Better Plants
U.S. DEPARTMENT OF ENERGY

In-Plant Trainings

Session 7 – System Volume vs Storage

Homework from Last Session

How Compressed is Possibly Used Inappropriately

Homework from Last Session

..ame: Tony Huynh

Is compressed air at your plant being used for any of the applications on this list? If so, explain how:

- **Padding**
  - We have some rubber pads that are filled with compressed air. It is controlled to apply a certain pressure on our product line.
- **Dense phase transport**
  - Sand and flour transport. We use the Macawber System to transport bulk materials from our silos.
- **Vacuum generation**
  - Our central vacuum system uses compressed air as part of its operations
- **Open handheld blowguns or lances**
  - This is a common use for our compressed air. The blowguns are often used to blow off dust and granules for housekeeping and functional purposes.
- **Cabinet cooling**
  - I have seen some cabinets with coolers that are fed from a compressed air line. The coolers are designed to use compressed air, so it is not a misuse of a compressed air line.
- Diaphragm pumps
  - A diaphragm pump was noted during one of our energy-savings treasure hunt walk

Homework from Last Session

Name: Samuel Davis

Is compressed air at your plant being used for any of the applications on this list? If so, explain how:

- Open blowing: No, except sometimes to blow powder from clothing. There is sign that says not to do this.
- Sparking (agitating, stirring, mixing): No, but only because we don't have enough compressed air. Instead there is discussion about using nitrogen for agitation. I have explained that it takes more energy and emissions to generate 1 SCFM of N2 than it does to generate 1 SCFM of air. The response is that because we receive nitrogen via pipeline, we just open the valve and buy more instantaneously. Getting more compressed air requires an investment and time. You can lead a horse to water....
- Dilute phase transport: Yes. The pneumatic transfer air system is separate from and equally as massive as the plant and instrument air system. Dilute phase transfer is recommended based on the properties of the solid product.
- Open handheld blowguns or lances: Yes. I am trying to end this practice.
- Cabinet cooling: I don't know
- Vacuum venturis: Yes. I am told that electric air movers have been purchased. The next challenge is to get people to use the electric air movers instead of the vacuum venturis.
- Diaphragm pumps: Yes. However, these do not run continuously.
- Timer drains/open drains: Yes

Homework from Last Session

Name: ______Ed Cooper________________________________

Is compressed air at your plant being used for any of the applications on this list? If so, explain how:

- Open blowing Yes Homemade air knifes for conveyor cleaning
- Sparking (agitating, stirring, mixing) No
- Dense phase transport – Yes used to transport bulk solids from ground level to receiver tanks 30 ft. up above.
- Open handheld blowguns or lances – Yes used to clean railcars
- Diaphragm pumps – Yes intermittent use to pump thick slurry.
- Timer drains/open drains – yes timer drain near air compressor
- Air Motors – Yes 1 small air vibrator

Homework from Last Session

Name: Dana DeRosier

Is compressed air at your plant being used for any of the applications on this list? If so, explain how:

- Timer drains/open drains – Compressors have timer activated drains

Homework from Last Session

Name: ___Nate Kirkeby____

Is compressed air at your plant being used for any of the applications on this list? If so, explain how:

- Open blowing – Part blow-off at some workstations
- Sparking (agitating, stirring, mixing) – Agitators for paint line and spray heads
- Atomizing – Humidifiers used for plant humidification. Large user of compressed air.
- Open handheld blowguns or lances - We restricted the opening blowing that was used to clean off dust (housekeeping). We still allow open blowing with a limited 30 PSI air gun within the woodworking machines where access is difficult by other means.
- Timer drains/open drains – In some instances we have air powered condensate drains
- Air Motors – Yes, we have been moving towards using more electric motors, but some of the manufacturing equipment have air motors on them.

Homework from Last Session

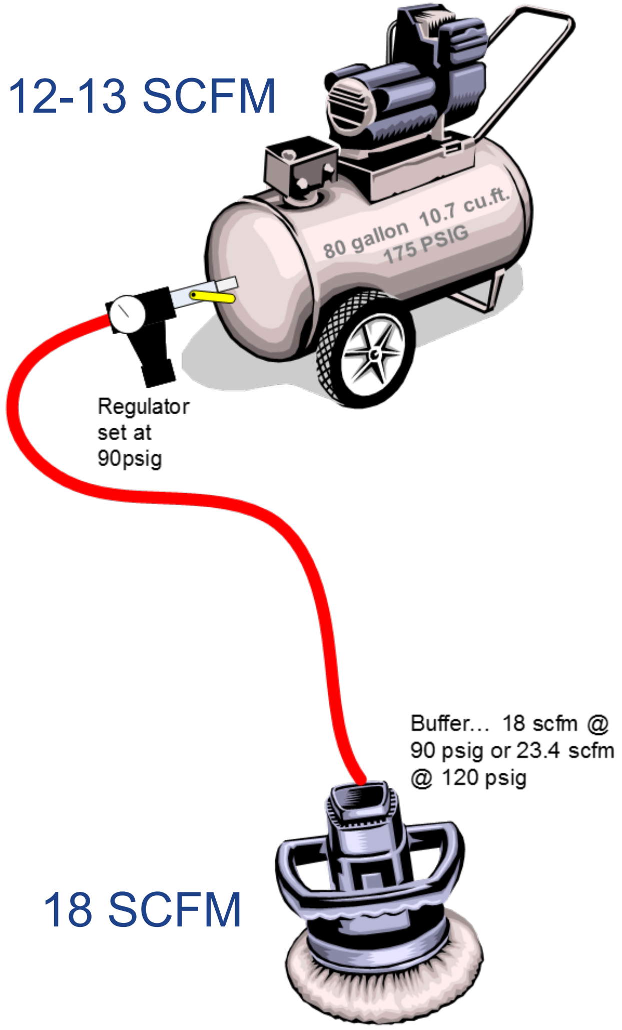
Name: Ken Stevens

- Open blowing-Drying off acid washed parts before liquid painting
- Sparking (agitating, stirring, mixing)-Air motors for paint agitation/stirring
- Open handheld blowguns or lances-Air drying washed parts
- Air Motors-Agitating/stirring liquid paint

System Volume vs Storage

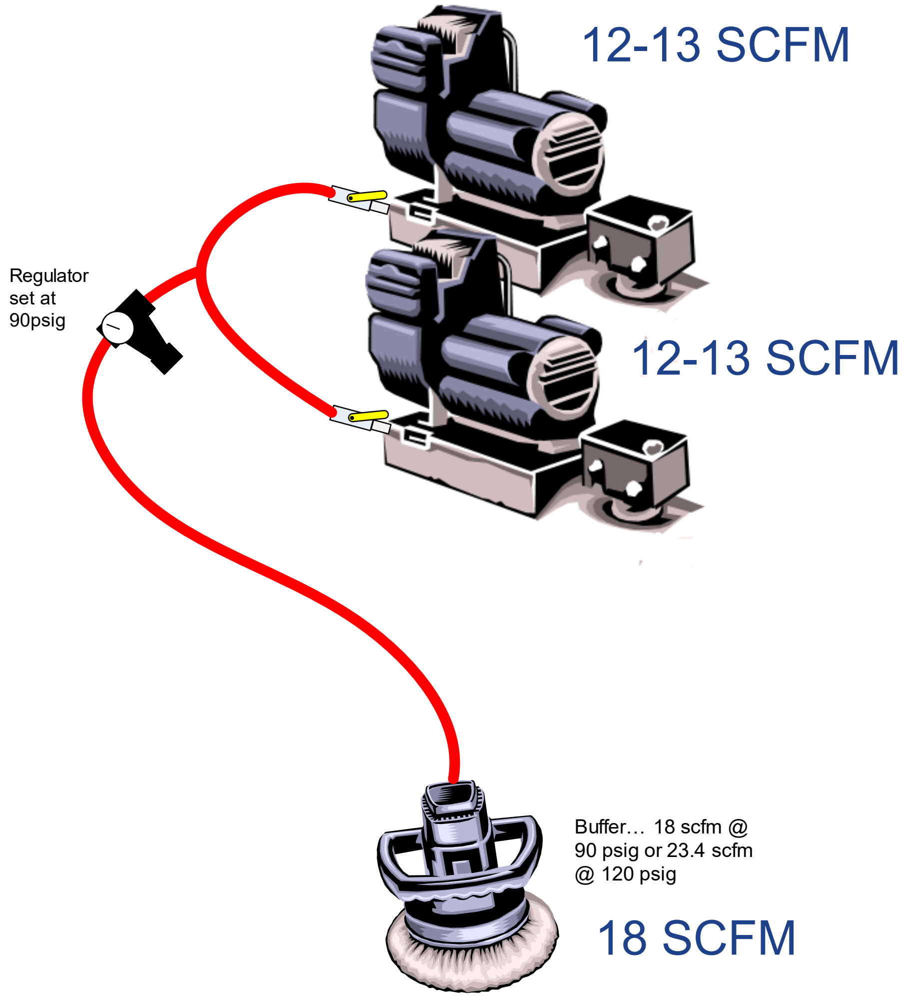
A Simple Example

- 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

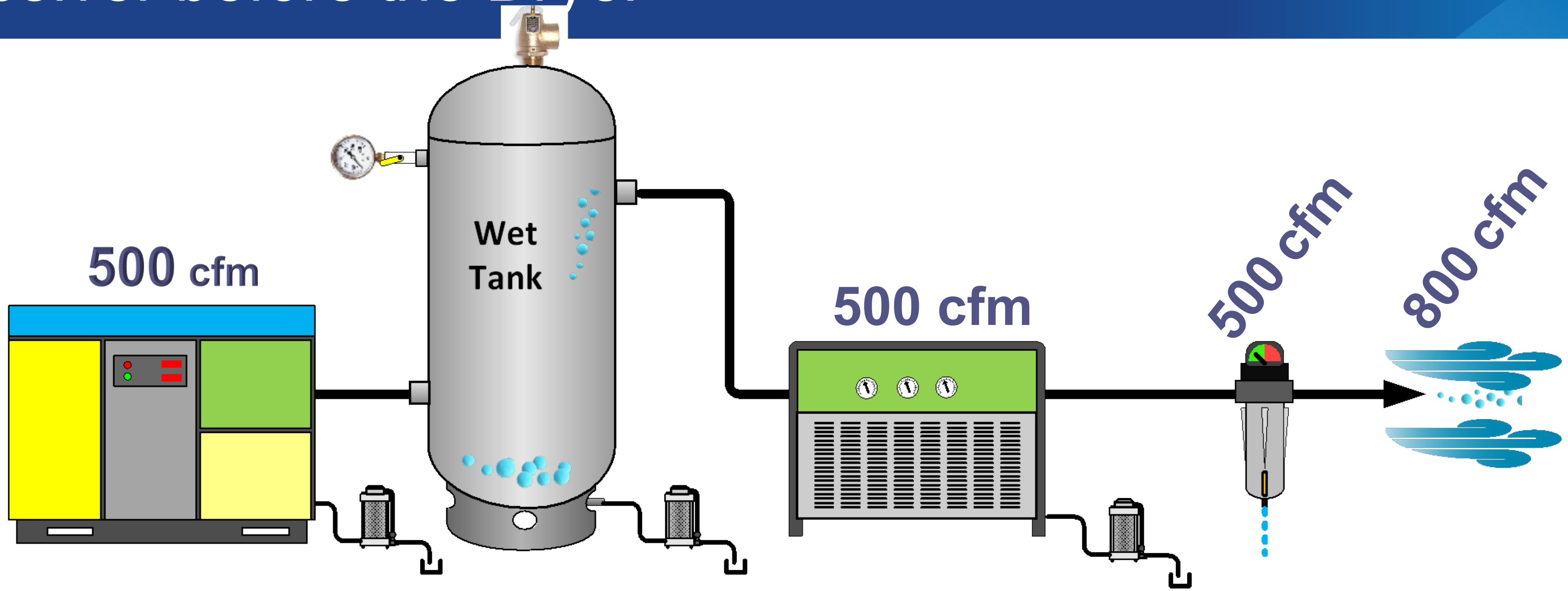
- With no receiver, the painter must install a second 5 hp compressor and therefore use twice the energy as before



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

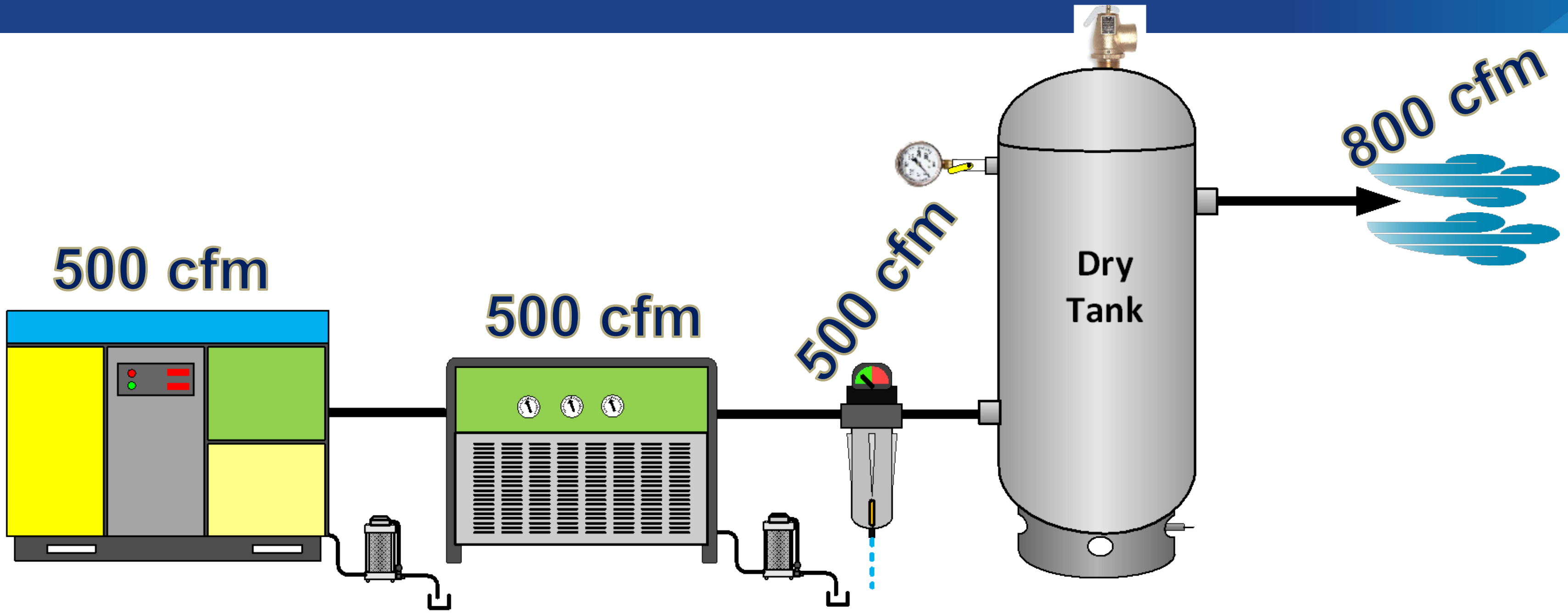


- A Wet Receiver creates radiant cooling and drops out some of the condensate and entrained oil, thus benefiting the dryer.
- However, the receiver will be filled with saturated air, and if there is a sudden demand that exceeds the capacity rating of the compressor and matching dryer, the dryer can be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

Where Does it Go?

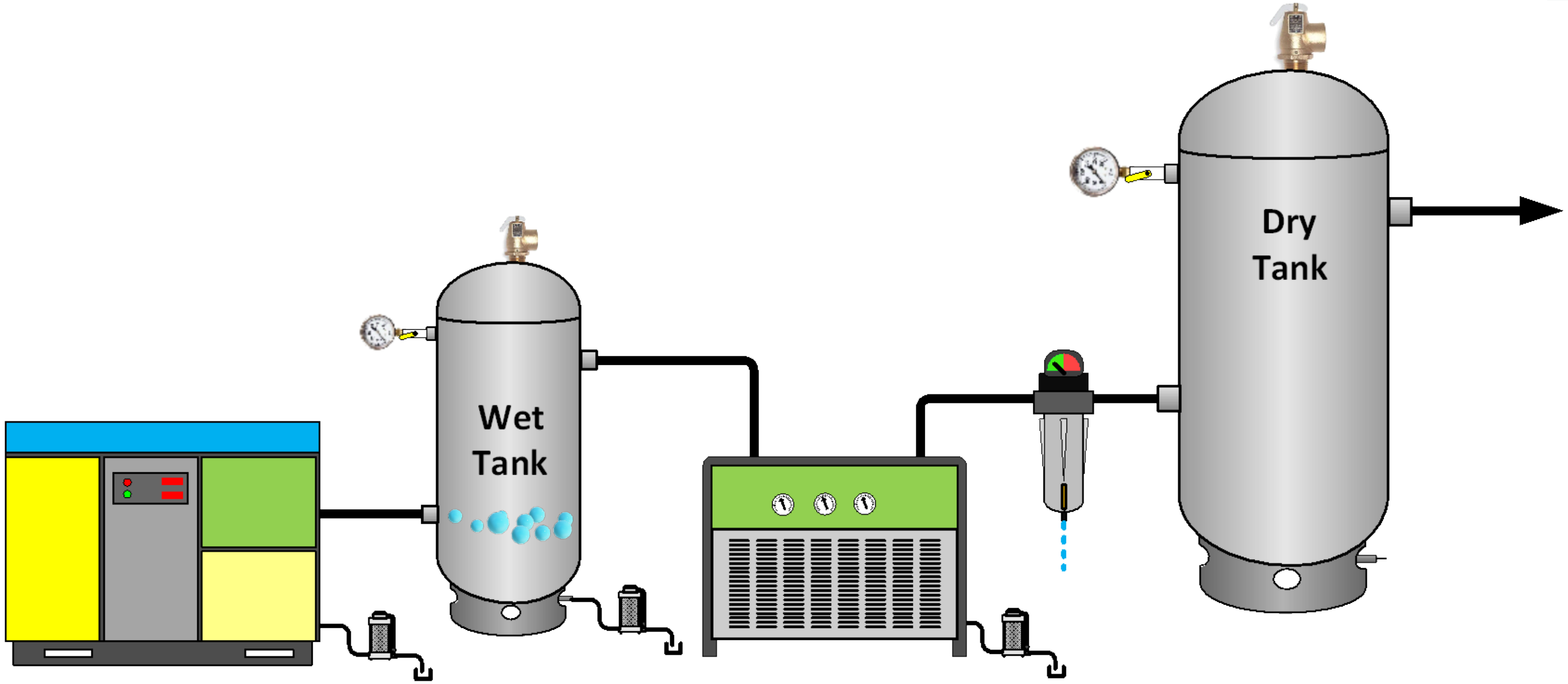
- Dry Receivers: Dry receivers are located immediately downstream of dryers and filters.
- When sudden large air demands occur, dry air receivers should have adequate capacity to minimize a drop in system air pressure.

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.


PLANT COMPRESSED AIR
PROCESS COMPRESSED AIR
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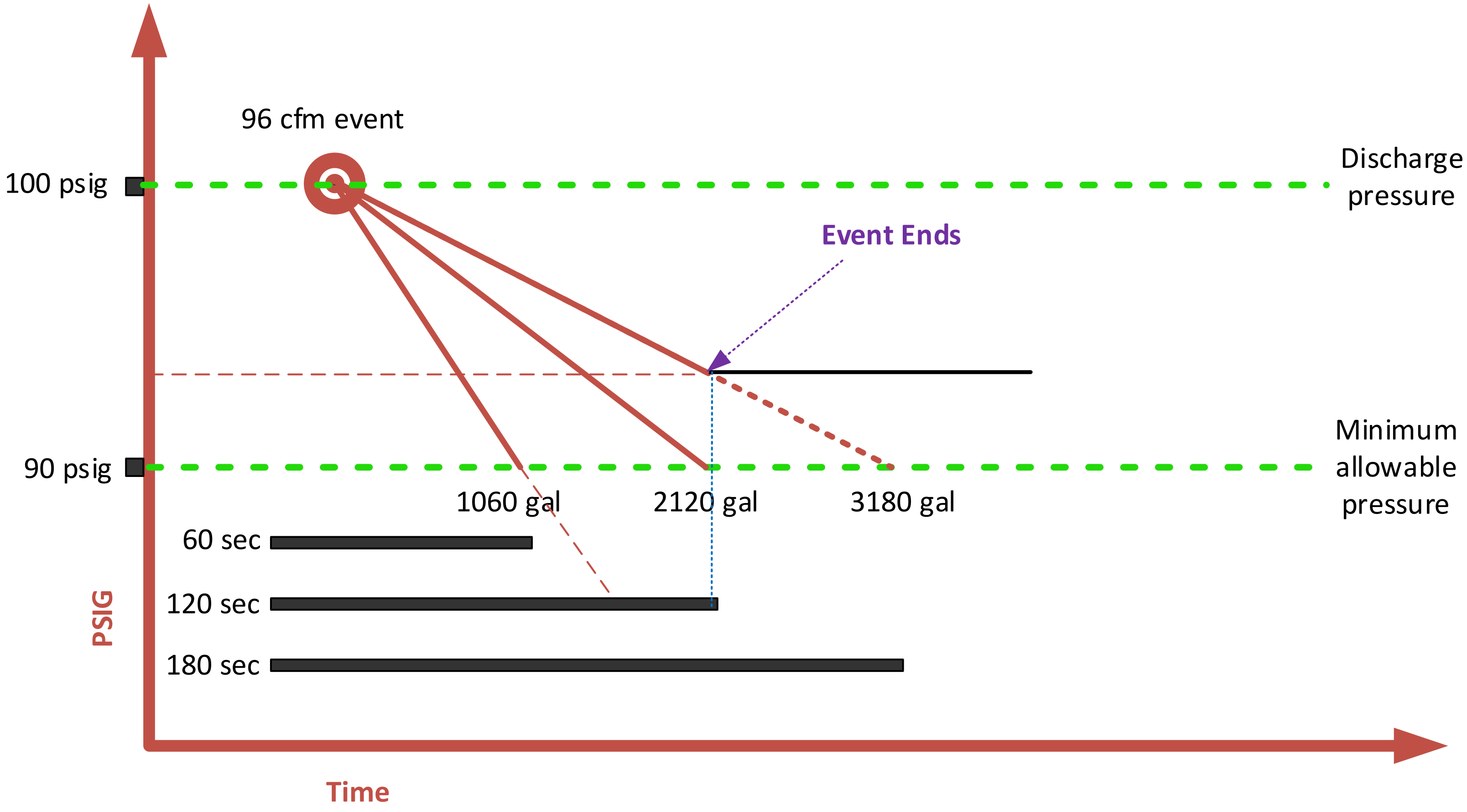
Effect of Storage on Rate of Change

- Control storage has a tremendous influence upon rate of change
- Larger control storage means slower rate of change.
- Slower rate of change allows the system to handle more demand events without adding on-line HP.
- Consider the following example:

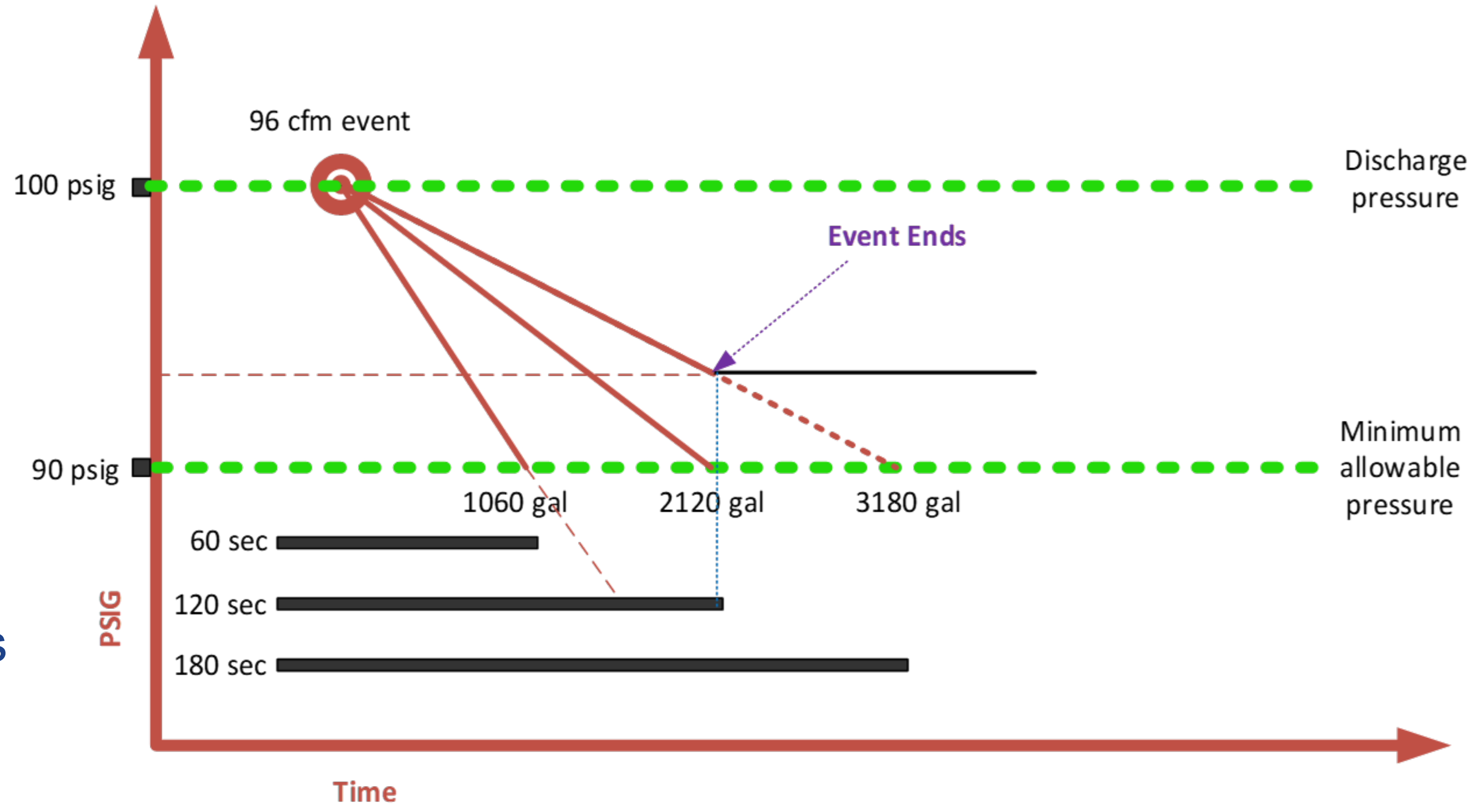
Effect of Storage on Rate of Change

- The minimum allowable, critical pressure, for a system is 90 psig.
- The one operating compressor in the system is fully loaded and maintaining the system at a discharge pressure of 100 psig.



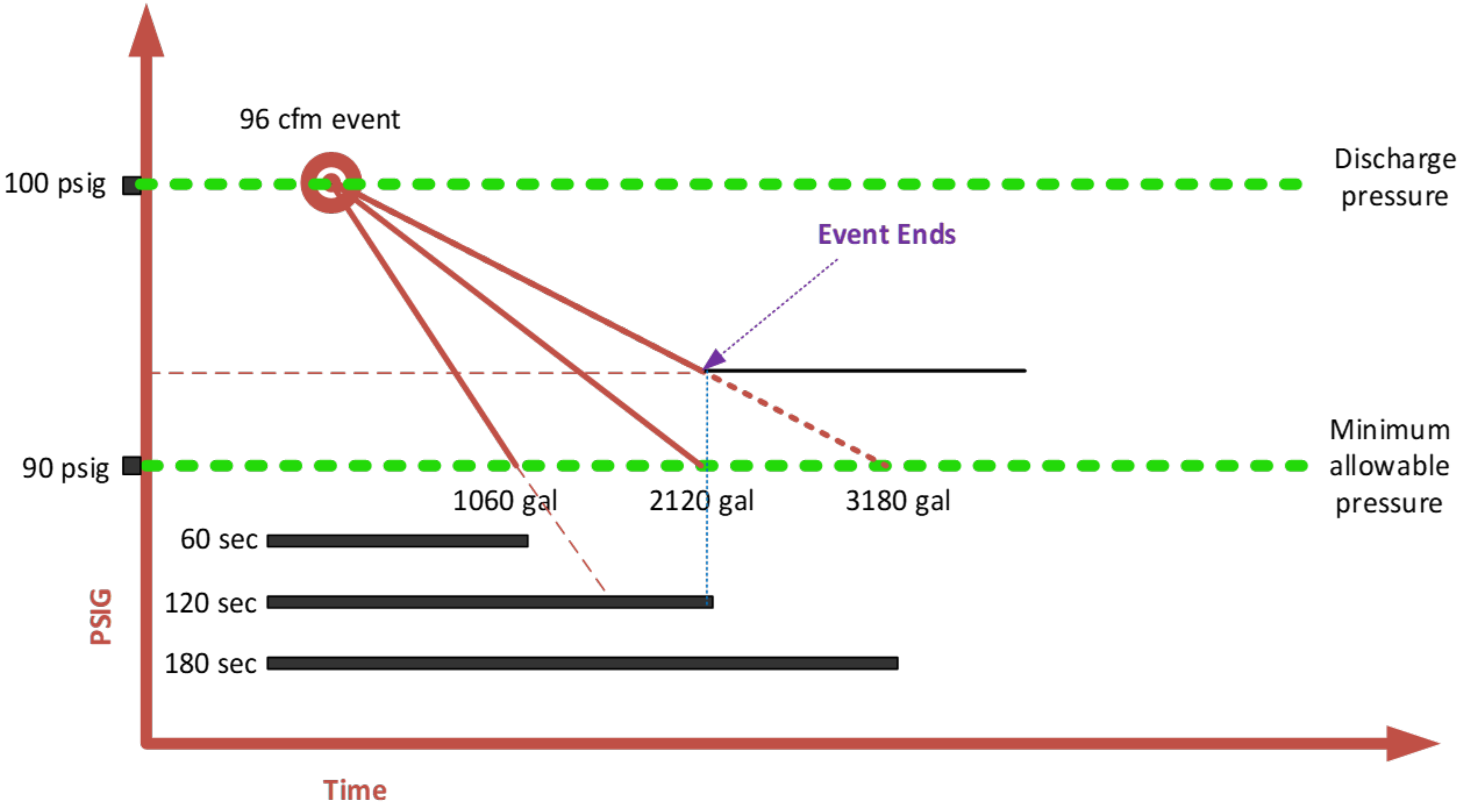
Effect of Storage on Rate of Change

- Someone operates a tool in the plant that consumes an additional 96 cfm.
- Since the compressor is fully loaded and cannot deliver the additional 96 cfm, there is a negative rate of change of 96 cfm and system pressure falls because demand is greater than supply.



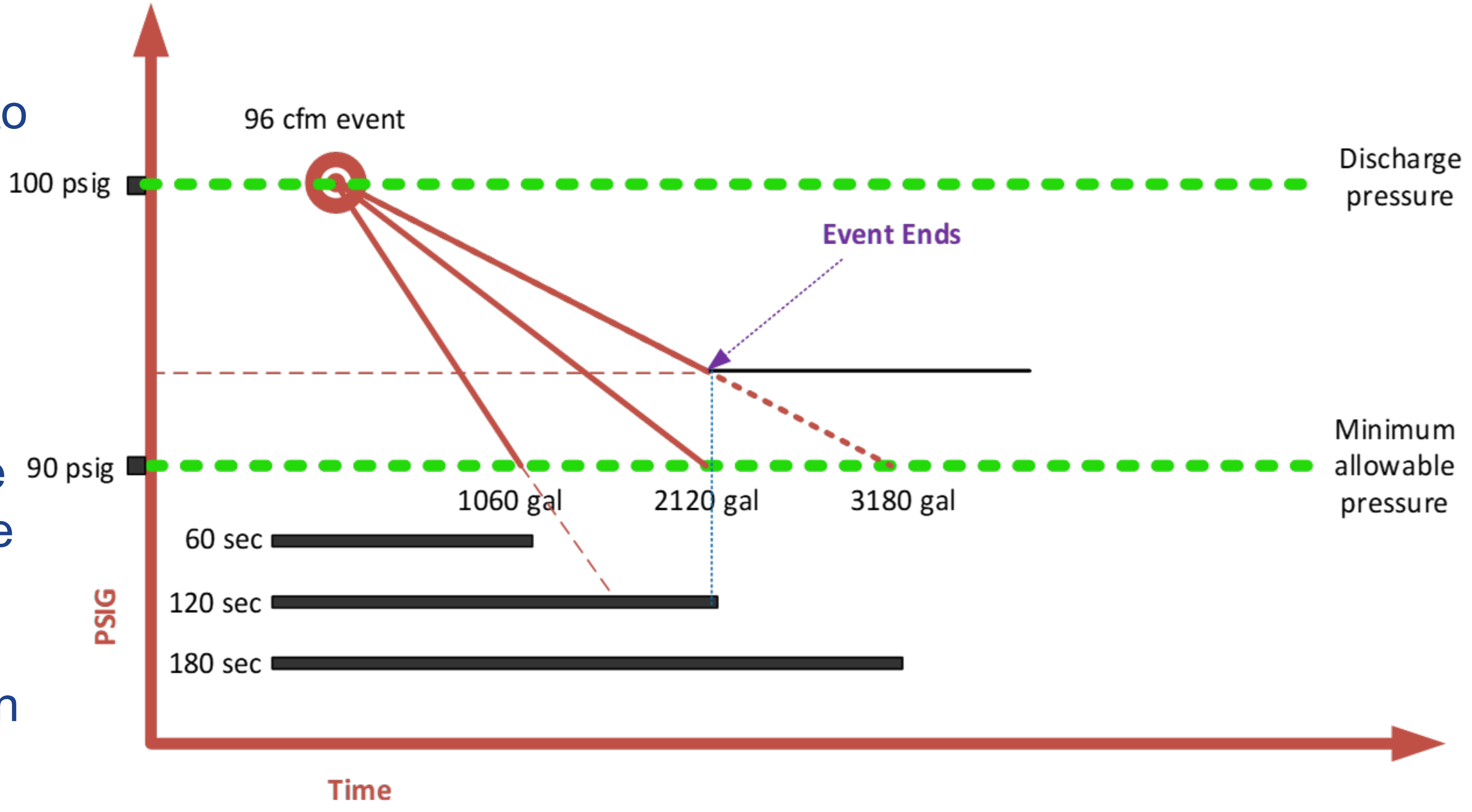
Effect of Storage on Rate of Change

- If the control storage is 1060 gallons, it will take 60 seconds, one minute, for the plant pressure to fall from 100 psig to 90 psig.
- If the control storage is doubled to 2120 gallons, it will take double the time, 2minutes, for the plant pressure to fall from 100 psig to 90 psig.
- If the control storage is tripled to 3180 gallons, it will take triple the time, 3 minutes, for the plant pressure to fall from 100 psig to 90 psig.



Effect of Storage on Rate of Change

- As this example shows, the time to reach the critical pressure during any event is directly proportional to the total amount of control storage in the system.
- By slowing the rate of change, control storage allows time for the system dynamics to change to the point that the demand becomes less than supply and pressure recovers without having to start an additional compressor.



System Drawdown

Capacitance:

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

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

Example: If the control storage is 1060 gallons, how long will it take the plant pressure to fall from 100 psig to 90 psig.

96 acfm = **1.6 cu ft/se**c and capacitance = 1060gal ÷ 7.48gal/cuft = 147.711 cuft

147.711/14.7 = **9.64cuft /psi**

1.6 cuft/sec ÷ 9.64 cu ft/psi = .166 psi/sec

.166 psi/sec x 60 sec = 9.96 psi

System Drawdown

Using Receiver Calculation:

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

Solve for ΔP

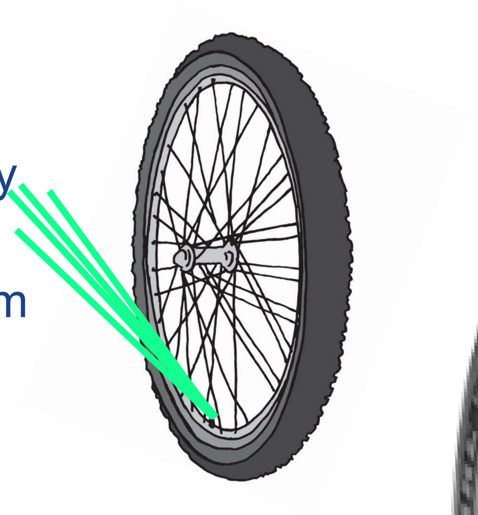
$$\Delta P = \frac{T_{\min} \times (DebitFlow) \times P_a}{V_{cf}}$$

$$\Delta P = \frac{(1_{\min}) \times (96_{cfm}) \times 14.7}{147.711_{cf}} = 9.9\,psig$$

Local Storage to Stabilize Pressure Fluctuations

System Volume

- System volume is very important to compressor control.
- Think of the real-world comparison of a bicycle tire to a heavy truck tire.
- Both run at the same 100psi, but when you tap the valve stem of the bicycle tire, it goes flat, the bike is un-rideable. Tap the valve stem of the heavy truck tire and it doesn't care. It's probably still at 100psi.
- This is the difference that system volume makes in a compressed air system. Larger volume makes the system more stable, making controls more effective.



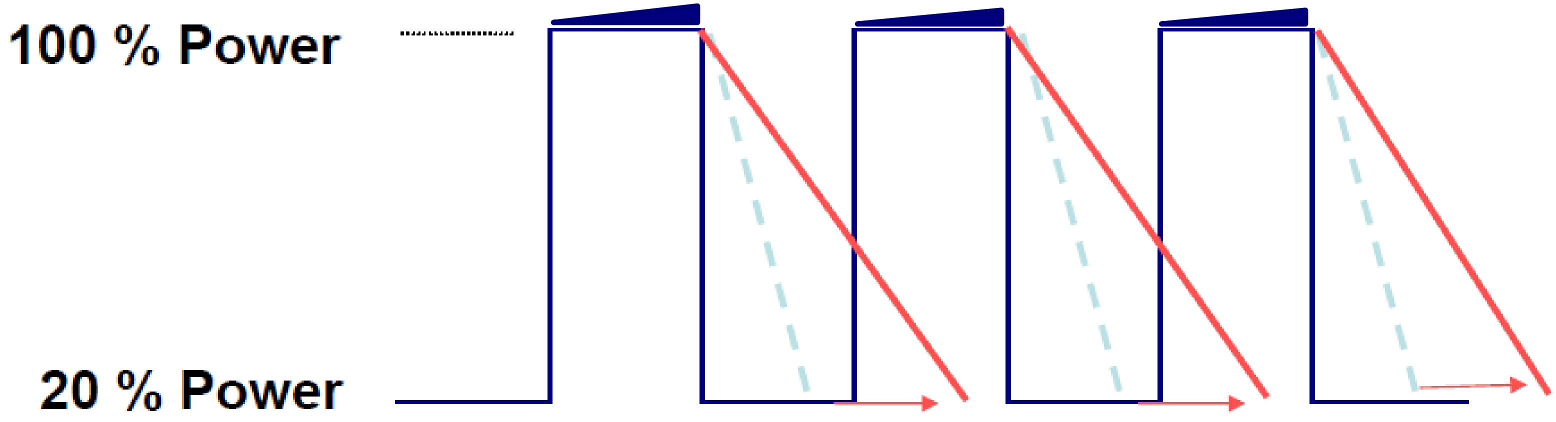
What Size for Control Storage?

- 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.
- You should be at 5 gal/cfm of the trim compressor.
- Rule of thumb is 3-5 but a system analysis will show you the proper control storage to be using.

What Size for Control Storage?

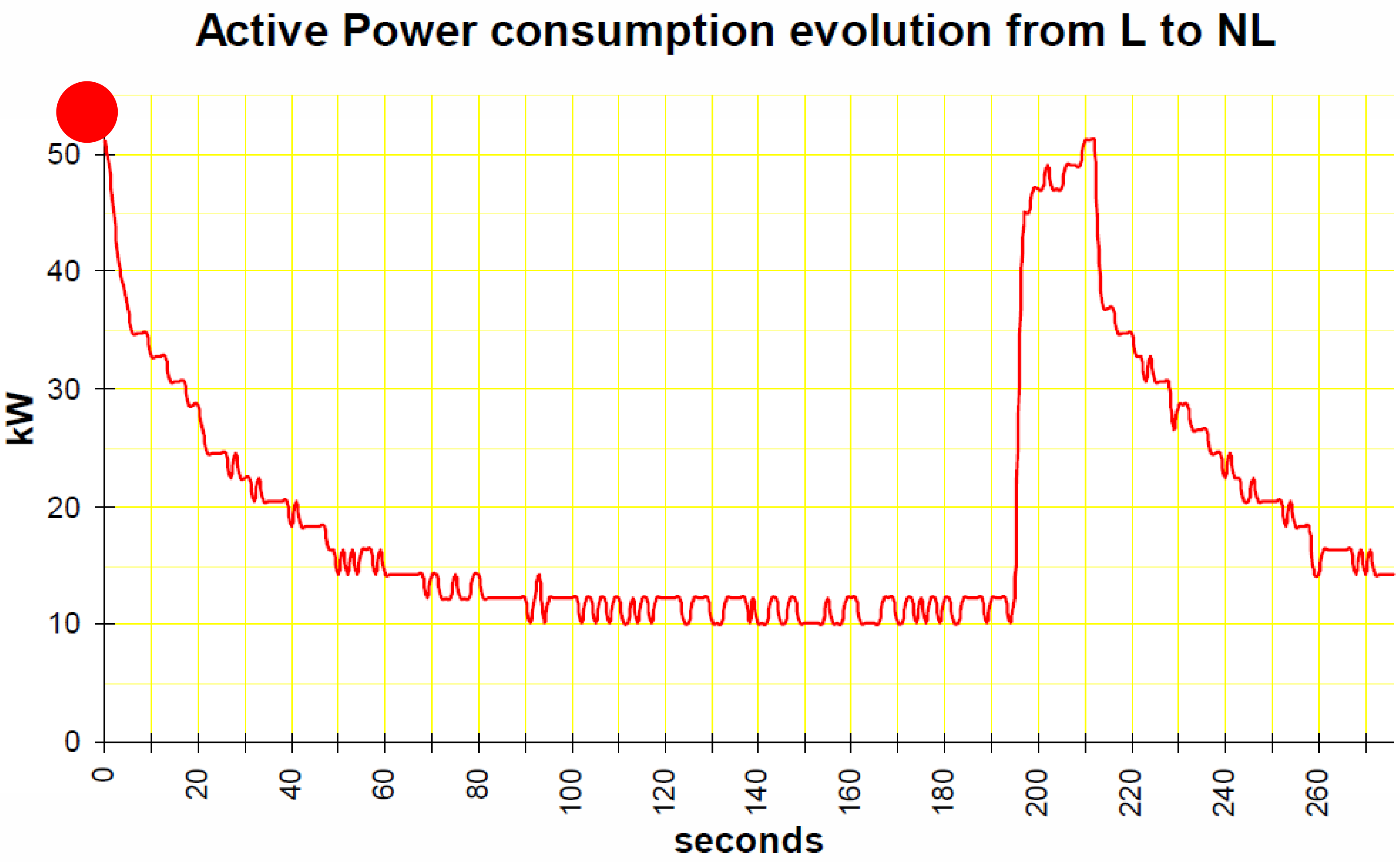
- Some oil injected rotary screw compressors are sold with load/unload capacity control, which is claimed to be the most efficient.
- This also can be misleading, since an adequate receiver volume is essential to obtain any real savings in energy.
- Some rules of thumb established many years ago for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

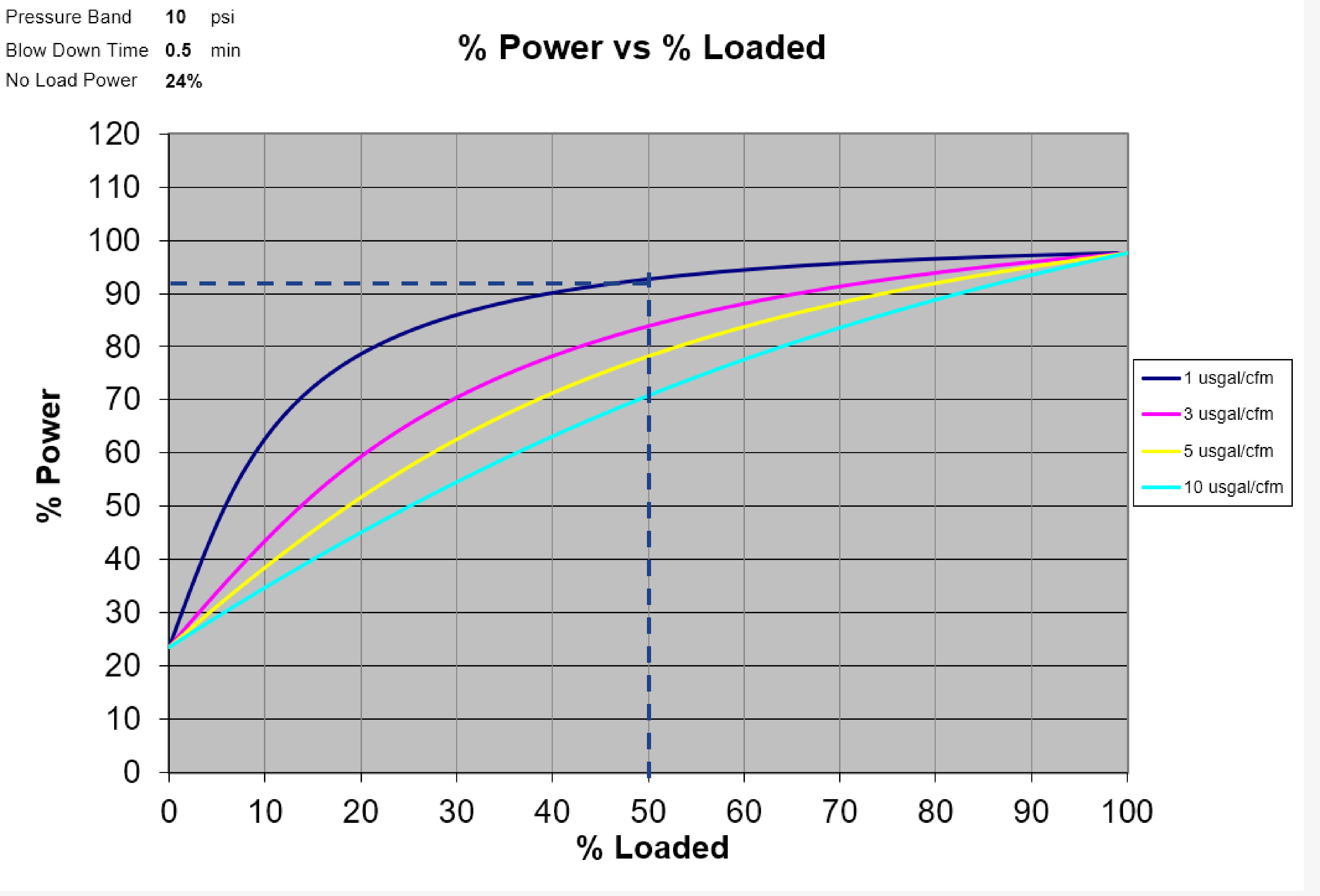
Capacity Control by Load/No-Load



- 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



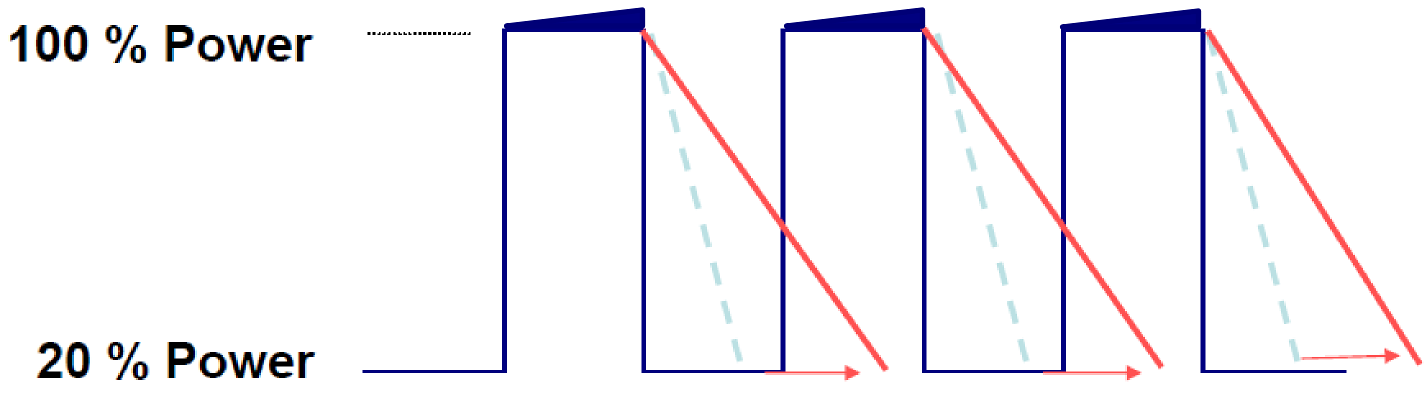


Pressure Band 10 psi
Blow Down Time 0.5 min
No Load Power 24%
% Power vs % Loaded
% Power
% Loaded
0
10
20
30
40
50
60
70
80
90
100
110
120
1 usgal/cfm
3 usgal/cfm
5 usgal/cfm
10 usgal/cfm

What Size For Variable Speed Compressors?

- For variable speed compressors the receiver size should still be 3 -5 gallons/cfm
- 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.

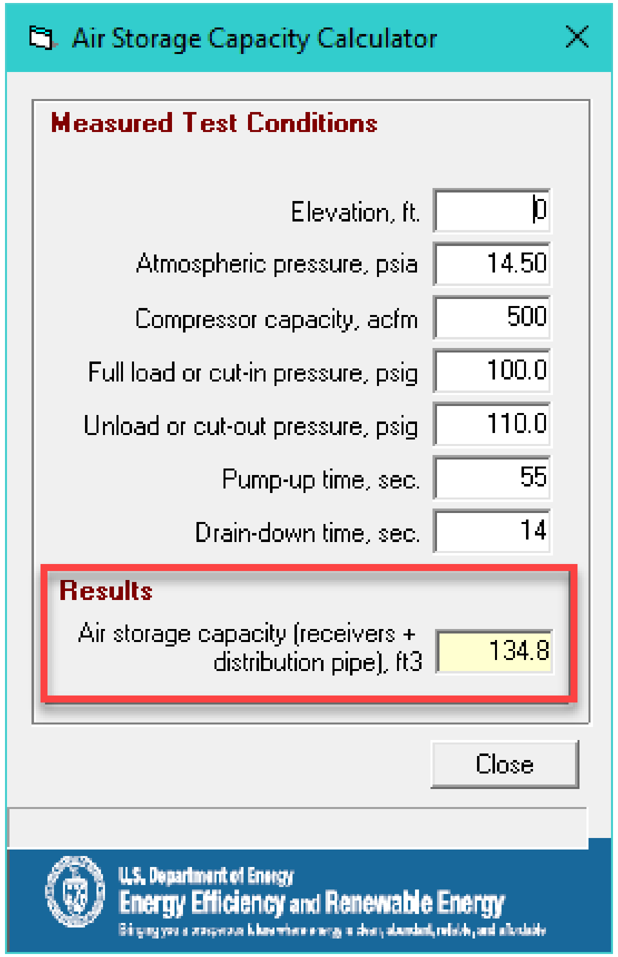
What Size For Oil Free Compressors?



- 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.

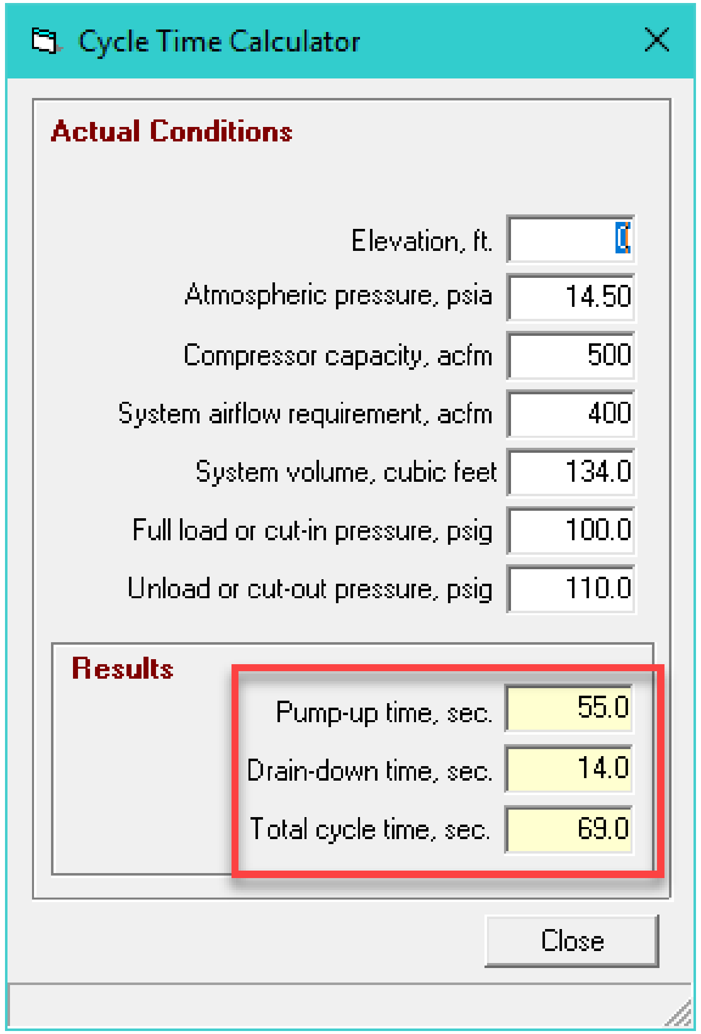
How do you determine "Effective" Volume?

- 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



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



Receiver Sizing for Demand Events

- A system operates with 100 scfm demand deficit for 30 seconds of time. If the system pressure must be no lower than 90 psig and at the beginning of the event the pressure is 100 psig, what size receiver is necessary?
  - Use the MEASUR Tool for “Receiver Tank Sizing”

Receiver Sizing for Demand Events

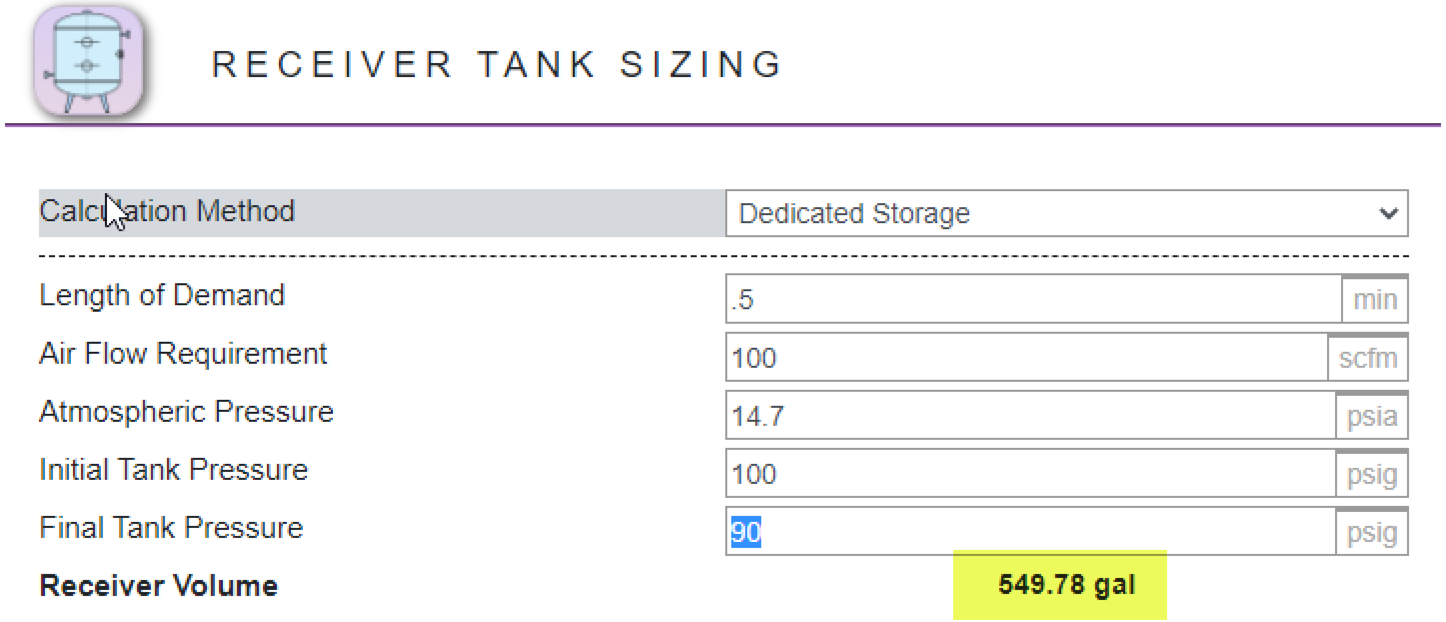
- Answer

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

$$V_{cf} = \frac{.5 \times (100) \times 14.7}{10}$$

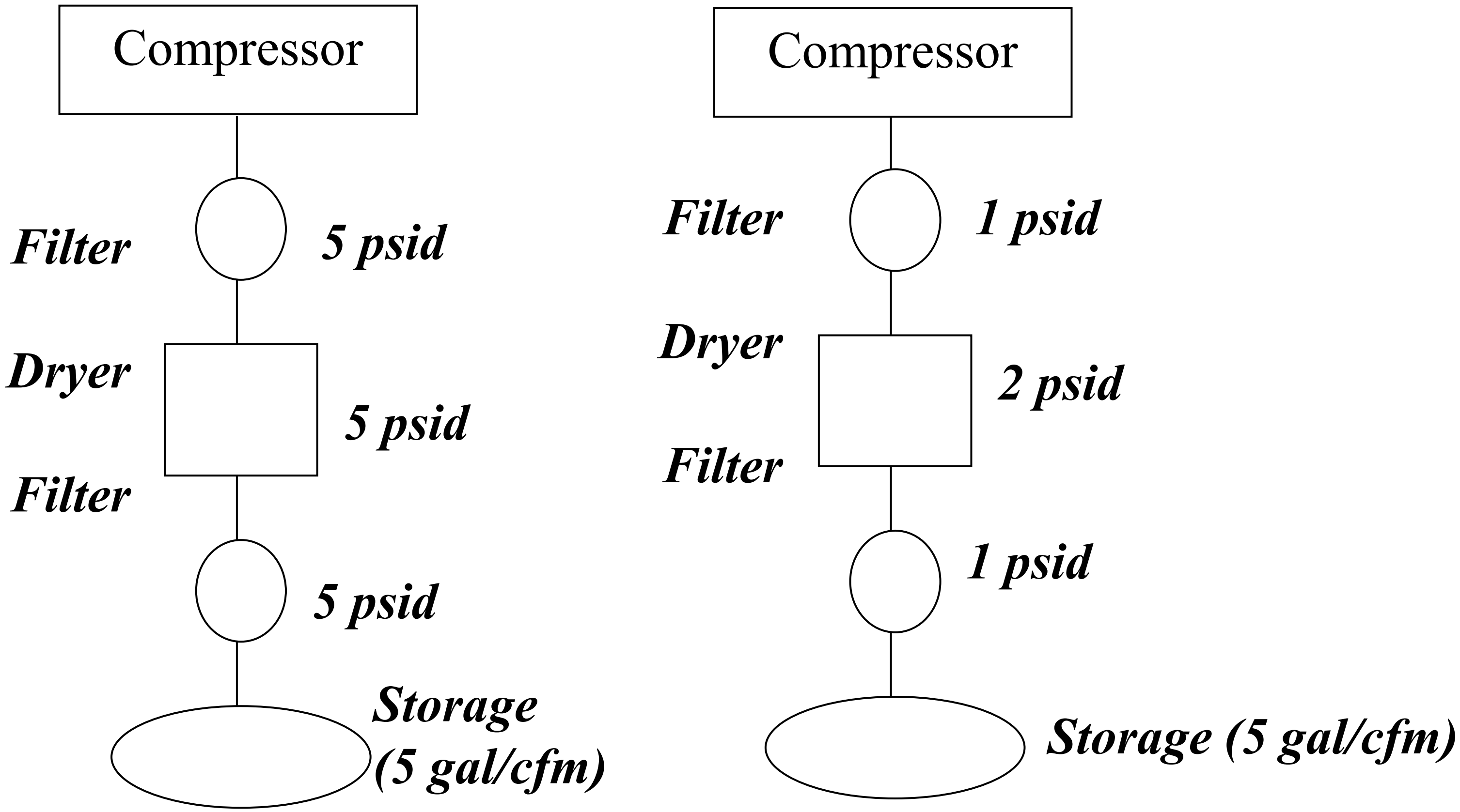
$$V_{cf} = 73.5$$

$$V_{gal} = 73.5_{cf} \times 7.48_{galcf} = 549.78_{gal}$$



Effectiveness of Storage

Compressor has a 10 psig Control Band

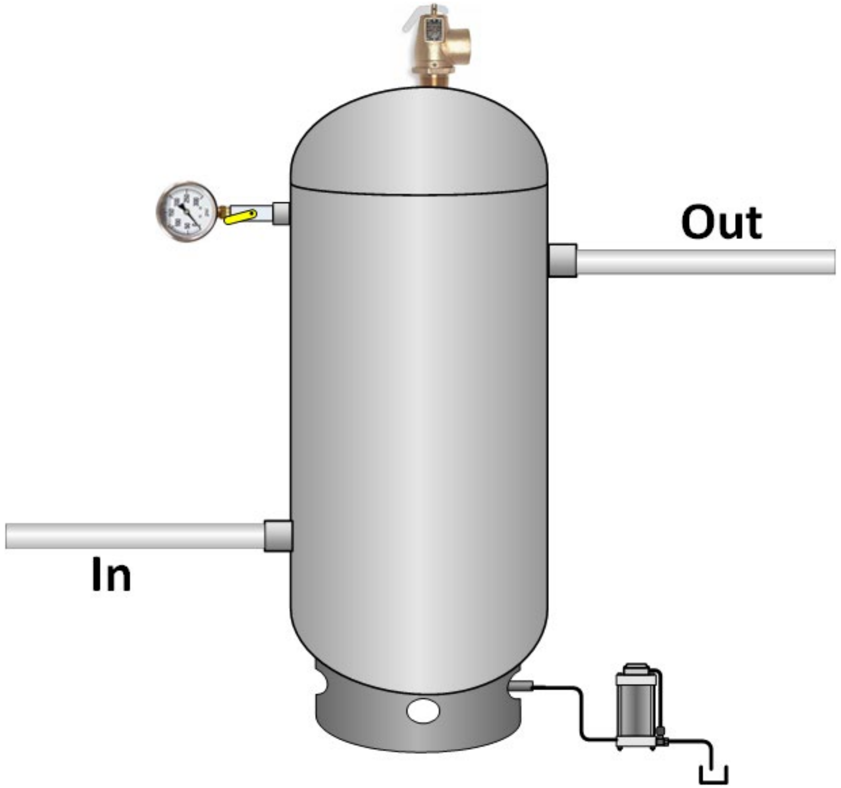


Some Best Practice Recommendations:

- 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

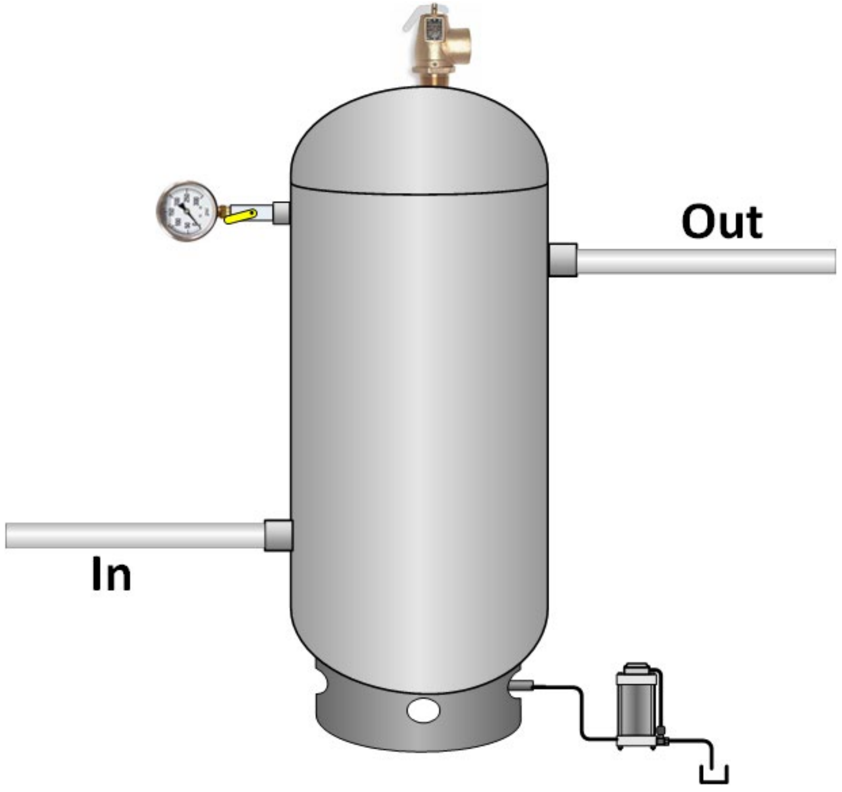
Some Best Practice Recommendations:

- 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

$$V = \frac{T(C-S)Pa}{P_1 - P_2}$$

- 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
- Pa = Absolute atmospheric pressure (psia)
- P1 = Initial receiver pressure
- P2 = 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**	

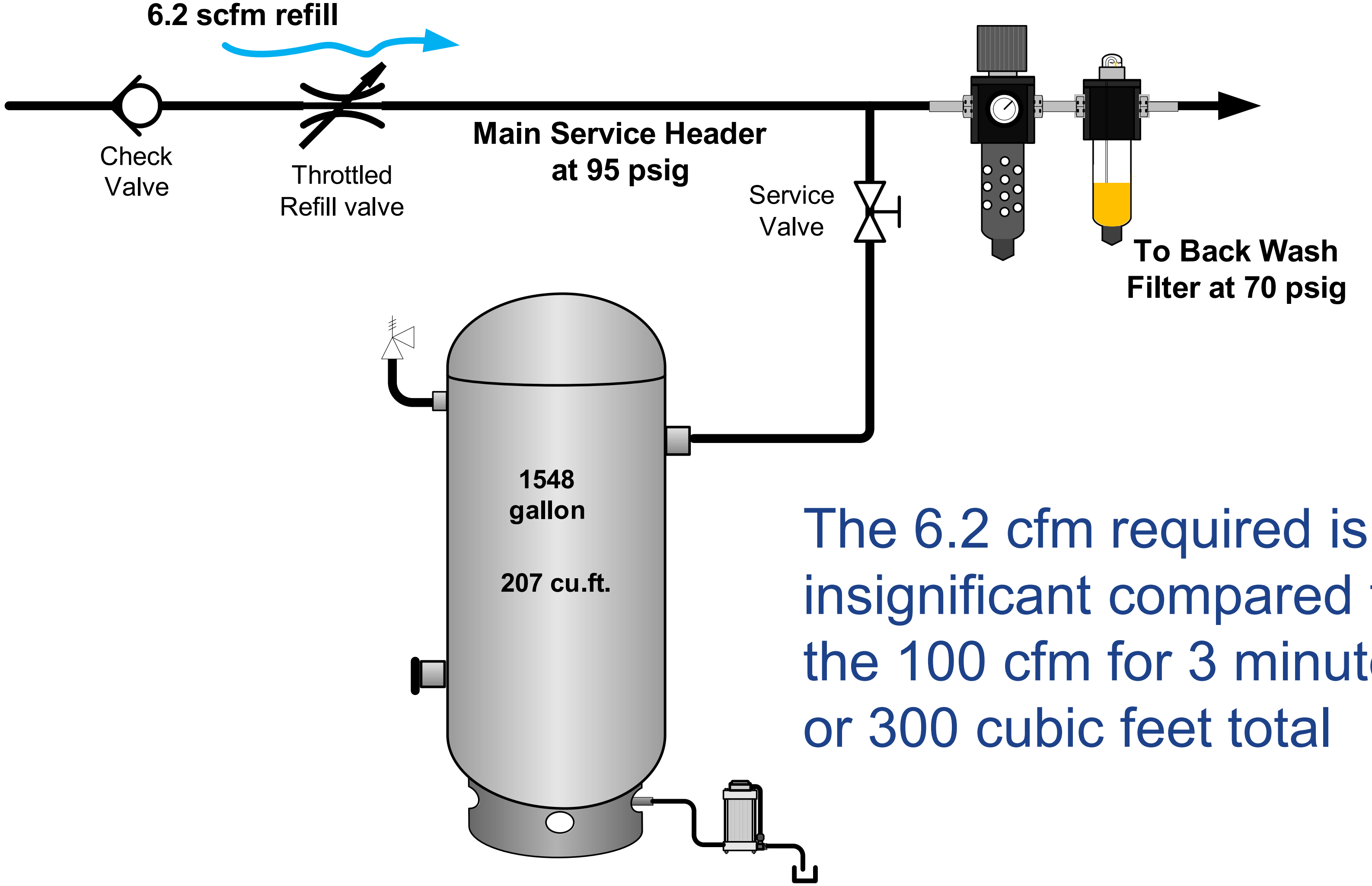
Generate Example | Reset Data

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.

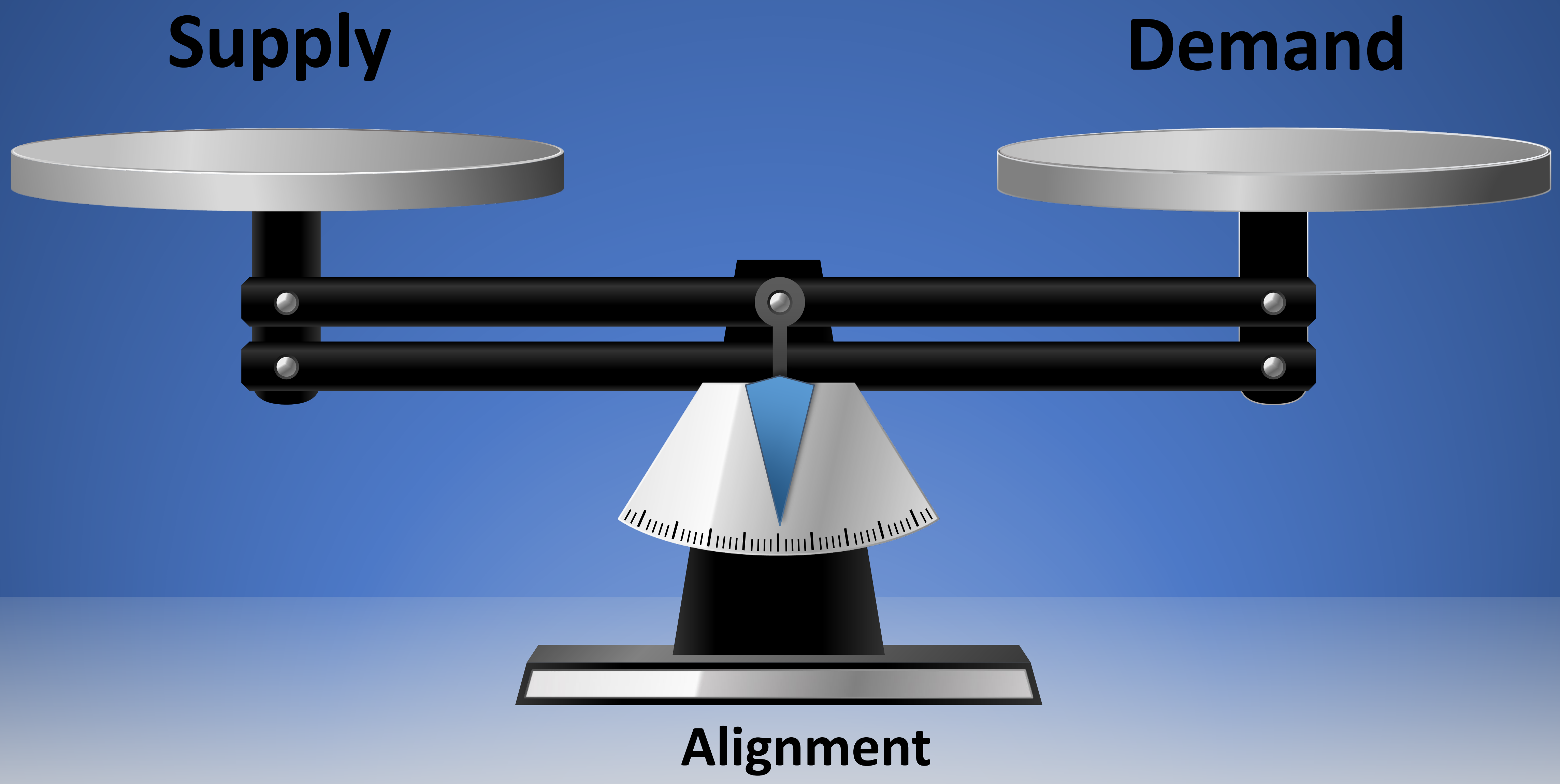
$$Solving\ For\ S = \frac{Vx(P_1 - P_2)}{T \times 14.7} \qquad S = \frac{207 \times (25)}{57 \times 14.7} = 6.2\ CFM$$

Example

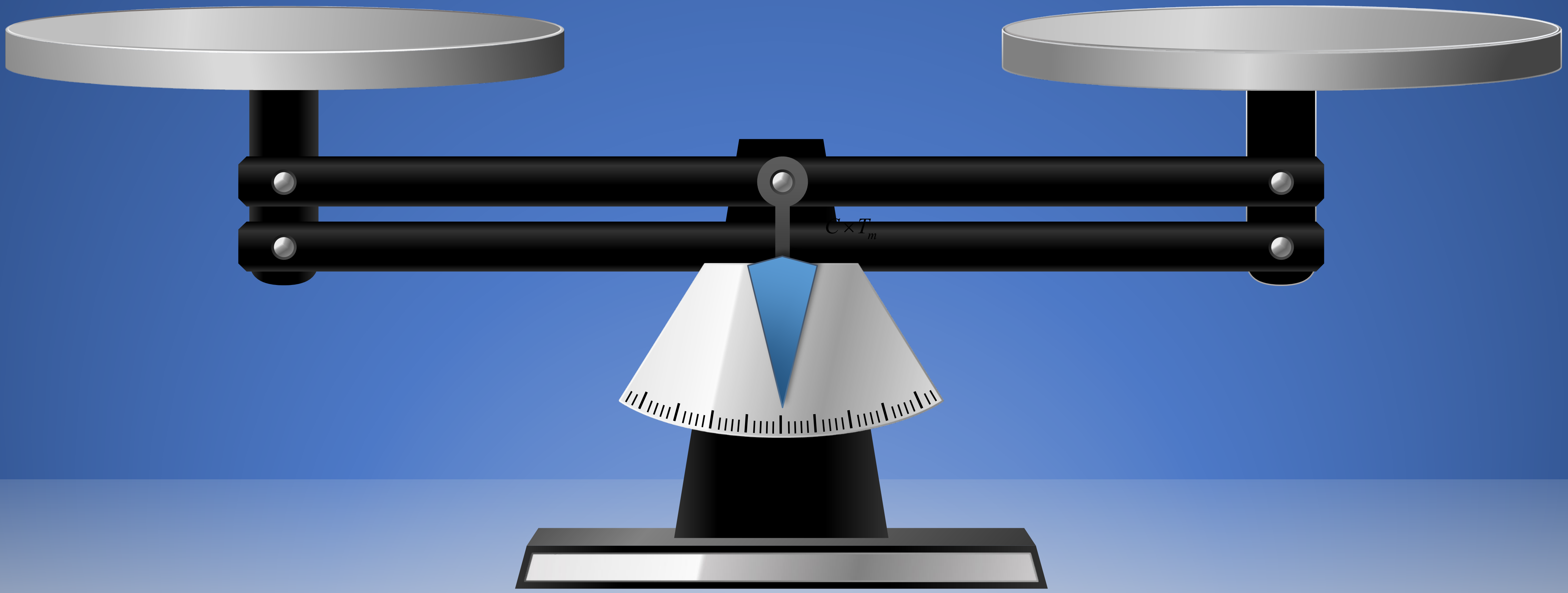


The 6.2 cfm required is insignificant compared to the 100 cfm for 3 minutes or 300 cubic feet total

Another way of looking at this Back Wash Filter Problem

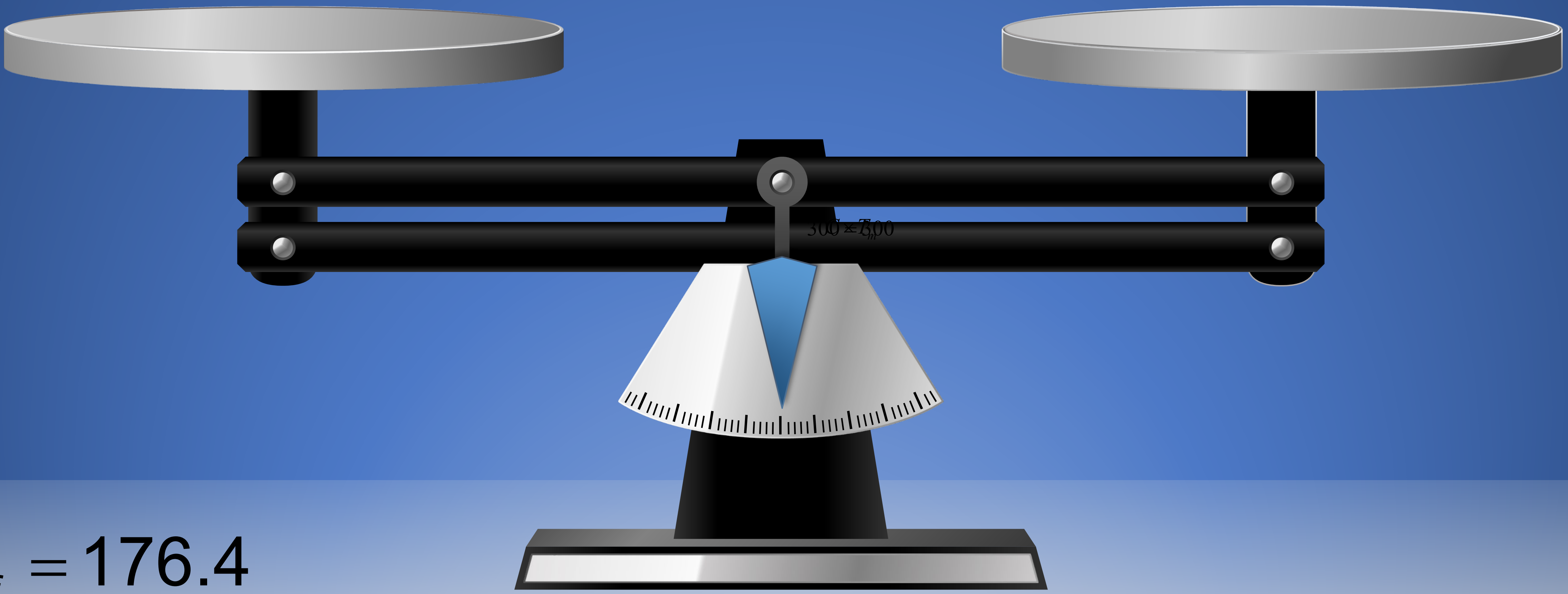


$$V_{cf} \times \frac{\Delta P}{P_a} = C \times T_m$$



Supply = Demand

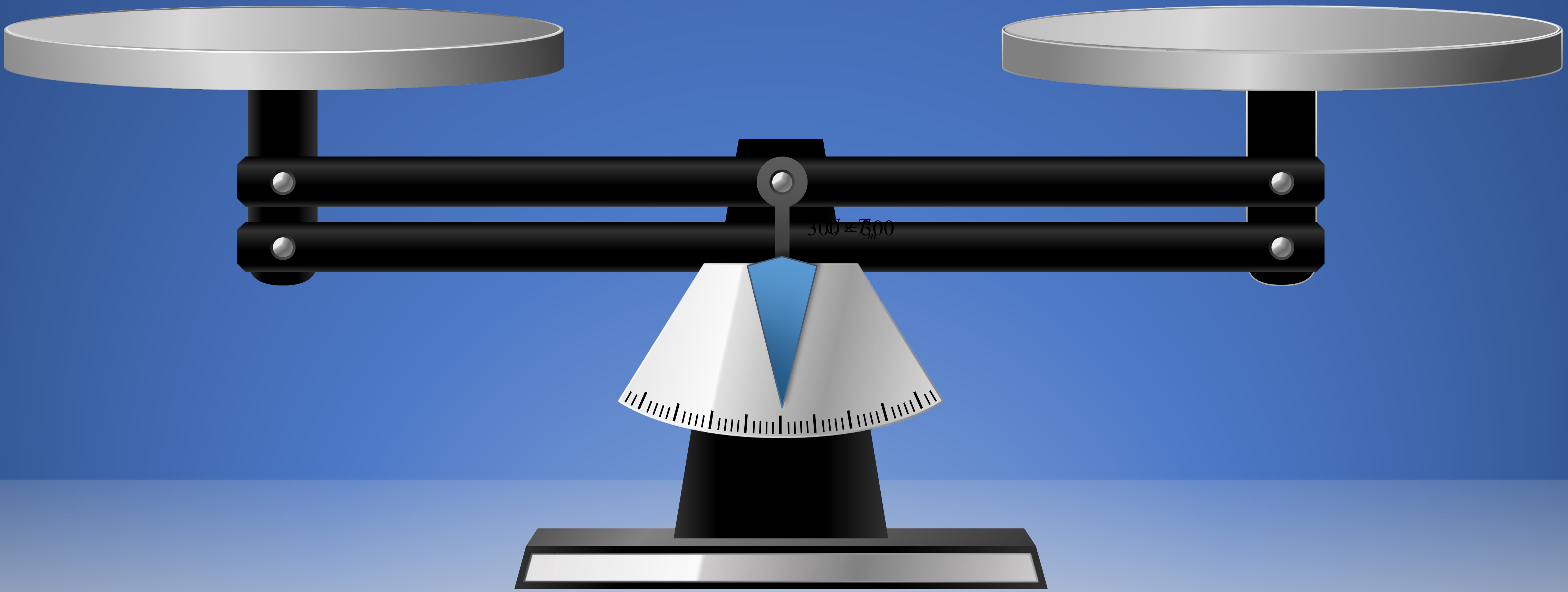
$$V_{cf} \times \frac{25}{14.7} = 100 \times 3$$



$$V_{cf} = 176.4$$

Supply = Demand

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

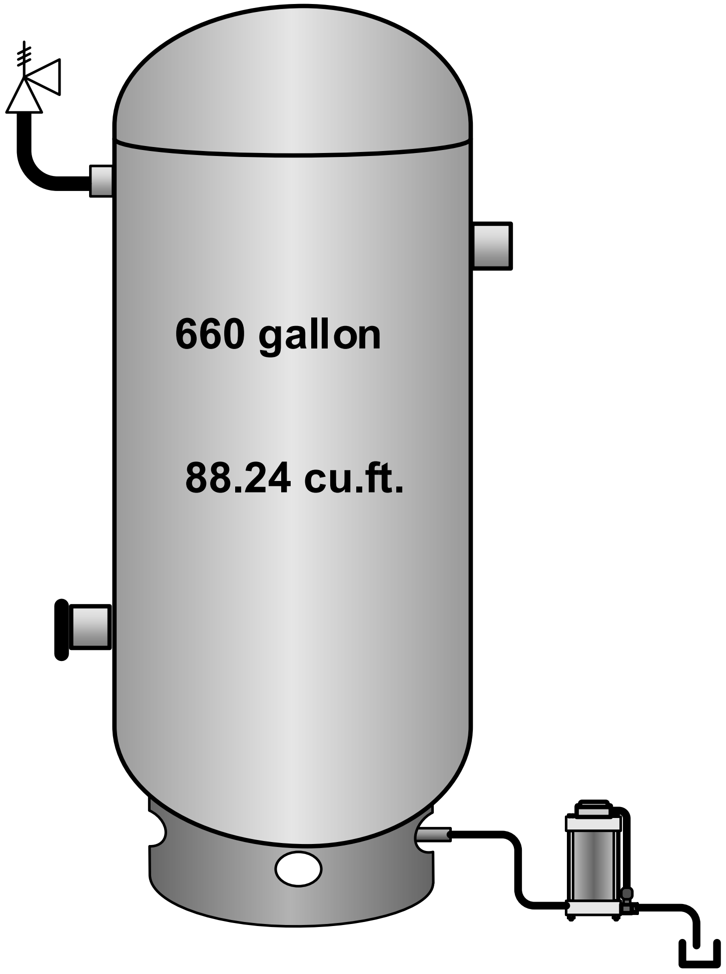
What is the usable (useful) storage?

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



Useful Storage

- Useful Storage = Capacity to Store x Allowable Pressure Drop

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

Given a 5000 gallon tank with pressure in at 100 and pressure out at 80

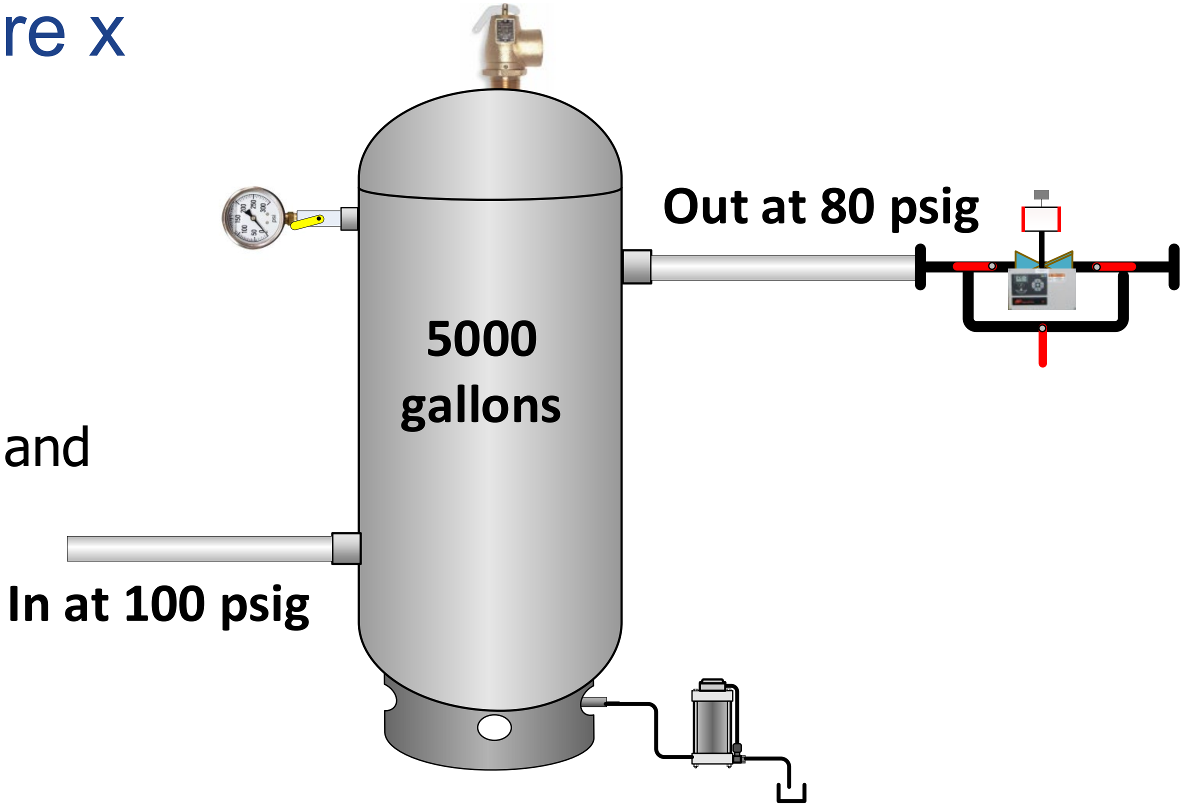
What is the usable (useful) storage?

5000 gallons / 7.48 gal/cuft =668.5 cubic feet

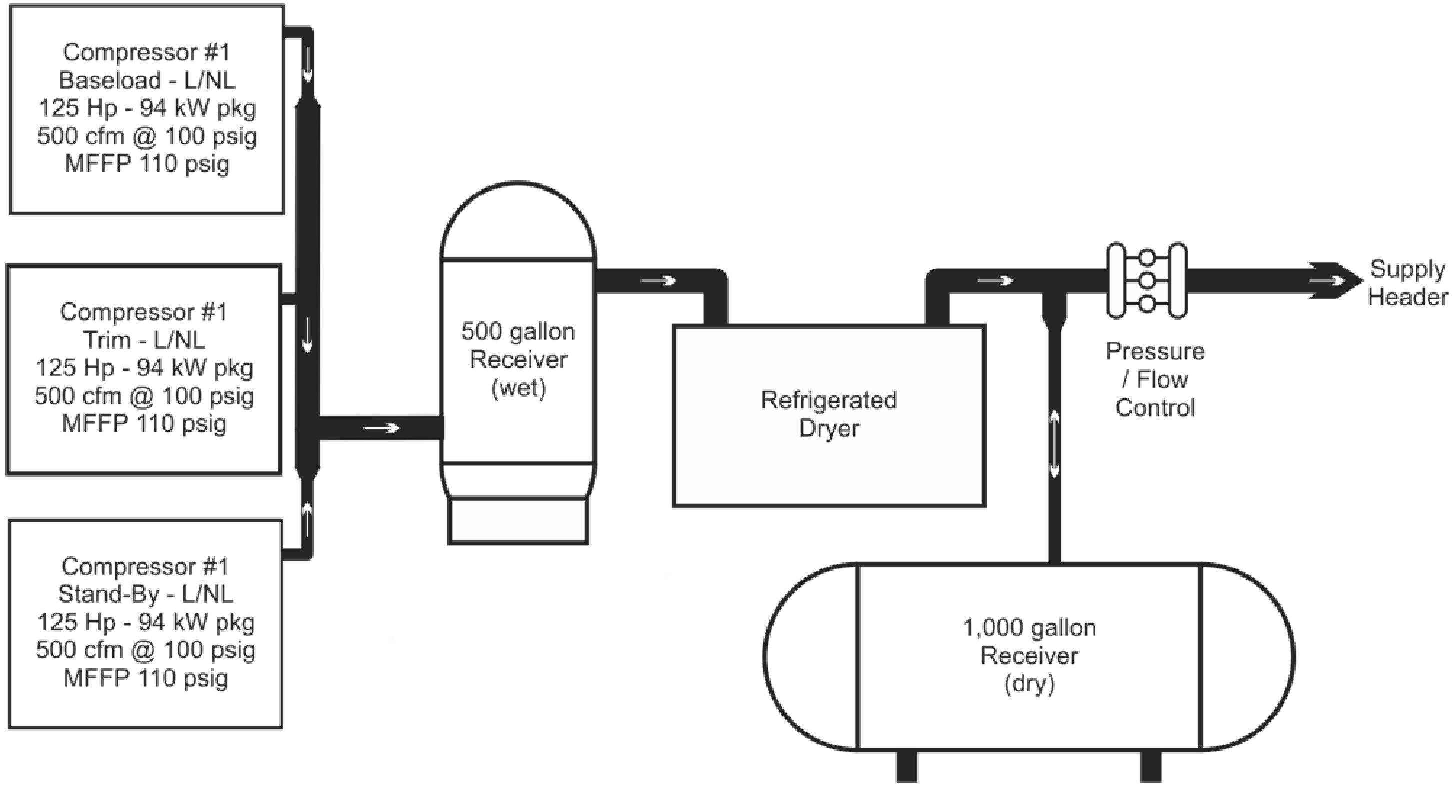
668.5 cuft / 14.5 psia = **46.1 cuft /psia**

46.1 cuft /psia x 20 psia =

= 922 cuft of usable storage

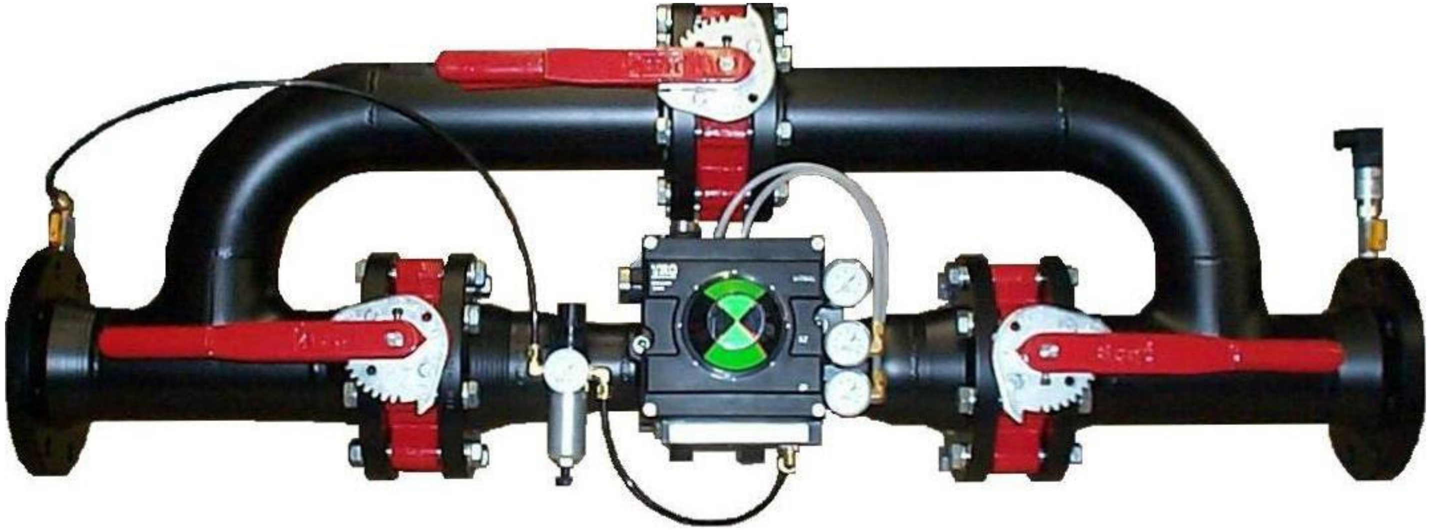


Pressure/Flow Controllers – Do I Need One?



- A typical block diagram of a pressure/flow controller in a compressed air system with one point of entry (single compressor room)

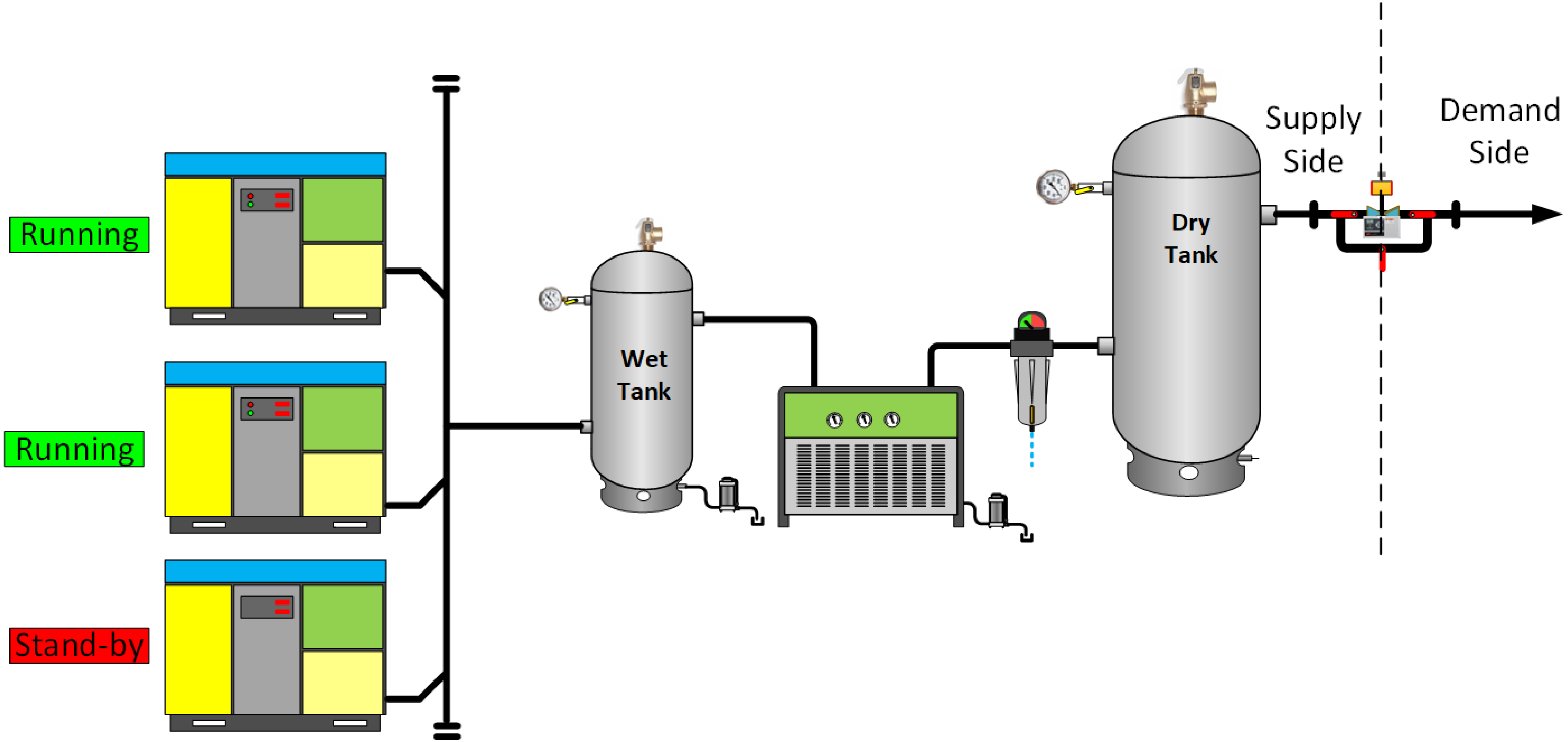
Pressure/Flow Controllers



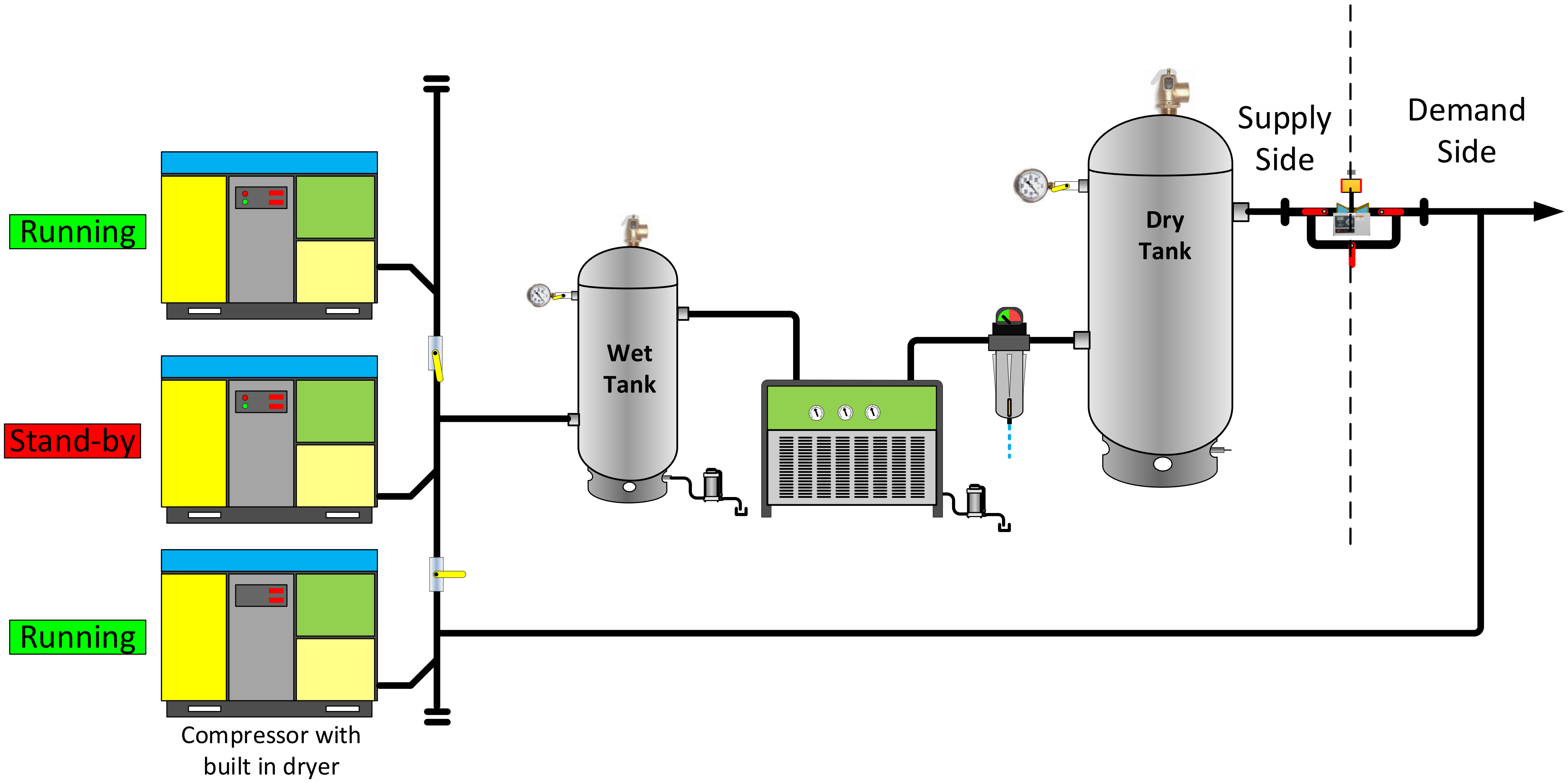
Pressure/Flow Controllers

- Make sure regulators are made for full flow with superior response time

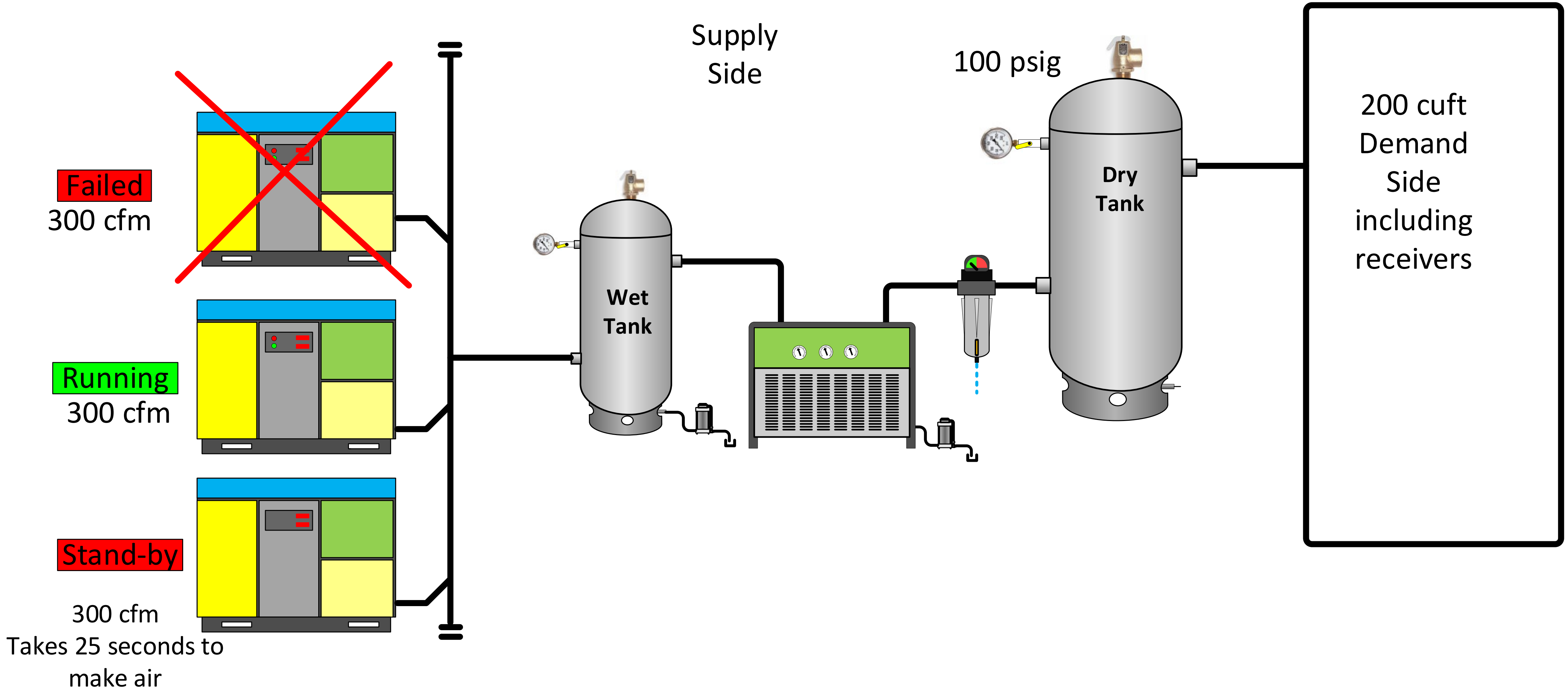
Best Practice with Pressure Flow Controller



Best Practice with Pressure Flow Controller



System Drawdown Without a Pressure Flow Control Valve



System Drawdown

Three different methods could be used to calculate:

#1 Capacitance:

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

$$DrawDownRate = \frac{DebitFlow_{cuft\,\mathrm{sec}}}{Capacit_{cuftpsi}} \times Time_{\mathrm{sec}}$$

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 cfs**

Capacitance = $200_{cuft}/14.7_{psia}$ = **13.6 cuft /psi**

$$DrawDownRate = \frac{5_{cuft\,\mathrm{sec}}}{13.6_{cuftpsi}} \times 25_{\mathrm{sec}}$$

$$DrawDownRate = .367_{psi/\mathrm{sec}} \times 25_{\mathrm{sec}} = 9\,psig$$

System Drawdown

Three different methods could be used to calculate:

#2 Receiver calc:

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

Solve for ΔP

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

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?

$$\Delta P = \frac{\left(25/60\right) \times (300_{cfm}) \times 14.7}{200_{cf}} = 9\,psig$$

System Drawdown

Three different methods could be used to calculate:

#3 Supply = Demand:

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

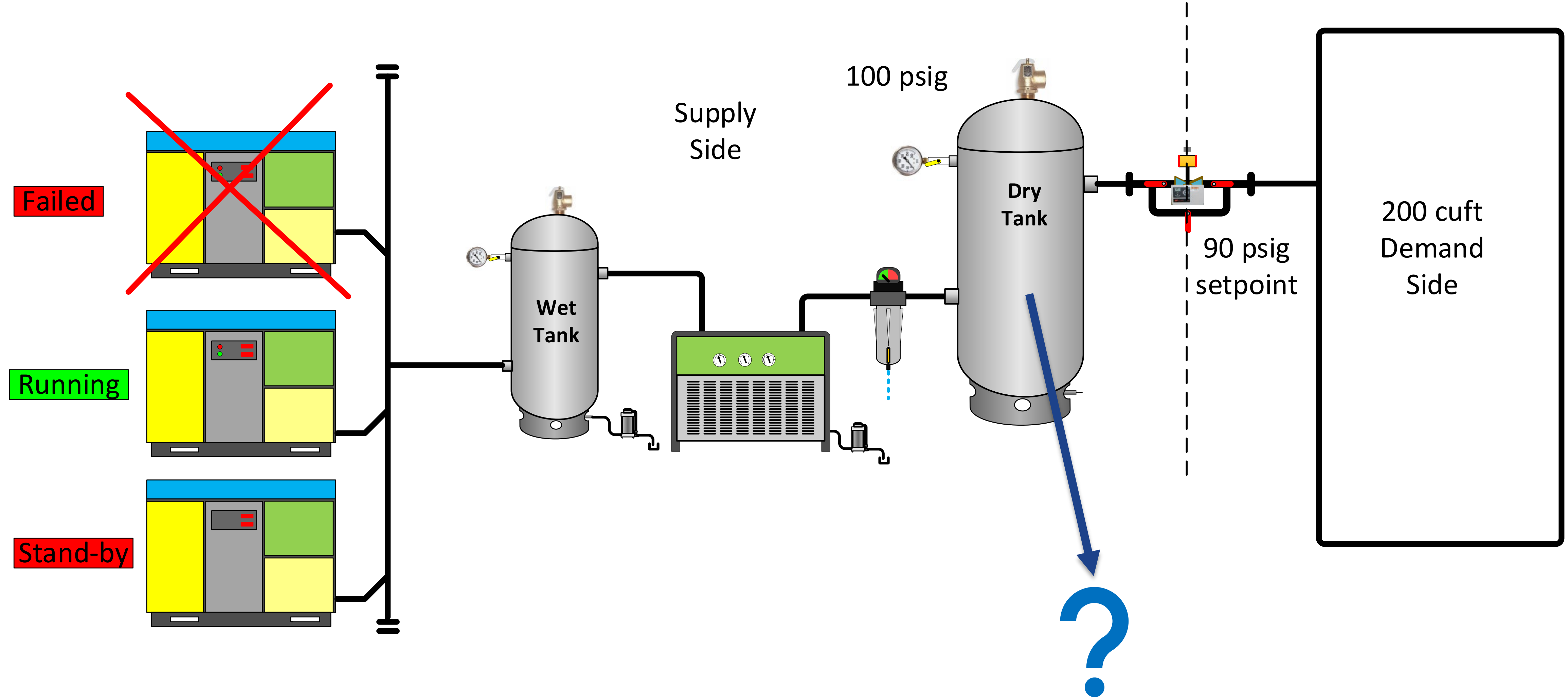
$$200_{cf} \times \frac{\Delta P}{14.7} = 300 \times \left(25/60 \right)$$

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?

$$\Delta P \times 13.6 = 125$$

$$\Delta P = 9$$

System Drawdown With Pressure Flow Control Valve



System Drawdown

Sizing a receiver for storage using PFC valve

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

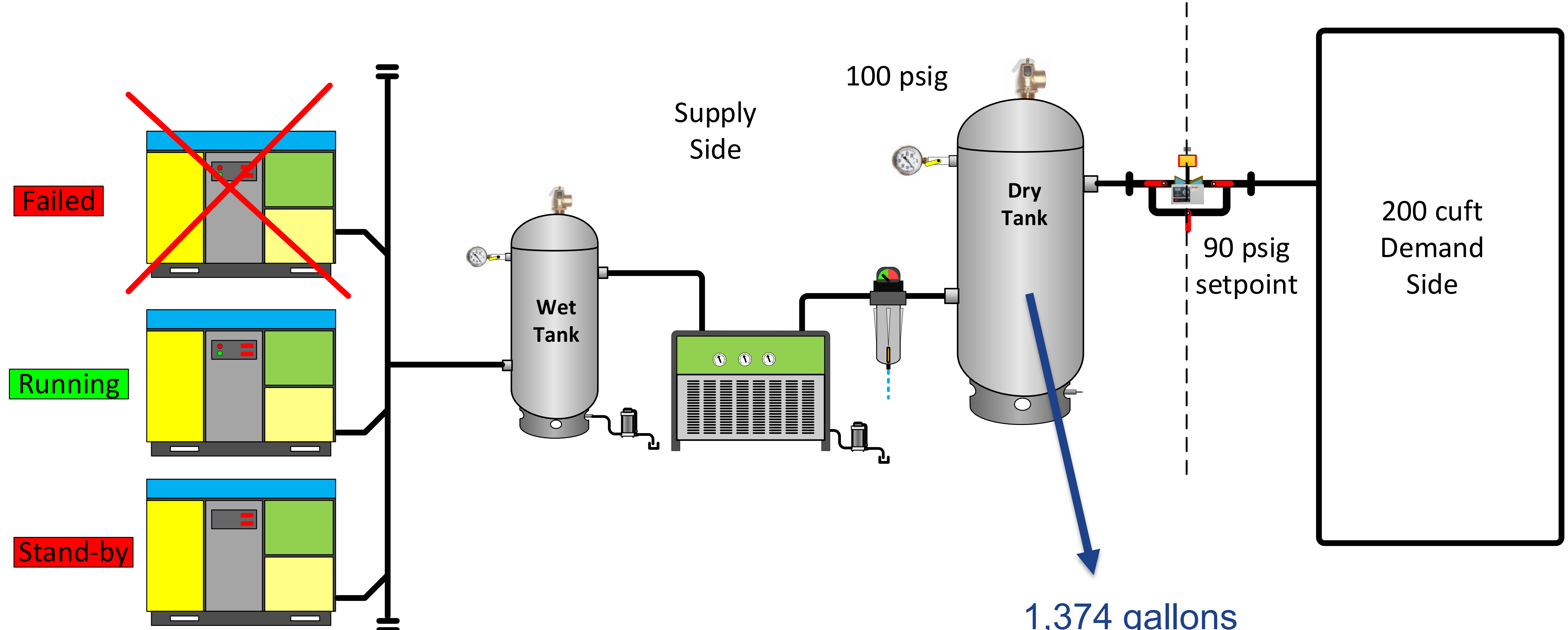
$$V_{cf} = \frac{\left(25/60\right) \times (300) \times 14.7}{10}$$

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 size receiver will prevent pressure drawdown while waiting 25 seconds for the backup compressor to make air? System pressure cannot fall below 90 psig

$$V_{cf} = 183.75 \qquad V_{gal} = 183.75 \times 7.48_{galcuft} = 1,374$$

A 1374-gallon receiver will deliver 200 cubic feet of air for 25 seconds. The pressure in the vessel will start at 100 psig and end up at 90 psig

System Drawdown With Pressure Flow Control Valve



1,374 gallons

Standby takes 25 seconds
to start delivering air

Example: System Drawdown

- A demand event results in a 200 scfm airflow rate being supplied from the system's air storage volume which is 133.7 cf ft (1,000 gallons). What is the pressure drawdown rate in psi/sec that will result?
  - This drawdown can take place in a storage tank behind a pressure flow control valve or will take place in the distribution volume.
  - Your choice

System Drawdown

- Answer

$$DrawDownRate = \frac{DebitFlow_{cuft\,\sec}}{Capacit_{cuftpsi}} \times Time_{\sec}$$

$$\frac{1000gal}{7.48gal / cf} = 133.7cf$$

$$DrawDownRate = \frac{3.333_{cfs}}{9.09_{cfpsi}} \times 1_{\sec}$$

$$\text{Capacitance} = \frac{133.7_{cf}}{14.7_{psia}} = 9.09_{cfpsi}$$

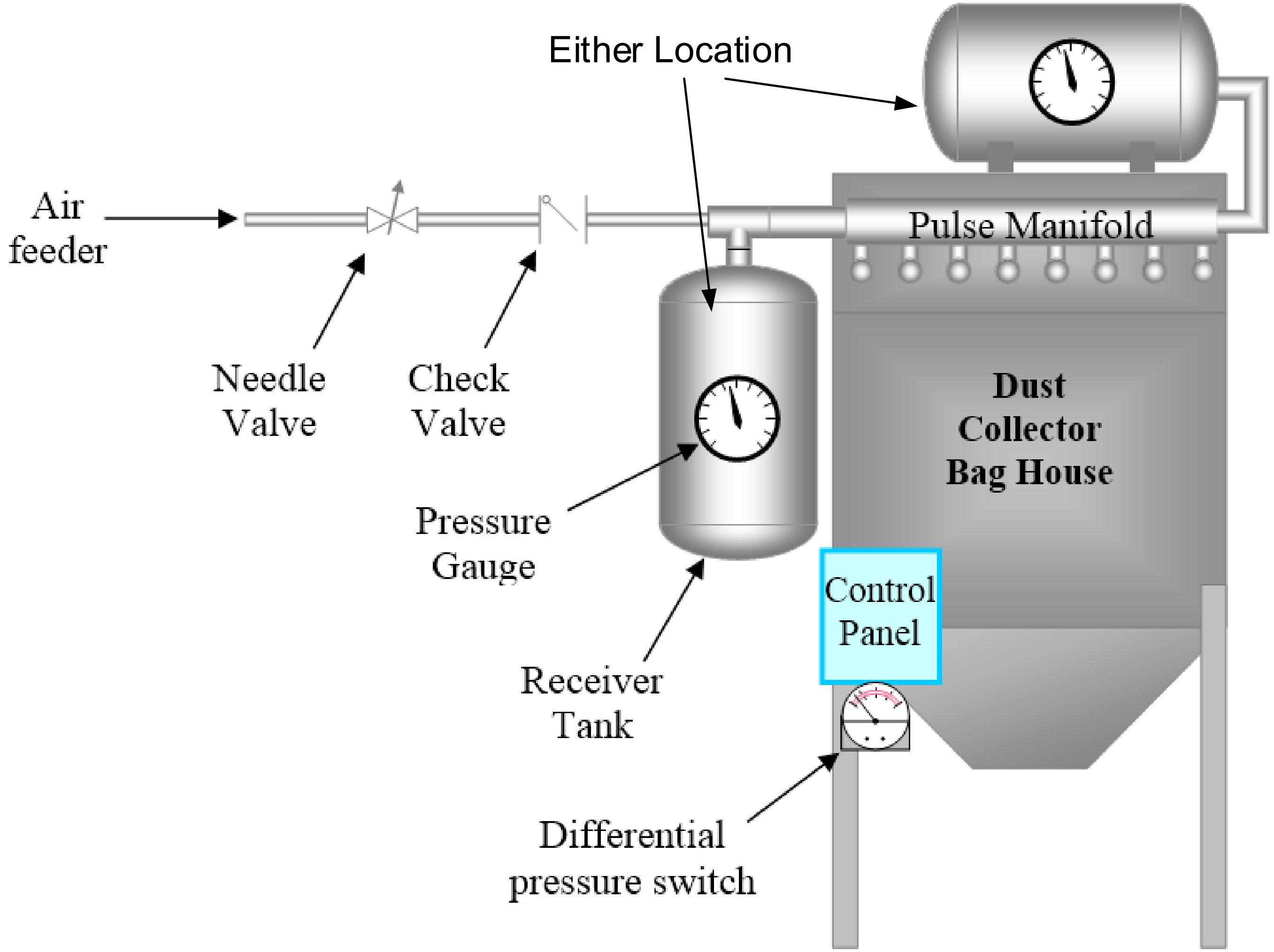
$$\frac{200cfm}{60} = 3.333cfs$$

$$DrawDownRate = .37\,psi / \sec$$

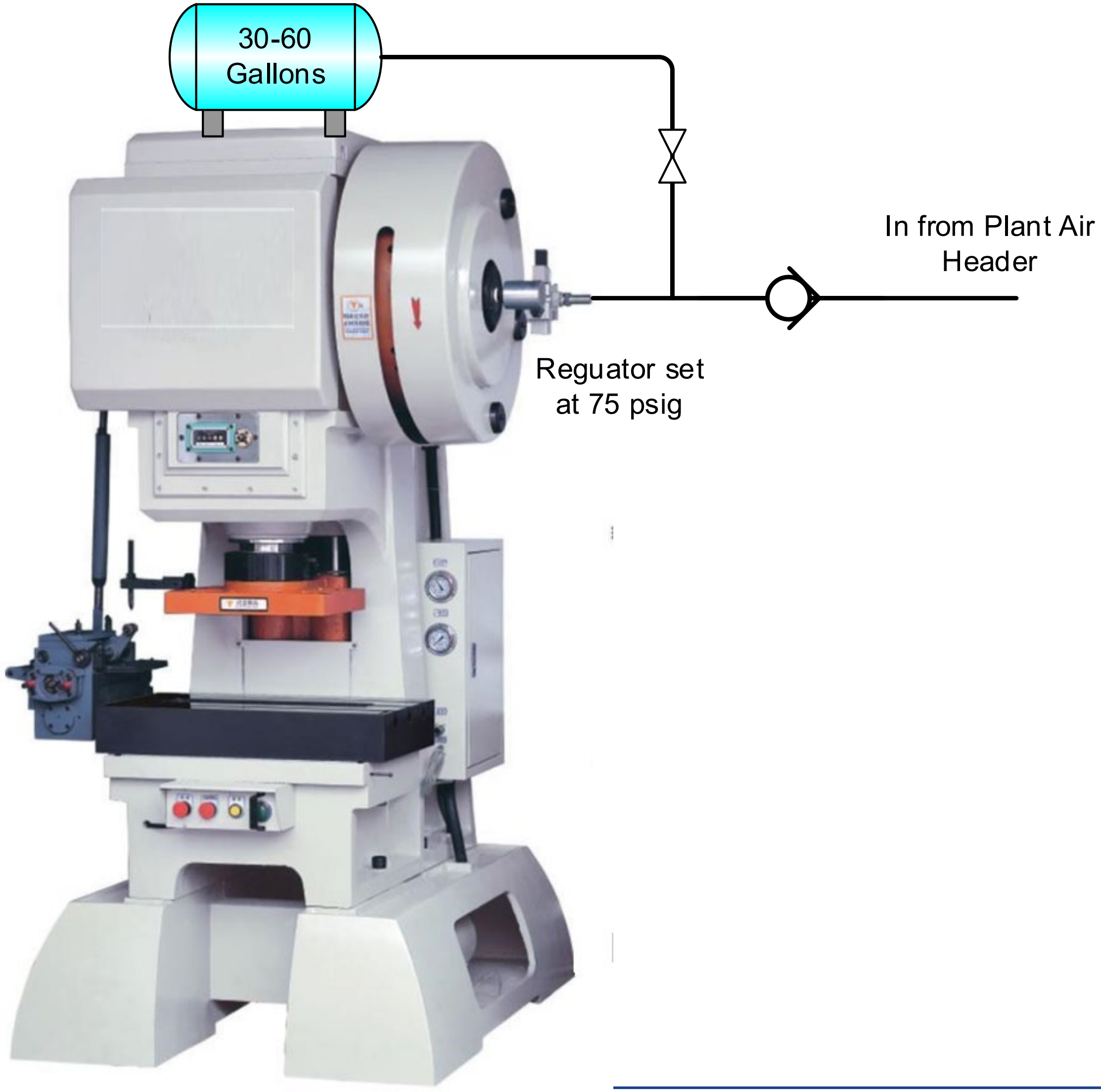
Storage Examples

High-volume intermittent events create the appearance of inadequate supply because they can cause the pressure to fall in the system before the compressors can react.

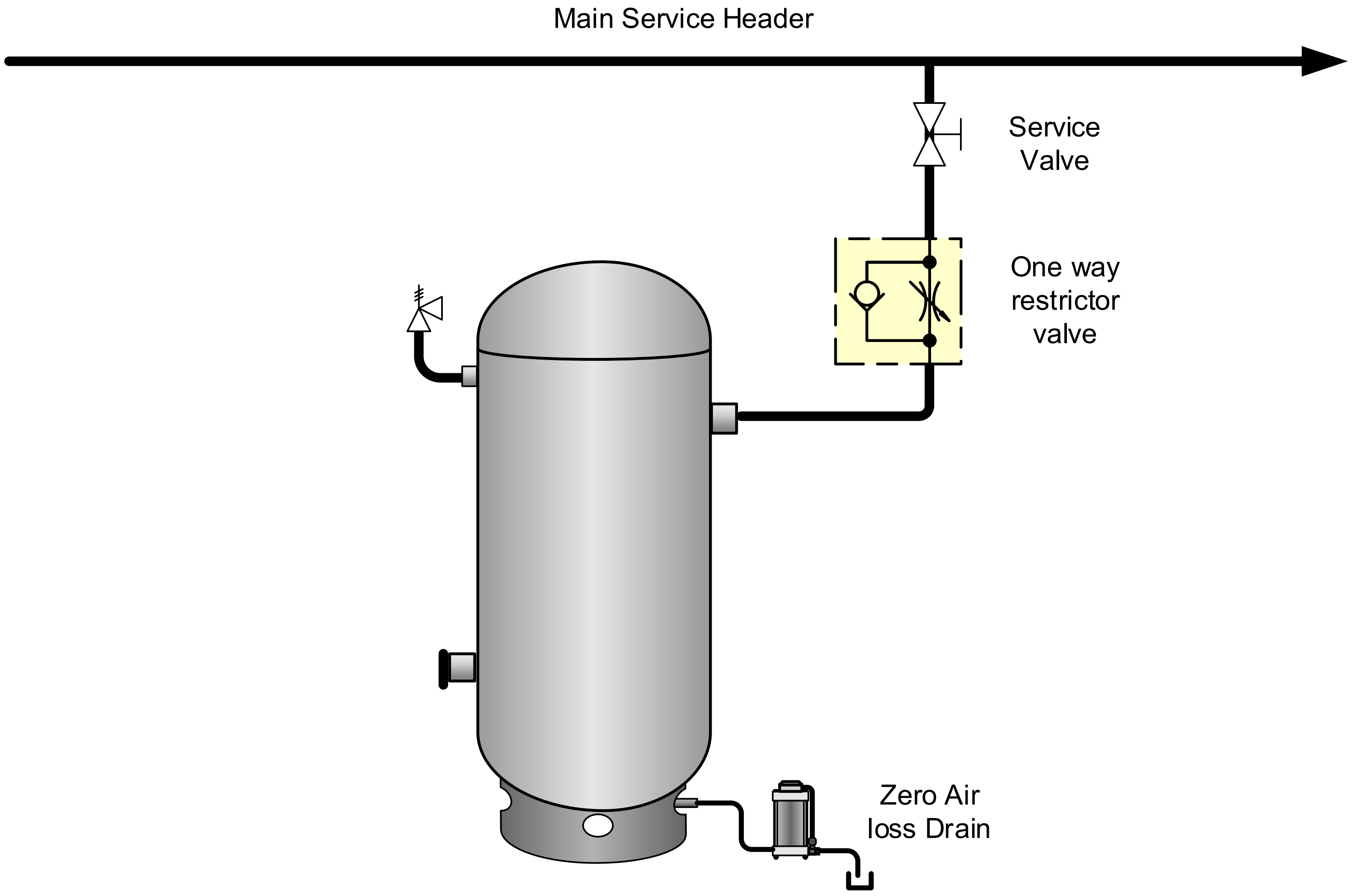
Dedicated Storage to Shield the system from a high flow end use application



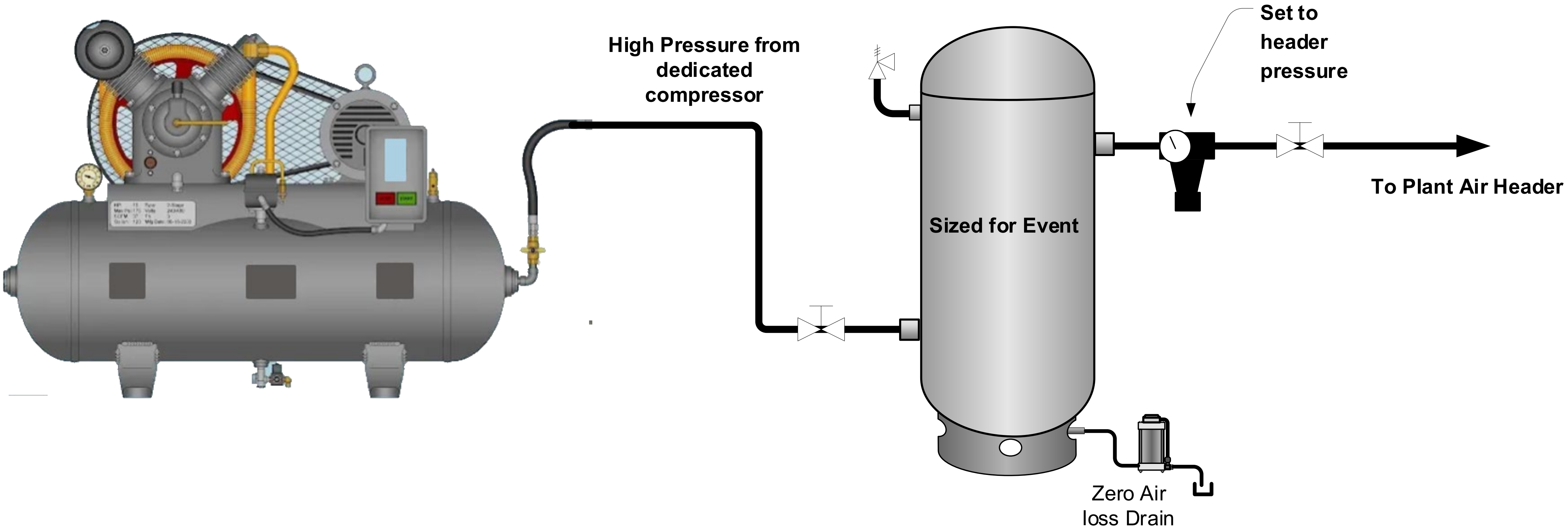
Critical Pressure End Use



General Storage



High Pressure Offline Storage



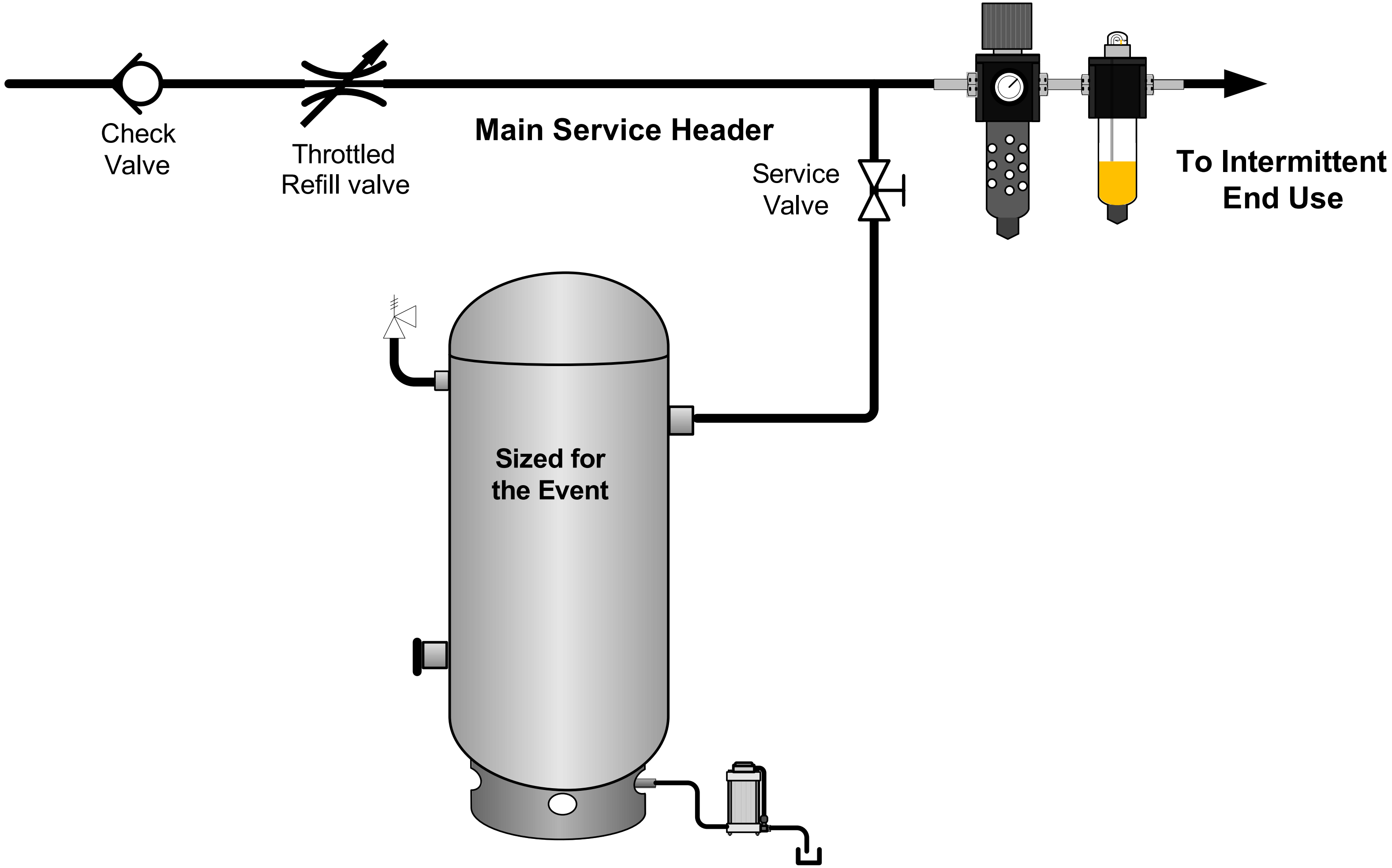
Example High Pressure Offline Storage

Assume a back wash filter requires **100 cfm every hour** for a duration of **3 minutes** at 70 psig. A high-pressure compressor is available for 200 psig operation. For this calculation assume S to be zero.

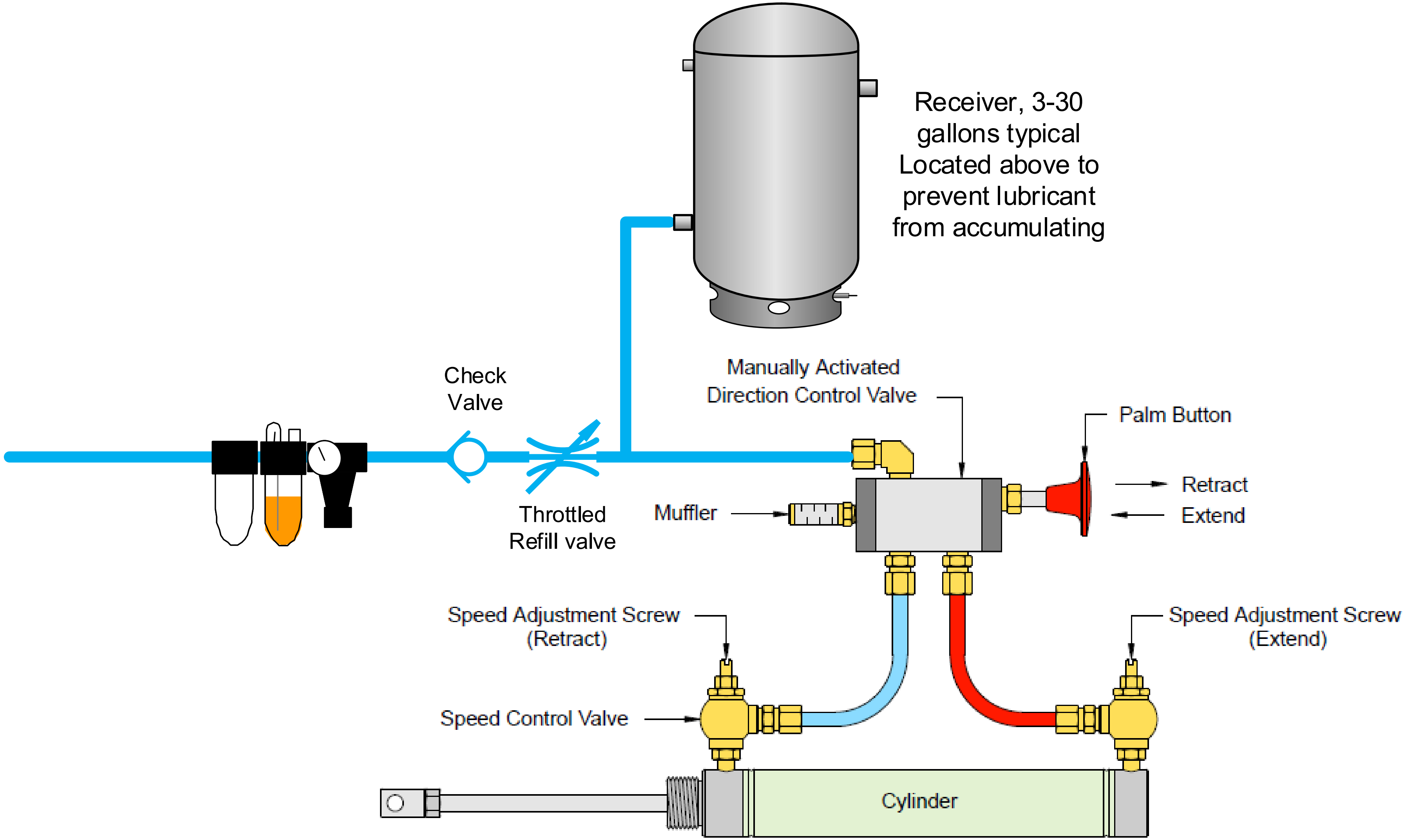
$$V = \frac{T(C-S)Pa}{P_1 - P_2} \qquad V = \frac{3(100-0)14.7}{200-70} = 33.92\ Cubic\ Feet$$

33.92 x 7.48 gal/cu.ft. = 253.7 gallons

Dedicated Storage with Metered Recovery

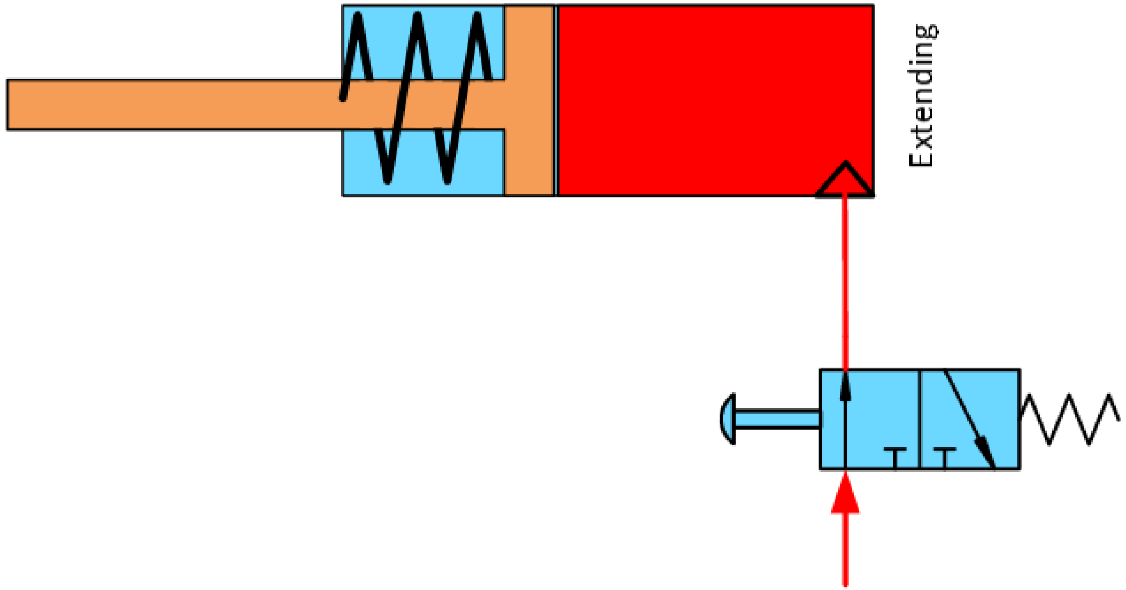


Dedicated Storage with Metered Recovery



Peak Flow vs Average Flow

- The single acting spring return air cylinder picture below requires 1 cubic foot of compressed air and actuates to full stroke in 3 seconds. If the cylinder actuates 2 x per minute, what is the peak and average flow?

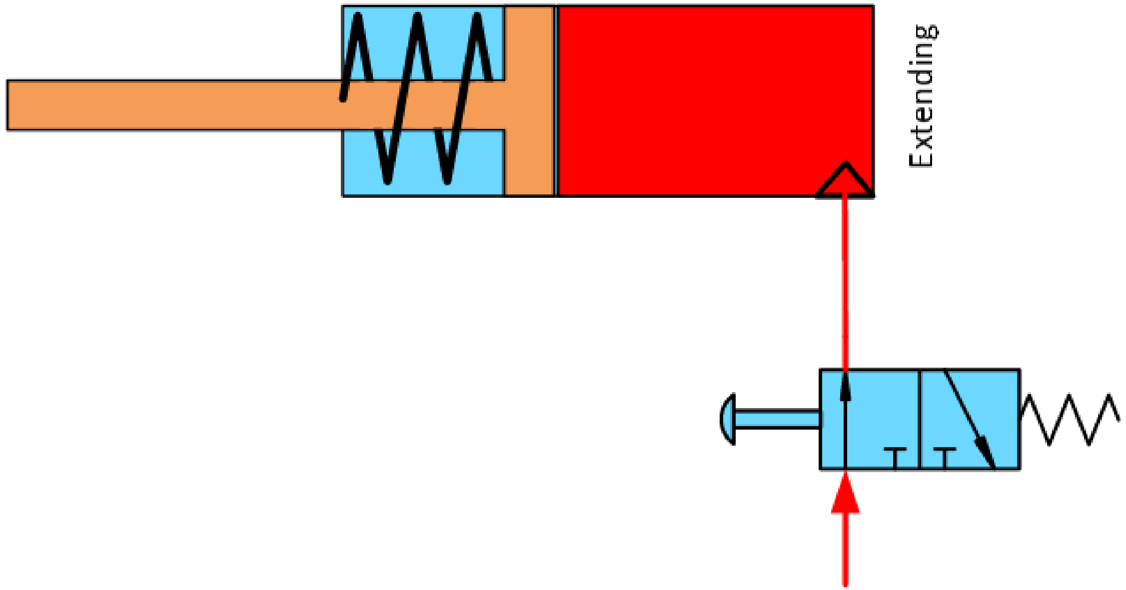


Peak Flow vs Average Flow

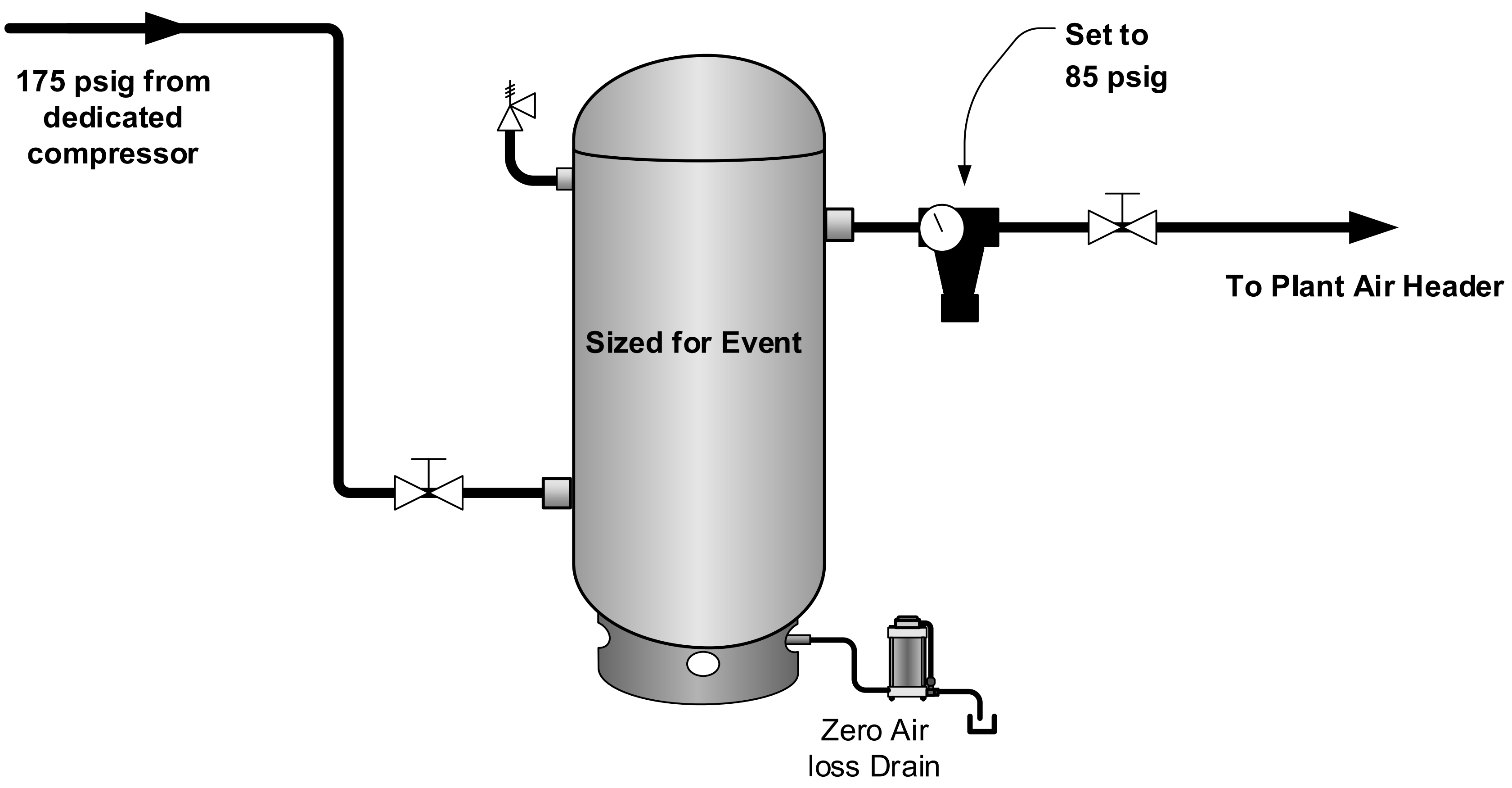
- Answers:
  - Average flow = 2 cfm
  - Peak flow – 20 cfm

$$\frac{1cf}{3\sec} \times \frac{60\sec}{1\min} = 20cfm$$

$$\frac{60}{3} = 20cfm$$



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.

MEASUR: Compressed Air Assessment!

Create Your Compressor Inventory

COMPRESSOR INVENTORY

Compressor Name	Compressor 1
Description	

Set Data From Existing Compressor

NAMEPLATE DATA

Compressor Type	Single stage lubricant-injected rotary screw
Motor Power	5 hp
Full Load Operating Pressure	100 psig
Rated Capacity at Full Load Pressure	18 acfm
Full Load Amps	7.5 amps
Total Package Input Power	4.6 kW

› CONTROLS

› INLET CONDITIONS

› DESIGN DETAILS

⌄ PERFORMANCE POINTS

	Discharge Pressure	Airflow	Power
Full Load (cut-in)	100 psig	18 acfm	4.6 kW
Max Full Flow (cut-out)	110 psig	18 acfm	4.9 kW
No Load (unloaded)	15 psig	0 acfm	2.3 kW

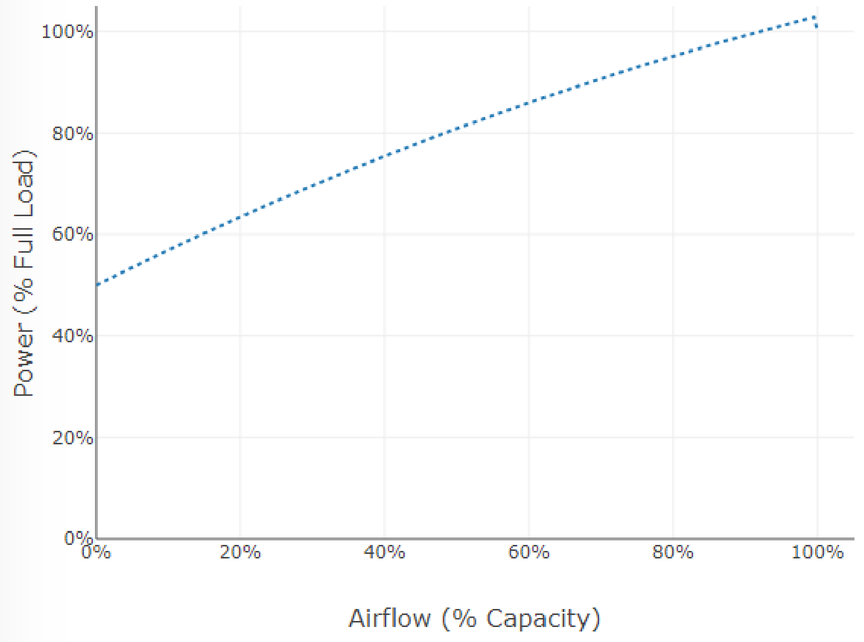
CURRENT INVENTORY | HELP

Name	Compressor Type	Control Type	Pressure Range
› Compressor 1	Single stage lubricant-injected rotary screw	Load/unload	100 - 110 psig
Compressor 2	Single stage lubricant-injected rotary screw	Start/Stop	100 - 110 psig

+Add New Compressor

Compressor Profile (Compressor 1)

☐ Graph All Compressors



Enter Your Operation Profile

1 Assessment Basics | 2 System Information | 3 Inventory | 4 Day Types | **5 System Profile**

Setup Profile | Profile Summary | Graphs | Annual Summary

Select Day Type: Standard Day Type

Profile Data Type: Airflow, % Capacity

Data Interval: 1 hr

Pressure Control Range: 100 - 110 psig

Compressor Ordering (No Sequencer)

☐ Fill right on change | Turn All Off | Turn All On

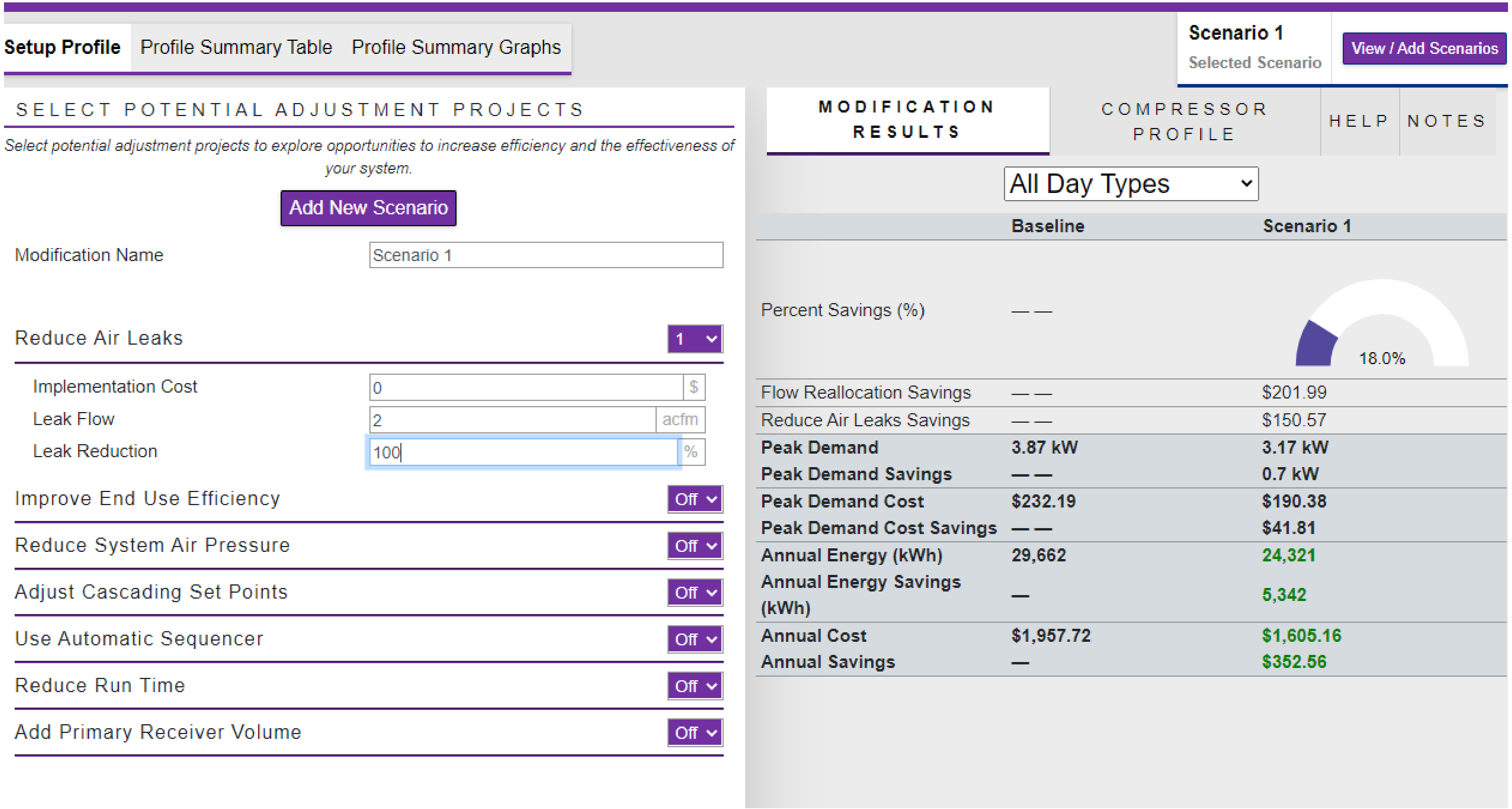
	FLP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Compressor 1	100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Compressor 2	100	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Profile Data

☐ Fill right on change

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Compressor 1	% Capacity	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Compressor 2	% Capacity	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

Find Energy Savings!



Example Presentation

U.S. DEPARTMENT OF
ENERGY

Better Plants
U.S. DEPARTMENT OF ENERGY

Compressed Air Systems VINPLT: Close out Presentation

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

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

Next Week Session 8 – Final Report Out

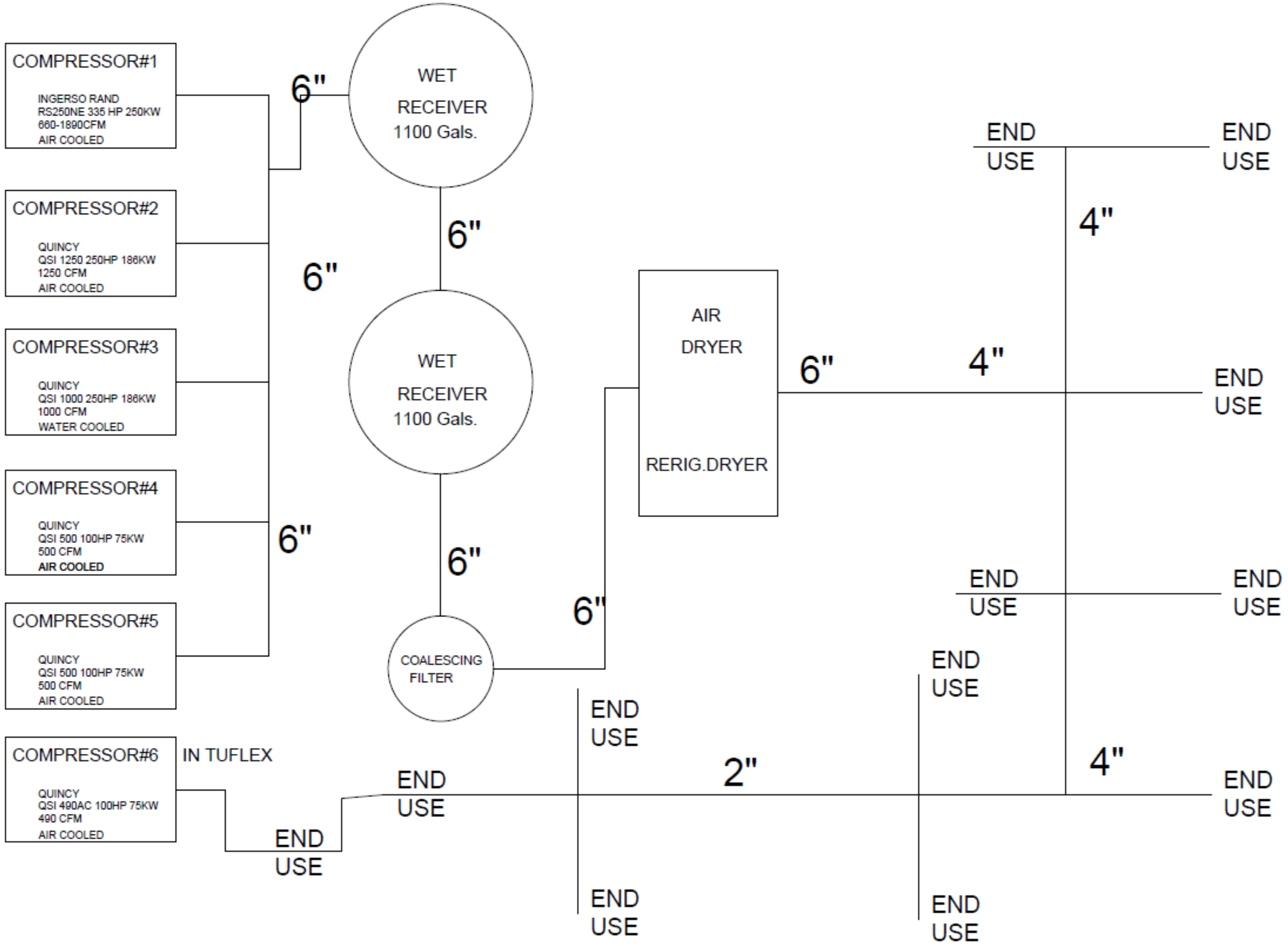
- The goal of this session:
  - To understand how to maintain an efficient compressed air system by managing wastes.
  - To take advantage of the heat emitted from a compressed air system.

Better Plants
U.S. DEPARTMENT OF ENERGY

Compressed Air Systems VINPLT: Close out Presentation Example for Last Online Training

Company Name: FLEXCO FLOORS
Facility Name: FLEXCO MAIN PLANT
Participant Name(s):Marcus Hyde, Steve Opheim

Block Diagram of the Compressed Air System



Savings Opportunities in Compressor Controls

Present Control system and problems

Our Air Compressor Control System was suppose to cycle on and off compressors as demand required. The system was purchased from Ingersoll Rand and their guy could never figure out how to tie in all the other compressors that were Quincy's.

System never worked correctly so Boiler Operator is in charge of manually turning on and off the compressor with demand requirements.

This works good for turning compressors on as required because he gets an alarm signal for low pressure. We use time of day experience to turn off the compressor that are not required for demand.

Savings Opportunities in Compressor Controls

We need to install an Automatic demand control system.

We need a system that can be setup and adjusted by our in-house technicians.
System that I believe would work best is to have the newest Ingersoll Variable Frequency Drive be the lead compressor. Once it reaches 100% Load for a given time and can not hold 90 psi. Other compressors need to be added. Turning on one of our 3 Quincy 100HP (4) valve stage compressor one at a time as compacity requires. The other Compressors in our system are only required for maintenance and emergency use.

Savings Opportunities in Pressure Setpoints

We currently run the compressors at what we have determined presently to be our lowest PSI possible for the majority of the Plant Operations. 90 PSI.

We do have (2) Machines that require higher pressure one for cutting hard rubber with a Air guillotine and one that lifts heavy rolls with a pneumatic manipulator. (Both of these operations have a small air amplifier that increases PSI. They are low usage and CFM requirement machines .)

Savings Opportunities in Compressed Air Distribution Systems

Our current Compressed Air Distribution system is Bad.
70 year old plant with lots of new systems without much distribution system up-grading.

Larger Main Distribution Line should be installed
New Main Line should be something other than Carbon Steel and be looped (feed from both ends) as possible.

Additional Dryer capacity would help for large demand times and for maintenance of current Dryer.

Savings Opportunities in Compressed Air Users

- Minimize all compressed air usage.
- Use Cordless Leaf Blowers for areas that currently use compressed air for cleaning.
- Convert air Knife/nozzles systems to LP Air Blowers
- Convert some of our high cycling guillotine cutoff systems to servo motor electric driven units.

Tips Learned from this Training

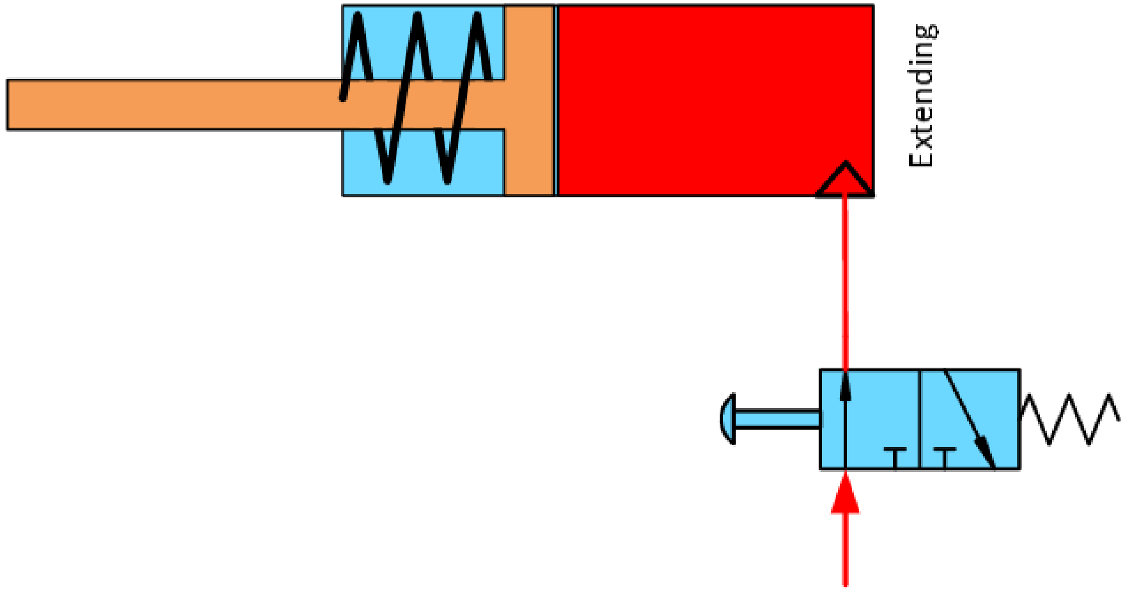
- Use of Aluminum Pipe for compressed air. (had not thought of this as an option.)
- The importance of going large with main distribution header.
- How bad air motors are in efficiency vs. Electric Motors
- Leaks detection program importance.

Next Steps or Action Items after the Compressed Air VINPLT

- What are your next steps to implement opportunities?
  - Incorporate alternative methods other than compressed air in all projects.
- What are you planning to do after the VINPLT?
  - Update systems as funding is available.
  - Track and communicate compressed air usage/cost with the tools provided.
- Lessons learned?
  - Having all employees involved in compressed air conservation.
  - Proper system flow to accommodate the most efficient usage at reduced cost.

Homework for Week 6 – Volume

- The single acting spring return air cylinder picture below requires 1 cubic foot of compressed air and actuates to full stroke in 3 seconds. If the cylinder actuates 2 x per minute, what is the peak and average flow?

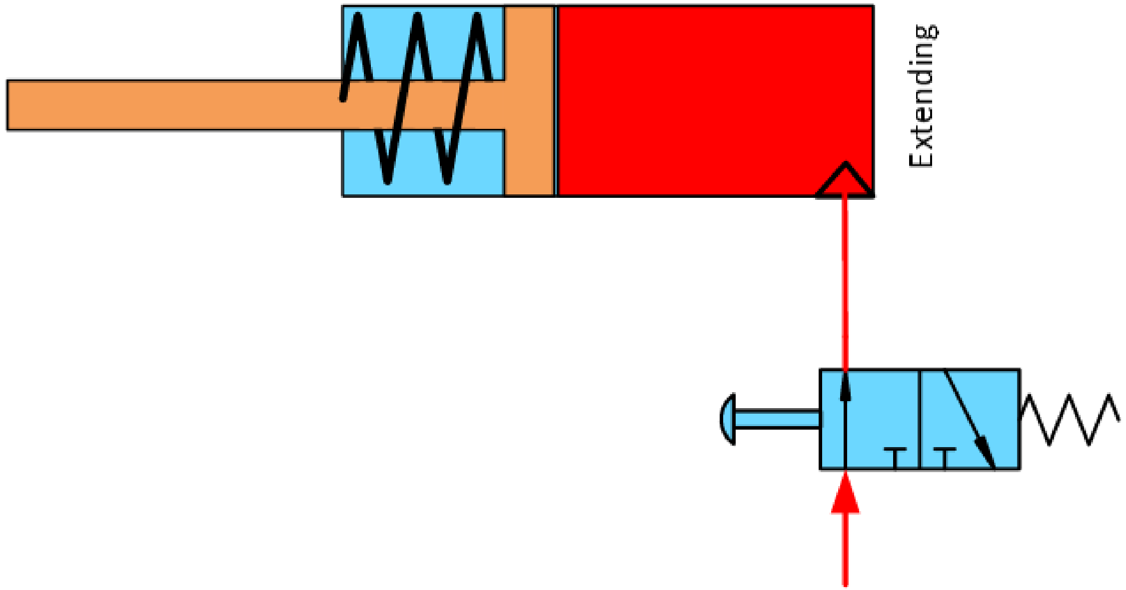


Homework for Week 7 – Volume

- Answers:
  - Average flow = 2 cfm
  - Peak flow – 20 cfm

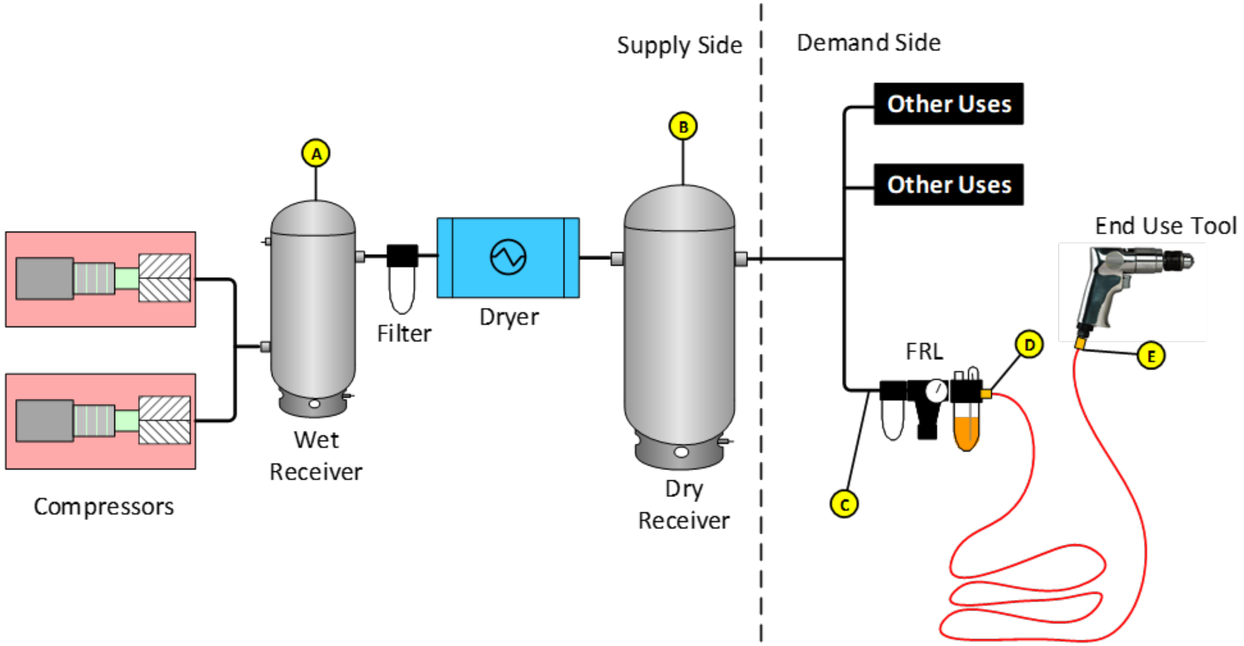
$$\frac{1cf}{3\sec} \times \frac{60\sec}{1\min} = 20cfm$$

$$\frac{60}{3} = 20cfm$$



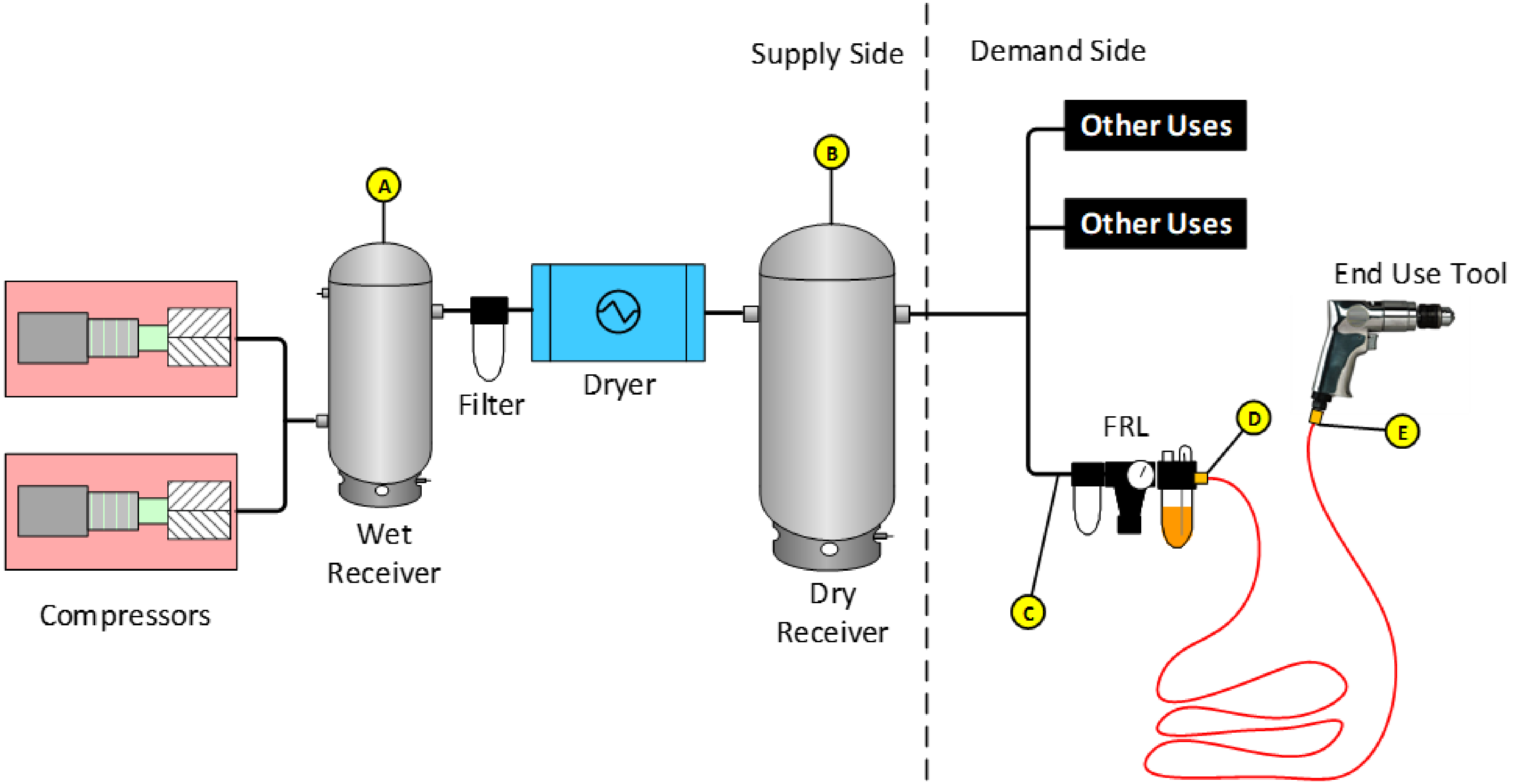
Homework for Week 7 – Volume

- The operator for the end use tool pictured below has complained of lower torque and has opened the regulator to full header pressure, yet the problem still exists. The regulator is holding pressure on its gauge when he pulls the trigger on the tool. Which two yellow flag locations would be the correct measurement points to identify the problem?



Homework for Week 7 – Volume

- Answer: D and E



Homework for Week 7 – Volume

- A demand event results in a 200 scfm airflow rate being supplied from the system’s air storage volume which is 1,000 gallons. What is the pressure drawdown rate in psi/sec that will result?

Homework for Week 7 – Volume and Flow

- Answer method one

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

$$DrawDownRate = \frac{3.333_{cfs}}{9.09_{cfpsi}} \times 1_{sec}$$

$$DrawDownRate = .37\, psi / \sec$$

$$\frac{1000\,gal}{7.48\,gal/cf} = 133.7\,cf$$

$$\text{Capacitance} = \frac{133.7_{cf}}{14.7_{psia}} = 9.09_{cfpsi}$$

Homework for Week 7 – Volume

- Answer method 2

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

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

$$\Delta P = \frac{.0166666666666667 \times 200 \times 14.7}{133.6898}$$

$$\Delta P = .366_{\text{sec}}$$

$$DrawDownRate = .37psi/sec$$

Homework for Week 7 – Volume

- A system operates with 100 scfm demand deficit for 30 seconds of time. If the system pressure must be no lower than 90 psig and at the beginning of the event the pressure is 100 psig, what size receiver is necessary?
  - Use the MEASUR Tool for “Receiver Tank Sizing”

Homework for Week 7 – Volume

- Answer

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

$$V_{cf} = \frac{.5 \times (100) \times 14.7}{10}$$

$$V_{cf} = 73.5$$

$$V_{gal} = 73.5_{cf} \times 7.48_{galcf} = 549.78_{gal}$$

RECEIVER TANK SIZING

Calculation Method	Dedicated Storage	
Length of Demand	.5	min
Air Flow Requirement	100	scfm
Atmospheric Pressure	14.7	psia
Initial Tank Pressure	100	psig
Final Tank Pressure	90	psig
Receiver Volume	549.78 gal	

Homework for Week 7 – Volume

- What is the pneumatic capacitance of a 2000-gallon receiver at sea-level 14.7 psia
- Answer should be in cubic foot/psi

Homework for Week 7 – Volume

- Answer:

$$Cap = \frac{cuft}{P_a}$$

$$Cap = \frac{267.38}{14.7}$$

$$Cap = \frac{267.38}{14.7} = 18.189_{cfpsi}$$

Homework for Week 7 – Volume

- Use the MEASUR Tool for this one:
  - A 55-gallon bag is placed over a leak and takes 10 minutes to fill up. What size leak is it in scfm?

Homework for Week 7 – Volume

- Use the MEASUR Tool for this one:
  - Answer

LEAK LOSS ESTIMATOR - BAG METHOD

Annual Operating Hours	8760 hrs/yr
Total Flow Rate	**4.55 SCFM**
Total Annual Compressed Air Leakage	**2,391,480 SCF**

Leak 1

Bag Fill Time	600 s
Height of Bag	40 in
Diameter of Bag	50 in
Flow Rate	**4.55 SCFM**
Annual Consumption	**2,391,480 SCF**