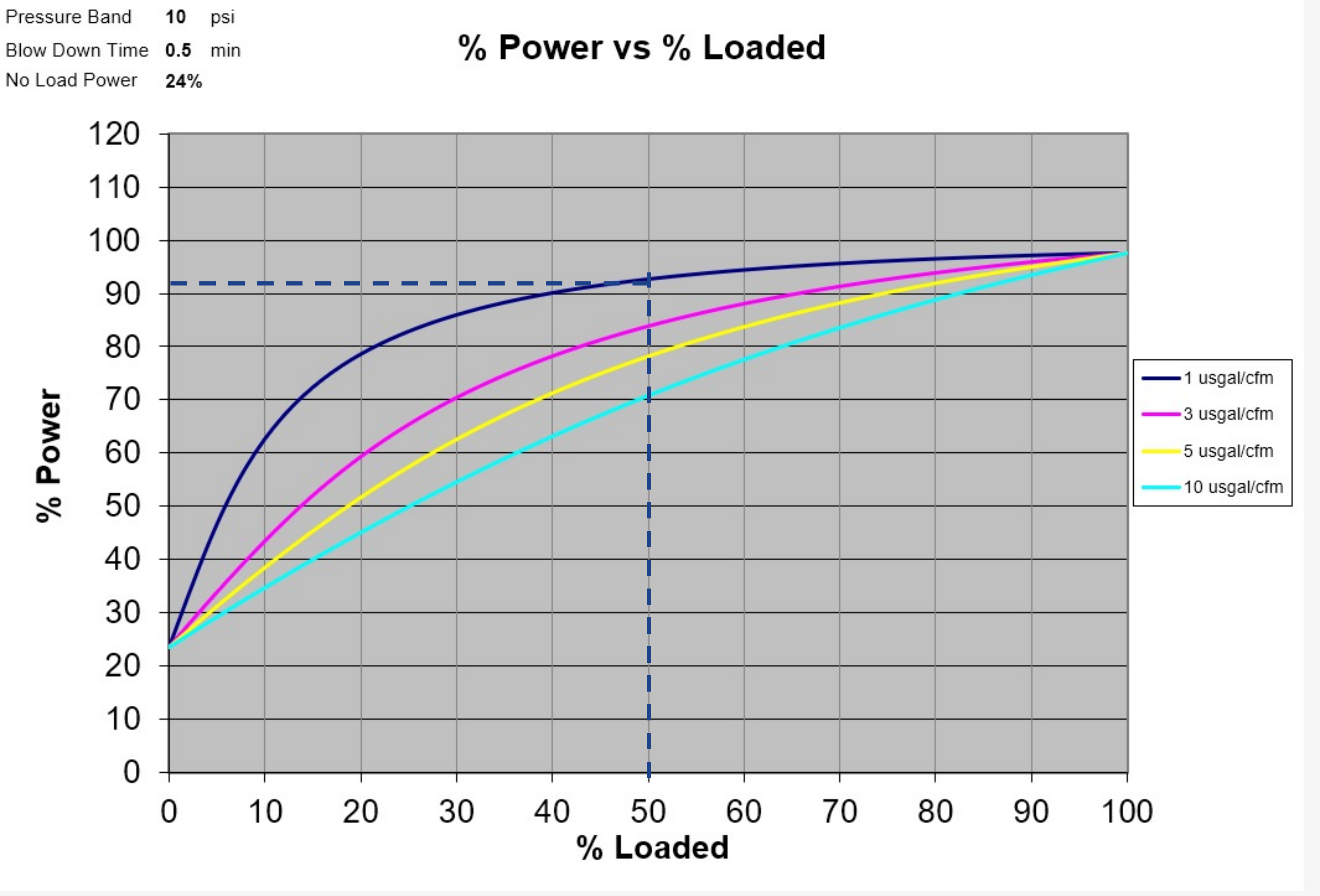
Capacity Control by Load/No-Load



- During un-load, the compressor is still running against significant back pressure and consuming power
- Bigger sump vessels lead to longer blow-off times and more energy consumption

Capacity Control by Load/No-Load





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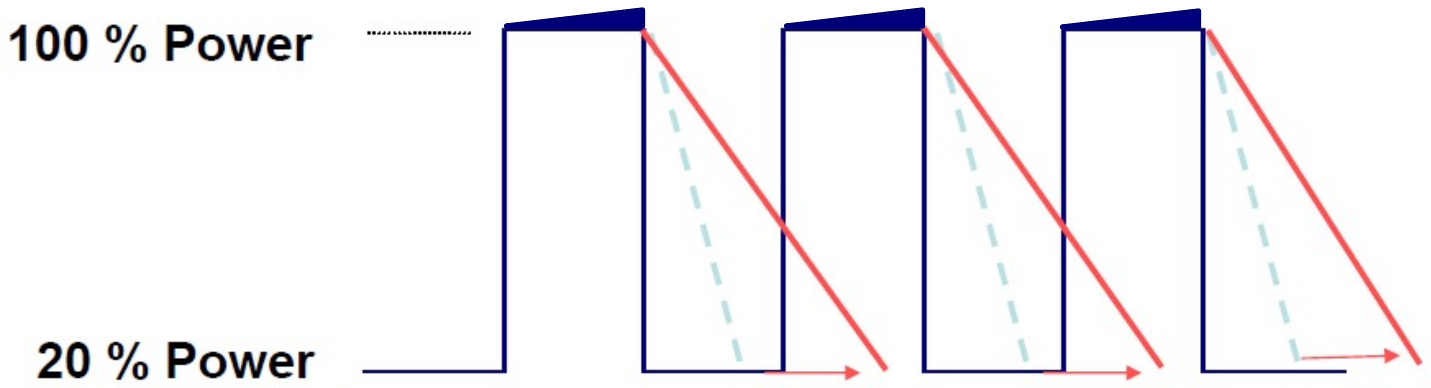
What Size For Variable Speed Compressors?

- For variable speed compressors the receiver size can be smaller.
- Variable speed compressors don’t tend to run unloaded so don’t have this period of wasted energy
- They can also vary their speed to meet demand, so the receiver doesn’t need to be so big.
- However, variable speed compressors do still need air receivers to smooth out downstream demand so they can adjust their speed efficiently.

What Size For Oil Free Compressors?

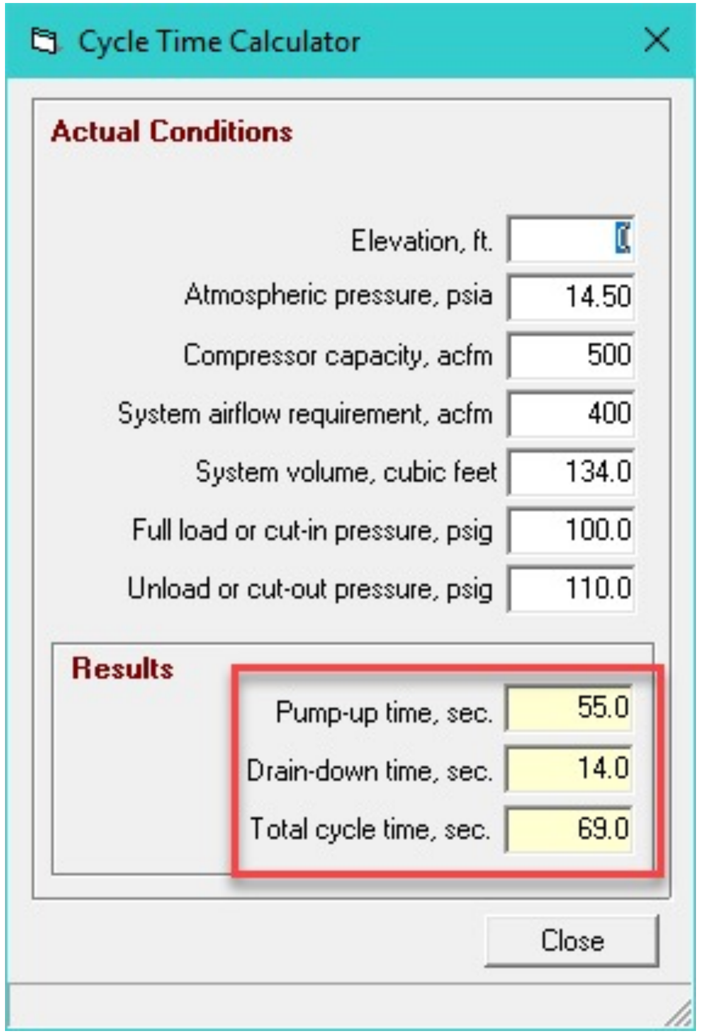


- Since there is no sump blowdown to ride out, the concern would be cycle time.
- Consult with the manufacturer
- Most do not want less than one cycle per 30 seconds. Desirable to have one cycle per minute.

What Size For Oil Free Compressors?

- How do you determine cycle time?

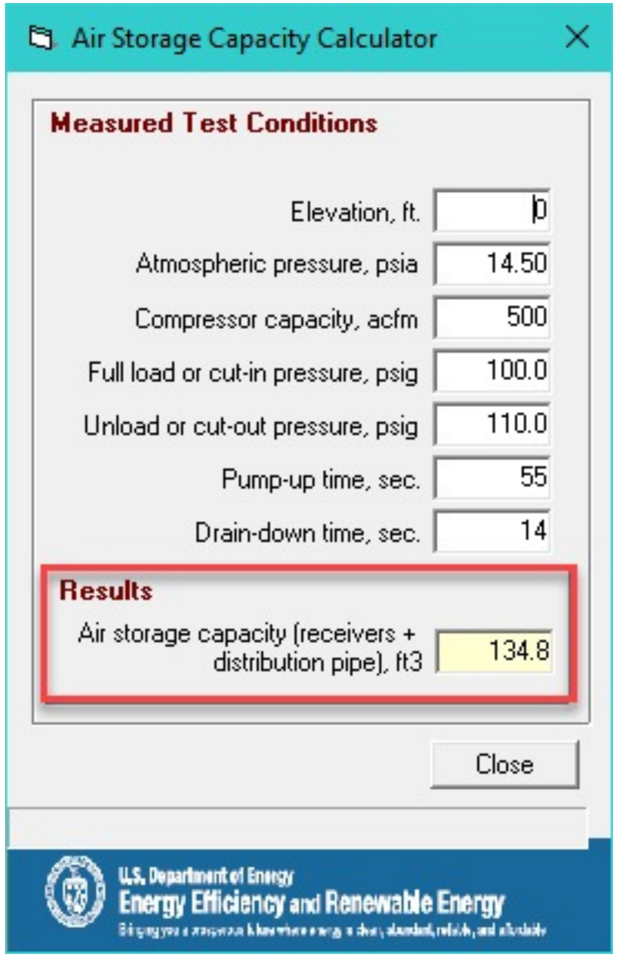
- Using one of the calculators from Airmaster+ software :
- A 100 hp 500 acfm compressor operating at 80% load (400/500) with volume at 2 gal per cfm will have a 69 second cycle time
- 134 cuft = 1000 gal



What Size For Oil Free Compressors?

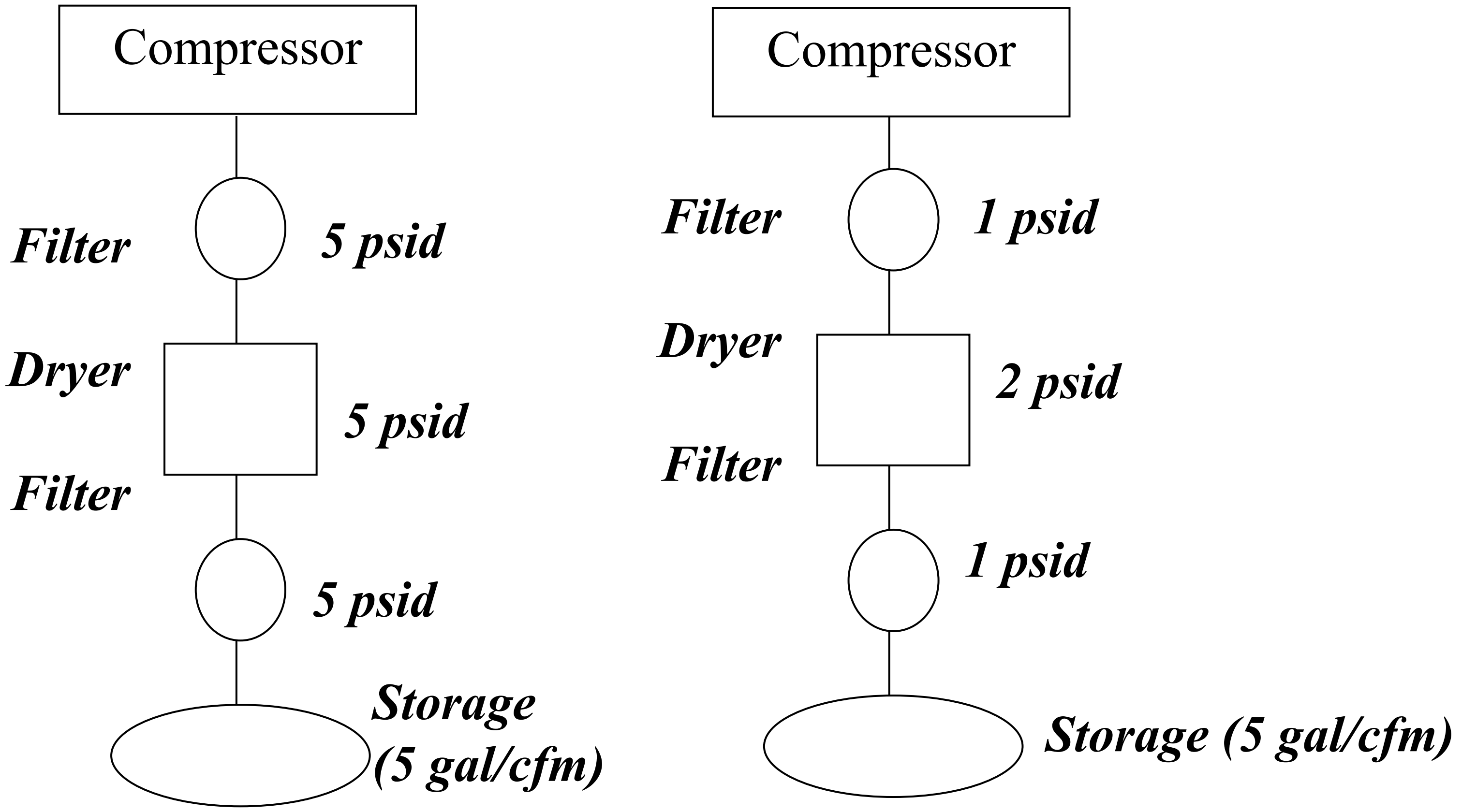
- How do you determine "Effective" Volume?

- Using one of the calculators from Airmaster+ software :
- During a period of constant air demand, the cycle time can be used to determine the effective volume
- A 100 hp 500 acfm compressor operating at 80% load with a 55 second load time and 14 second unload time equates to an effective volume of 134.8 cubic feet
- 134 cuft = 1000 gal



Effectiveness of Storage

Compressor has a 10 psig Control Band

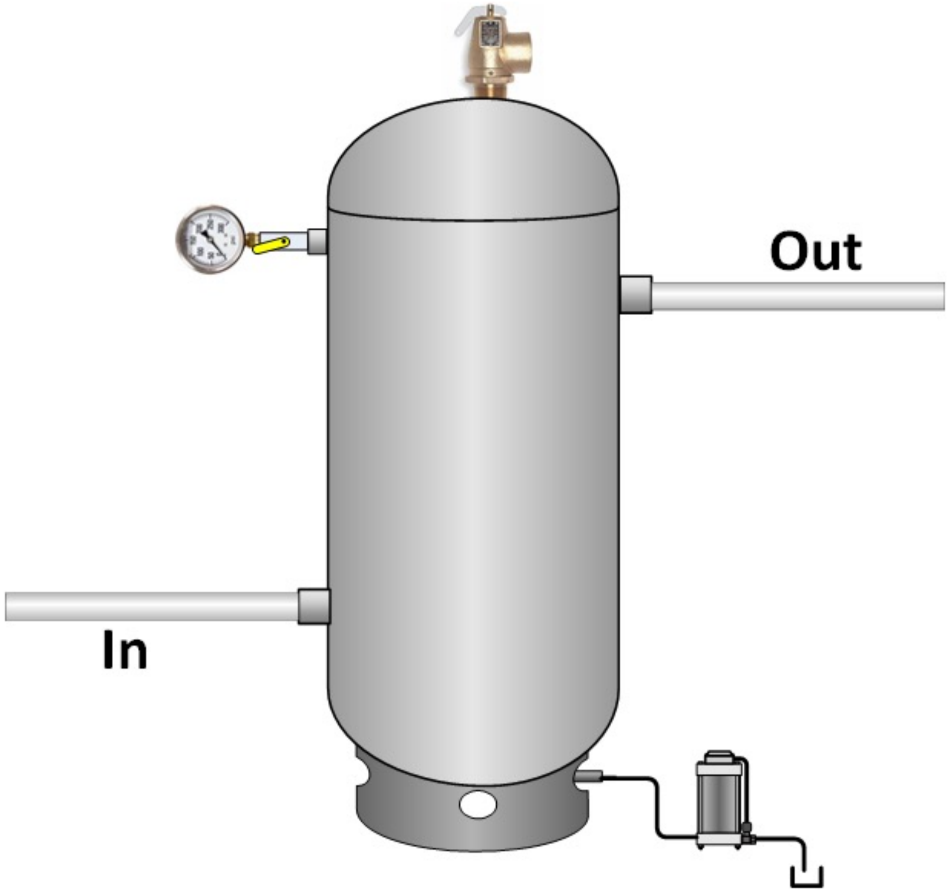


Some Best Practice Recommendations:

- Locate the receiver as close to the compressors as practical in the coolest location with the fewest possible elbows.
- When manifolding compressor connections, ensure that the pipe to the receiver is at least equal in cross sectional area to the sum of the areas of the compressor discharge connections
- Do not connect a reciprocating compressor into the same manifold as a rotary or centrifugal compressor

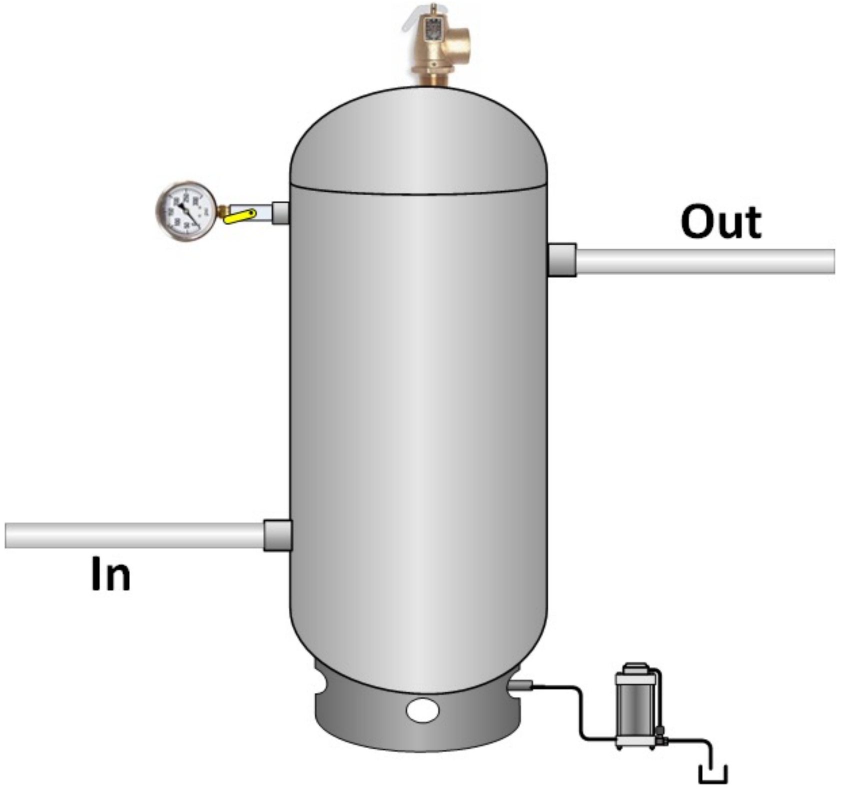
Some Best Practice Recommendations:

- Air should enter the air receiver at the largest port in the lower section, and discharge from the largest appropriate port in the upper section.
- Adequate automatic zero air loss drain traps should be installed for removal of accumulated condensate in lieu of timer or manual drains.
- Each air receiver should be equipped with a PRV valve and a pressure gauge with a valve to facilitate replacement when necessary.



Some Best Practice Recommendations:

- When used with lubricant free compressors, it is advisable to specify an air receiver having a galvanized interior or special epoxy coating to prevent corrosion.
- Safety valve capacity shall be sized to prevent receiver pressure from exceeding 110 percent or 3 psi (which ever is greater) of the maximum allowable working pressure.



Secondary Storage

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Secondary Storage

- Secondary Storage Receivers can be used to:
  - Supplement the primary receivers to stabilize system pressure and thus keep unneeded compressors from operating
  - Supply adequate compressed air for a single intermittent event of a known duration.

Calculating the size of the Receiver

$$V_{cf} = \frac{T_{\min}(C-S)P_a}{P_1 - P_2}$$

- V = Volume of the receiver in cubic feet
- T = Time interval in minutes during which the receiver can supply air to the specific event
- C = Total air required by the event in cubic feet per minute
- S = Spare air for restoring the pressure from P2 back to P1
- P_a = Absolute atmospheric pressure (psia)
- P_1 = Initial receiver pressure
- P_2 = Final receiver pressure required to support the event

Example

Assume a back wash filter requires **100 cfm every hour** for a duration of **3 minutes** at 70 psig. Normal system pressure is maintained at a nominal 95 psig. For this calculation assume S to be zero.

$$V = \frac{T(C-S)Pa}{P_1 - P_2} \qquad V = \frac{3(100-0)14.7}{95-70} = 176.4\ Cubic\ Feet$$

176.4 x 7.48 gal/cu.ft. = 1319.5 gallons

Select the next largest standard air receiver size which would be 1548 gallons

1548 gallons ÷ 7.48 gal/cu.ft. =207 cu.ft.

Example Using MEASUR

MEASUR

Manufacturing Energy Assessment Software for Utility Reduction

RECEIVER TANK SIZING

Calculation Method	Dedicated Storage
Length of Demand	3 min
Air Flow Requirement	100 scfm
Atmospheric Pressure	14.7 psia
Initial Tank Pressure	95 psig
Final Tank Pressure	70 psig
Receiver Volume	**1,319.47 gal**

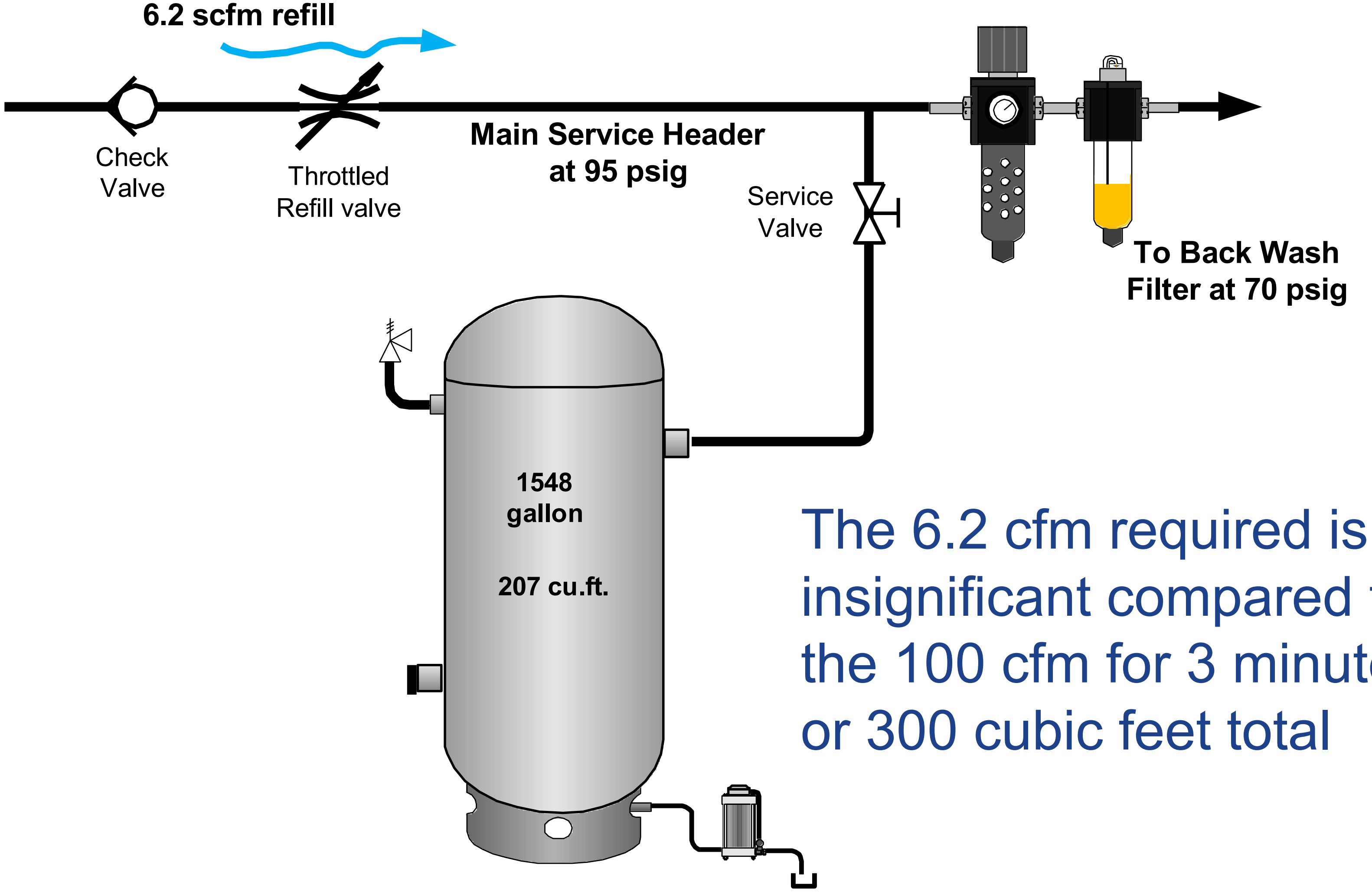
Generate Example   Reset Data

Example

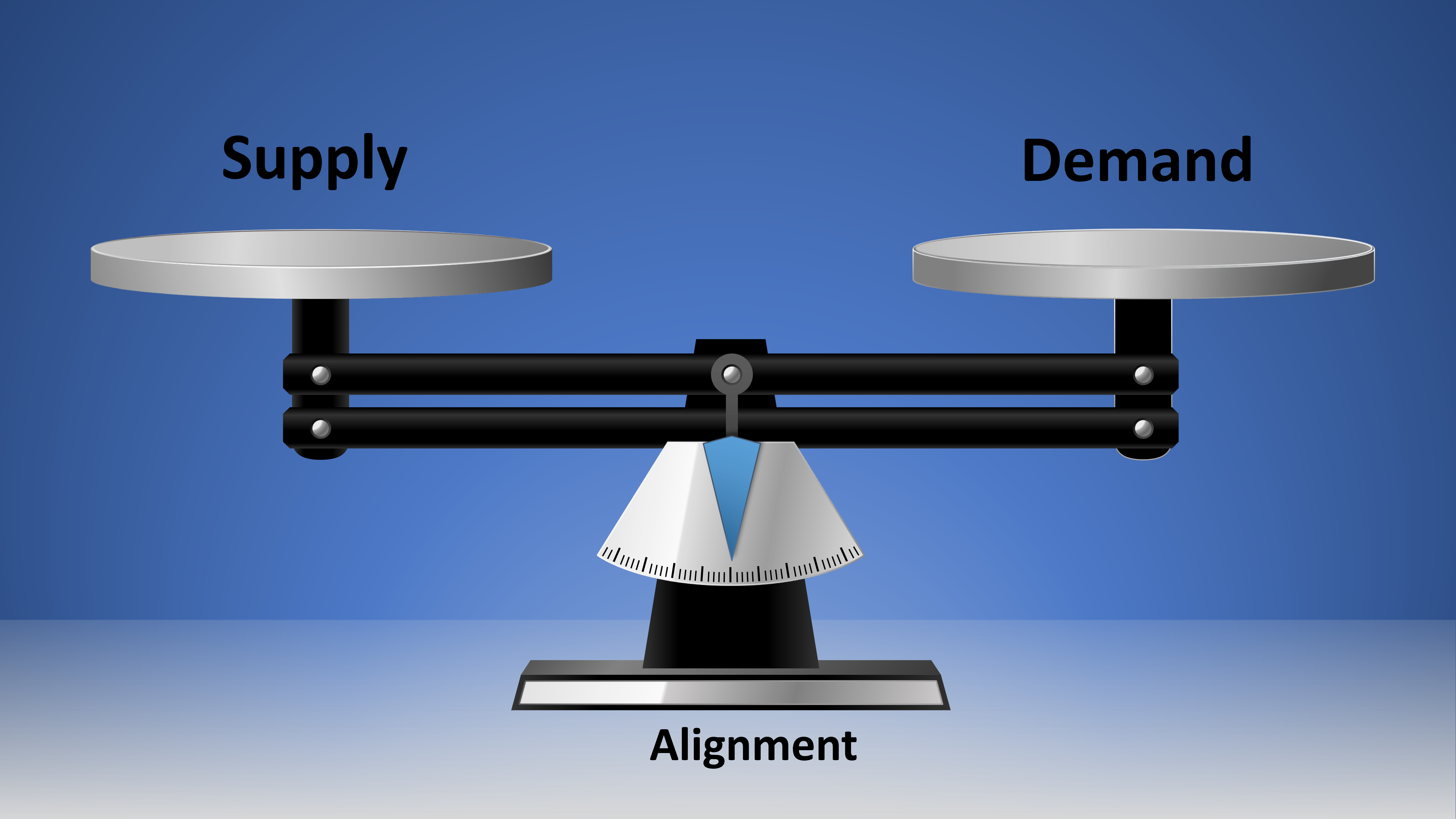
The next part of the calculation is to calculate the metered refill rate. Restating the formula, "S" required to restore the pressure to 95 psig within the 57 minutes until the next backwash.

$$Solving\ For\ S = \frac{Vx(P_1 - P_2)}{T \times 14.7} \qquad S = \frac{207 \times (25)}{57 \times 14.7} = 6.2\ CFM$$

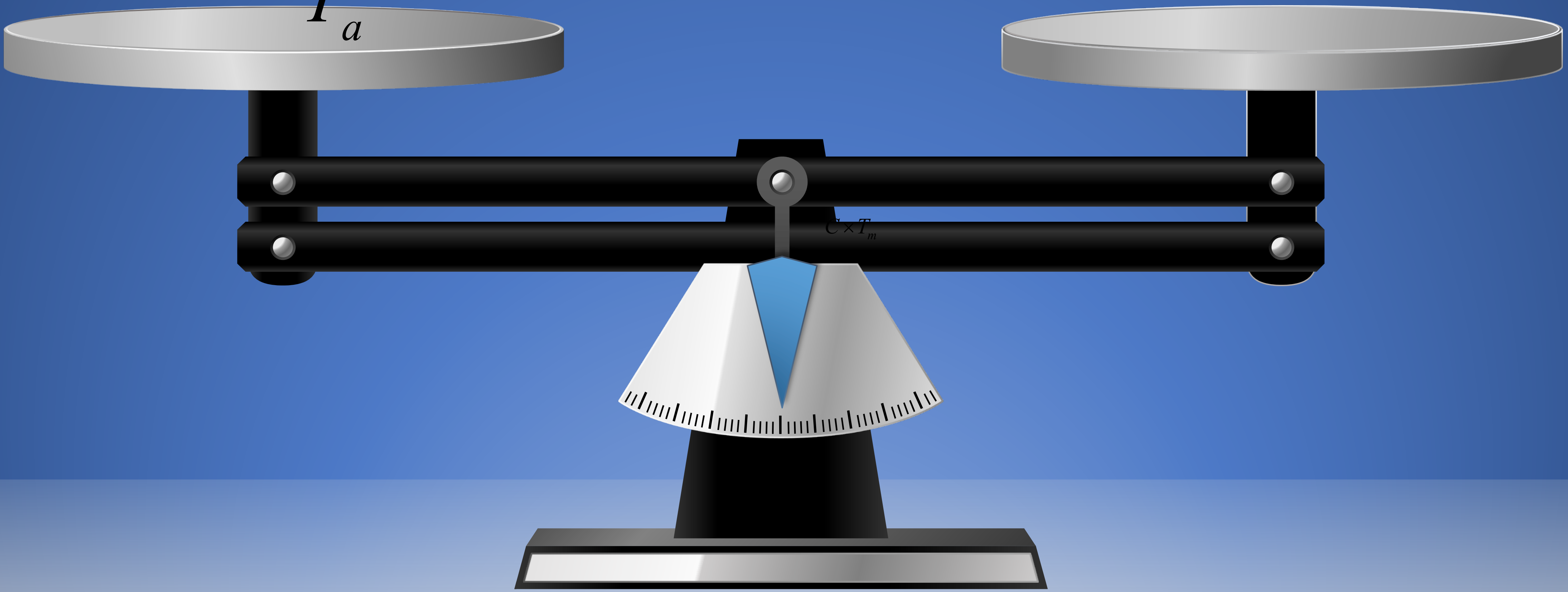
Example



The 6.2 cfm required is insignificant compared to the 100 cfm for 3 minutes or 300 cubic feet total


Supply
Demand
Alignment

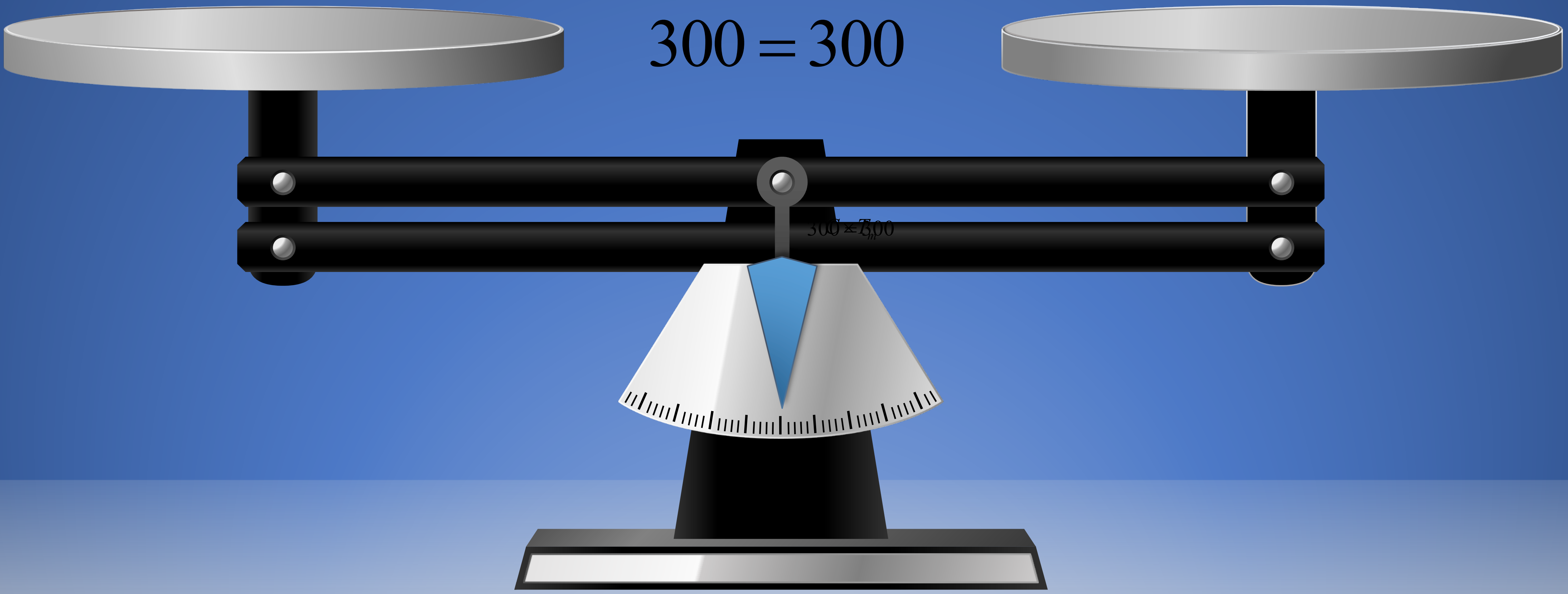
$$V_{cf} \times \frac{\Delta P}{P_a} = C \times T_m$$



Supply = Demand

$$176.4 \times \frac{25}{14.7} = 100 \times 3$$

$$300 = 300$$



Supply = Demand

Example of Local Storage for Critical End Use Pressure

Example of Local Storage

Pneumatic capacitance

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Storage or Volume

- Pneumatic capacitance is the stored air within a compressed air system –
- Capacitance is expressed as the ratio of stored air volume (scf) to the storage pressure differential
- In order for there to be any stored energy, there has to be a pressure differential across the storage device.

Useful Storage

- Useful Storage = Capacity to Store x Allowable Pressure Drop

$$\frac{V_{cf}}{P_a} \times \Delta P$$

Given a 660 gallon tank and the pressure can drop 10 psi

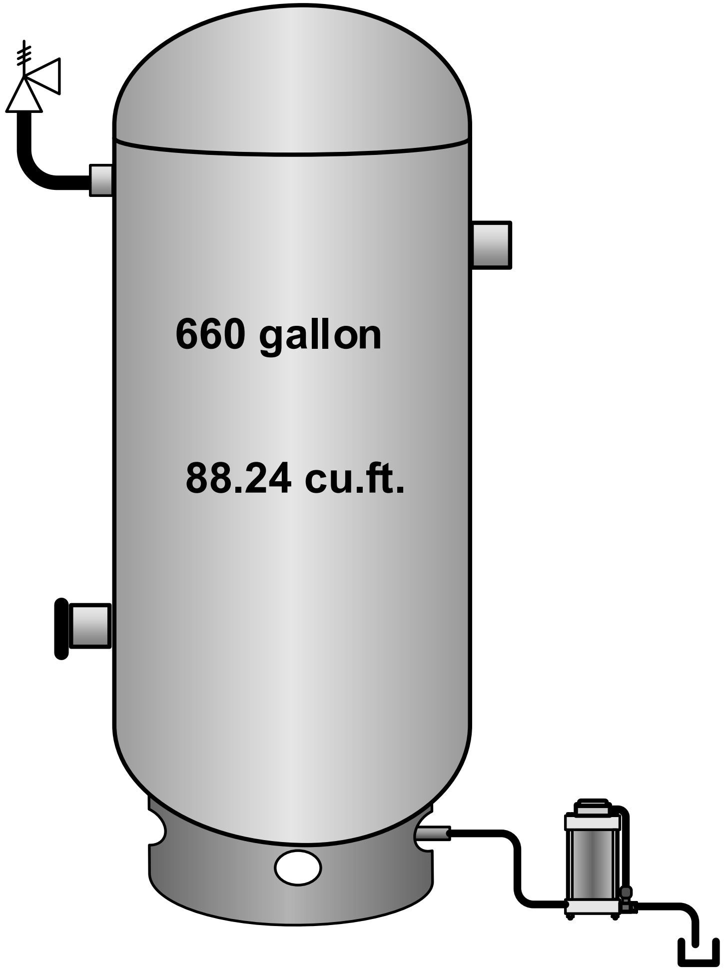
What is the usable (useful) storage?

660 gallons / 7.48 gal/cuft =88.24 cubic feet

88.24 cuft / 14.5 psia = **6.09 cuft /psia**

6.09 cuft /psia x 10 psia =

= 60.9 cuft of usable storage



System Drawdown

Three different methods could be used to calculate:

#1 Capacitance:

Volume in cuft ÷ 14.7 = capacitance in cu. ft./psi

$$DrawDownRate = \frac{debitflow_{cuftsec}}{capacit_{cuftpsi}} \times Time_{sec}$$

Example: a 200-cu ft system is operating at 100 psig with a total demand of 600 acfm using two 300 acfm compressors online. If one compressor fails, what will the drawdown of pressure be in 25 seconds?

300 acfm = **5 cu ft/se**c and capacitance = 200/14.7 = **13.6 cuft /psi**

5 cuft/sec ÷ 13.6 cu ft/psi = .367 psi/sec x 25 sec = **9 psig drawdown**

System Drawdown

Three different methods could be used to calculate:

#2 Receiver calc:

Draw down rate = solve for ΔP

$$V_{cf} = \frac{T_{\min} \times (C - R) \times P_a}{P_1 - P_2}$$

$$\Delta P = \frac{T_{\min} \times DebitFlow \times P_a}{V_{cf}}$$

Example: a 200-cuft system is operating at 100 psig with a total demand of 600 acfm using two 300 acfm compressors online. If one compressor fails, what will the drawdown of pressure be in 25 seconds?

200 cu ft = ((25/60) x (300 cfm) x 14.7)) ÷ ΔP

ΔP = (.416min x 300 x 14.7) ÷ 200 cuft = **9 psig**

System Drawdown

Three different methods could be used to calculate:

#3 Supply = Demand:

Draw down rate = solve for ΔP

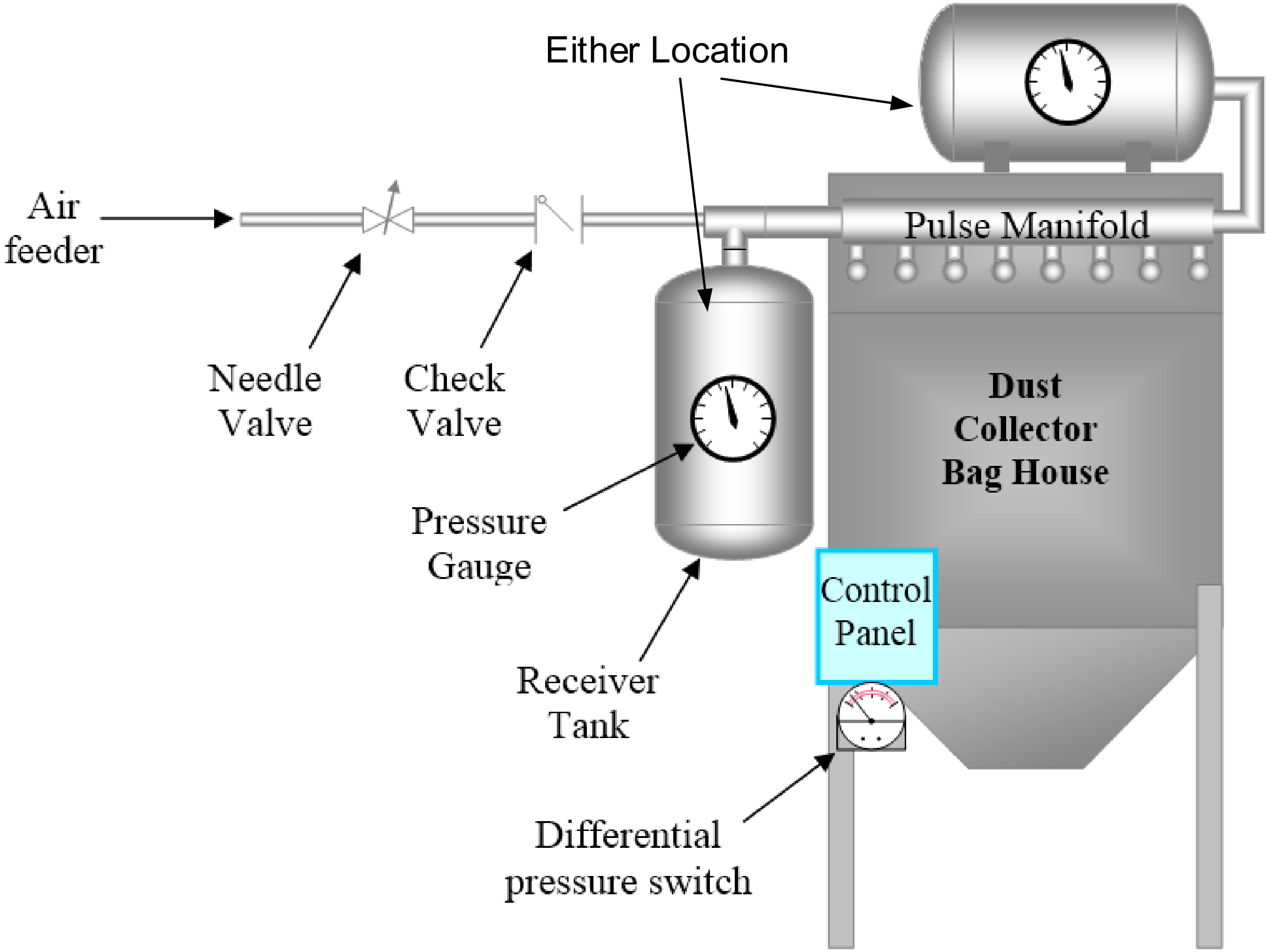
$$V_{cf} \times \frac{\Delta P}{P_a} = DebitFlow \times T_{\min}$$

Example: a 200 cu ft system is operating at 100 psig with a total demand of 600 acfm using two 300 acfm compressors online. If one compressor fails, what will the drawdown of pressure be in 25 seconds?

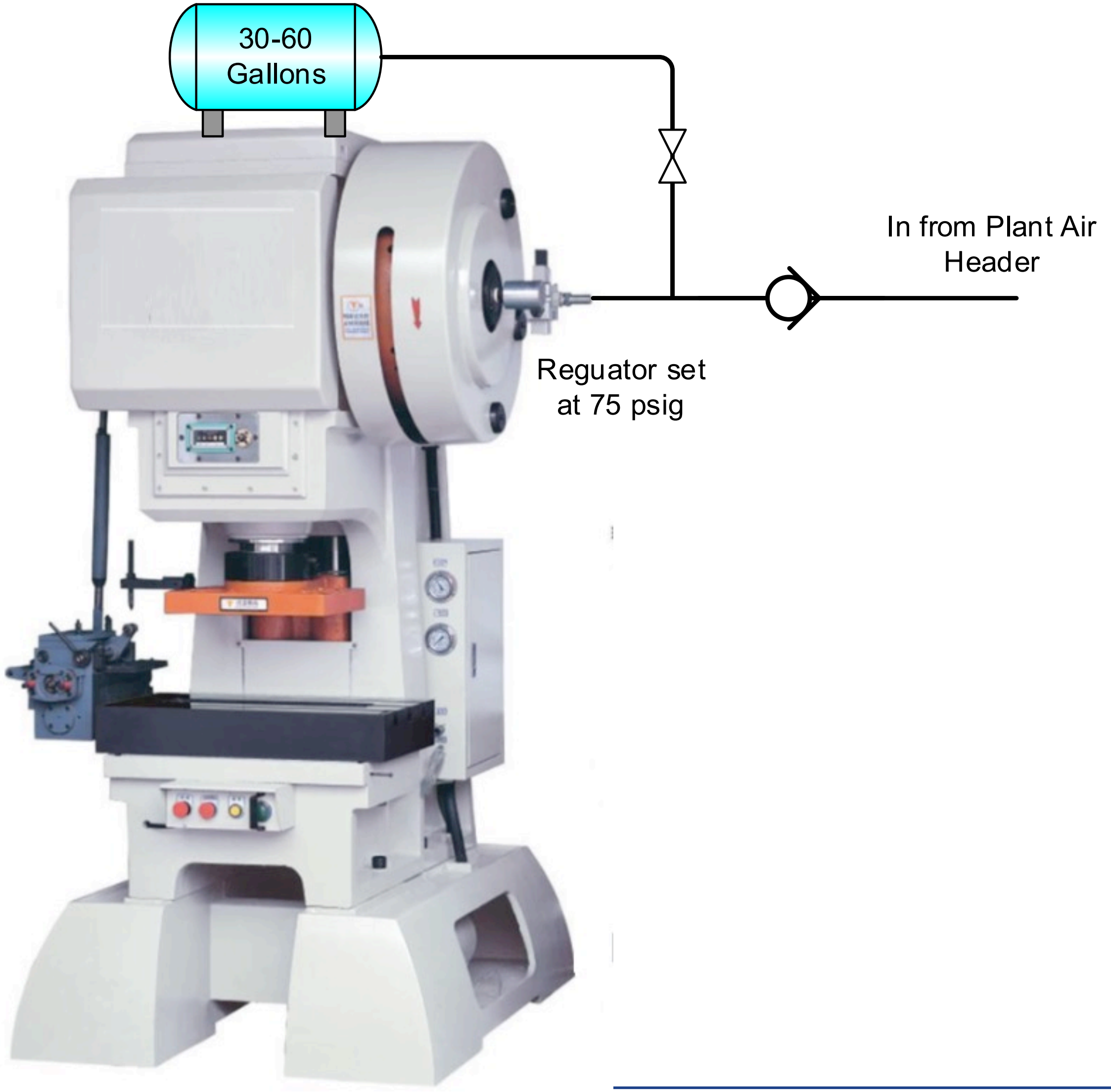
200 cu ft X (Δp/14.7) = 300cfm x 25/60

ΔP = 9 psig

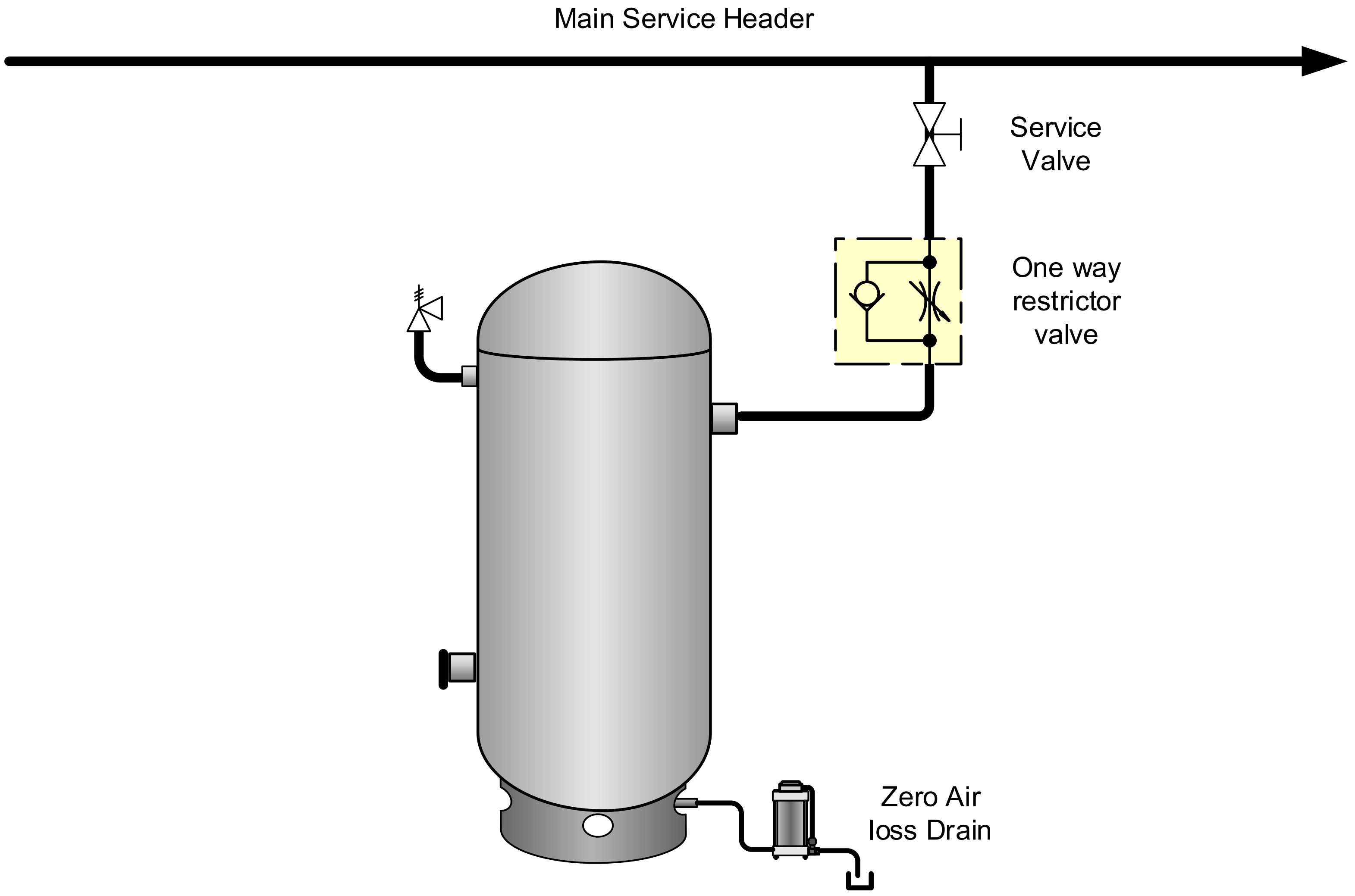
Dedicated Storage to Shield the system from a high flow end use application



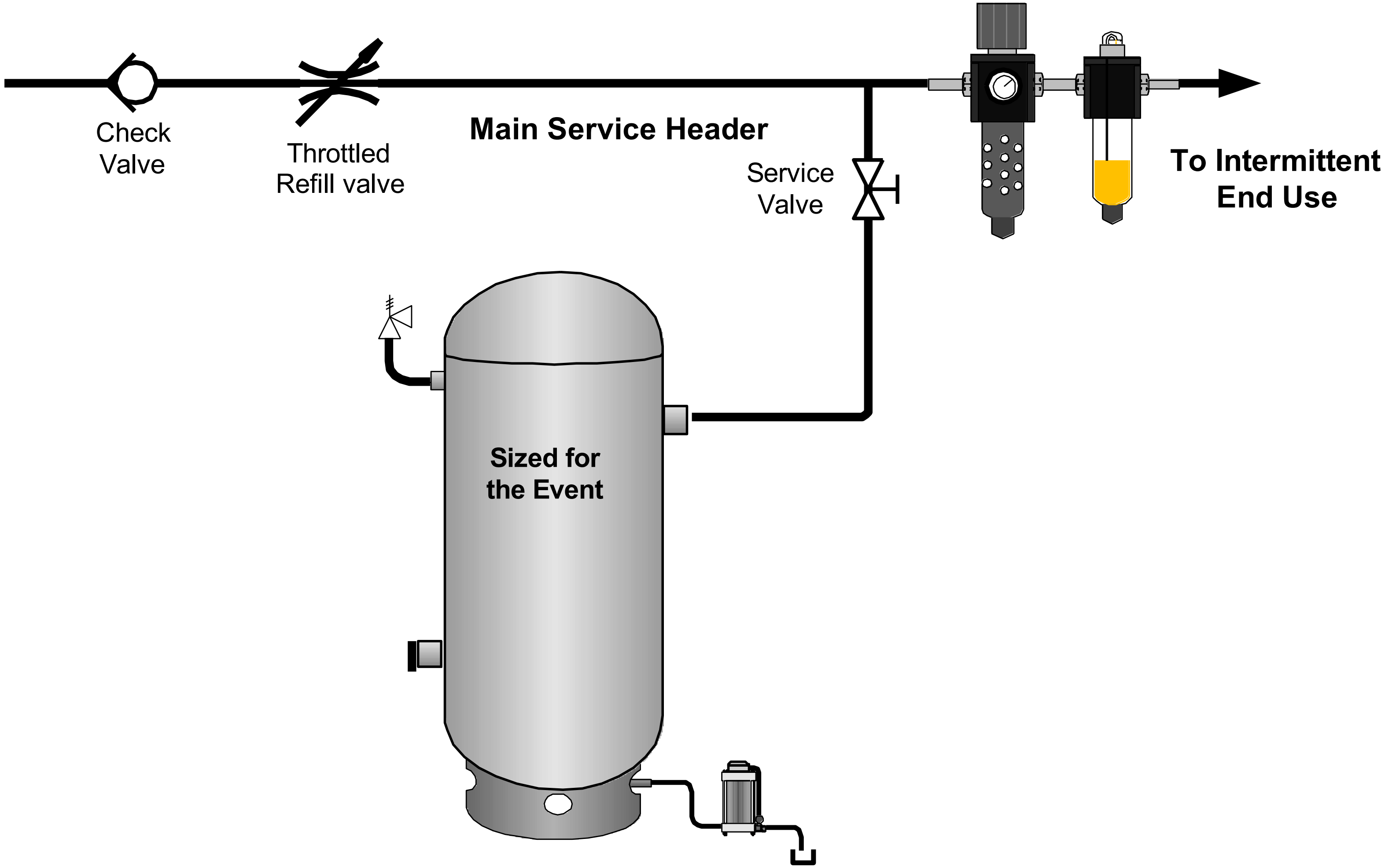
Critical Pressure End Use



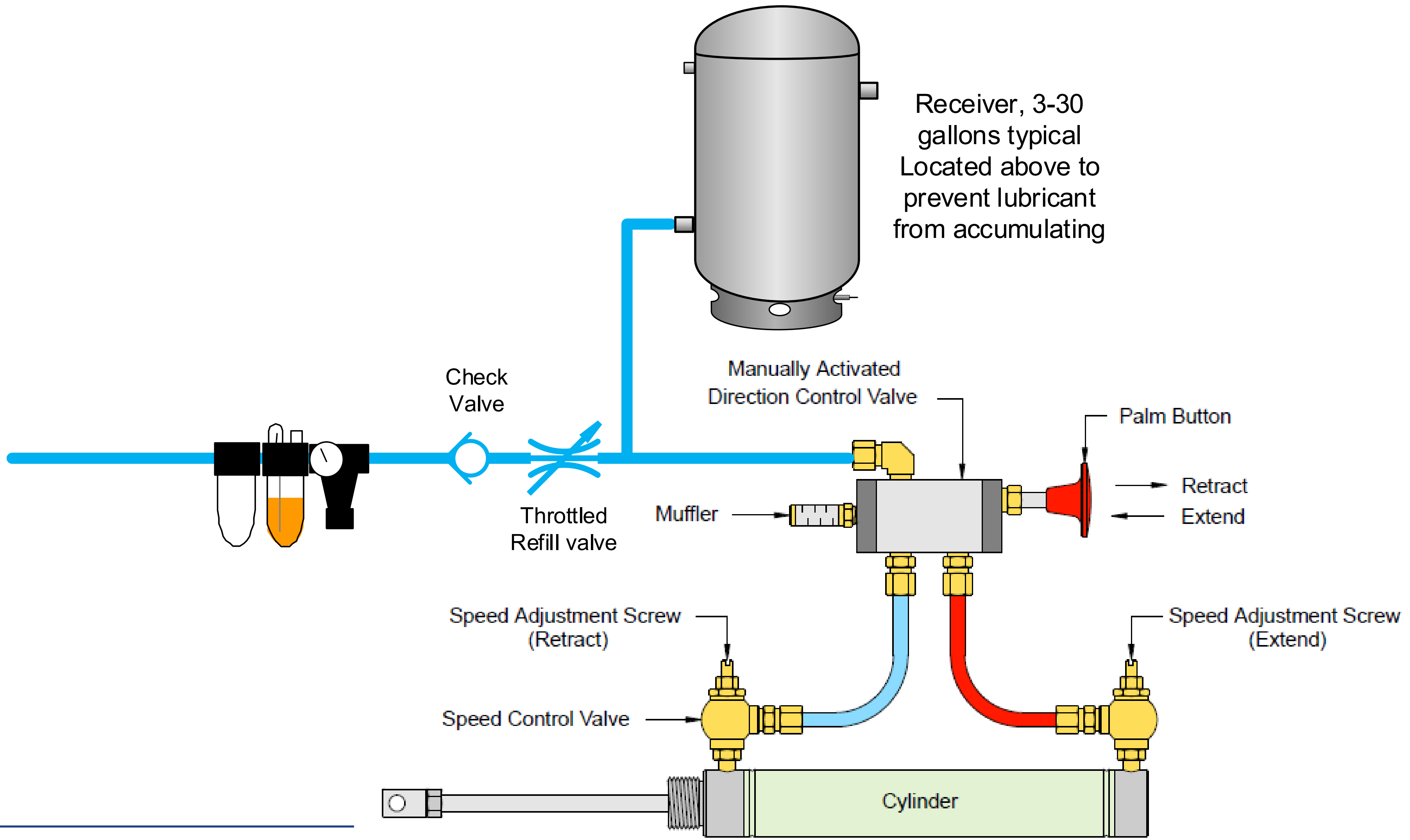
General Storage



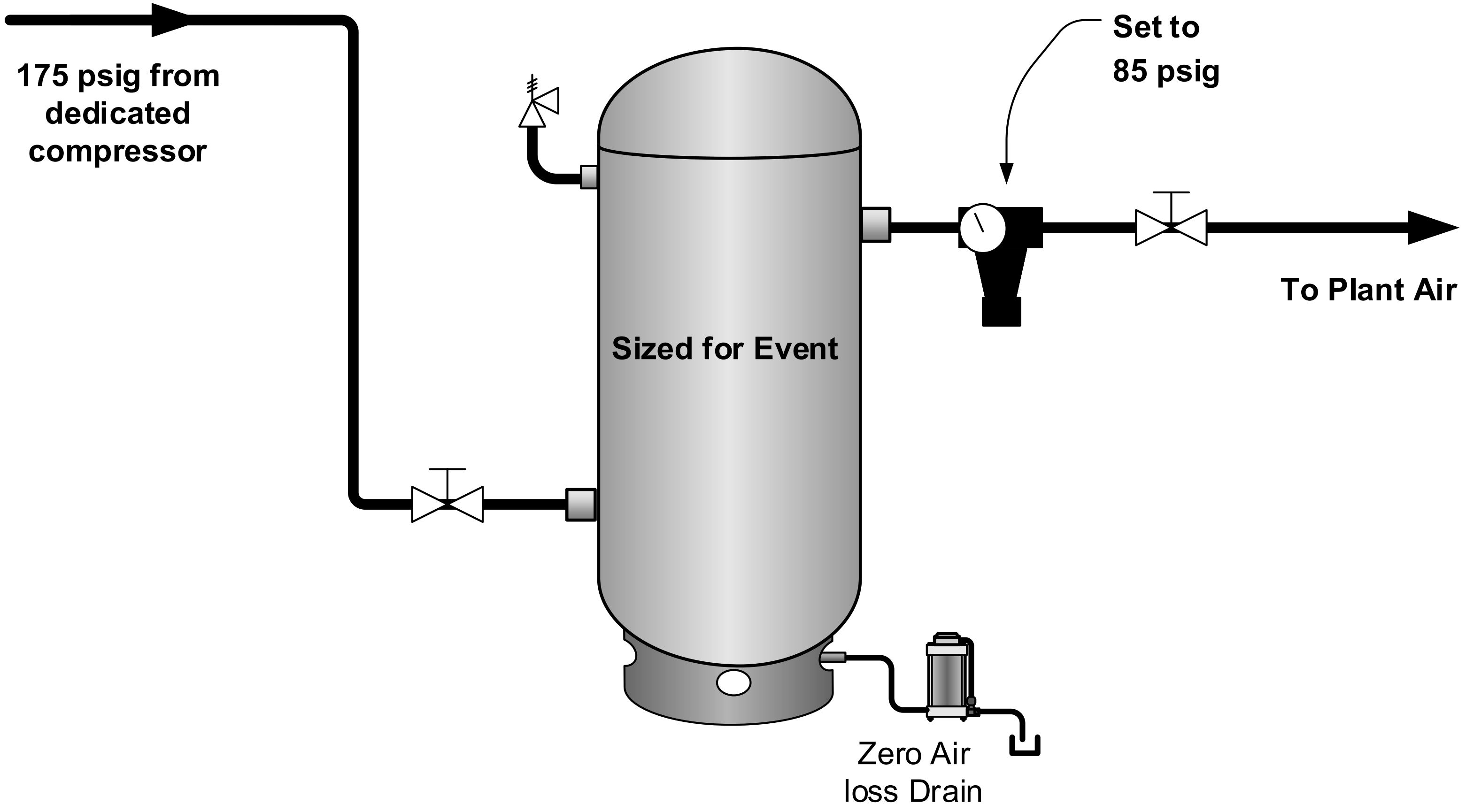
Dedicated Storage with Metered Recovery



Dedicated Storage with Metered Recovery



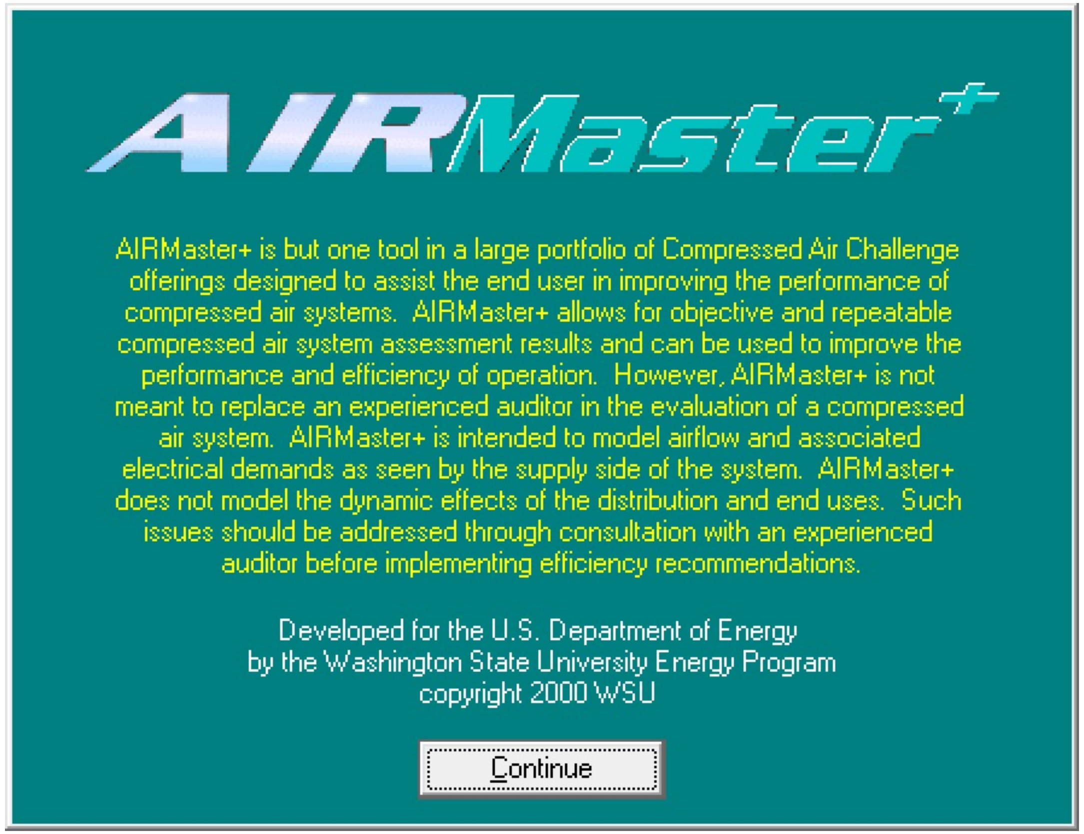
Offline High-Pressure Storage



Conclusion

- By applying the basic storage principles involved in a compressed air system, you can immediately improve the performance of production equipment in terms of productivity and quality and make major reductions in the operating costs of your compressed air system.
- The alternative to applying these basic storage principles in the system is to operate too much pressure and power all of the time to compensate for the lack of storage.
- The next time someone complains about insufficient air pressure, remember there are alternatives to raising the pressure and buying or operating another compressor.

Airmaster+ and LogTool Reveiw



Example Presentation

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Compressed Air Systems VINPLT: Close out Presentation

Company Name:
Facility Name:
Participant Name(s):

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Block Diagram of the Compressed Air System

Savings Opportunities in Compressor Controls

Savings Opportunities in Pressure Setpoints

Savings Opportunities in Compressed Air Distribution Systems

Savings Opportunities in Compressed Air Users

Tips Learned from this Training

Next Steps or Action Items after the Compressed Air VINPLT

- What are your next steps to implement opportunities?
- What are you planning to do after the VINPLT?
- Lessons learned?

Questions and Answers