Better Plants
U.S. DEPARTMENT OF ENERGY

In-Plant Trainings

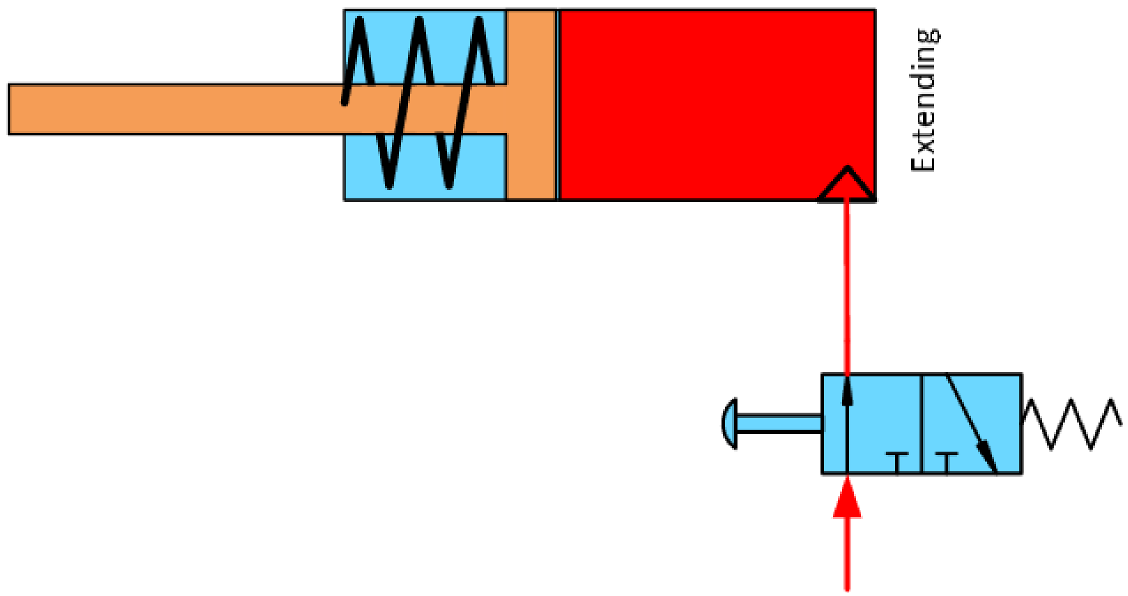
Final Session 8
Review and Report Outs

Homework Answers:

Homework Answers from Week 7 Volume

Homework from Week 7 – 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?

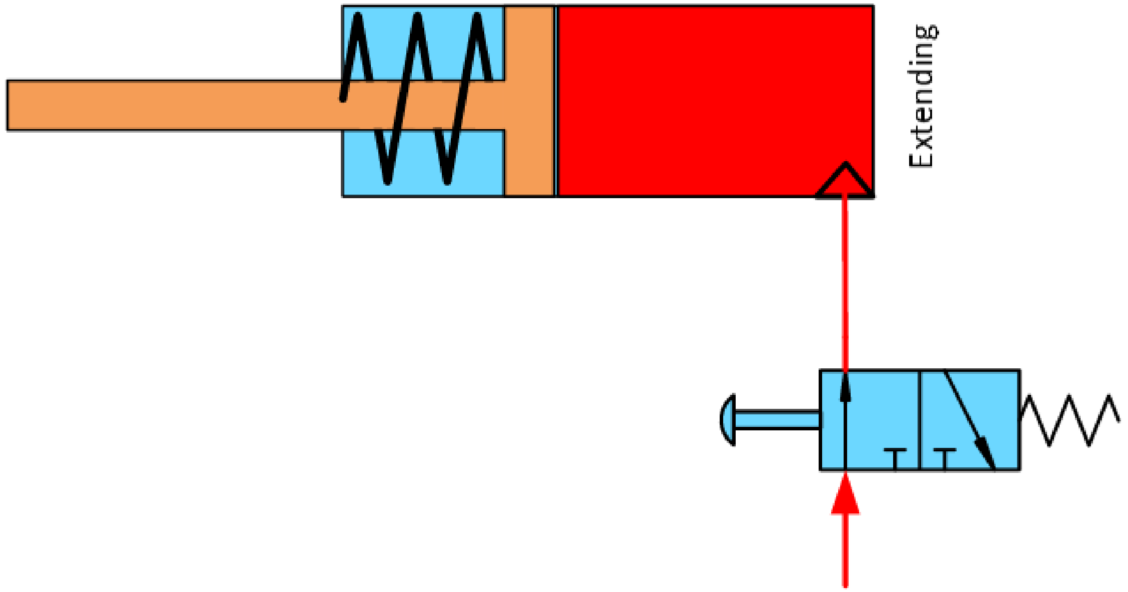


Homework from Week 7 – Volume

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

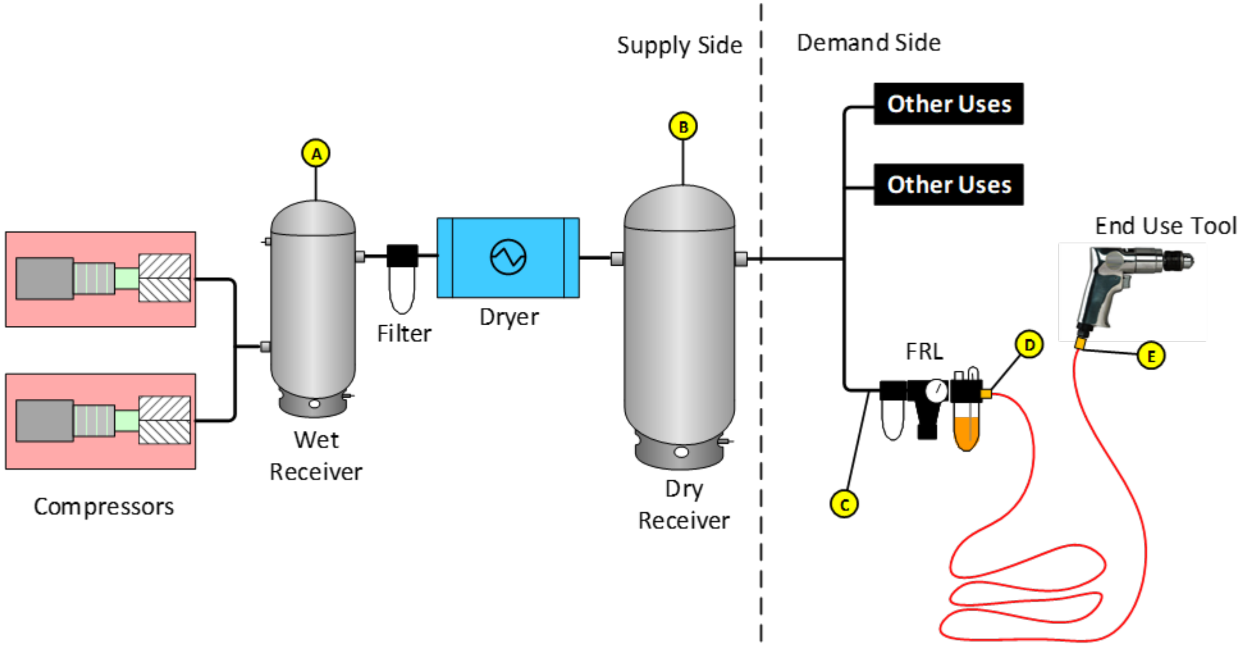
$$\frac{1cf}{3\sec} \times \frac{60\sec}{1\min} = 20cfm$$

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



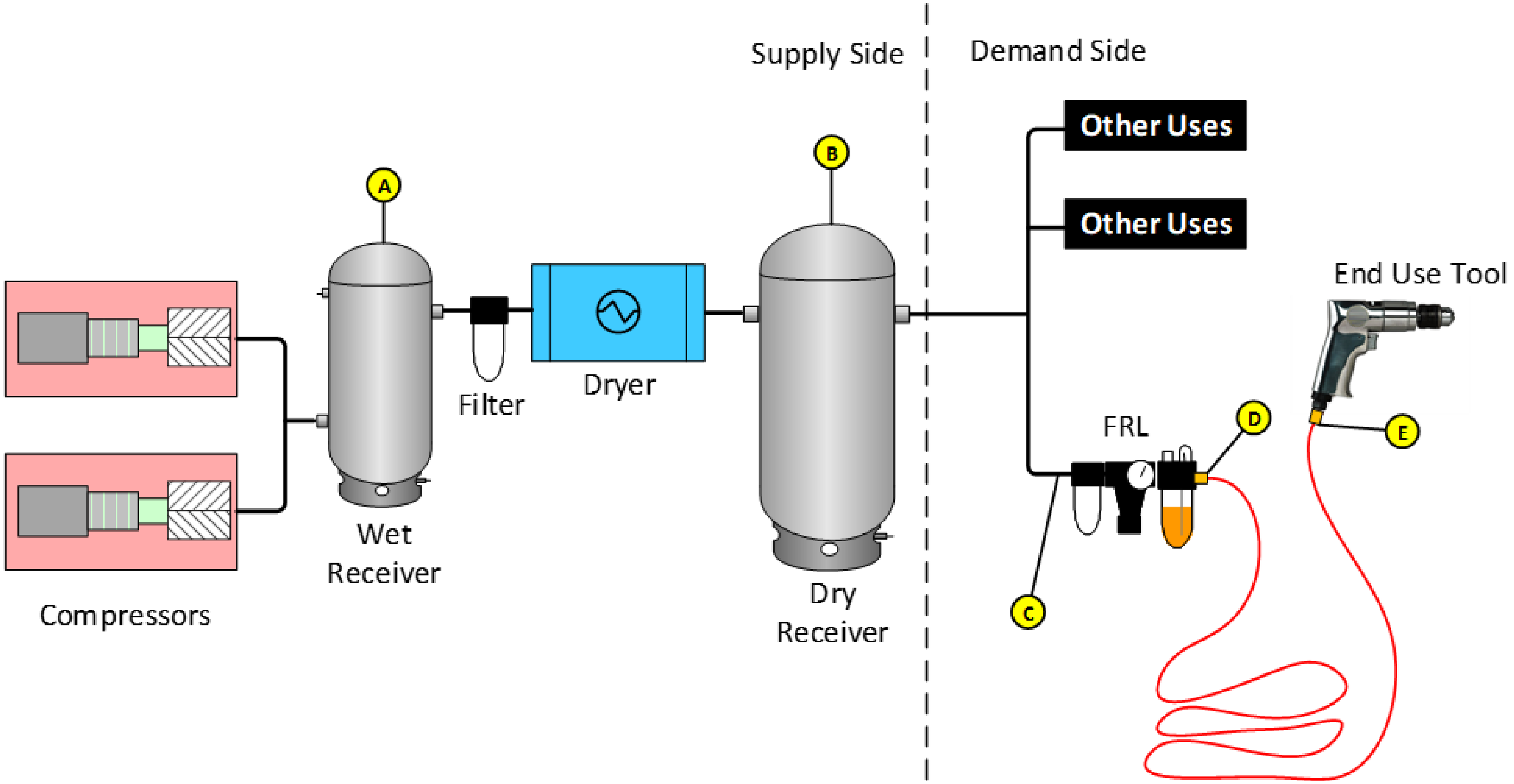
Homework from Week 7 – Volume

- 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 from Week 7 – Volume

- Answer: D and E



Homework from 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 from Week 7 – Volume

- Answer method one

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

$$\frac{200cfm}{60s/m} = 3.333cfs$$

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

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

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

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

Homework from Week 7 – Volume

- Answer method 2
  - Rewrite the equation to solve for ΔP

$$T_{\min} = \frac{1\sec}{60\sec\min} = 0.0166666\min$$

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

$$\Delta P = \frac{.0166666666666667 \times 200 \times 14.7}{133.7}$$

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

$$DrawDownRate = .37psi/sec$$

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

Homework from 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 from 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 from Week 7 – Volume

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

Homework from Week 7 – Volume

$$\frac{2000gal}{7.48gal/cf} = 267.38cf$$

- Answer:

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

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

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

Homework from 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 from Week 7 – Volume

- Use the MEASUR Tool for this one:
  - Answer

LEAK LOSS ESTIMATOR - BAG METHOD

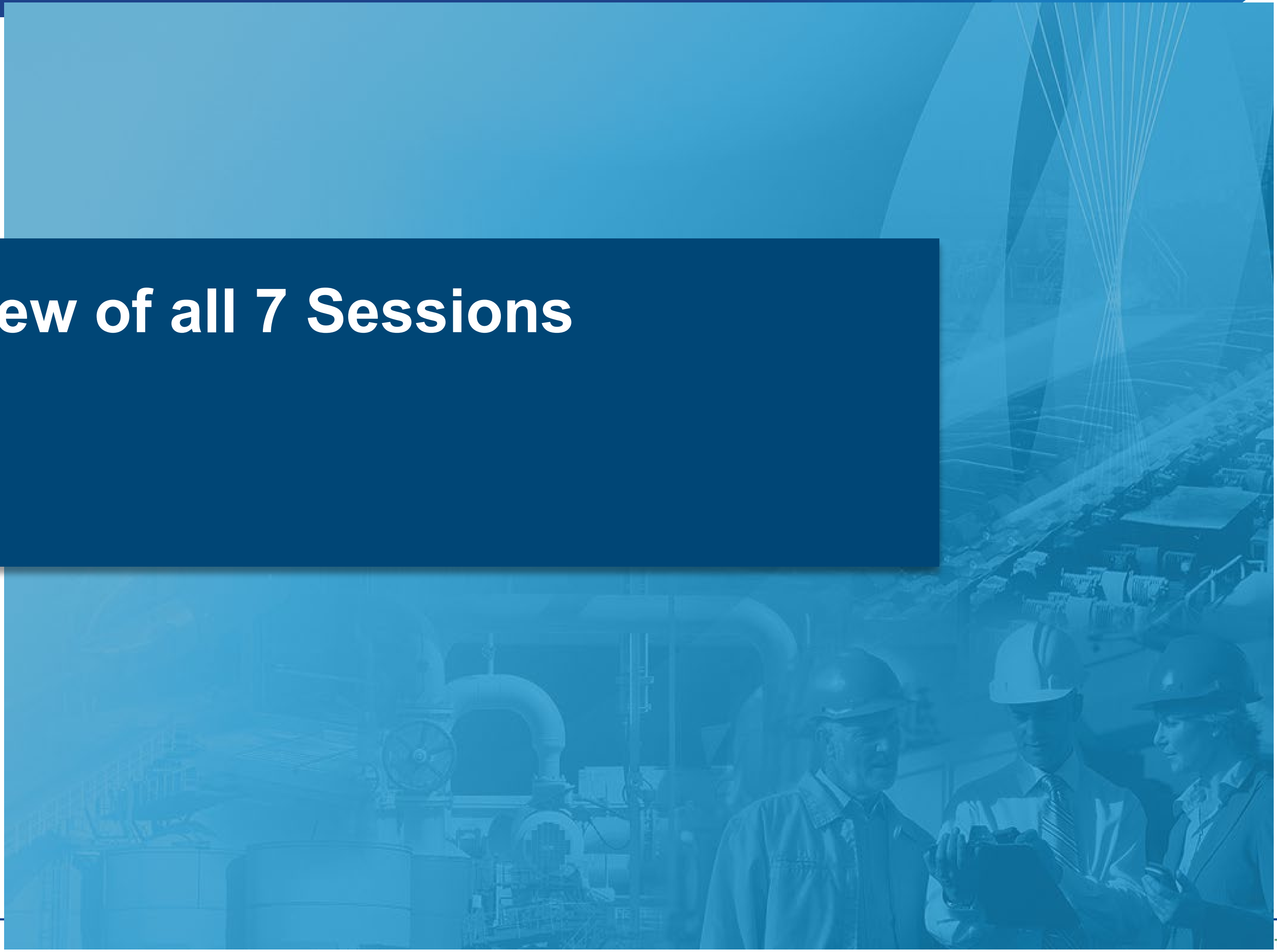
Annual Operating Hours	8760 hrs/yr
Total Flow Rate	**4.55 SCFM**
Total Annual Compressed Air Leakage	**2,391,480 SCF**

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**

Common Trash bag Sizes:

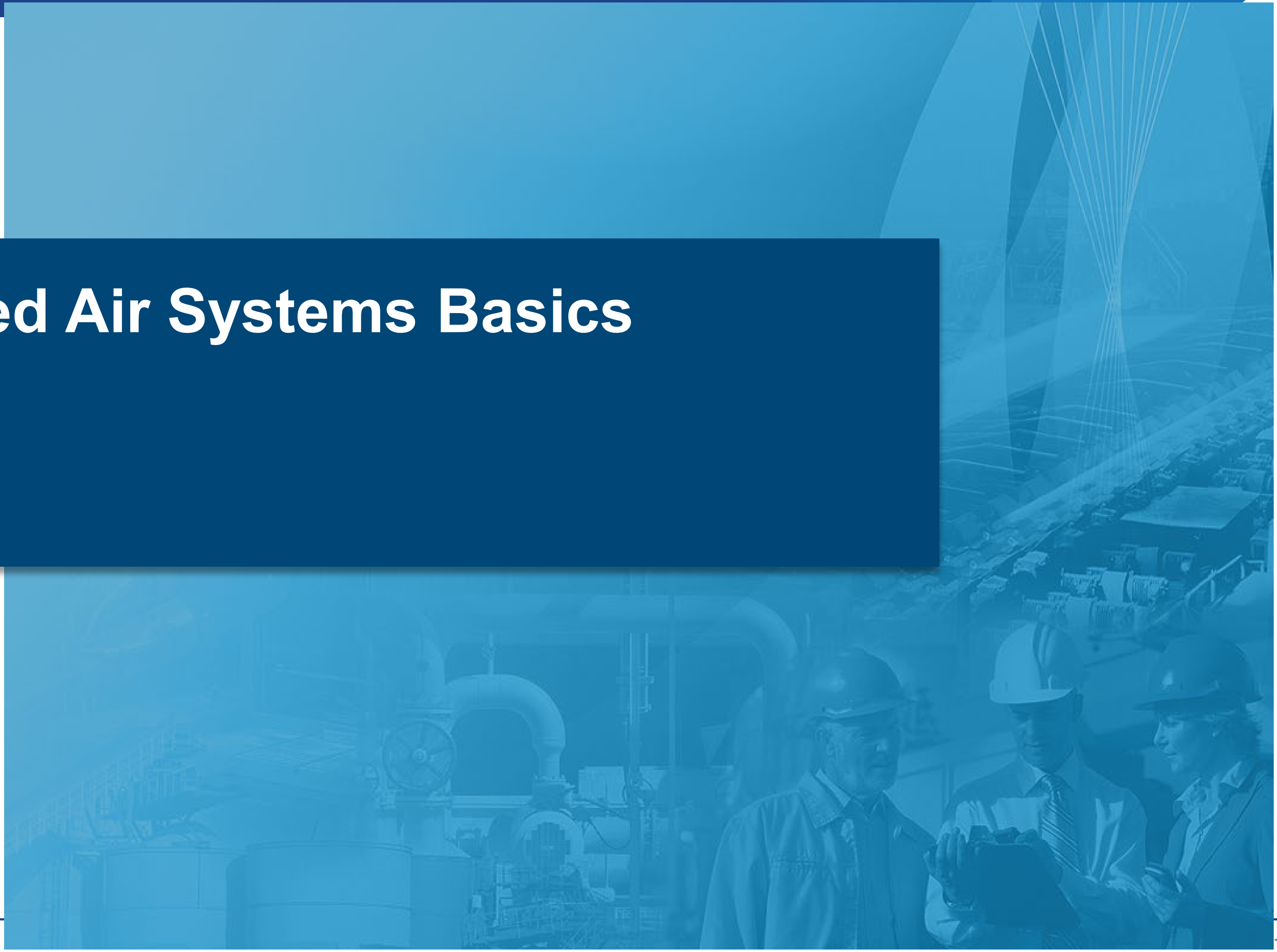
Bag Dimension	Bag Size
40"W x 46"H	40-45 Gallon
40"W x 50"H	55 Gallon
50"W x 48"H	65 Gallon



Quick Review of all 7 Sessions

Week 1 we discussed:

Compressed Air Systems Basics



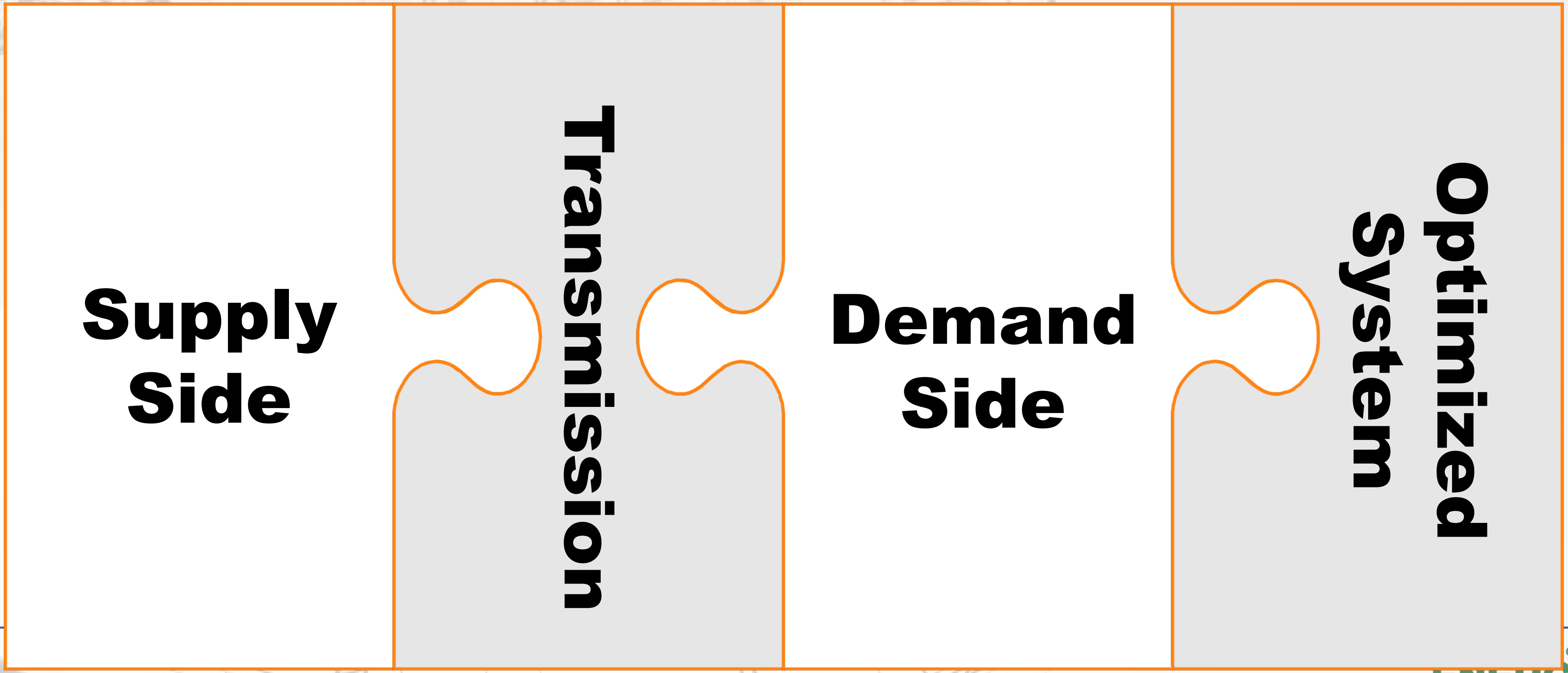
It's a Treasure Hunt

What am I looking for?

The prime consideration for any compressed air system is the ability to generate air with the least amount of energy.

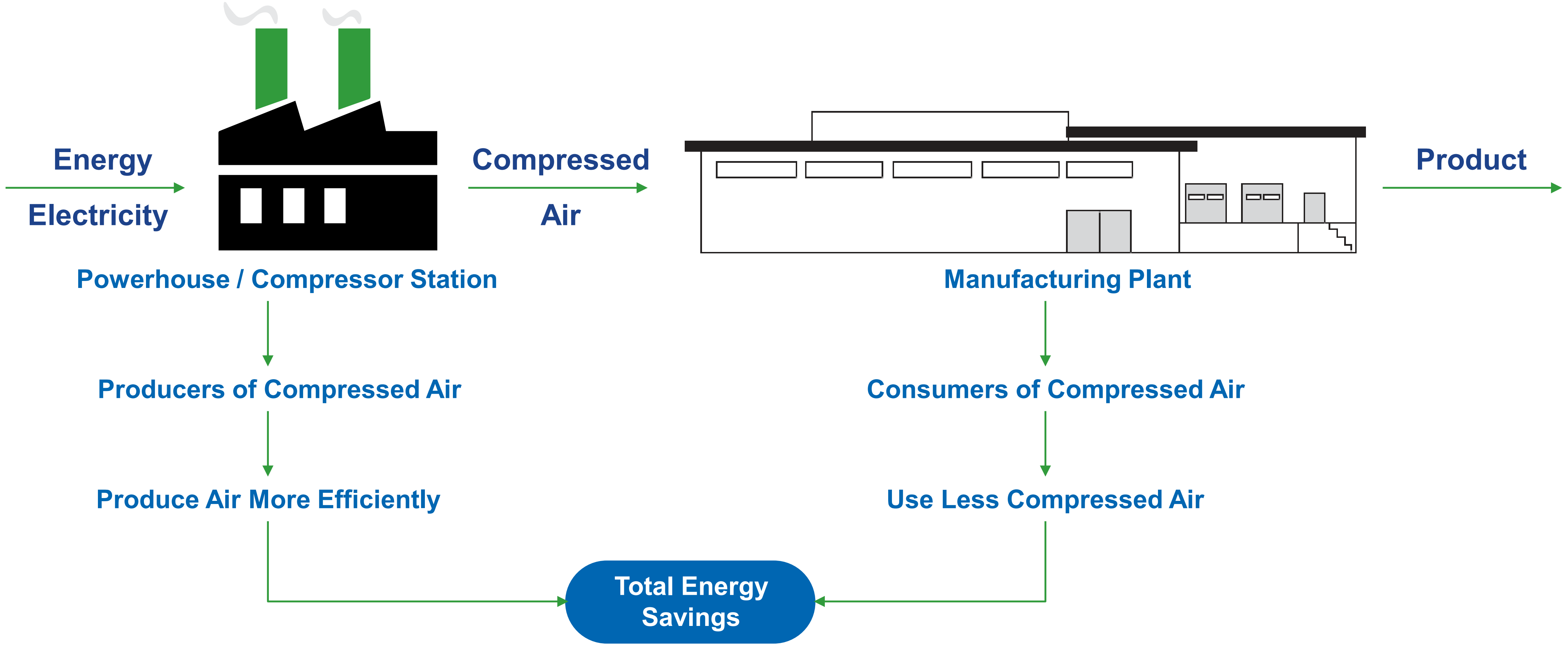
Having done this, the next consideration is to transmit energy from the point of generation to the point of use with the least loss.

The final consideration is to eliminate waste and use the least amount of air for the production process.



Compressed Air Systems Approach
plant efficiency: energy -- product

There are two basic ways to reduce the energy consumption of a compressed air system: produce compressed air more efficiently; and consume less compressed air.



What Are My Goals?

Produce more efficiently

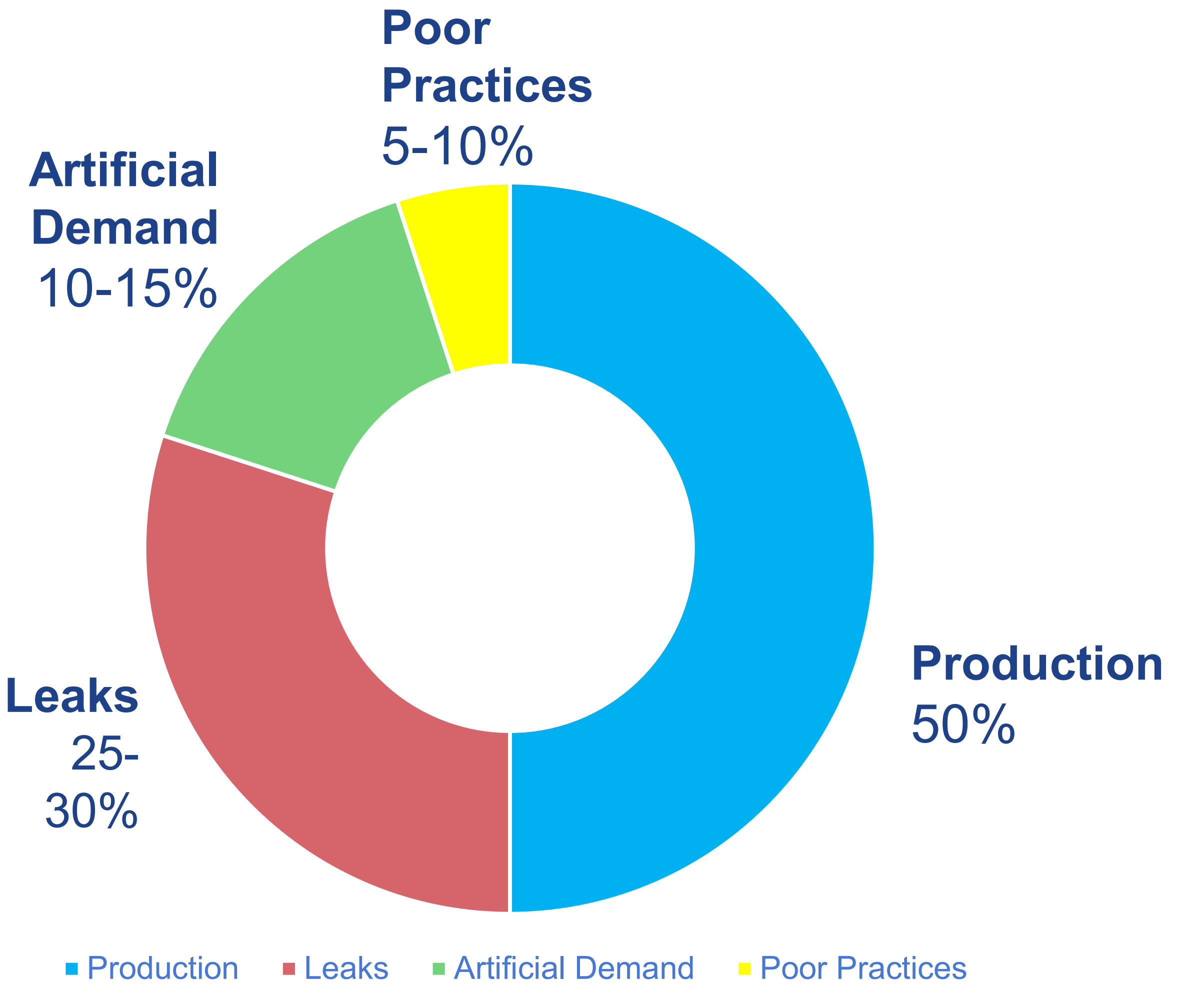
- Improve Compressor Control
- Discharge Pressure?

Use less compressed air

- Reduce Air Demand (Leaks, Inappropriate Uses, etc…)
- What is the Pressure at End Uses
- How does compressed air support production?

Understanding how compressed air is used is the single most important step to effective management.

Where does the air go?



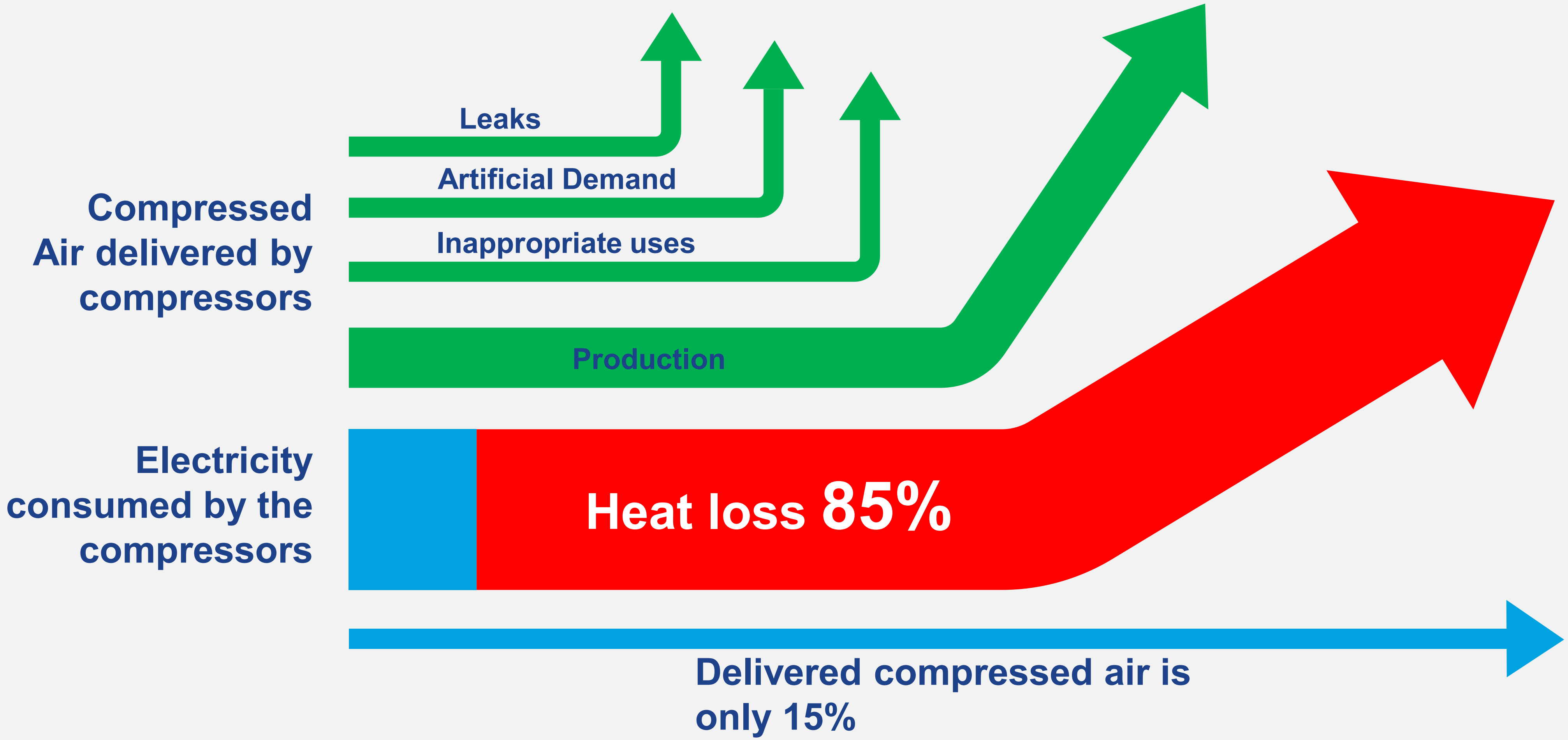
Leakage Losses

Leaks can account for 20% - 30% of the total amount of air being compressed.

The acoustic camera uses microphones and sophisticated signal processing and software to identify the loudest source of noise when many sources are present.

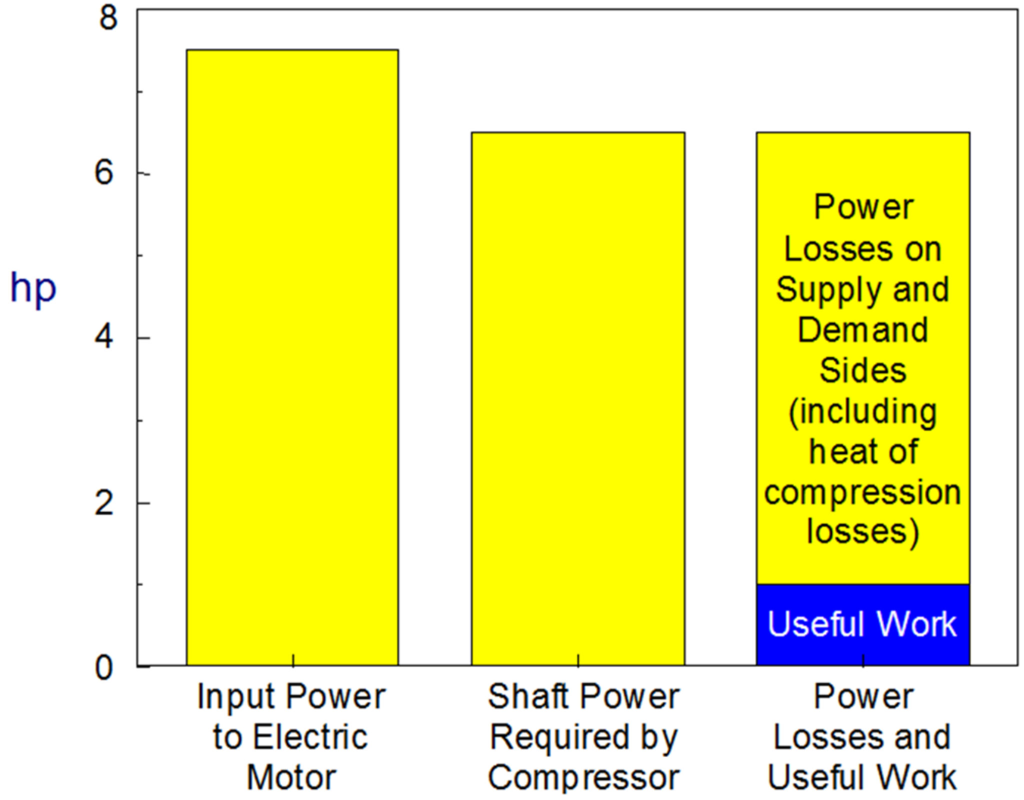
It allows the user to pinpoint sound leaks in walls, doors, and floors and target the leak

Not very efficient!

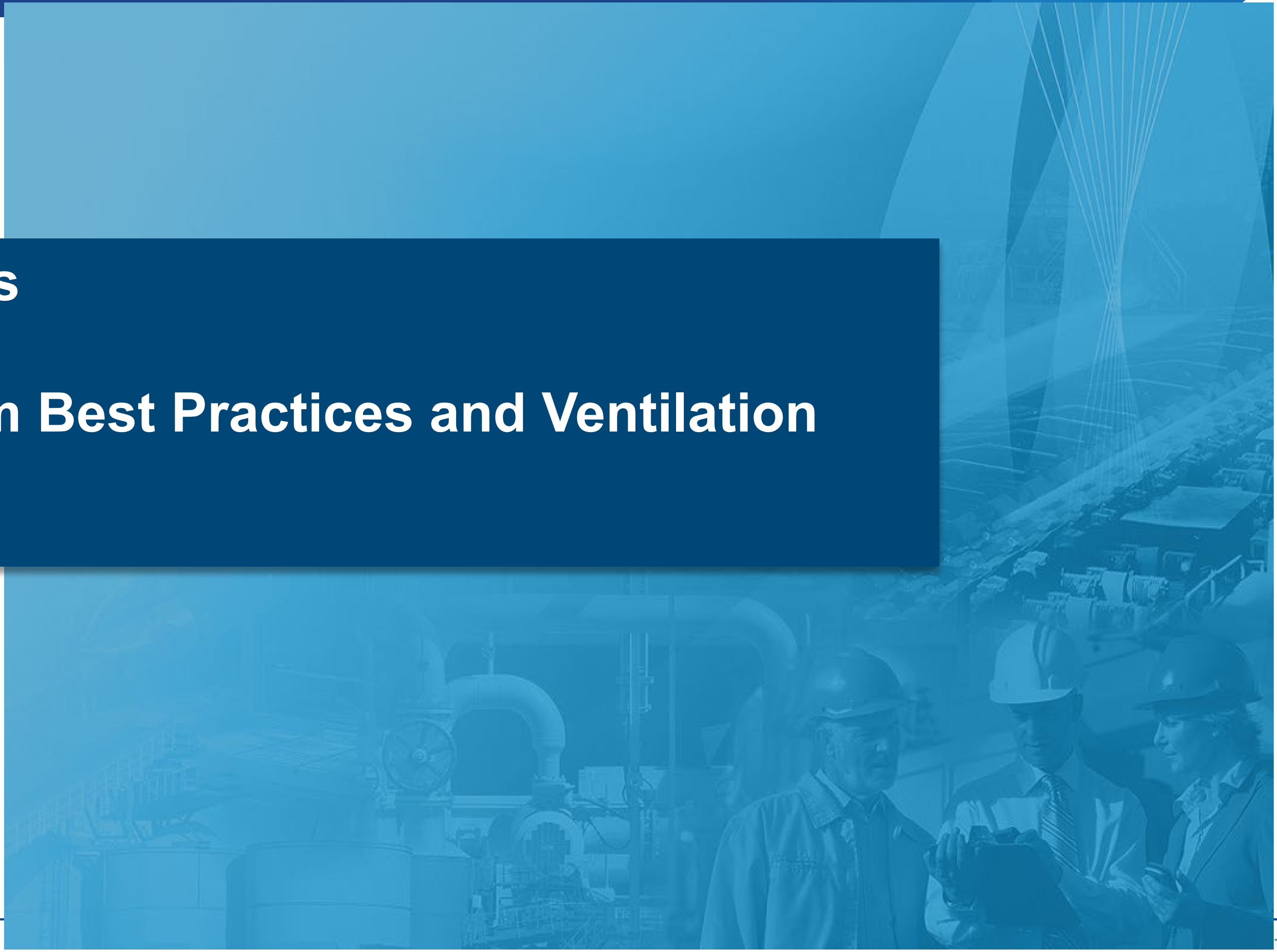


Compressed Air Versus Other Energy Sources

- 1 hp air motor = 7-8 hp of electrical power
  - 30 scfm @ 90 psig is required by the air motor
  - 6 - 7 bhp at compressor shaft required for 30 scfm
  - 7 - 8 hp electrical power required for this
- Annual energy cost for a 1 hp air motor versus a 1 hp electric motor, 5-day per week, 2 shift operation, $0.05/kWh
- **$ 1,164 vs. $ 194**



Week 2 we discussed:



Compressor Types
Maintenance
Compressor Room Best Practices and Ventilation

Ventilation

Exhaust Size Fan Ventilation Simplified Equation

- The following formula can be used to determine the fan size needed to vent a compressor room given a certain horsepower online and venting into the room:

$$\text{Fan cfm} = \frac{Heatload(BTU\ /\ Hr)}{1.08 \times \text{Temp Rise (deg } F)}$$

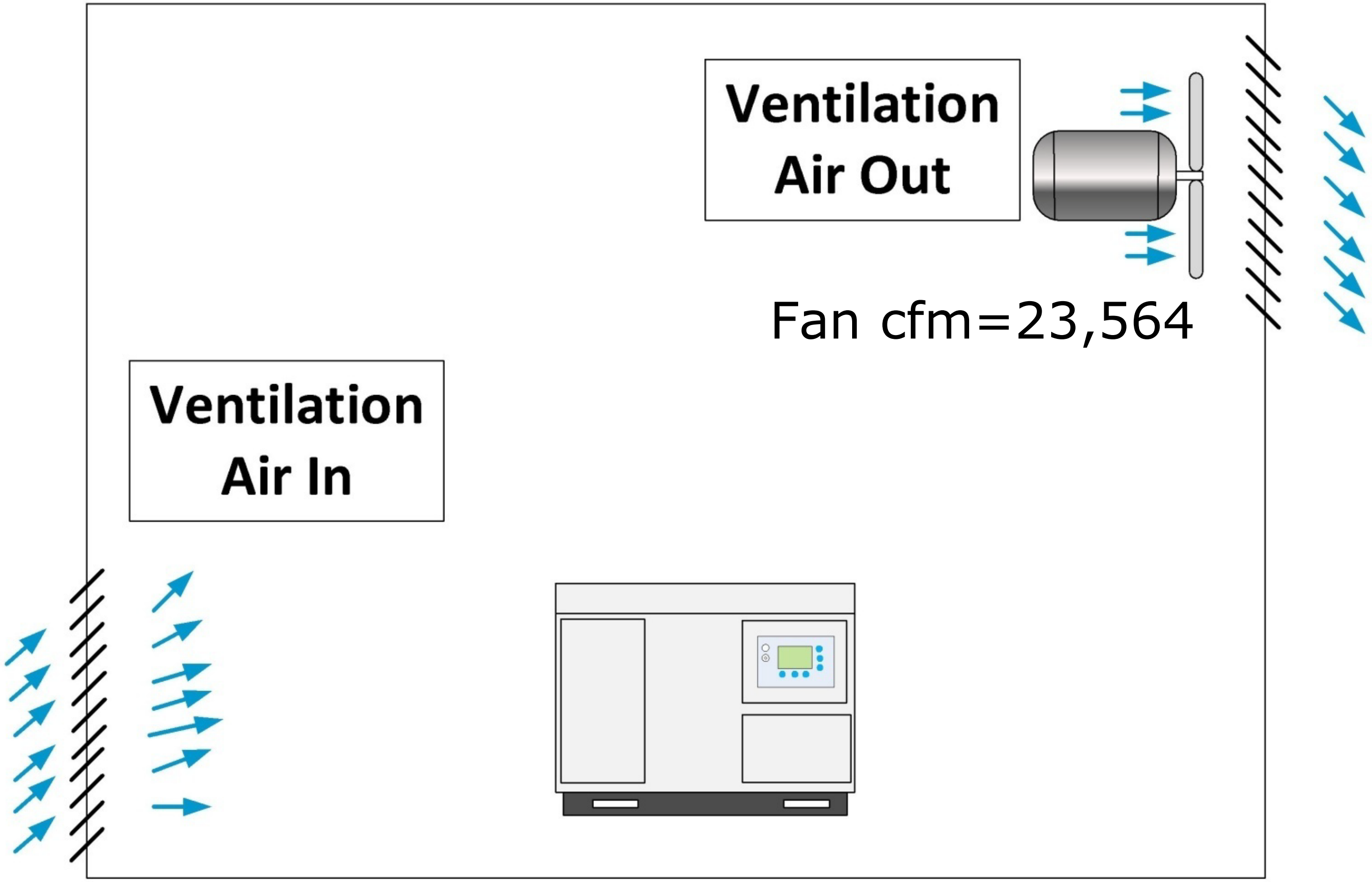
- 1 HP = 2,545 BTU / hr
- The heat load is sensible duty only.
- Temp rise is above make-up air temp.
  - A 10-degree rise is all you really need.

Ventilation Example 100 HP Compressor

$$\text{Fan cfm} = \frac{Heatload(BTU / Hr)}{1.08 \times \text{Temp Rise (deg } F)}$$

$$\text{Fan cfm} = \frac{(100 \times 2{,}545\ BTU / Hr)}{1.08 \times 10}$$

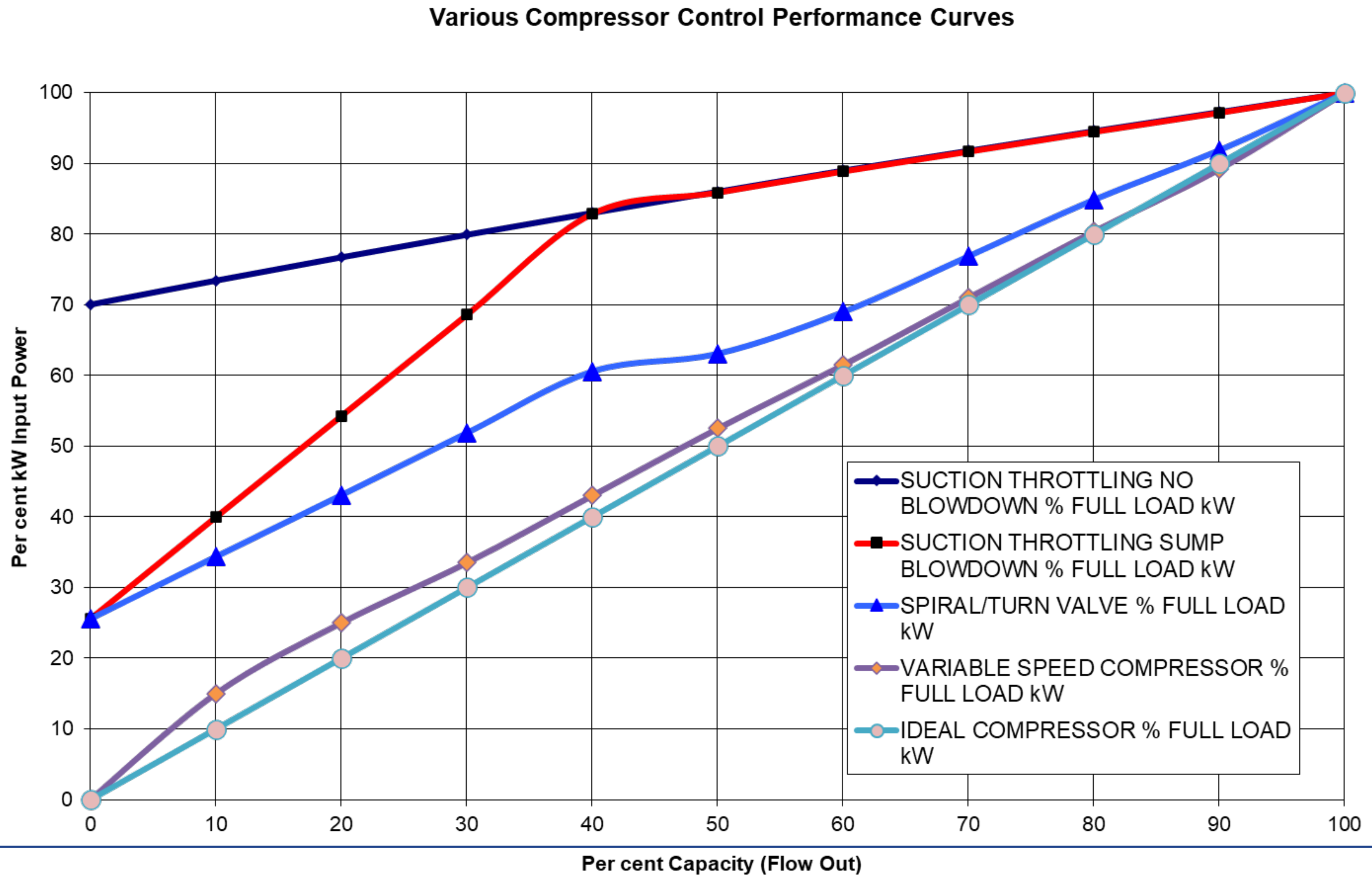
$$\text{Fan cfm} = 23{,}564$$



Session 3 – Week 3, we discussed:

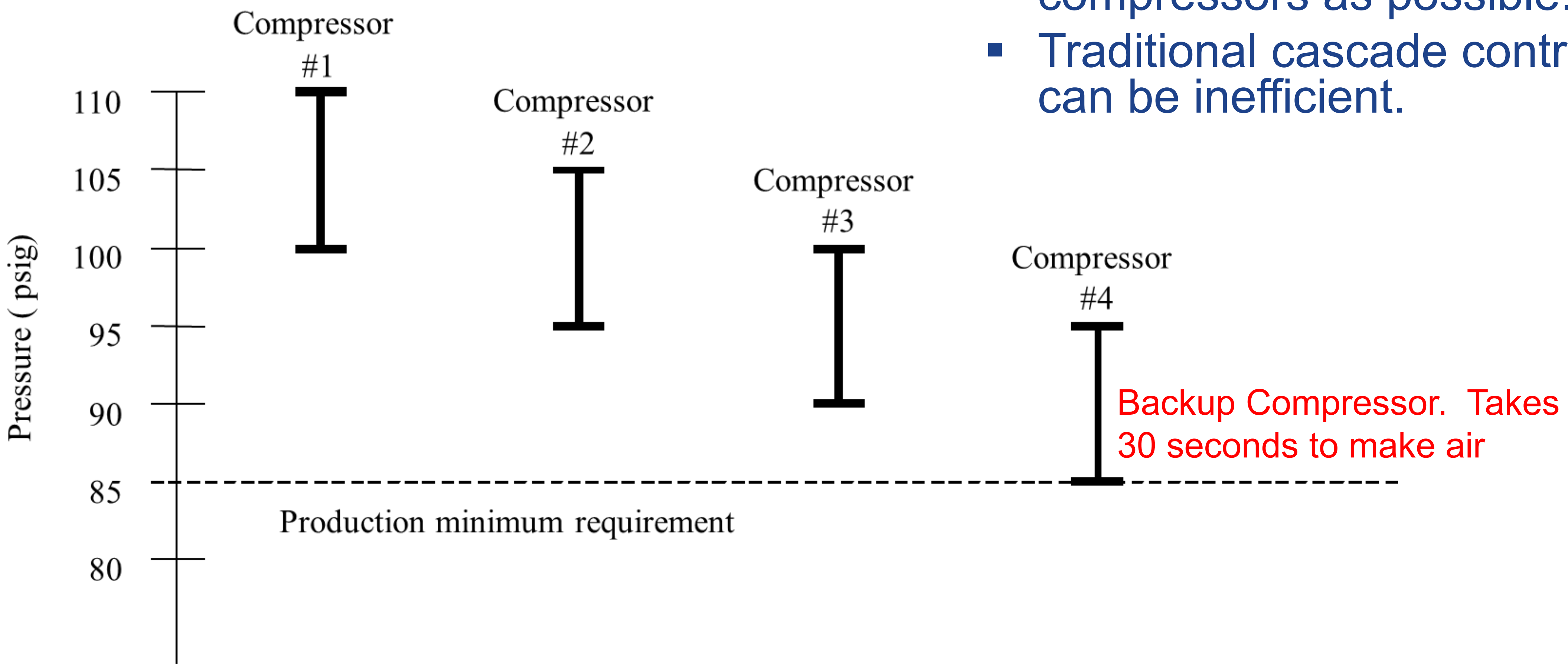
Compressor Controls
Intro to LogTool
Intro to MEASUR

Performance Curves



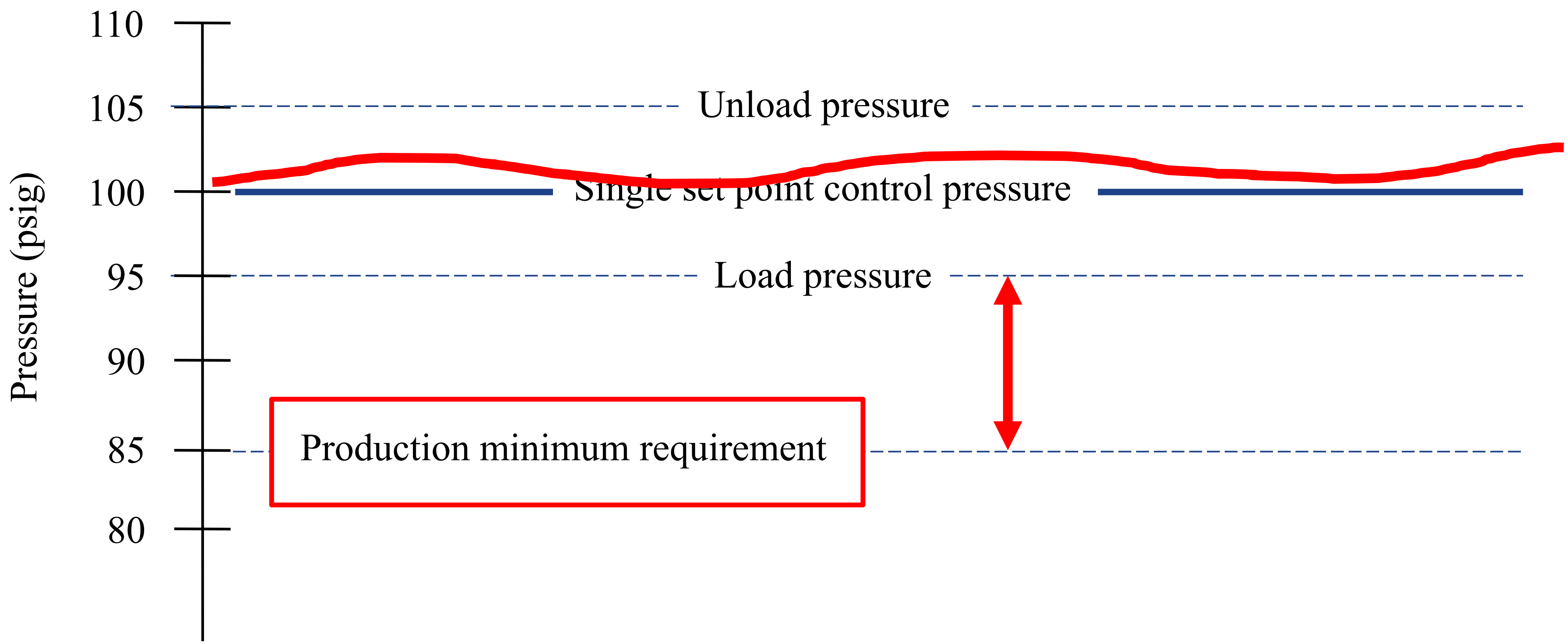
Cascade Compressor Control

- Base load as many compressors as possible.
- Traditional cascade control can be inefficient.



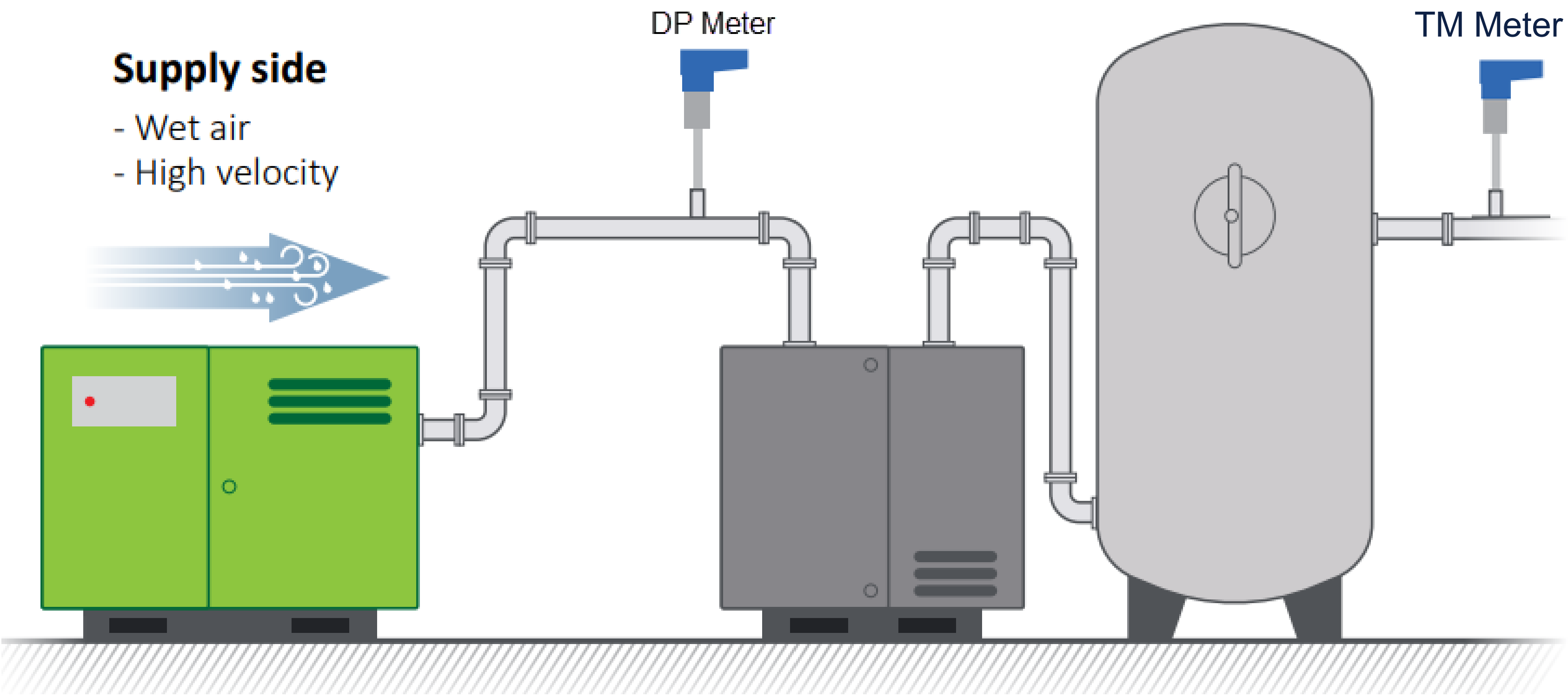
Master Controls

- Basic single set point control scheme



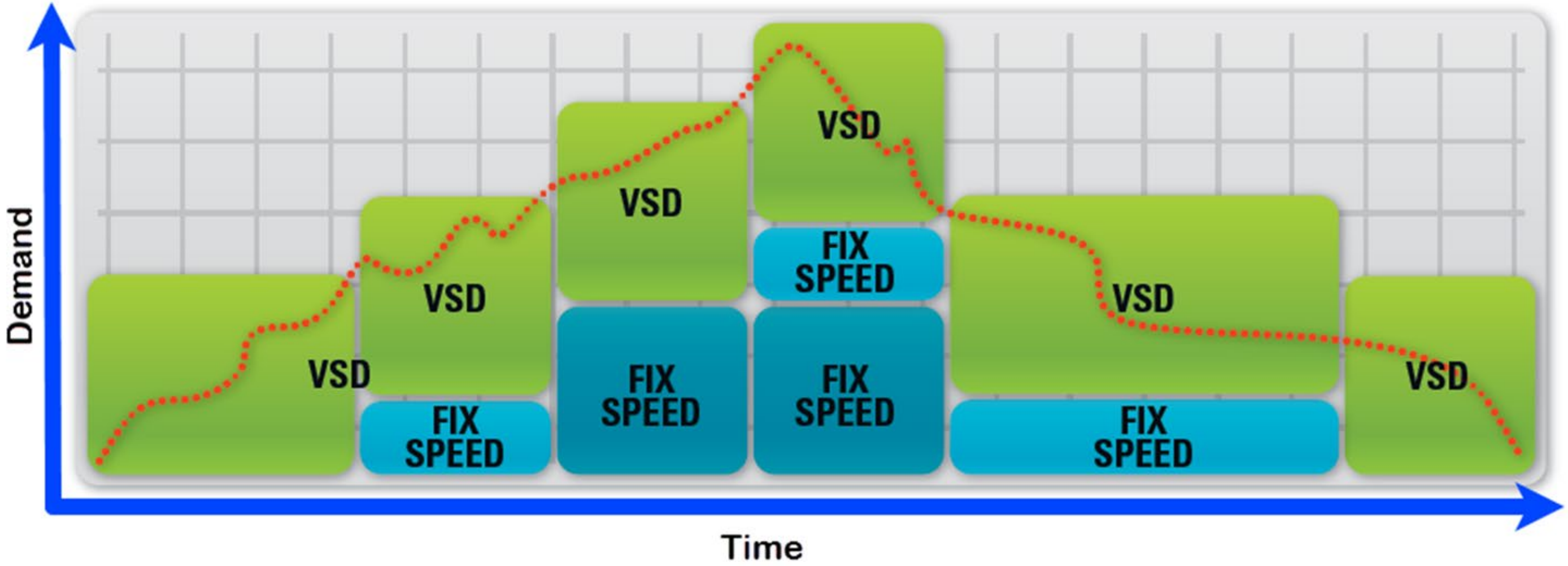
DP Insertion Flow Meters

- Insertion style Differential Pressure meter for saturated compressed air flow measurements.
- A differential pressure flow sensor measures bi-directional flow, pressure, temperature and total flow simultaneously.
- They are intended for use in high velocity applications where there is a continuous flow over a minimum value, such as compressor efficiency monitoring.

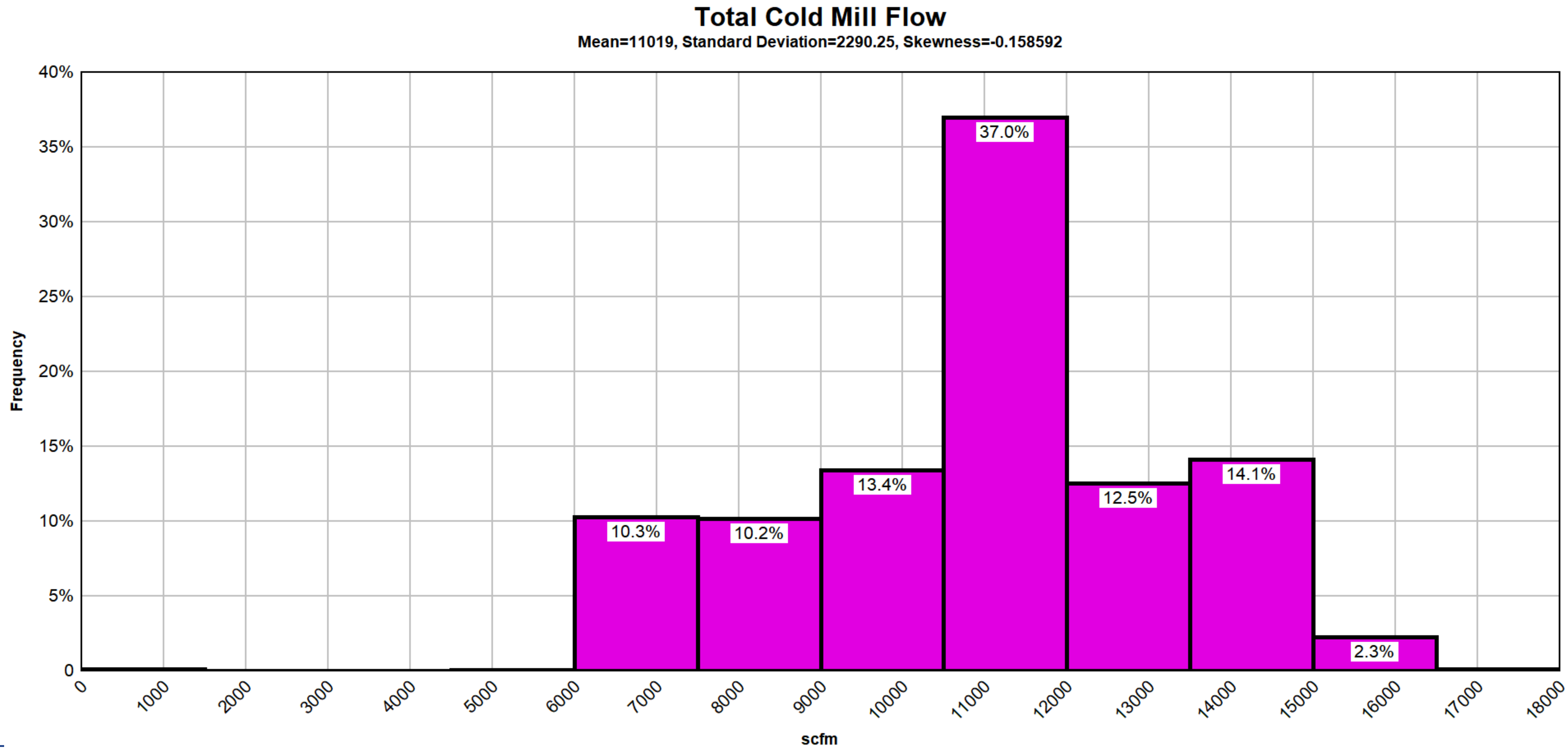


Variable Speed Compressors

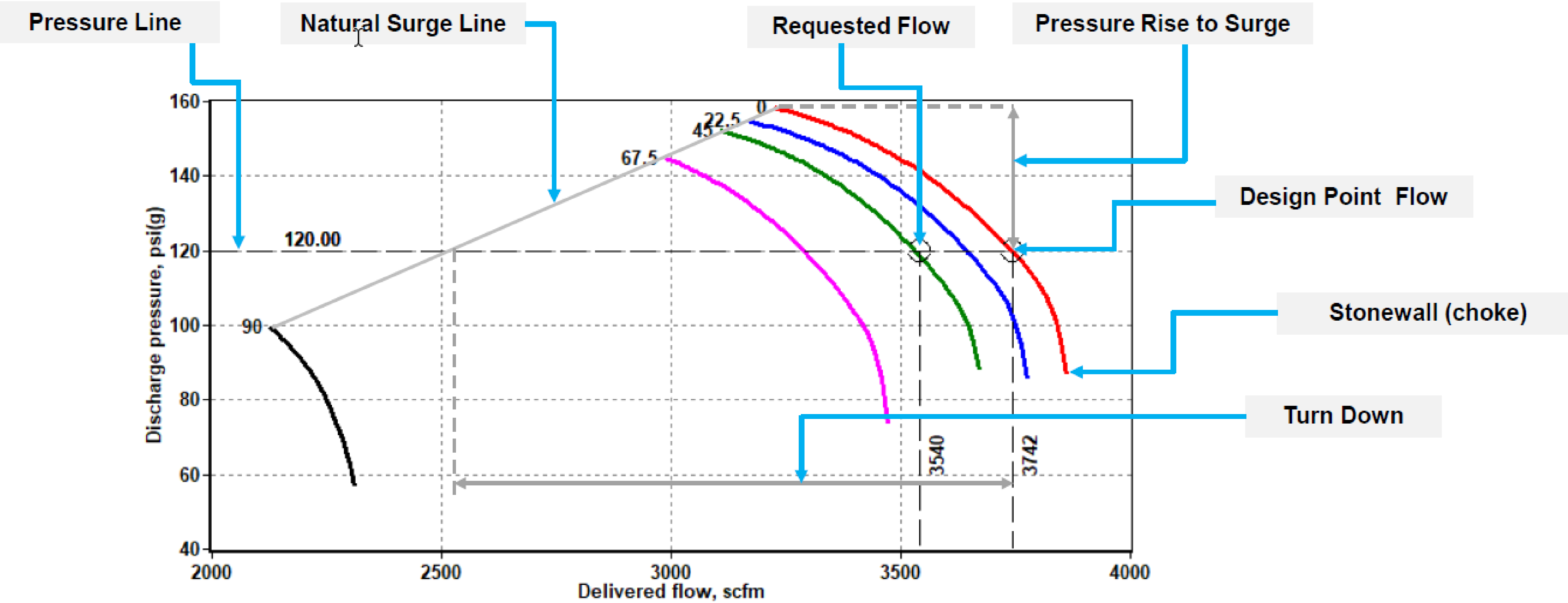
- In order to provide efficient VSD regulation over the complete range of the customer's air profile, the range of the VSD from min to max needs to be sized greater than the load/no load machine



How do I know my flow patterns to size a VSD Correctly?



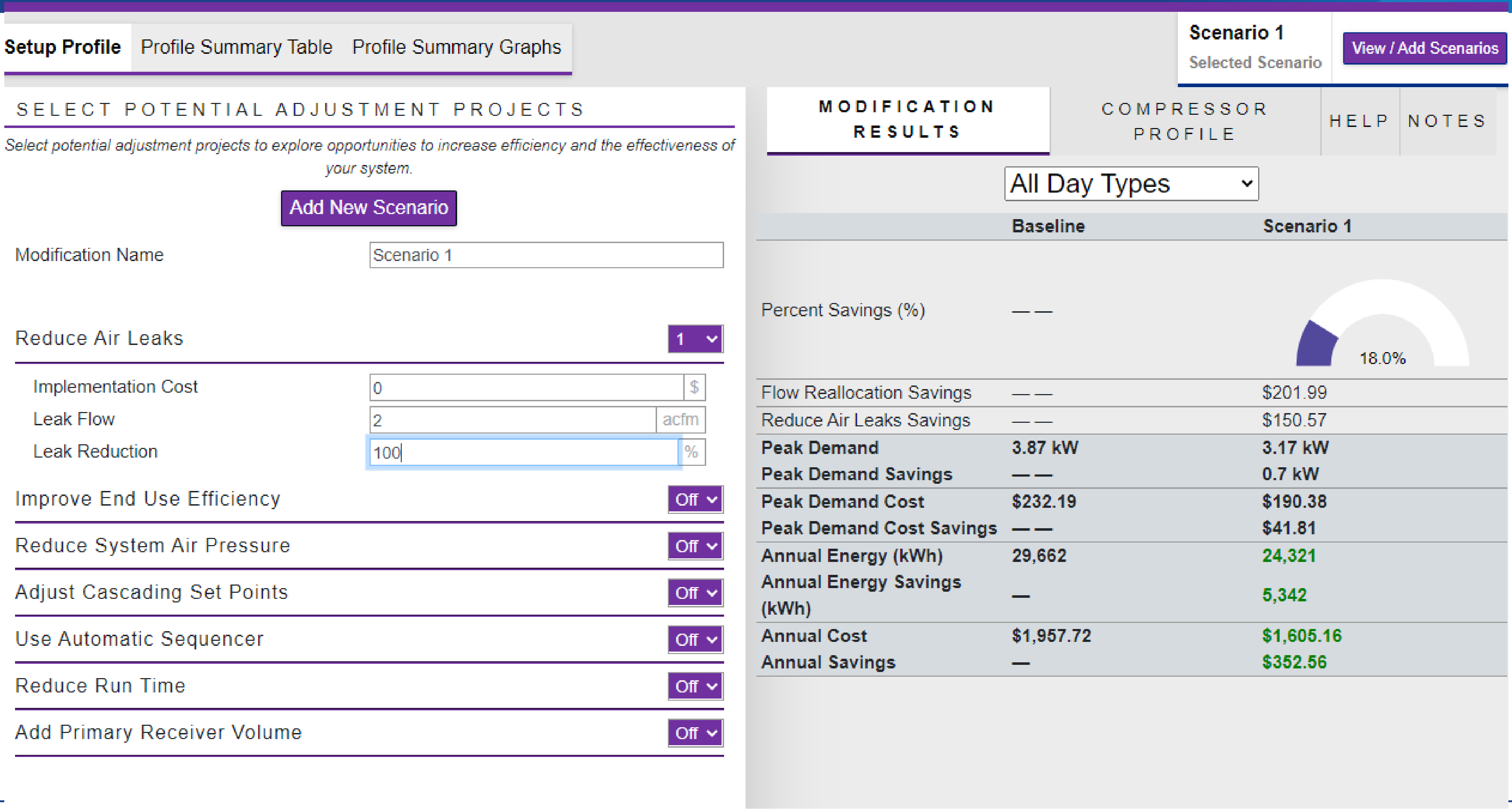
Centrifugal Performance



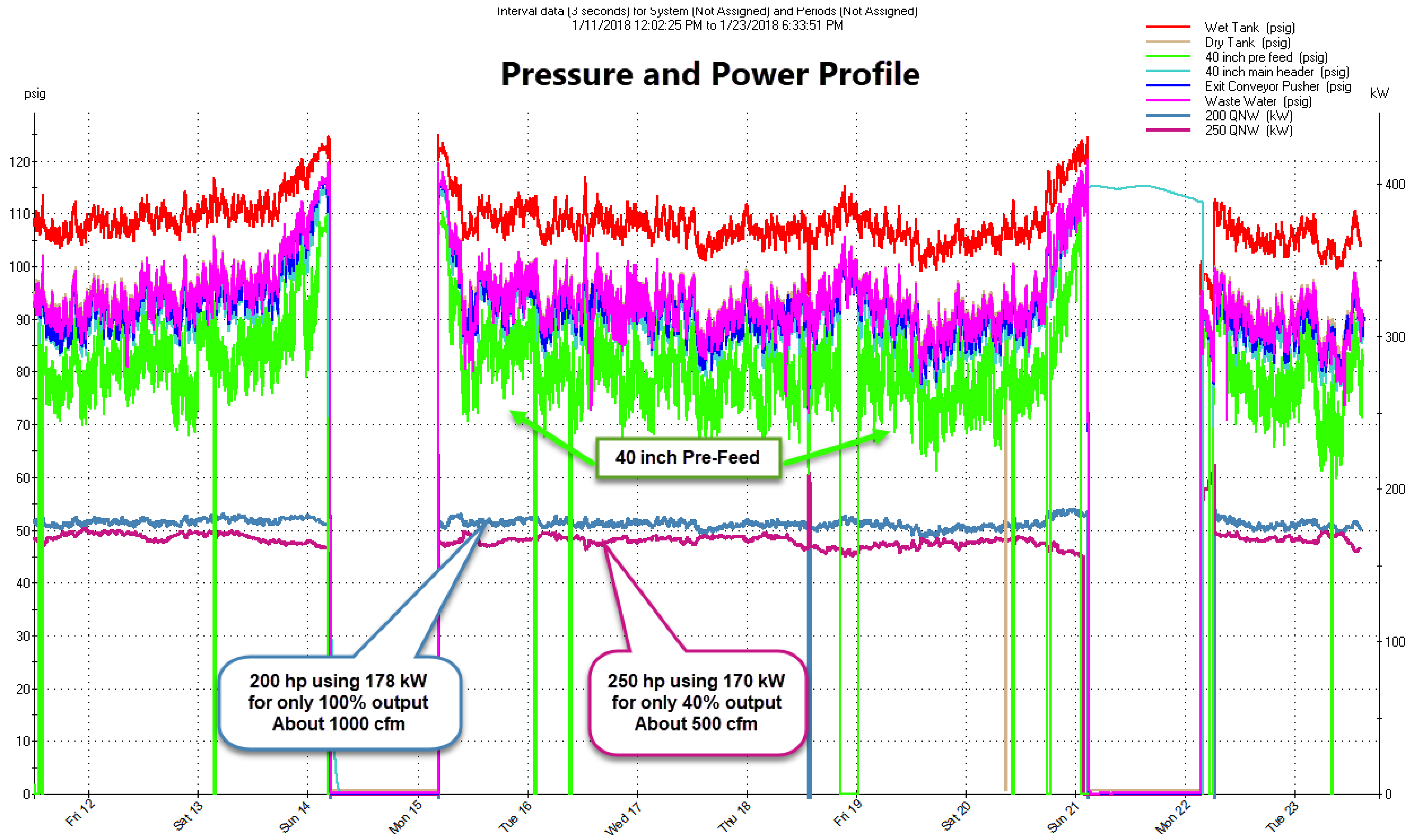
MEASUR Tool


U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy
Add New
Home
All Assessments
Coca Cola v2
Coca Cola v2
Coca Cola v2
Coca Cola
Cleveland Cliffs Burns Harbor
Lockheed Martin
New Assessment
Lockheed Martin
International Paper
International Paper
New Assessment
International Paper
IP
Lennox
UTLX Ville Platte LA
Owens Corning Amarillo
Fuji Jan 2023
Fuji New
International Paper
Hon
Fujifilm
Fuji
Corning Inc
Corning Inc
SRP
MEASUR
Welcome to the most efficient way to manage and optimize your facilities' systems and equipment.
Create an assessment to model your system and find opportunities for efficiency or run calculations from one of our many property and equipment calculators.
Get started with one of the following options.
If you need help at any point along the way, click on a User Manual icon.
View Assessments
Equipment Calculators
Pump Assessment
Compressed Air Assessment
Process Heating Assessment
Fan Assessment
Steam Assessment
Treasure Hunt
Wastewater Assessment
Motor Inventory
Pump Inventory
Data Exploration
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

Find Energy Savings!



LogTool Trend Plot



Session 4 we discussed:

Air Treatment

Dryers

Filters

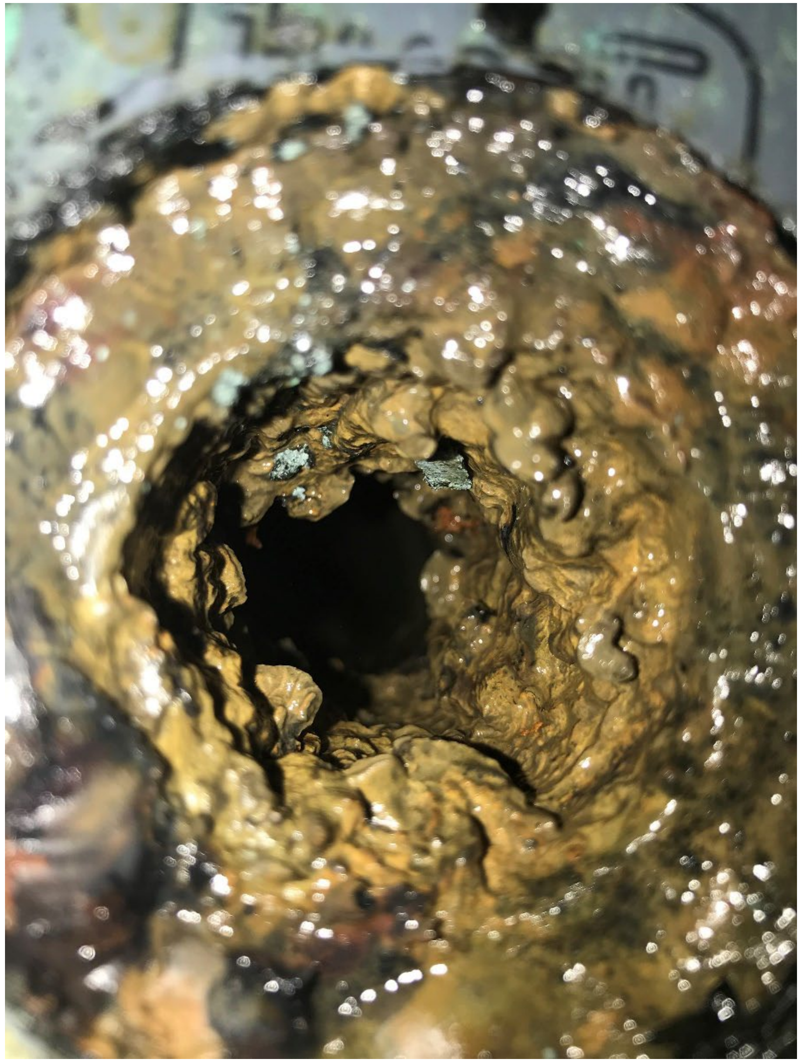
Condensate Removal

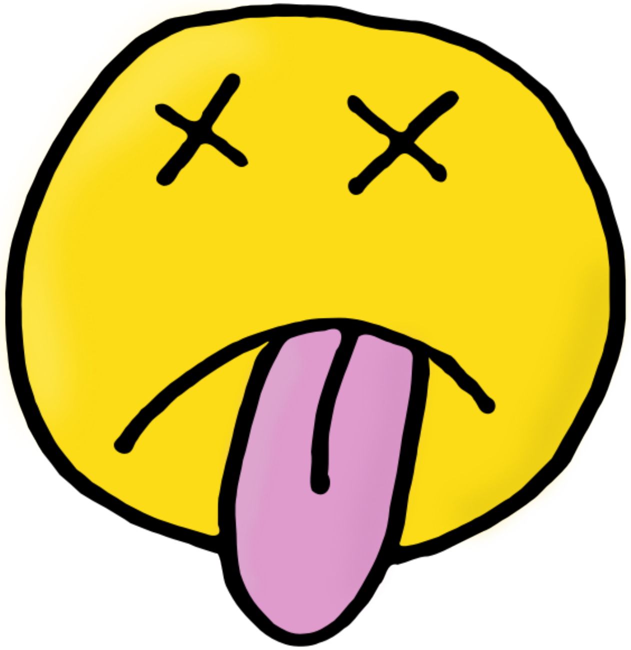
Specifying the Right Dryer

versus

- Do not dry compressed air more than is required by the application.
- Consider initial drying with a refrigerant type dryer then drying further only to meet the requirement at a specific point of use.
- Leaks in the piping can degrade the Pressure-Dewpoint.

EFFECTS OF WATER CONTAMINATION

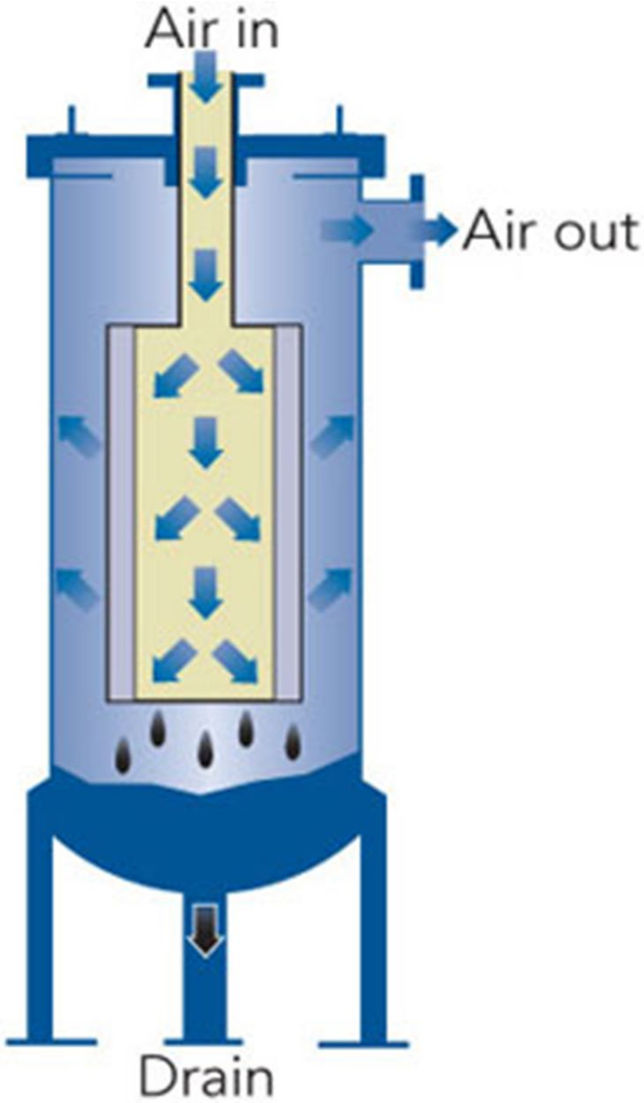




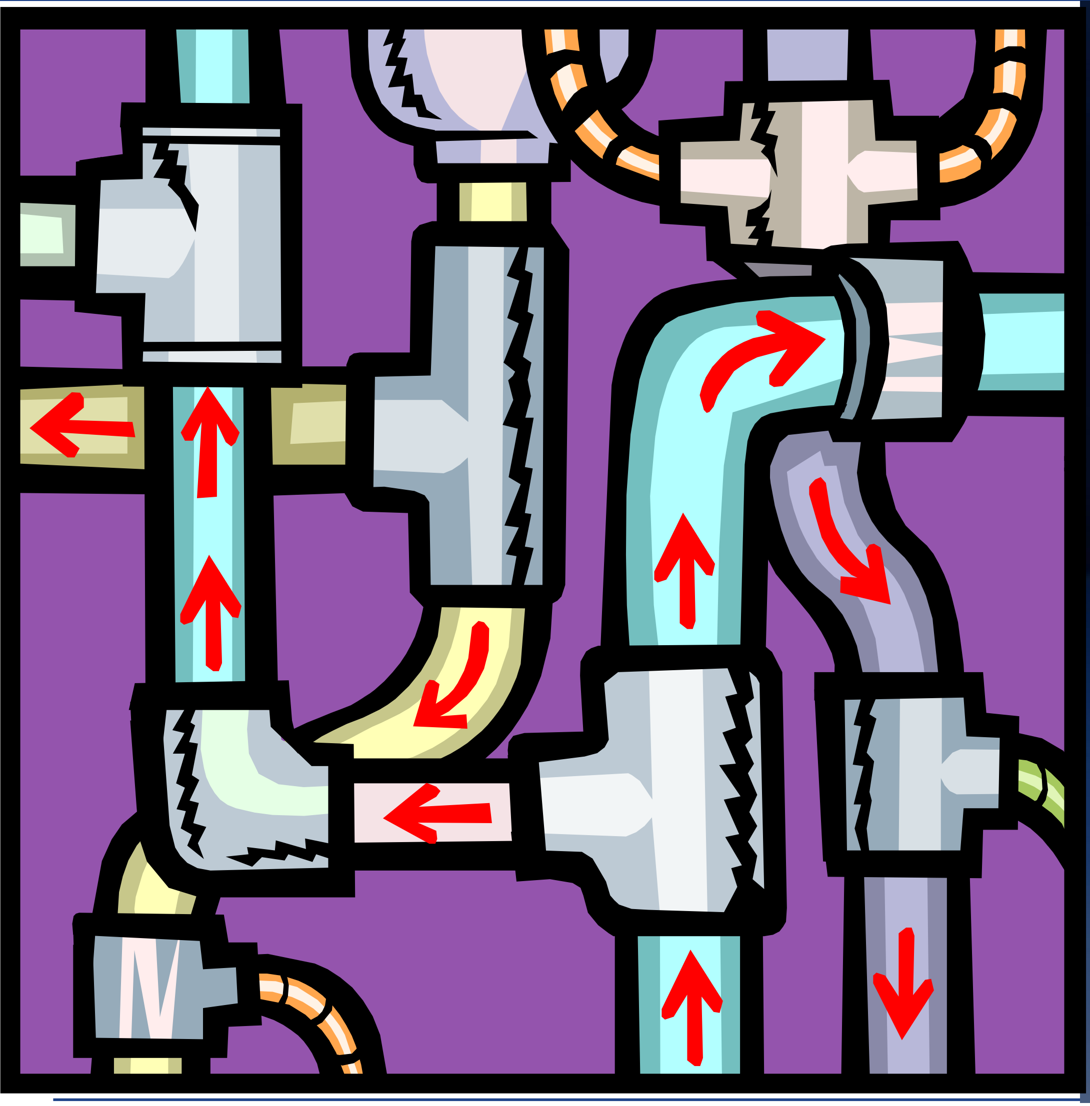
So How Do I Measure My Dewpoint?

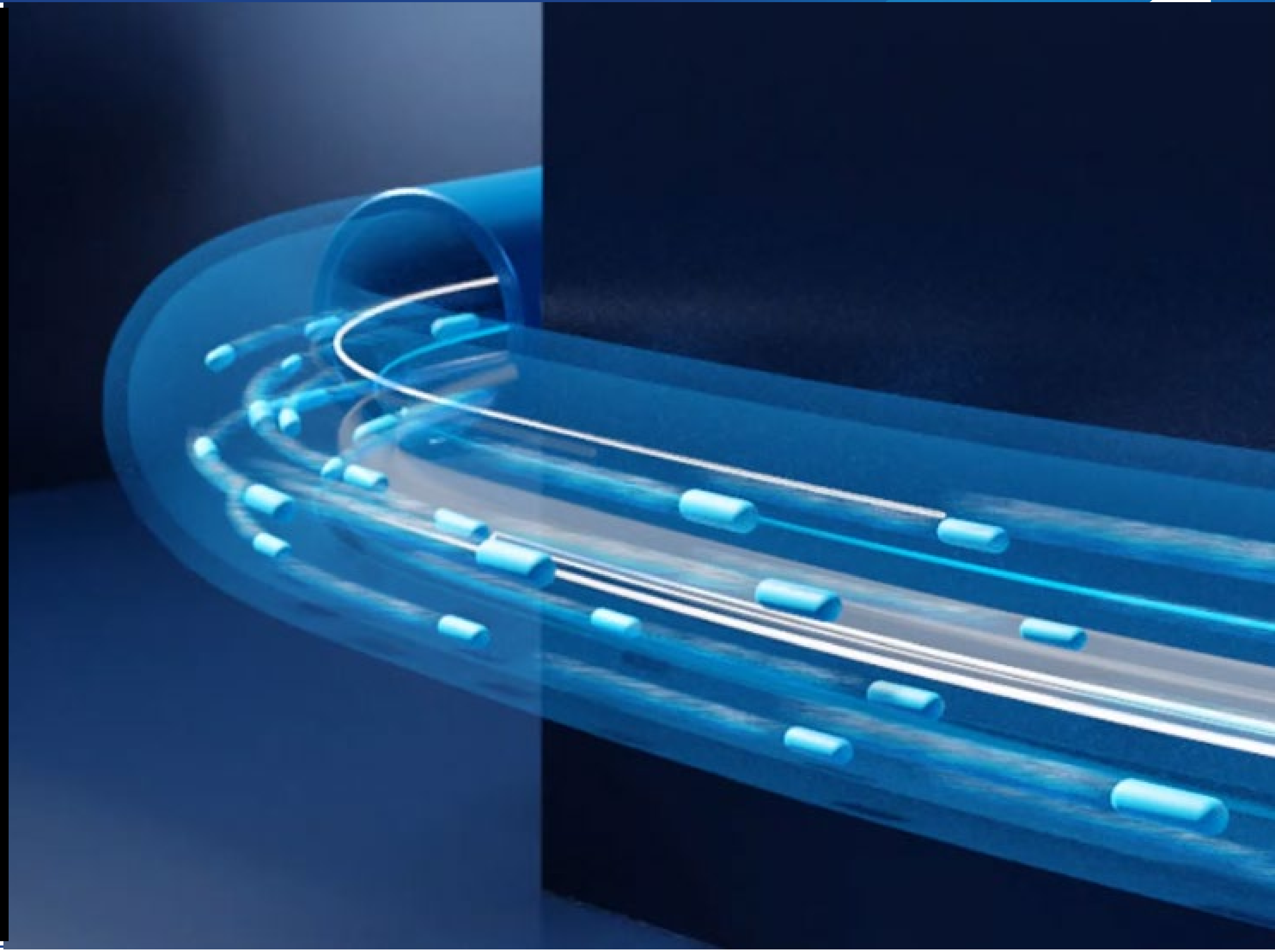
- Maintaining the dew point of your air or gas system will prolong the lifetime of your equipment and reduce maintenance costs.
- For dew points related to production processes, guarding the dew point is critical for the end-product and key in preventing costly production losses.
- Permanent monitoring enables you to detect and prevent problems quickly and may provide visibility that a change in dew point is capacity or maintenance related.

Reduce System Pressure Drop Losses



Session 5 we discussed: **Distribution System**





Reducing Pressure Drops Throughout the System

- The following equation is for calculating Velocity:

$$V_{fps} = \frac{cfm \times P_a}{60 \times a \times (P_2 + P_a)}$$

  - Where:
    - V = Velocity in feet per second,
    - P_a = local barometric pressure
    - cfm = air flow, free air in ft^3/min
    - a = cross sectional area of pipe bore inches ft2
    - d = pipe bore diameter in inches
    - P_2 = gauge pressure in header or pipe

$$a = \frac{\pi \times d^2}{4 \times 144}$$

Using the MEASUR Tool Calculator for Velocity

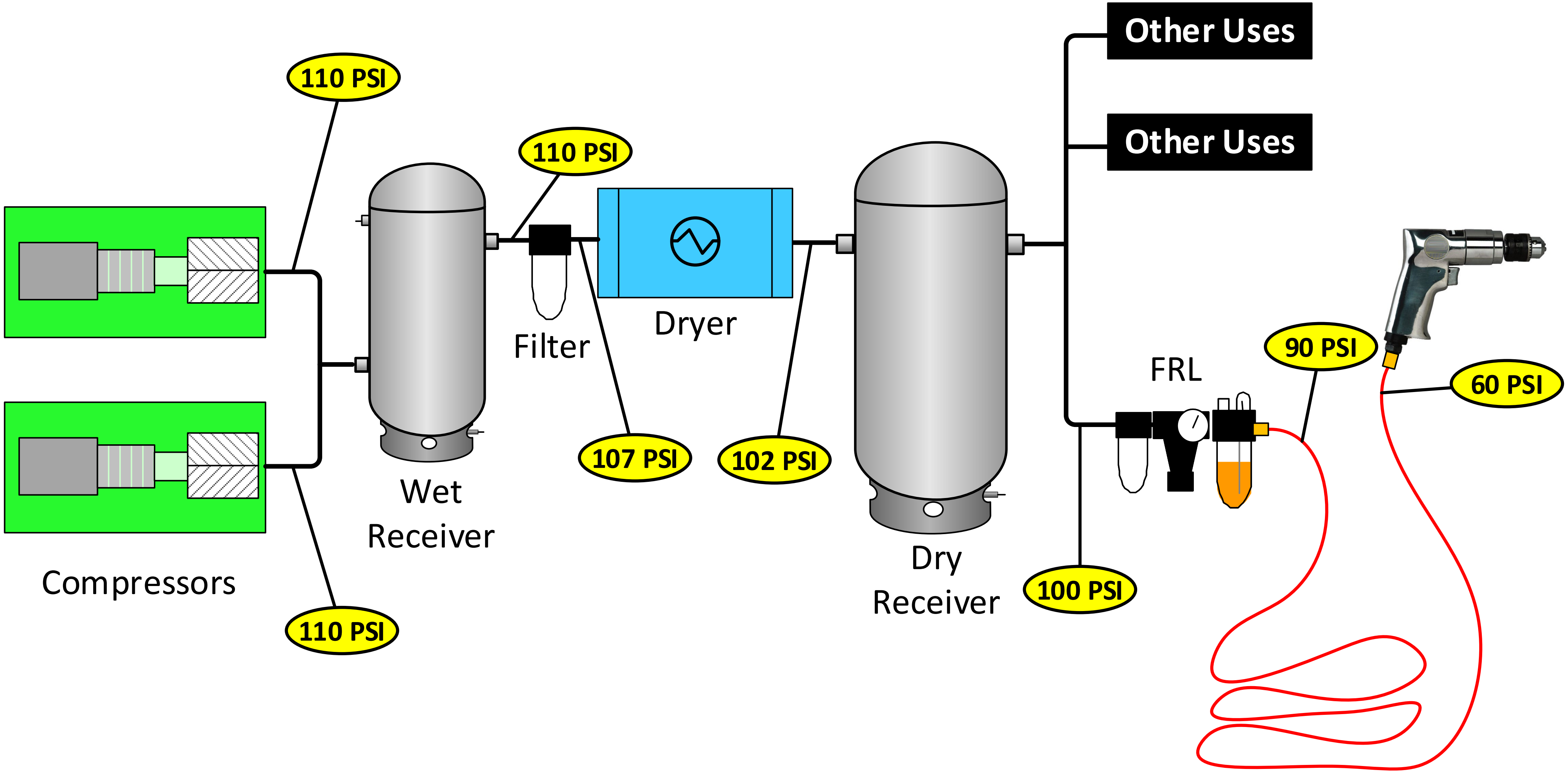
VELOCITY IN THE PIPING

Air Flow	500	SCFM
Pipe Pressure	100	psig
Atmospheric Pressure	14.5	psia

Compressed Air Velocity in the Piping

Pipe Size (in)		Pipe Size (in)	
1/2	506.55 ft/s	5	7.6 ft/s
3/4	286.73 ft/s	6	5.26 ft/s
1	176.7 ft/s	8	3.04 ft/s
1 1/4	101.31 ft/s	10	1.93 ft/s
1 1/2	74.49 ft/s	12	1.36 ft/s
2	45.23 ft/s	14	1.12 ft/s
2 1/2	31.73 ft/s	16	0.86 ft/s
3	20.56 ft/s	18	0.68 ft/s
3 1/2	15.37 ft/s	20	0.55 ft/s
4	11.94 ft/s	24	0.38 ft/s

Developing a System Profile

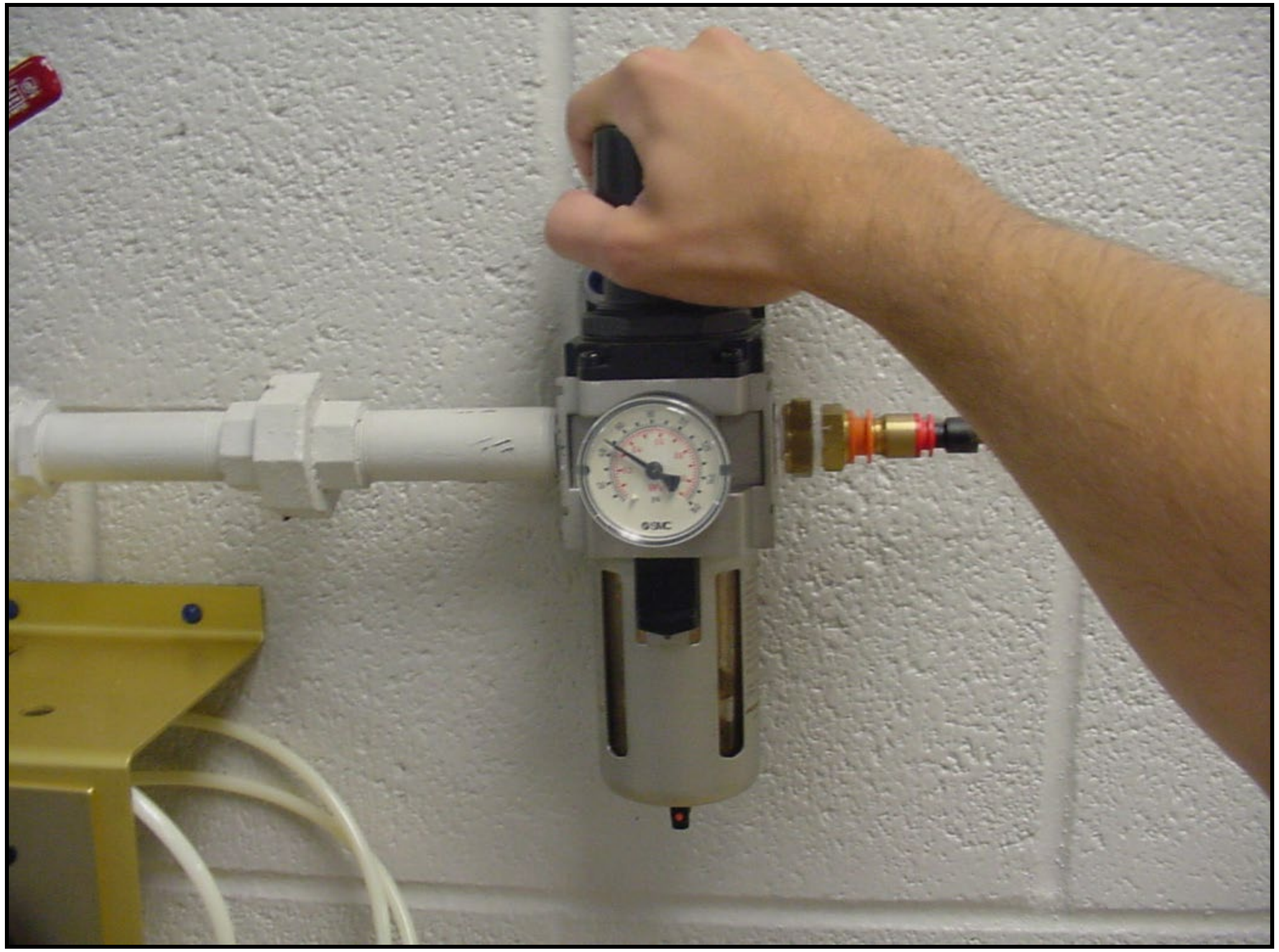


Session 6 we discussed:

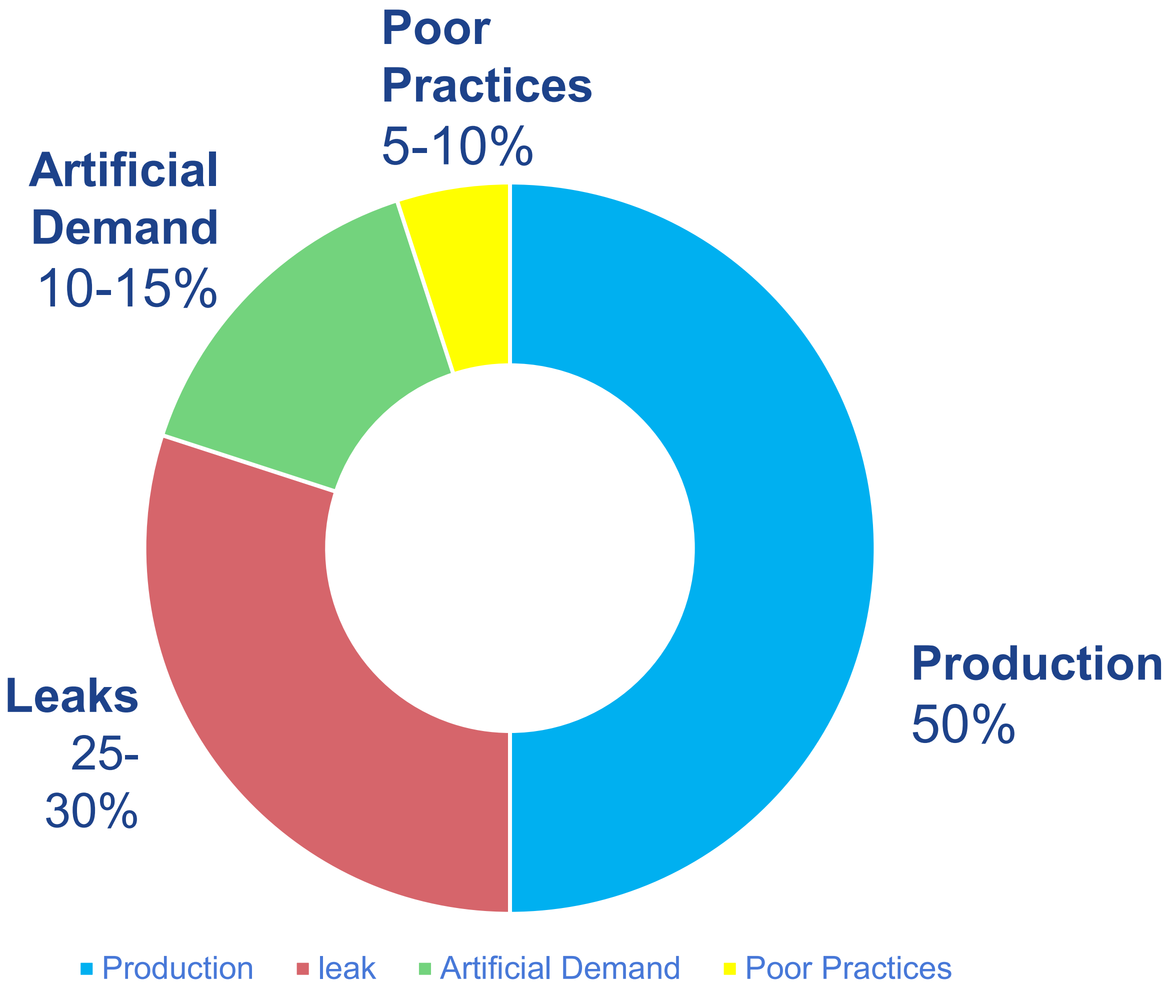
Demand Side

Over-Pressurization Examples

- Equipment operators rarely understand the relationship between flow and pressure.
- What leads to excessive pressurization of pneumatic systems?
- Misdiagnosis of equipment malfunction
- Flow rate increases force a “droop” in downstream pressure
- Mismanaged point-of-use filtration
- In each case, equipment operators respond by increasing the pressure at the regulator.



We looked at the waste



How Acoustic Camera Leak Detection Works

- The acoustic camera uses microphones and sophisticated signal processing and software to identify the loudest source of noise when many sources are present.
- It allows the user to pinpoint sound leaks in walls, doors, and floors and target the leak

Potentially Inappropriate Applications

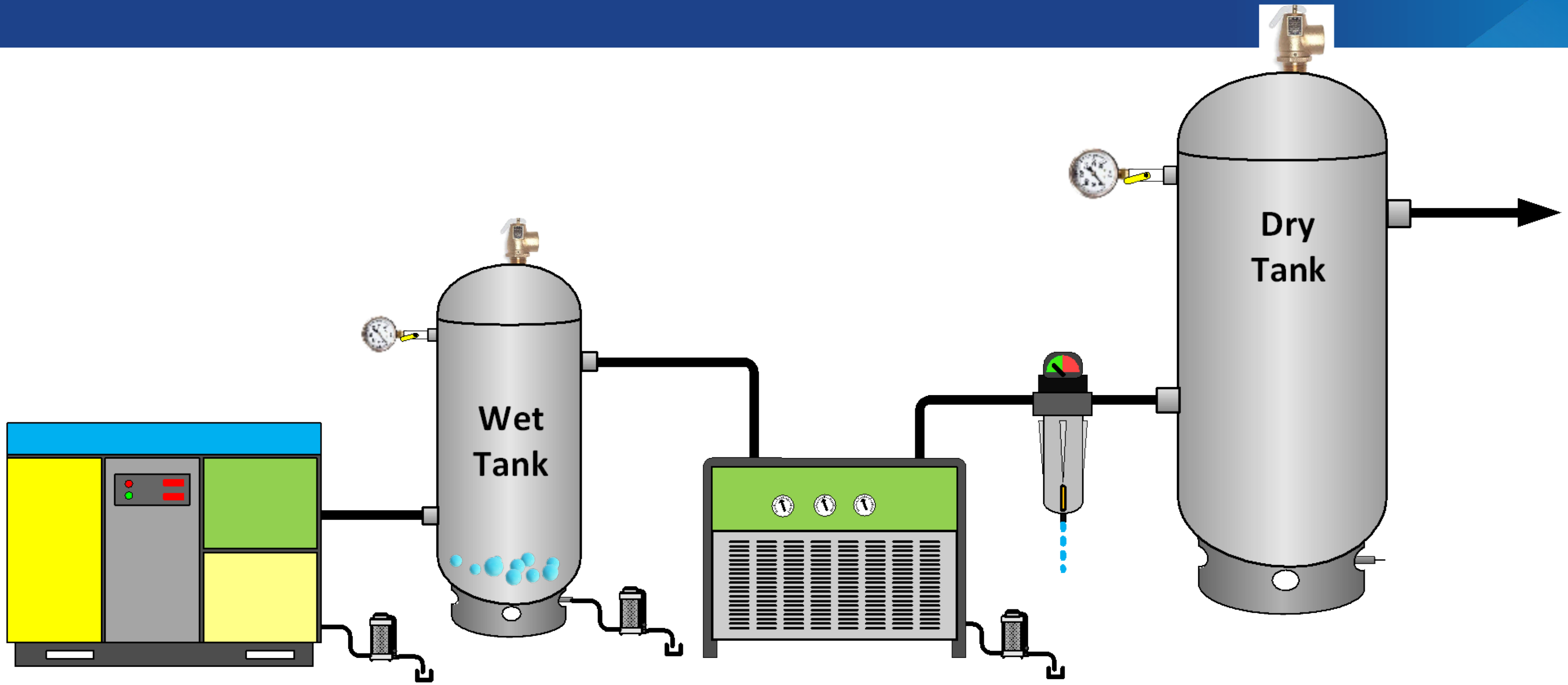
- Many applications can be served more efficiently by low pressure air from a fan, a blower; or by a vacuum pump, rather than by compressed air. Examples:

  - Open blowing
  - Sparging (agitating, aerating stirring, mixing)
  - Aspirating
  - Atomizing
  - Padding
  - Dilute phase transport
  - Dense phase transport
  - Vacuum generation
  - Personnel cooling
  - Open hand-held blow guns or lances
  - Cabinet cooling
  - Vacuum venturi
  - Diaphragm pumps
  - Timer drains/open drains
  - Air motors

Session 7 we discussed:

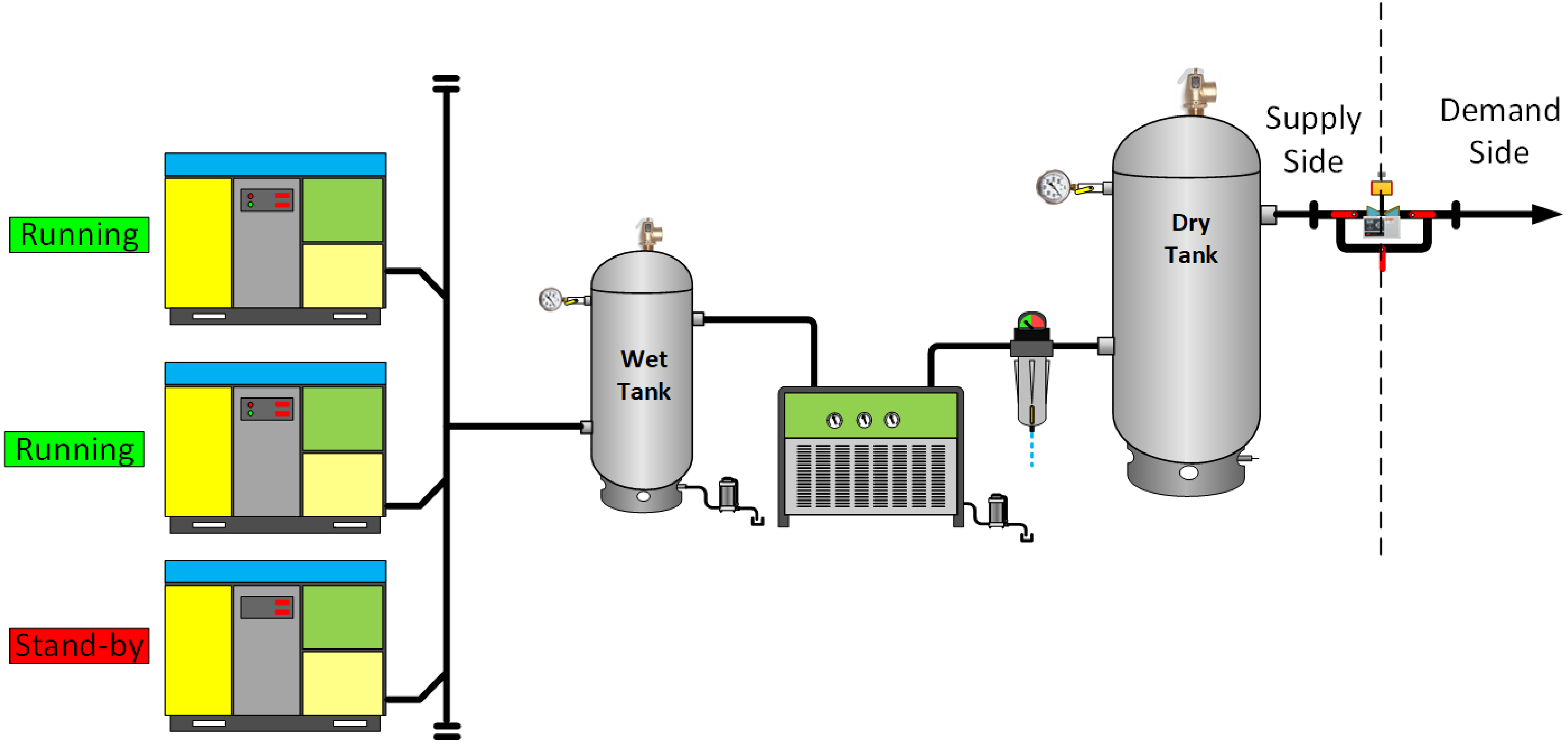
System Volume vs Storage

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 with Pressure Flow Controller



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.

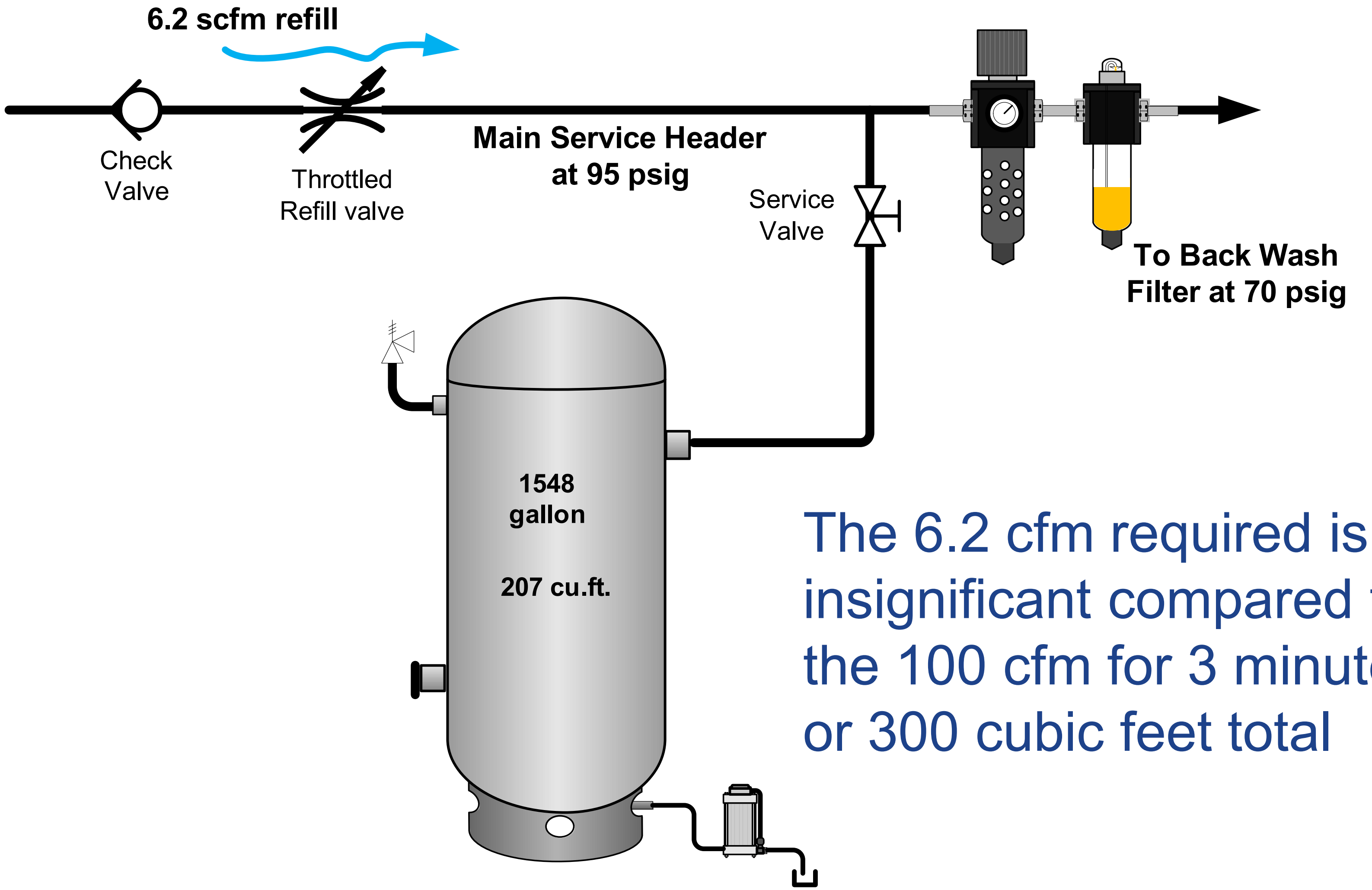
$$V = \frac{T(C-S)Pa}{P_1 - P_2} \qquad V = \frac{3(100-0)14.7}{95-70} = 176.4\ Cubic\ Feet$$

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

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

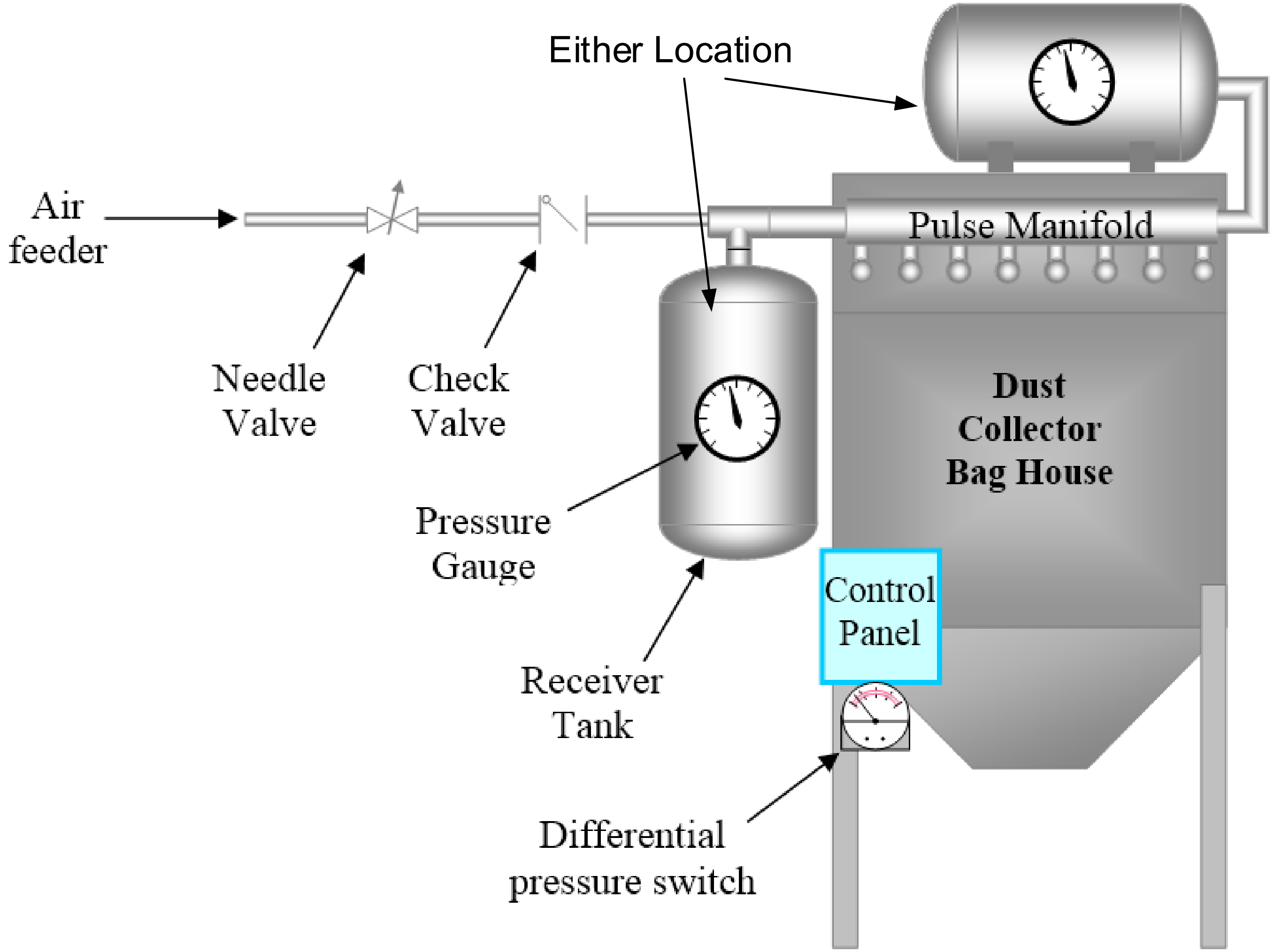
1548 gallons ÷ 7.48 gal/cu.ft. =207 cu.ft.

Example



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

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



Example of Local Storage for Critical End Use Pressure

Summary

- You need to be able to understand what is happening with your compressed air system - things are not always as they seem.
- Controls will help you to align supply with demand.
- Heat recovery can lead to substantial energy savings.
- Properly addressing air quality issues can greatly affect system performance (and economics).
- High pressure requirements should not drive your system.
- System profiles can help you understand what is happening.
- There are ways to effectively deal with high volume/intermittent needs.

Now let’s look at some of the close out presentations from our attendee's