Better Plants
U.S. DEPARTMENT OF ENERGY

In-Plant Trainings

Session 7 – Demand Side

U.S. DEPARTMENT OF
ENERGY

Session 7

Homework Review

Demand Side Homework

Name: Robert Barrier

Company: 9/14/2022

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

- Open blowing:
  - label applicators (15psi): air knife assembly,
  - Filler Capper(60psi): air assists caps in guides.
- Vacuum generation:
  - case packers (80psi): pick cases and cups
  - cup fillers(80psi): lid pick applications
  - robotic palletizers(90psi): pick arm
- Personnel cooling - Vortec Cooling Vest (40psi): for equipment cleanup rooms.
- Open handheld blowguns or lances(80psi): case packing area, no wet cleaning
- Diaphragm pumps(90psi): Murzan pumps: used daily with plant.

Demand Side Homework

Name: ___Igor Ryabov____

Company: ______P&G_______________________________________

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

- Open blowing - *Compressed air usage for equipment cleaning In the workshop (dust build up removal), reject stations, air shower*
- Sparking (agitating, stirring, mixing)
- Aspirating - pulse *manifold in dust collector*
- Atomizing - *glue spraying in production lines*
- 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 - *Used for online printing process. Processibility to have an electrical drive due to process safety requirements*

Demand Side Homework

Name: Nahian Ismail Chowdhury

Company: Volvo Group

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

- Open blowing - Used in most of the machines too clear metal chip, especially CNC machines
- Sparking (agitating, stirring, mixing) - None
- Aspirating - None
- Atomizing - None
- Padding - None
- Dilute phase transport - None
- Dense phase transport - None
- Vacuum generation - None
- Personnel cooling - None
- Open handheld blowguns or lances - Located across the facility for cleaning purposes
- Cabinet cooling - None
- Vacuum venturis - None
- Diaphragm pumps - None
- Timer drains/open drains - None
- Air Motors - None
- Additional - Used for spray paint

Demand Side Homework

Name: ___Miroslav Trifunovic____________________________

Company: ____Hollingsworth & Vose______________________

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

- **Open blowing** (nozzles at several paper scanners that continuously blow air to clear the scanner cameras)
- **Sparking (agitating, stirring, mixing),** (several smaller tanks that use air for mixing enhancement)
- Aspirating
- Atomizing
- Padding
- Dilute phase transport
- Dense phase transport
- Vacuum generation
- Personnel cooling
- **Open handheld blowguns or lances** (number of stations where air Is used to clean the dust / paper off)
- **Cabinet cooling** (several electrical cabinets within higher temp. areas)
- Vacuum venturis
- **Diaphragm pumps** (we use number of those air pumps)
- Timer drains/open drains
- **Air Motors** (a few application where compressed air is used to turns things)

Session 7

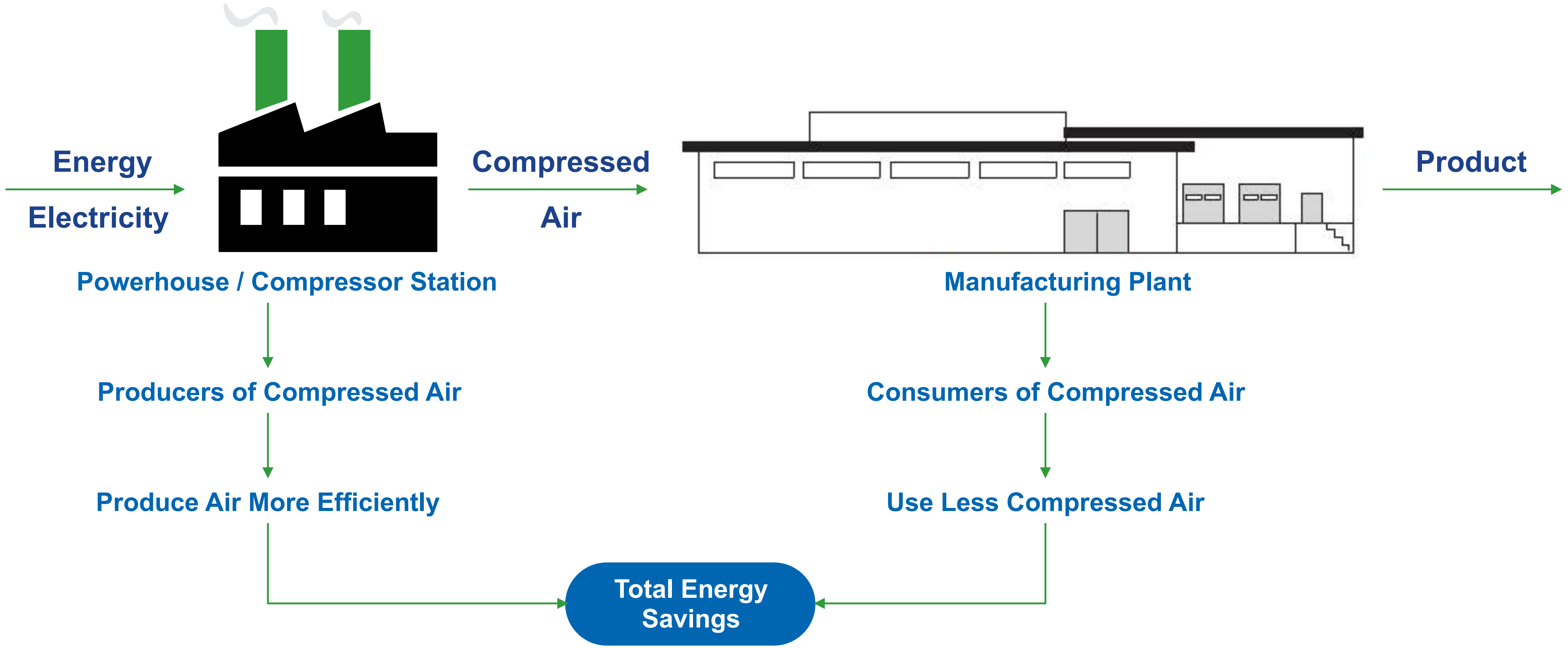
Demand Side

The Demand Side

- The goals of this session:
- To understand how to maintain an efficient compressed air system by managing wastes.

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 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.

Todays Focus

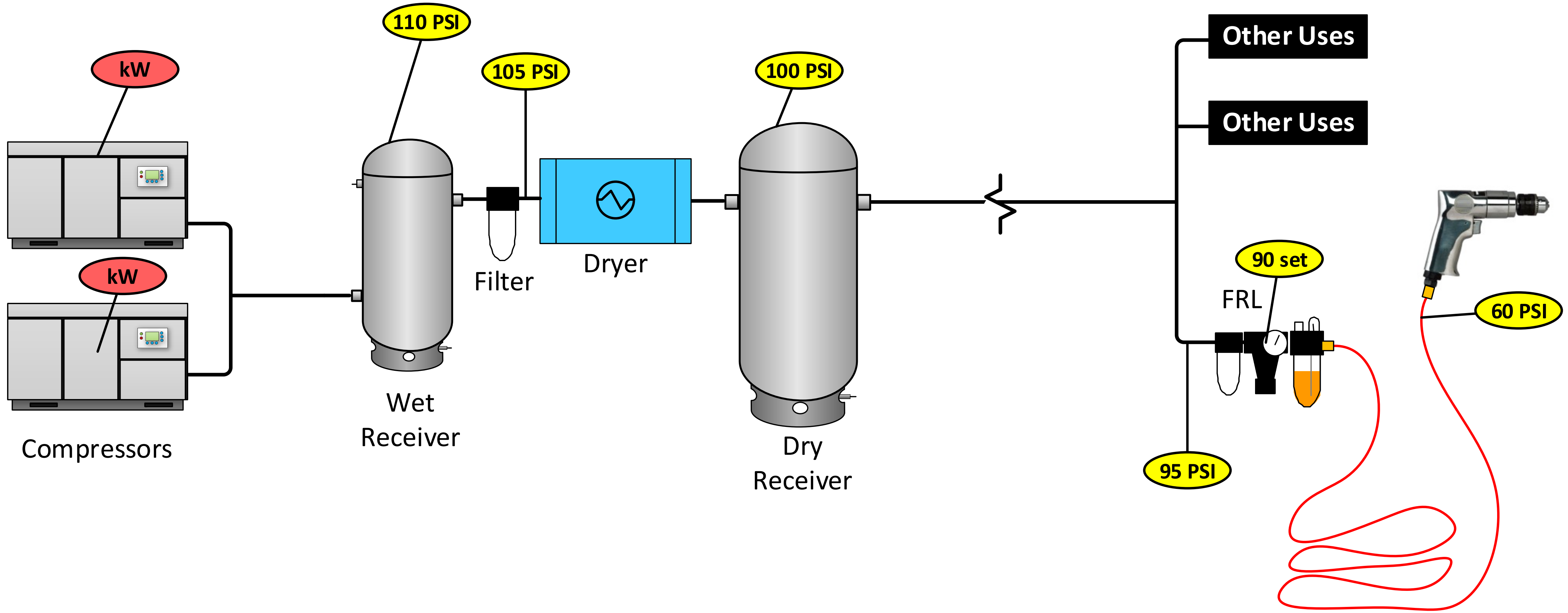
Compressed Air Versus Other Energy Sources

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

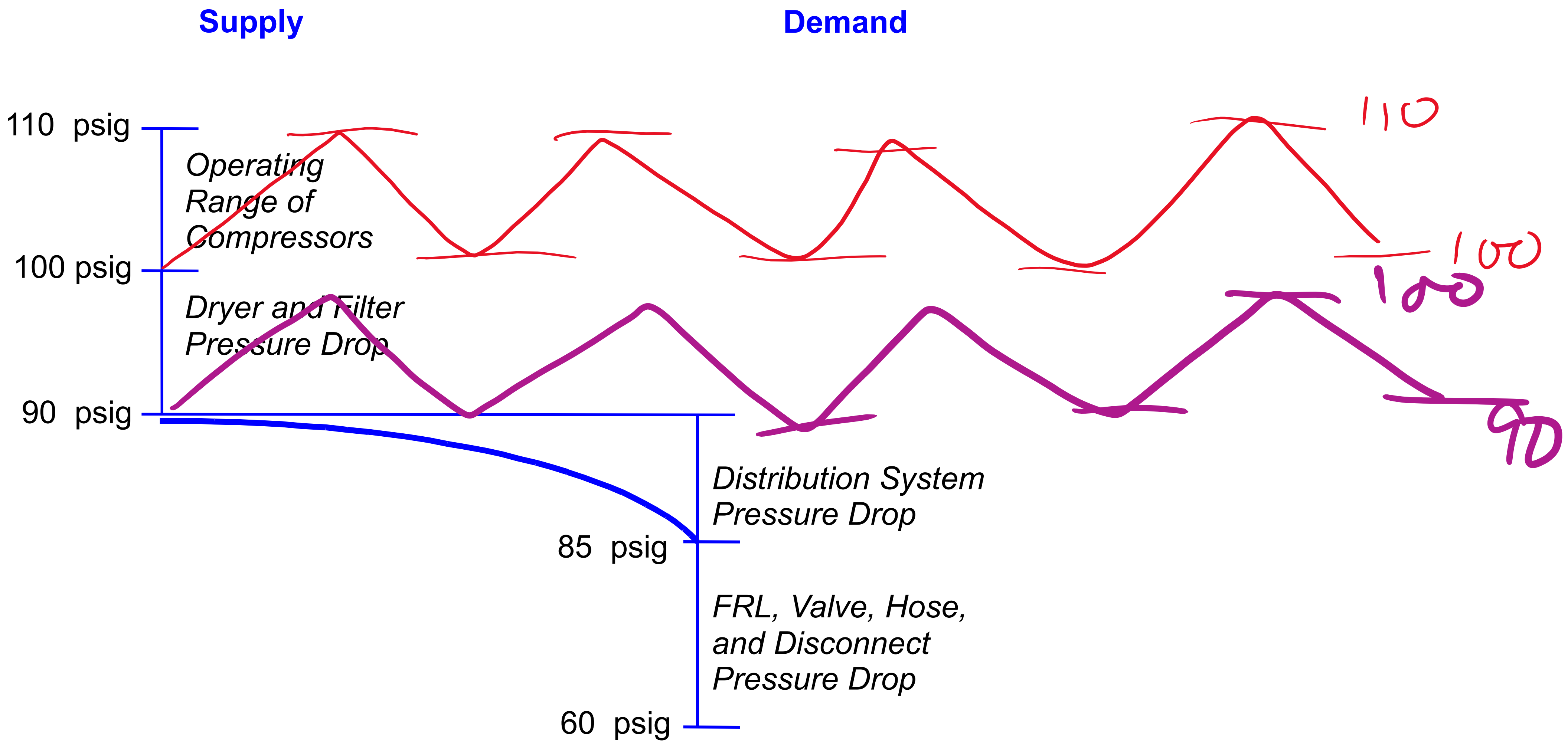
- You may be surprised, in most industrial plants, only 50% of the compressed air generated supplies productive air use.
- The other 50% is consumed by various losses.
- The losses are

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

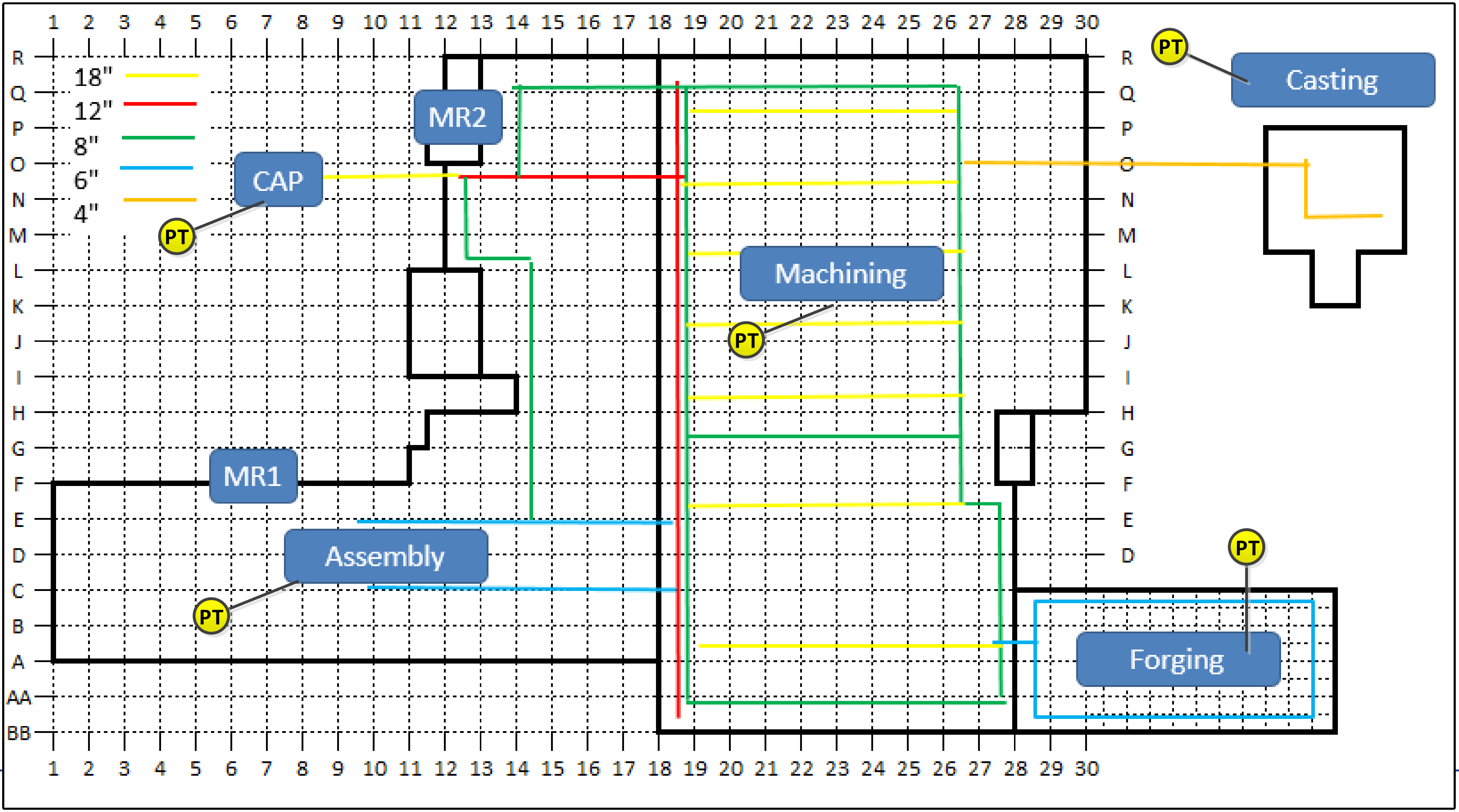
What Measurements Should I Record?



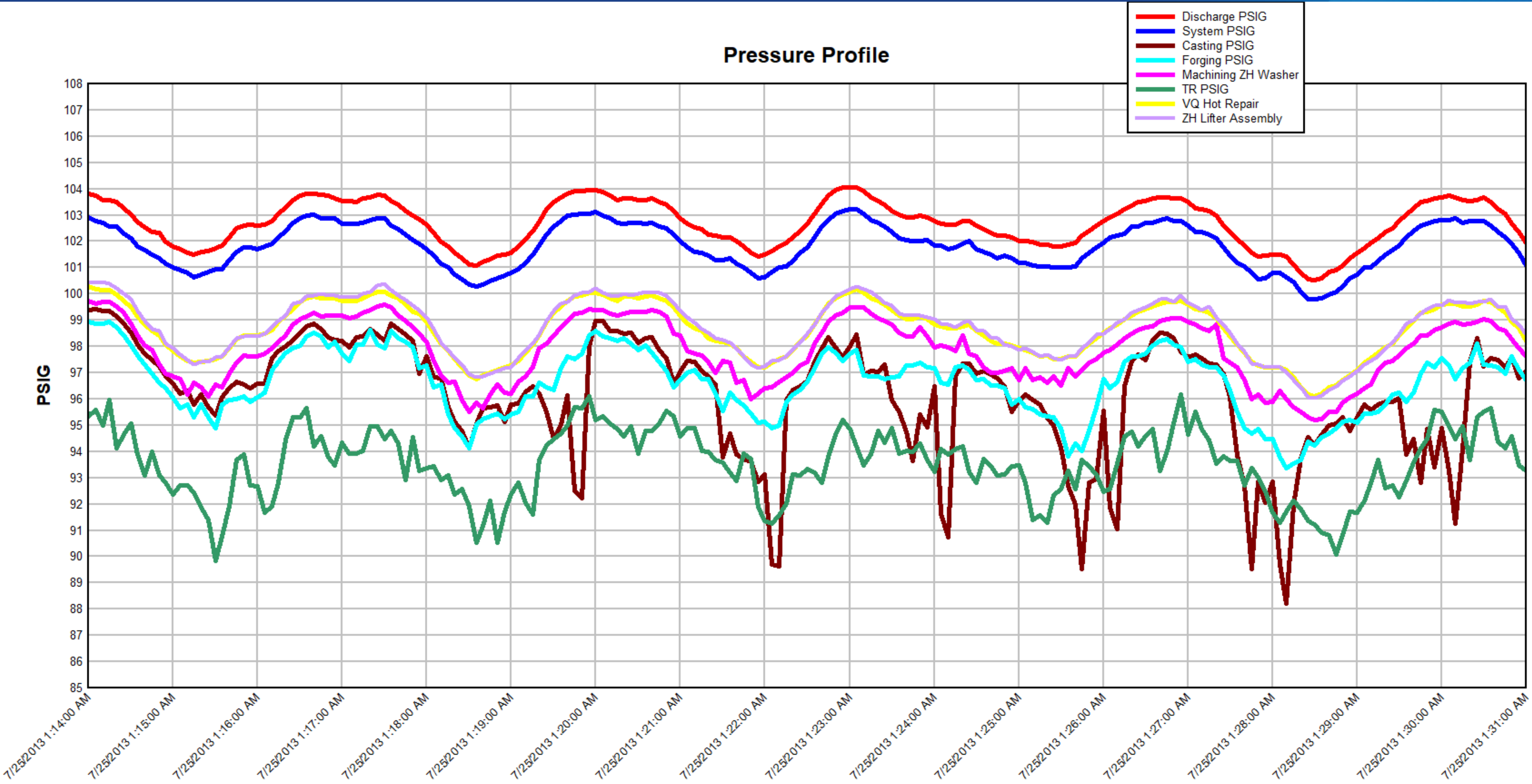
System Pressure Profile



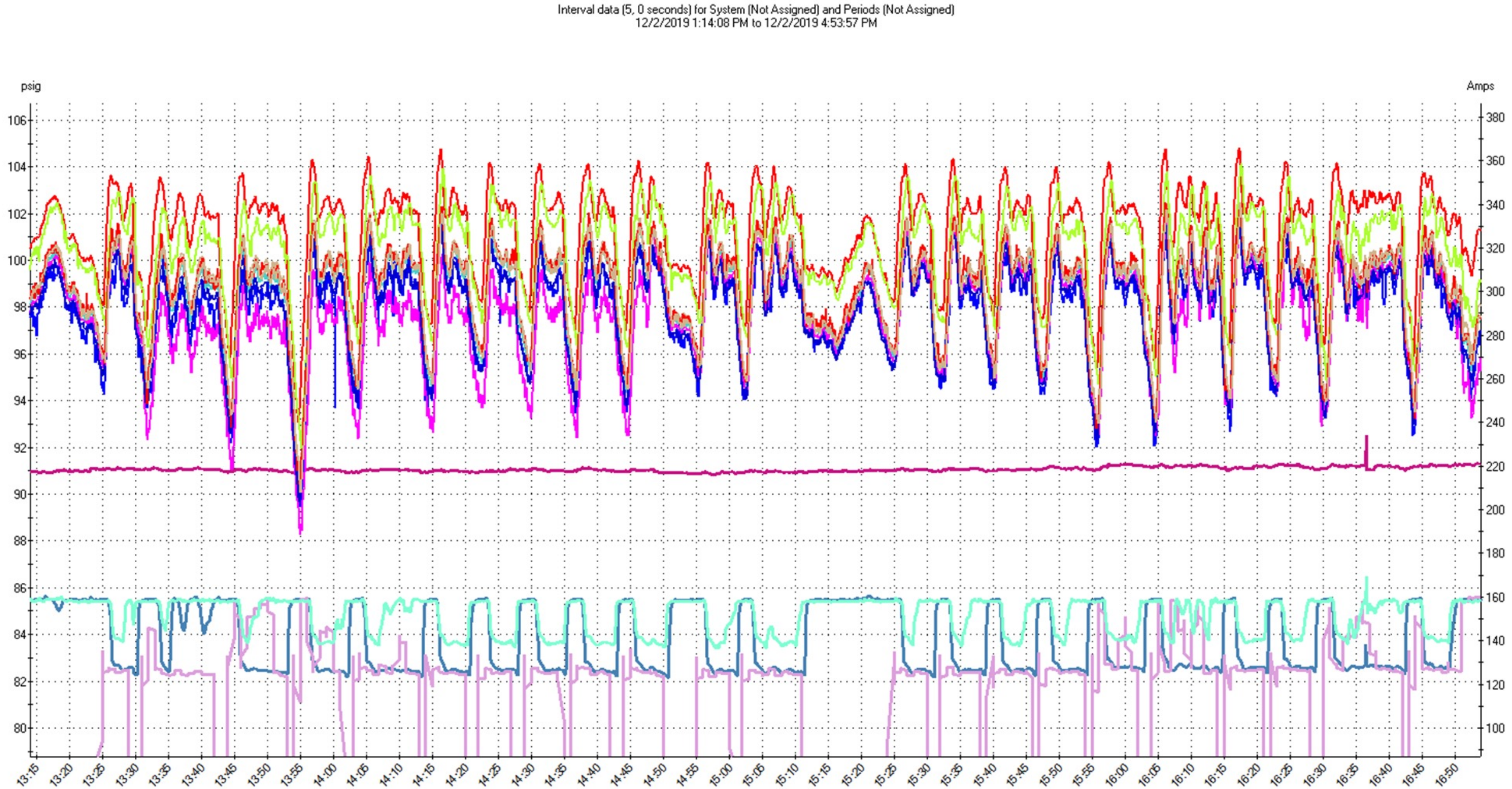
What Measurements Should I Record?



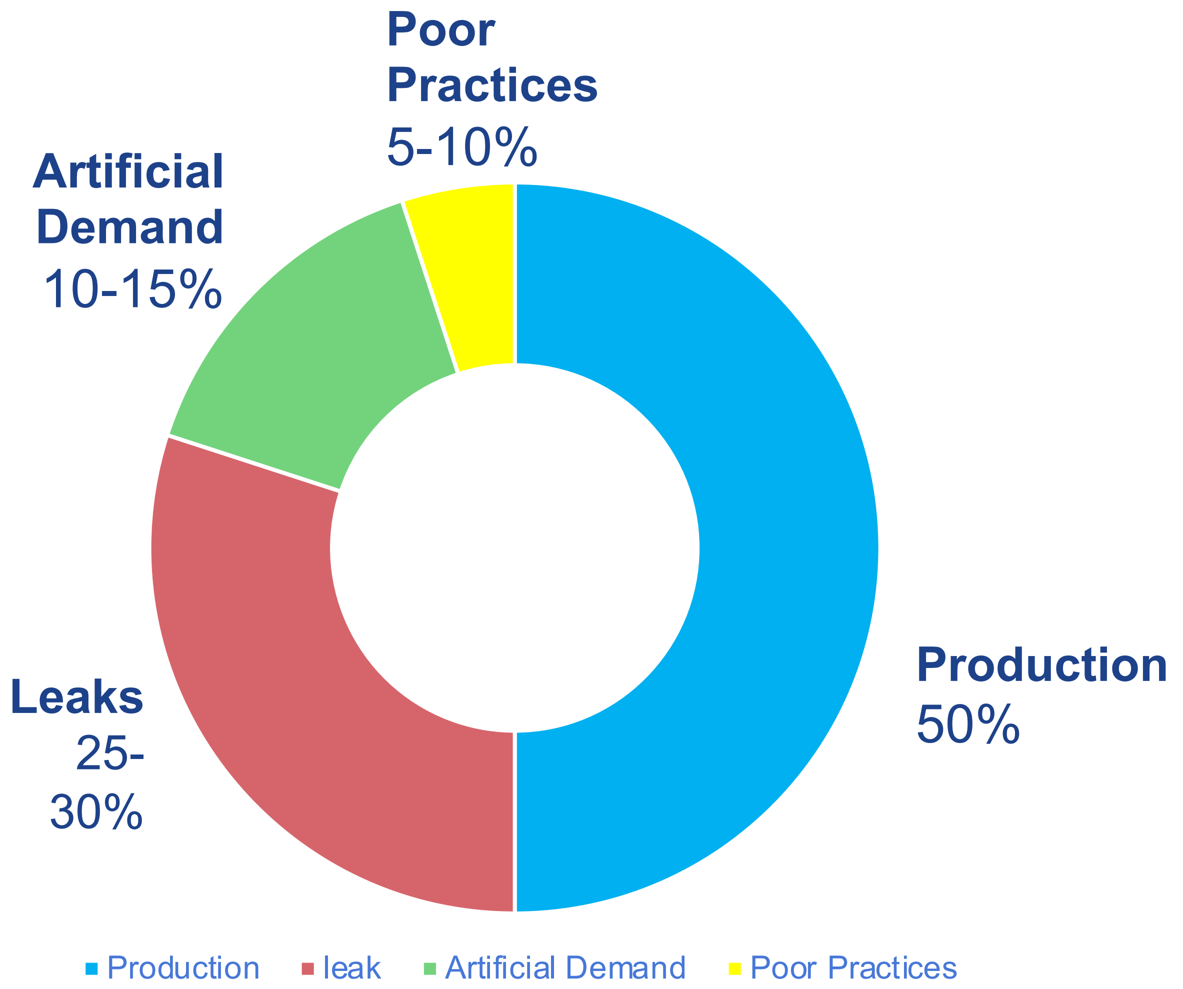
Data Collection Can Be Interpreted



Comparing Pressure and Power



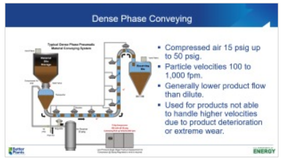
Lets have a look at the waste

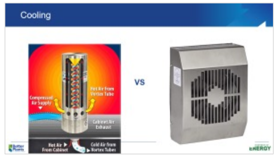


Potentially Inappropriate Applications

- 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:

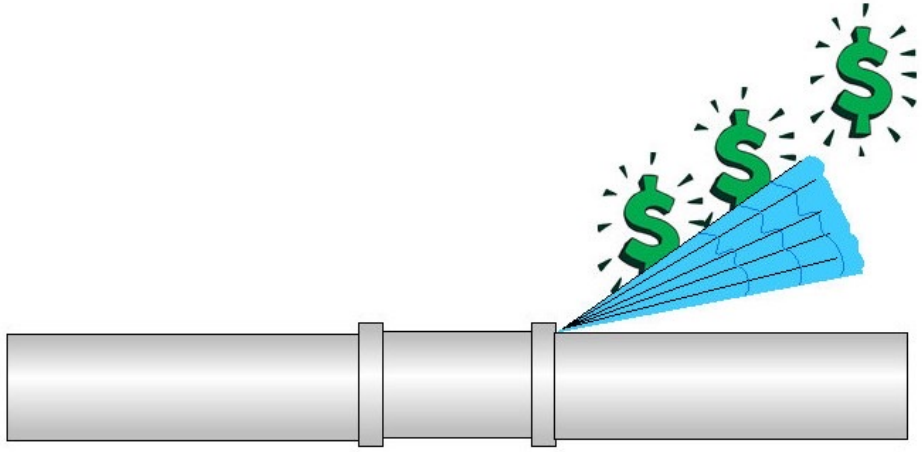
- Open blowing
- Sparging (agitating, aerating stirring, mixing)
- Aspirating
- Atomizing
- Padding
- Dilute phase transport
- Dense phase transport
- Vacuum generation
- Personnel cooling
- Open hand-held blow guns or lances
- Cabinet cooling
- Vacuum venturi
- Diaphragm pumps
- Timer drains/open drains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



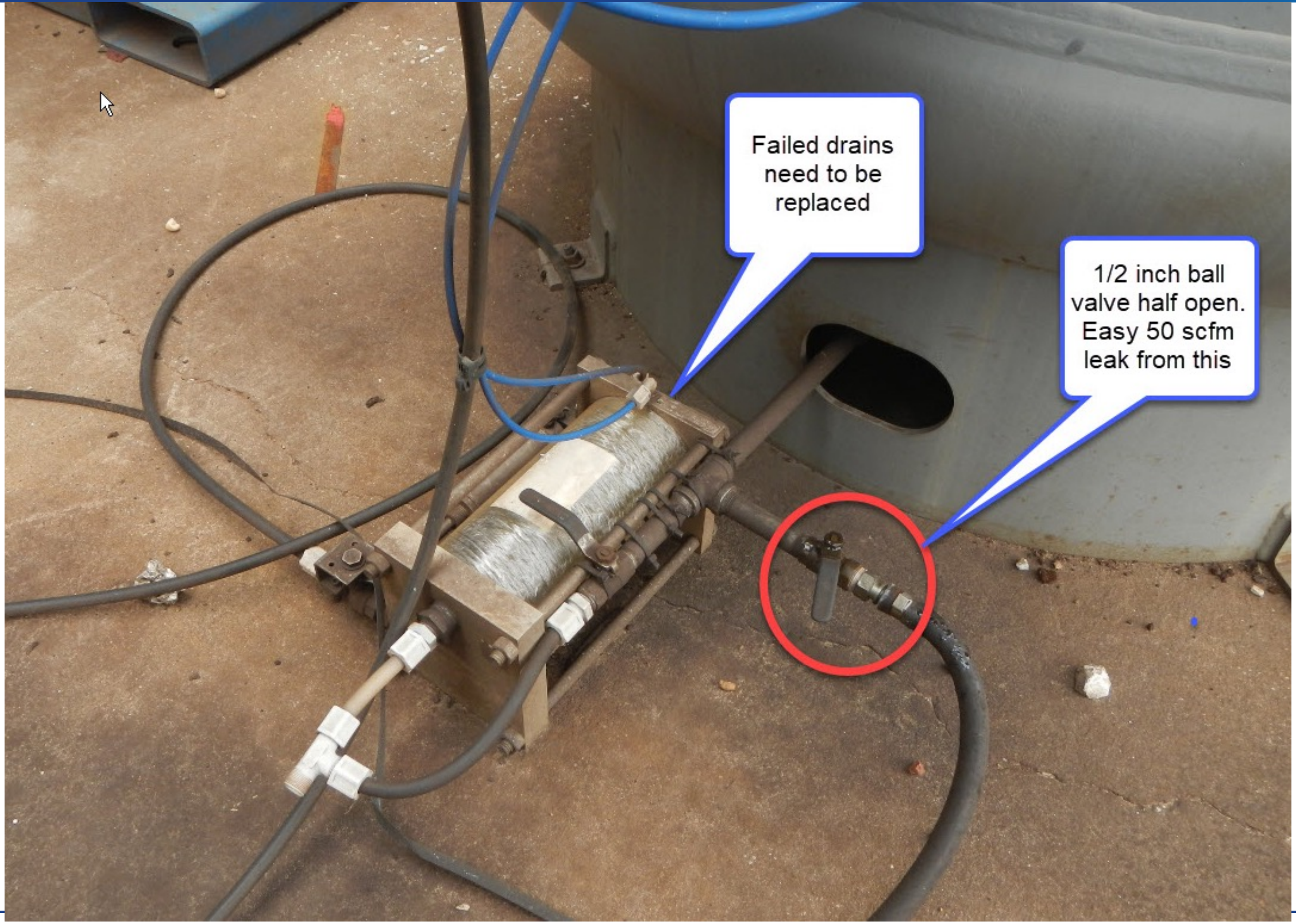


Leaks

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

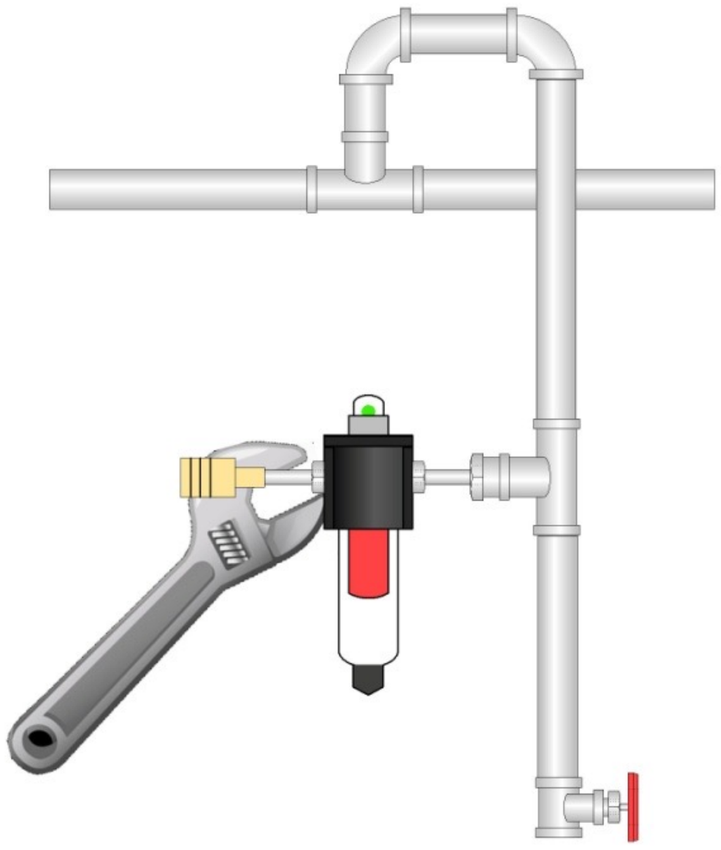


Leaks


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

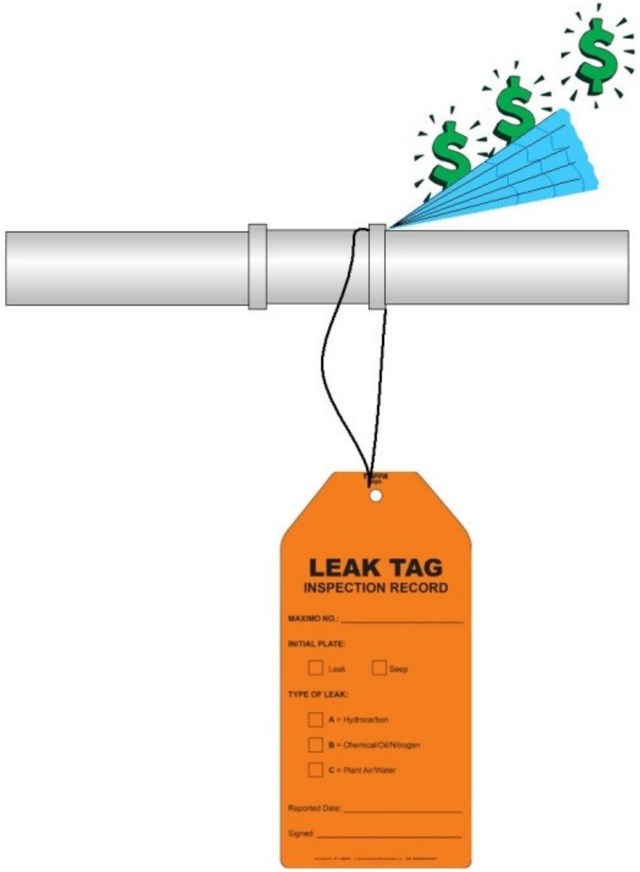
Leaks

- 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.

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Quantifying Leakage Loss using Bag M

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

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?

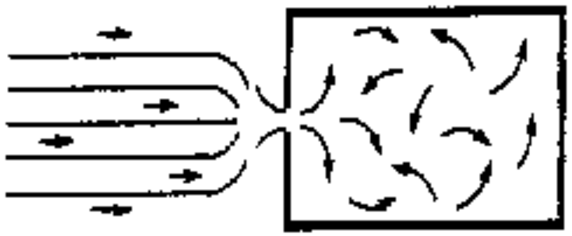
At $0.10/kWh electricity:

- 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

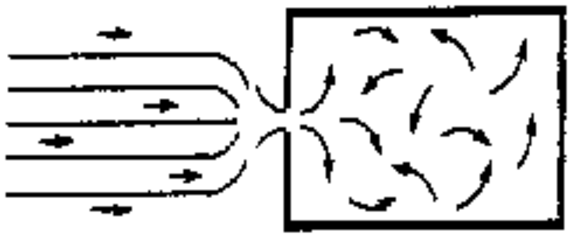


VACUUM LEAK

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

PRESSURE LEAK



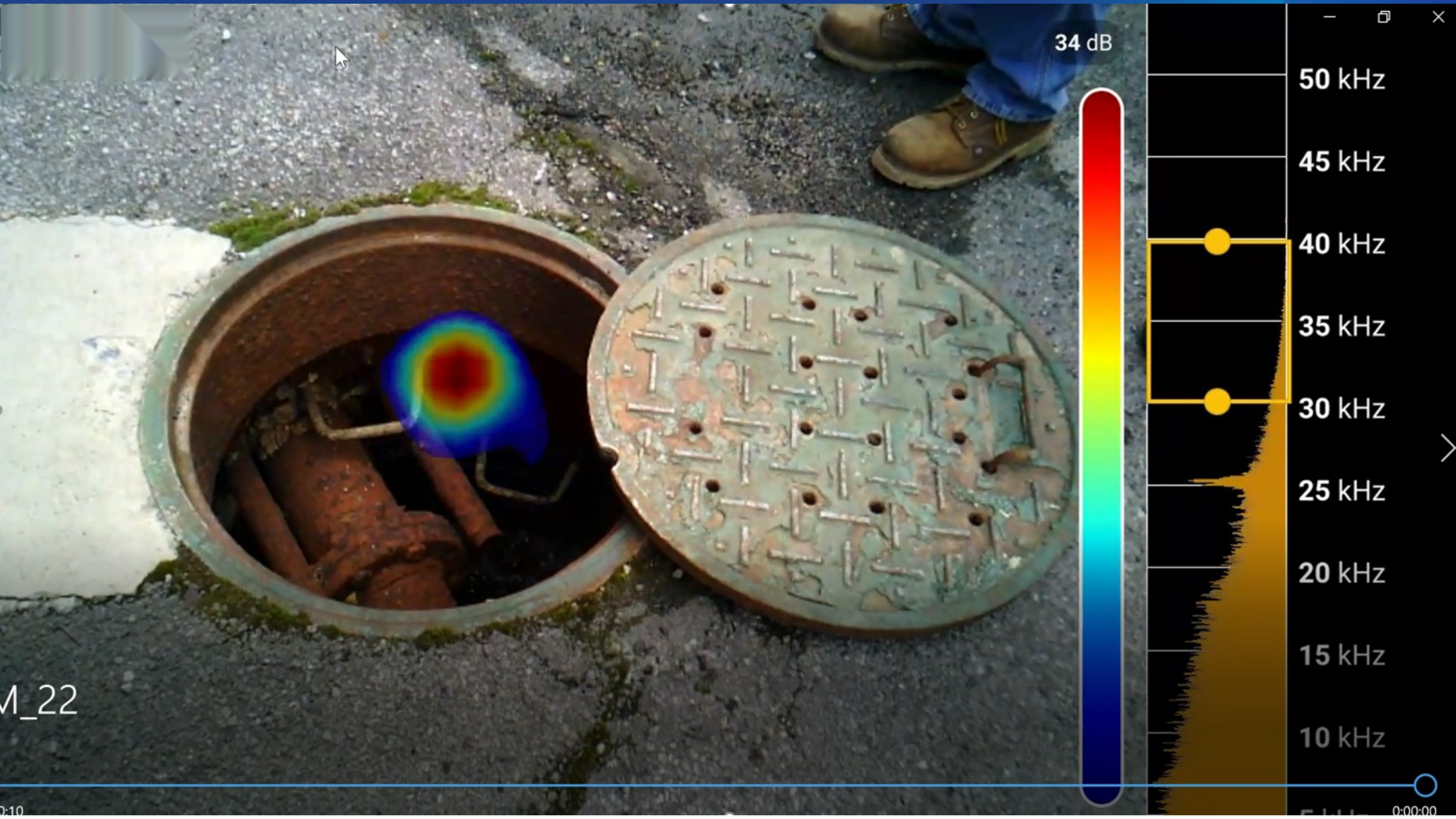
VACUUM LEAK

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

How Acoustic Camera Leak Detection Works

- An example of the graphical user interface of the Acoustic Camera is shown here.
- The measured sound value (in dB) is displayed top left of the screen.
- The Acoustic Camera converts this sound value to a leak flow estimation (in scfm or l/min), using the distance to the leak.
- This distance can be selected using the distance slider to the right of the display.
- Some meters calculate their own distance from the leak source.


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

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

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

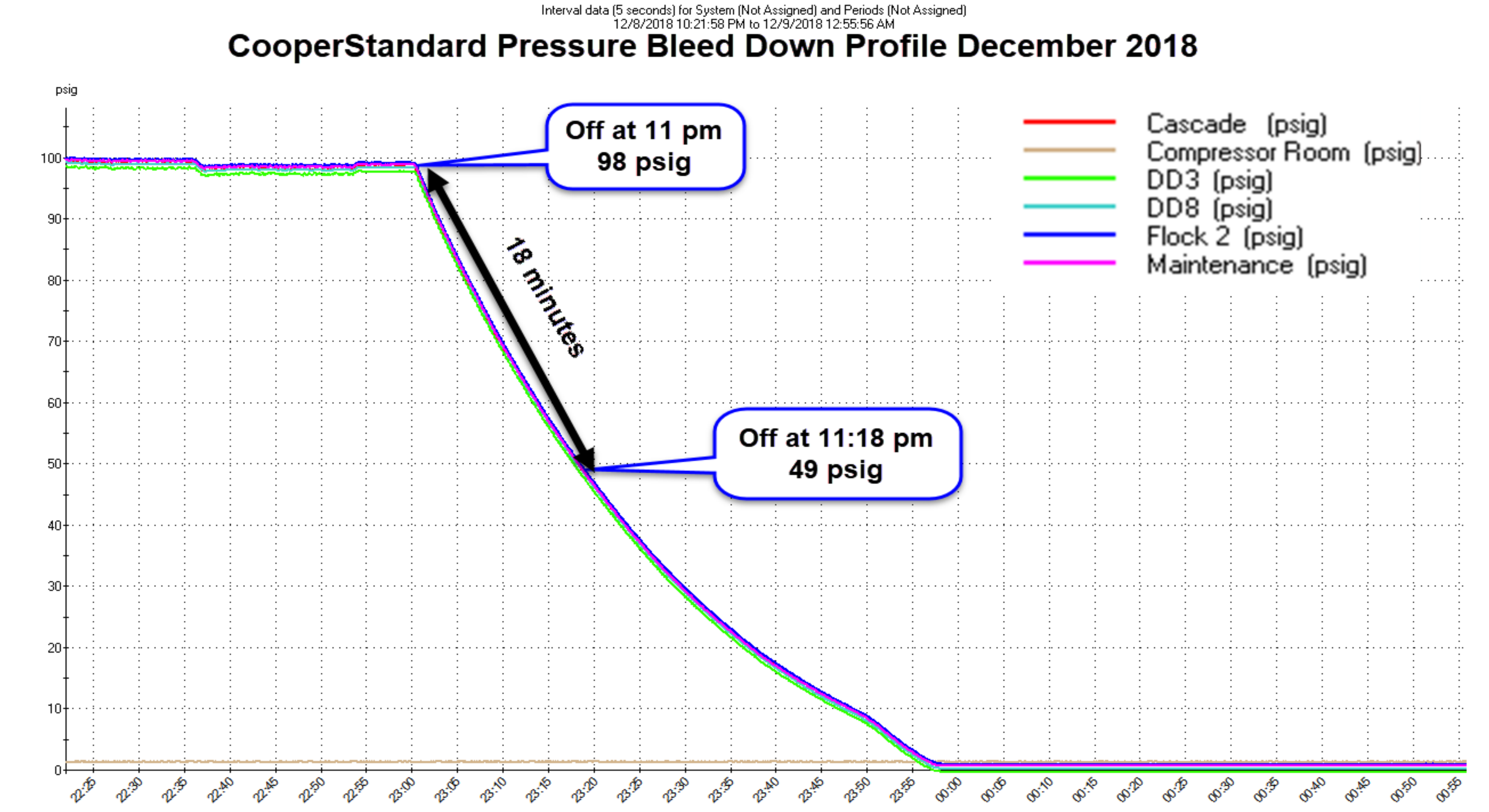
$$\text{Leakage (\%)} = \left(\frac{226}{226+156}\right)\times 100 = 59.2\%$$

Estimating Leak Load in Systems with Other Controls

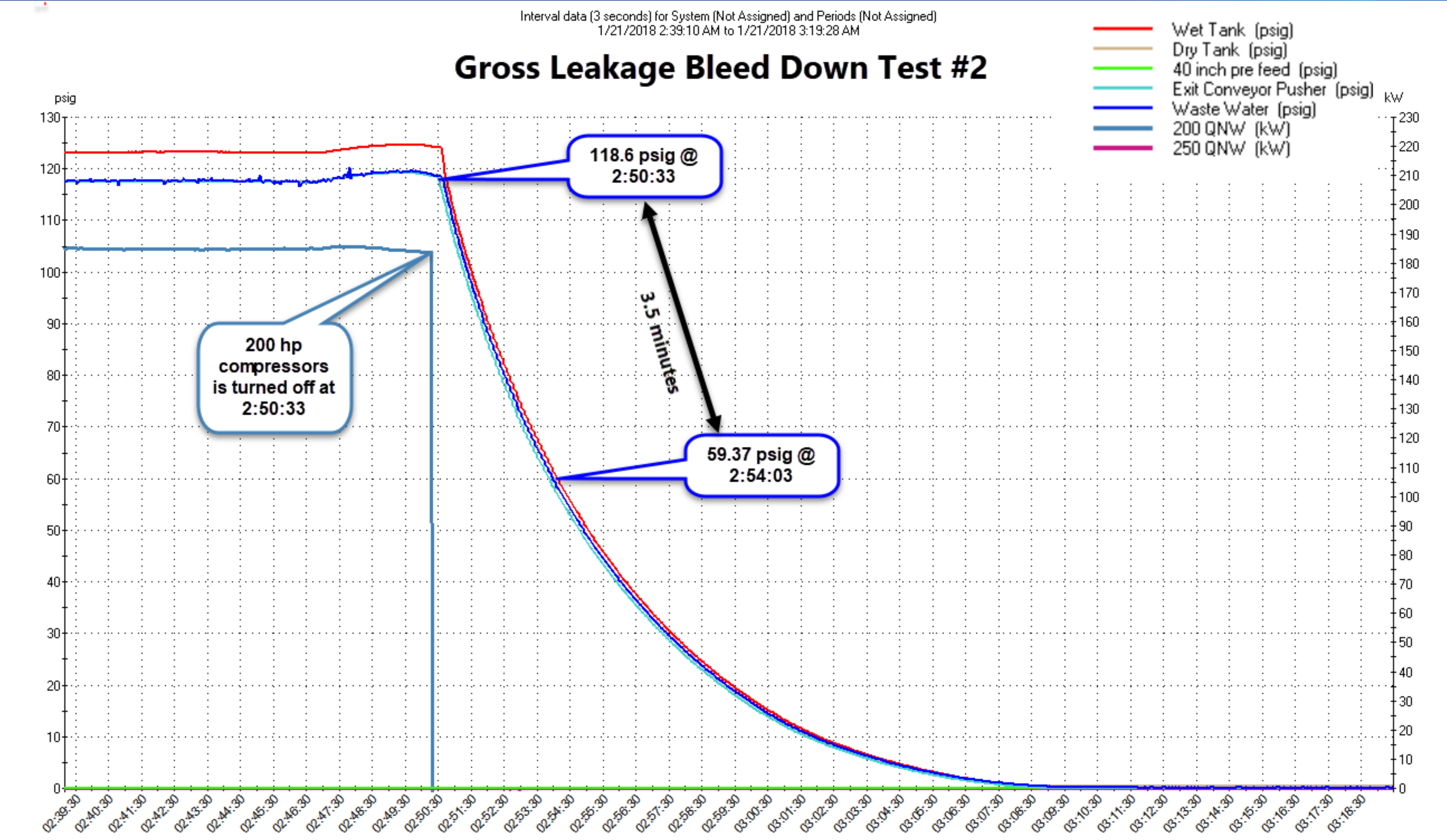
- Requires an estimate of total system piping volume
- Include all receivers
- Bring system to normal operating pressure
- Turn compressors off
- Measure time for system to drop to ½ of starting pressure
- The following calculation can be used with other controls.

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

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



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)


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							

Use the MEASUR Tool

SYSTEM CAPACITY

Pipes

Pipe Size (in)	Pipe Length (ft)
2	200 ft
3	300 ft
6	200 ft

Add Pipe

Receiver Tanks

Receiver 1	1050 gal
Receiver 2	3000 gal

Add Receiver Tank

Leak Rate Calculator

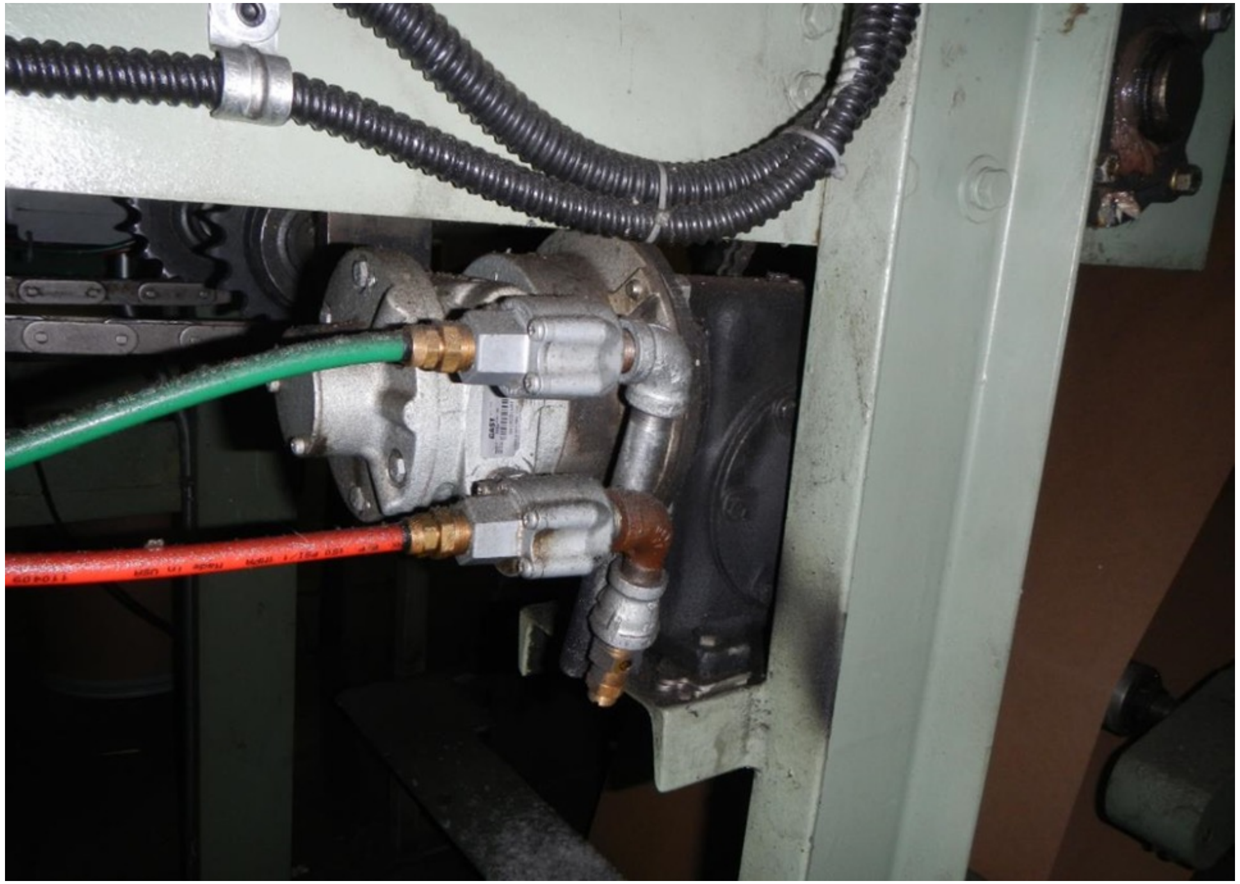
Air Pressure - High	100 psi
Air Pressure - Low	50 psi
Discharge Time	300 s
Atmospheric Pressure	14.7 psia

Total Pipe Volume	**450 gal**
Total Receiver Volume	**4,050 gal**
Total Capacity of Compressed Air System	**4,500 gal**

Leak Rate	**409.26 ACFM**

Open Blowing

Air Motors



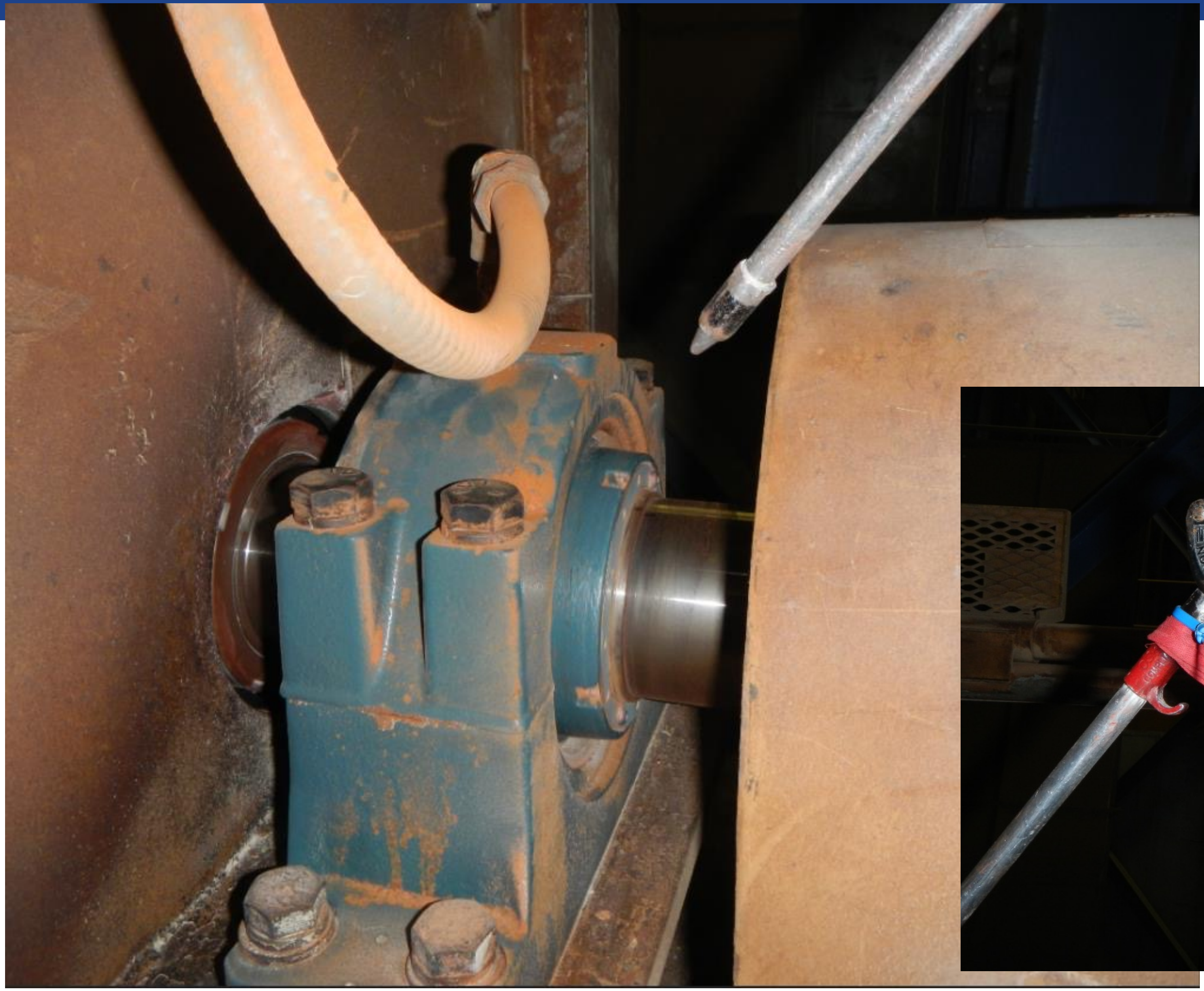
Air Motors

VS

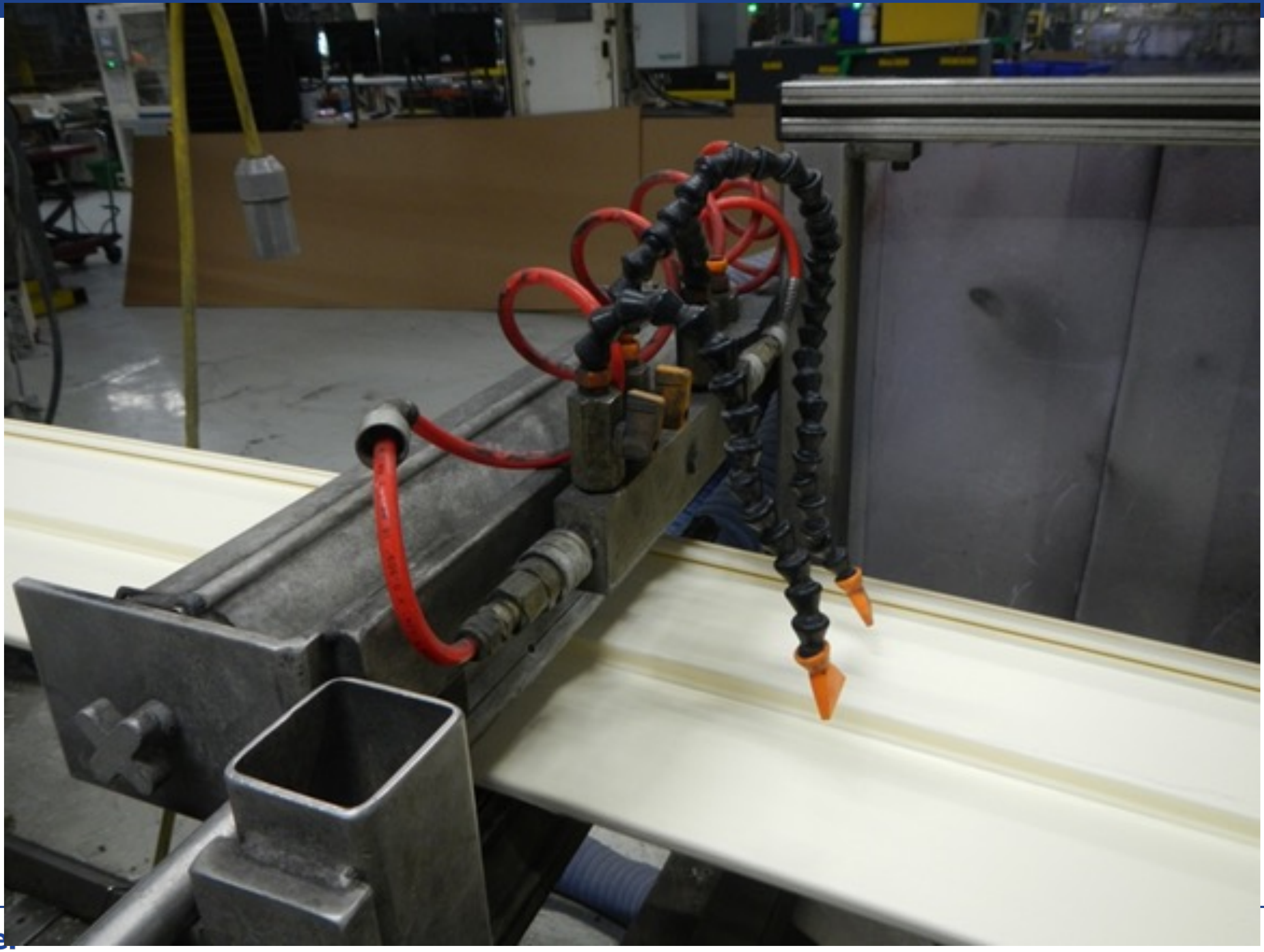
Air Motors

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

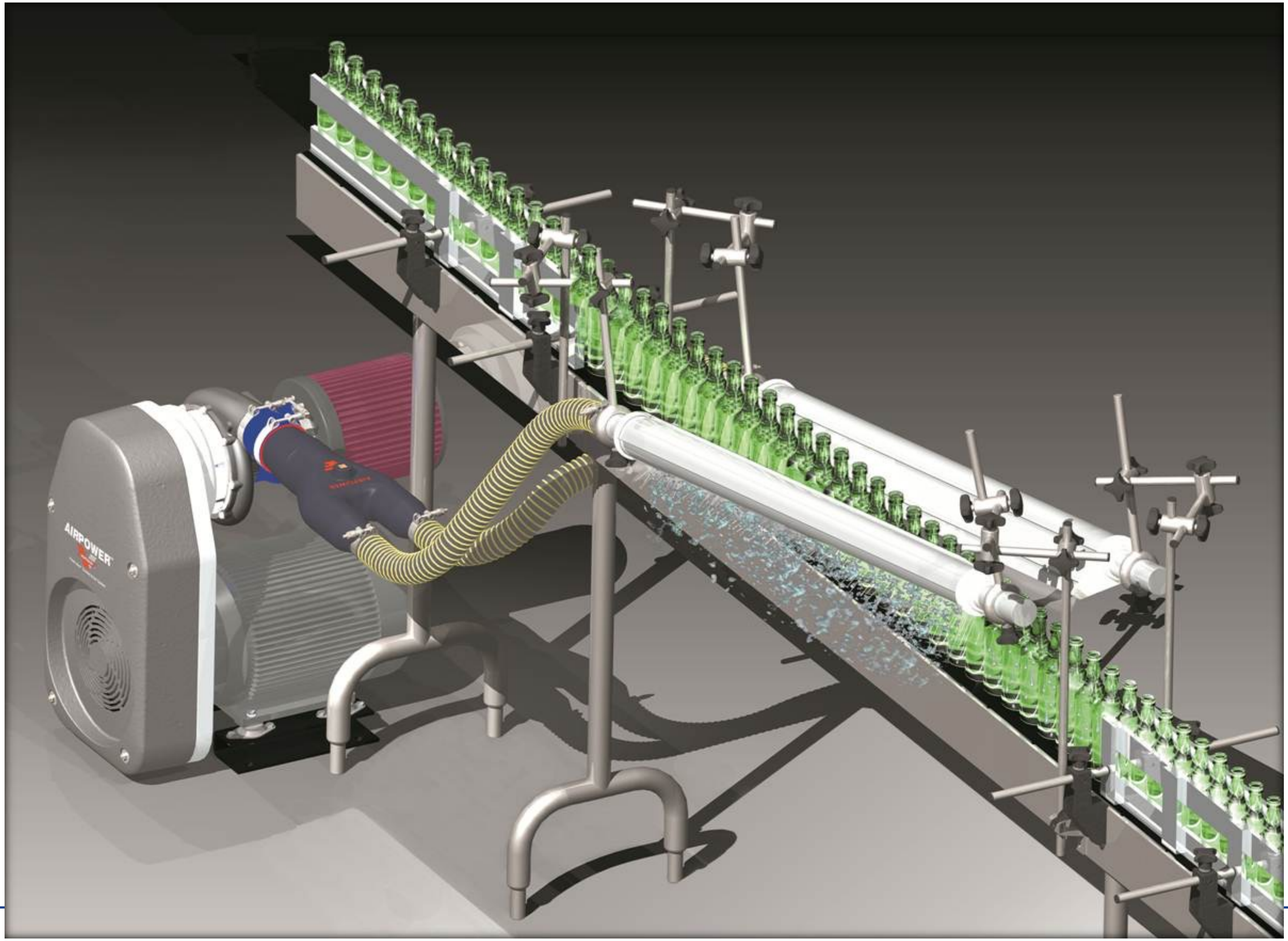
3 hp blower 70 cfm, using 2.2 kW running all year = $1,156
Blower plus manifold cost $3,000

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**

Potentially Inappropriate Applications

Appropriate Applications



Appropriate Applications

Appropriate Applications

Appropriate Applications

Appropriate Applications

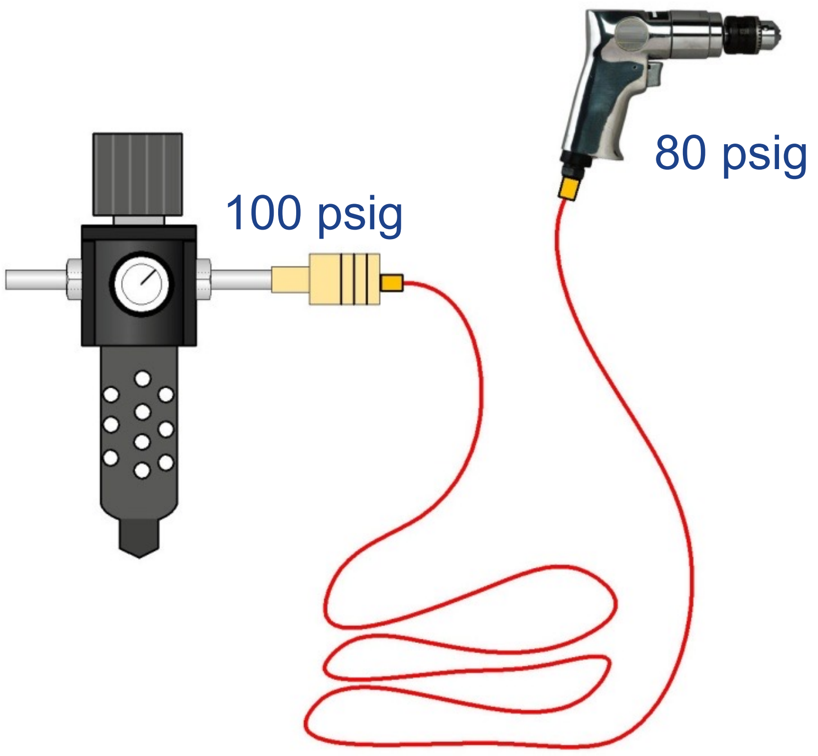
Appropriate Applications

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.

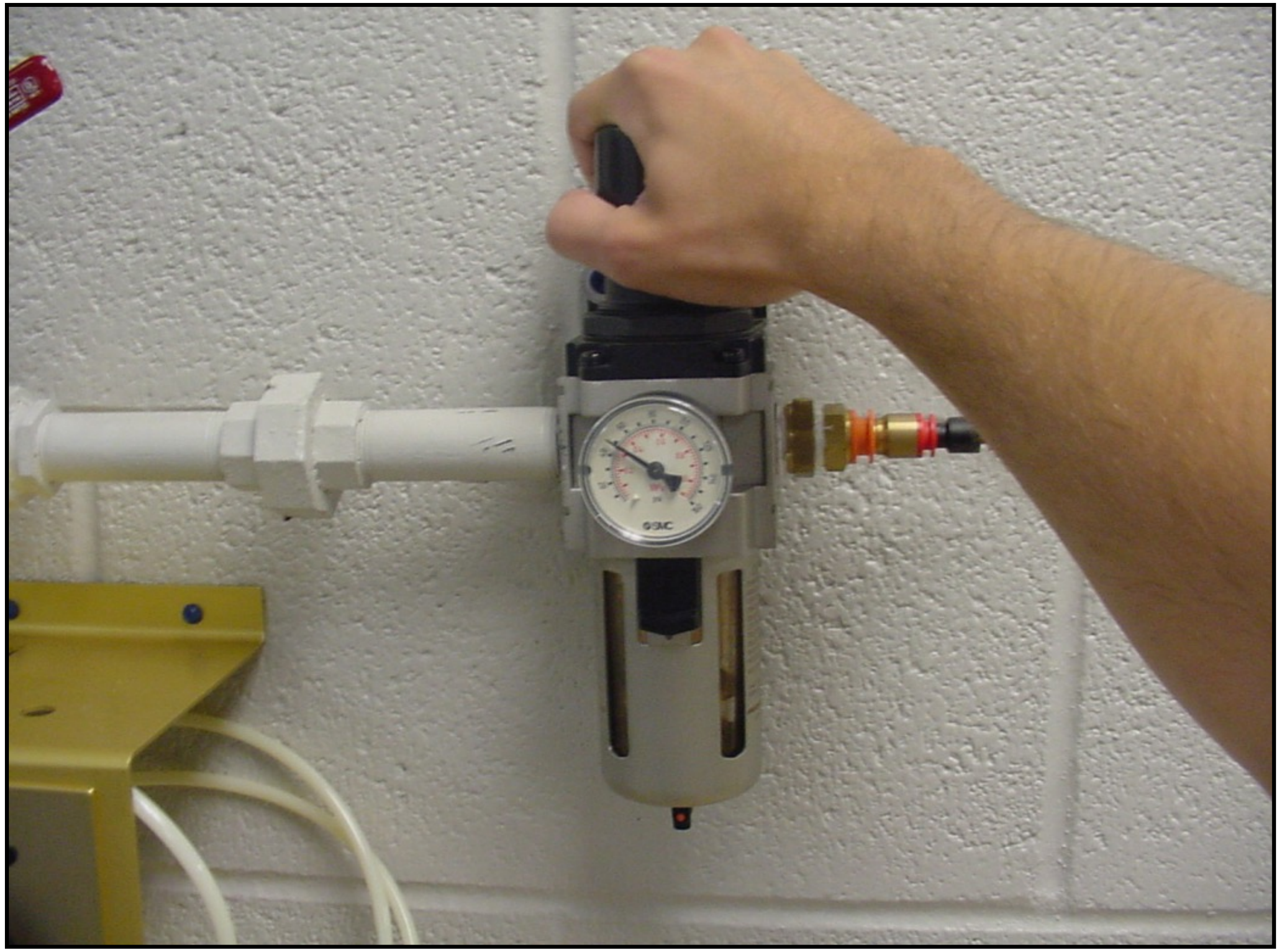
End Use Control

- 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.

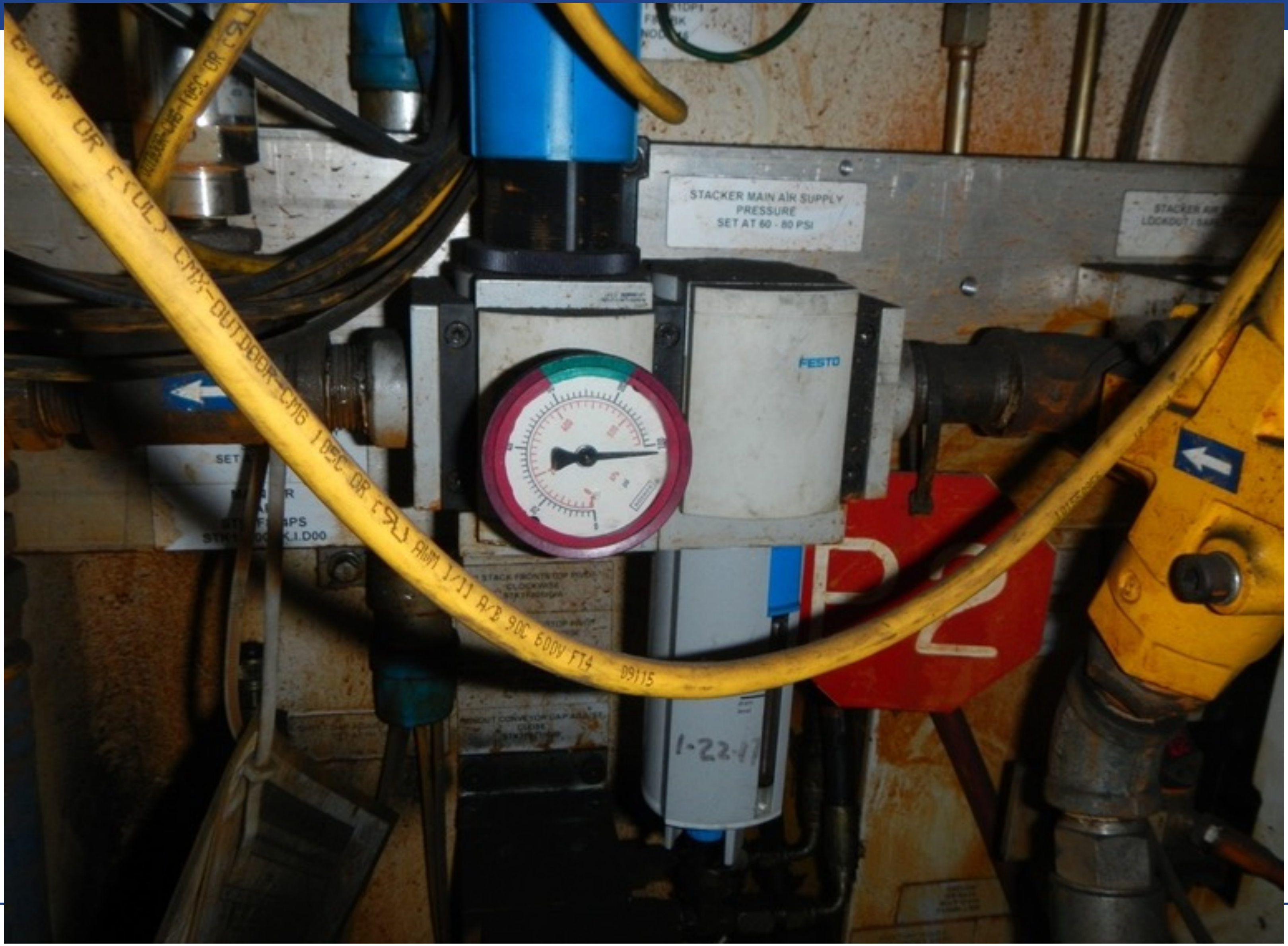


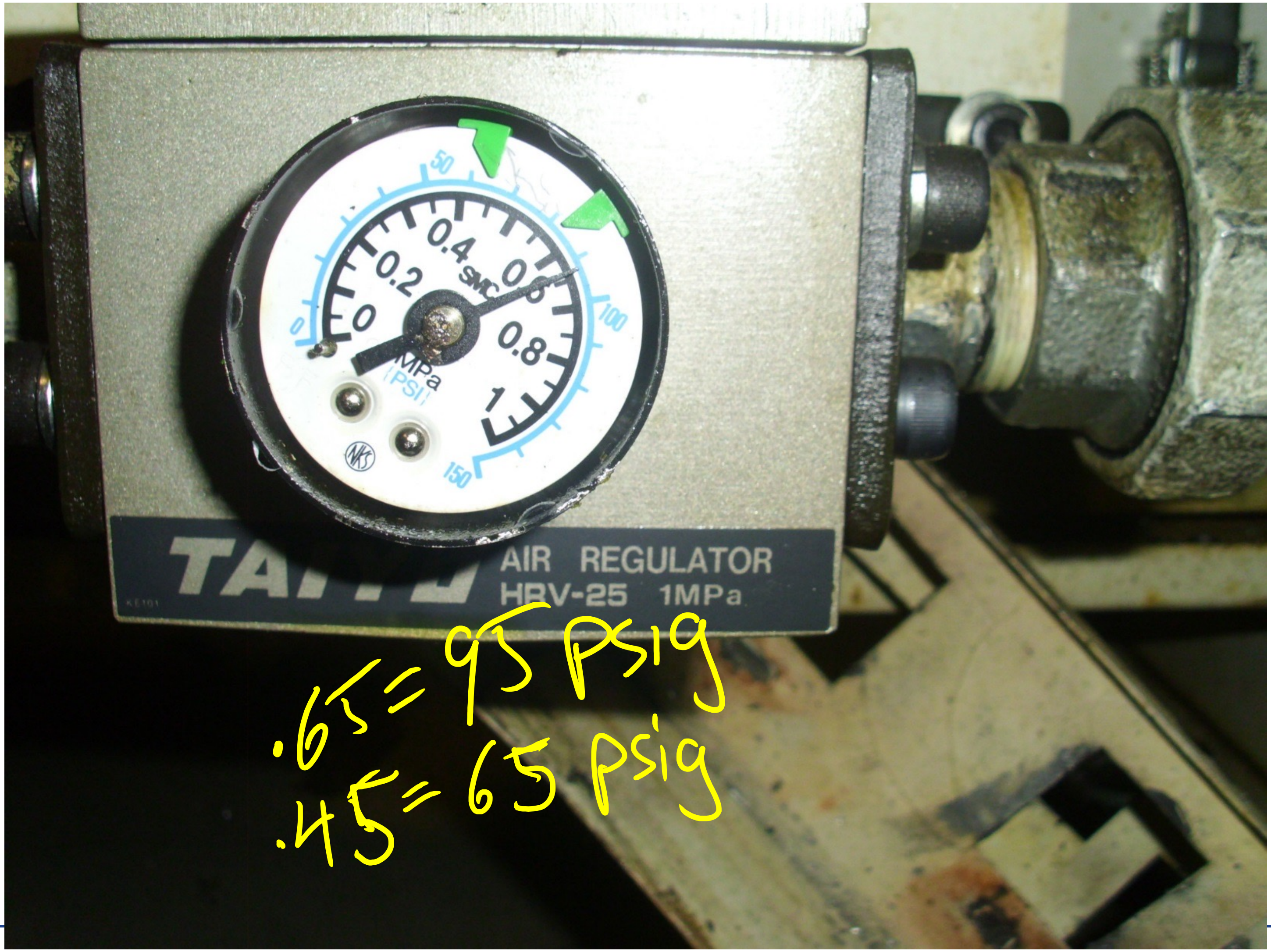
Over-Pressurization Examples

- 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.

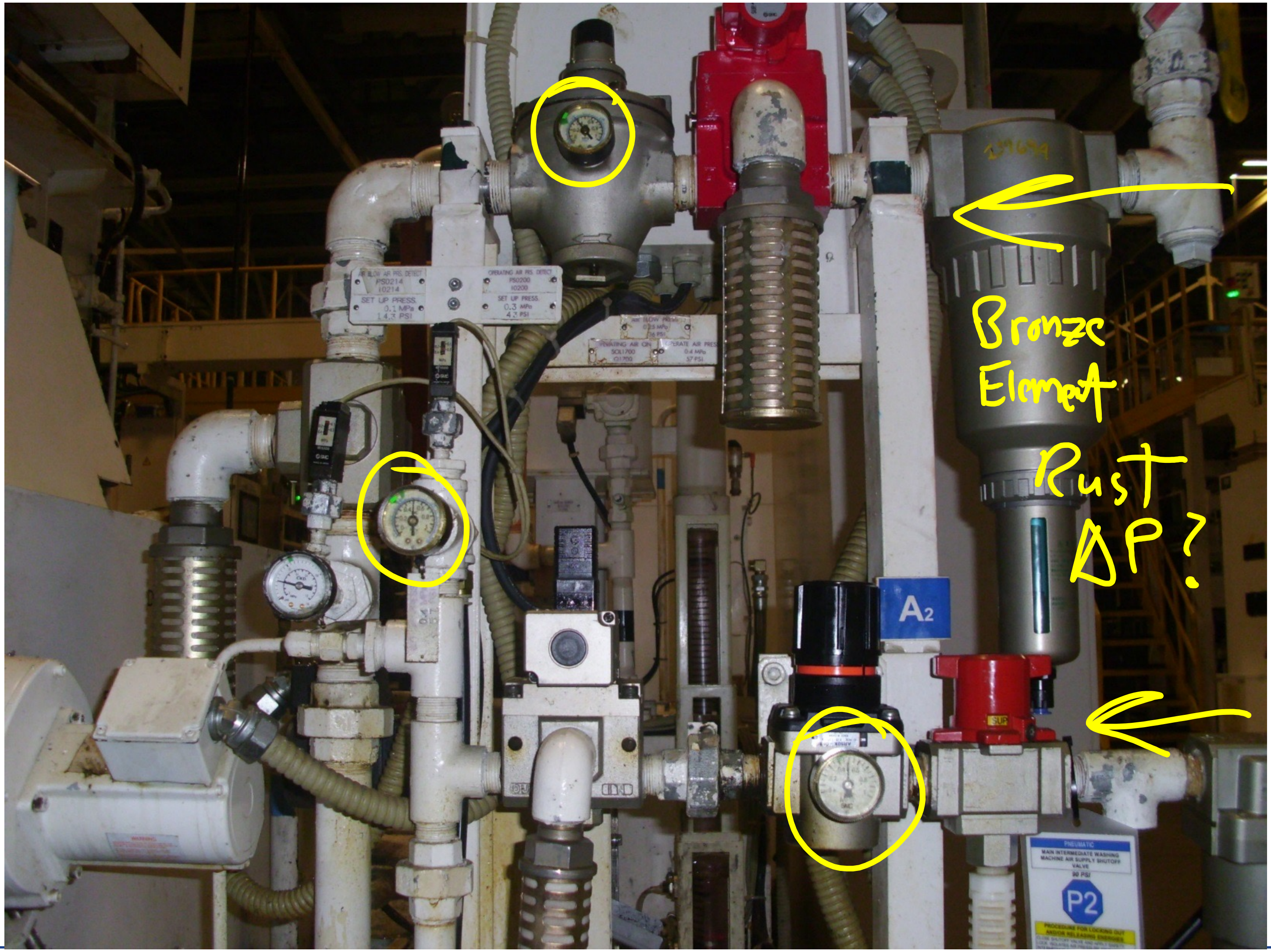


Pressure at points of use.



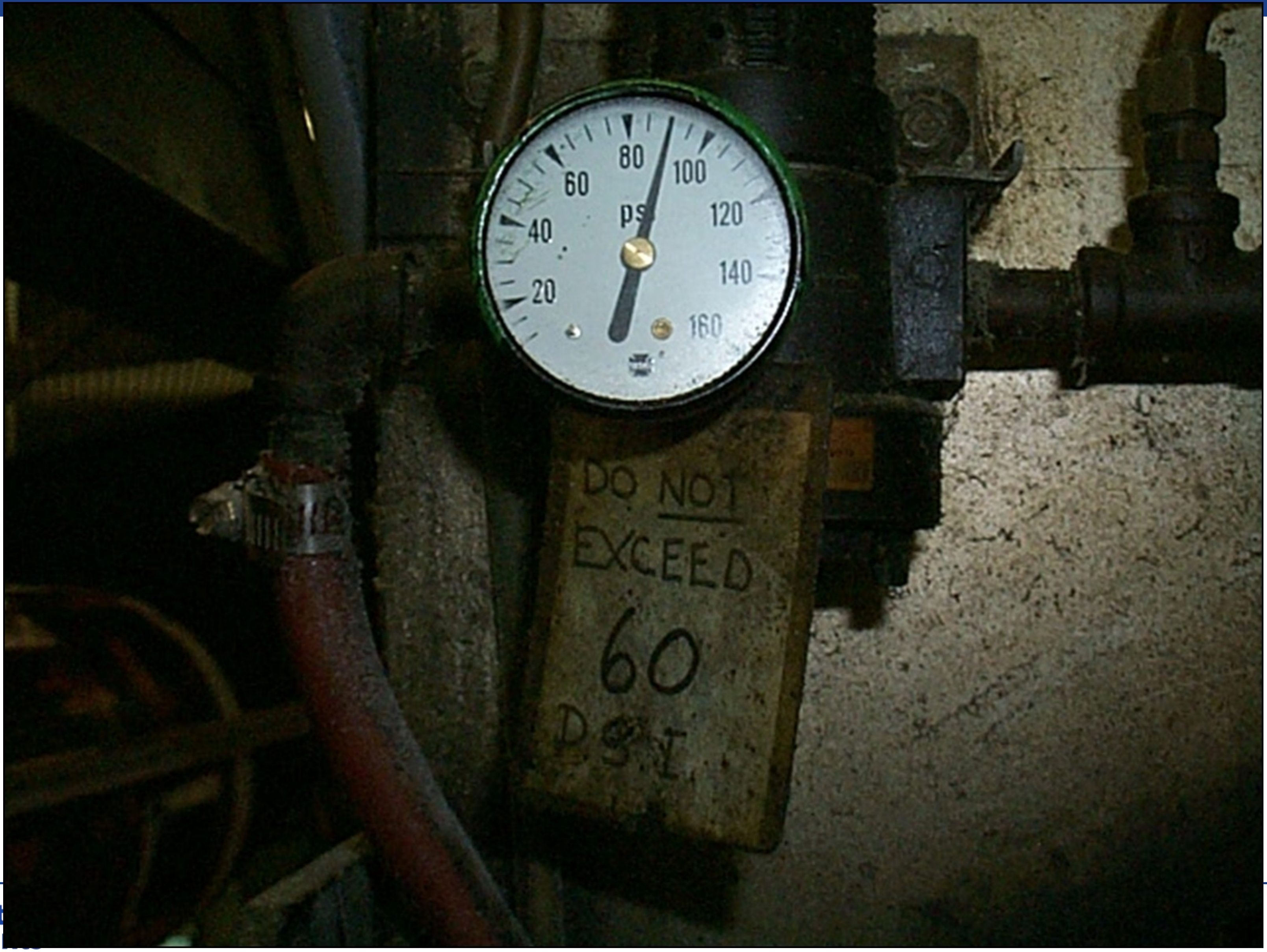


0
0.2
0.4
0.6
0.8
1
SMC
MPa
(PSI)
0
50
100
150
TAIYO
AIR REGULATOR
HRV-25 1MPa
.65=95 psig
.45=65 psig



Bronze
Element
Rust
ΔP?
A2
P2

Pressure at points of use.



Pressure Drop

Rubber H0se

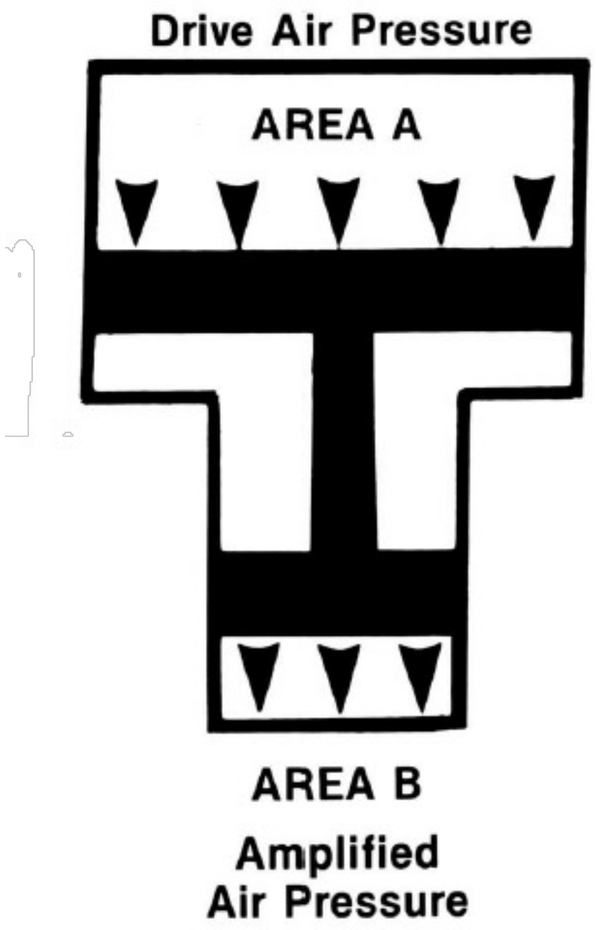
- What size rubber hoses do you use?

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
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
25 - 30		6.6	2.1	1.0	1.5	2.3					5.2	9.8	3.8
30 - 35		9.5	3.1	1.3	2.1	3.6					7.3	13.7	5.3
35 - 40		12.8	4.2	1.7	2.8	5.2					9.6	18.4	7.1
40 - 50		19.3	6.3	2.4	4.1	8.0					14.0		10.4
50 - 60			9.6	3.7	6.3	12.2					21.8		16.0
60 - 70			13.5	5.3	9.0	17.4	0.9	1.4	1.9				22.8
70 - 80			18.7	7.1	12.4		1.1	1.7	2.5				
80 - 90			25.0	9.0	16.1		1.4	2.2	3.2				
90 - 100				11.0			1.7	2.7	4.0				

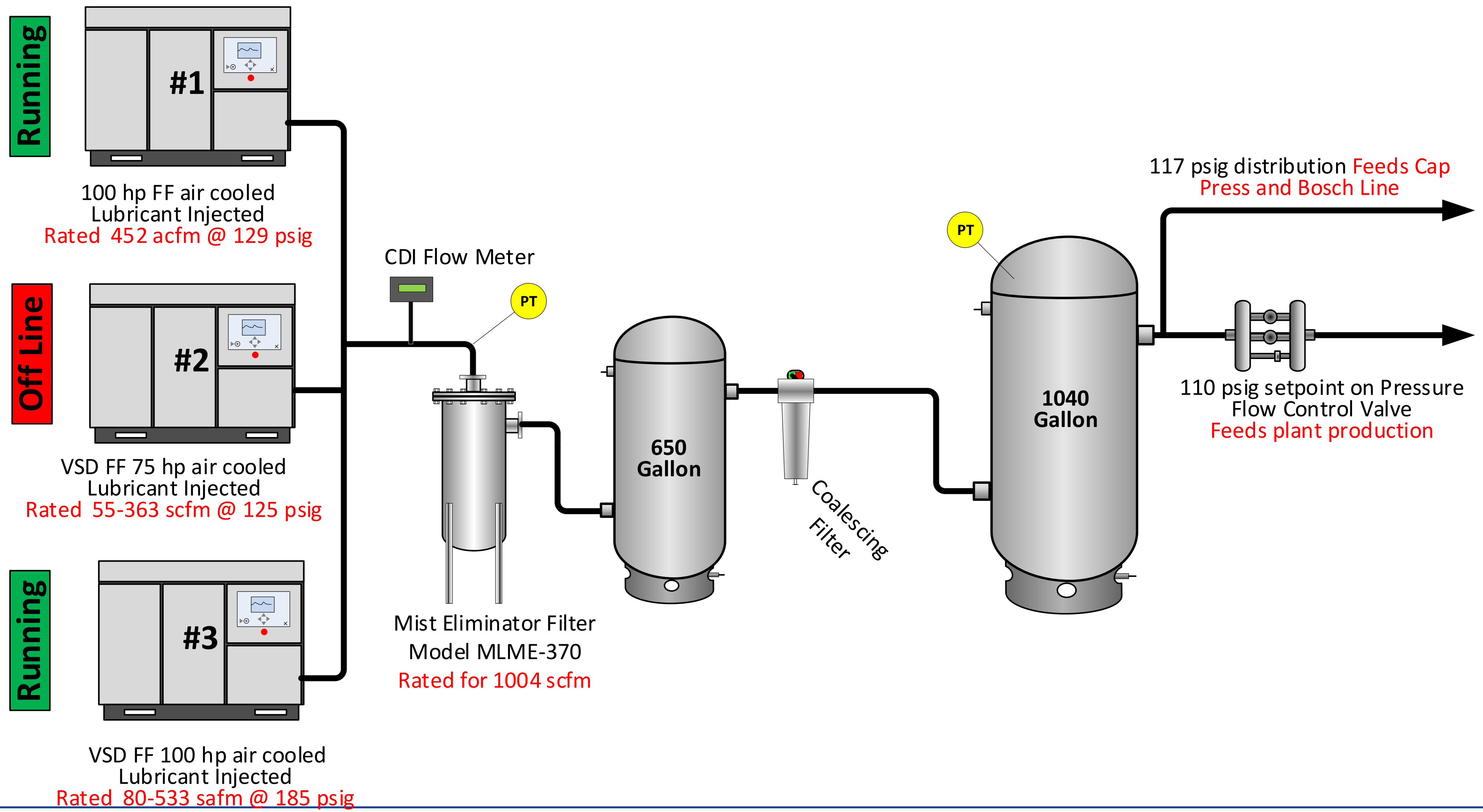
Pressure at points of use.

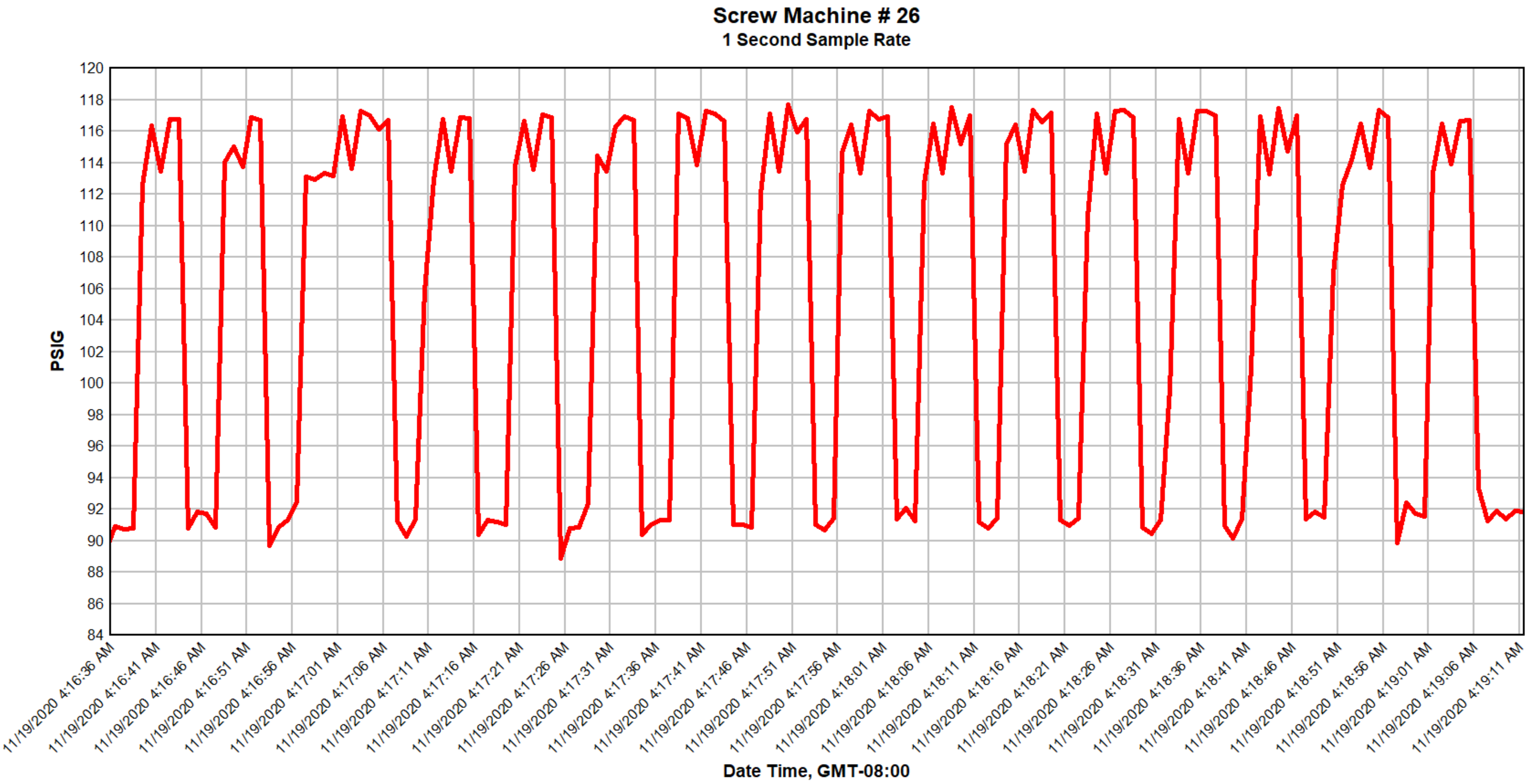
- The total system may be running at a higher pressure to satisfy the needs of only one point of use.
  - If the high-pressure application can be modified to operate at lower pressure, make the fix.
  - **If the high-pressure application is valid, find a better way to serve it.**
  - The single high-pressure 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.



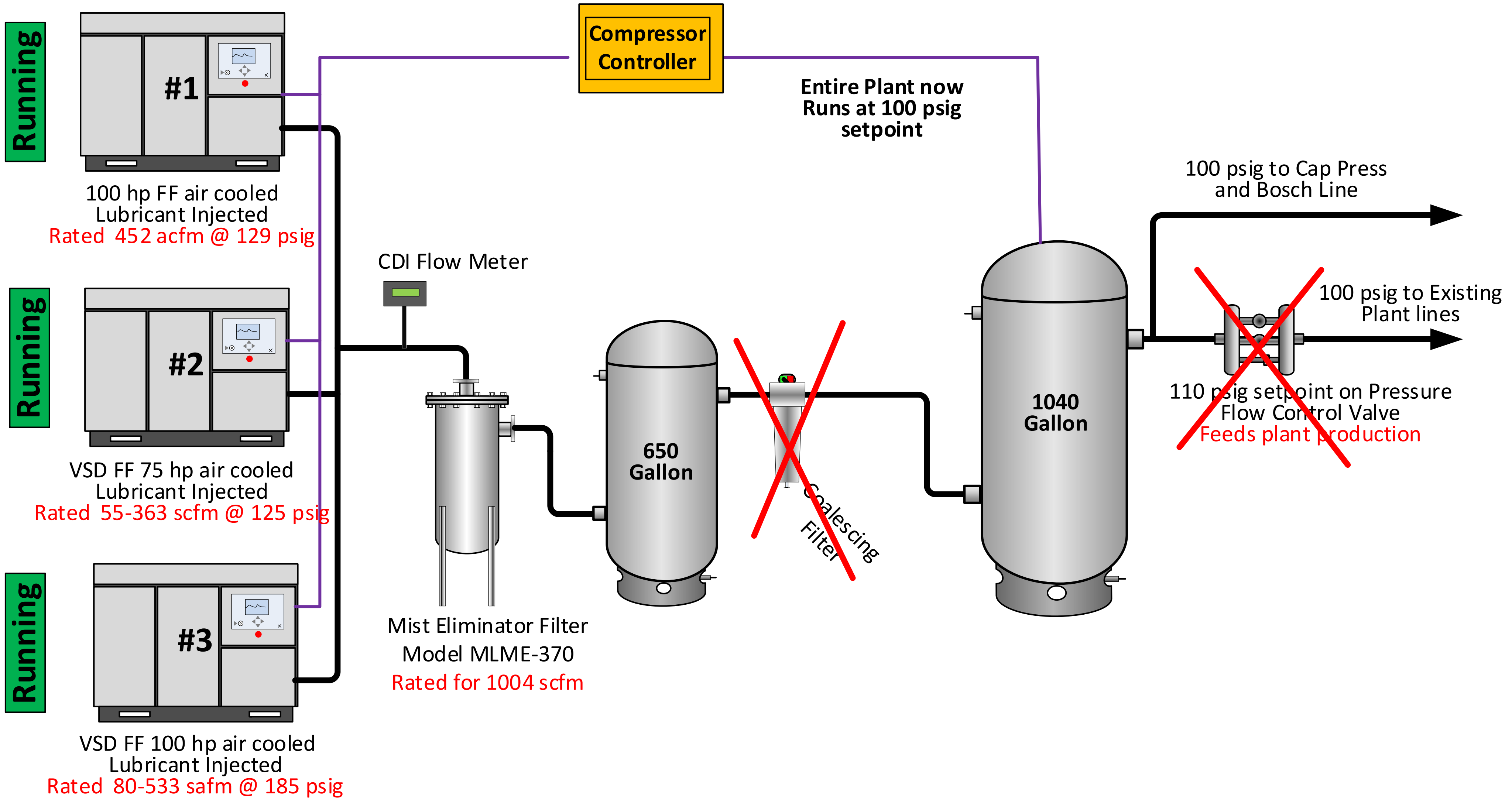
Pressure at points of use.



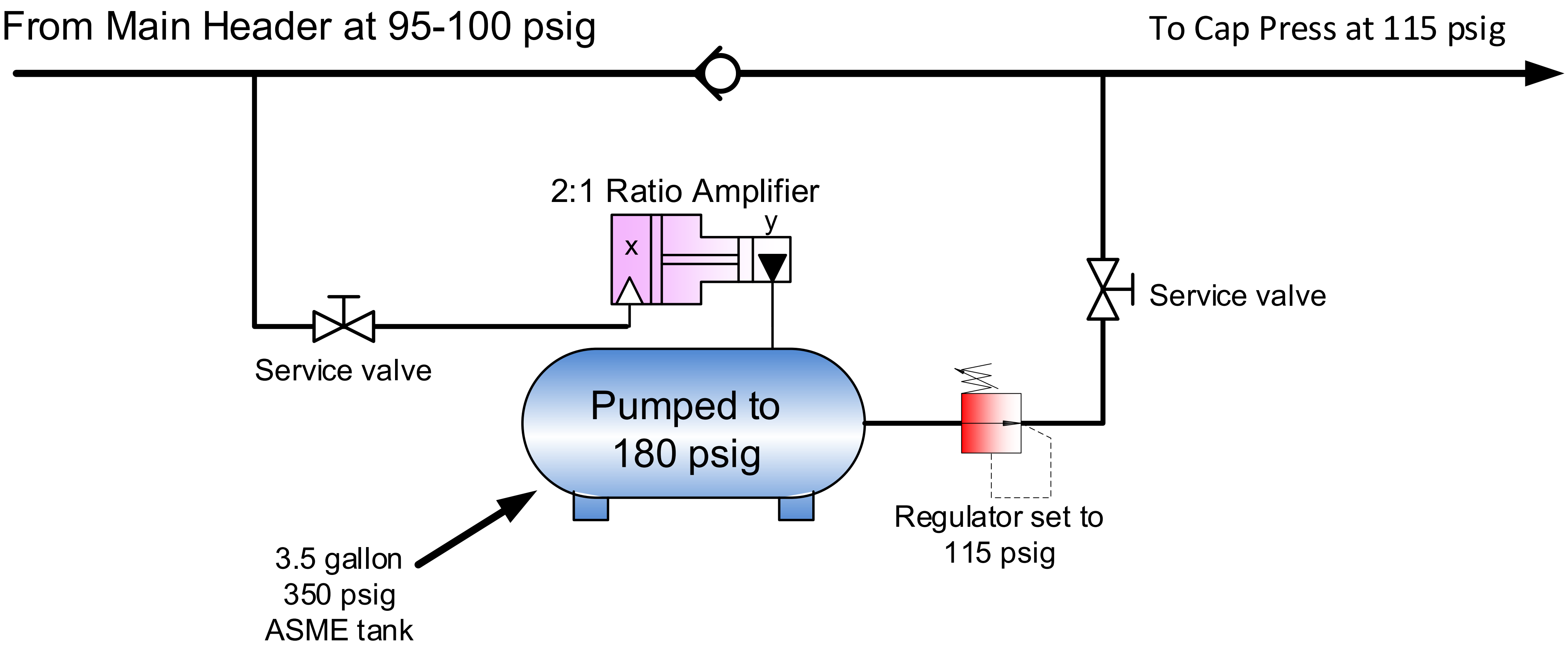


Screw Machine # 26
1 Second Sample Rate
PSIG
120
118
116
114
112
110
108
106
104
102
100
98
96
94
92
90
88
86
84
11/19/2020 4:16:36 AM
11/19/2020 4:16:41 AM
11/19/2020 4:16:46 AM
11/19/2020 4:16:51 AM
11/19/2020 4:16:56 AM
11/19/2020 4:17:01 AM
11/19/2020 4:17:06 AM
11/19/2020 4:17:11 AM
11/19/2020 4:17:16 AM
11/19/2020 4:17:21 AM
11/19/2020 4:17:26 AM
11/19/2020 4:17:31 AM
11/19/2020 4:17:36 AM
11/19/2020 4:17:41 AM
11/19/2020 4:17:46 AM
11/19/2020 4:17:51 AM
11/19/2020 4:17:56 AM
11/19/2020 4:18:01 AM
11/19/2020 4:18:06 AM
11/19/2020 4:18:11 AM
11/19/2020 4:18:16 AM
11/19/2020 4:18:21 AM
11/19/2020 4:18:26 AM
11/19/2020 4:18:31 AM
11/19/2020 4:18:36 AM
11/19/2020 4:18:41 AM
11/19/2020 4:18:46 AM
11/19/2020 4:18:51 AM
11/19/2020 4:18:56 AM
11/19/2020 4:19:01 AM
11/19/2020 4:19:06 AM
11/19/2020 4:19:11 AM
Date Time, GMT-08:00

Pressure at points of use.



Pressure at points of use.

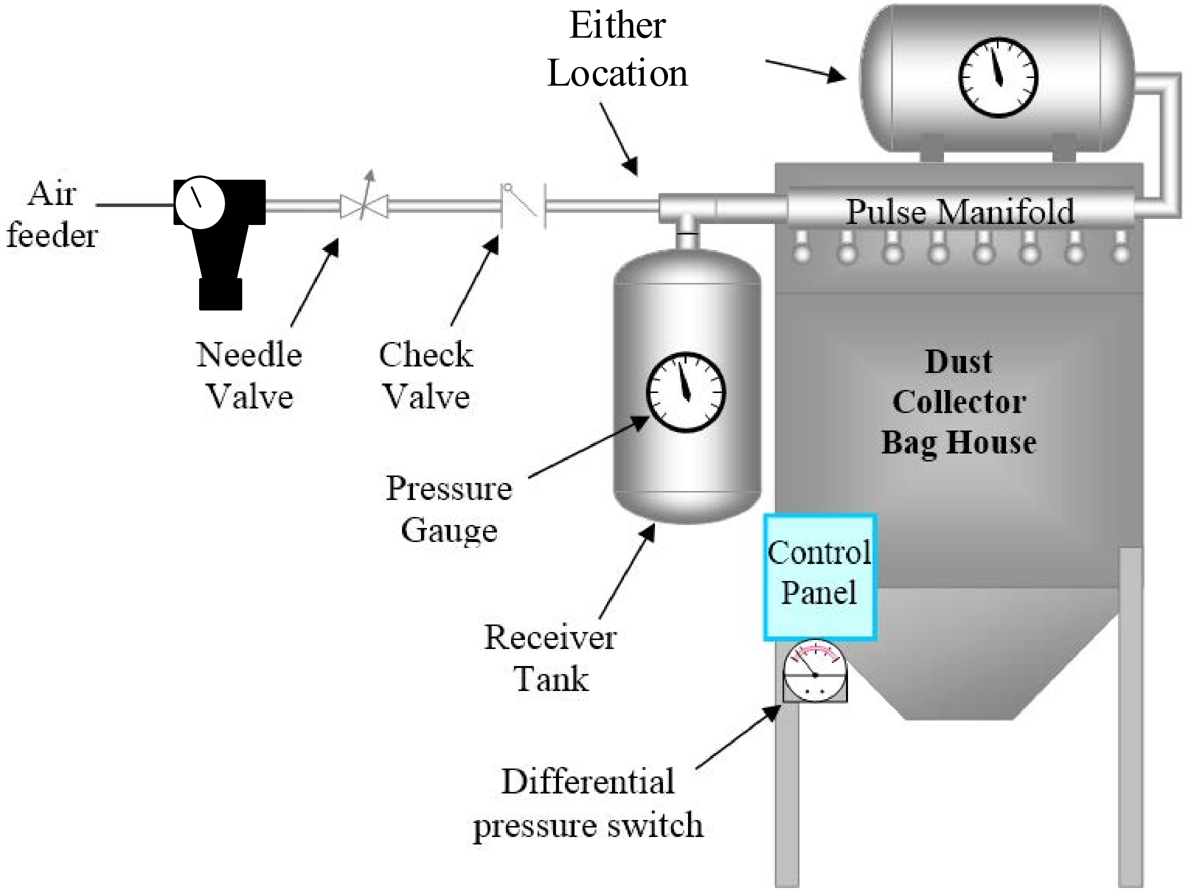


Dust Collector (Bag House)

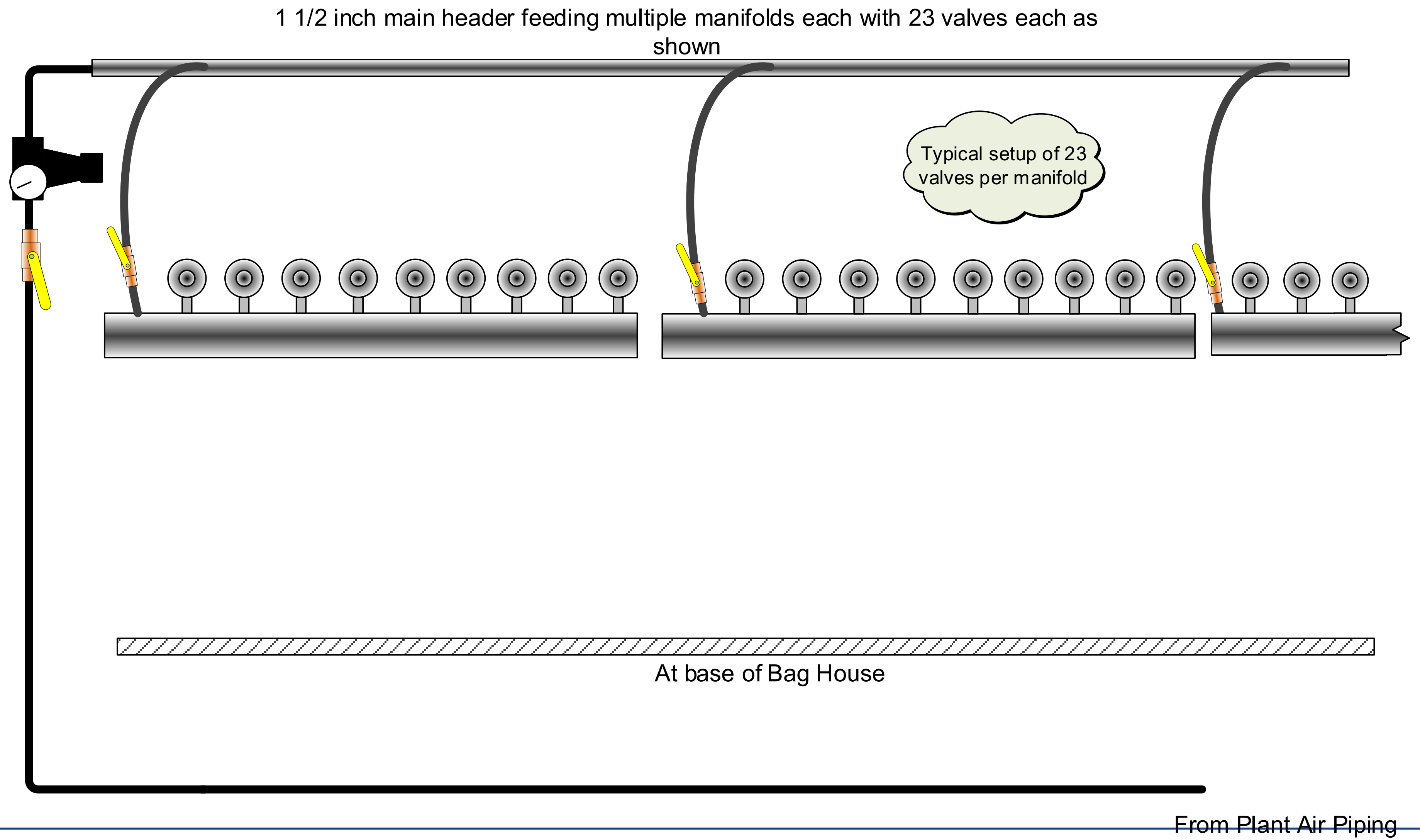
- **Designing “By the Book”**
  - When a plant or operation with significant dust collecting is audited, it is very rare to find anyone in operations who is aware of what the dust collectors operating specifications are and how or why the pipe sizes were selected.
  - When you get the facts and go "by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

Dust Collector (Bag House)

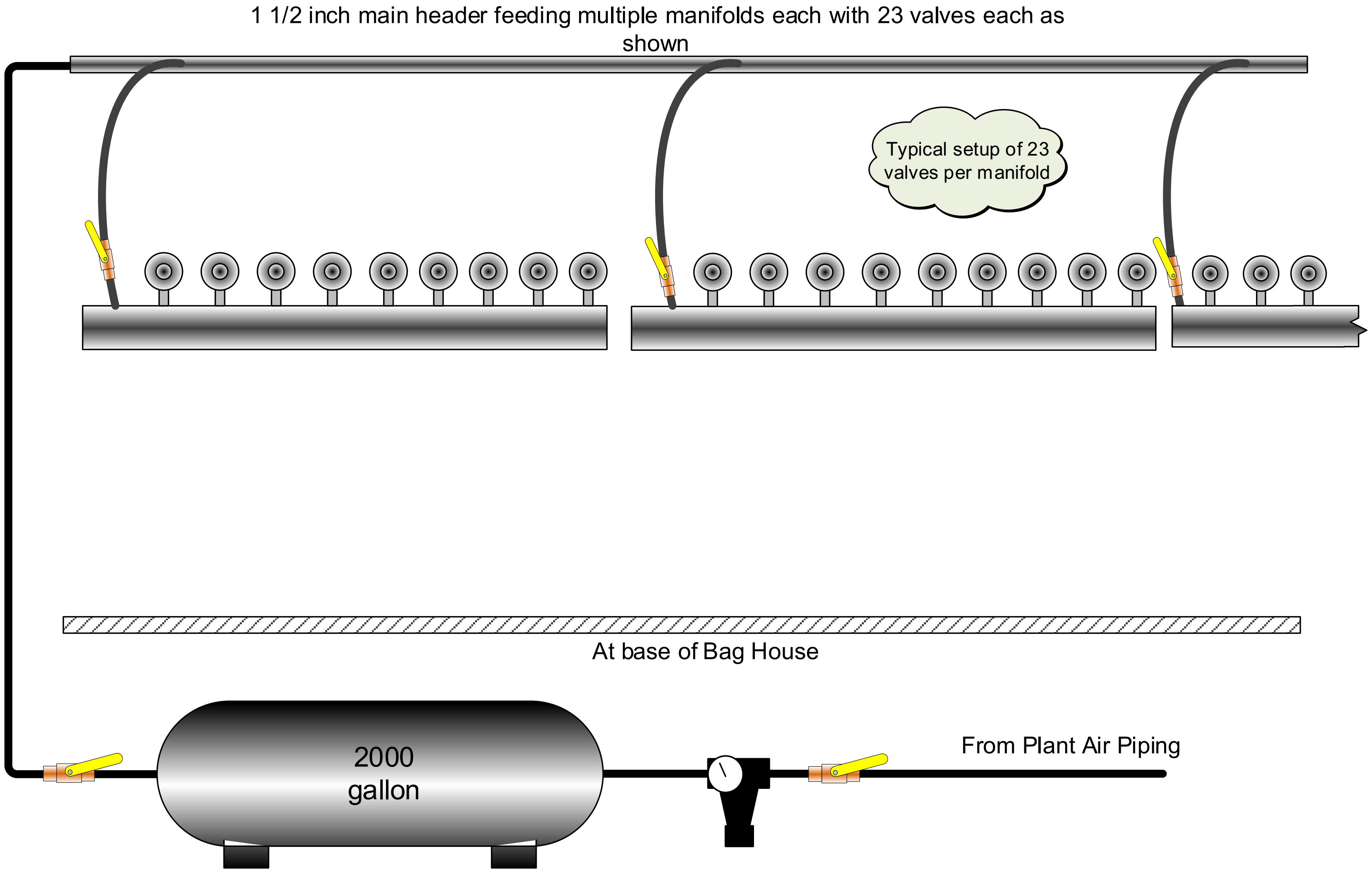
- The rated flow of compressed air per pulse is usually 2 to 3 cubic feet, with normal pulse durations of .1second (100 milliseconds).
- One valve typically opens every 15 seconds.
  - Obviously, there are other designs with different specifications.
  - Most of the time there will only be one valve 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.



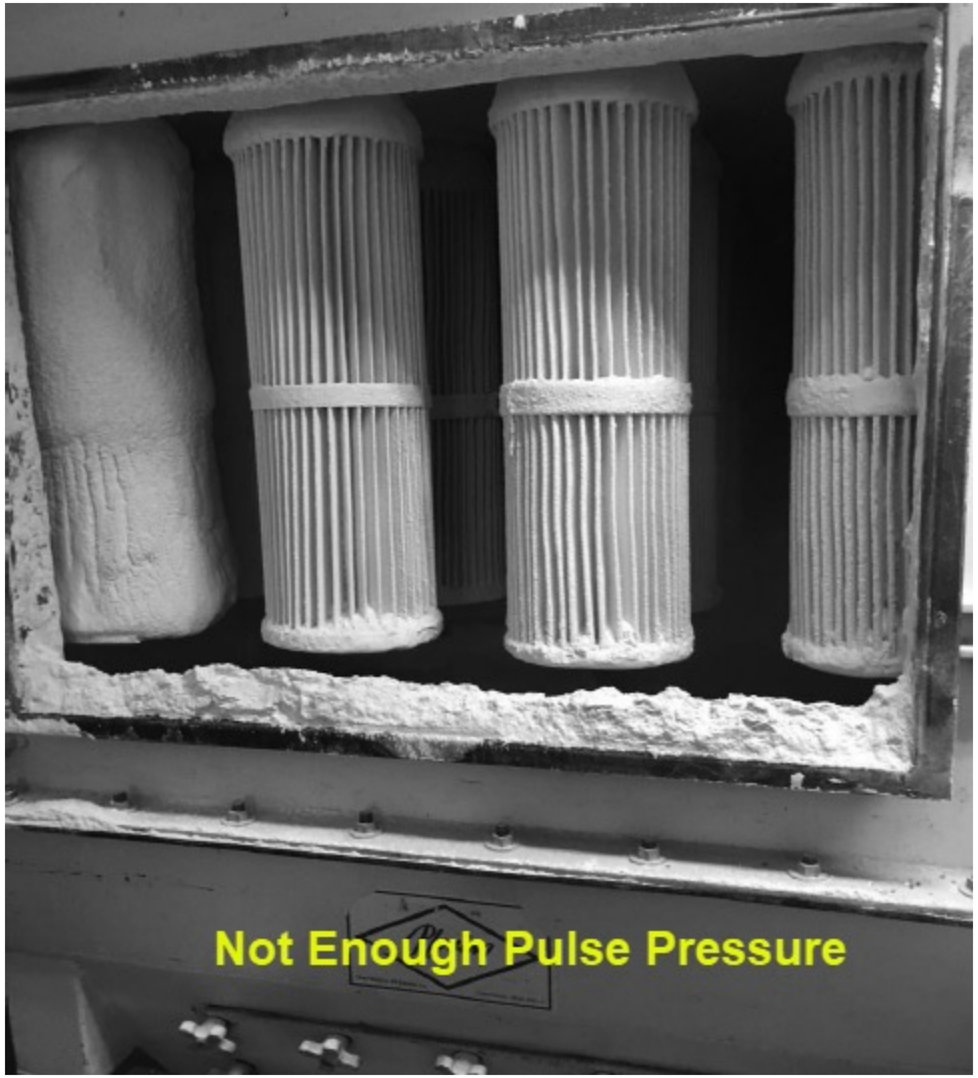
Dust Collector (No Storage Volume)

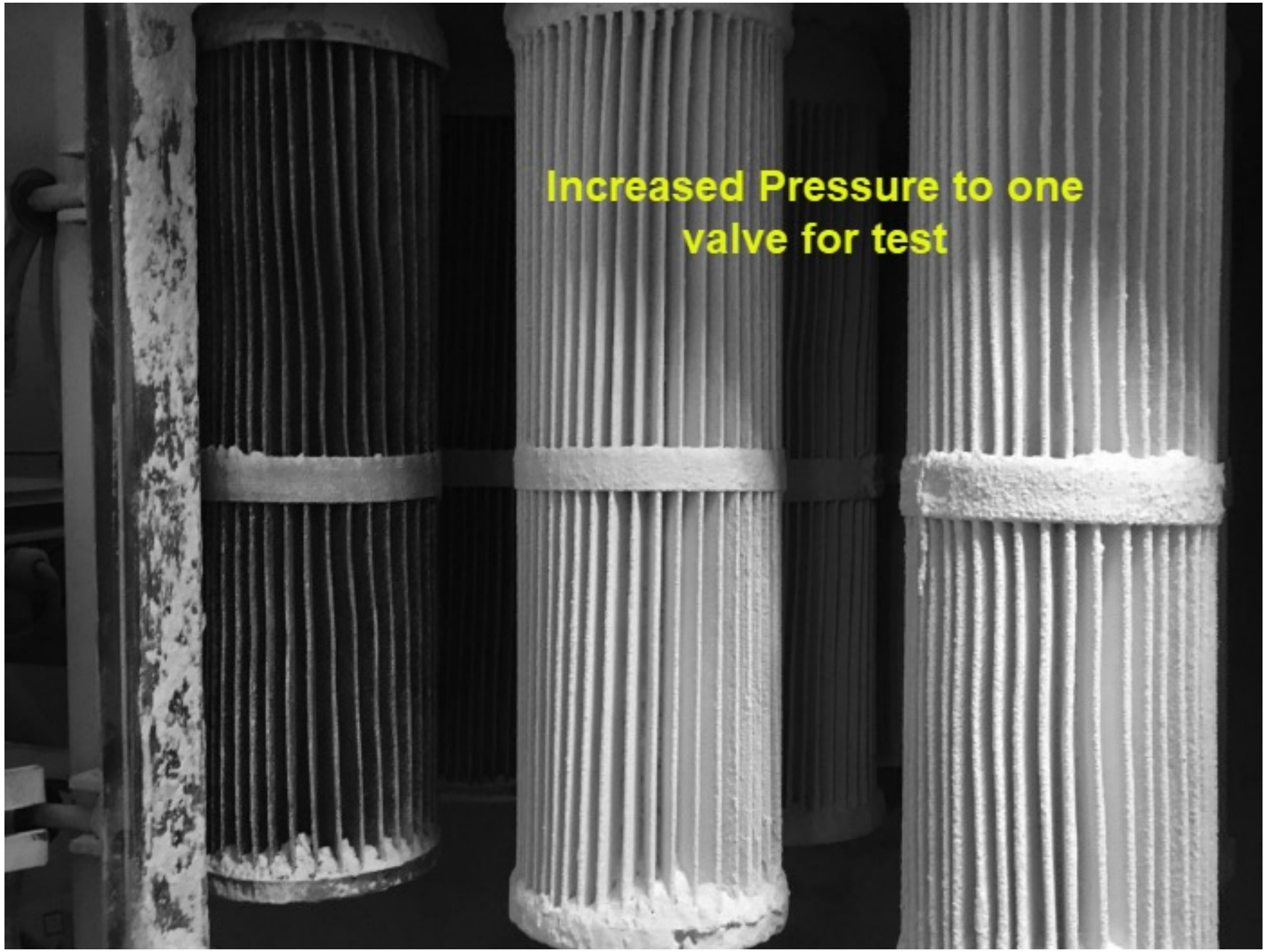


Dust Collector (No Storage Volume)



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.

Air Operated Diaphragm Pumps (AODP)

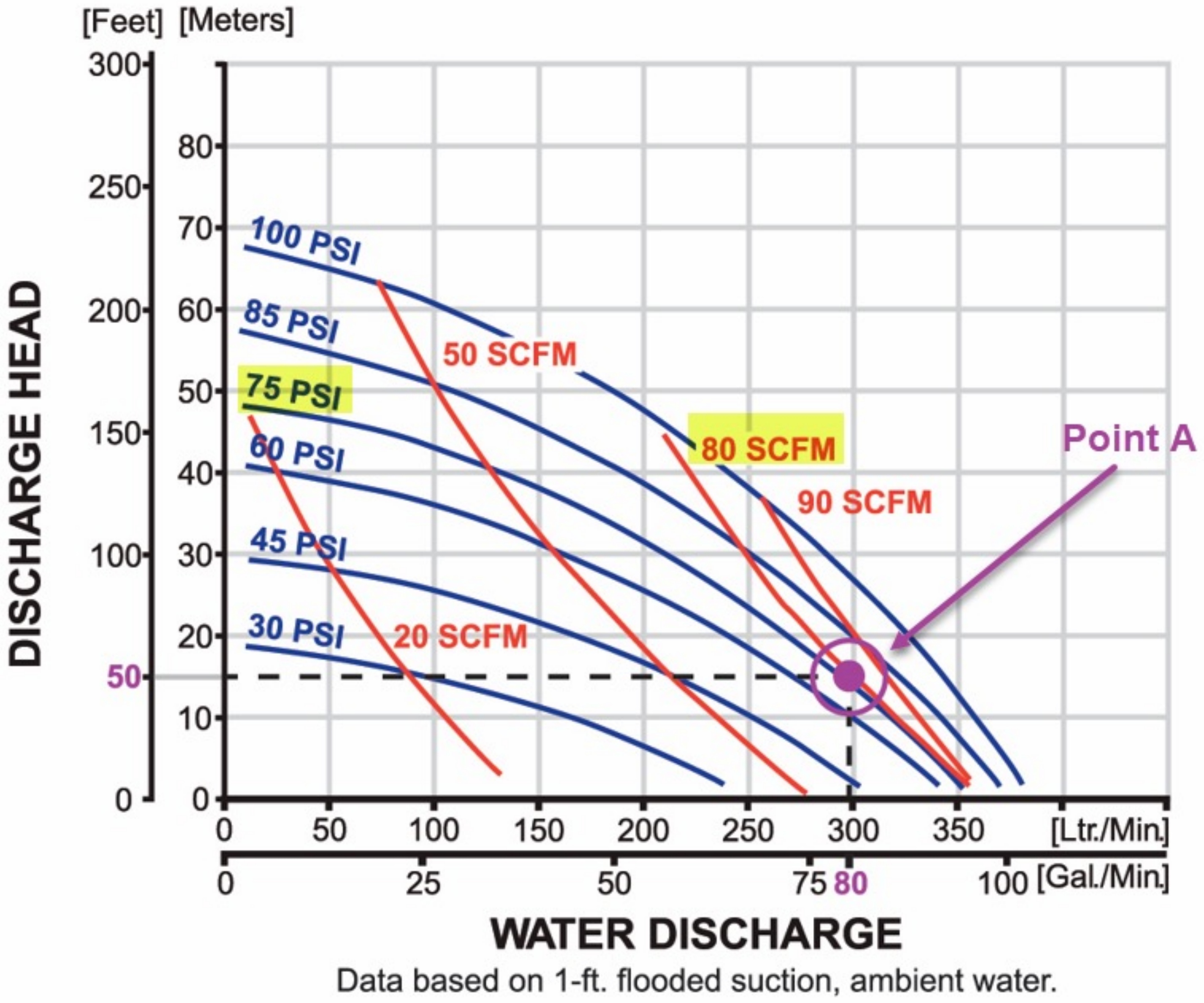
- Diaphragm pumps driven by electric motors can easily substitute for AOD pumps using compressed air. Other AOD pumps can be simply substituted with electric centrifugal pumps.
- An industrial rule of thumb is that an AODP will use about 7 times the electrical energy of an efficient centrifugal pump 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.

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.

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



Summary

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

Summary

An energy efficient compressed air system also can improve product quality, reduce scrap rates and increase profits

Reduced energy costs of a compressed air system go right to the bottom line of the financial statement as increased profits.

An efficient compressed air system pays dividends!

You must walk the system. Most waste is obvious.

Next and Final Session

Review

Quick review of the past 7 sessions

Report Out

Using the template provided, report out on what your plans for optimization are

Final Steps

Continue with your improvements and get Management involved