Better Plants
U.S. DEPARTMENT OF ENERGY

In-Plant Trainings

Session 6 Demand Side

U.S. DEPARTMENT OF ENERGY

Session 7

Homework Review

Session 5 Homework

Name: Alvin Boyon

1. What is the pressure going into the main header?

   Pressure: 110 psig

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: 70 psig

3. List any applications that require high than typical pressure:

Application	Approximate End-Use Pressure Required
Oil and gas	psig
Chemical Processing	psig
HVAC	psig
Power Generation	psig

4. List any applications that require lower than typical pressure.

Application	Approximate End-Use Pressure Required
Aeration	psig
Pneumatic conveying	psig
Humidification	psig
Heating or Cooling materials	psig

6. Have compressor setpoints been raised to try and compensate for low pressure at end-use applications? Yes

Comments: Loses pressure travel distance

Session 5 Homework

Name: James Barron and Felipe Rocha

1. What is the pressure going into the main header?

   Pressure: ____110___________psig

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: ______90 min____________psig

3. List any applications that require high than typical pressure:

Application	Approximate End-Use Pressure Required
___________None______________________	__________________psig

4. List any applications that require lower than typical pressure.

Application	Approximate End-Use Pressure Required
_____________None________________	________________psig

5. List any applications where users complain about low pressure.

Application	Approximate End-Use Pressure Required
Small Packing – Pulverized Black No lower than	___84_____psig
_________________________________	________________psig

6. Have compressor setpoints been raised to try and compensate for low pressure at end-use applications? Yes

Comments: To maintain the normal delivery pressure to ensure consistent jet pulse cleaning with our HP air solenoids.

Session 5 Homework

Name: _____Ed Cooper________________________________

1. What is the pressure going into the main header?

   Pressure: ___105-115_____________psig

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: ___100___________psig

3. List any applications that require high than typical pressure:

Application	Approximate End-Use Pressure Required
__Air Cylinders on diverters____________	___105-115______psig

4. List any applications that require lower than typical pressure.

Application	Approximate End-Use Pressure Required
__Cooling/Purge air on temp sensors_____	________________psig
______Pulse air on baghouses___________	____65-100______psig

Session 5 Homework

Name: ____Nate Kirkeby____

In many cases, misapplication of compressed air at the end-use causes systems to perform poorly.

Please fill out the information below.

1. What is the pressure going into the main header?

   Pressure: ____100-105_____________psig

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: _____20-80____________psig (air pressure gets regulate down at each user)

3. List any applications that require high than typical pressure:

   Application — Approximate End-Use Pressure Required

   _____None_____________________________ _________________psig

4. List any applications that require lower than typical pressure.

   Application — Approximate End-Use Pressure Required

   ________None________________________ _________________psig

5. List any applications where users complain about low pressure.

   Application — Approximate End-Use Pressure Required

   None (unless a compressor is being serviced and is offline) _________________psig

6. Have compressor setpoints been raised to try and compensate for low pressure at end-use applications? Yes No

Comments:

Pressure does not get adjusted and there are no complaints about end user needs, unless one of the compressors is down for maintenance. All of the end users use between 20- and 80-psig.

Session 5 Homework

Name: Ken Stevens

1. What is the pressure going into the main header?

   Pressure: 110 psig

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: 90 psig

3. List any applications that require higher than typical pressure:

Application	Approximate End-Use Pressure Required
Air agitators on paint line	100 psig
Dry off wand at liquid wash booth	100 psig

4. List any applications that require lower than typical pressure.

Application	Approximate End-Use Pressure Required
None I am aware of	________psig

Session 5 Homework

Name: Tony Huynh

1. What is the pressure going into the main header?

   Pressure: **100 psig**

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: **40 psig** (high end of typical equipment that requires actuation)

3. List any applications that require high than typical pressure:

Application	Approximate End-Use Pressure Required
Sand silo	70 psig
Limestone flour silo	90 psig
Air knife	80 psig

4. List any applications that require lower than typical pressure.

Application	Approximate End-Use Pressure Required
Actuating parts	40 psig
Auto press	30 psig
Electrical Cabinet Coolers	6 psig

Session 5 Homework

5. List any applications where users complain about low pressure.

Application	Approximate End-Use Pressure Required
Auto press (controls)	~ 30 psig
Actuating parts	~ 40 psig

6. Have compressor setpoints been raised to try and compensate for low pressure at end-use applications? **Yes** ~~No~~

Comments:

Raised setpoints – we have a new compressor system now that shouldn't cause anyone to raise the setpoints. However, I can see how the team in the past prior to the compressor upgrade might have raised the setpoint.

Session 5 Homework

Name: ___________Ravi Kumar_______________________________________

1. What is the pressure going into the main header?

   Pressure: ___105______________psig

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: ______95___________psig

3. List any applications that require high than typical pressure:

   Application | Approximate End-Use Pressure Required

   _________________Stitching ________________ ______95___________psig

   ________________________Winder Machine __________ ____88_____________psig

4. List any applications that require lower than typical pressure.

   Application | Approximate End-Use Pressure Required

   _____________Bulker Unloading _____________________ __________35_______psig

   _______ Raw material transfer powder_ _________30_________psig

5. List any applications where users complain about low pressure.

   Application | Approximate End-Use Pressure Required

   ______________Stitching_____________________ _________95_________psig

6. Have compressor setpoints been raised to try and compensate for low pressure at end-use applications? Yes

Comments: Earlier We have 6.6 – 7.6 to meet the required pressure we increased it to 7-8 kg/cm^2
93-108 psig
99-113 psig

Session 5 Homework

Name: Abhijeet Kalantri

1. What is the pressure going into the main header?

   Pressure: 102 psig

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: 70-90 psig

3. List any applications that require high than typical pressure:

Application	Approximate End-Use Pressure Required
Stenciling on the Steel plates	130 psig
X-Ray Gauge	110 psig
Pneumatic Cylinders	105 psig

4. List any applications that require lower than typical pressure.

Application	Approximate End-Use Pressure Required
Furnace Inside Cameras	50 psig
Ross valves in the Pump actuations	65 psig
Fleet Maintenance	5-30 psig
Air Blow-off systems	10-20 psig

5. List any applications where users complain about low pressure.

Application	Approximate End-Use Pressure Required

6. Have compressor setpoints been raised to try and compensate for low pressure at end-use applications? Yes No

Comments: Yes, we run two compressors at a time, with a lead-lag combination. But a few of our leaks, which we know the location of, waste all our efforts. For areas where high pressure is required, we install air boosters.

Session 5 Homework

Name: Leo Peace

1. What is the pressure going into the main header?

   Pressure: High system: 145 psig Low system: 125 psig

2. What is the end-use pressure required for typical applications in the plant?

   Pressure: High system: ~125 psi Low system: ~110 psi

3. List any applications that require high than typical pressure:

Application	Approximate End-Use Pressure Required

   Texturizer Jets 125 psi

4. List any applications that require lower than typical pressure.

Application	Approximate End-Use Pressure Required

   Solenoid piston actuation 110 psi

   Vortex Cooler 90 psi

   Tac Jets 80 psi

   Scanner Roll pressure ~40 psi

6. Have compressor setpoints been raised to try and compensate for low pressure at end-use applications? They have not.

Comments:

Within the last couple of years, loops were added to the previously single tee machines. With that, most if not all issue with supply have gone away.

Session 7

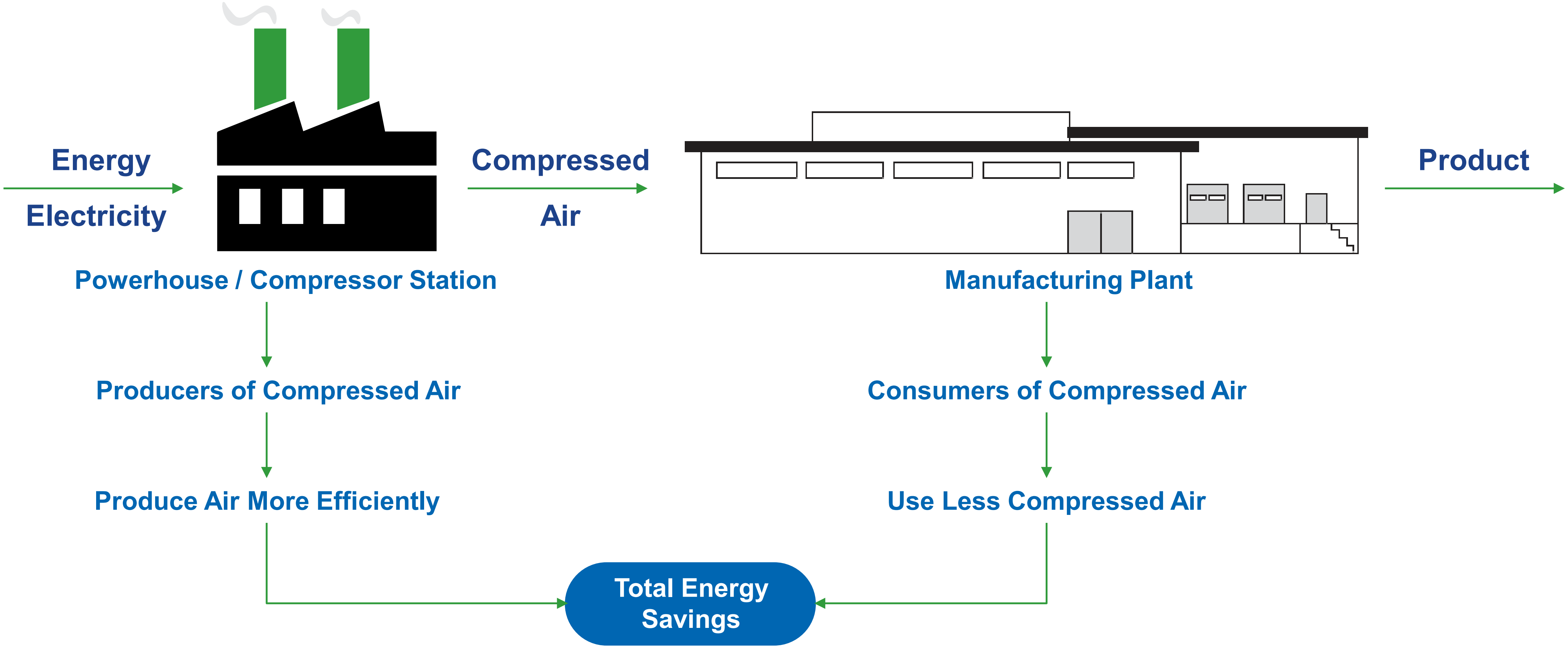
Demand Side

The Demand Side

- The goals of this session:
- To understand how to maintain an efficient compressed air system by managing wastes.
- Learn various methods of energy-saving measures and their applicability for the industrial equipment.
- What is an inappropriate use of air?

Waste

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.

System Pressure Drop Losses (Most Important)

01 –

Many systems have outgrown their original size requirements.

02 –

Filters should be sized for maximum flow conditions. (Peak Flows)

03 –

Distribution pipe diameters are too small . Velocities should not exceed 20 ft/sec in supply and 30 ft/sec in the demand side.

04 –

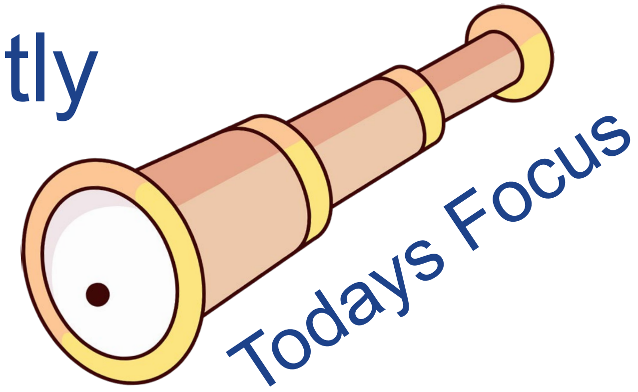
Hoses and connectors are problematical.

Look from the System Level Approach

- Improve Compressor Control
- Reduce System Pressure
- Reduce Air Demand

What Do I Look For?

- Produce compressed air more efficiently
  - Improve Compressor Control response.
  - 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.



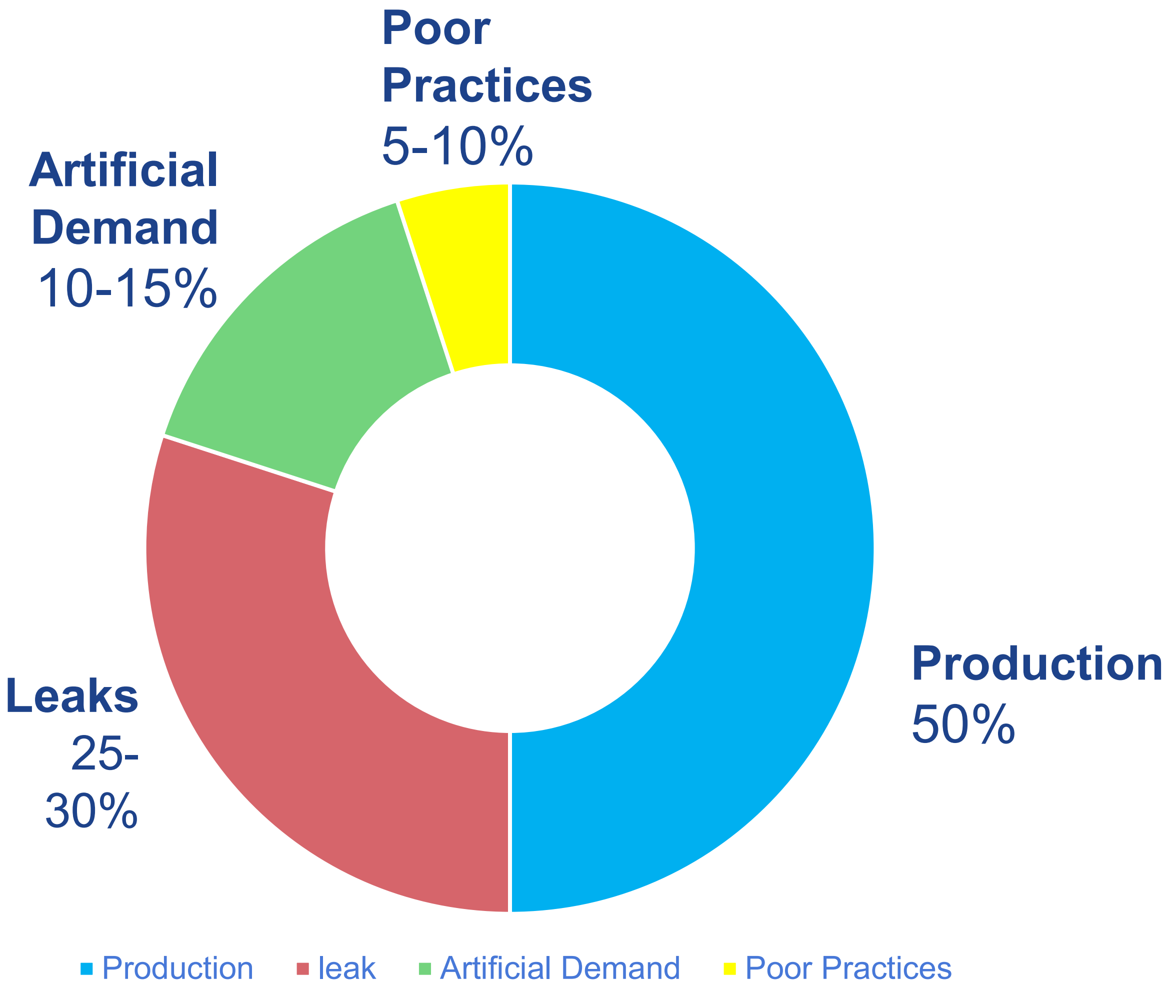
Compressed Air Versus Other Energy Sources

Where does the air go after it leaves the compressor room?

- You may be surprised, in most industrial plants, only 50% of the compressed air generated supplies productive air use.
- The other 50% is consumed by various losses.
- The losses are

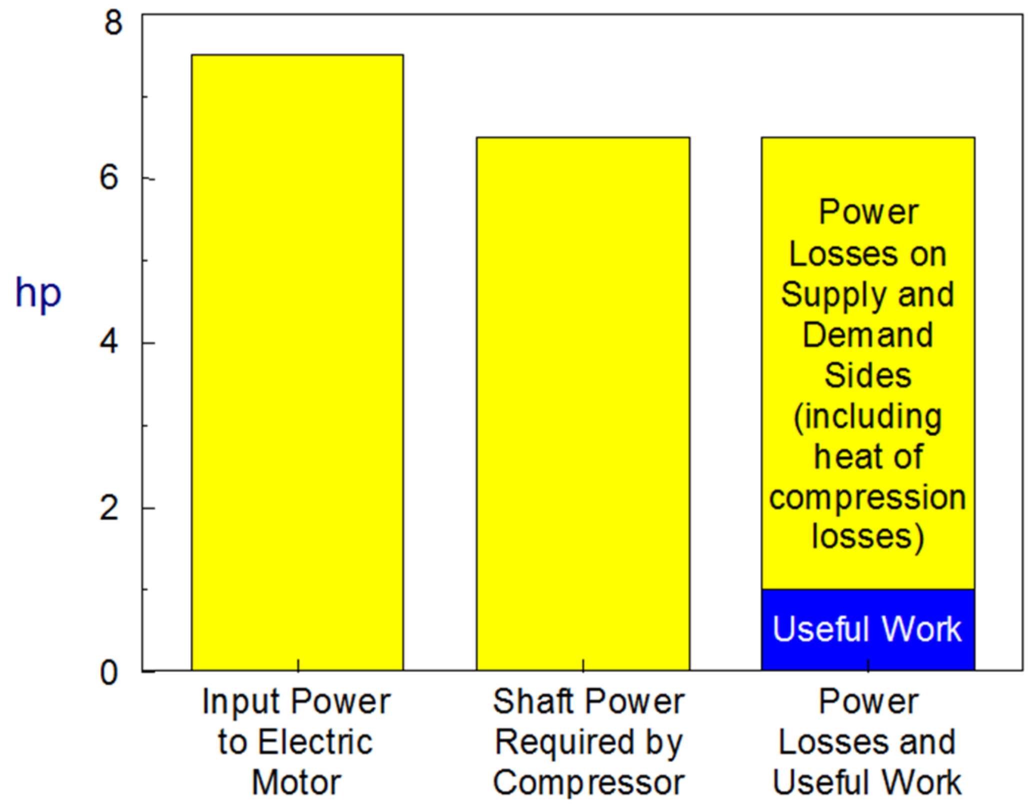
Artificial Demand (10-15%)	**Leakage (20-30%)**	**Poor Applications (5-10%)**

Where does the air go?

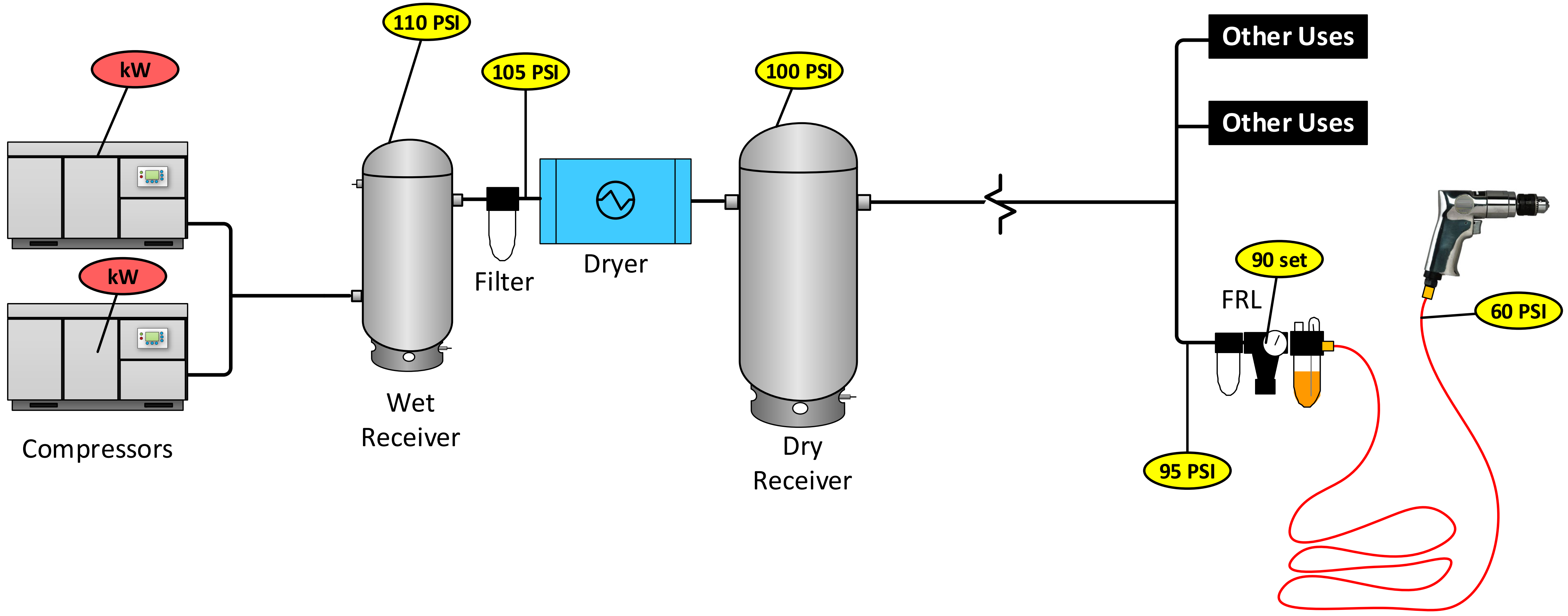


Compressed Air Versus Other Energy Sources

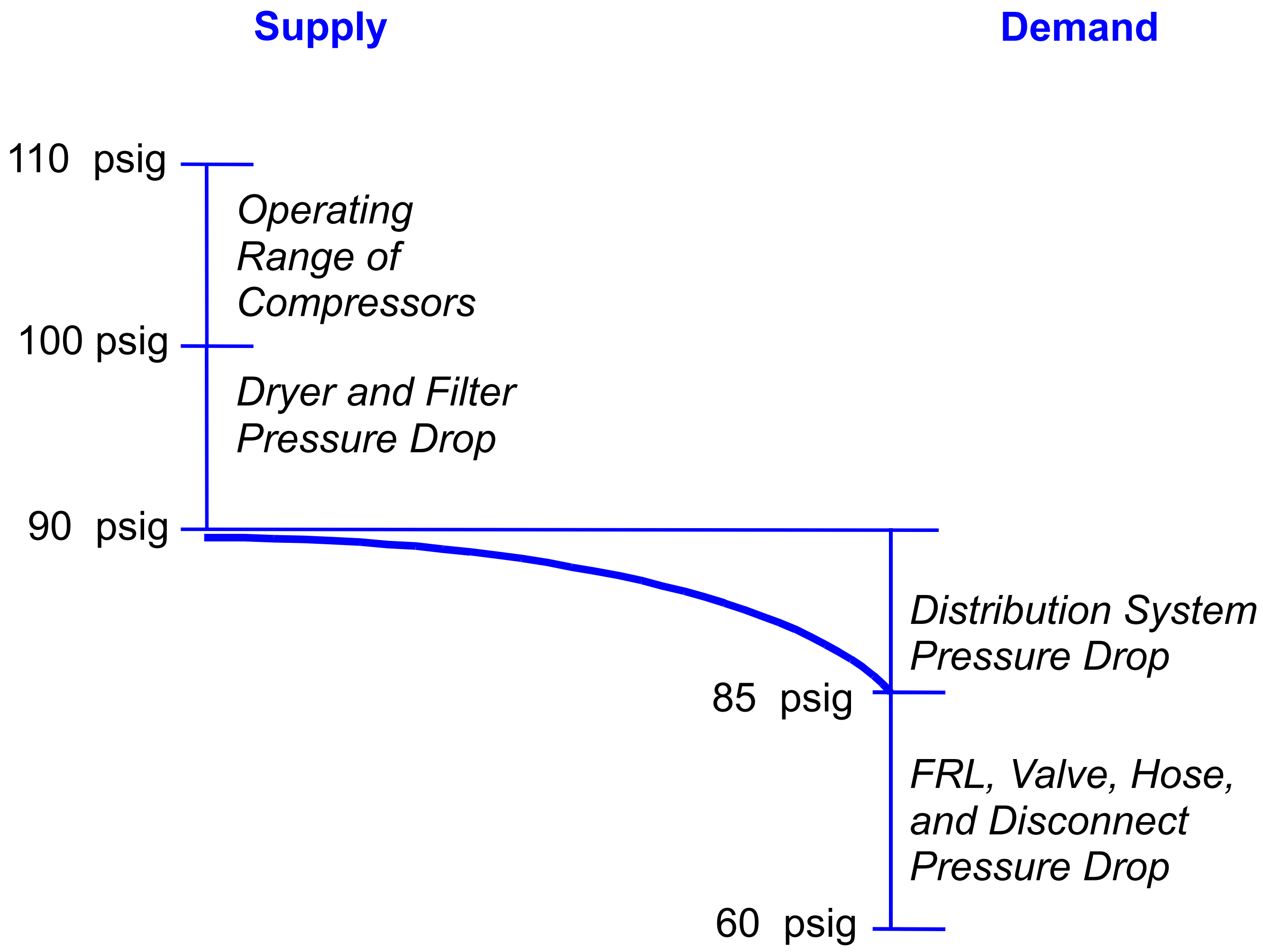
- 1 hp air motor = 7-8 hp of electrical power
  - 30 scfm @ 90 psig is required by the air motor
  - 6 - 7 bhp at compressor shaft required for 30 scfm
  - 7 - 8 hp electrical power required for this
- Annual energy cost for a 1 hp air motor versus a 1 hp electric motor, 5-day per week, 2 shift operation,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



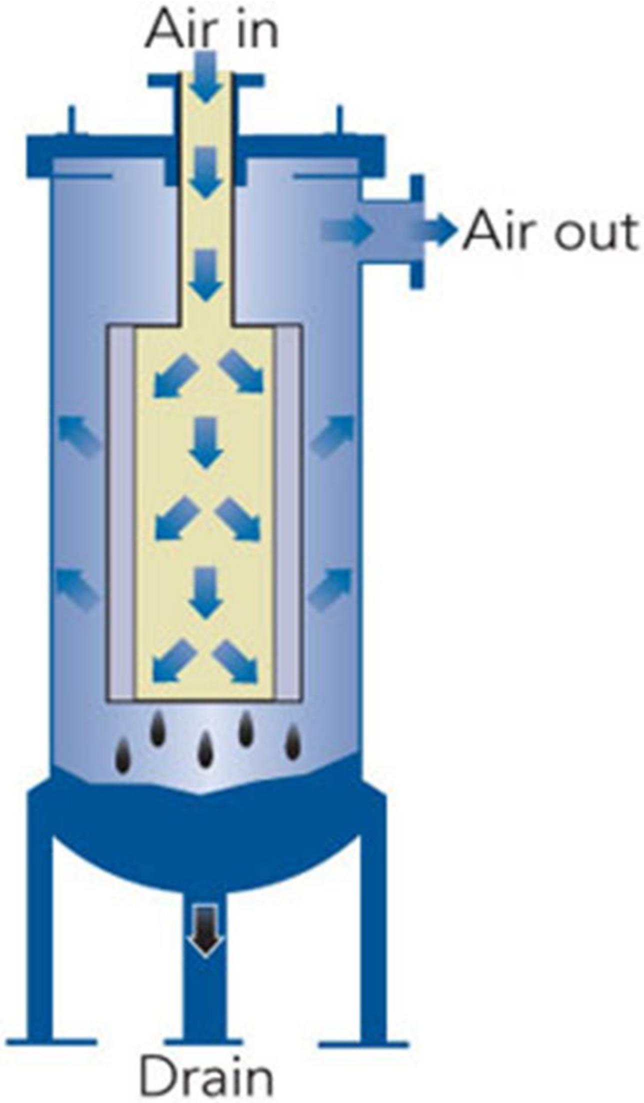
What Measurements Should I Record?



System Pressure Profile

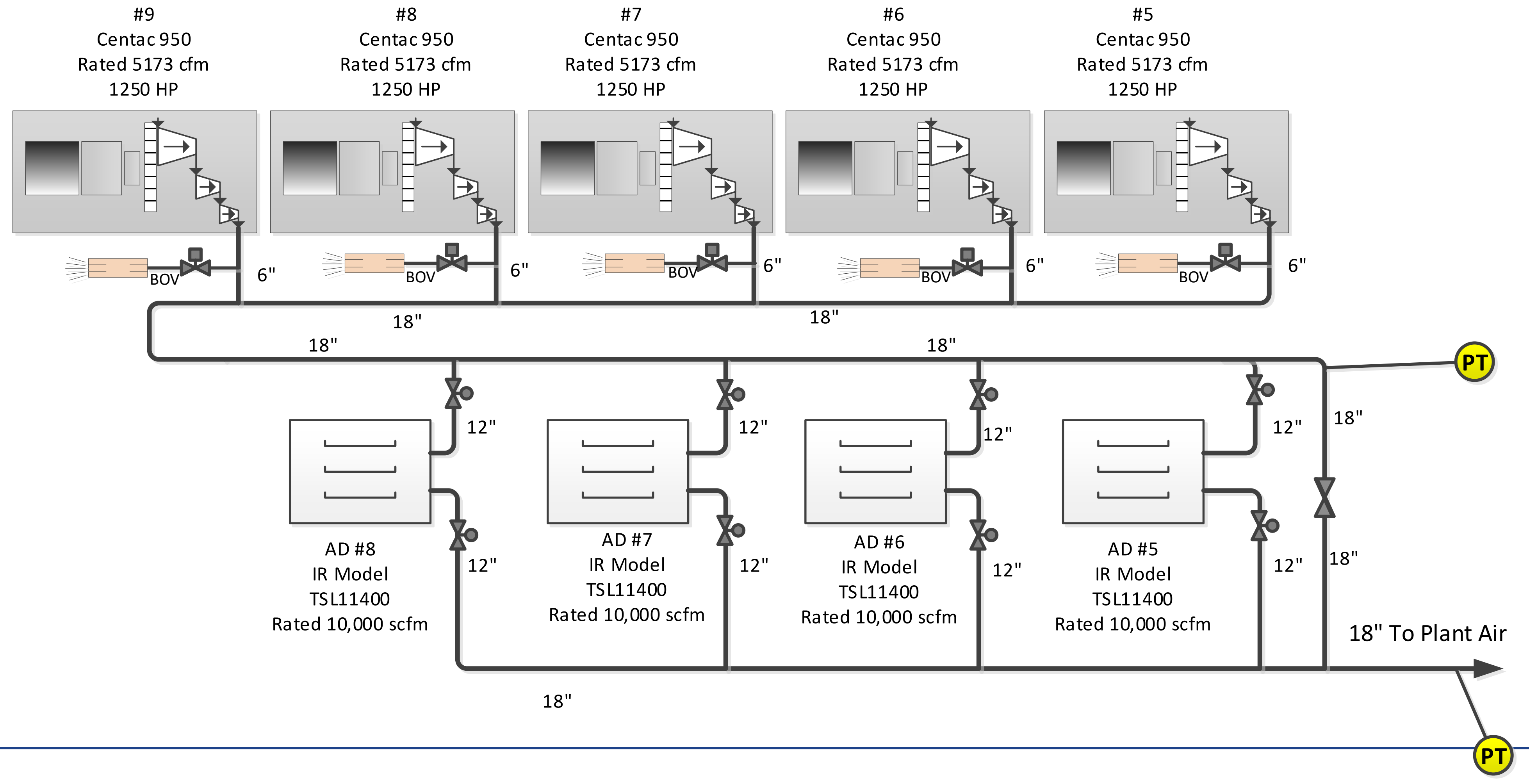


Reduce System Pressure Drop Losses

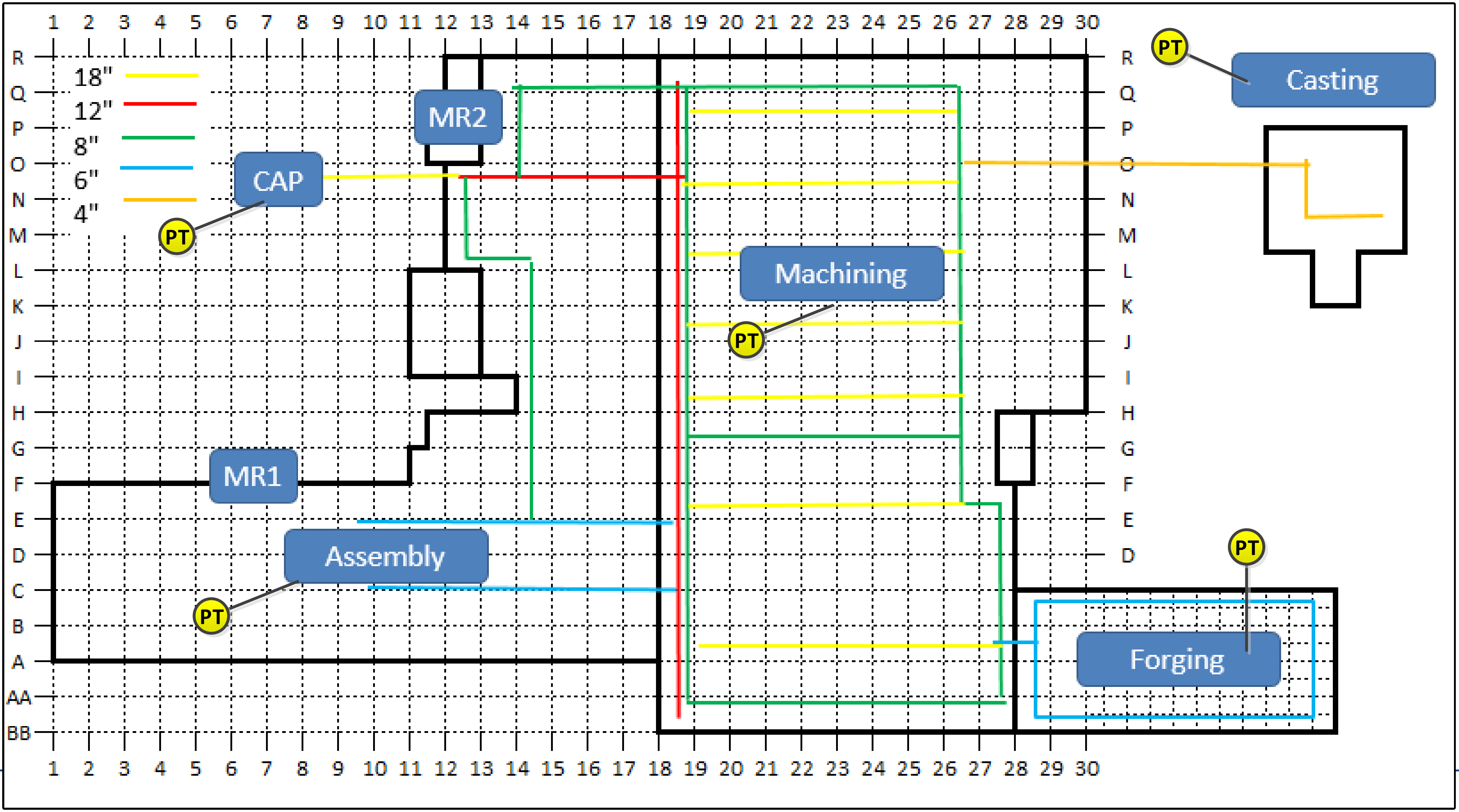


What Measurements Should I Record?

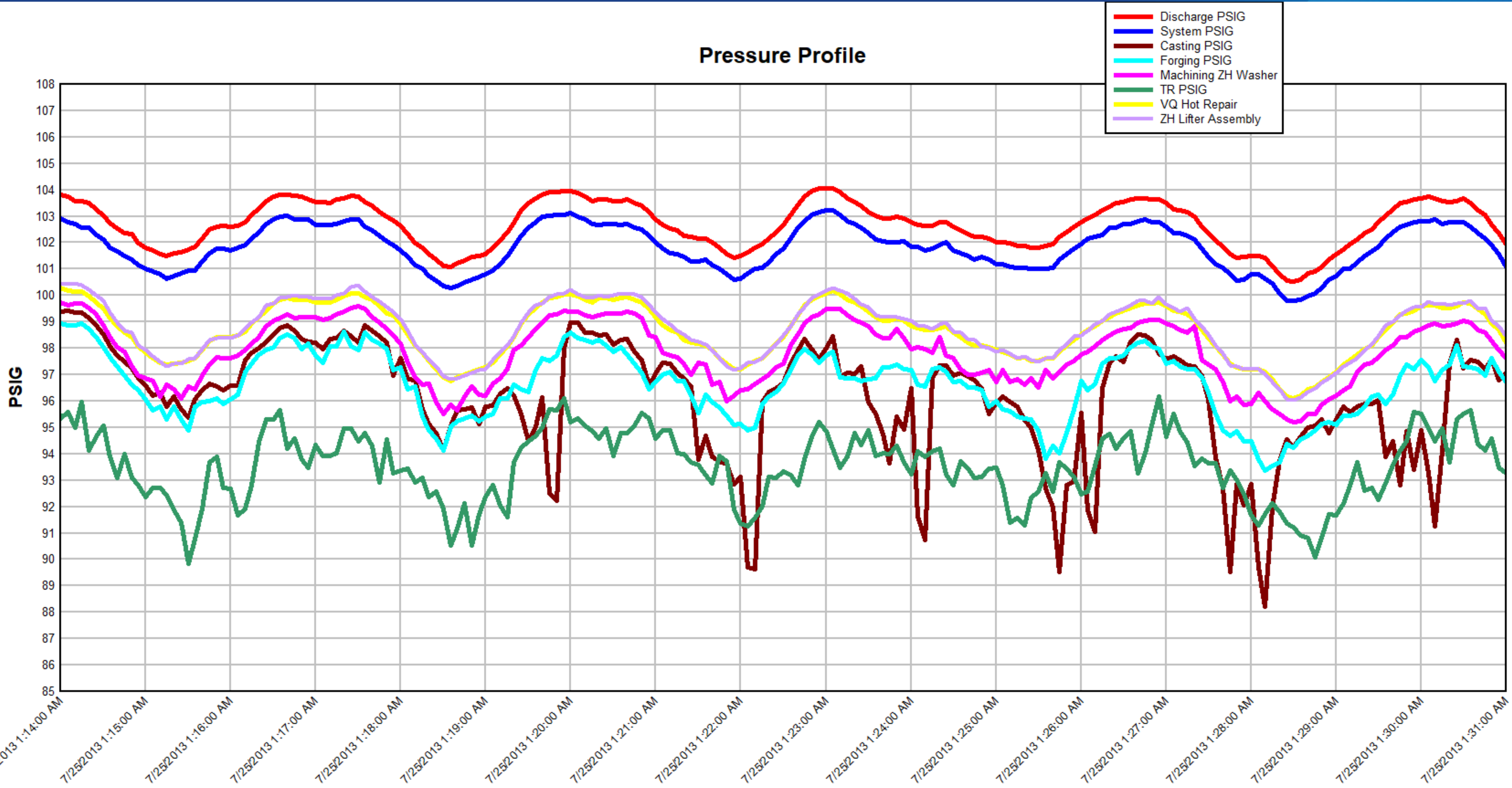
Compressed Air Plant



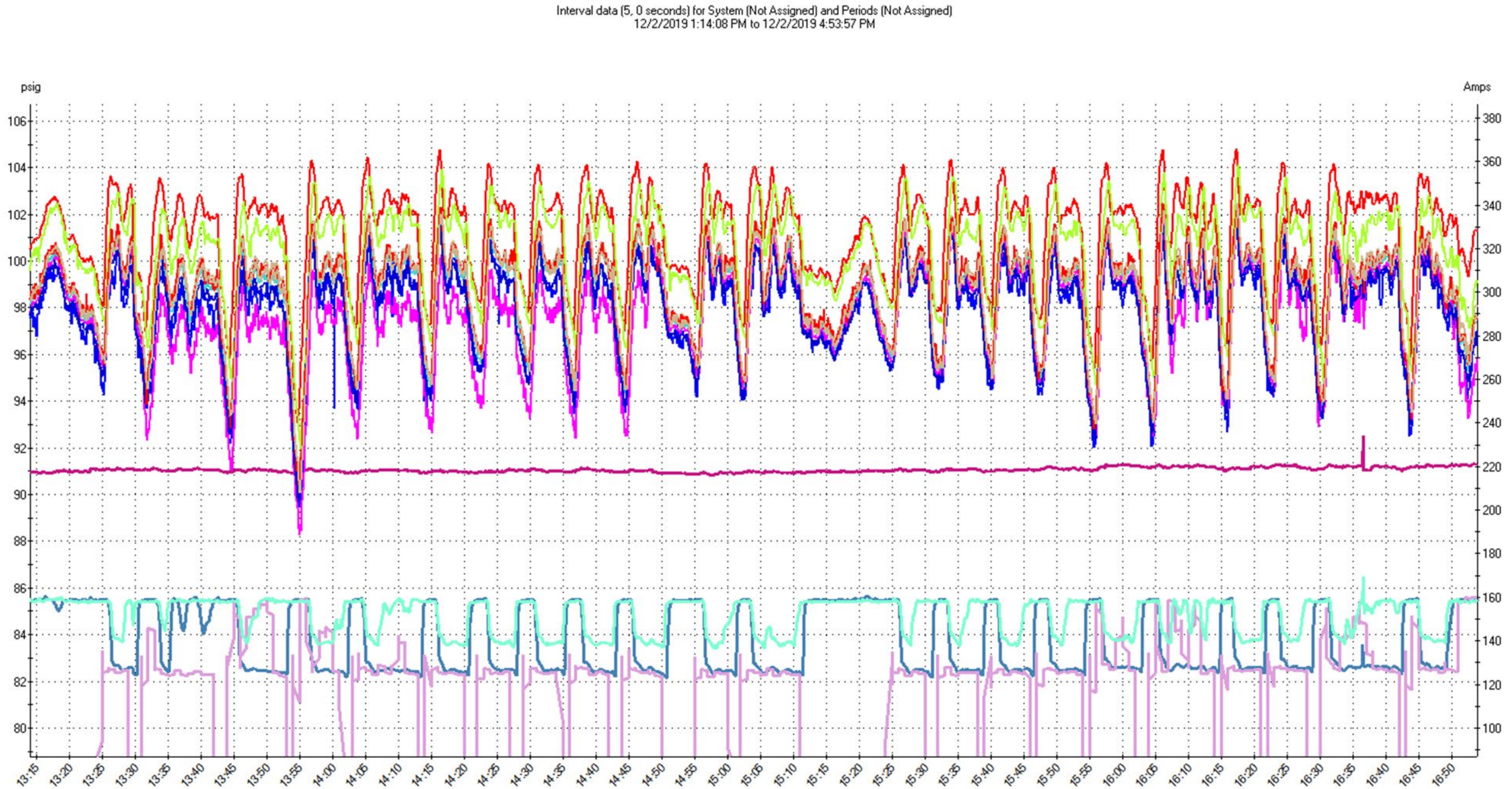
What Measurements Should I Record?



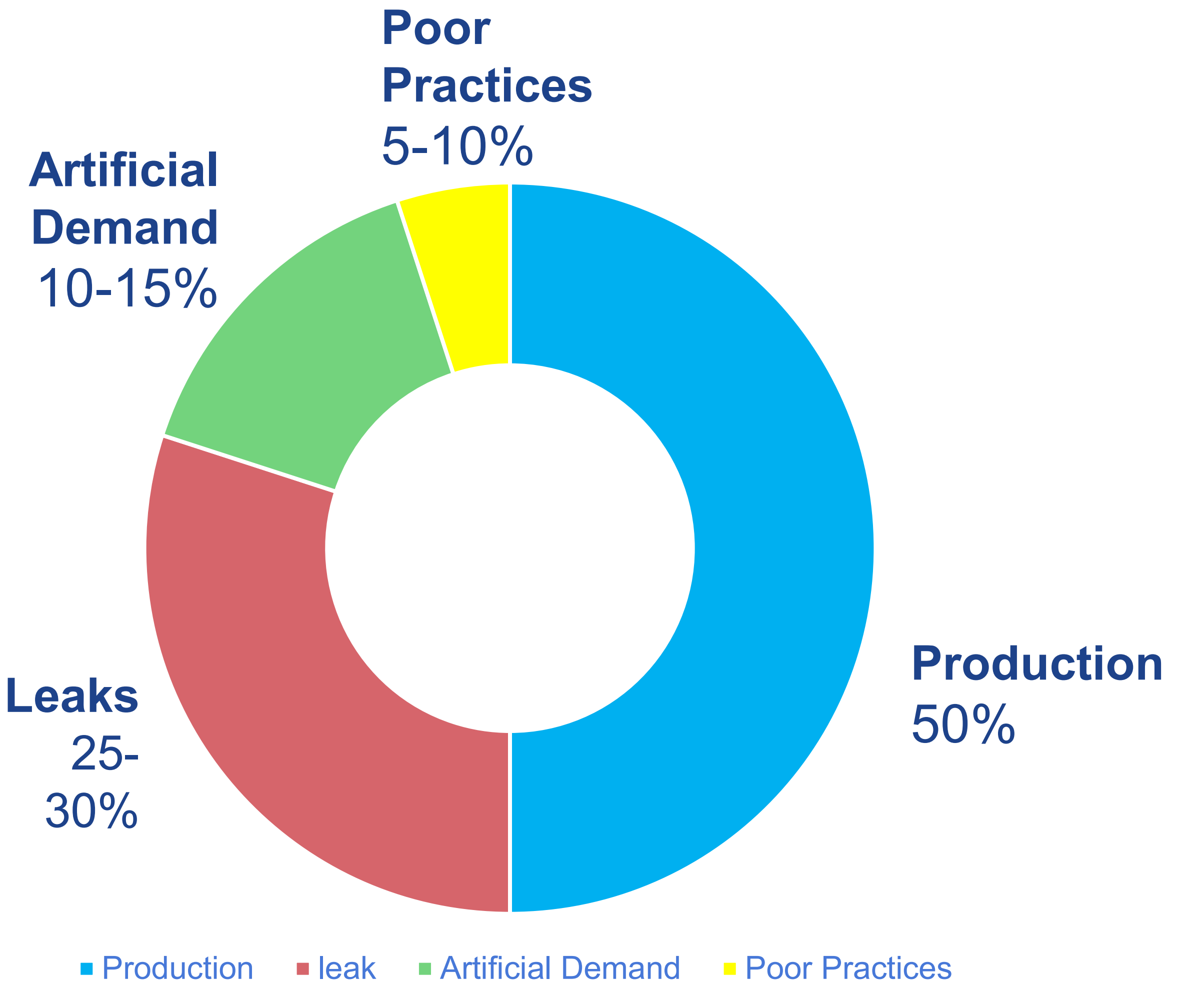
Data Collection Can Be Interpreted



Comparing Pressure and Power



Lets have a look at the waste

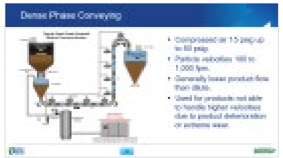


Potentially Inappropriate Applications

- 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:

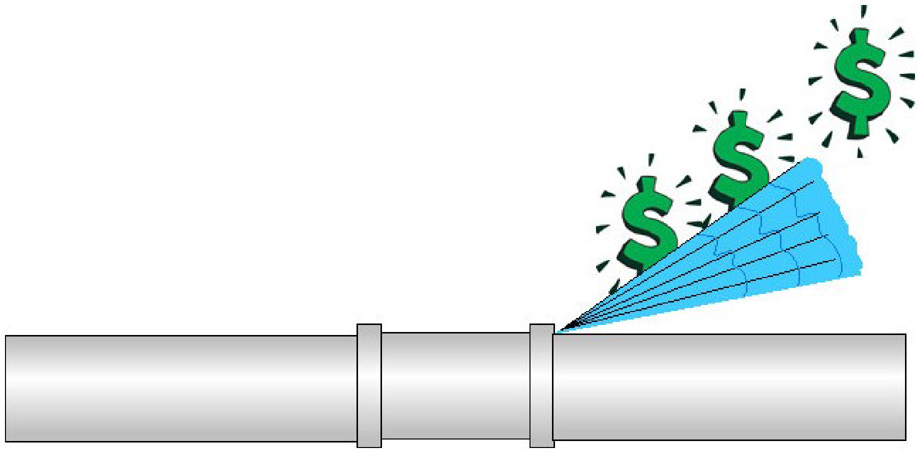
- Open blowing
- Sparging - (agitating, aerating stirring, mixing)
- Aspirating
- Atomizing
- Padding
- Dilute phase transport
- Dense phase transport
- Vacuum generation

- Personnel cooling
- Open hand-held blow guns or lances
- Cabinet cooling
- Vacuum venturi
- Diaphragm pumps
- Timer drains/open drains
- Air motors

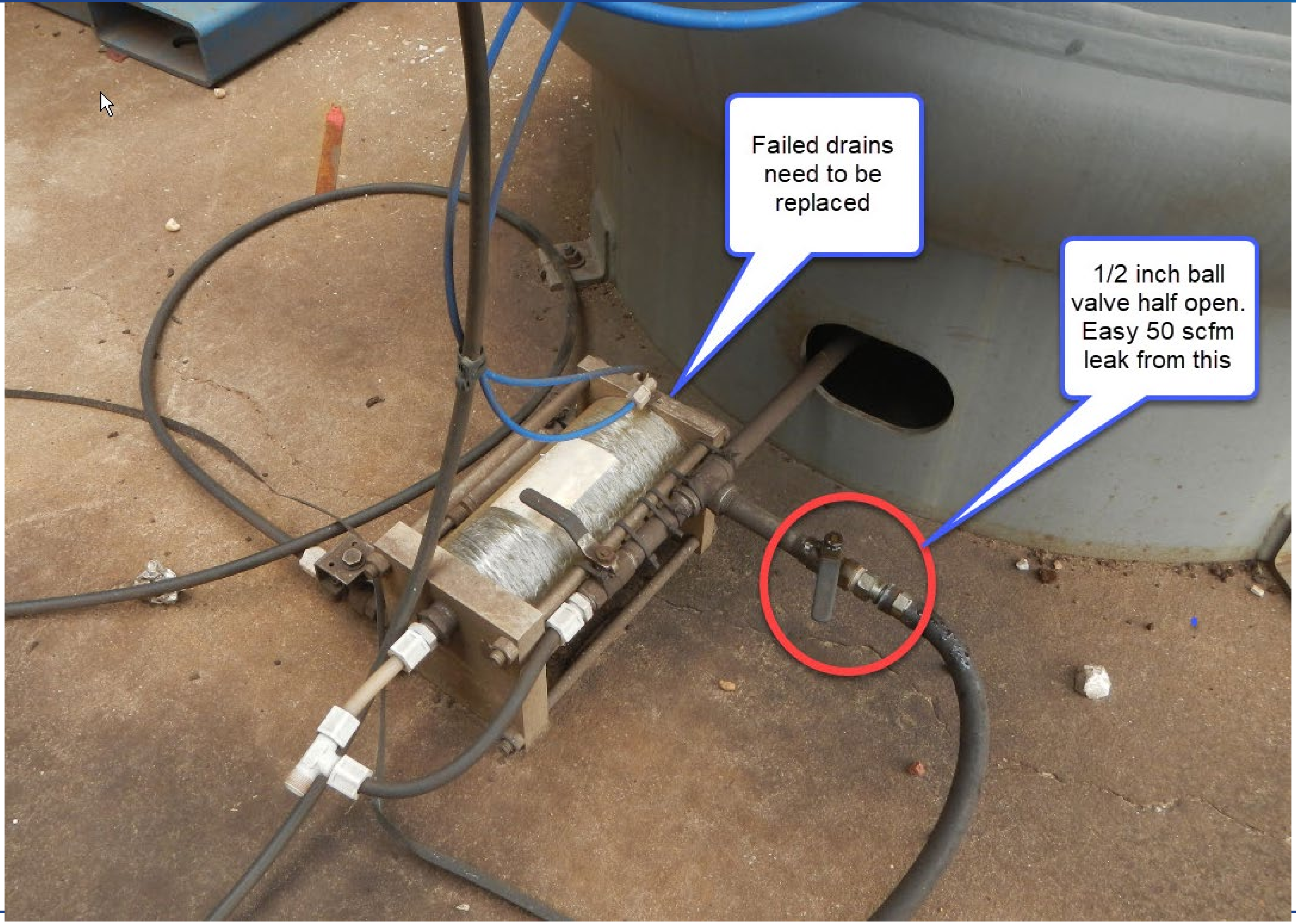


Leaks

- One of the most common types of waste in compressed air system is leaks.
- Leaks can be expensive.



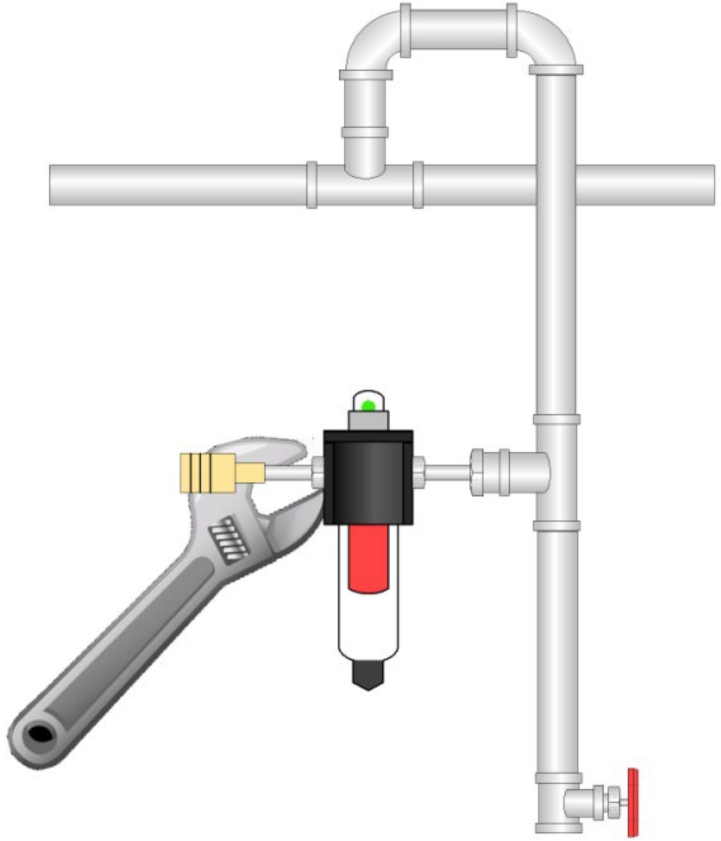
Leaks



Failed drains need to be replaced
1/2 inch ball valve half open. Easy 50 scfm leak from this

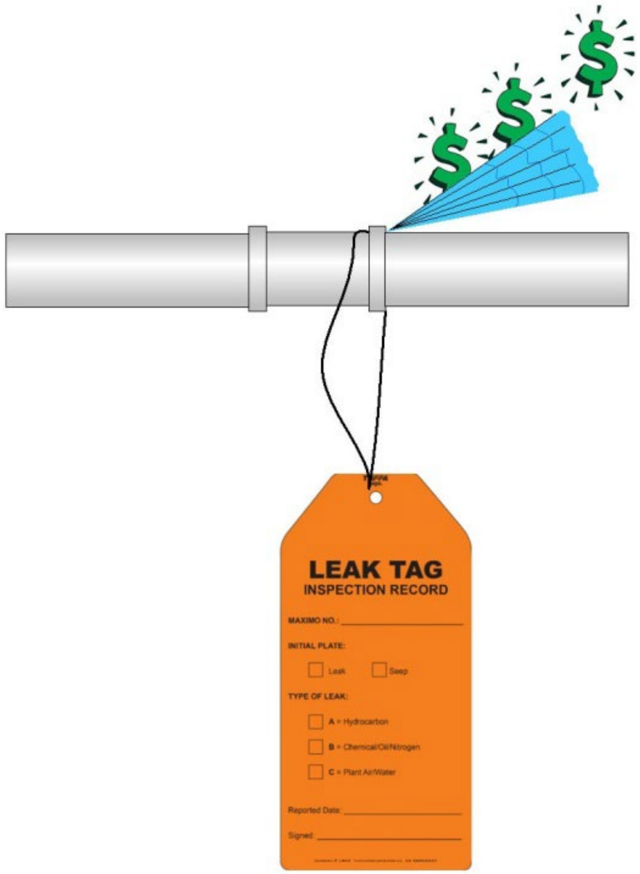
Leaks

- Leaks occur most often at joints and connections.
- Stopping leaks can be as simple as tightening a connection, or as complex as replacing faulty equipment.
- In many cases, leaks are caused by bad or improperly applied thread sealant.
- Select high quality fittings, disconnects, hose, tubing, and install them properly with the appropriate thread sealant.



Leaks

- Leak Tag Program
- Leak is identified with a tag and logged for repair at a later time.
- Tag is often a two-part tag
  - One part stays on leak
  - Other part is turned into maintenance, indentifying the location, size and description of the leak to be repaired.



Leakage Losses

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

An Ultrasonic or acoustic imager leak detector is the best tool for the job.

An ongoing program involving all departments is essential for success.

Quantifying Leakage Loss using Bag Method

Gallon size	Time to fill (seconds)	scfm
50	10	40.1
50	60	6.6
50	120	3.3
30	2	120.3
50	15	26.7

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Quantifying Leakage Loss using Bag Method

MEASUR

Manufacturing Energy Assessment Software for Utility Reduction

LEAK LOSS ESTIMATOR - BAG METHOD

Annual Operating Hours	8760	hrs/yr
Total Flow Rate	**7.28 SCFM**	
Total Annual Compressed Air Leakage	**3,826,368 SCF**	

Leak 1

Bag Fill Time	300	s
Height of Bag	50	in
Diameter of Bag	40	in
Flow Rate	**7.28 SCFM**	
Annual Consumption	**3,826,368 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

Other Common Trash Bag Sizes

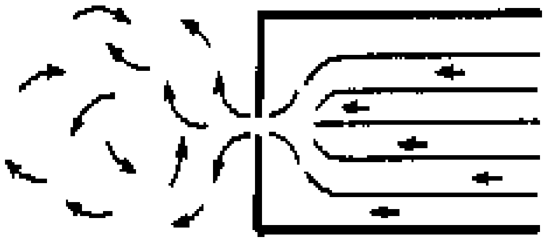
How Do You Find Leaks?

At $0.10/kWh electricity:

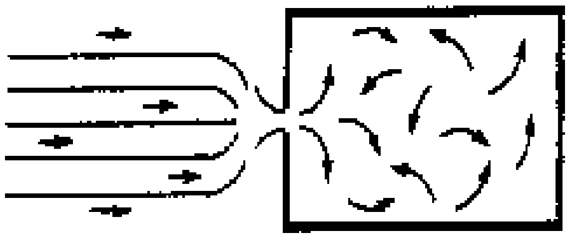
- A **$200/year** leak cannot be felt or heard
- A **$800/year** leak can be felt, but not heard
- A $**1,400/year** leak can be felt and heard

How Ultrasonic Leak Detection Works

- During a leak, a fluid (liquid or gas) moves from a high pressure to a low pressure
- As it passes through the leak site, a turbulent flow is generated with strong ultrasonic components, which are heard through headphones and seen as intensity increments on the meter
- It can be generally noted that the larger the leak, the greater the ultrasound level



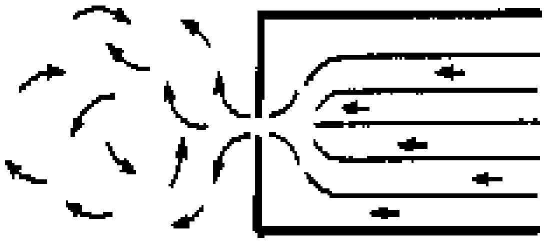
PRESSURE LEAK

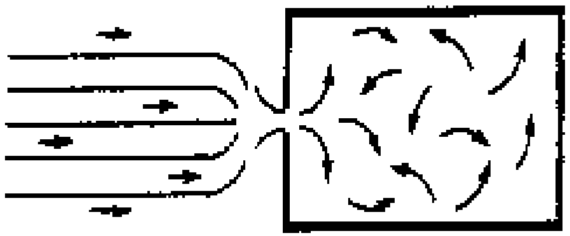


VACUUM LEAK

How Ultrasonic Leak Detection Works

- Ultrasound is a high frequency, short wave signal with an intensity that drops off rapidly as the sound moves away from its source
- The leak sound will be loudest at the leak site, which makes locating the source (i.e. the location) of the leak quite simple





Reduce Leakage Losses

- Leaks often account for more than 20% of the total amount of air being compressed.
  - Ultrasonic leak detectors are available.
  - An ongoing program involving all departments is essential.

How Acoustic Camera Leak Detection Works

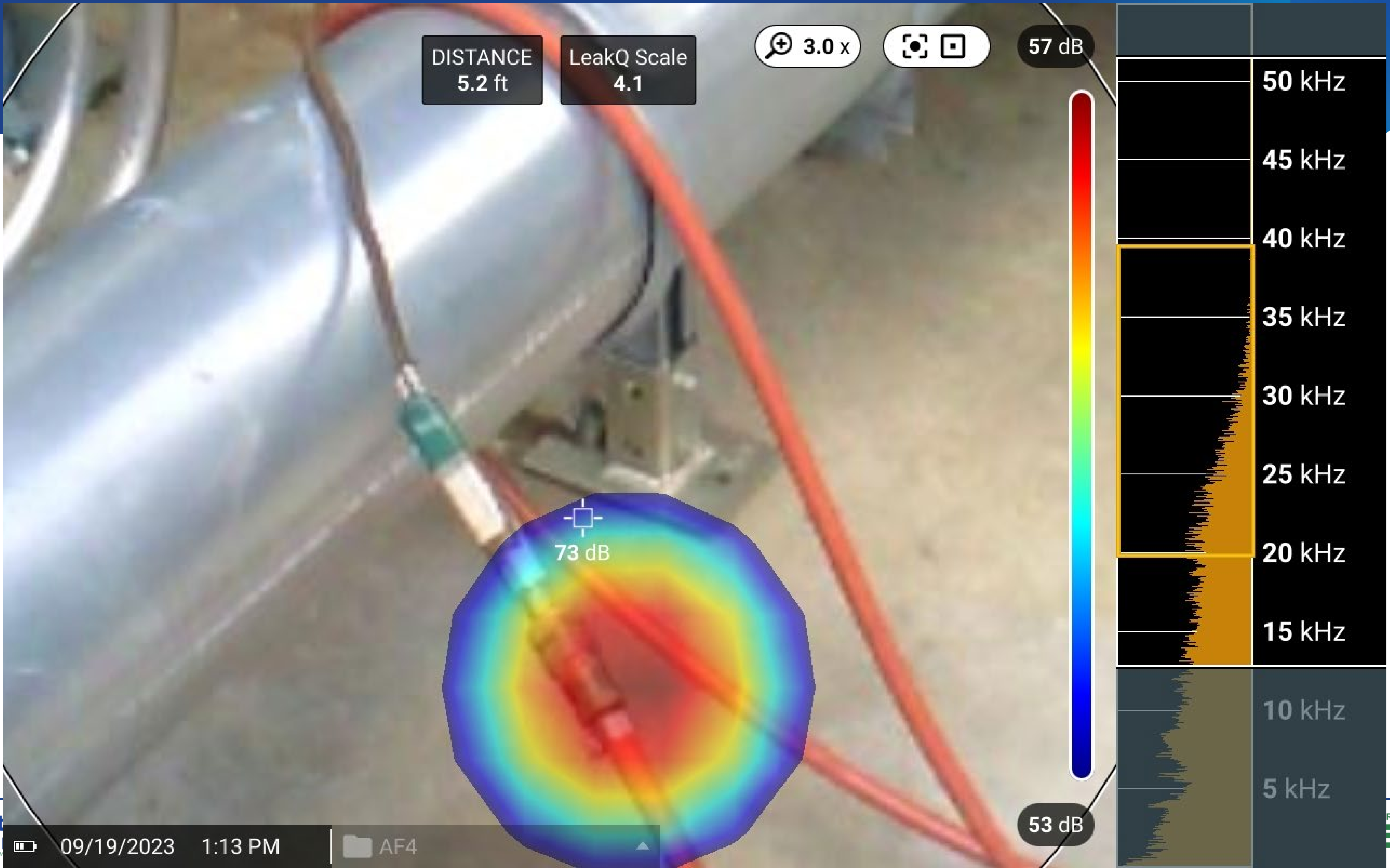
- The acoustic camera uses microphones and sophisticated signal processing and software to identify the loudest source of noise when many sources are present.
- It allows the user to pinpoint sound leaks in walls, doors, and floors and target the leak


34 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
M_22
0:10
0:00:00


51 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
0:00:01
0:00:09
10
30

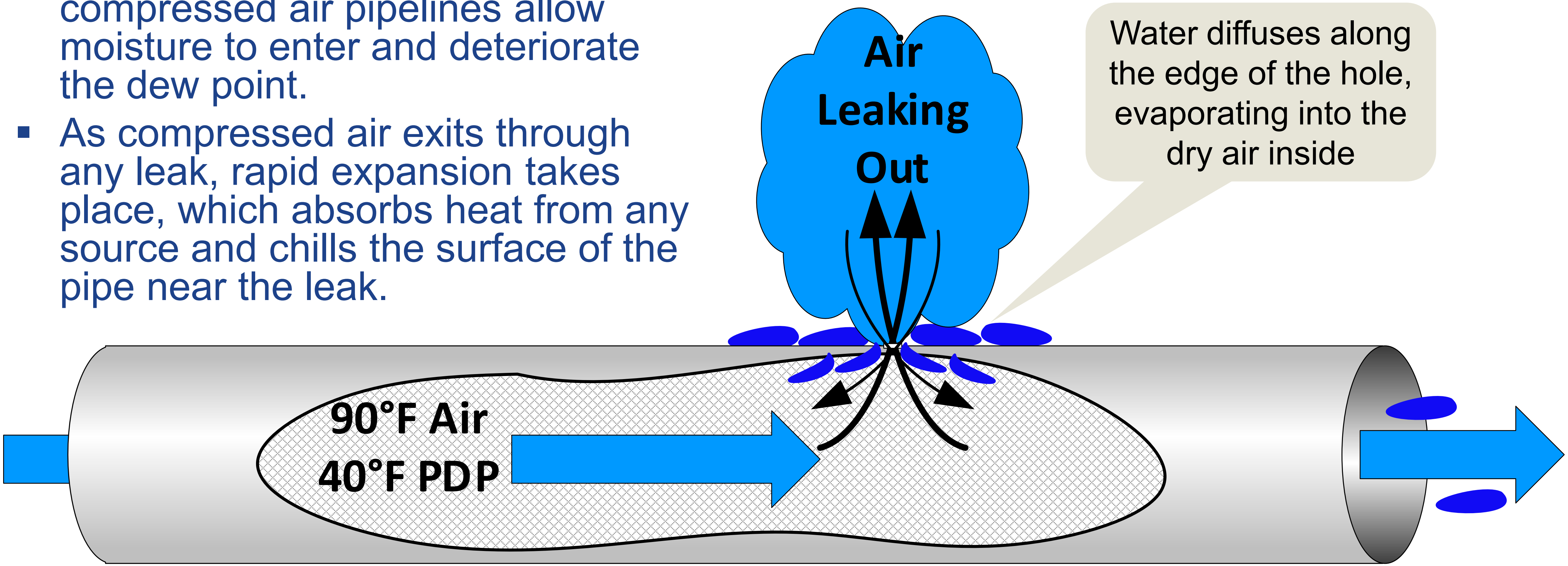

UNABLE TO ESTIMATE DISTANCE.
ENTER MANUALLY
3.0 x
50 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
69 dB
47 dB
09/19/2023
1:04 PM
AF4


51 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
0:00:01
0:00:09

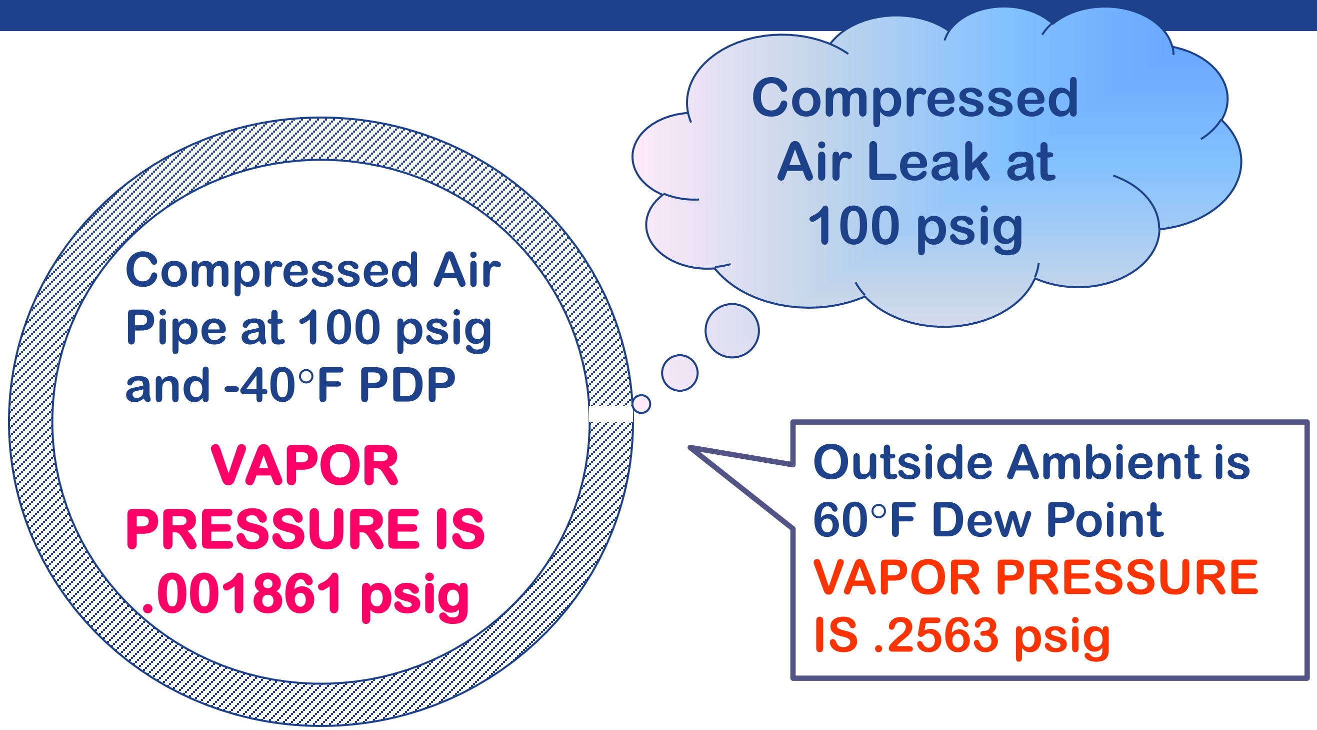

DISTANCE
5.2 ft
LeakQ Scale
4.1
3.0 x
57 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
73 dB
53 dB
09/19/2023
1:13 PM
AF4

Deterioration of Dew Point Through Compressed Air Leaks

- Small pinhole leaks that develop in compressed air pipelines allow moisture to enter and deteriorate the dew point.
- As compressed air exits through any leak, rapid expansion takes place, which absorbs heat from any source and chills the surface of the pipe near the leak.



Deterioration of Dew Point Through Compressed Air Leaks (Ficks Law)



- Water and air will always seek to reach equilibrium.
- Any dryer will create an unstable gas that will aggressively seek water vapor.
- If the entire compressed air supply is dried to -20 F or below, the piping must be completely free of any leaks, or the dewpoint will degrade.
- Maintaining such a dry air condition would involve welding every connection throughout the entire pipeline.

Vapor Pressure Differential

Ratio (VPDR) for -40°F is .2563/.001861 = 138

Moisture Driving Force Into Compressed Air is 138 Times!

At a -100°F VPDR it would be 11,192!

Estimating Leak Load

- Leak load should be estimated periodically.
- On a well maintained system, leakage should be less than 5-10% of full system flow.
- Tests should be undertaken quarterly.
- The following calculation should be used with load/unload controls.

$$\text{Leakage (\%)} = \left(\frac{T}{T+t}\right) \times 100$$

Where: T = total loaded time (seconds)

t = total unloaded time (seconds)

Estimating Leak Load

Here is an example of 100 hp 460 cfm compressor loading and unloading with no production running.

Time loaded	55 sec	58 sec	55 sec	58 sec
Time unloaded	40 sec	38 sec	40 sec	38 sec

$$\text{Leakage (\%)} = \left(\frac{T}{T+t} \right) \times 100$$

$$\text{Leakage (\%)} = \left(\frac{226}{226+156} \right) \times 100 = 59.2\%$$

$$\text{Leakage} = 59.2\% \times 460 = 272 cfm$$

Estimating Leak Load in Systems with Other Controls

- Requires an estimate of total system piping volume
- Include all receivers
- Bring system to normal operating pressure
- Turn compressors off
- Measure time for system to drop to ½ of starting pressure
- The following calculation can be used with other controls.

$$\text{Leakage (cfm free air)} = \left[\frac{V \times (P_1 - P_2)}{T \times P_a}\right] \times 1.25$$

The 1.25 multiplier corrects leakage to normal system pressure, allowing for reduced leakage with falling system pressure to 50% of the initial reading.

System Capacity

SYSTEM CAPACITY

Pipes

Pipe Size (in)	Pipe Length (ft)
3	1150 ft
2	800 ft

Add Pipe

Receiver Tanks

Receiver 1	1000 gal
Receiver 2	1020 gal
Receiver 3	800 gal

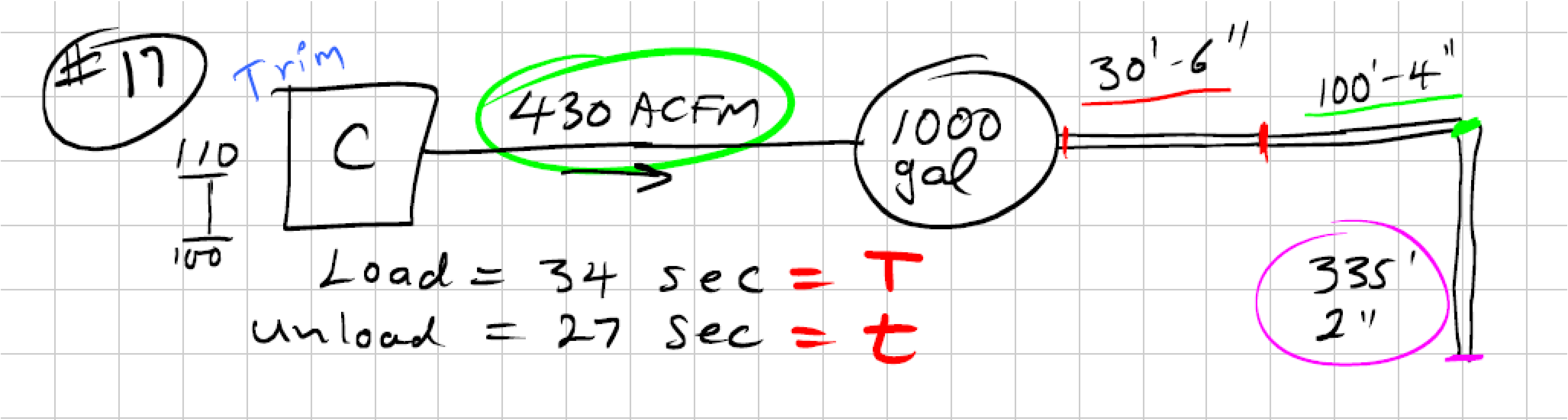
Add Receiver Tank

Leak Rate Calculator

Air Pressure - High	0 psi
Air Pressure - Low	0 psi
Discharge Time	0 s
Atmospheric Pressure	0 psia

Total Pipe Volume	**77.63 ft^3**
Total Receiver Volume	**377.01 ft^3**
Total Capacity of Compressed Air System	**454.64 ft^3**

System Capacity



$$V_{cf} = \frac{T_m \times C \times P_a}{P_1 - P_2}$$

$$V_{cf} = \frac{\left(\frac{27}{60}\right) \times 239.7 \times 14.5}{10}$$

$$V_{cf} = 156$$

S (#17) cont

method 3

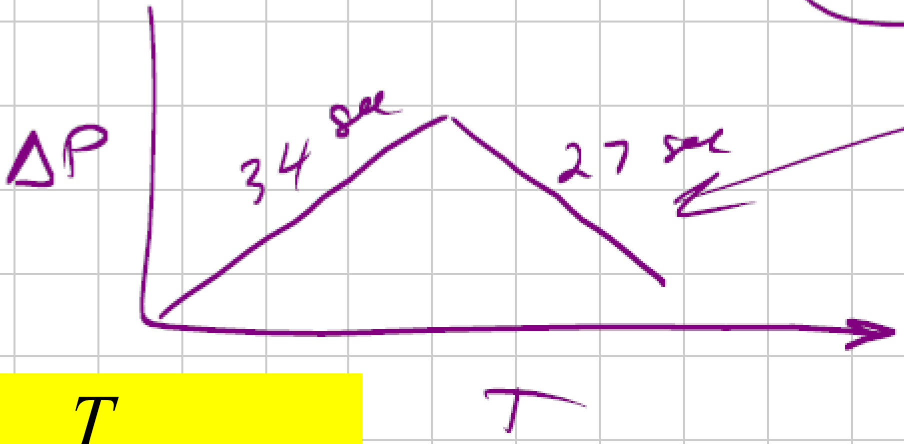
loaded time = 34 sec = T

unloaded time = 27 sec = t

$$\frac{T\ 34}{T\ 34+27\ t} \times 430 = 239.7\ \text{scfm} = \text{comp flow}$$

(34+27 = 61)

Look at unloaded portion



$$V_{cf} \times \frac{\Delta P}{14.5} = C \cdot T$$

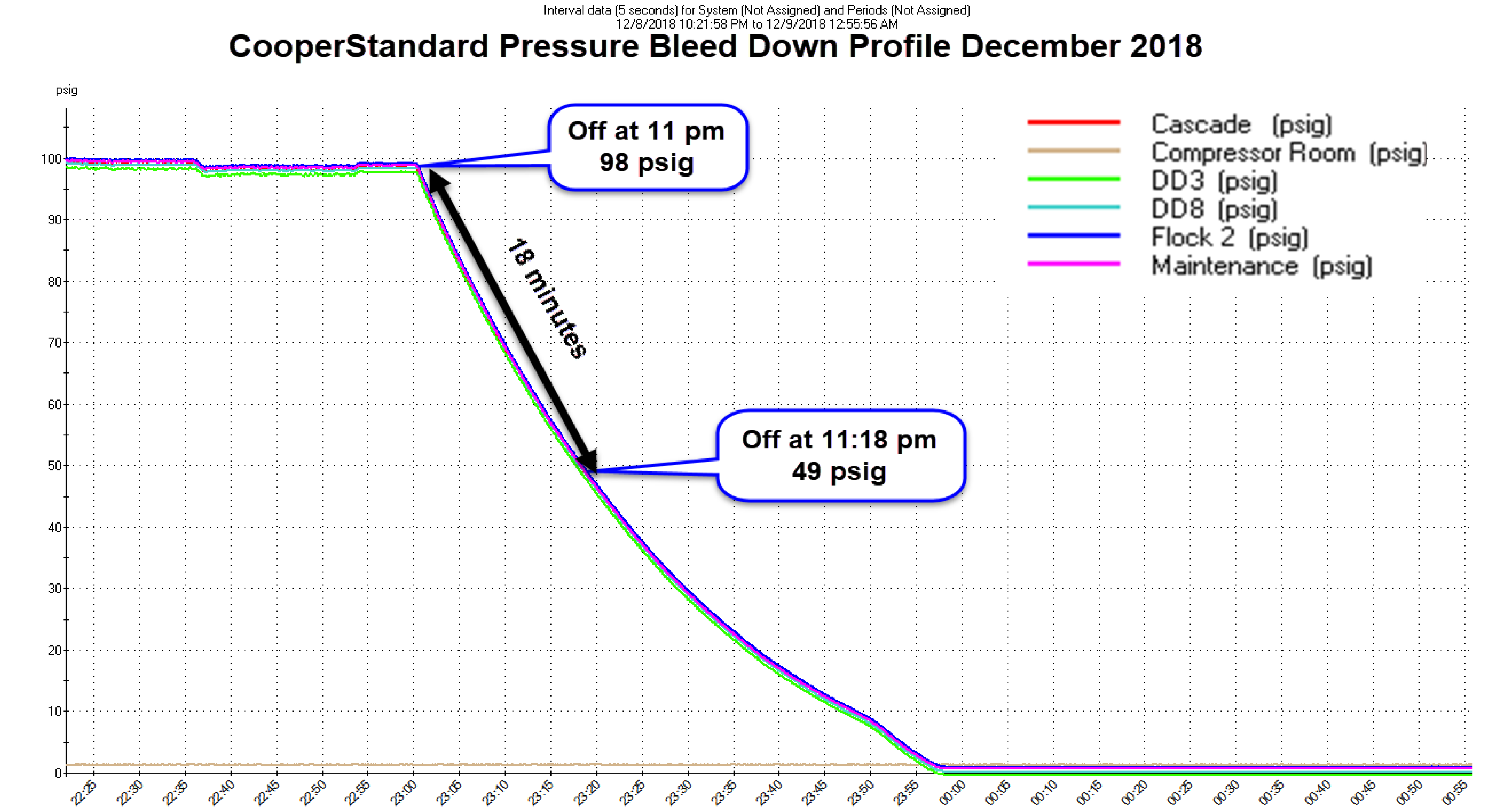
$$V_{cf} \times \frac{10}{14.5} = 239.7 \left(\frac{27}{60}\right)$$

$$V(.69) = 107.9$$

$$V = 156.3\ ft^3$$

1169 gallons ⟸

$$\%Flow = \frac{T}{T+t} \times 100$$


Interval data (5 seconds) for System (Not Assigned) and Periods (Not Assigned)
12/8/2018 10:21:58 PM to 12/9/2018 12:55:56 AM
CooperStandard Pressure Bleed Down Profile December 2018
psig
Off at 11 pm
98 psig
18 minutes
Off at 11:18 pm
49 psig
Cascade (psig)
Compressor Room (psig)
DD3 (psig)
DD8 (psig)
Flock 2 (psig)
Maintenance (psig)
100
90
80
70
60
50
40
30
20
10
0
22:25
22:30
22:35
22:40
22:45
22:50
22:55
23:00
23:05
23:10
23:15
23:20
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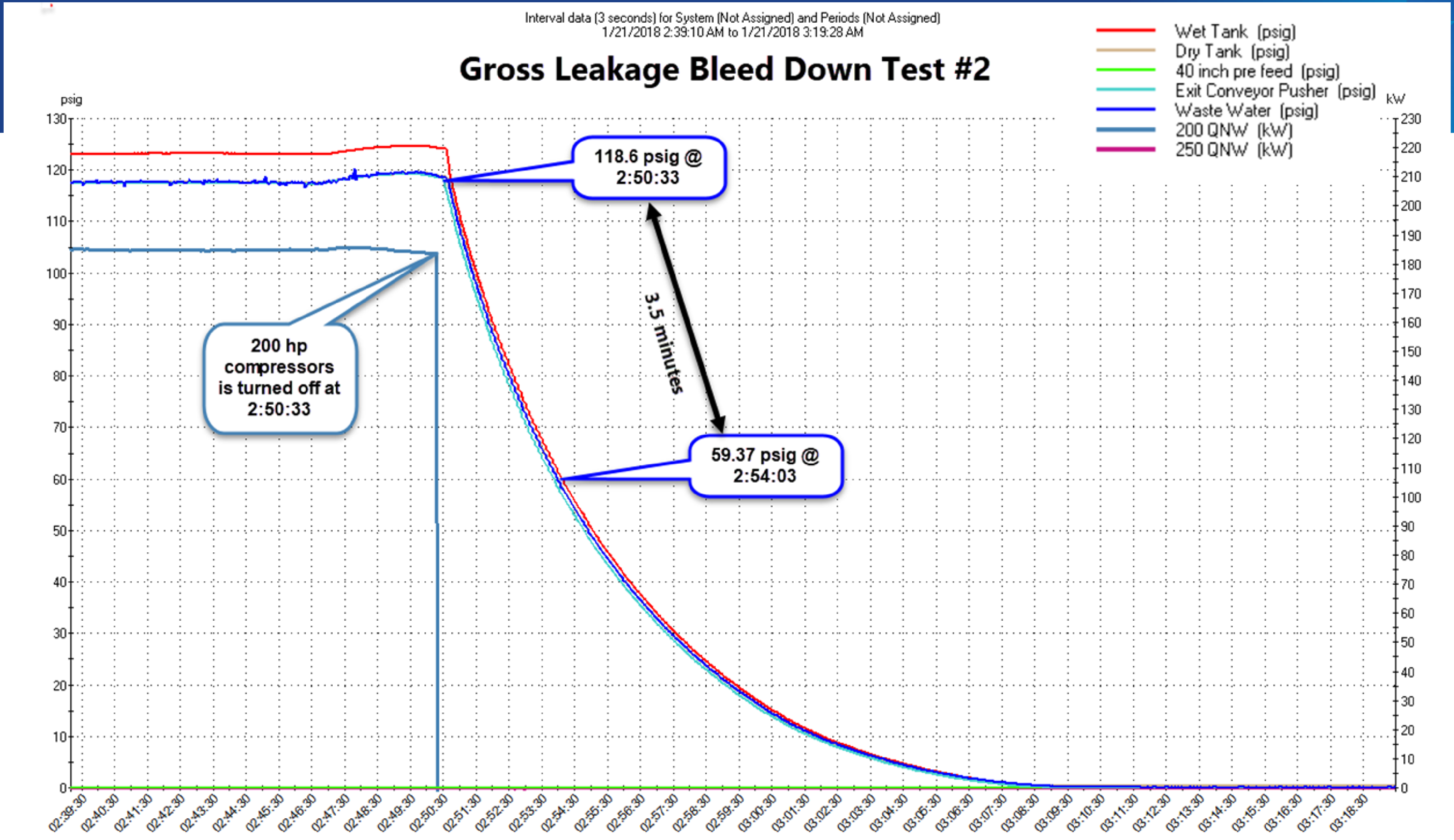
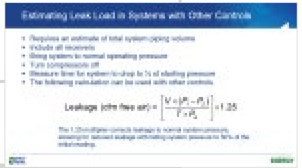

Interval data (3 seconds) for System (Not Assigned) and Periods (Not Assigned)
1/21/2018 2:39:10 AM to 1/21/2018 3:19:28 AM
Gross Leakage Bleed Down Test #2
Wet Tank (psig)
Dry Tank (psig)
40 inch pre feed (psig)
Exit Conveyor Pusher (psig)
Waste Water (psig)
200 QNW (kW)
250 QNW (kW)
psig
kW
118.6 psig @ 2:50:33
3.5 minutes
59.37 psig @ 2:54:03
200 hp compressors is turned off at 2:50:33

Bleed Down Test Calculation

Cfm Leakage =	[V x (P1 - P2) x 1.25]/(T x 14.7)		
Where	V=	453.9	Cu ft
	P1=	118.66	Psig
	P2 =	59.33	Psig
	T =	3.50	Minute
Cfm Leakage =	654.34		
% Leakage =	Measured cfm leakage/total cfm output of plant compressors		
% Leakage =	**32.3%**	Assuming 4cfm/hp and total HP of 450	

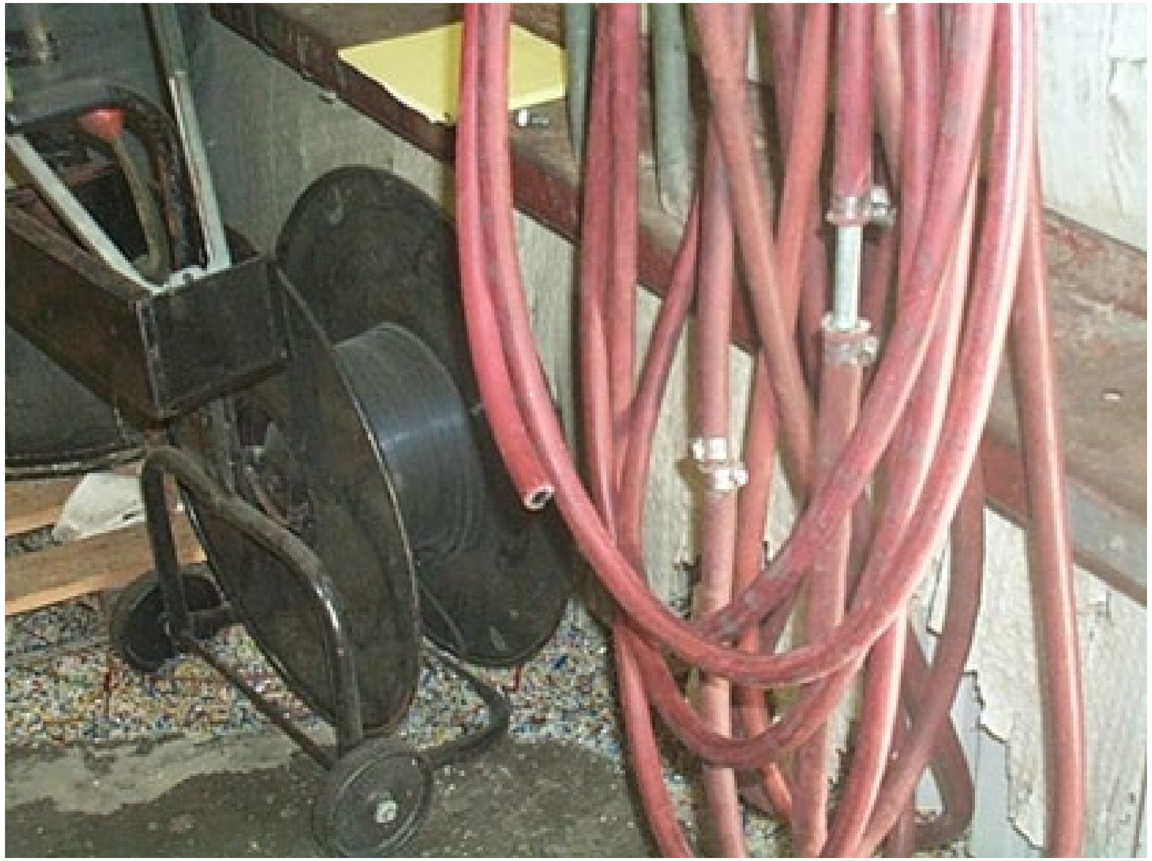


Potentially Inappropriate Applications

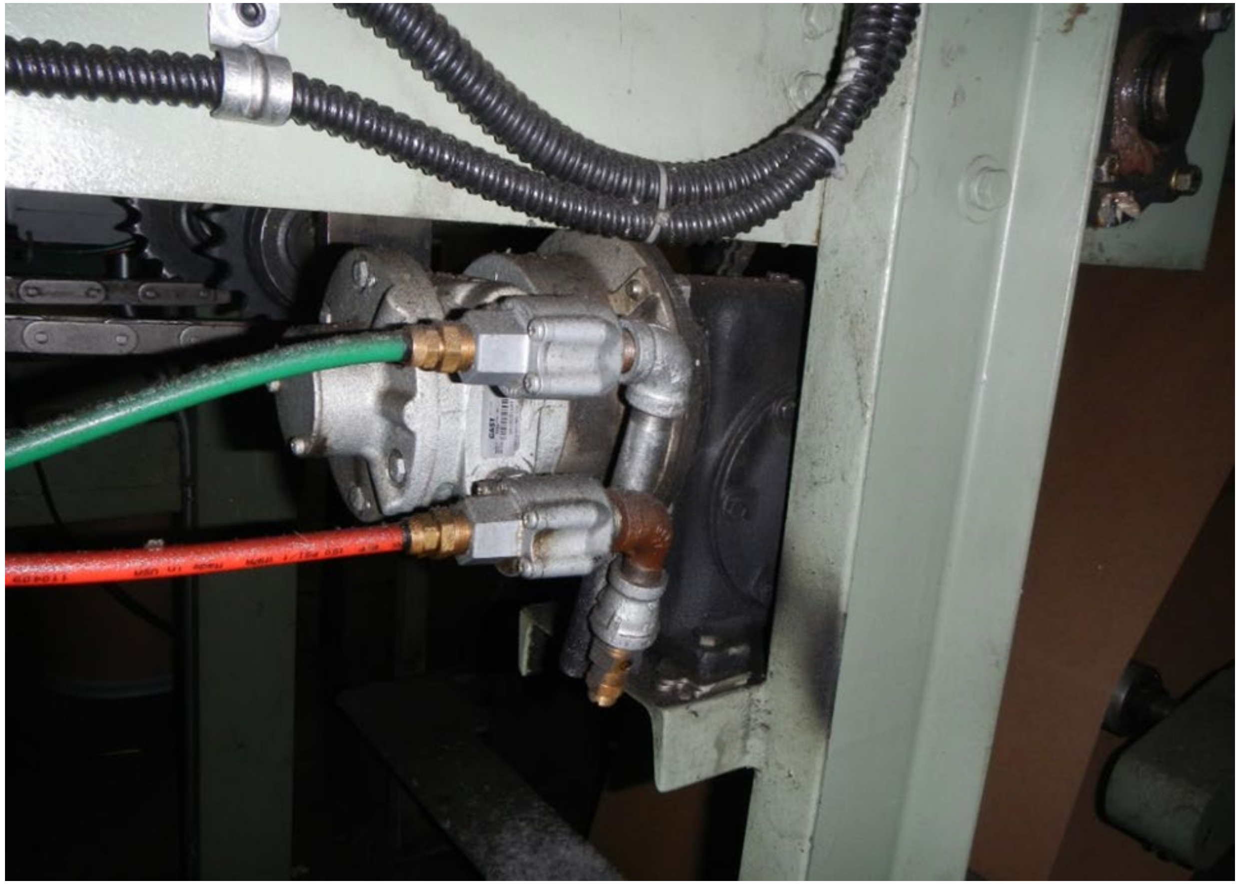
- Many applications can be served more efficiently by low pressure air from a fan, a blower; or by a vacuum pump, rather than by compressed air. Examples:

- 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

Open Blowing



Air Motors



Cooling

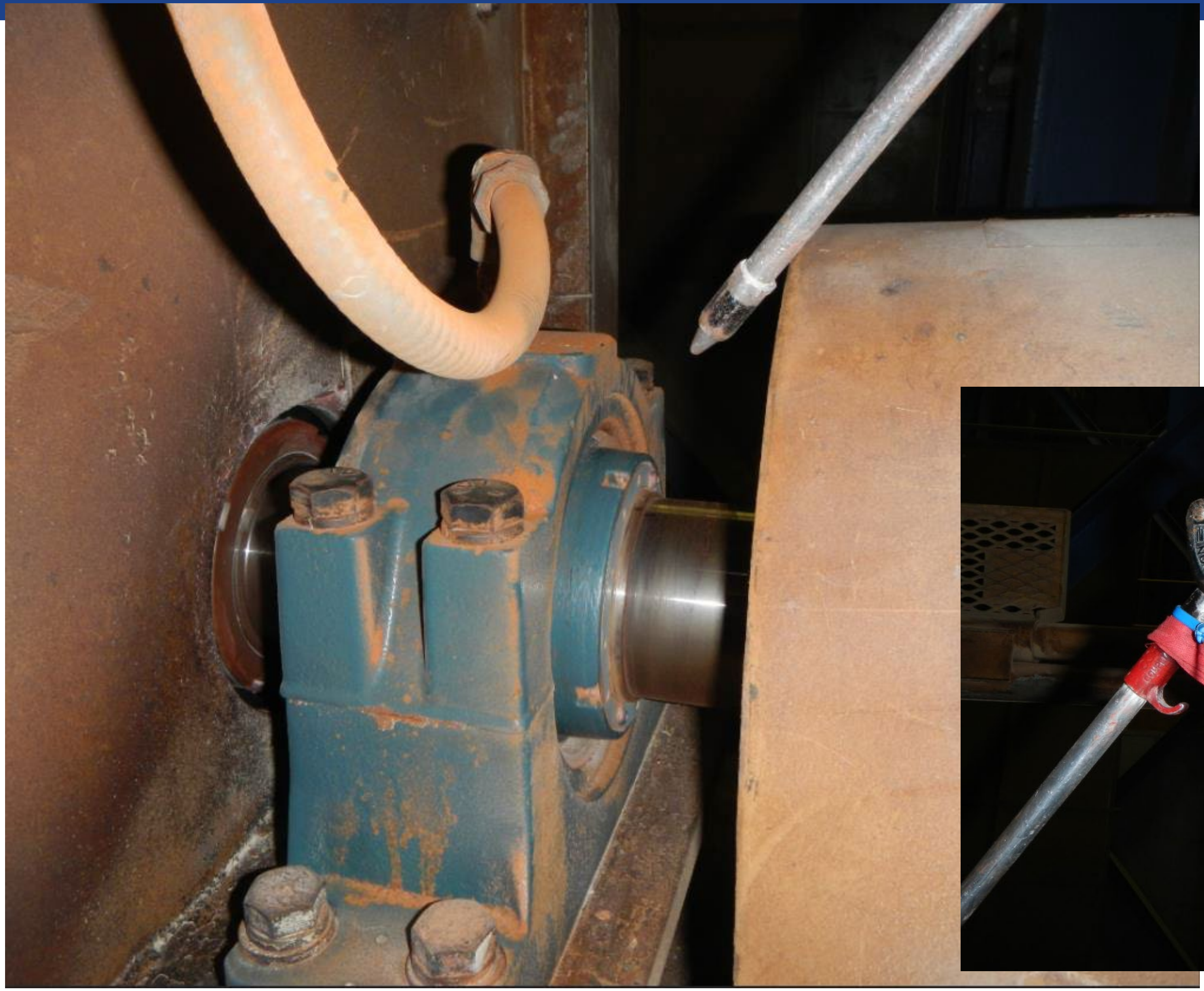
Cooling

Inlet Pressure- Air Consumption

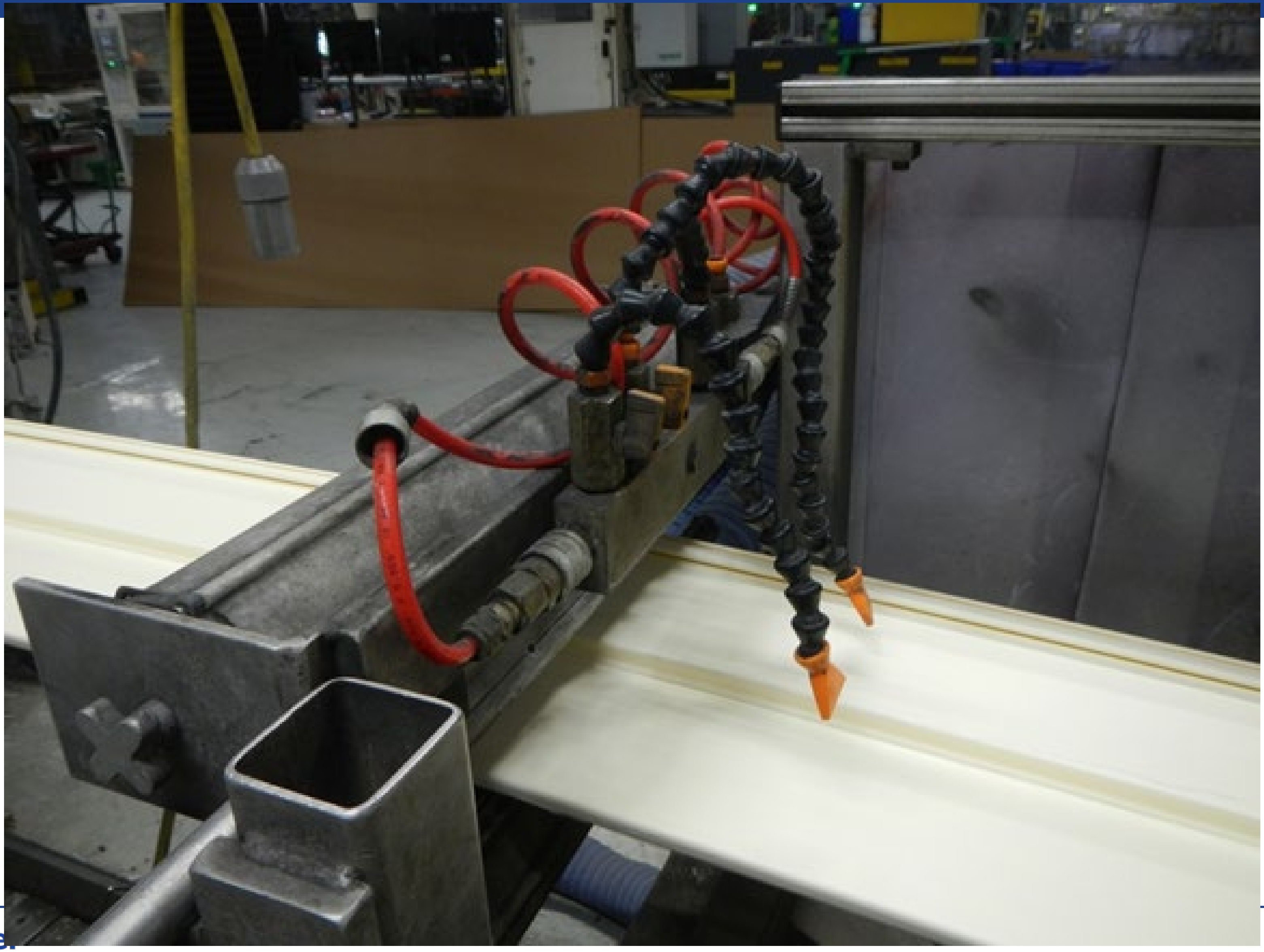
Model No.	40 psig	60 psig	80 psig
T4-3AMS	36 scfm	50 scfm	62 scfm
T4-3AM	35 scfm	45 scfm	62 scfm
T4-6AM	73 scfm	98 scfm	124 scfm
T4-8AM	114 scfm	152 scfm	193 scfm
T4-10AM	154 scfm	209 scfm	274 scfm

Cooling

Cooling



Example



Example:

Energy Saving Measures

One nozzle full open valve = 14 scfm, partial open valve = 10 scfm
This one line with 3 nozzles = 42 scfm x $117/cfm/year = $4,914/yr

50 air nozzles at 10 scfm each = 500 scfm x $117/cfm/year = $58,500

3 hp blower 70 cfm, using 2.2 kW running all year = $1,156
Blower plus manifold cost $3,000

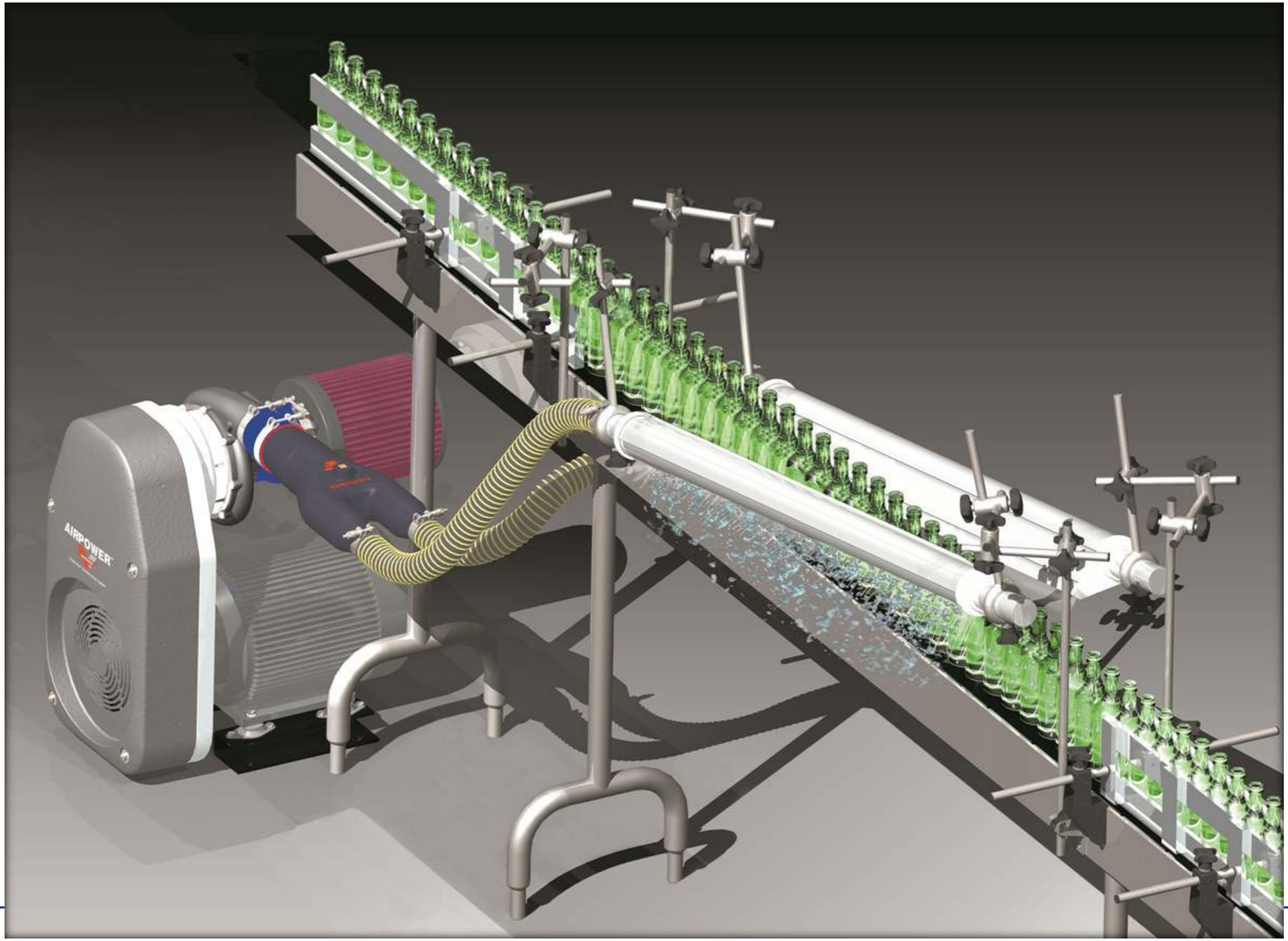
Life Cycle Cost Example

- **Proposed Nozzle replacement with blower:**
- Three Nozzles consumes 42 cfm
- Compressed Air costs $117/cfm/year
- Blower to replace Nozzles
  - $3,000 investment
  - $1,156 per year to operate
- **Annual uniform benefit:**
  - 42 cfm x ($117/cfm/yr) - $1,156/yr = $3,758/yr
  - $4,914/yr - $1,156/yr = $3,758/yr
- **Simple payback:**
  - **$3,000 (investment) ÷ $3,758 (AUB) = 0.79 years or just over 9 months**

Energy Saving Measures

Potentially Inappropriate Applications

Appropriate Applications



Appropriate Applications

Appropriate Applications

Appropriate Applications

Appropriate Applications

Appropriate Applications

Air Operated Diaphragm Pumps (AODP)

- Diaphragm pumps driven by electric motors can easily substitute for AOD pumps using compressed air. Other AOD pumps can be simply substituted with electric centrifugal pumps.
- An industrial rule of thumb is that an AODP will use about 7 times the electrical energy of an efficient centrifugal pump to move the same volume of water.
  - This energy differential does not consider leaks and line losses in the compressed air system, which makes the AODP even more energy wasteful.

AOD Pumps

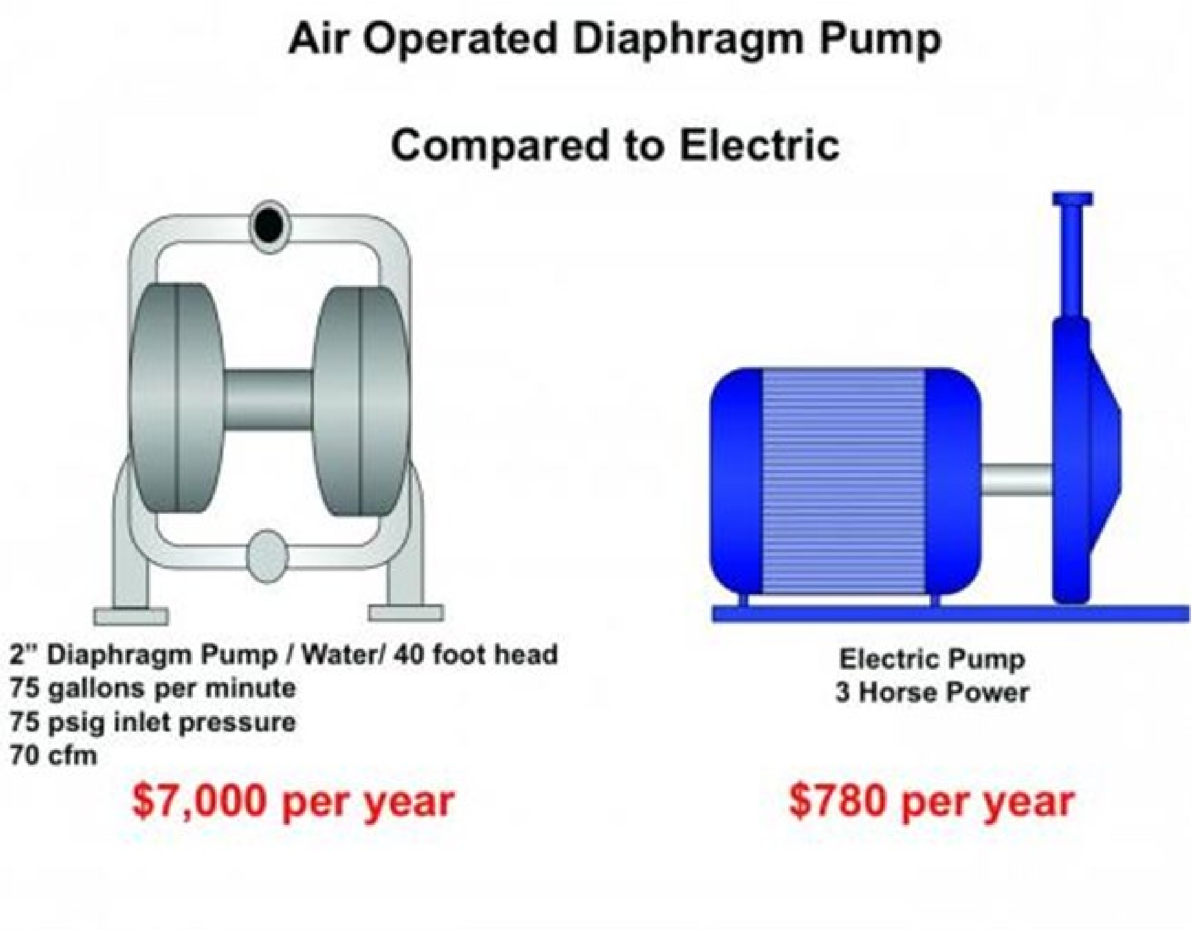
- It is not unusual for an operation to have AOD pumps already in place because there's a good chance they arrived at the plant from an equipment supplier as part of the package, or someone selected them in the past.
- Regardless of how they got to the plant, there are number of reasons why they are widely used in a variety of industries.
- For one, they work well if they are "big enough."

Costs to Operate Air Operated Diaphragm Pumps (AODP)

- For example, a 2 hp, 460-volt, 3-phase electrical centrifugal pump will use about 3,000 kWh/year of electric power if operated 8 hours/day, 250 days/year.
- Assuming electrical rates of $0.07 per kWh, the annual electrical cost is $208.
- An AODP doing the same amount of work has an additional cost of $1,500 per year or more, and this does not include any maintenance costs for the air compressor and system.

AOD Pumps

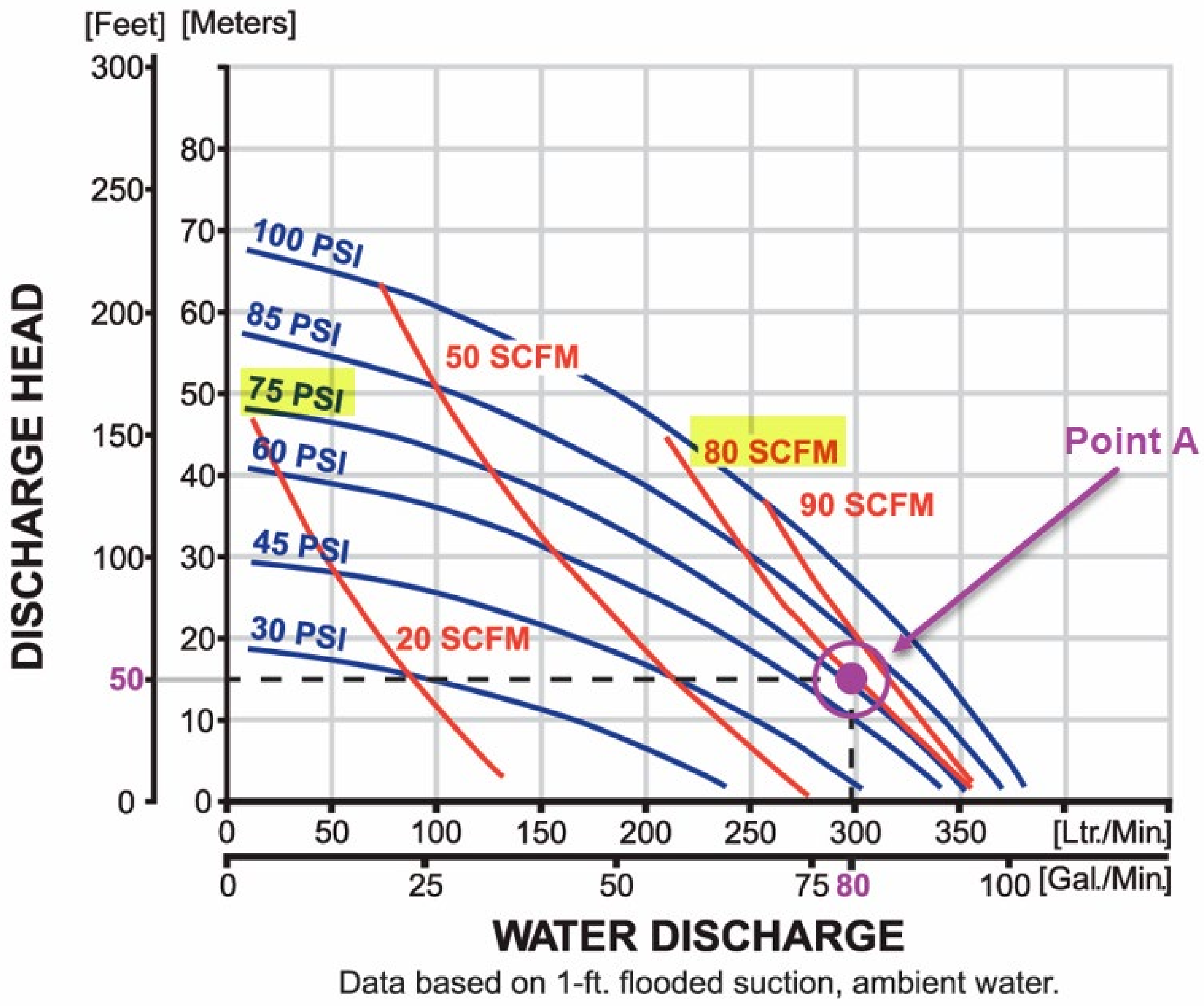
- A 2-inch AODD pump will use an average of 90-120 cfm of compressed air at 95psig or 23 hp to 30 hp of compressed air supply.
- An electric-driven pump under the same conditions would draw between 3 hp and 5 hp.
- If the net horsepower savings here is an average of 21 hp, it translates to a savings of $7,000 per year (21 x.746 = 15.66kw x $.056kwh x 8000 hr/y) when an electric-driven pump is used for power rather than compressed air under these conditions.



Appropriate Applications

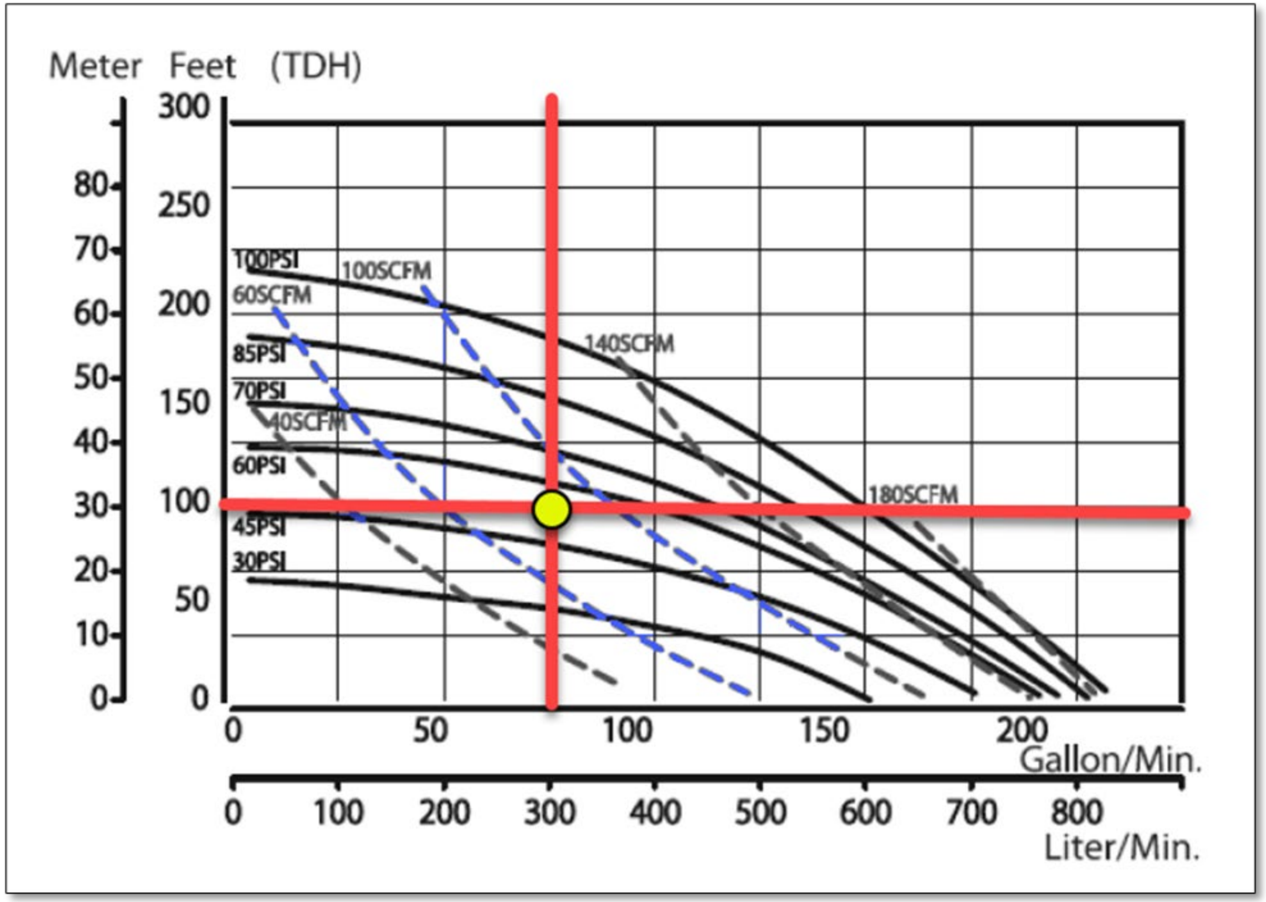
Reading an AODP Curve

- As an example, consider a pump that you want, pumping at 80 GPM at 50-ft TDH.
- This pump will require 75 psi and use 80 scfm



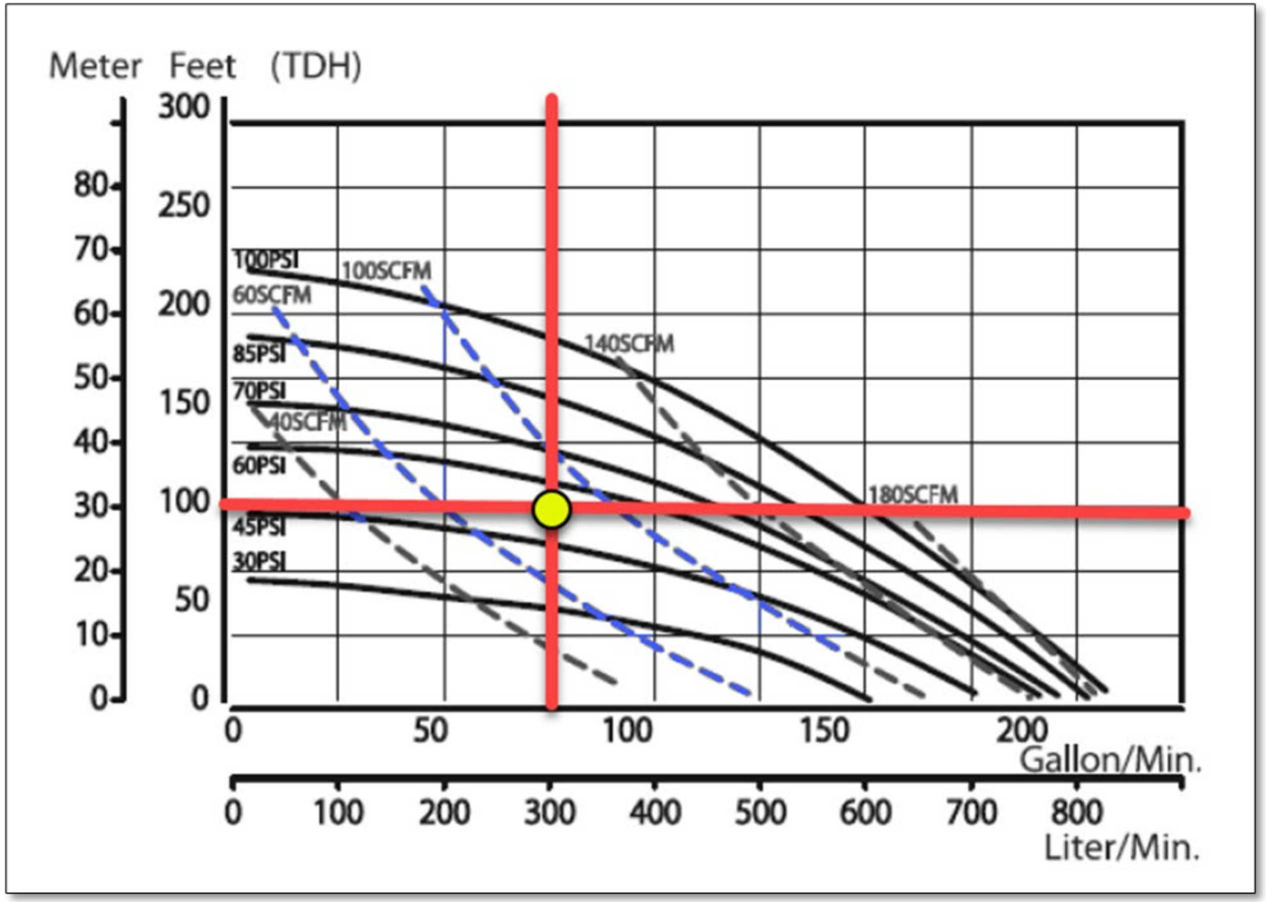
Reading an AODP Curve

- First you need to know the height of the storage tank you will be pumping to and the rate of gallons per minute you would like to pump.
- The pump curve shown, shows Total Dynamic Head (Y1 Axis) and Gallons per Minute (X Axis).
- You should always pick a pump that will be close to the middle or sweet spot of the curve.



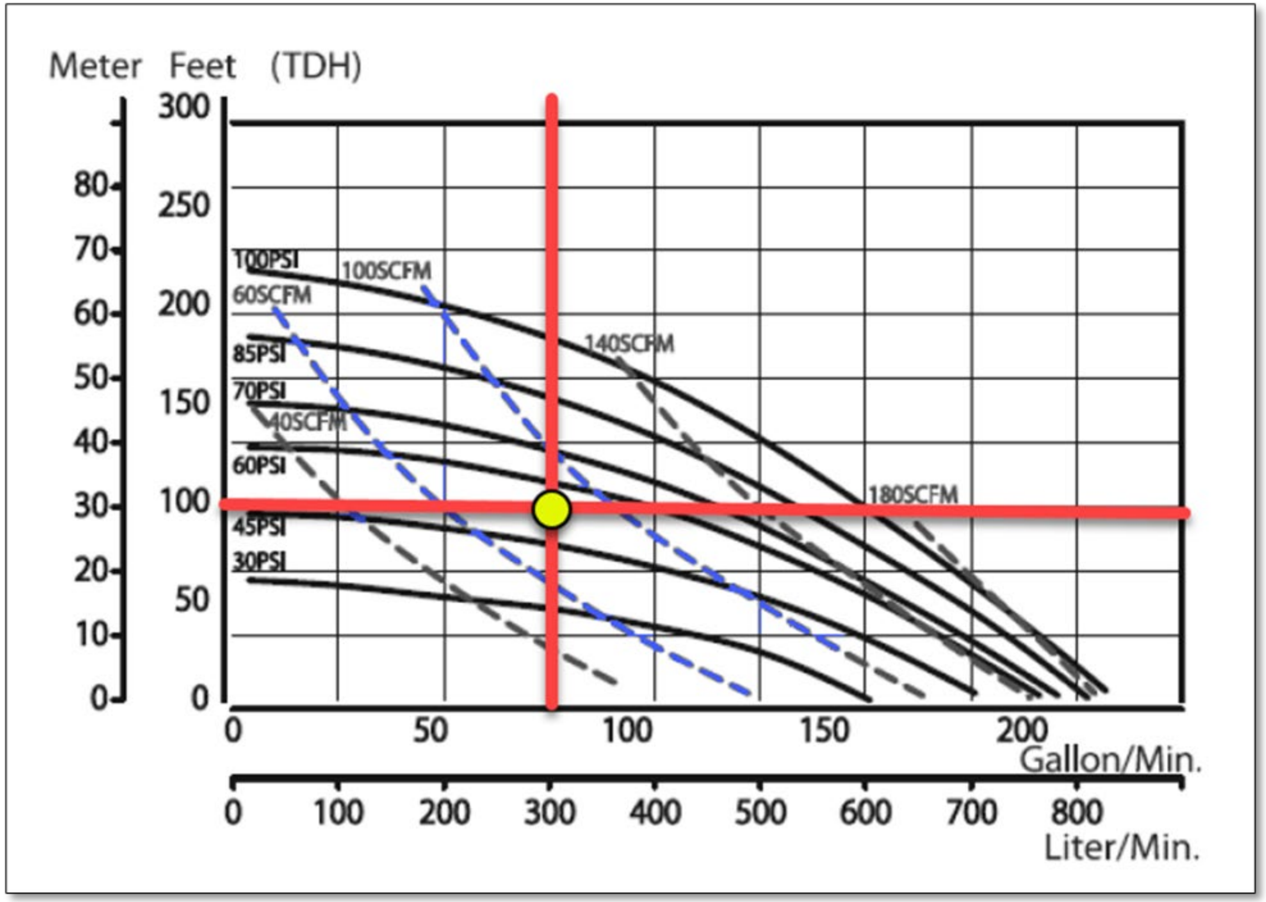
AOD Pumps

- Let's assume we want a head pressure of 100 in feet (100') and we want the flow to be 75 gallons per minute (75 GPM); where they intersect is the duty point shown with the yellow dot.
- This seems to be the middle of the curve for best performance and parts life expectations.



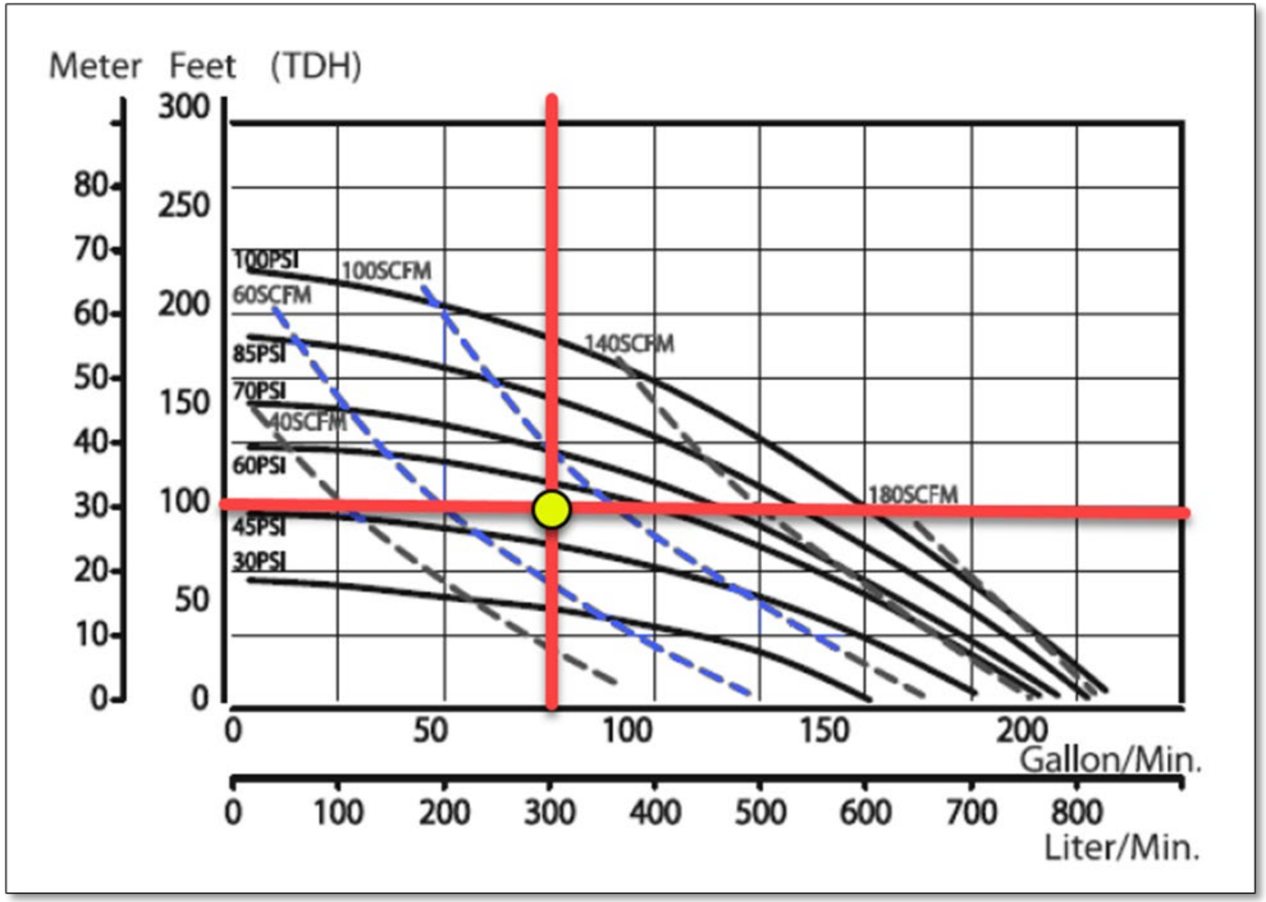
AOD Pumps

- Based on that duty point, when you follow the nearest solid black line back up and to the left, you will see it is about half-way between the 45 and 60 PSI lines
- You would need about 52 PSI inlet air pressure to the pump to get it to perform at the required duty rate of 75 gallons per minute.



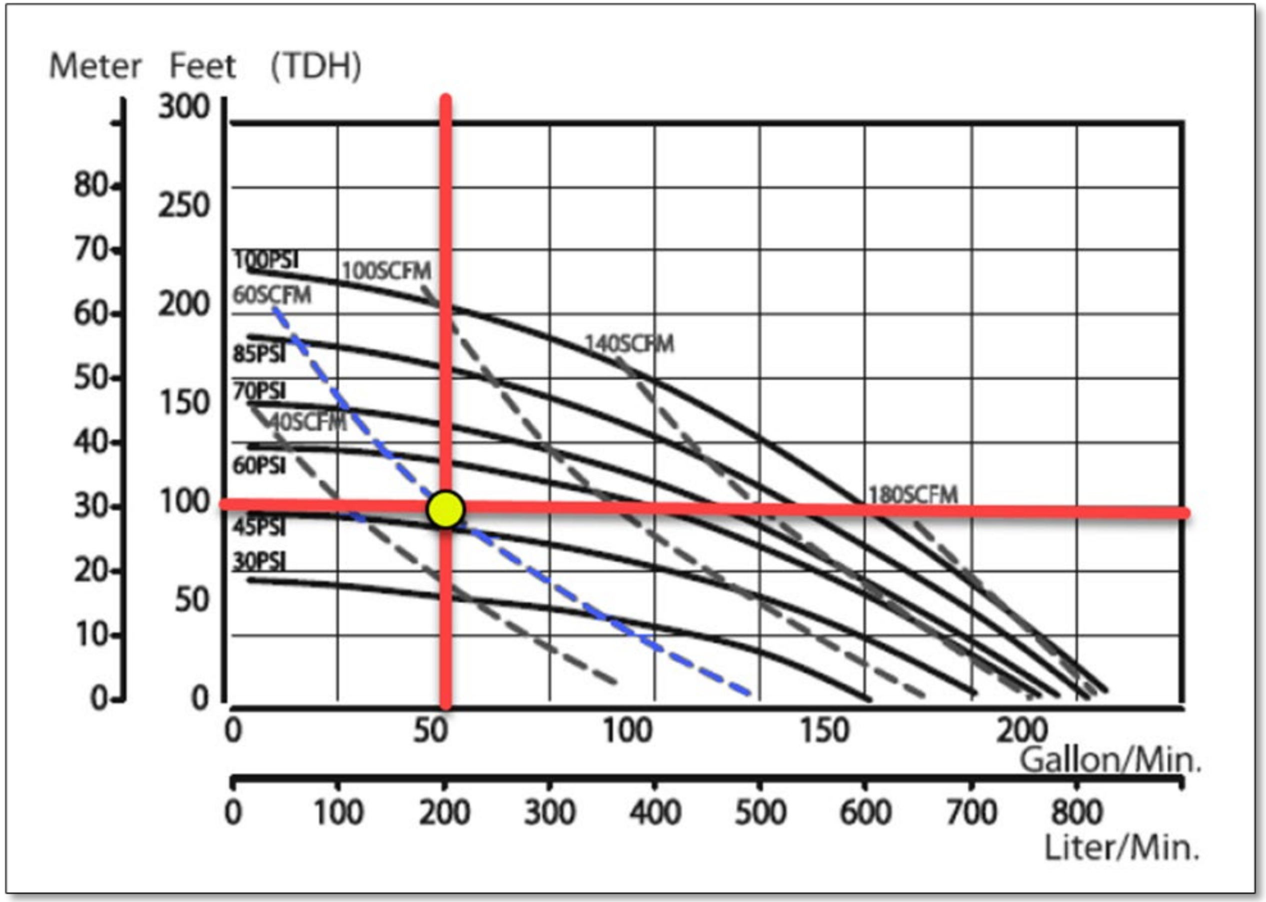
AOD Pumps

- Next, you follow the nearest dotted blue line upwardly, you see it is in the middle of the 60 SCFM and 100 SCFM
- You need about 85 SCFM from your compressor to meet the requirements of the required duty point.



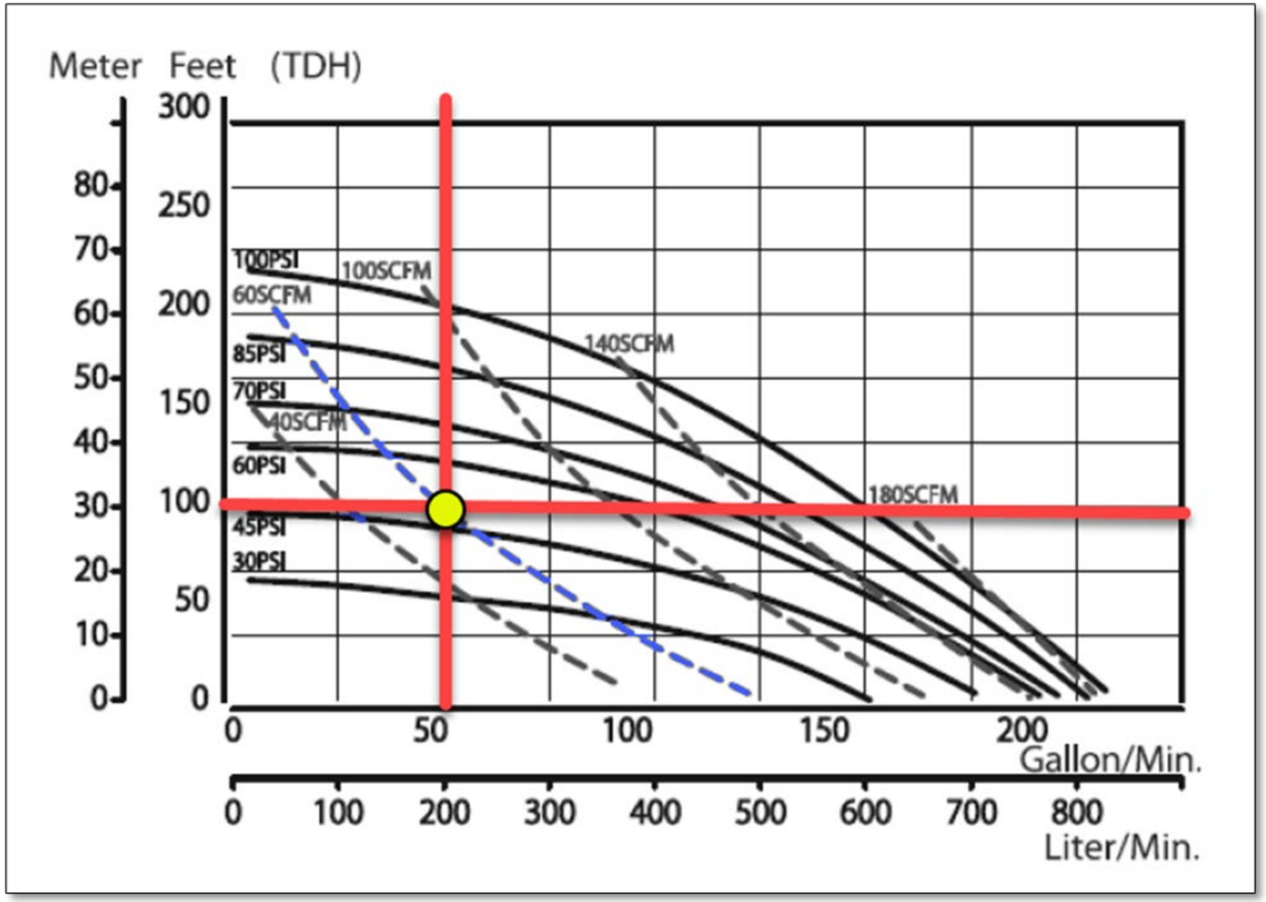
AOD Pumps

- Let's assume we still want a head pressure of 100 in feet (100') and we want the flow to be 50 gallons per minute (50 GPM); where they intersect is the duty point shown with the yellow dot.
- Based on that duty point, when you follow the nearest solid black line back up and to the left, you will see it is just above the 45-psi line – so you would need about 48 PSI inlet air pressure to the pump to get it to perform at the required duty rate of 50 gallons per minute.



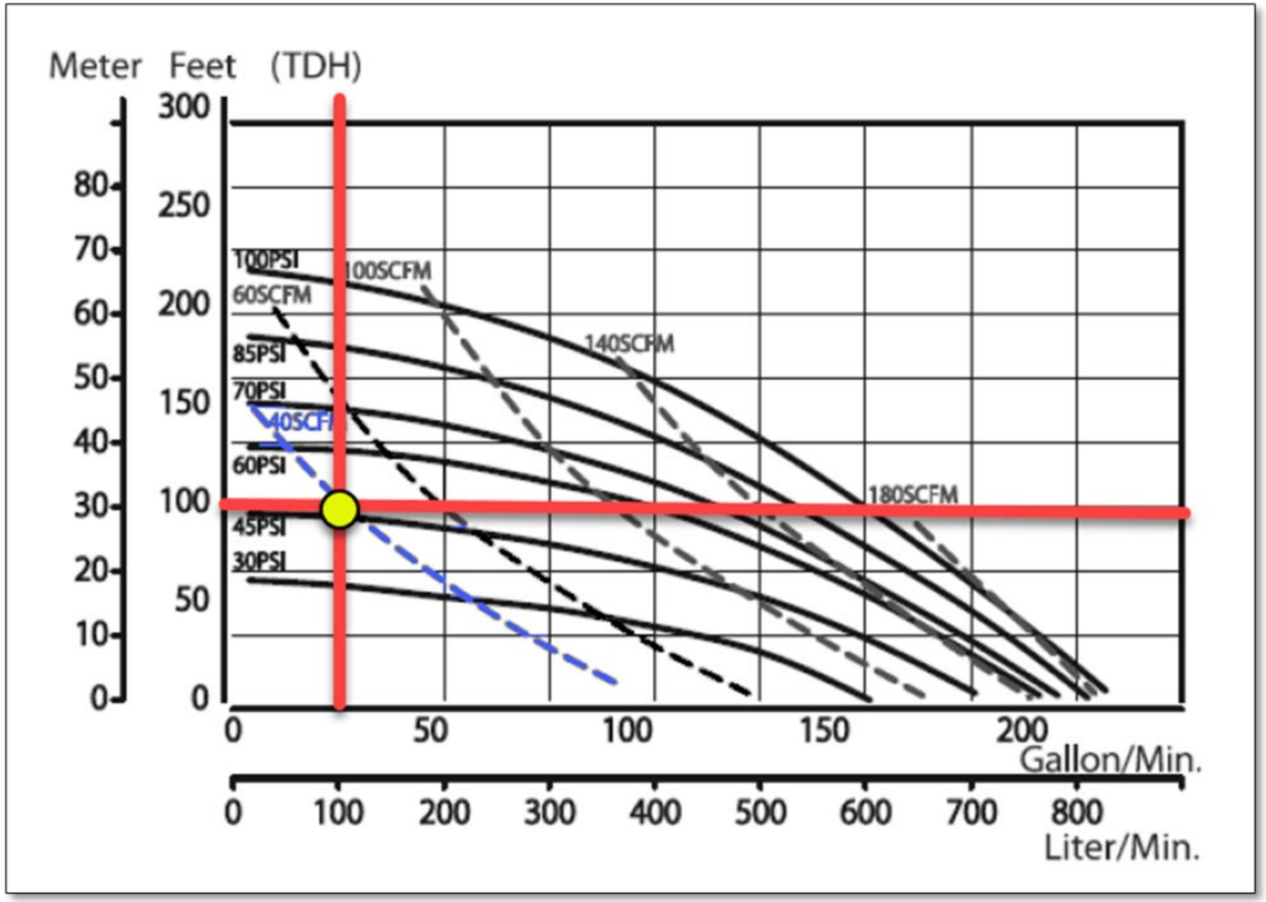
AOD Pumps

- Next, you follow the nearest dotted blue line upwardly, you see it is right on the 60 SCFM dotted line – so we would say you need only 60 SCFM from your compressor to meet the requirements of this required duty point.



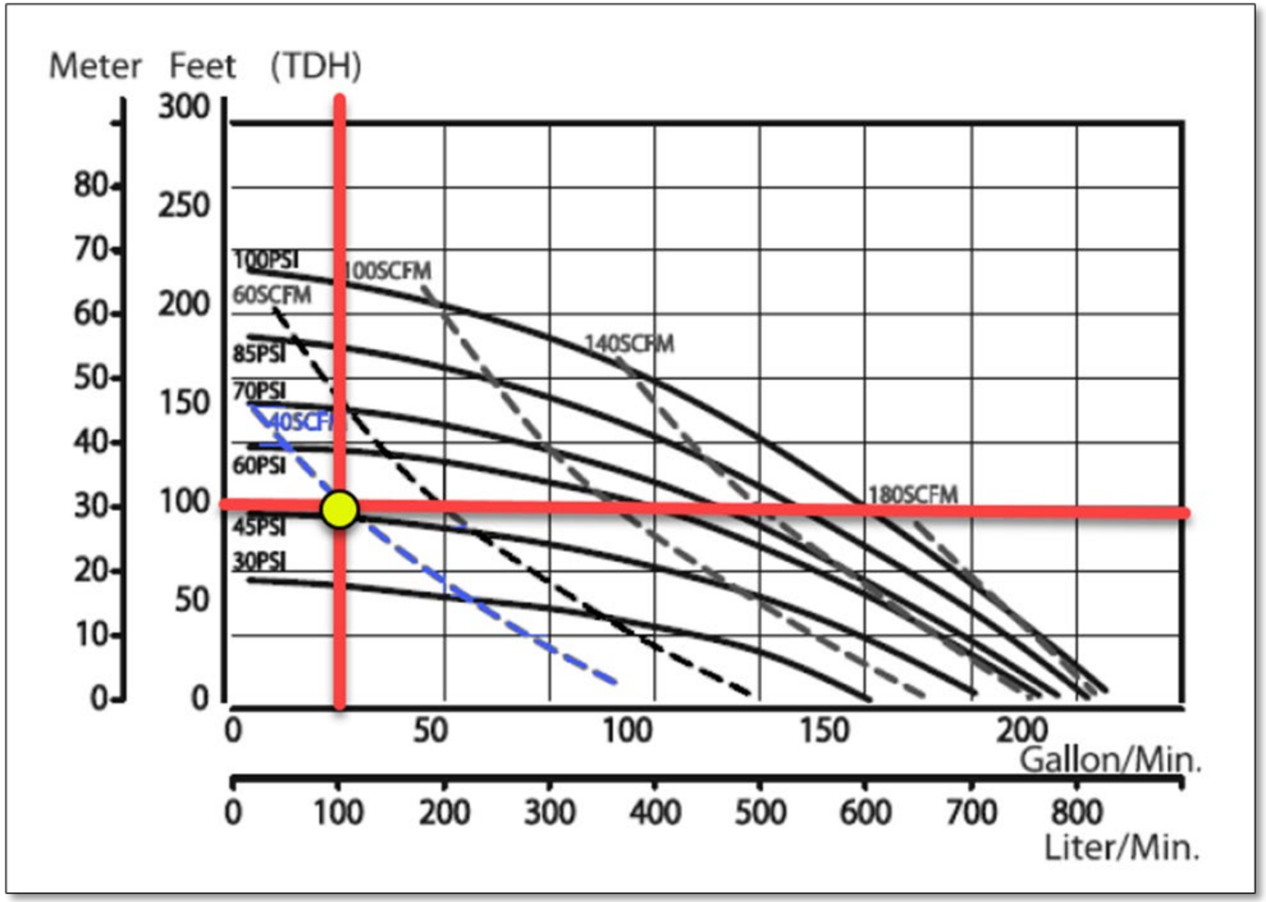
AOD Pumps

- Third scenario is we still want a head pressure of 100 in feet (100’) and we want the flow to be only 25 gallons per minute (25 GPM); where they intersect is the new duty point shown with the yellow dot.
- This flow just means it will take a few minutes longer to transfer the liquid.
- Based on that duty point, when you follow the nearest solid black line back up and to the left, you will see it is just above the 45-psi line – so you would need about 48 PSI inlet air pressure to the pump to get it to perform at the required duty rate of 25 gallons per minute.



AOD Pumps

- Then as before, you follow the nearest dotted blue line upwardly, you see it is right on the 40 SCFM dotted line – so we would say you need only 40 SCFM from your compressor to meet the requirements of this required duty point.
- This reveals how important it is to understand the pump curve and be able to select a flow that will not require excessive amounts of compressed air just for the sake of completing the pumping task quicker.

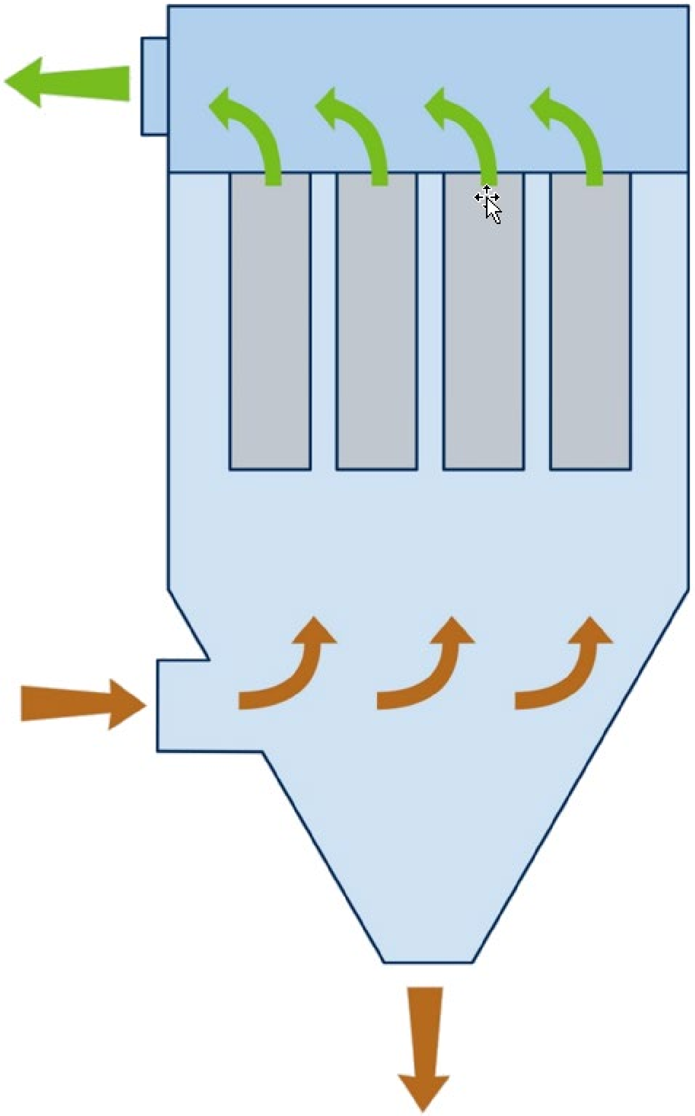


Dust Collectors

- Most industrial dust collectors use compressed air to clean and extend the life of their filters.
- This is typically accomplished using short pulses of compressed air inside of the individual bag filters or cartridge filters in order to blow or knock the dust off of the outside of the filter.
- Those responsible for the operation of industrial dust collectors need to manage the compressed air supplied to the dust collector to ensure proper performance while controlling operational costs.
- Doing so helps reduce costly compressed air consumption, maximizes dust collector airflow performance, and reduces collector maintenance and down-time costs.

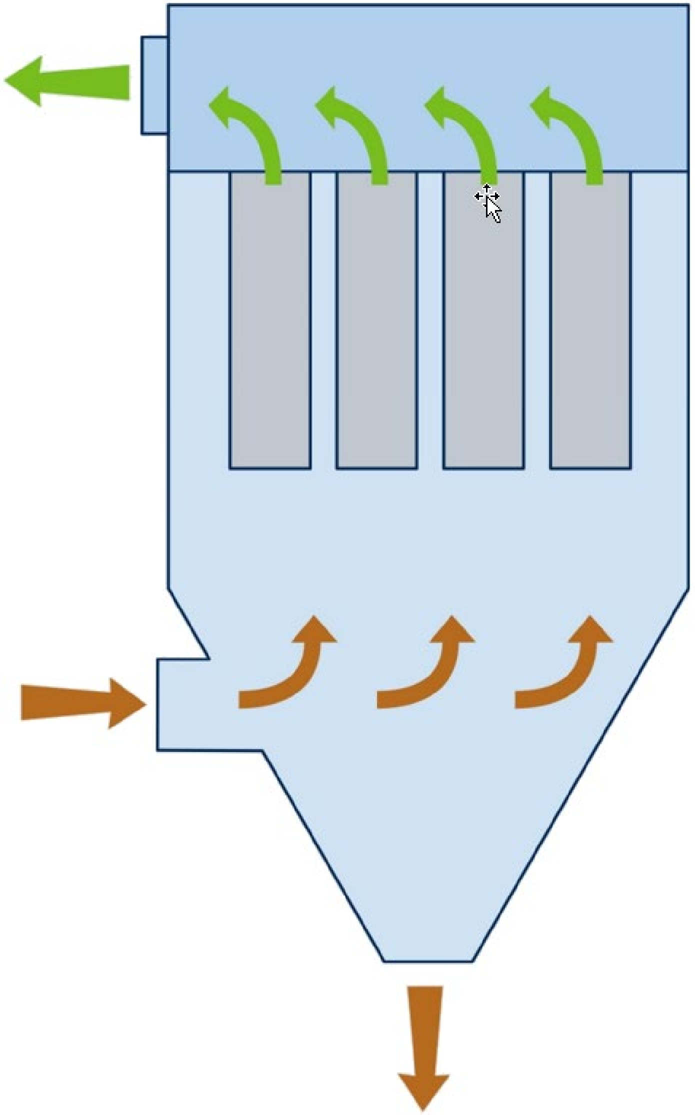
Dust Collectors

- Clean-On-Demand vs. Continuous Cleaning
  - The first tip for controlling compressed air consumption for industrial dust collectors is to invest the extra money for quality on-demand-cleaning controls when buying your industrial dust collector.
  - Many collectors come standard with a control panel that continuously and automatically pulses filters with compressed air every 10 or 15 seconds — whether the filters need to be cleaned or not. This adds unnecessary costs for multiple reasons.

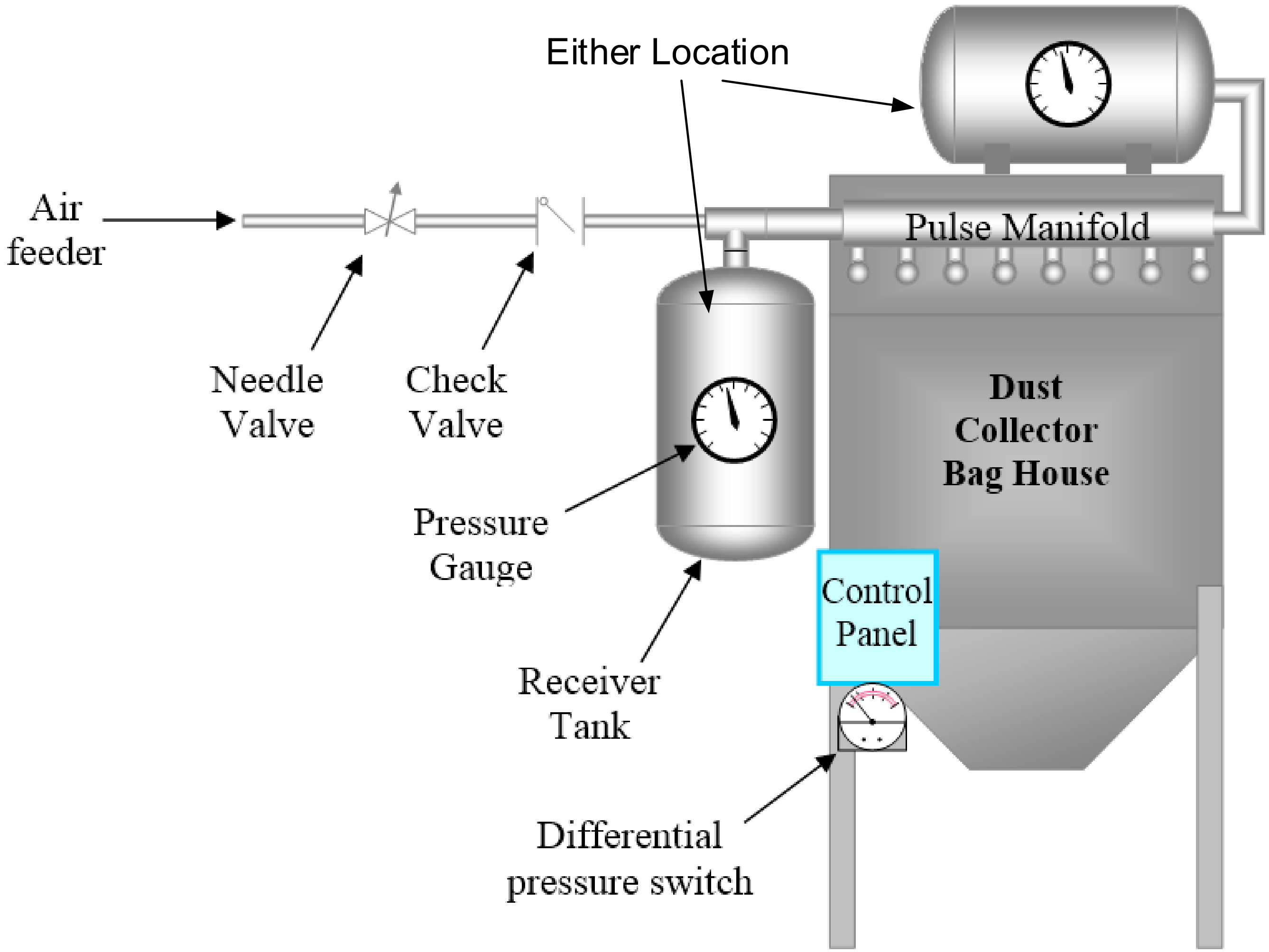


Dust Collectors

- First, in most situations with continuous cleaning, more compressed air is being consumed than is needed to maintain stable collector operation.
- Depending on how a collector was initially sized and the volume of dust the collector is handling, it is likely that the frequency of cleaning (and the compressed air consumption) can be cut in half.
- In the case of a 50,000-cfm dust collector, a 50% reduction in pulsing could result in an annualized savings of over $1,300.
- This calculation assumes the collector is running two 8-hour shifts per day, 5 days per week.
- This kind of savings could easily offset the investment of an on-demand controller in a month or two.

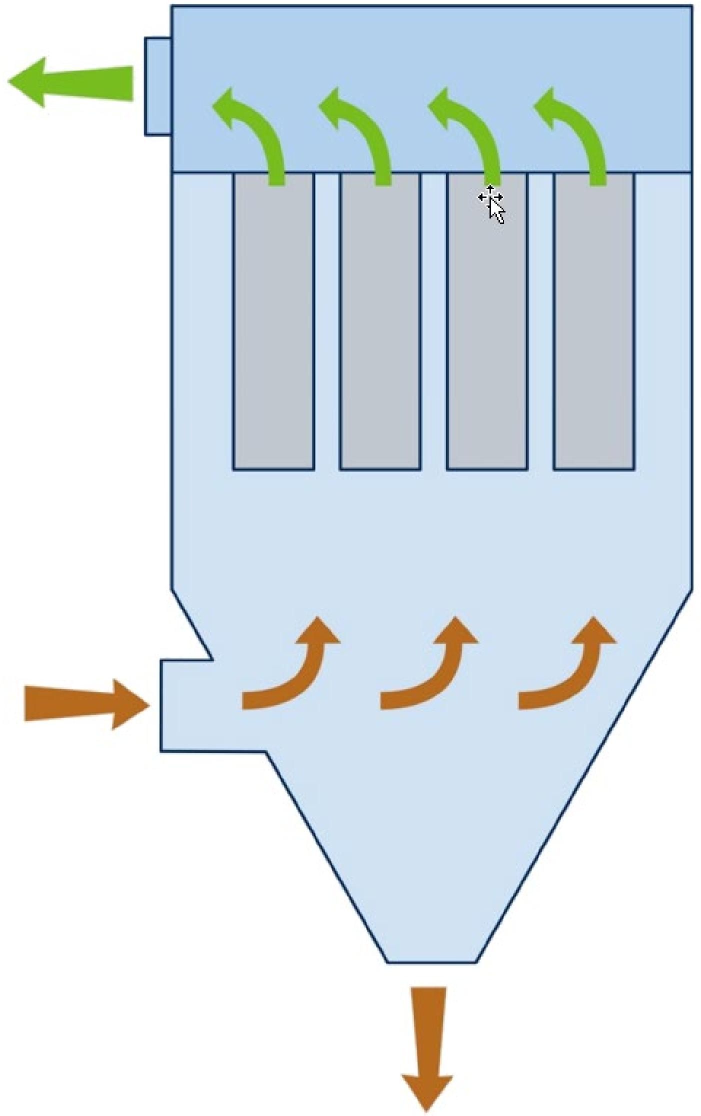


Point of Use Storage



Dust Collector Best Practices

- Use proper line size to handle rate of flow without high pressure loss.
- Monitor inlet pressure and drop at pulse.
- Monitor flow.
- Use appropriate regulator with dedicated storage and metered refill to supply air without pulling down local pressure in surrounding piping.
- Too much pressure loss at pulse will deliver incomplete cleaning.
- When you are dealing with pulse demands of less than several seconds, regulation of the actual air to the pulse jet is **almost never** appropriate.



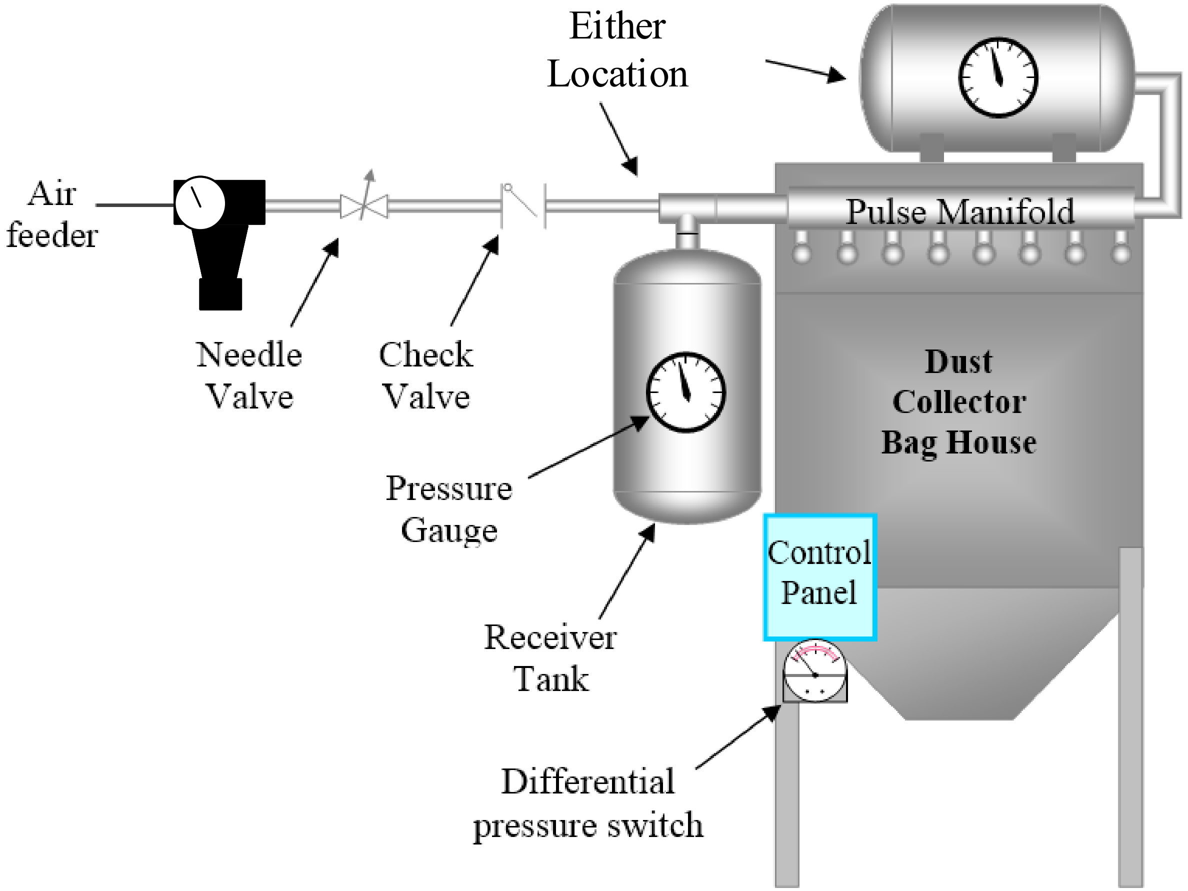
Dust Collector (Bag House)

Designing “By the Book”

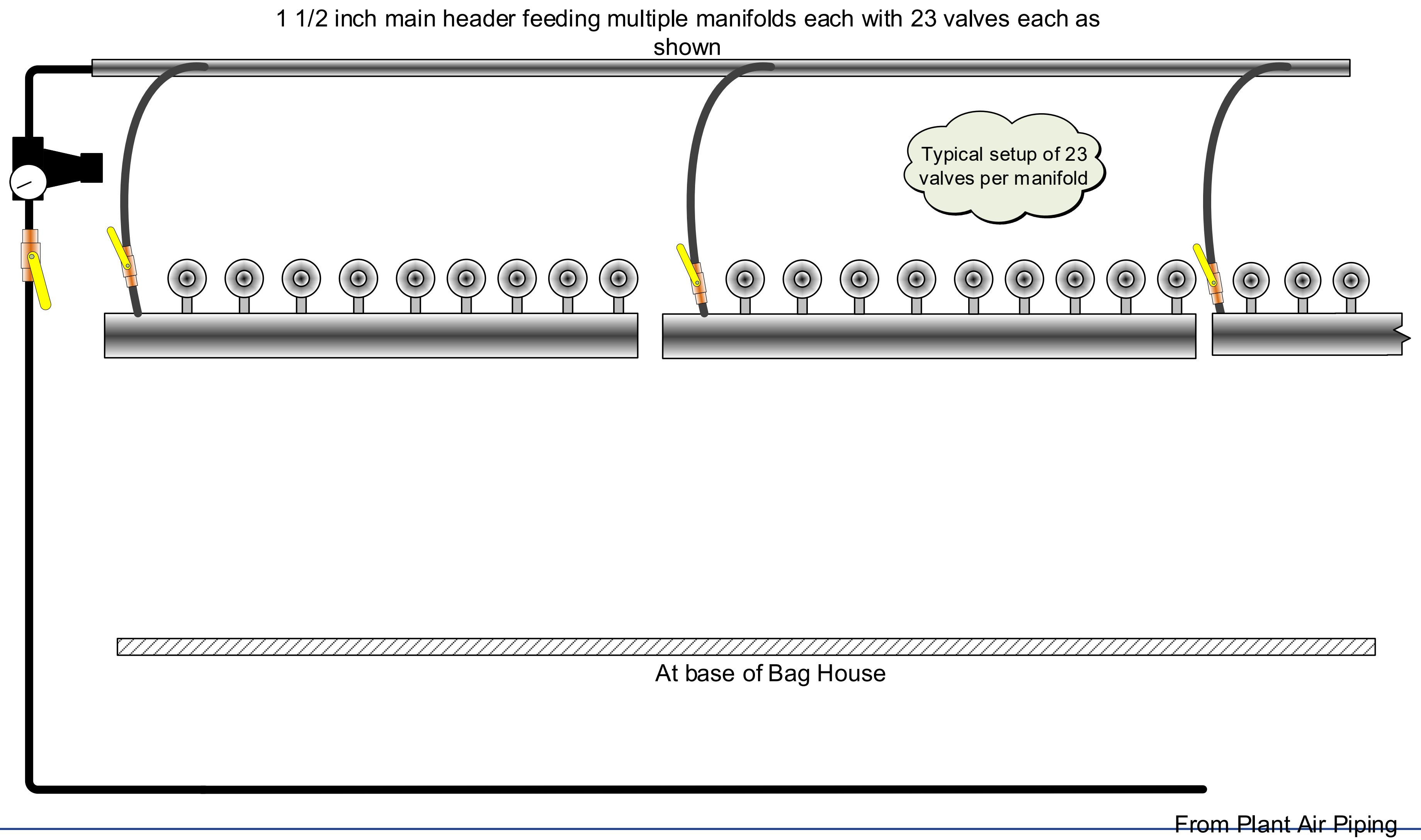
- When a plant or operation with significant dust collecting is audited, it is very rare to find anyone in operations who is aware of what the dust collectors operating specifications are and how or why the pipe sizes were selected.
- When you get the facts and go "by the book," an amazing thing happens — the system works like it’s supposed to.

Dust Collector (Bag House)

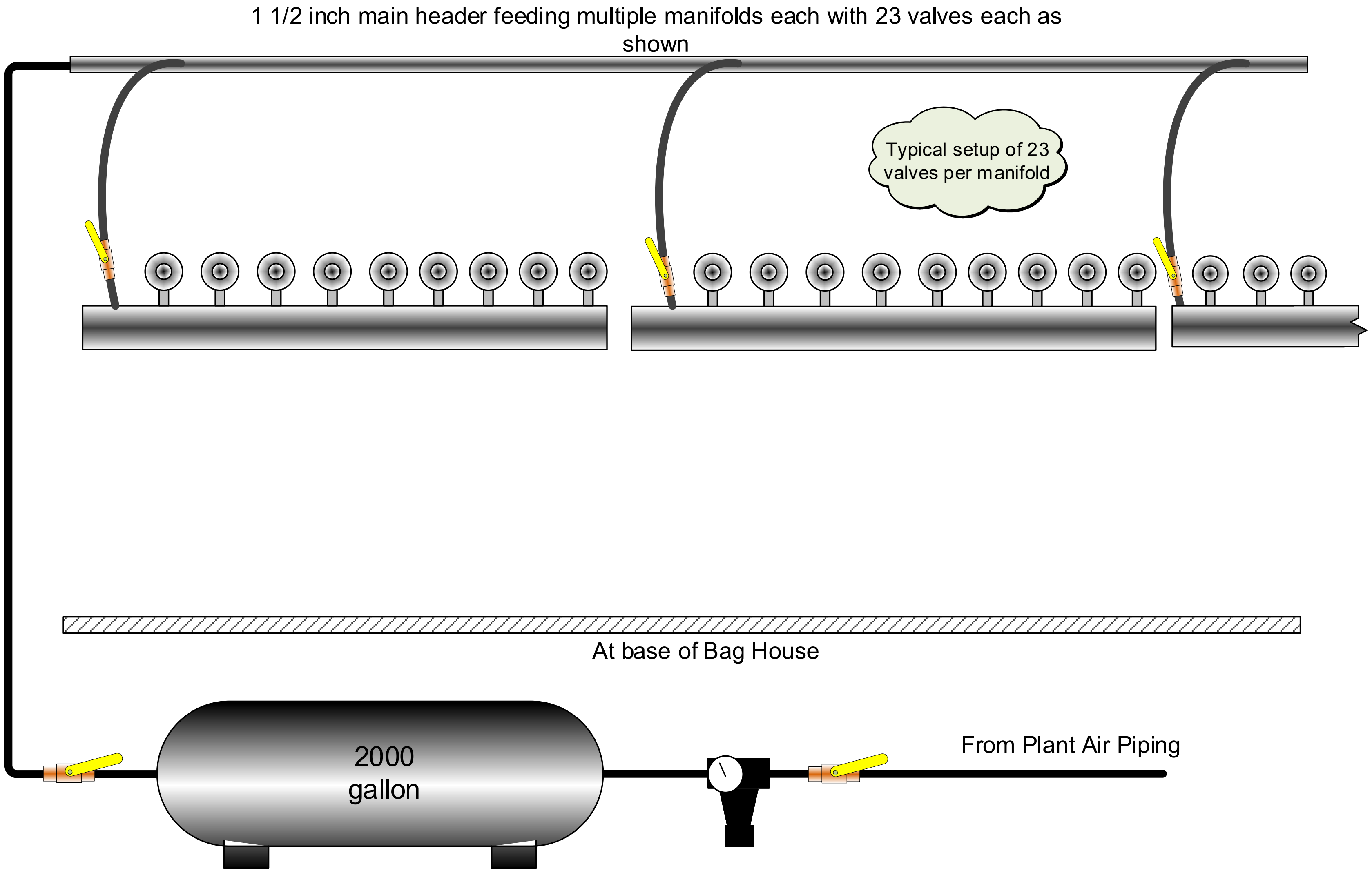
- The rated flow of compressed air per pulse is usually 2 to 3 cubic feet, with normal pulse durations of .1second (100 milliseconds).
- One valve typically opens every 15 seconds.
  - Obviously, there are other designs with different specifications.
  - Most of the time there will only be one valve opening every 15 seconds, but sometimes there could be two or more pulses simultaneously.
  - Regardless of whether the pulse-jet dust collector is bag or filter type, the critical support system of piping, storage and controls is important.



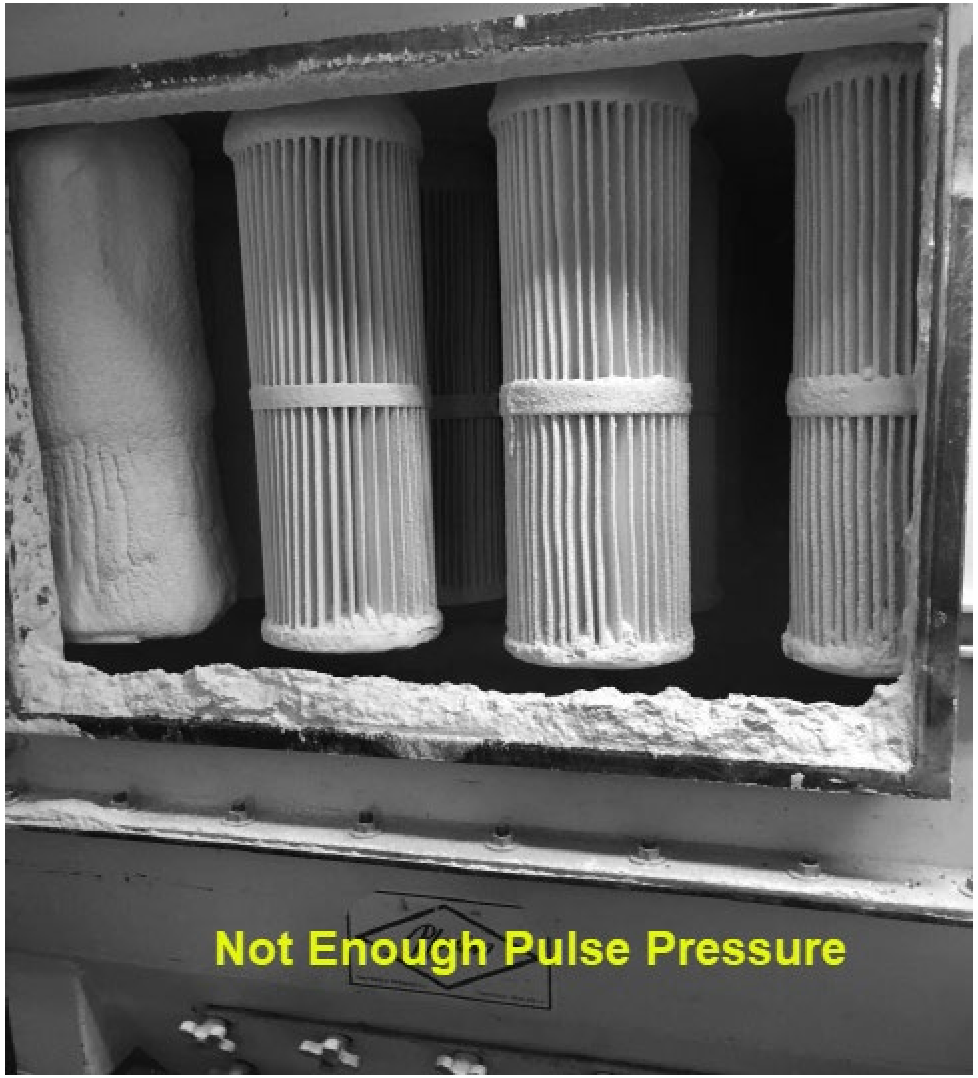
Dust Collector (No Storage Volume)

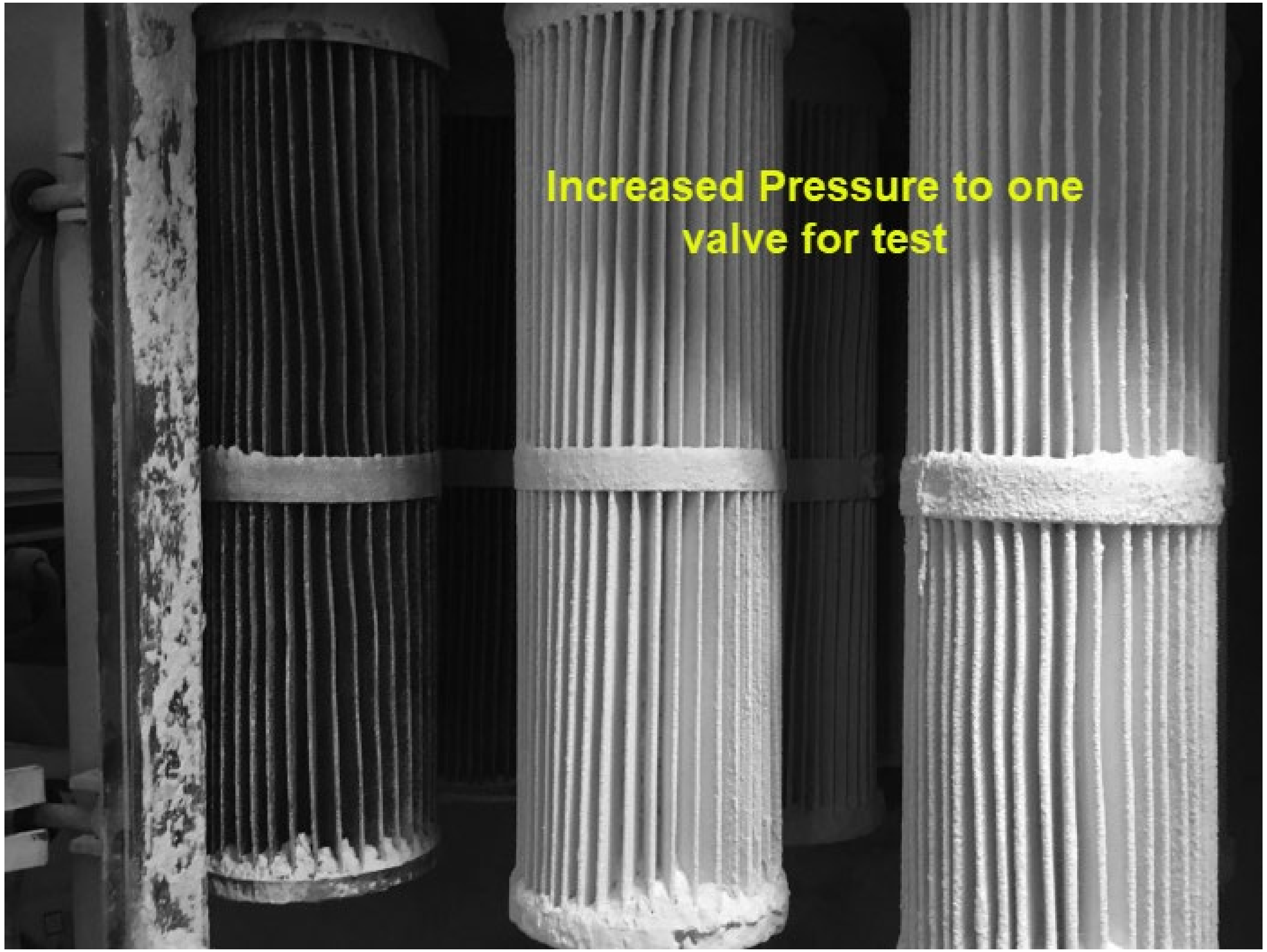


Dust Collector (Storage Volume)



Dust Collector (Not Very Efficient)





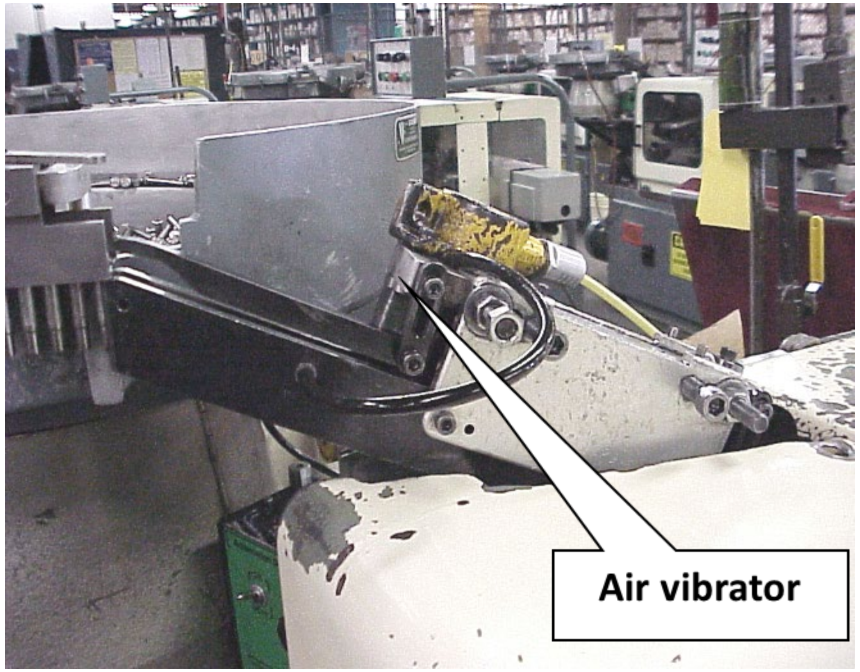
Dust Collector (How Old are the Valves?)

- A 20 year-old dust collector with original pulse valve diaphragms. Notice diaphragm tab is painted same color at unit.
- Every dust collector air manifold should be fitted with an air pressure gauge.
- The pressure gauge will allow you to observe pulse cycling and check for equal pressure surge during each pulse cycle.
- Inconsistent pressure surge is the first indicator of faulty pulse valve diaphragms or solenoid issues.
- That means the valves are a candidate for a complete set of new diaphragms and springs.

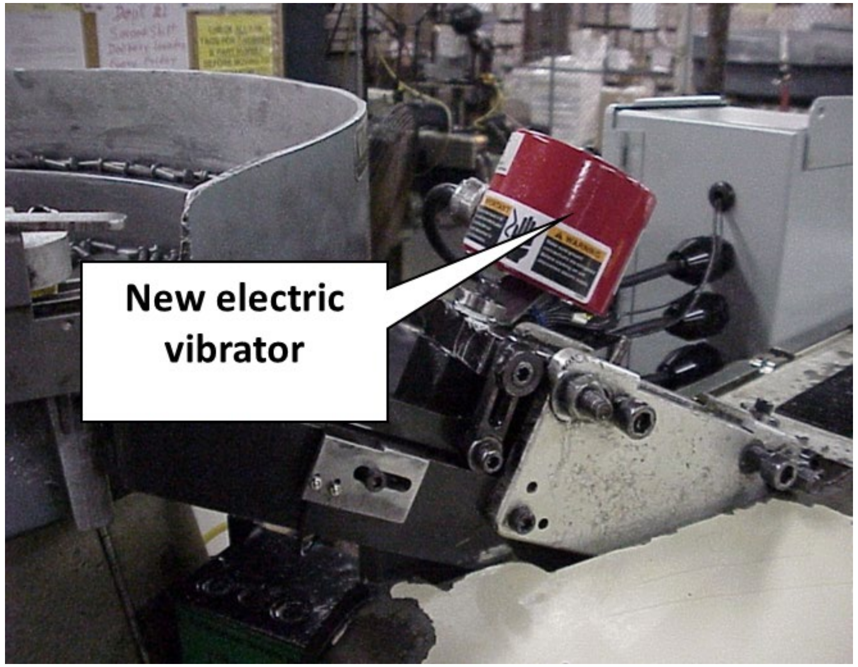
Other Missed Demand Reduction Opportunities

- Additional and often missed demand reductions include the following:
  - Air Vibrators
  - Industrial Vacuums
  - Air Movers and Air Horns
  - Agitation
  - Air Motors
  - Air Hoists
  - Air Motor – Driven Mixers

Air Vibrators vs. Electric Vibrators



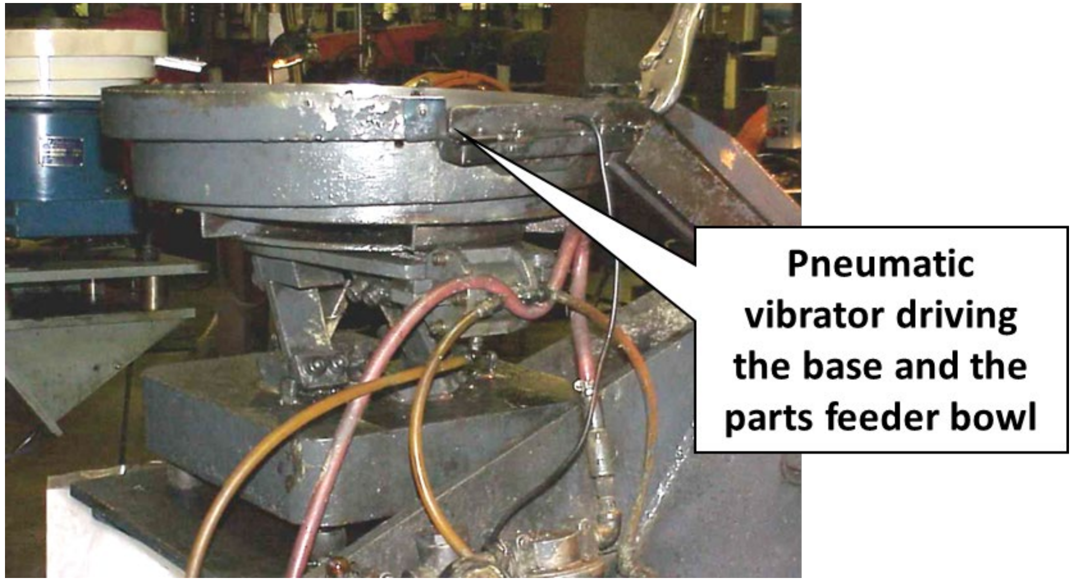
Air Vibrators - $700/year

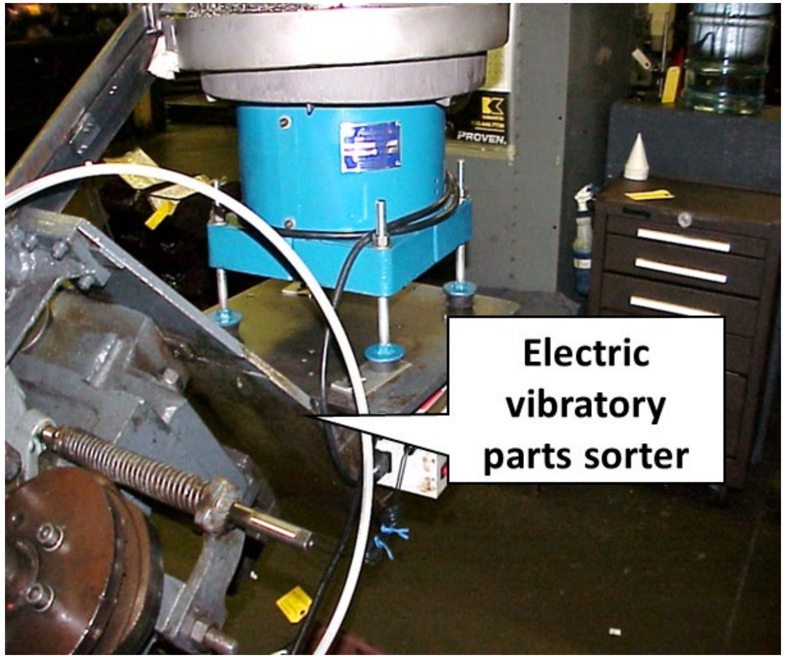


Electric Vibrators $109/year

Vibrator Parts Sorters

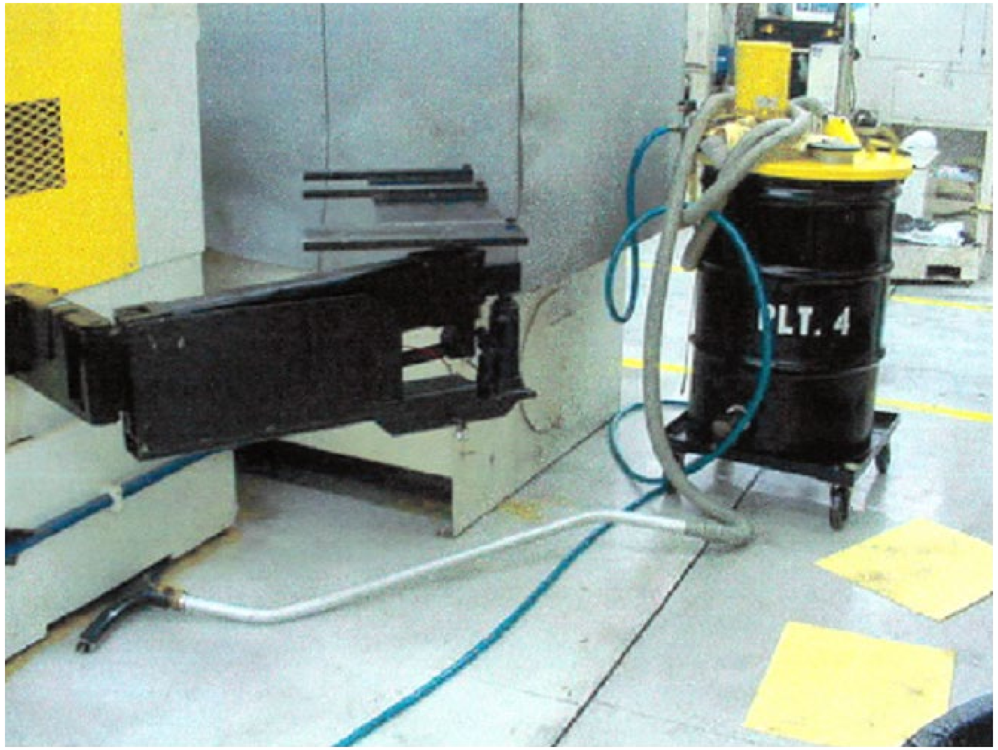
Compressed Air
$800/yr.





Electric
$100/yr.

Industrial Vacuum Cleaners Liquid & Cuttings



Air-driven vacuum system for cutting fluids, running continuously with machine off – 24/7 operation
$6,000 year

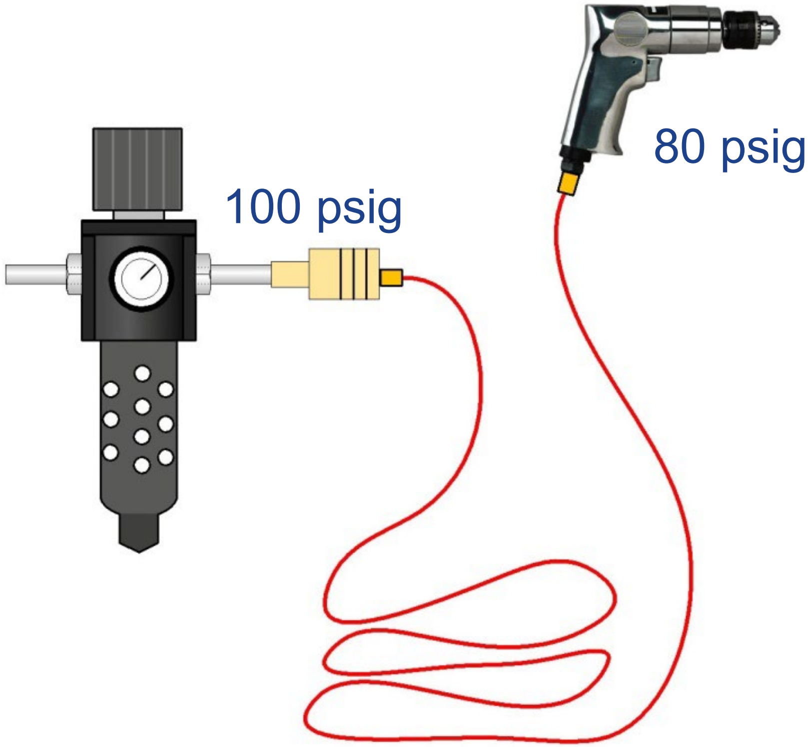
Electric motor-driven vacuum system for cutting fluids. Off, not running
$878 year

System Pressure Drop Losses (Most Important)

- Many systems have outgrown their original size requirements.
- Distribution pipe diameters are too small . Velocities should not exceed 20 ft/sec.
- Filters should be sized for maximum flow conditions. (Peak Flows)
- Hoses and connectors are problematical.

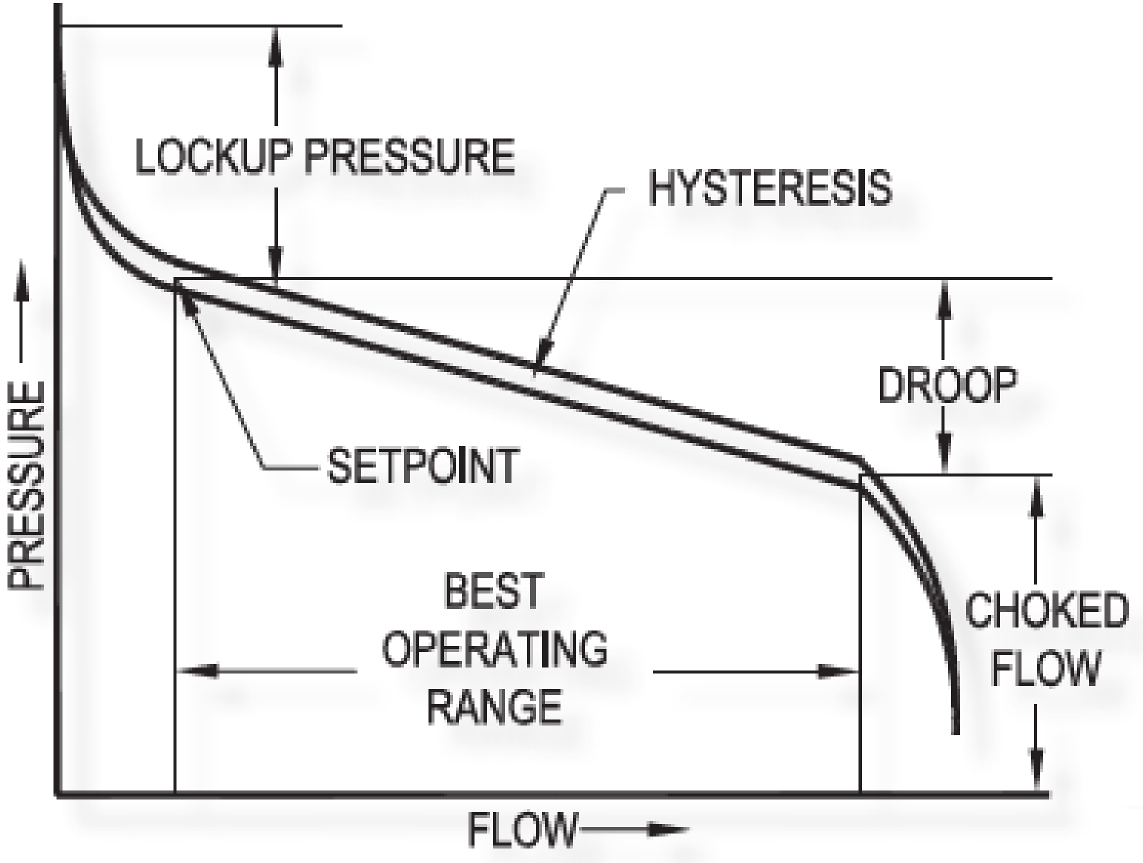
End Use Control

- A pressure regulator is used to limit maximum end-of-use pressure and is placed in the full distribution system just prior to the tool.
- If a tool operates without a regulator, it uses full system pressure.
- This results in increased system air demand and energy use, since the tool is using air at this higher pressure.
- High pressure levels can also increase equipment wear, resulting in higher maintenance costs and shorter tool life.



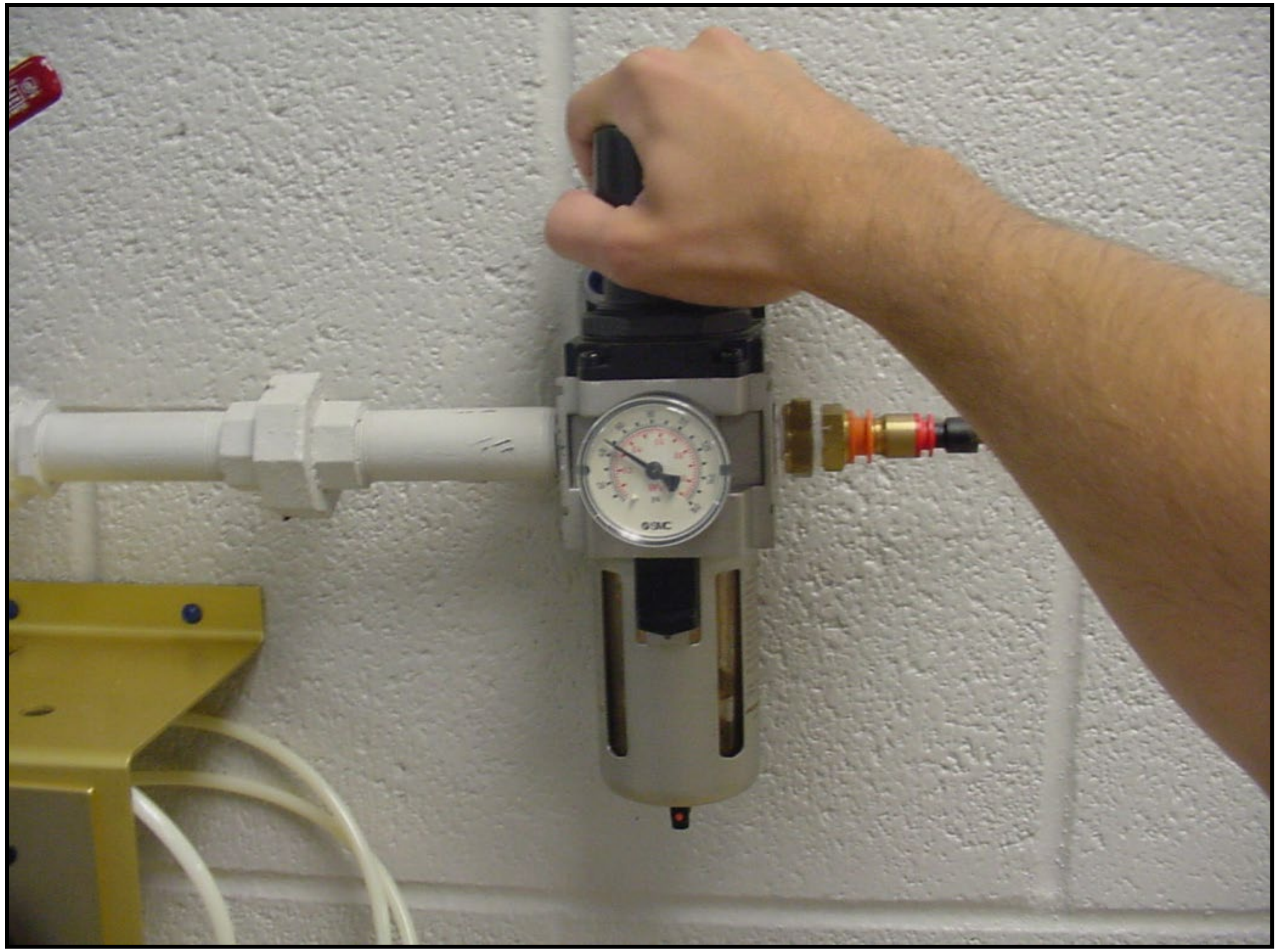
Regulators

- The accuracy of a pressure regulator is determined by charting outlet pressure versus flow rate.
- The resulting graph shows the drop in outlet pressure as the flow rate increases.
- This phenomenon is known as droop.
- Pressure regulator accuracy is defined as how much droop the device exhibits over a range of flows; less droop equals greater accuracy.
- When selecting a regulator, you should examine pressure versus flow curves to ensure the regulator can meet the performance requirements necessary for the proposed application.
- Size these components based upon the actual flow rate (peak flow), not the average flow rate.

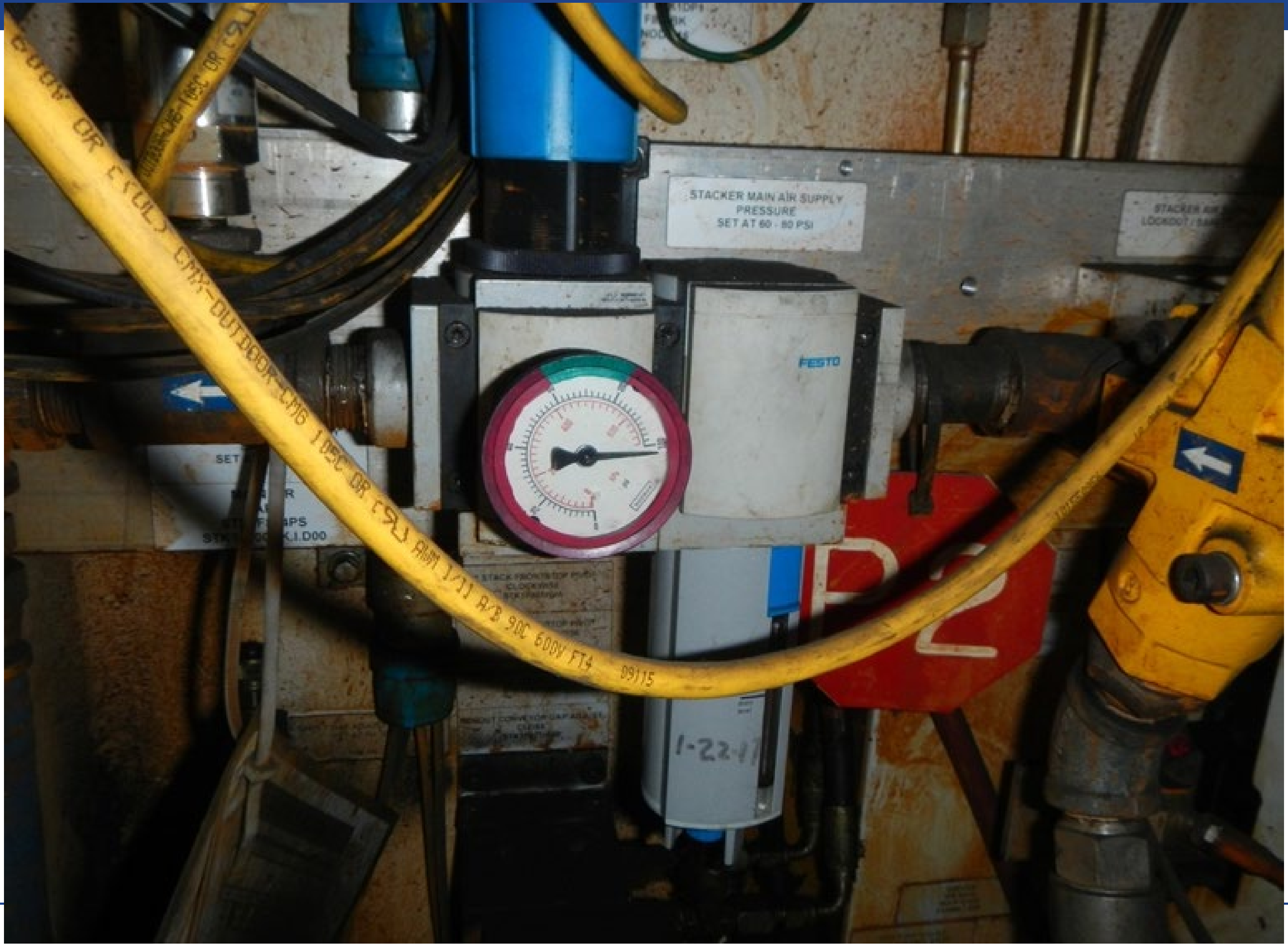


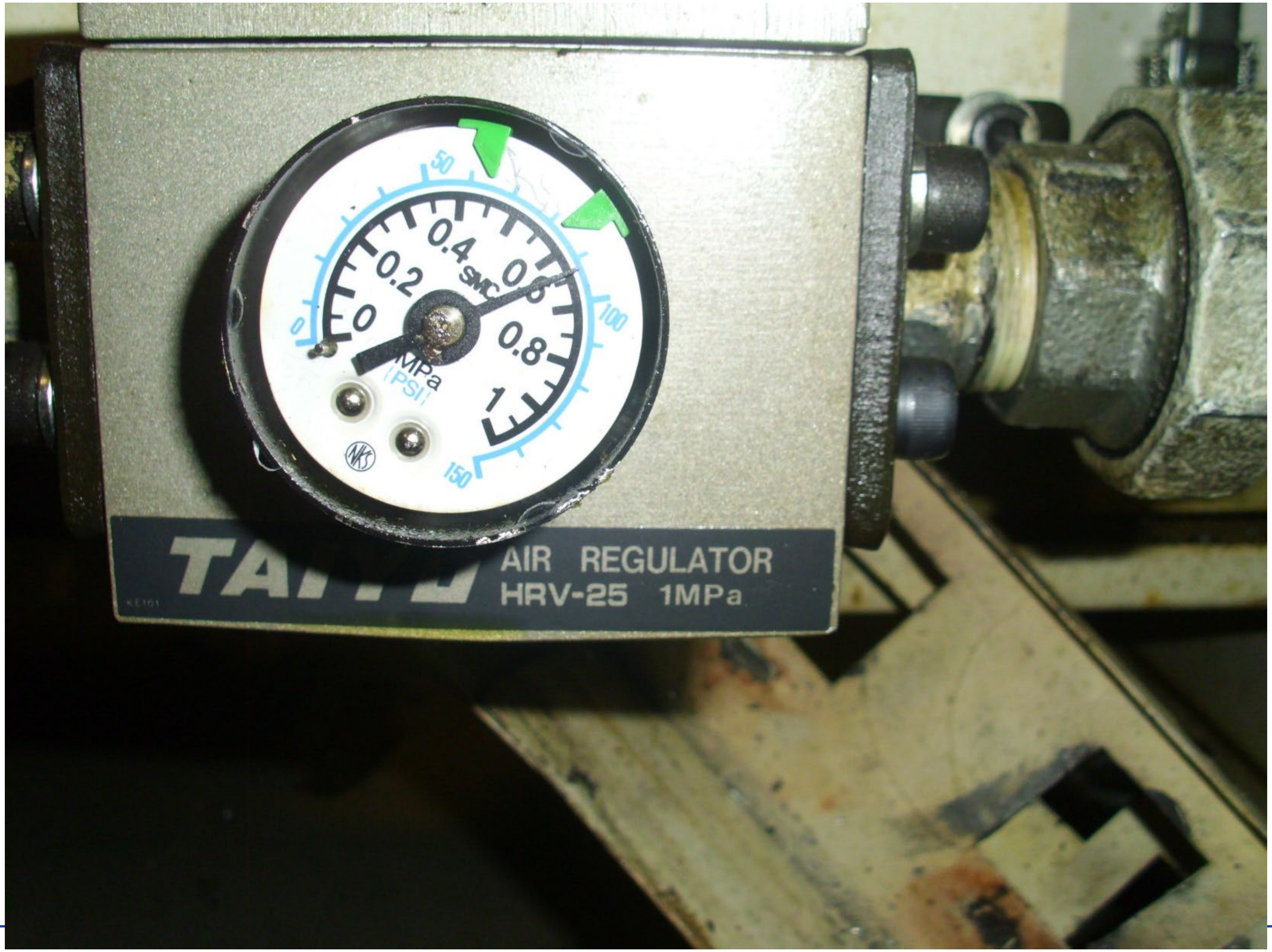
Over-Pressurization Examples

- 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.

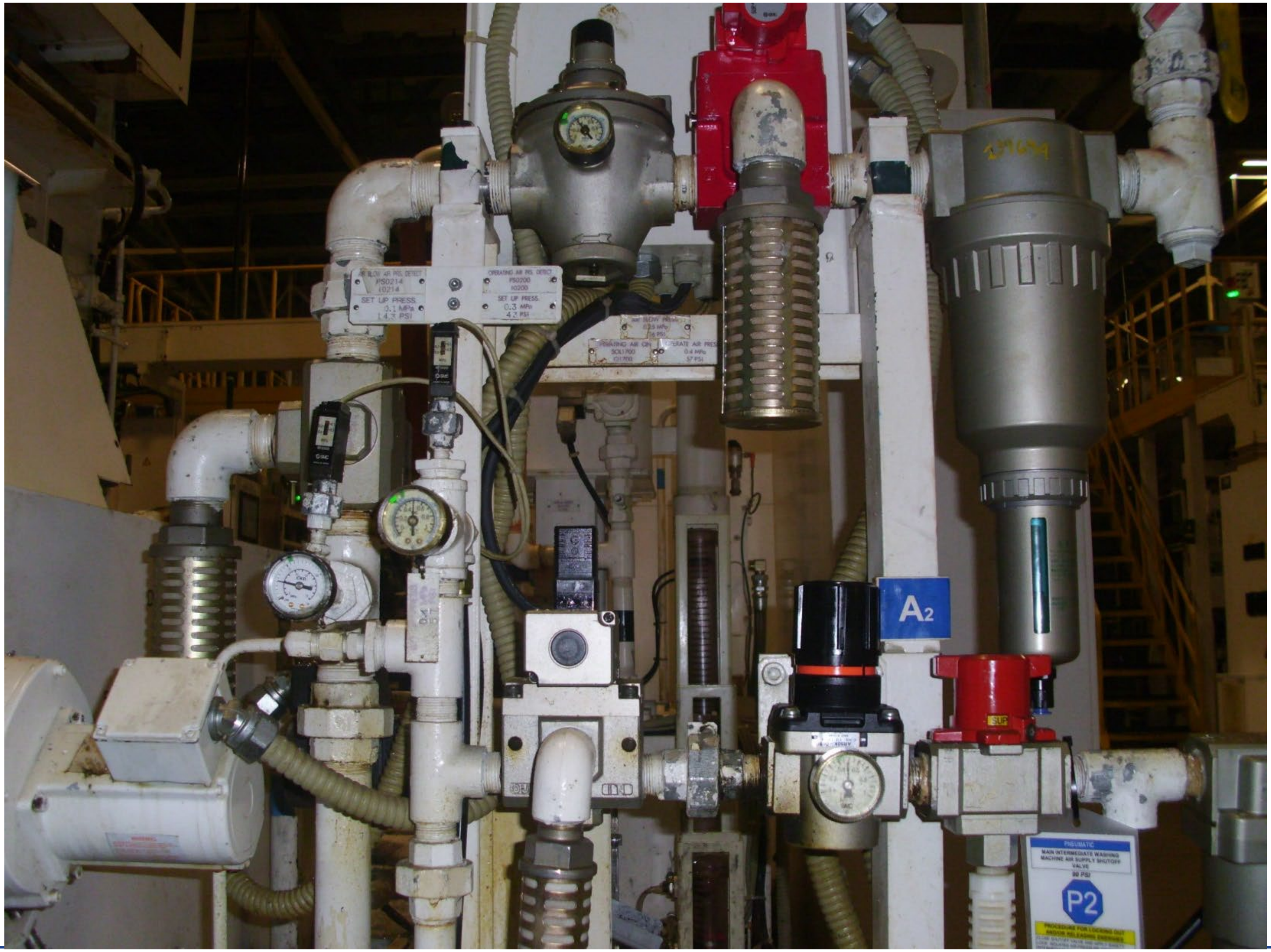


Pressure at points of use.

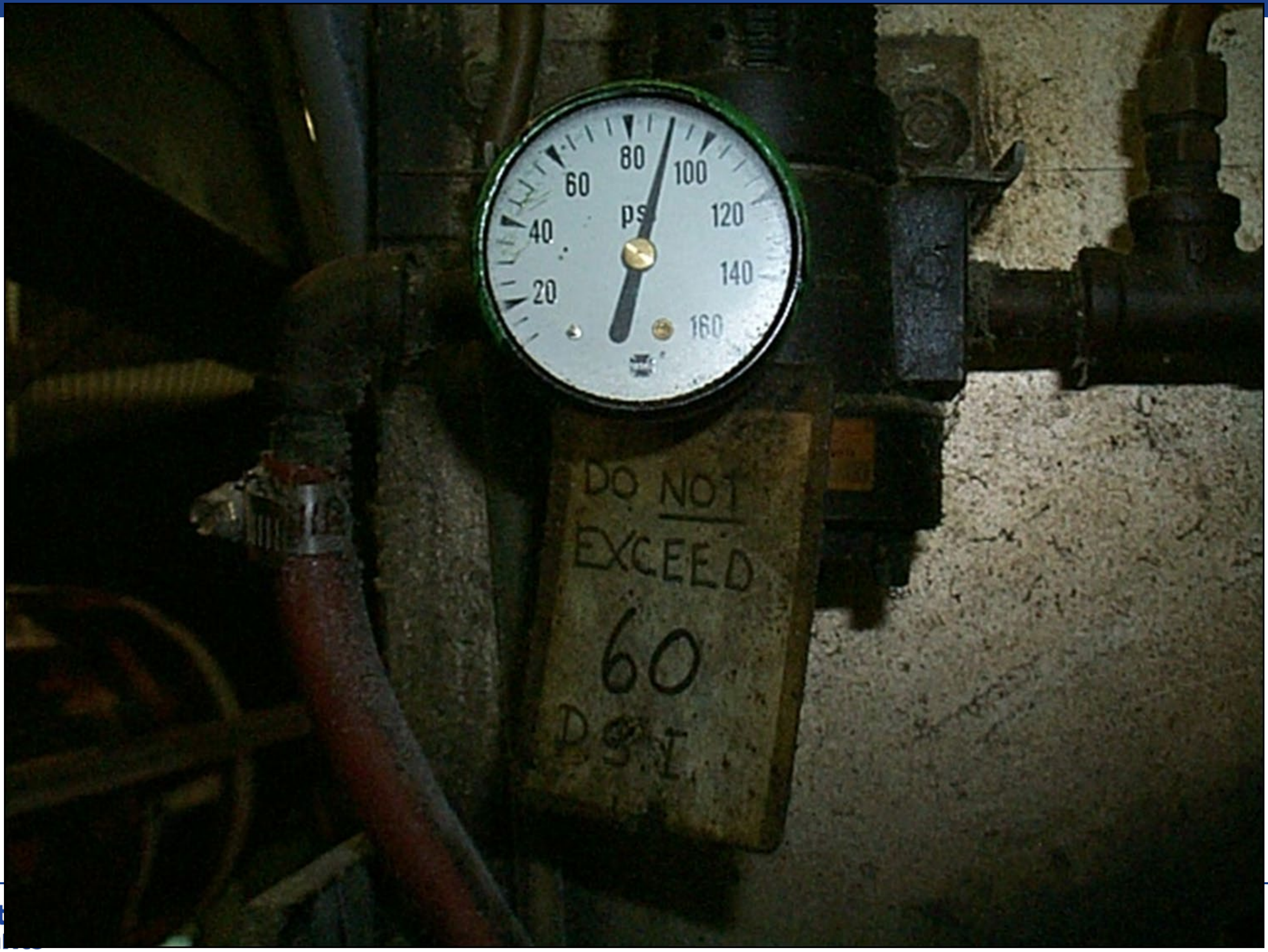




TAITO
AIR REGULATOR
HRV-25 1MPa
MPa
PSI
SMC


SET UP PRESS.
A2
P2

Pressure at points of use.



Pressure Drop

Rubber Hose Losses Without the Fittings

Air Flow CFM	Air Pressure Loss (PSI) in Standard power tool hoses Based on 100 psi Line Pressure														
	Hose Number and Size														
	1/4" x 10'	5/16" x 8'	3/8" x 10'	1/2" x 12 1/2	1/2" x 25'	1/2" x 50'	3/4" x 12.5'	3/4" x 25'	3/4" x 50'	1/2" x 50' + 1/4" x 10'	1/2" x 50' + 3/8" x 10'	1/2" x 50' + 5/16" x 10'	1/2/" x 50' + 1/2" x 12.5'	3/4" x 50' + 1/2" x 25'	3/4" x 50' + 3/4" x 12.5'
10 - 11	5.0	0.9								5.3	0.7	1.4			
11 - 12	5.9	1.0								6.2	0.8	1.6			
12 - 13	6.8	1.2	0.4							7.2	0.9	1.9			
13 - 14	8.0	1.4	0.5							8.4	1.1	2.2			
14 - 15	9.3	1.3	0.6							9.8	1.3	2.5			
15 - 16	11.0	1.9	0.7							11.6	1.5	2.9			
16 - 18	14.0	2.4	0.8							15.0	1.9	3.5	1.7		
18 - 20	19.6	3.0	1.0							21.4	2.4	4.5	2.0		
20 - 25		4.3	1.4	0.7	1.0	1.3					3.5	6.4	2.6	1.3	
25 - 30		6.6	2.1	1.0	1.5	2.3					5.2	9.8	3.8	1.9	
30 - 35		9.5	3.1	1.3	2.1	3.6					7.3	13.7	5.3	2.6	
35 - 40		12.8	4.2	1.7	2.8	5.2					9.6	18.4	7.1	3.5	
40 - 50		19.3	6.3	2.4	4.1	8.0					14.0		10.4	5.2	1.8
50 - 60			9.6	3.7	6.3	12.2					21.8		16.0	7.8	2.3
60 - 70			13.5	5.3	9.0	17.4	0.9	1.4	1.9				22.8	11.1	3.0
70 - 80			18.7	7.1	12.4		1.1	1.7	2.5					15.0	3.7
80 - 90			25.0	9.0	16.1		1.4	2.2	3.2					19.8	4.6
90 - 100				11.0			1.7	2.7	4.0						5.8
100 - 120							2.3	3.5	5.6						7.9
120 - 140							3.2	4.8	8.0						11.2
140 - 160							4.6	6.6	11.0						15.5
160 - 180							5.6	8.7	15.2						20.4
180 - 200							7.2	11.0							
200 - 220							9.0								

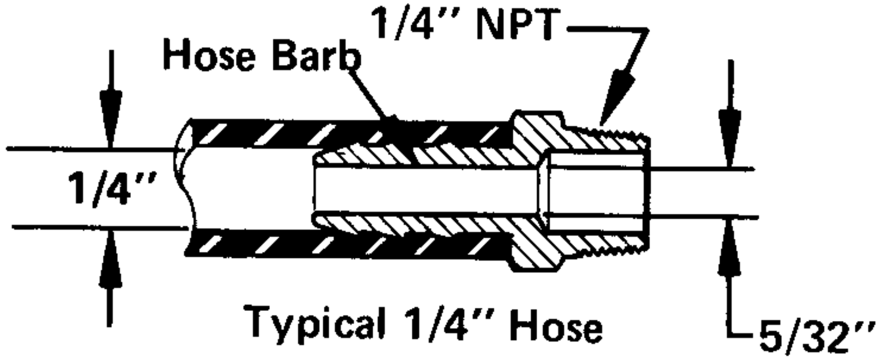
Rubber Hose

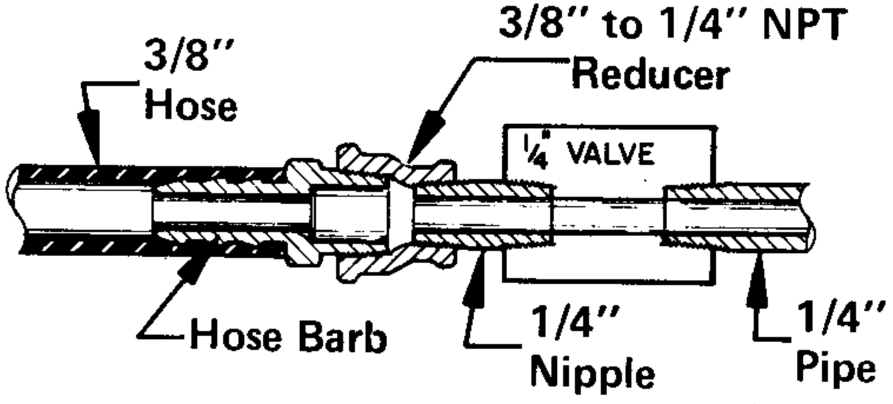
Air Flow CFM	Air Pres				
	1/4" x 10'	5/16" x 8'	3/8" x 10'	1/2" x 12 1/2	1/ 2
10 - 11	5.0	0.9			
11 - 12	5.9	1.0			
12 - 13	6.8	1.2	0.4		
13 - 14	8.0	1.4	0.5		
14 - 15	9.3	1.3	0.6		
15 - 16	11.0	1.9	0.7		
16 - 18	14.0	2.4	0.8		
18 - 20	19.6	3.0	1.0		
20 - 25		4.3	1.4	0.7	1

Rubber hose creates large pressure resulting in working pressure that is insufficient

Hose Fittings

- A restriction to flow is introduced wherever a hose fitting is attached to a length of hose
- The hose barb must fit inside the hose, and this reduces the inside diameter for a short distance.
- To reduce the restriction at a hose fitting, use a larger size hose and bush down at the porthole

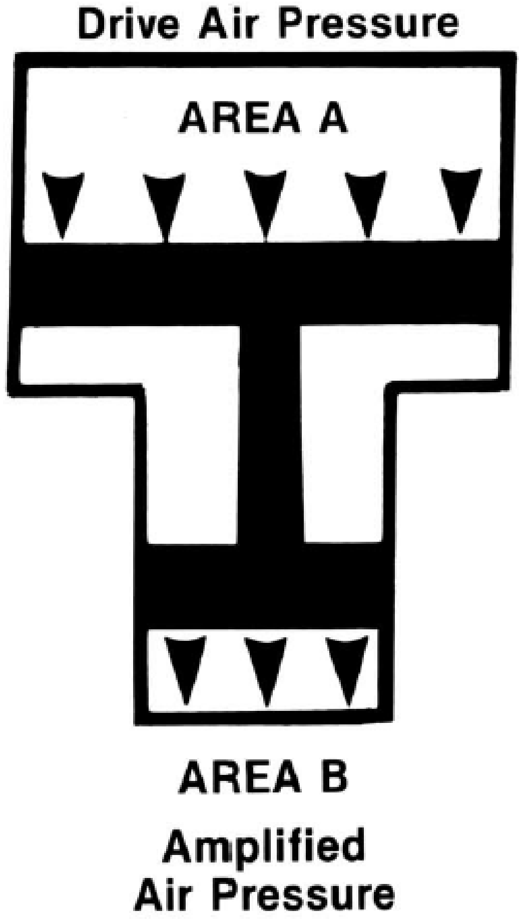




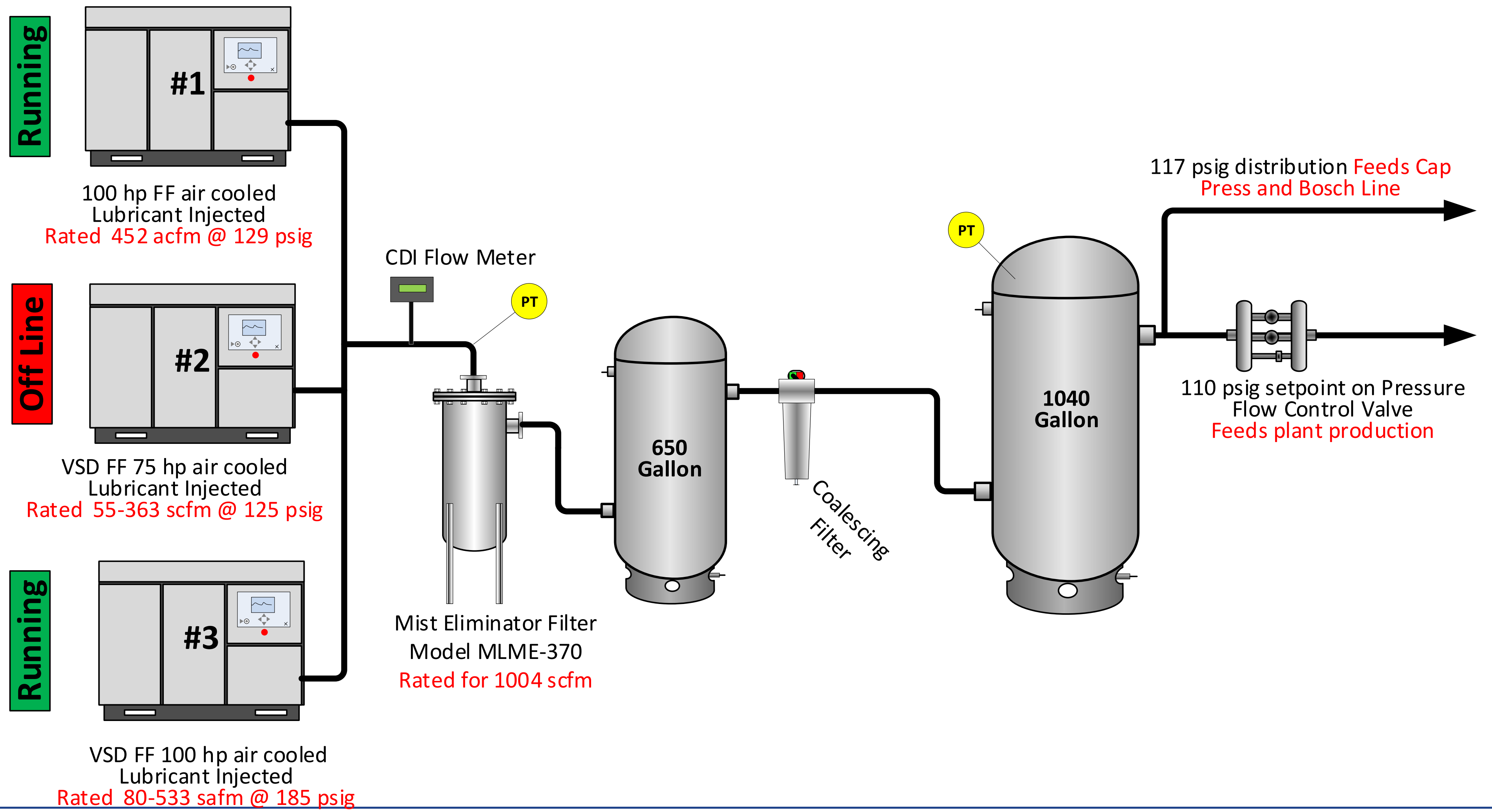
Pressure at points of use.

- The total system may be running at a higher pressure to satisfy the needs of only one point of use.
  - If the high-pressure application can be modified to operate at lower pressure, make the fix.
  - **If the high-pressure application is valid, find a better way to serve it.**
  - The single high-pressure point of use can be met with a separate compressor or by a booster.
  - The remainder of the system can operate at a lower pressure, reducing leakage and usage rates and at reduced energy consumption.

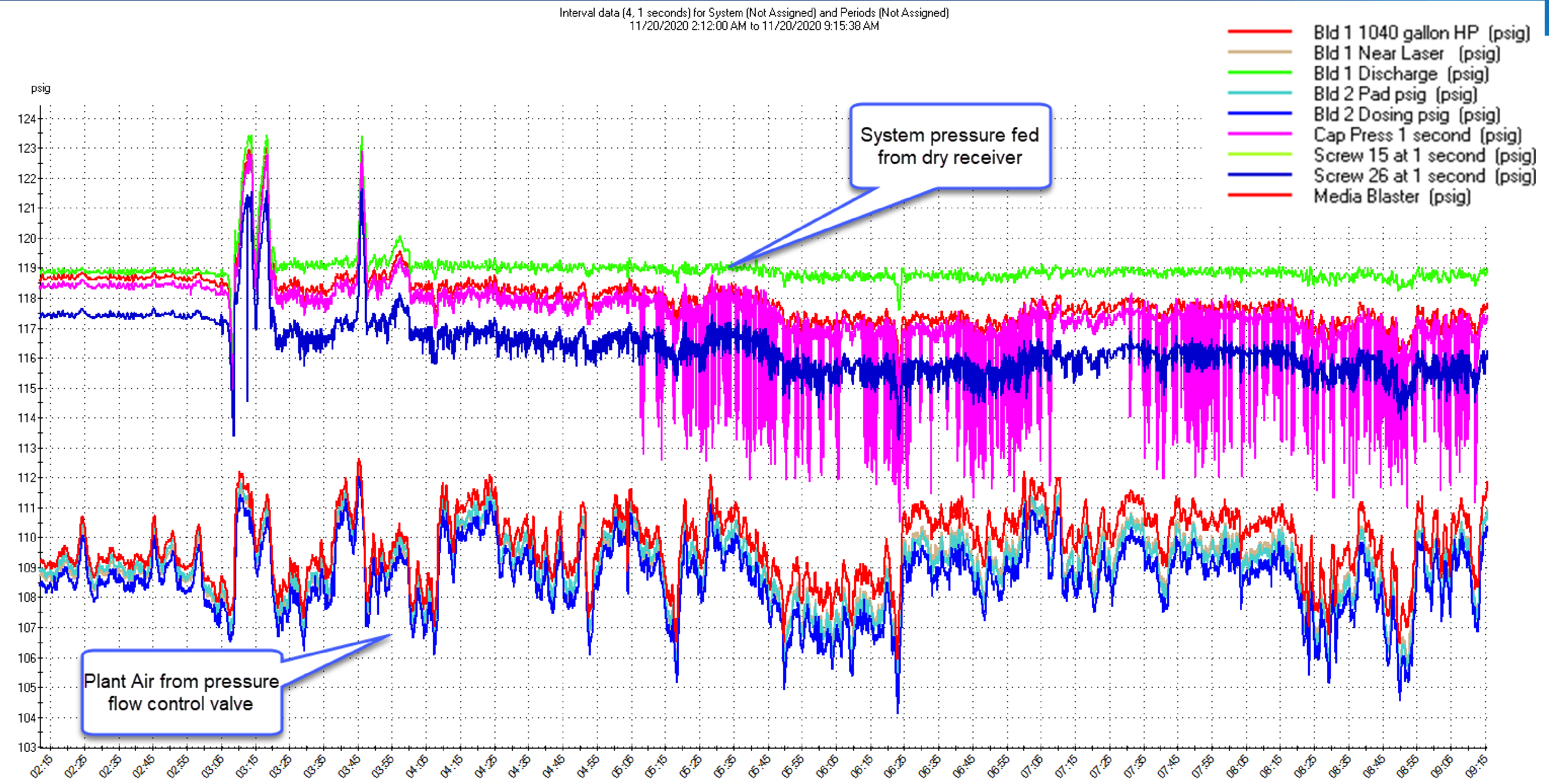
Pressure at points of use.



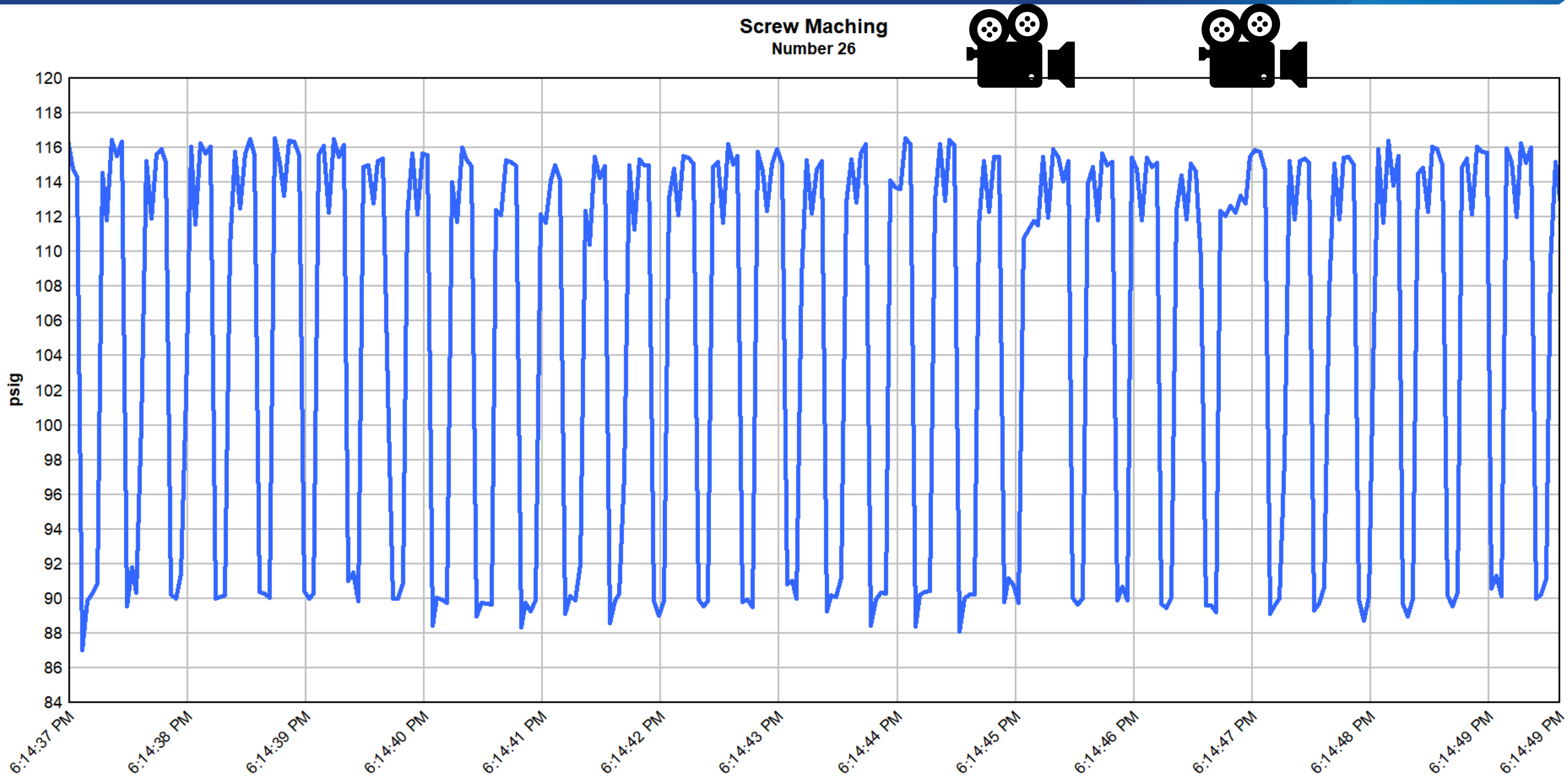
Pressure at points of use.



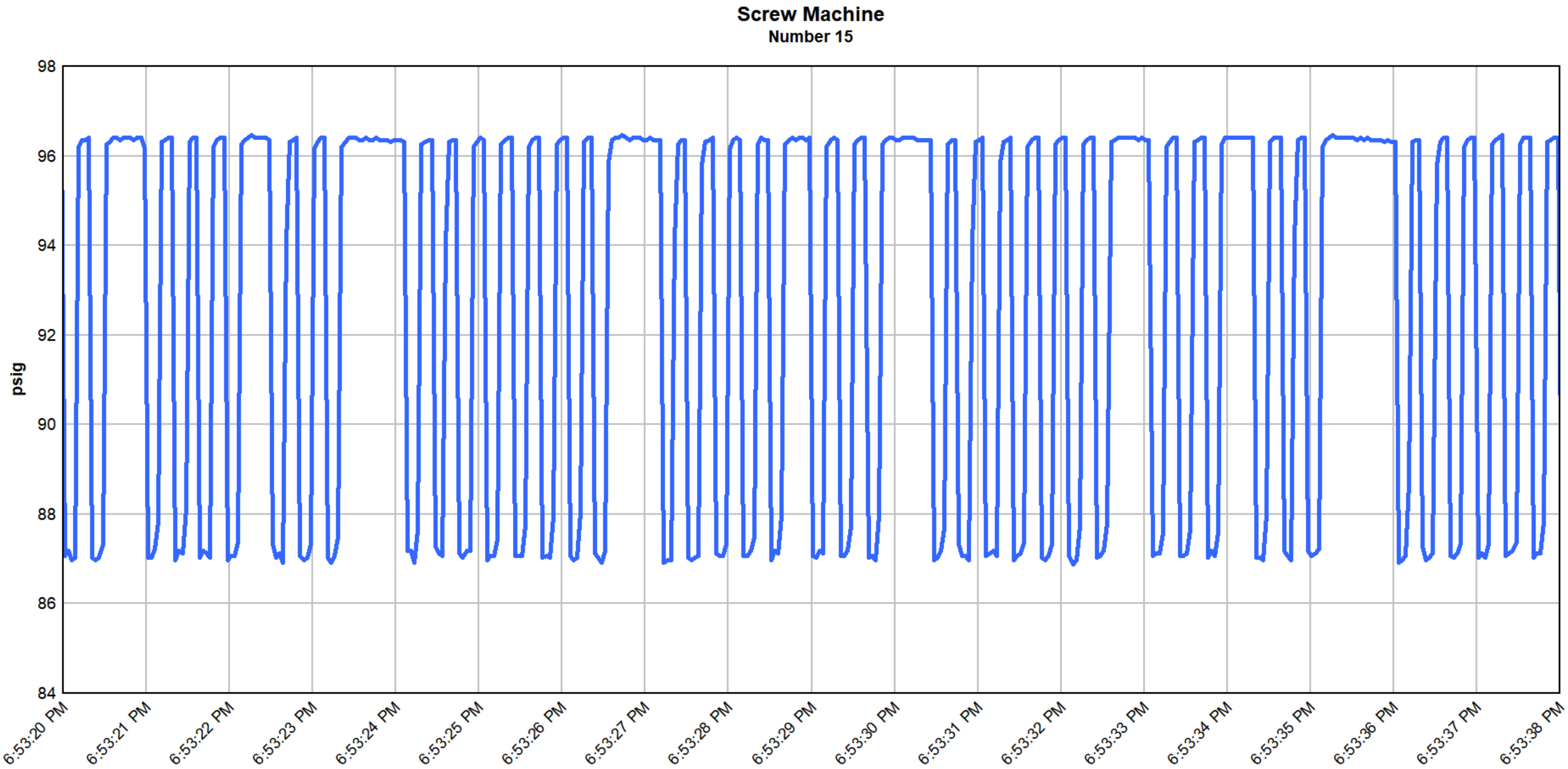
Pressure at points of use.



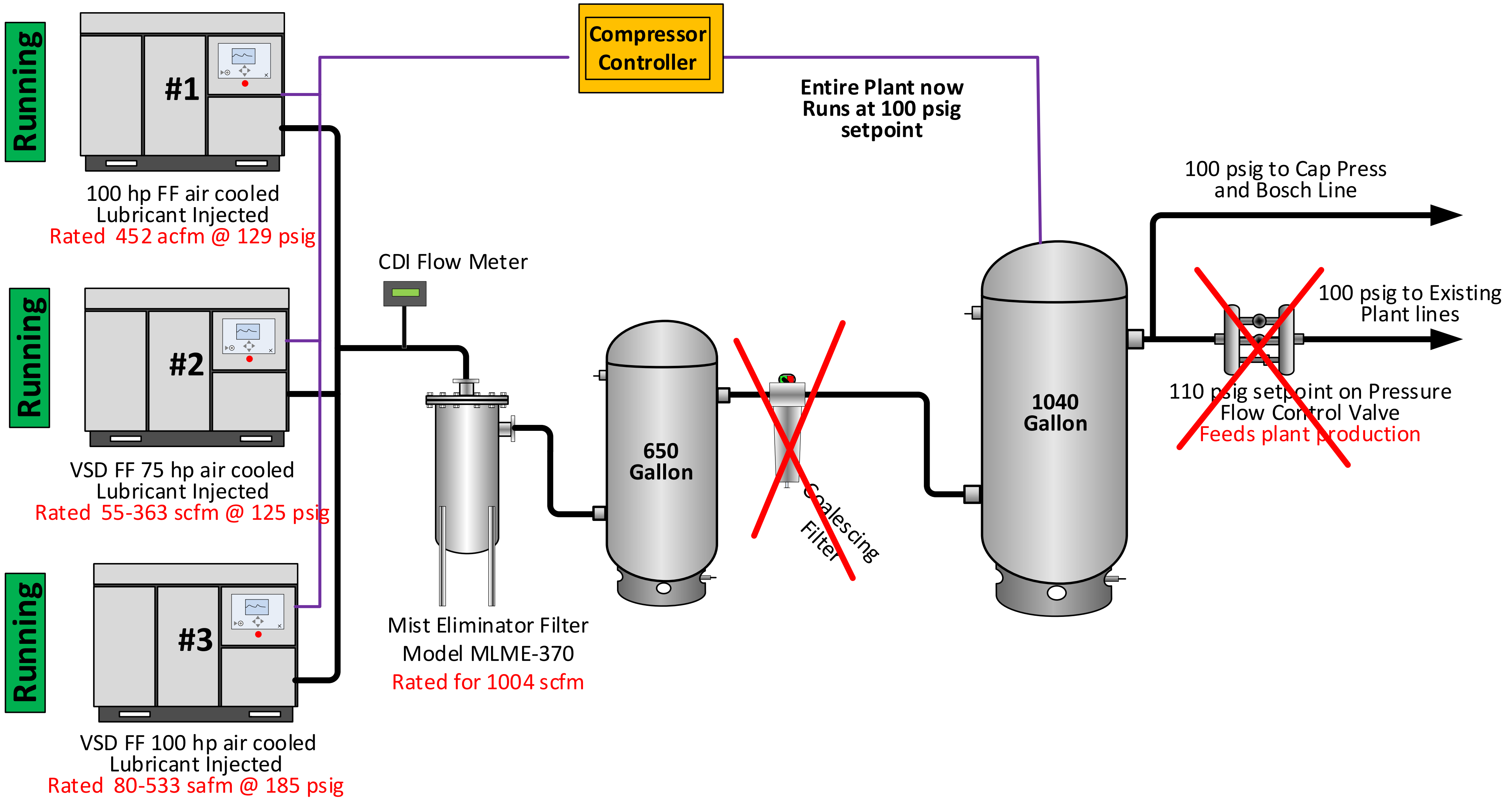
Pressure at points of use.



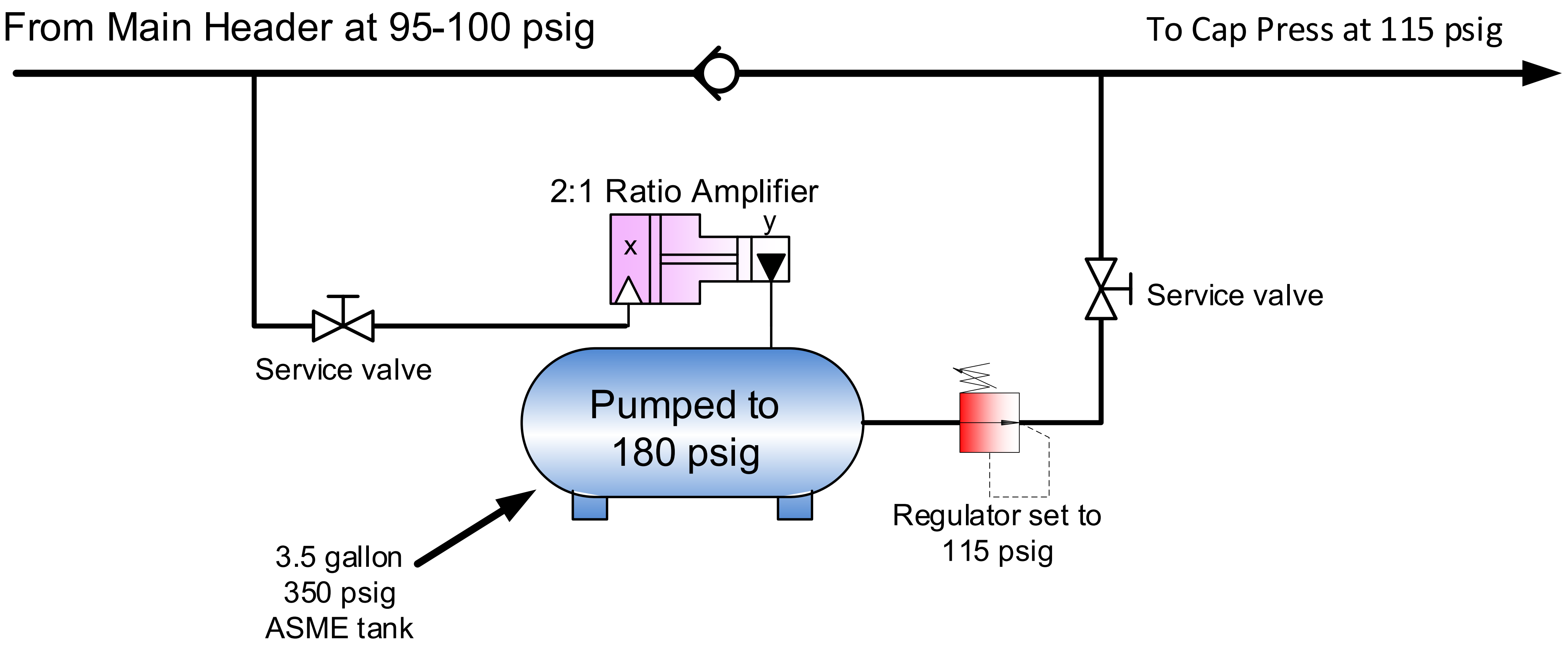
Pressure at points of use.



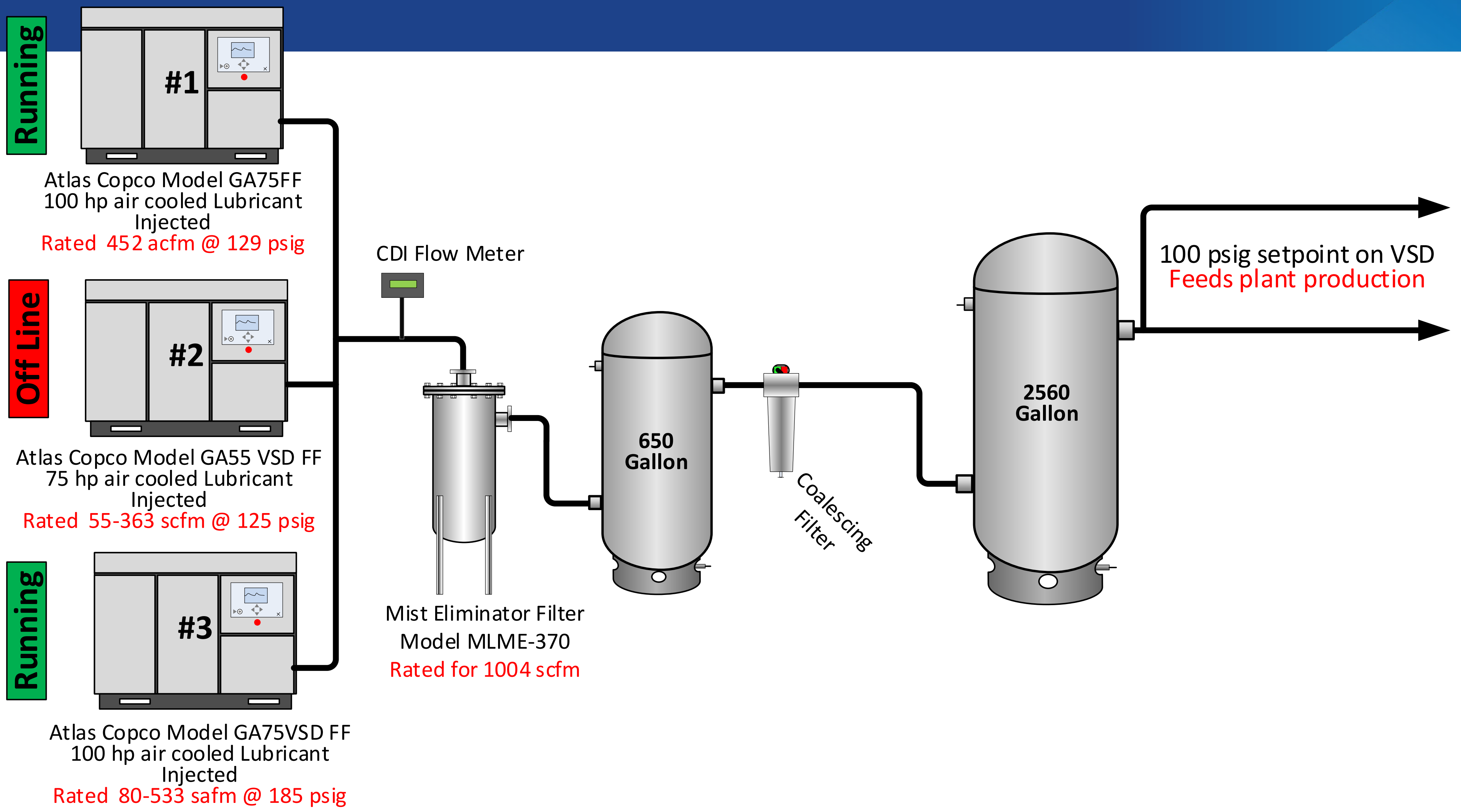
Pressure at points of use.



Pressure at points of use.

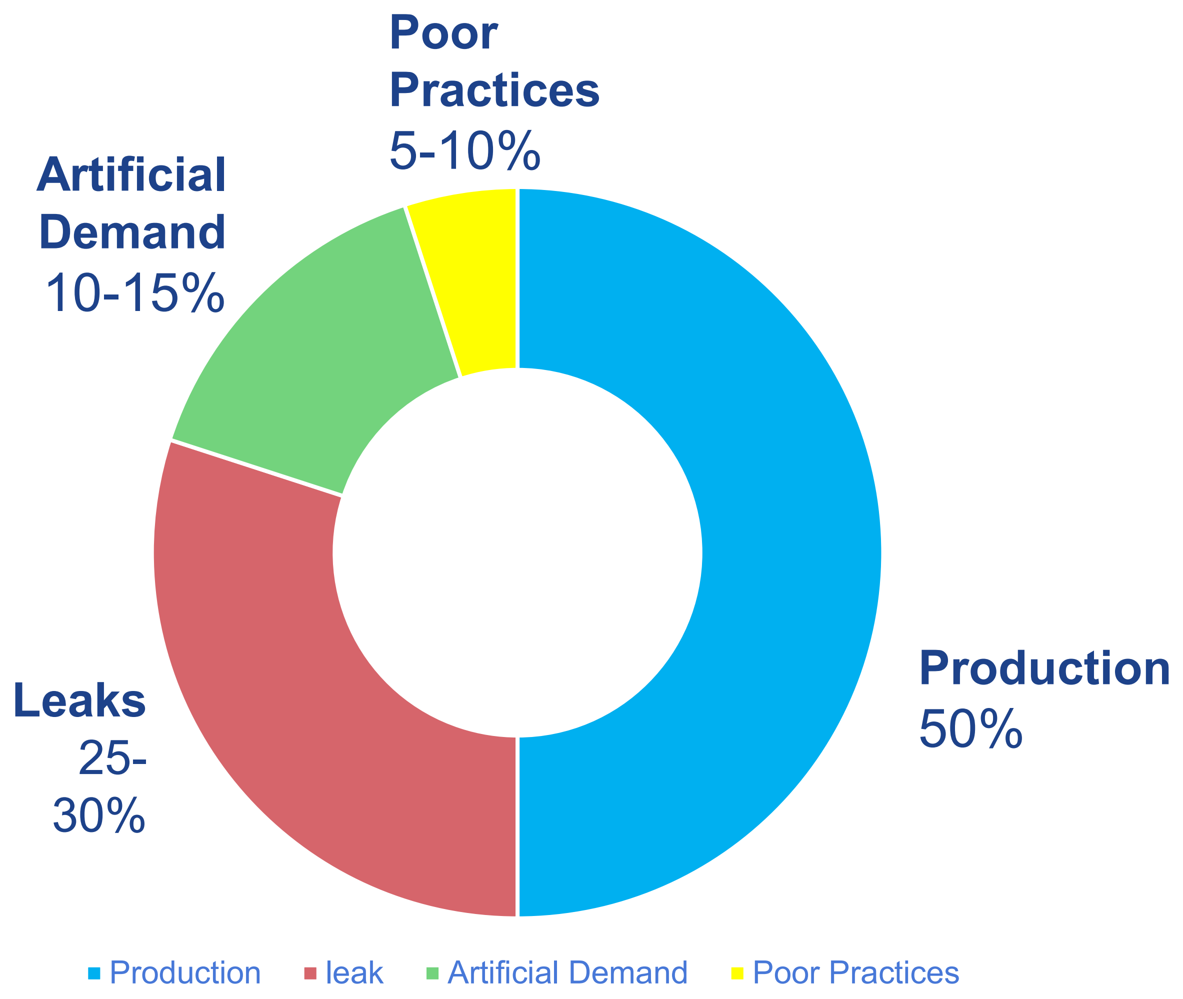


Modified System



Summary

- Look for these three unproductive demands:
  - Inappropriate Uses
  - Leaks
  - Increased demand due to excessive system pressure (Artificial Demand)



Summary -Top 10 Ways to Increase Compressed Air Energy Efficiency

To help get you started on the path to energy savings, we've summarized the top 10 ways to increase the energy efficiency of your compressed air system today.

1. Turn It Off.
   - Set your machines to switch off when they are not being used. Depending on your shift pattern, turning your compressors off during evenings and weekends could reduce your energy bills up to 20 percent.
2. Fix Existing Leaks.
   - Start with the oldest and biggest pipes; remember that approximately 80 percent of air leaks are not audible so you may need a third-party auditor to help detect leaks.
3. Prevent New Leaks.
   - It's simple: dry and filtered compressed air keeps piping dust- and sludge- free, which helps prevent new leaks from forming.
4. Reduce Pressure.
   - Run at required pressures, not beyond, and remember each 2 psig reduction cuts energy consumption by one percent.
5. Check Drains.
   - Are your timer condensate drains stuck open? If so, you could be wasting compressed air. Go one step further and replace timer drains with zero-loss drains to save.

Summary -Top 10 Ways to Increase Compressed Air Energy Efficiency

6. Review Piping Infrastructure.
   - Increasing the size of your pipe from two to three inches can reduce pressure drops by up to 50 percent. Shortening the distance air must travel can further reduce pressure drops by about 20 to 40 percent.
7. Change Filters Systematically.
   - Just as you change the oil in your car at scheduled intervals to ensure optimum performance, be sure to change the filters in your air compressor and air system regularly to ensure air quality and to prevent pressure drops.
8. Recover Heat.
   - Compressing air generates heat; you can recover as much as 90 percent of the heat from compressed air for use in your operation.
9. Emphasize Proper Maintenance.
   - Proper compressor maintenance cuts energy costs by approximately one percent and helps prevent breakdowns that result in downtime and lost production.
10. Stop inappropriate use of compressed air.
    - Inappropriate uses of compressed air include any application that can be done more effectively or more efficiently by a method other than compressed air.

Next Week Session 7

System Volume vs Storage

We will focus on applications that consume a relatively high volume of air for short durations of time (sometime called “events”) and how to minimize them. A common solution to high volume, intermittent needs is compressed air storage. Learn the math behind calculating air storage.

Homework for Week 6 – Inappropriate Applications

- Is compressed air at your plant being used for any of the applications on this list? If so explain how:
  - Open blowing
  - Sparging (agitating, stirring, mixing)
  - Aspirating
  - Atomizing
  - Padding
  - Dilute phase transport
  - Dense phase transport
  - Vacuum generation
  - Personnel cooling
  - Open handheld blowguns or lances
  - Cabinet cooling
  - Vacuum venturis
  - Diaphragm pumps
  - Timer drains/open drains
  - Air Motors