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In-Plant Trainings

8 – Session Virtual Platform
Session 5 Distribution

Homework from last session:

1. A factory is located in the Southeast USA. All of piping is located indoors and not subject to freezing temperatures. The compressed air use in the factory is primarily in manufacturing production. What would be the most appropriate type of dryer to use and why?

   A: For a factory located in the Southeast USA, the most appropriate type of dry system for compressed air use would be a compressed air system. This system is designed to provide low-pressure compressed air for manufacturing production, ensuring efficient and reliable air supply for various industrial processes.

2. What type of dryer uses a porous material that adsorbs the moisture with compressed air or heat reactivation?

   A: The type of dryer that uses a porous material that adsorbs moisture with compressed air or heat reactivation is known as a desiccant dryer. These dryers utilize a porous desiccant material, such as silica gel or activated alumina, to absorb moisture from the compressed air. The desiccant material is regenerated with compressed air or heat, allowing it to be reused after the moisture is removed.

3. What type of dryer uses a drying medium that absorbs the moisture in compressed air?

   A: Refrigerant Type

4. What type of dryer uses a material that allows water vapor to pass through pores faster than other gases thus reducing the water vapor?

   A: Deliquescent desiccant dryer

5. What type of dryer cools the air to remove the condensed moisture before the air is reheated and discharged?

6. A: Refrigerated Dryer

7. Refrigerated dryer ratings are based on standard dryer inlet conditions. Dryer ratings must be corrected for conditions other than these standard conditions. What are the three conditions used for rating an air-cooled refrigerated dryer?

   A: Inlet Compressed Air Temperature: Typically rated at 100°F.

   Inlet Compressed Air Pressure: Usually rated at 100 psig.

   Ambient Temperature: Generally rated at 100°F.

8. What type of filter can remove oil aerosols?

A: Coalescing Filters

1. A factory is located in the Southeast USA. All of piping is located indoors and not subject to freezing temperatures. The compressed air use in the factory is primarily in manufacturing production. What would be the most appropriate type of dryer to use and why?

Answer: Refrigerated dryer - indoor piping and no freezing risk, so a ~35–50°F pressure dew point is typically sufficient; also, it has lower cost and energy use than desiccant.

2. What type of dryer uses a porous material that adsorbs the moisture with compressed air or heat reactivation?

Answer: Desiccant (adsorption) dryer (heatless/purge or heat-regenerated).

3. What type of dryer uses a drying medium that absorbs the moisture in compressed air?

Answer: Deliquescent (absorption) dryer (salt/chemical drying medium).

4. What type of dryer uses a material that allows water vapor to pass through pores faster than other gases thus reducing the water vapor?

Answer: Membrane dryer.

5. What type of dryer cools the air to remove the condensed moisture before the air is reheated and discharged?

Answer: Refrigerated dryer.

6. Refrigerated dryer ratings are based on standard dryer inlet conditions. Dryer ratings must be corrected for conditions other than these standard conditions. What are the three conditions used for rating an air-cooled refrigerated dryer?

Answer: Inlet air temperature, inlet pressure, and ambient (cooling air) temperature.

7. What type of filter can remove oil aerosols?

Answer: Coalescing (oil aerosol removal) filter.

1. A factory is located in the Southeast USA. All of piping is located indoors and not subject to freezing temperatures. The compressed air use in the factory is primarily in manufacturing production. What would be the most appropriate type of dryer to use and why?

   A refrigerated air dryer. Since the piping is indoors and wont be subjected to extreme conditions there is no need for a desiccant dryer. The refrigerated air dryer should achieve an approximate 40F pressured dew point or a -10 atmospheric dew point.

2. What type of dryer uses a porous material that adsorbs the moisture with compressed air or heat reactivation?

   Desiccant Dryer

3. What type of dryer uses a drying medium that absorbs the moisture in compressed air?

   Deliquescent dryer. (salt)

4. What type of dryer uses a material that allows water vapor to pass through pores faster than other gases thus reducing the water vapor?

   Membrane dryer.

5. What type of dryer cools the air to remove the condensed moisture before the air is reheated and discharged?

   Refrigerated air dryer.

6. Refrigerated dryer ratings are based on standard dryer inlet conditions. Dryer ratings must be corrected for conditions other than these standard conditions. What are the three conditions used for rating an air-cooled refrigerated dryer?

   Inlet temperature, inlet pressure, ambient temperature.

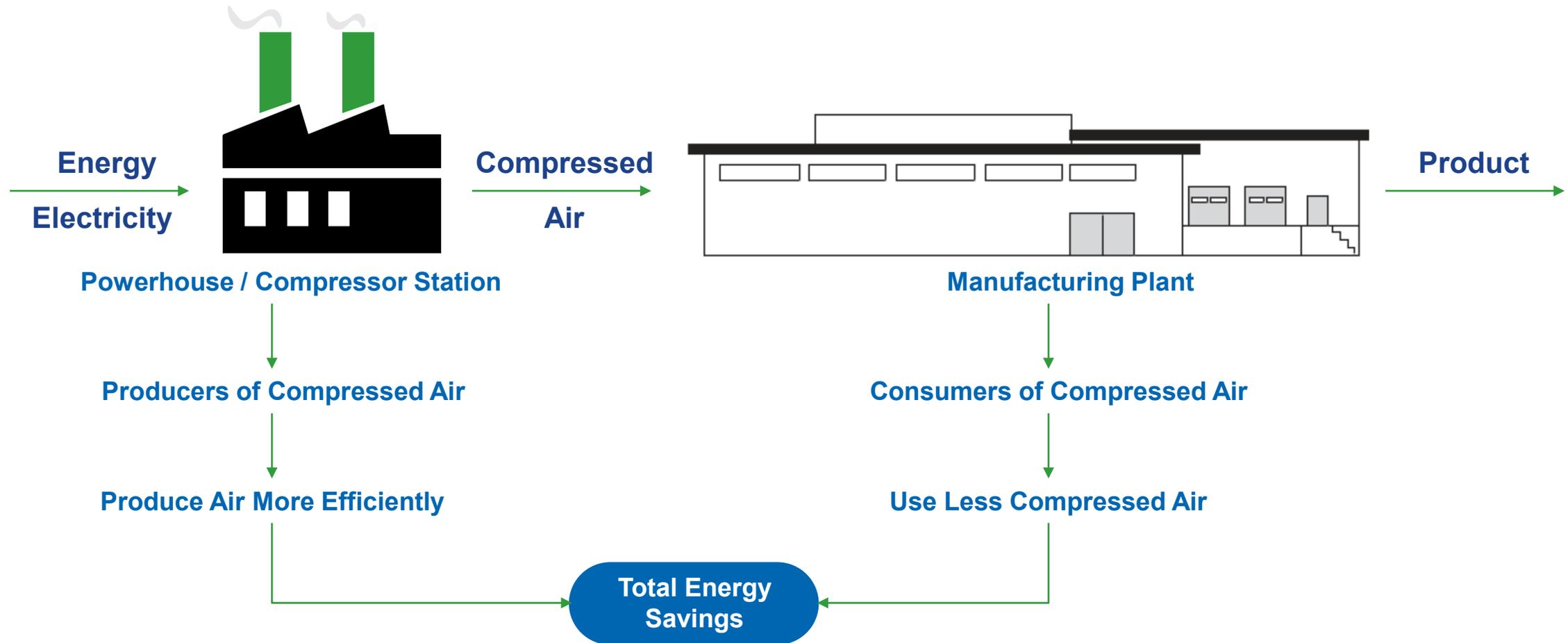7. What type of filter can remove oil aerosols?

   Coalescing filters.

Let's look back:

Session 1 Compressed Air Basics

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.

Energy Electricity → Compressed Air → Product

Powerhouse / Compressor Station

Manufacturing Plant

Producers of Compressed Air

Consumers of Compressed Air

Produce Air More Efficiently

Use Less Compressed Air

Total Energy Savings

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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.

Compressed Air Versus Other Energy Sources
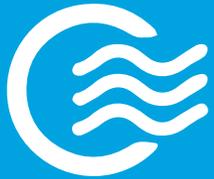
Where does the air go after it leaves the compressor room?

- 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%)

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Session 2 we reviewed:

Compressor Types
Maintenance
Compressor Room Best Practices and Ventilation

Compressor Types

- Positive displacement compressors can be reciprocating or rotary.

- Reciprocating Compressor   Rotary Compressor

Compressor Types

Centrifugal Compressor
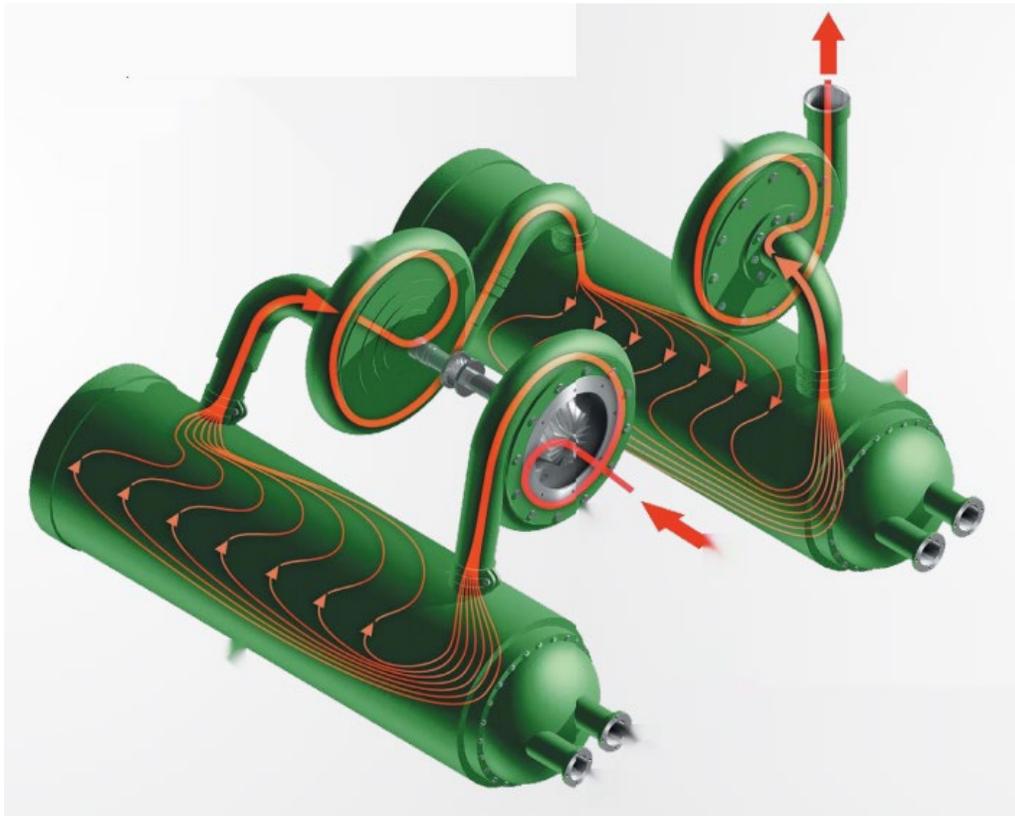
Oil Free Rotary Compressor

Timing Gears

Oil-free Rotors & Casing

Oil Seals

Two Stage Compressor
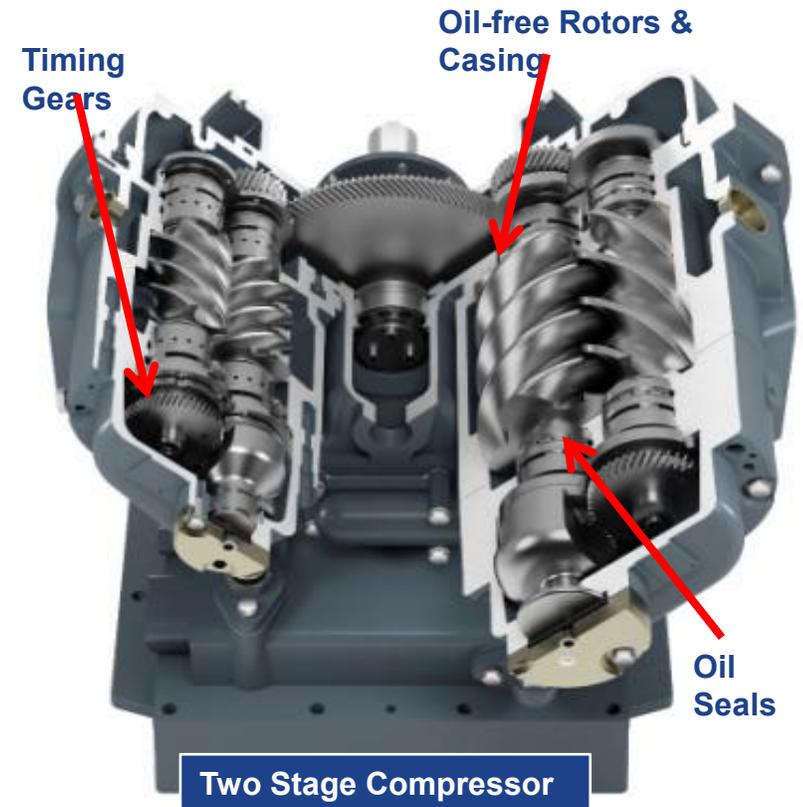
Ventilation

- All air-cooled air compressors need to operated in well ventilated and clean environments with fairly constant temperatures.

Six Common Maintenance Mistakes

1. Not performing leak management
2. Not maintaining filters, end-use filters, and lubricators
3. Ignoring air dryer and condensate trap maintenance
4. Poor ventilation
5. Not taking temperature measurements
6. Not performing lubricant analysis

Compressor Controls

Various Compressor Control Performance Curves
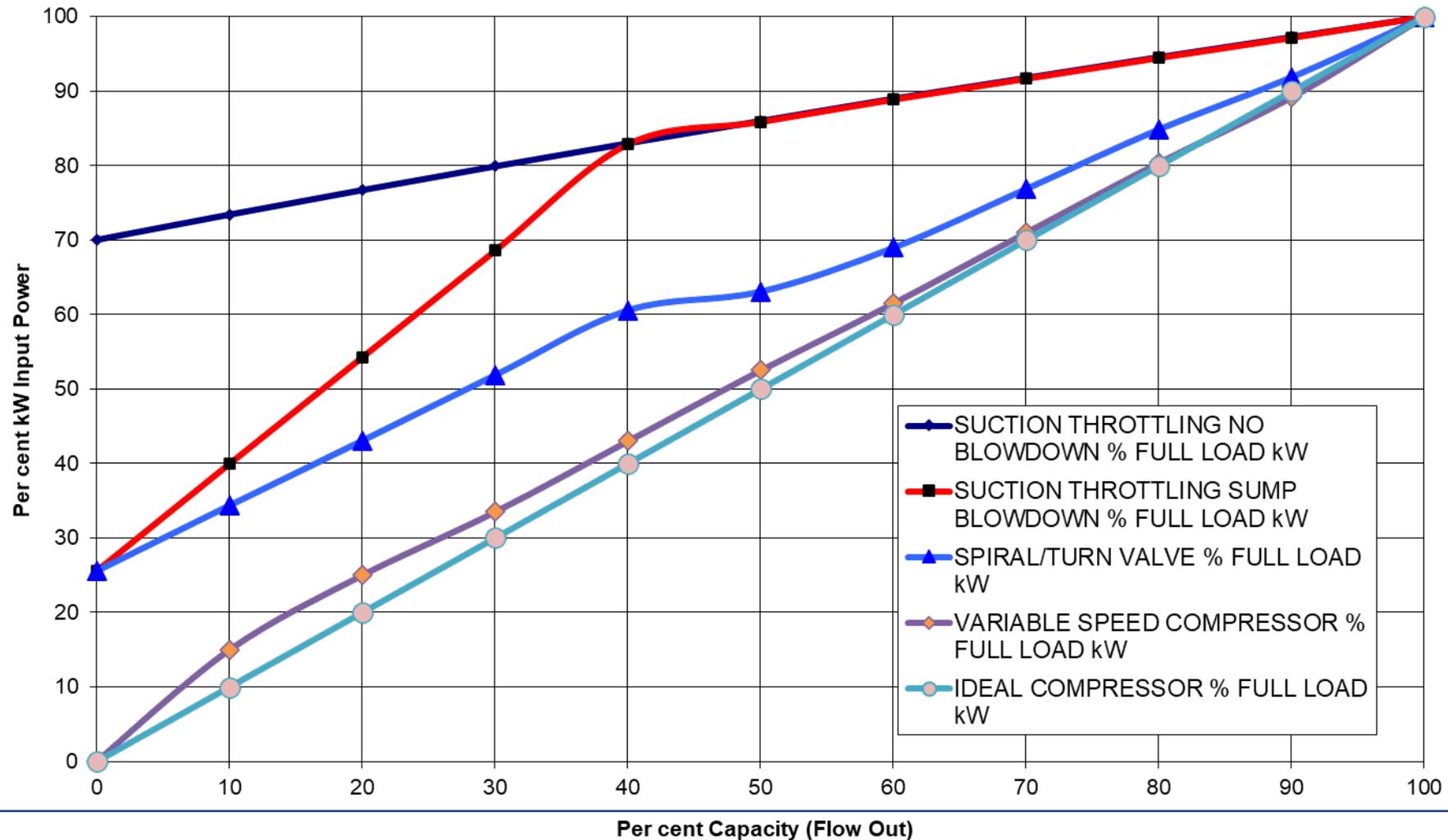
Compressor Control

300 ACFM
Base

Running

300 ACFM
Trim L/NL
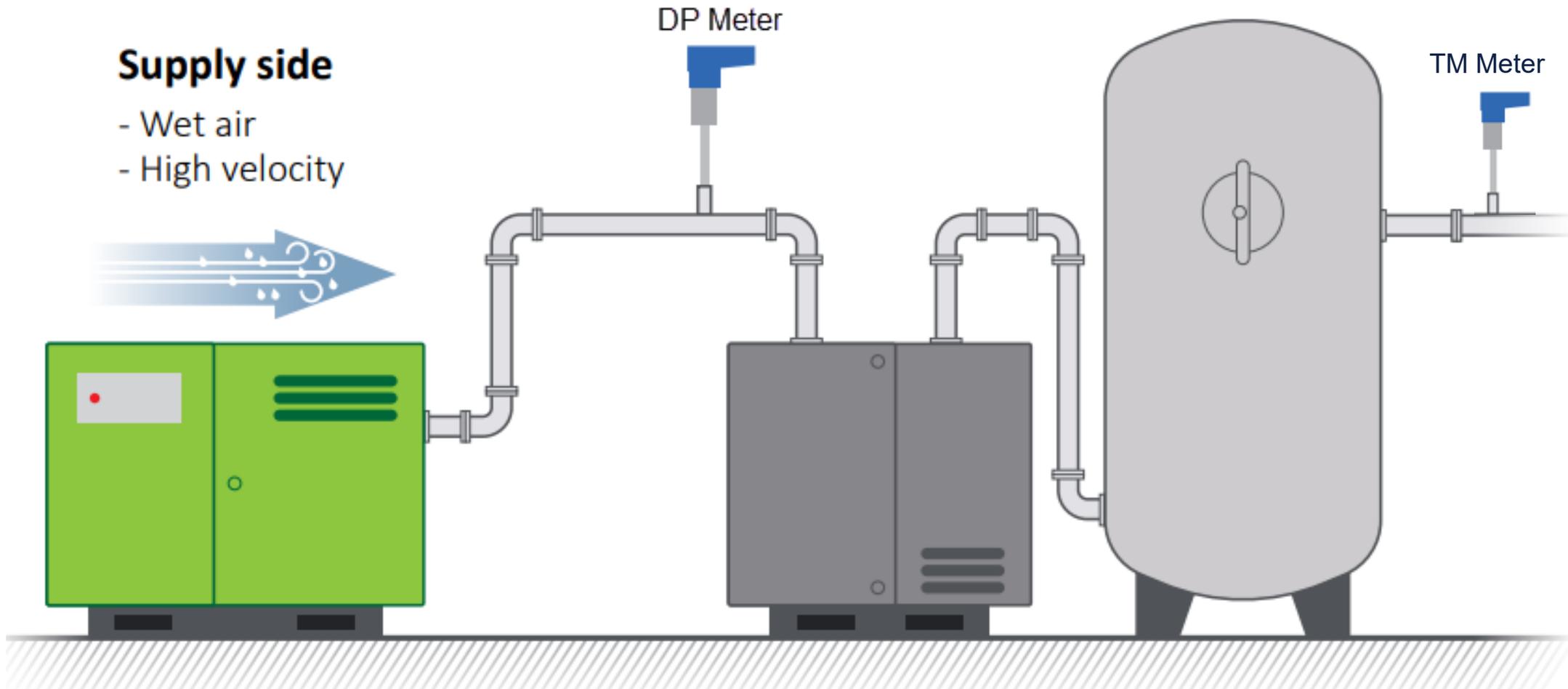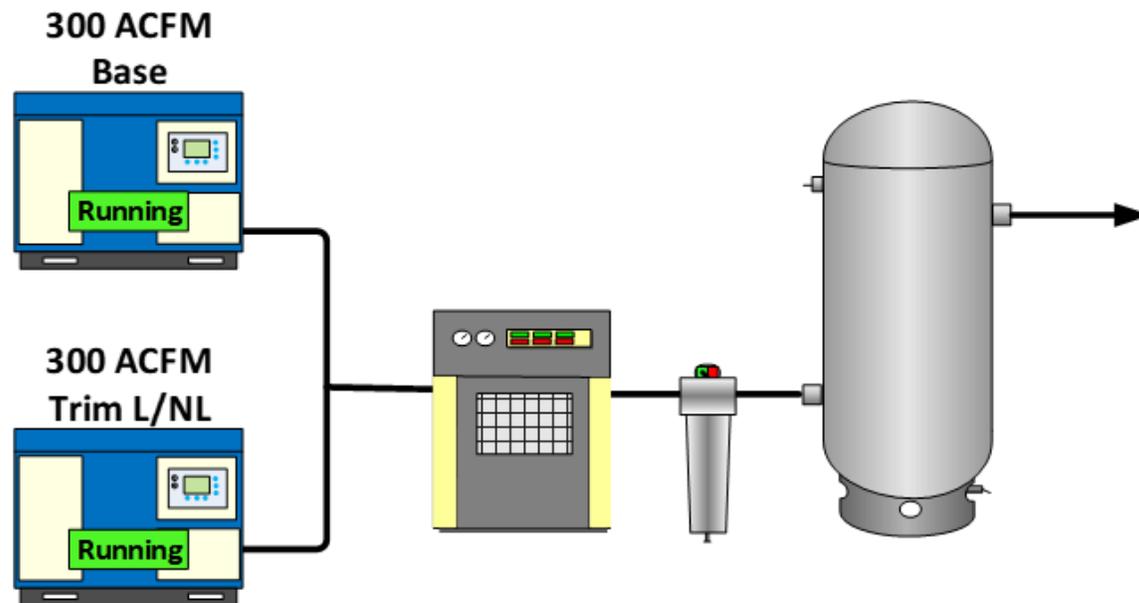
Running

- 100 ft of 6" pipe, 80 ft of 4" pipe 100 ft of 3" pipe and 600-gallon receiver.
- #1 running base load and #2 running trim
  - **40 seconds load @ 100 psig**
  - **25 seconds unload @ 110 psig**
- What is the load supplied by the trim compressor?

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

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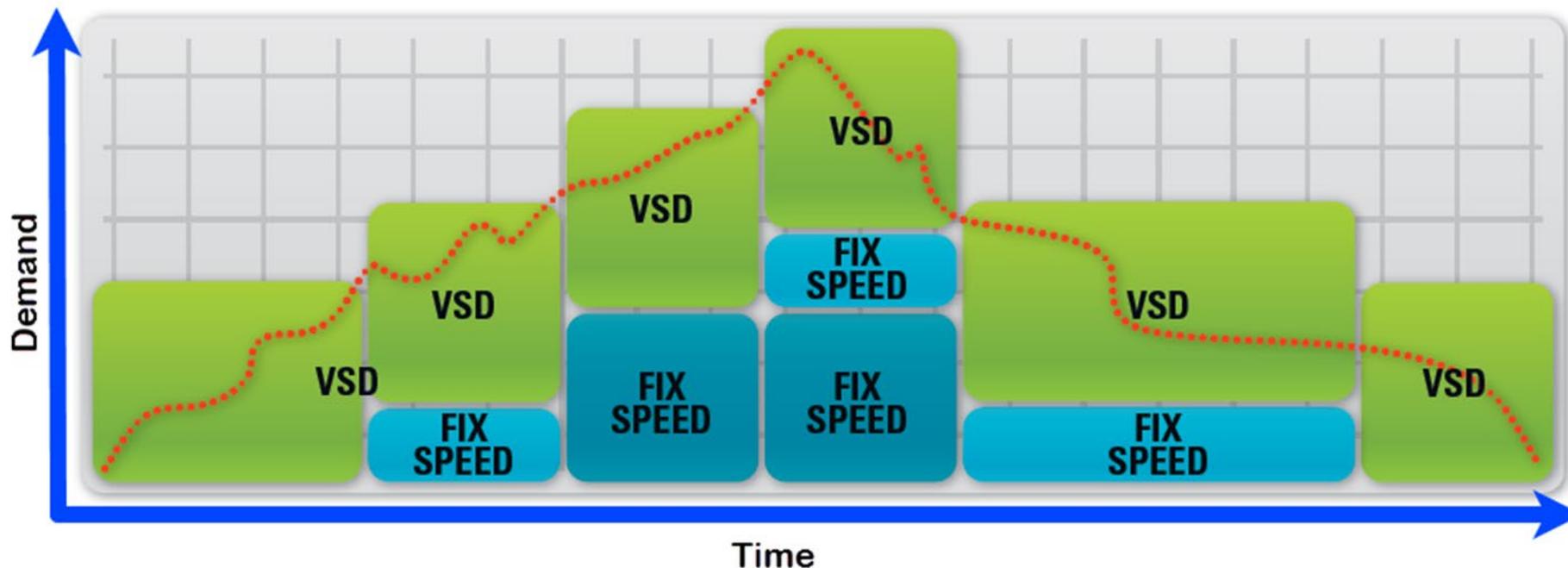
How do I know my flow patterns to size a VSD Correctly?

Flow Histogram
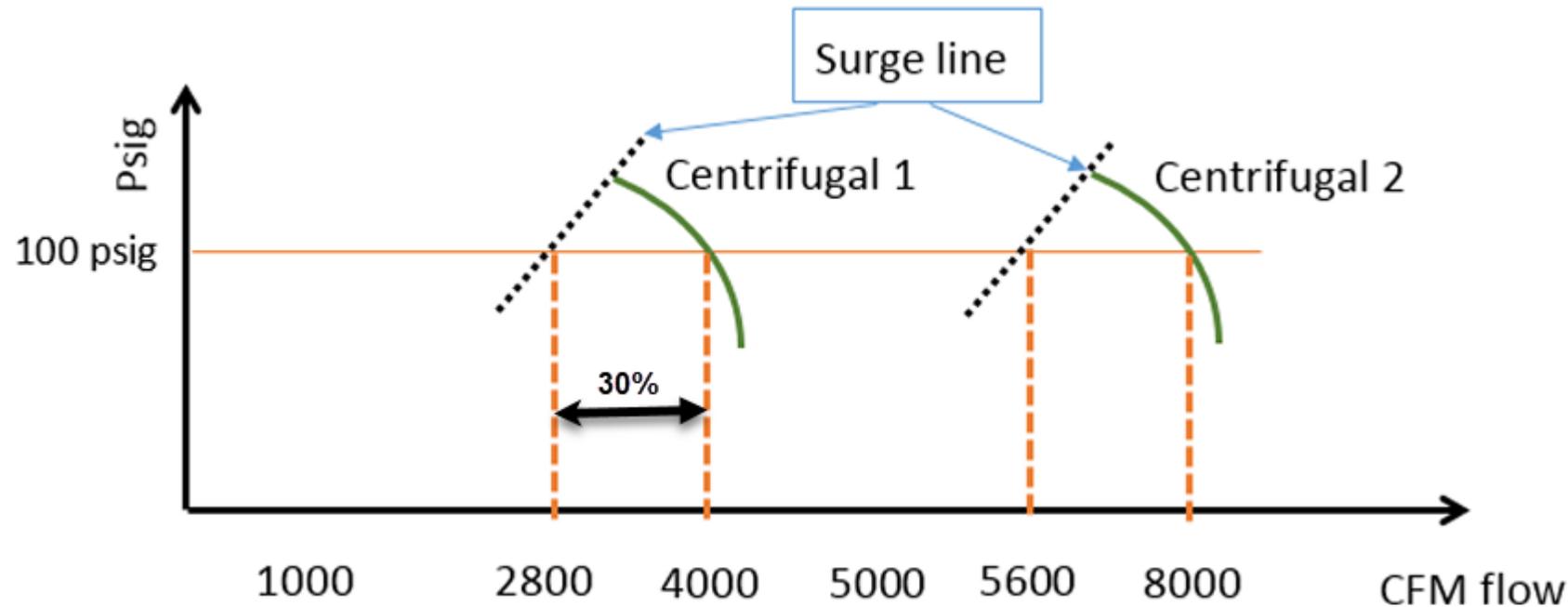Mean=658.2, Standard Deviation=124.469, Skewness=-0.238556
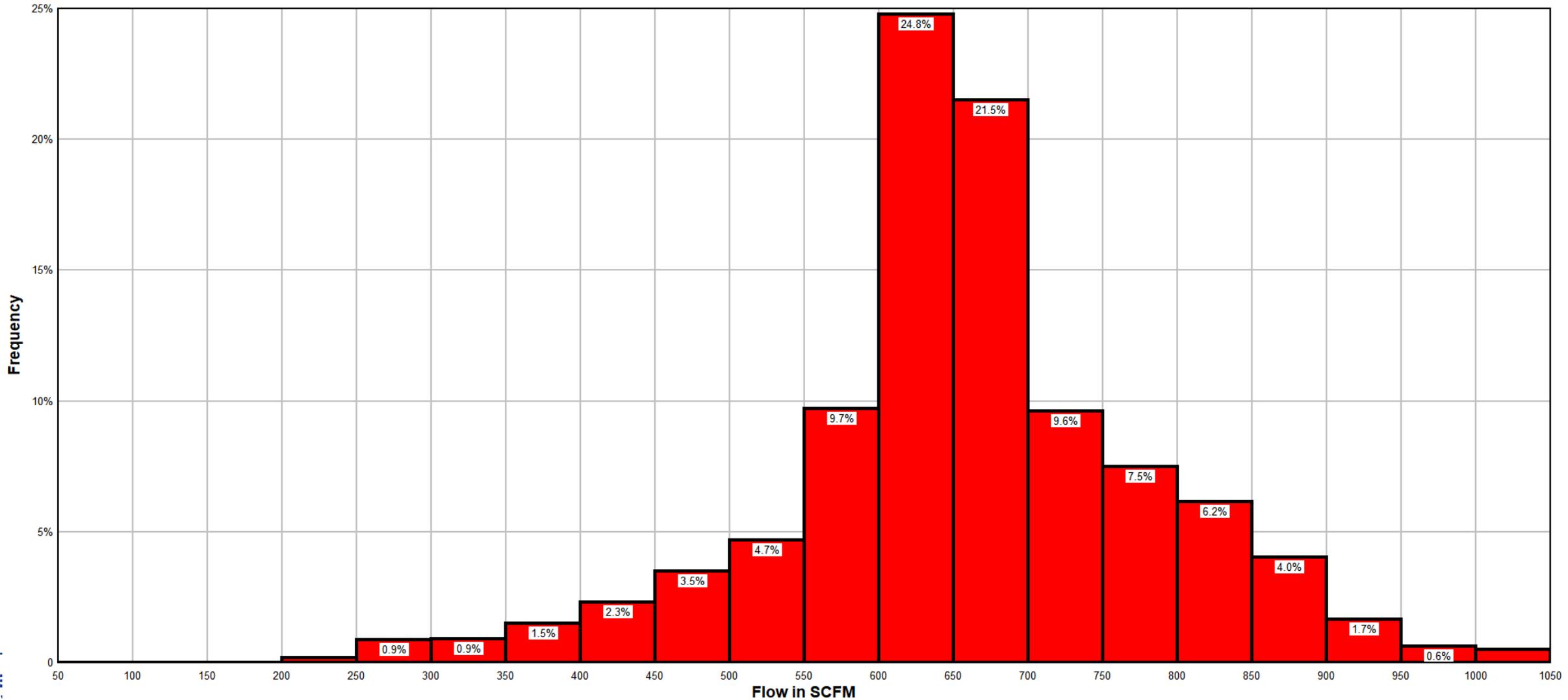
# How do I know how to size Centrifugal to my flow Patterns?
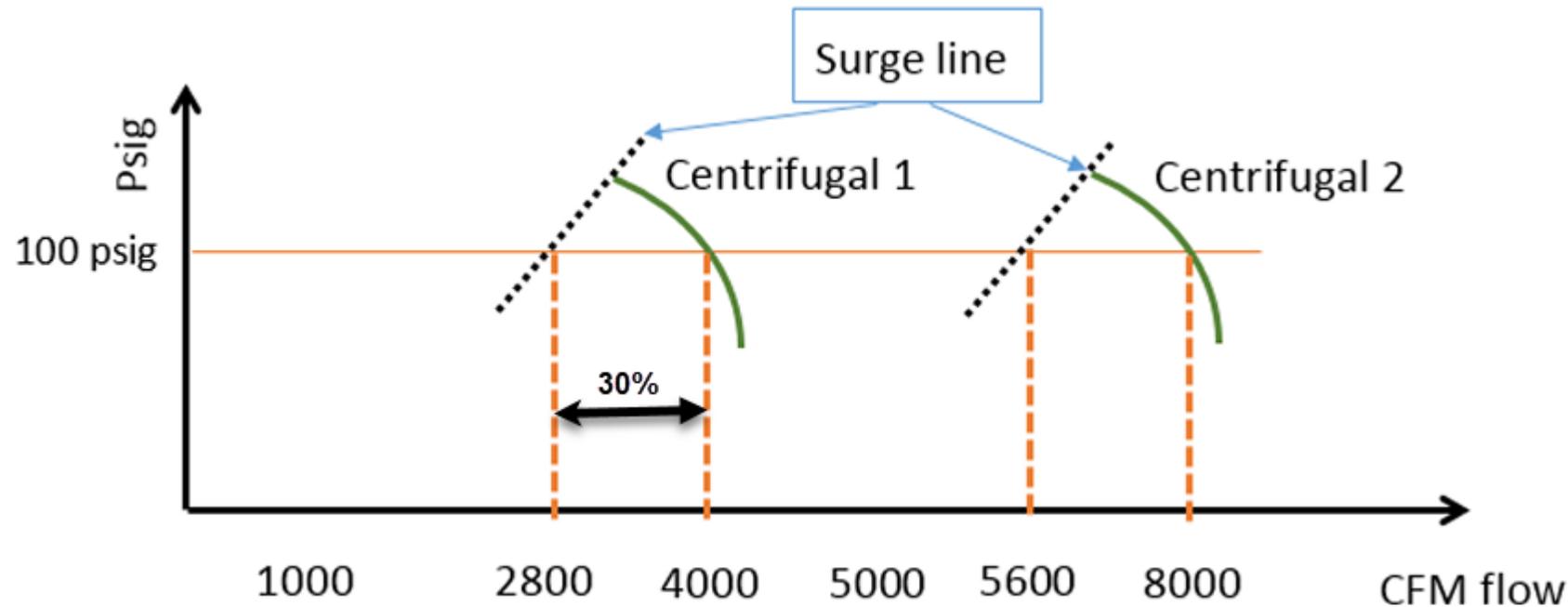
- Plant has 8000 cfm peak demand, 5800 cfm average demand, and 3000 cfm minimum demand during weekends at operating pressure of 100 psig.
- Two 4000 cfm centrifugals with a 30% turndown to 2800 cfm

How do I know how to size Centrifugal to my flow Patterns?

- During peak demand of 8000 cfm, both compressors will run at full load.
- When the flow demand is reduced to the average demand of 5800 cfm, the two centrifugal compressors will close the inlet guide valve and run in its turndown range without exhausting any compressed air to atmosphere.

How do I know how to size Centrifugal to my flow Patterns?
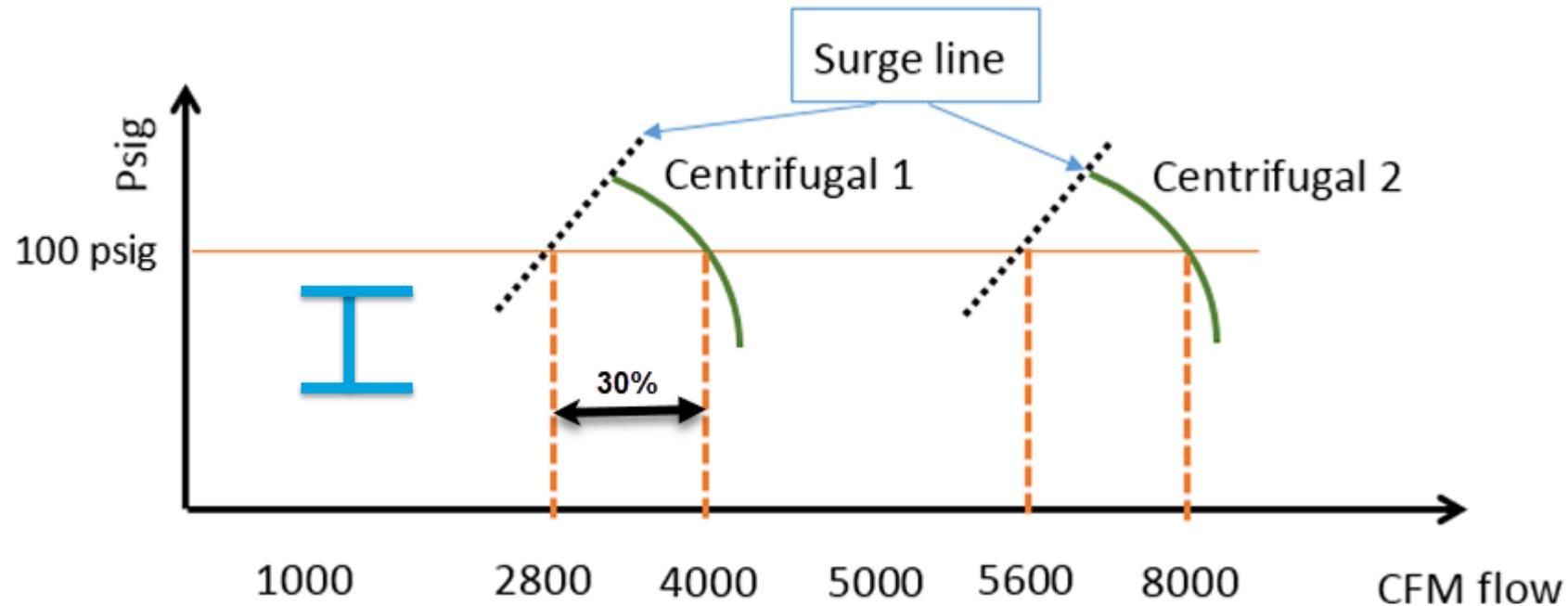
- During the weekend, when the demand reaches to minimum flow of 3000 cfm, one centrifugal compressor will stop and only one compressor will run in its turndown range.
- With this combination, the centrifugal compressors will work most efficiently and save a plant significant energy.
- If flow drops below min flow of the centrifugal, a rotary screw can be added to assist with keeping the plant operating and allowing the centrifugal to stay out of blow down.

Air Treatment

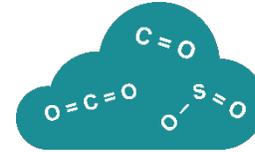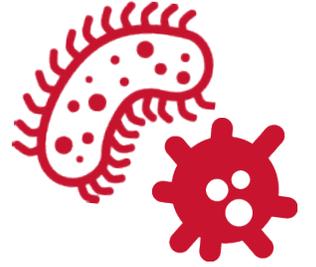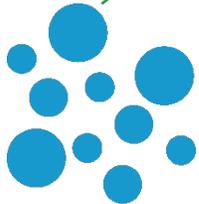# Which Contaminants do we find in compressed air?
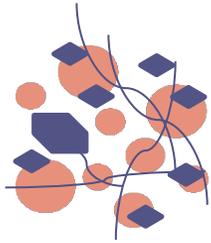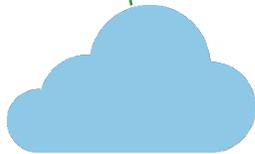
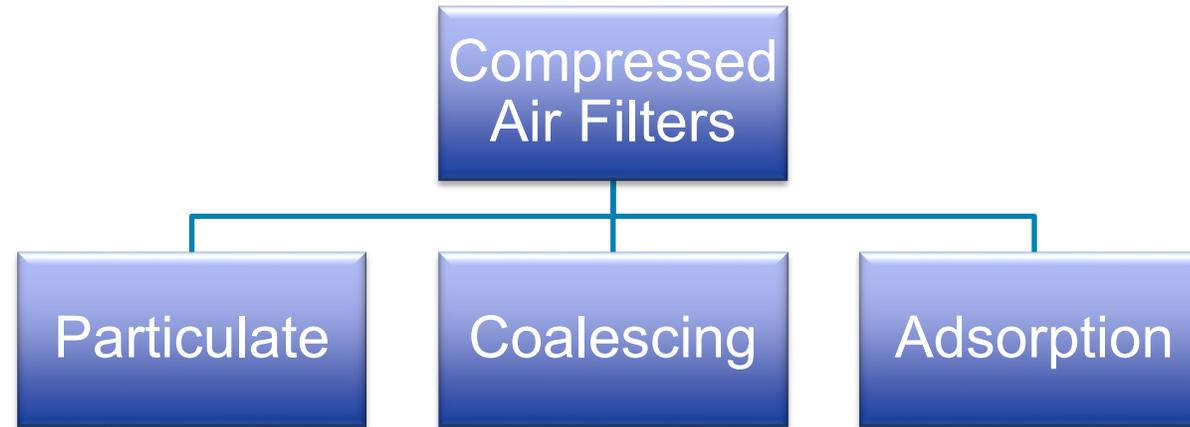| SOLID - PARTICLES | WATER | OIL | GASEOUS CONTAMINANTS | MICROBIOLOGICAL CONTAMINANTS |

| LIQUID | VAPOR (HUMIDITY) | LIQUID (AEROSOL) | VAPOR (HYDROCARBON) |

Compressed Air Filters

ISO 8573-1 Compressed Air Quality Classes Simple Chart

ISO 8573-1:2010 Compressed Air Quality Classes

Class	Max. Particle Size		Pressure dewpoint		Max Oil Content
	(μm)	(mg/m^3)	(°C/°F)	(g/m^3)	(mg/m^3)
0	Specified by the equipment manufacturer/supplier and greater than class 1				
1	0.1	0.1	-70/-94	0.003	0.01
2	1	1	-40/-40	0.12	0.1
3	5	5	-20/-4	0.88	1
4	15	8	3/37	6	5
5	40	10	7/45	7.8	25
6	--	--	10/50	9.4	--
7	--	--	Not Specified		--

Note: the Class 0 certification was created in response to industry needs for oil-free air. Stating Class 0 without an agreed specification will mean it is not in accordance with the standard. Class 0 air purity is best achieved at the point of use to minimize cost.
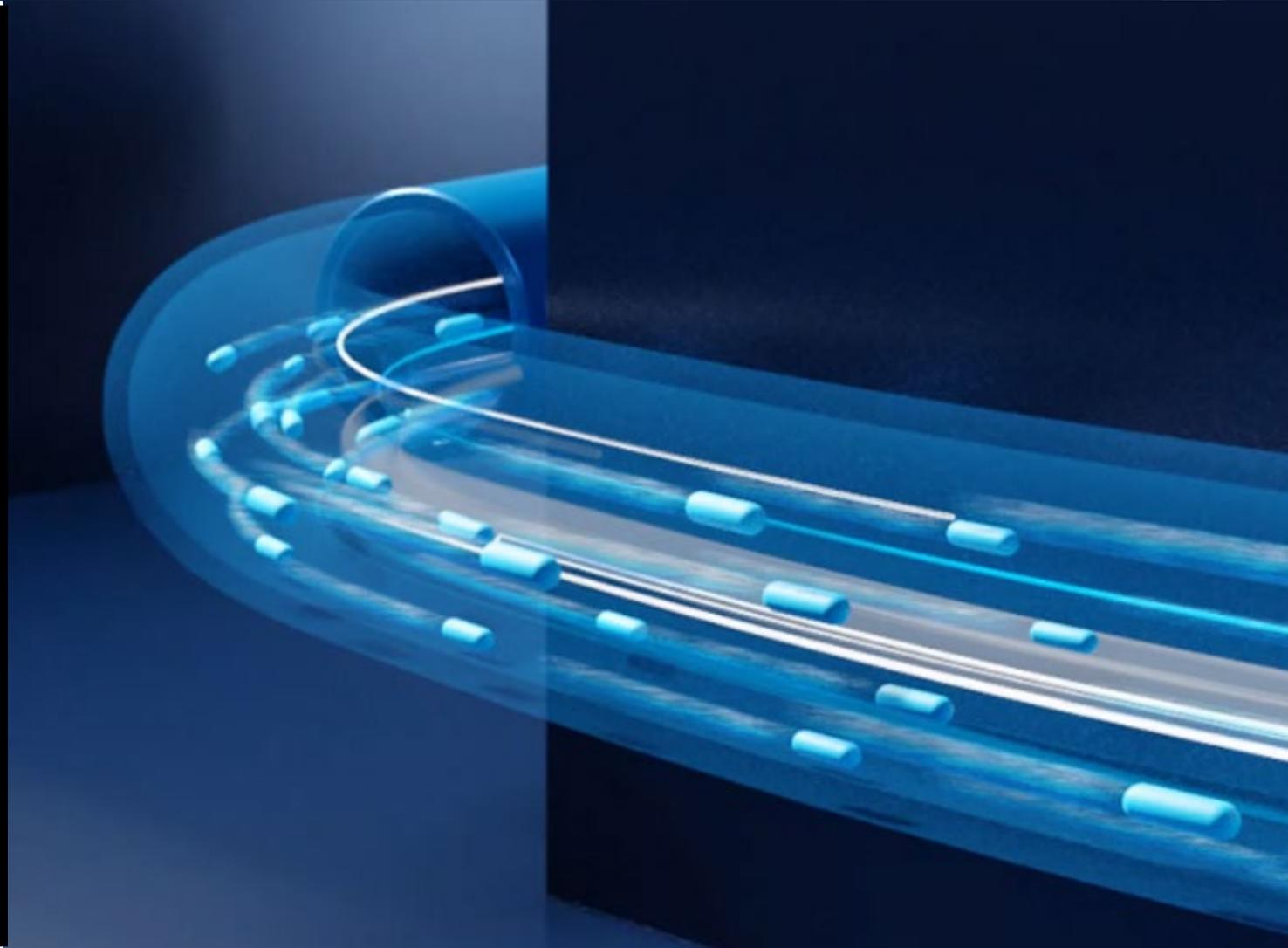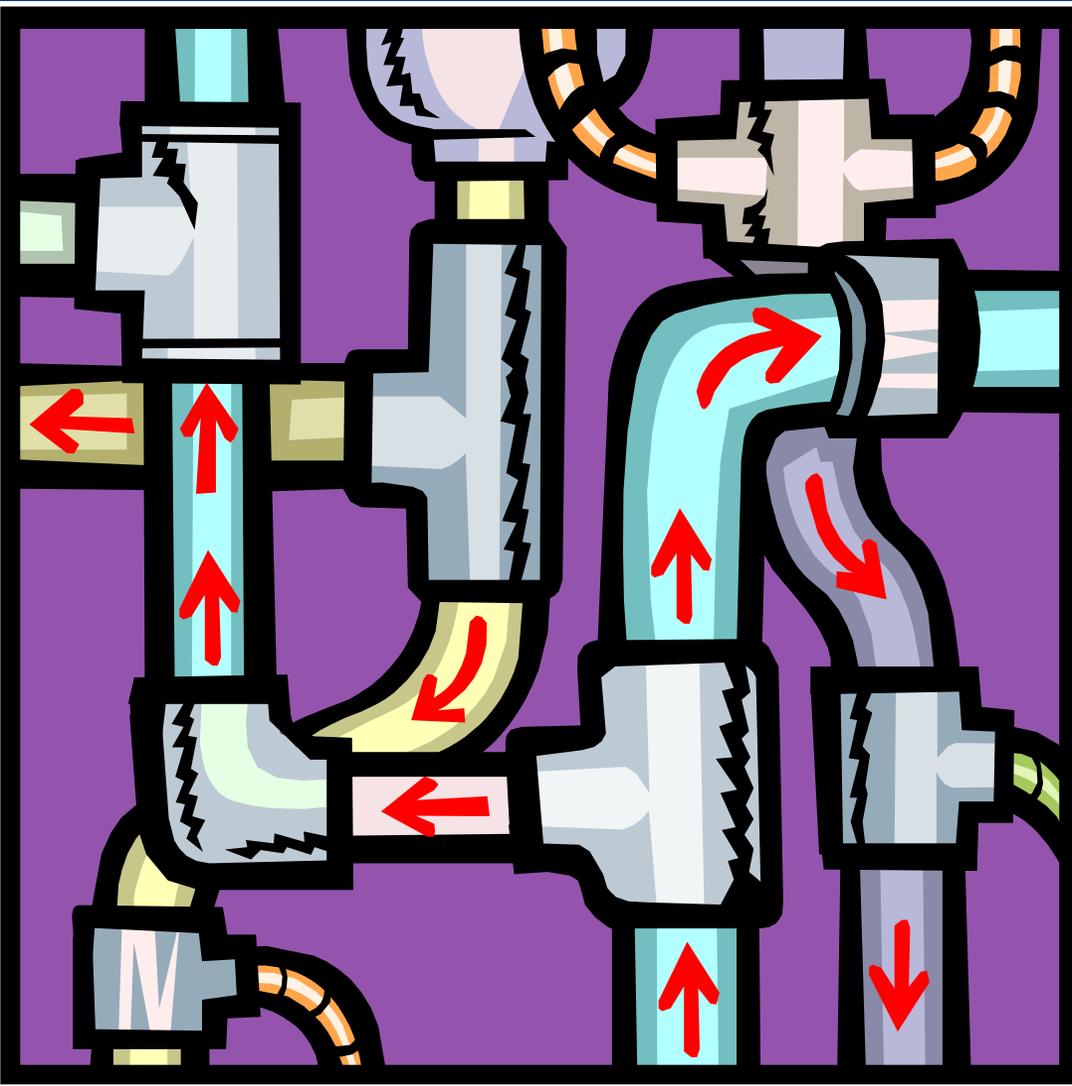
Specifying the Right Dryer

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.

Distribution System

- The purpose of the distribution system is to ensure the right rate of flow of compressed air, at the right pressure, temperature and quality, for each end use application.
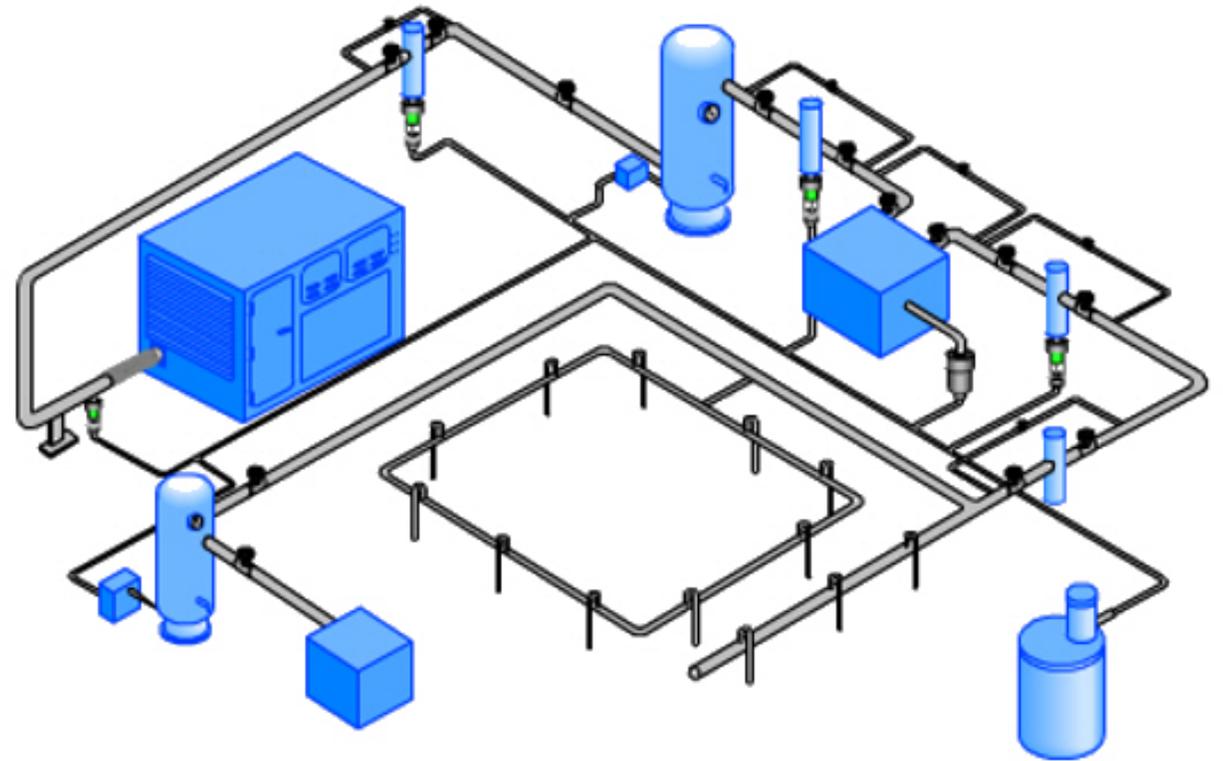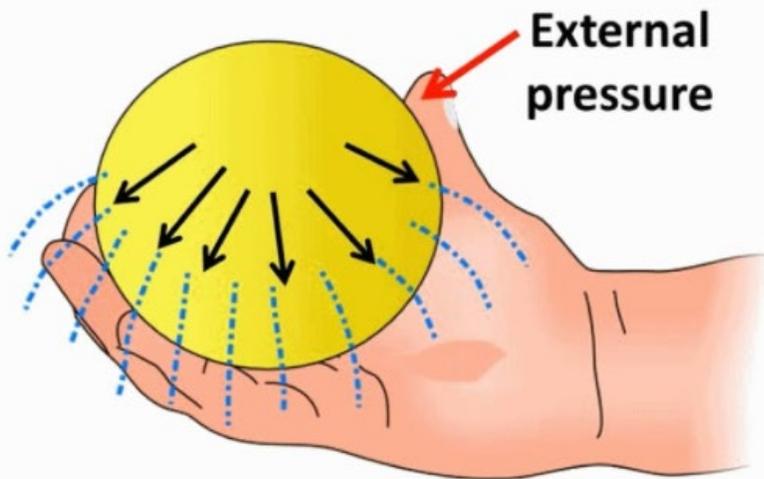
Pascal's Law

His principle of Hydrostatics is stated as follows:
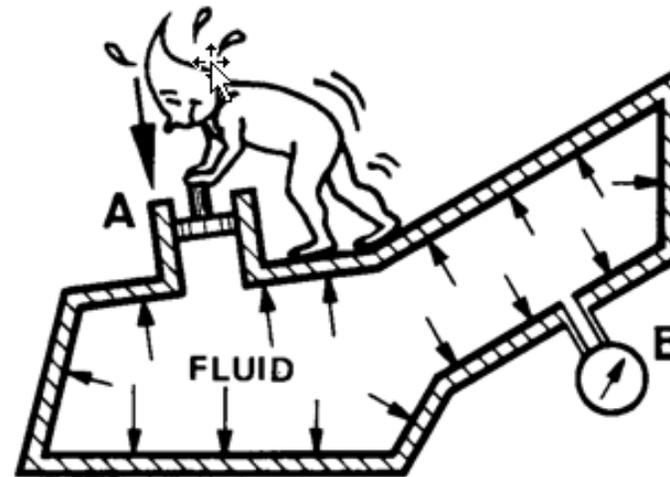
"pressure set up in a confined body of fluid acts equally in all directions and always at right angles to the containing surfaces"

Pascal's law

External pressure

Pressure applied on one point of liquid transmits equally in all direction
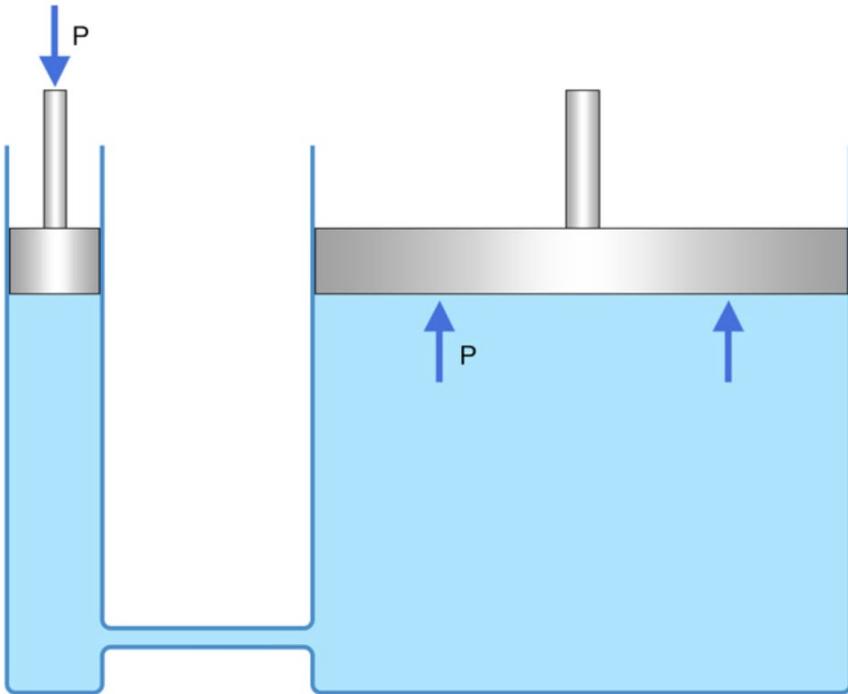

A

FLUID

B

Blaise Pascal (1623 – 1662). His discoveries are important to the technology of modern fluid power transmission.

Pascal's Law

Pascal's Law

Pressure (P) applied in one part of an incompressible fluid is transmitted undiminished in all directions

Pascal's Law

Original Force F1 = P1 x A1

Output Force F2 = P2 x A2
10 x greater than original force

A1 (Area)

A2 (Area) 10 x A1

Fluid

Pressure

$$P1 = \frac{F1}{A1}$$

Pressure

$$P2 = \frac{F2}{A2}$$

Pascal's Principle
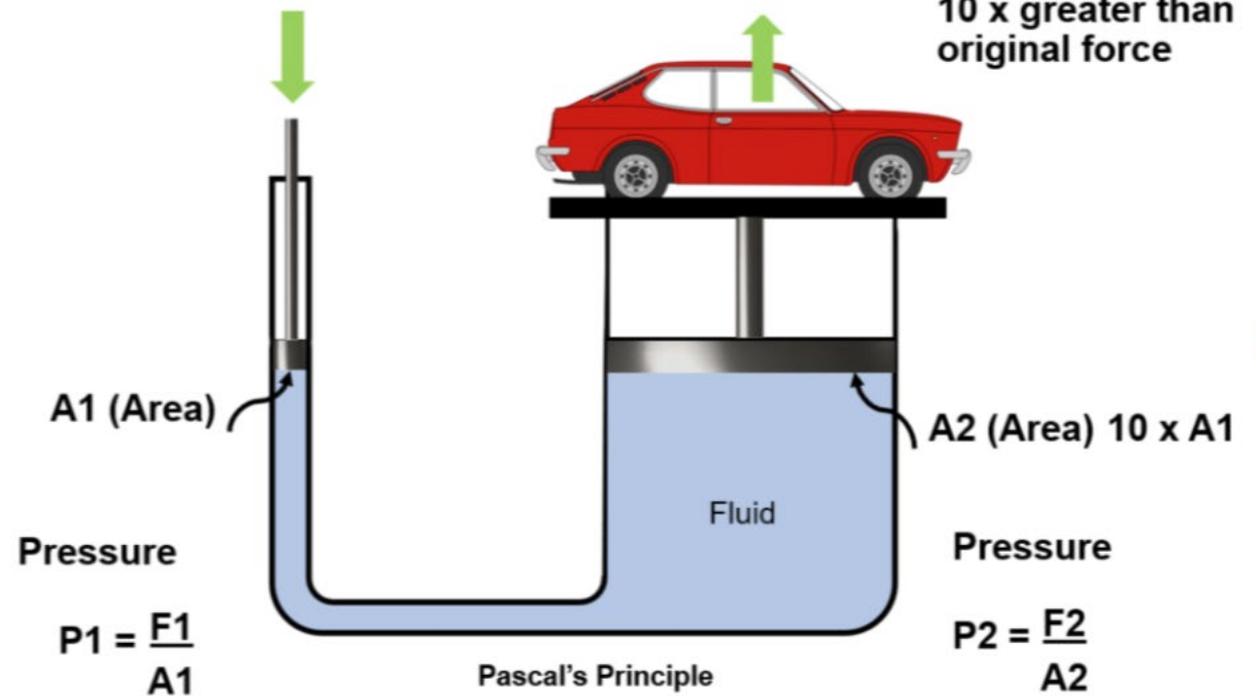
Pressure equal throughout. Therefore P1 = P2

French mathematician Blaise Pascal established this law in 1653 and published it in 1663.

Transmission of Force Through Fluids
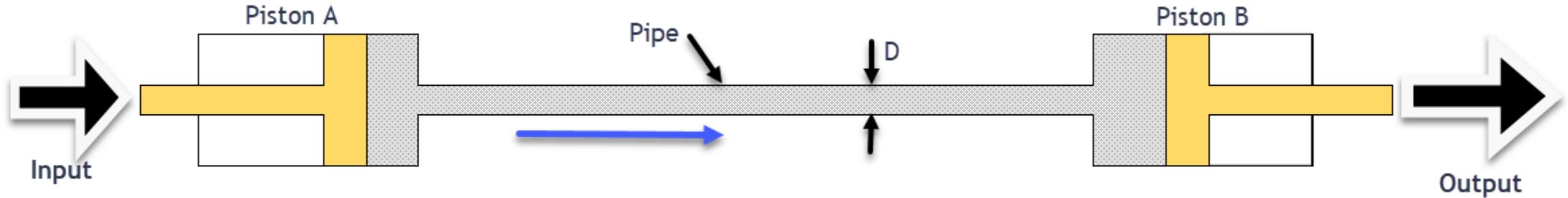
How large in diameter must this connecting pipe be?

- If pistons A and B are used simply to transmit force with no movement of the pistons, they will do equally well no matter how small the diameter of the connecting pipe. PASCAL's law still applies.
- If the fluid must move through the pipe for transmitting work or power, the pipe diameter should be selected by the volume of free air that will be conveyed through it.
- If the diameter is too small, frictional losses might be too high and if the diameter is unnecessarily large, the plumbing costs might be excessive.

Transmission of Force Through Fluids
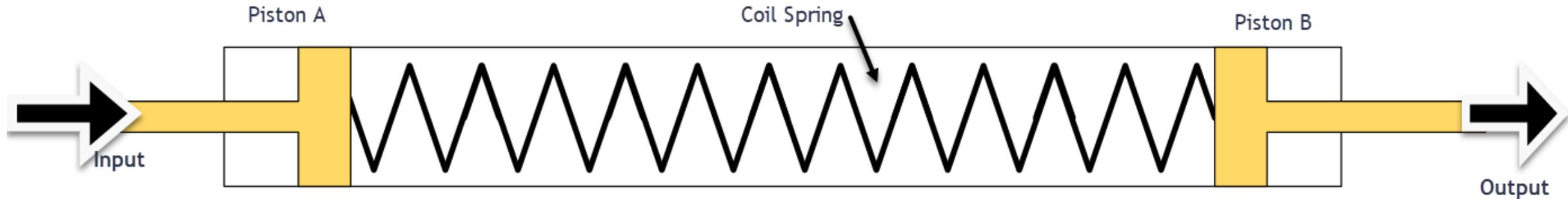
- Transmitting force through compressed air is like transmitting force through a spring.
- Force applied on piston A will produce a force output on piston B although the spring will compress to some extent while transmitting the force.
- While compressed air is an excellent medium for transmitting power, its greater compressibility does limit its use on certain applications where fluid rigidity is required to get a smooth (non-erratic) movement of a piston or similar device.

Reducing Pressure Drops Throughout the System
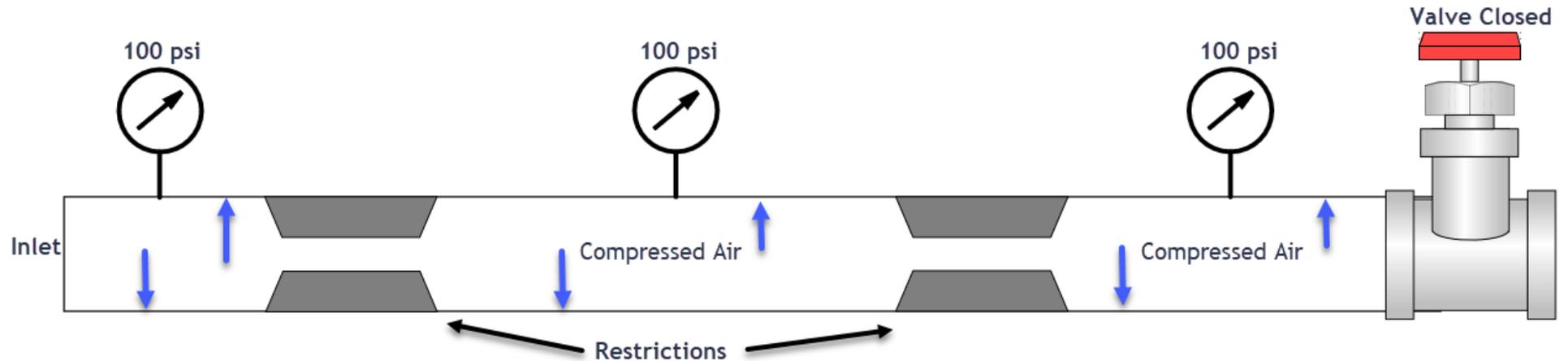
- A very important point to remember about pressure loss is that it only appears when fluid starts to flow.

- As long as the fluid is static, (non-moving) there is no pressure loss.

- Pure force without movement of compressed air can be transmitted through extremely long piping systems.

- This is analogous to an electrical circuit where there is no loss of voltage until current starts to flow.

- In above diagram, the air is not moving through the pipe, therefore pressure only can be transmitted through the pipe no matter how long the pipe is.

- This represents a confined body of fluid which obeys PASCAL's law.

Reducing Pressure Drops Throughout the System
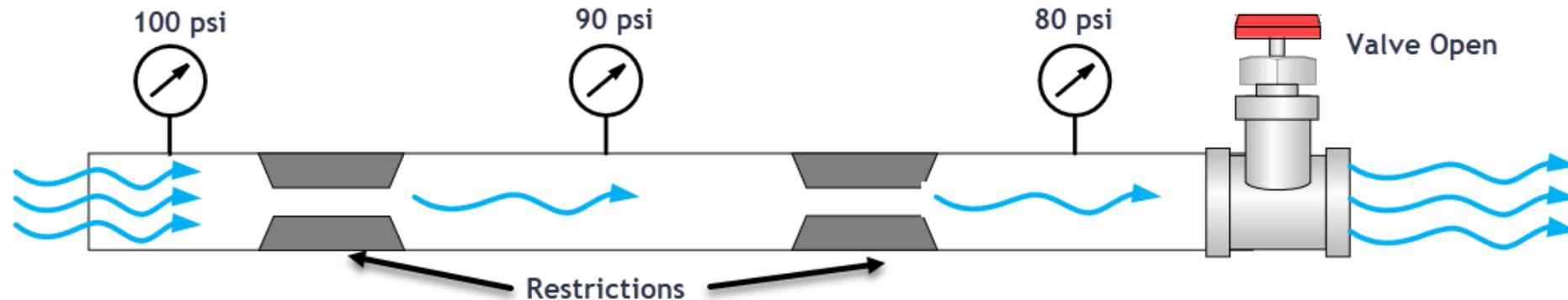
- When an operator opens the valve, the fluid (compressed air) starts to flow

- The system no longer qualifies as a "confined body" under Pascal's law

- Now the pipe diameter and restrictions in the pipe become very significant

- A large part of the inlet 100 psi may be used up in pushing the flow of air through the various restrictions.

- Full inlet pressure is no longer available on the outlet end of the pipe.

- Since the restrictions consume a part of the inlet pressure, they also consume the same proportion of horsepower which is being transported through the pipe

Reducing Pressure Drops Throughout the System
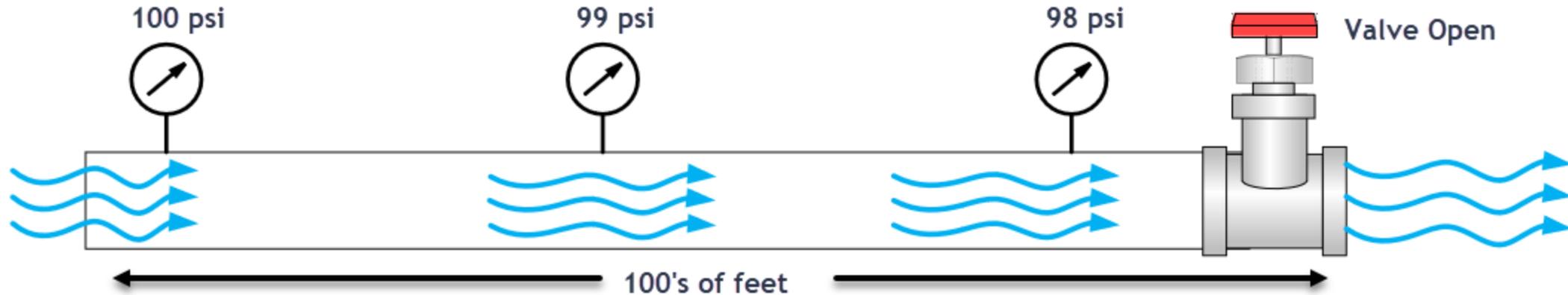
- When major restrictions are removed and the pipe is made sufficiently large to carry the flow, a relatively small proportion of inlet pressure will be sacrificed to flow losses.

Pipe Fittings

- Every fitting adds its share to the overall power loss in the system
- A certain amount of energy is lost every time the compressed air changes direction
- It must decelerate to zero velocity, in the direction it was going, then accelerate back up to speed in the new direction
- The kinetic energy lost in changing direction escapes from the system in the form of heat
- The compressed air has a better chance of remaining in laminar flow if bends are kept smooth and gradual
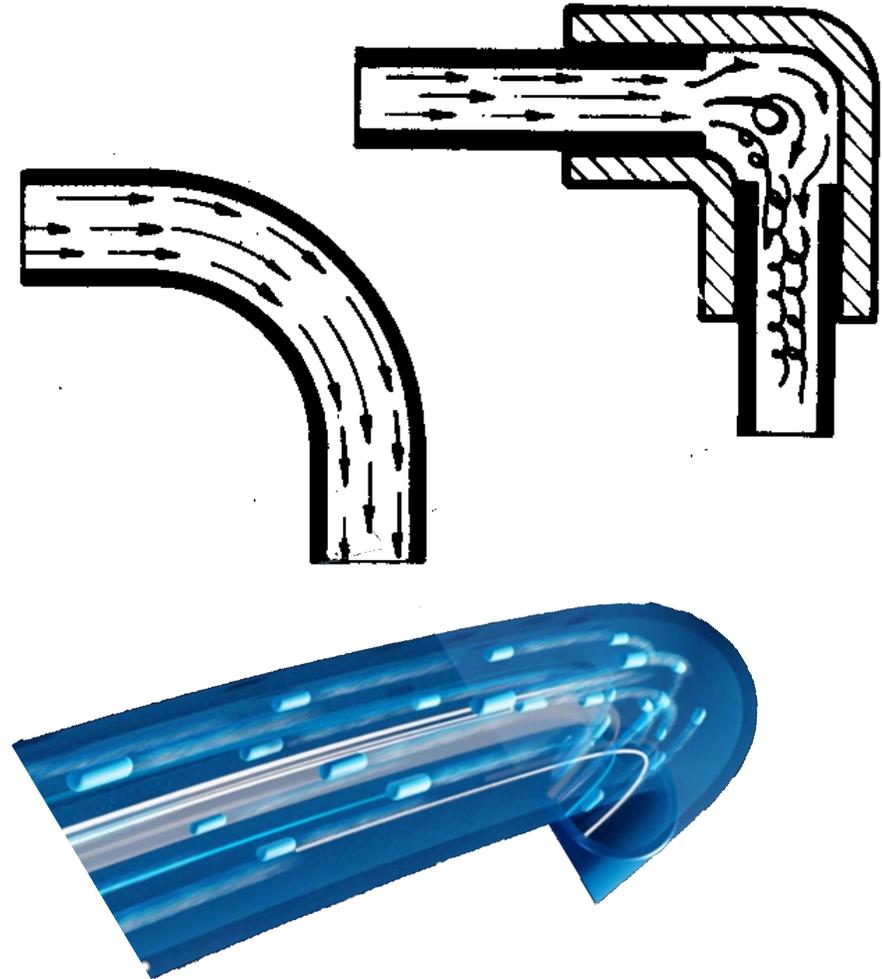
Piping Systems
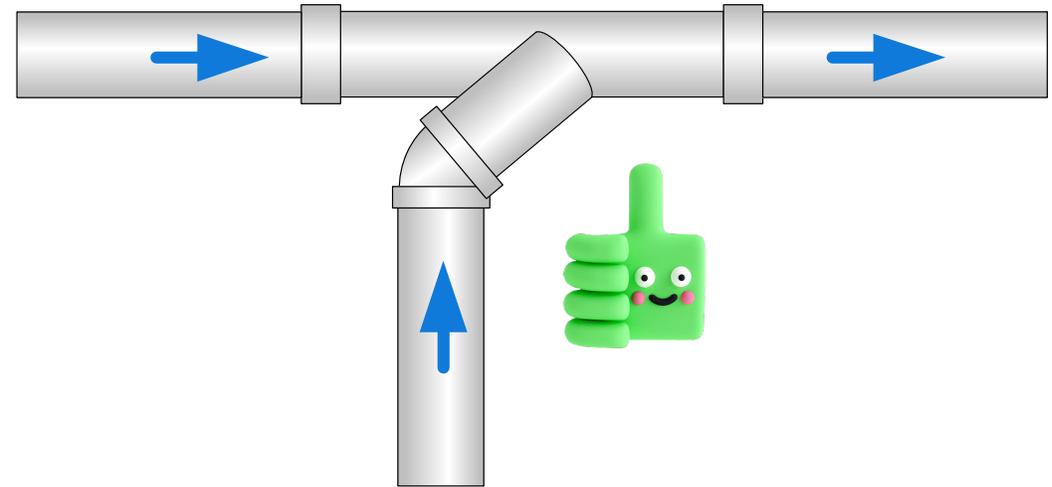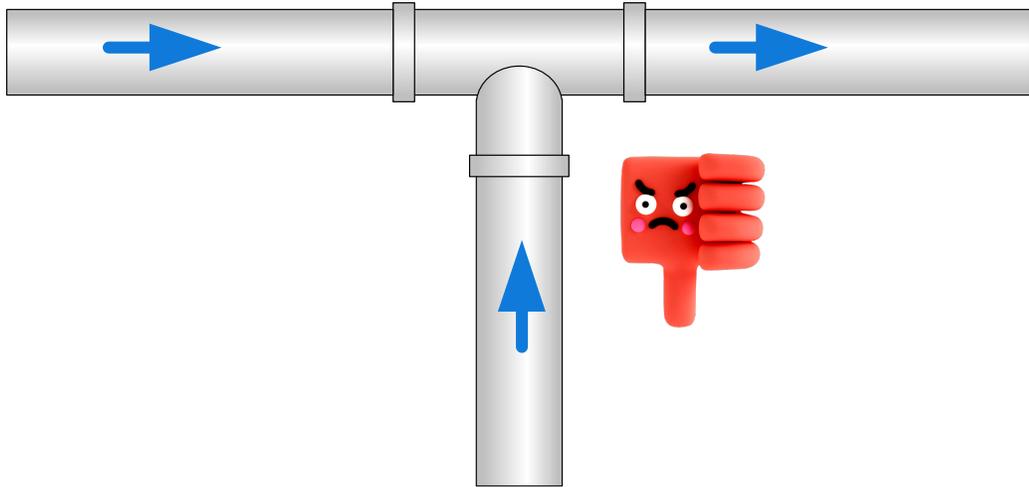
Condensate Removal

Condensate Removal

Poorly drained compressed air or steam pipe

Waves generate in pipe dip

Air or Steam flow

Condensate

Slug forms and is carried forward possibly damaging fittings

Air or Steam flow

Condensate

Superior drain tee

Air

Air & Water

Water drains

Connects to float trap
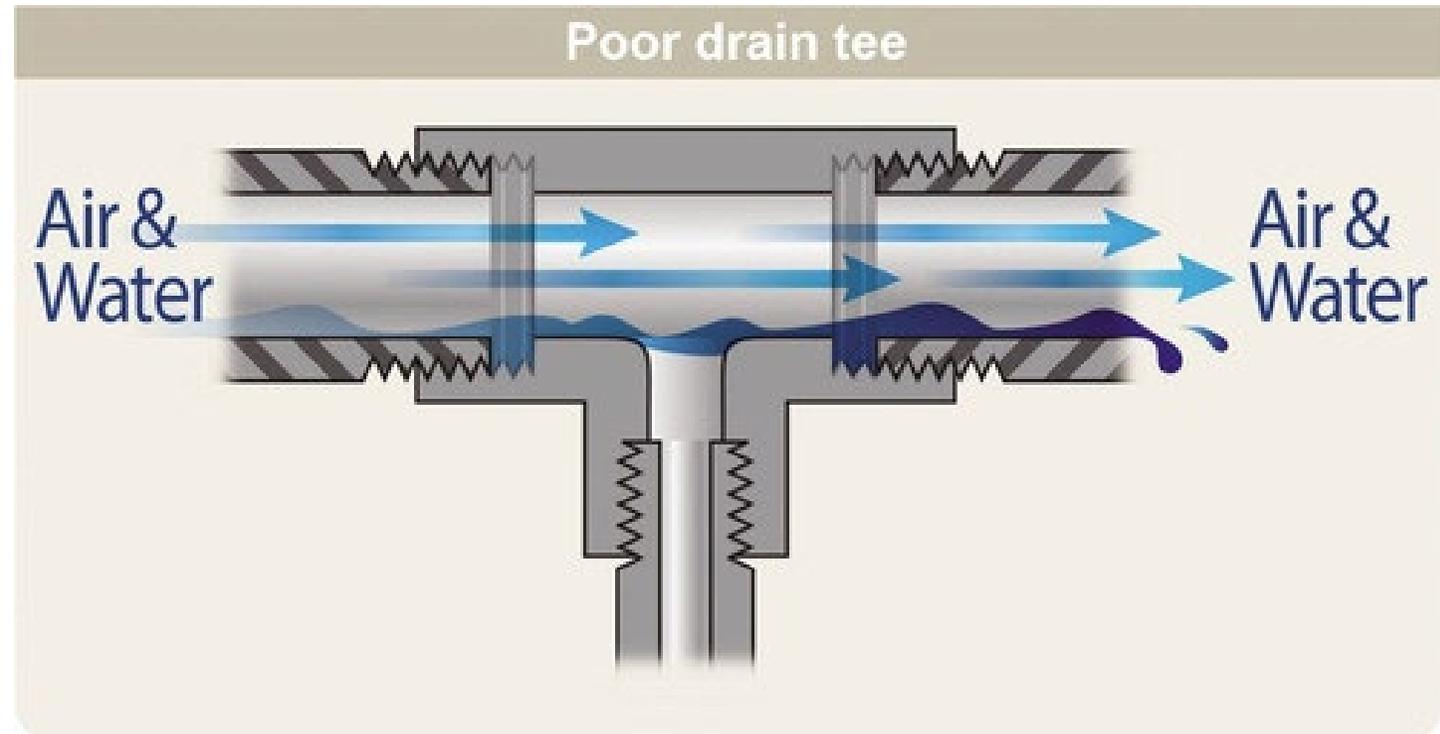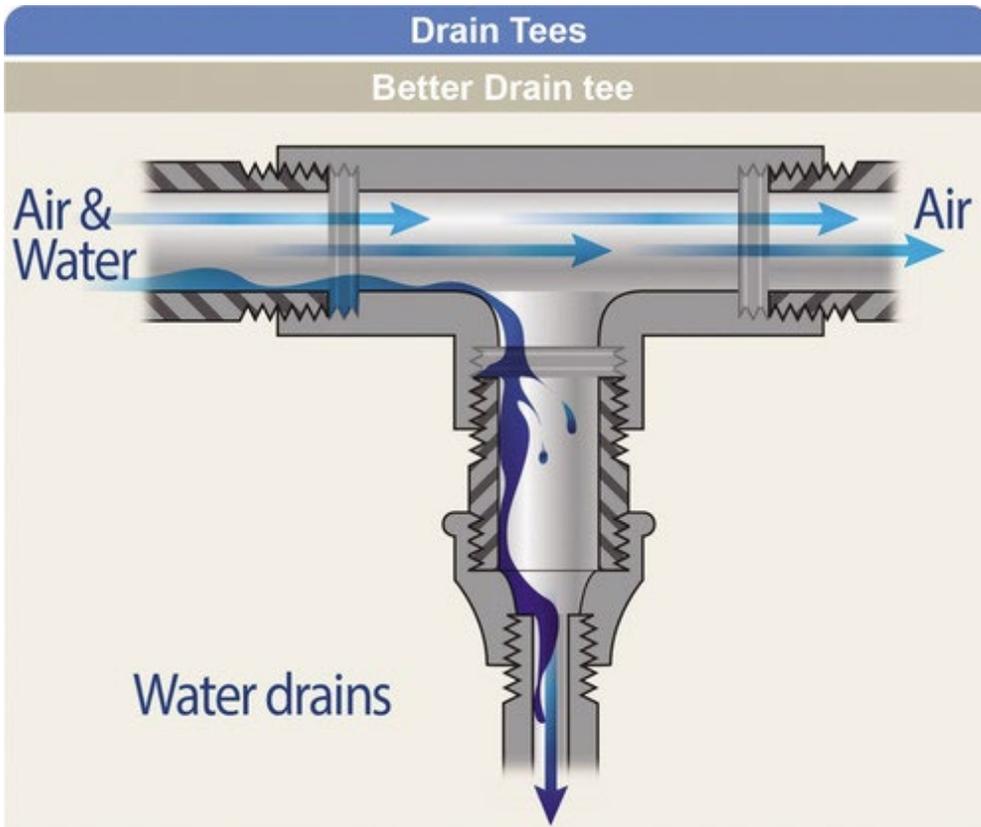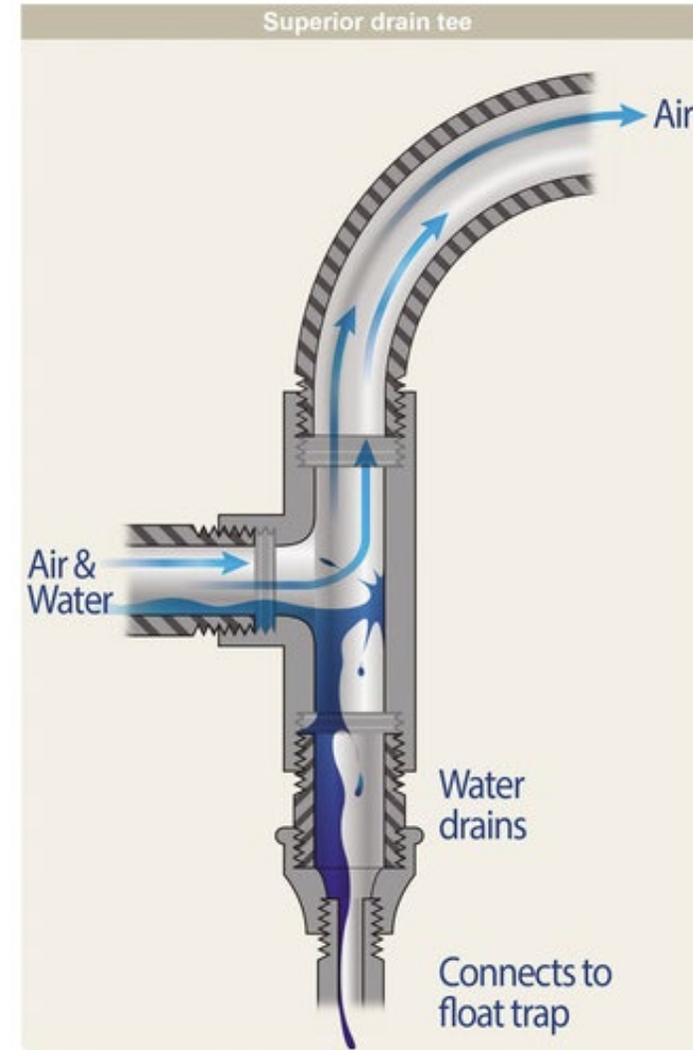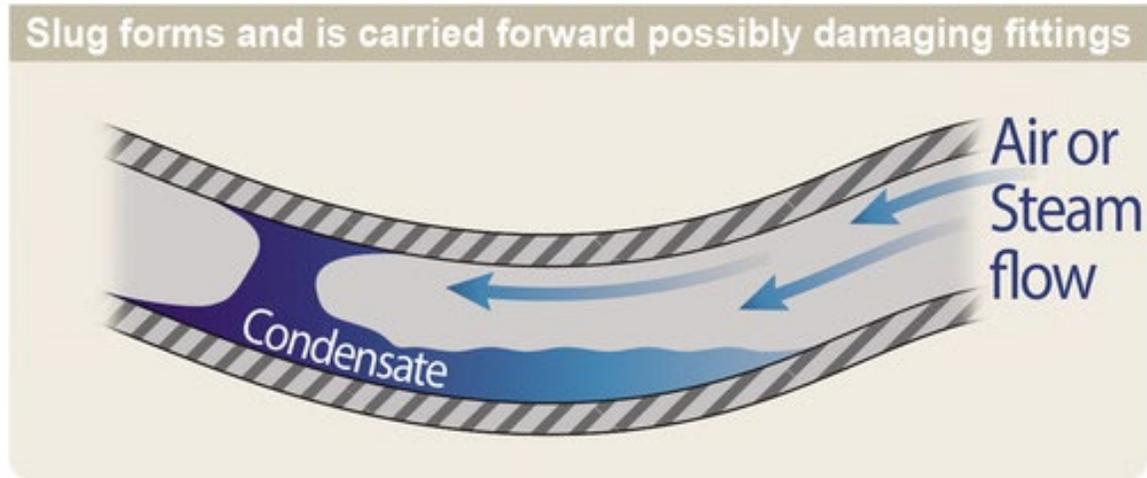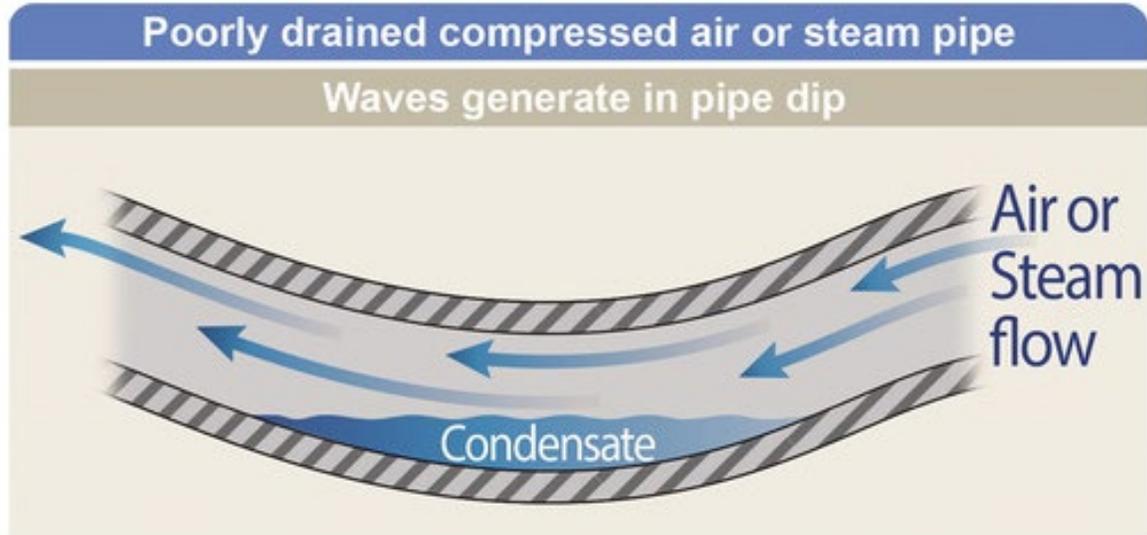
Rubber Hose Losses Without the Fittings

| 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
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

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
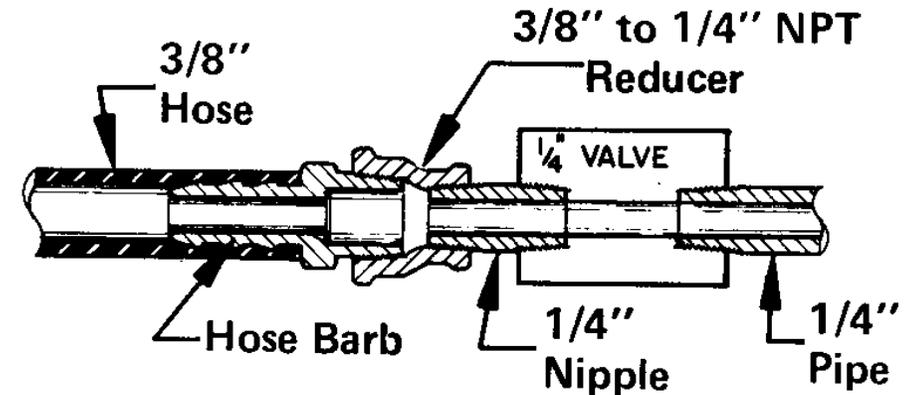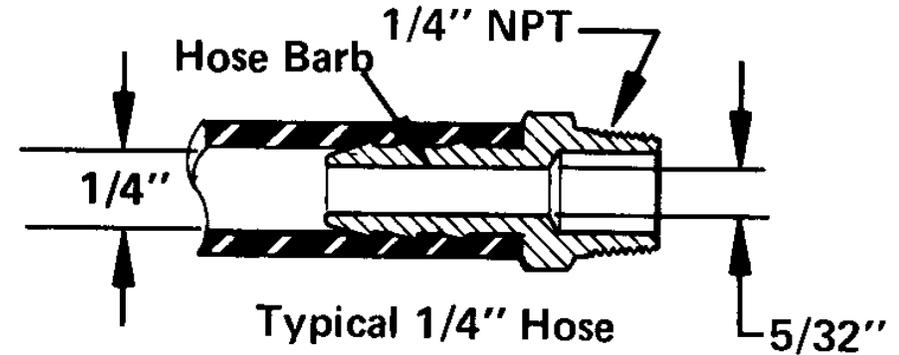
Pressure Drop

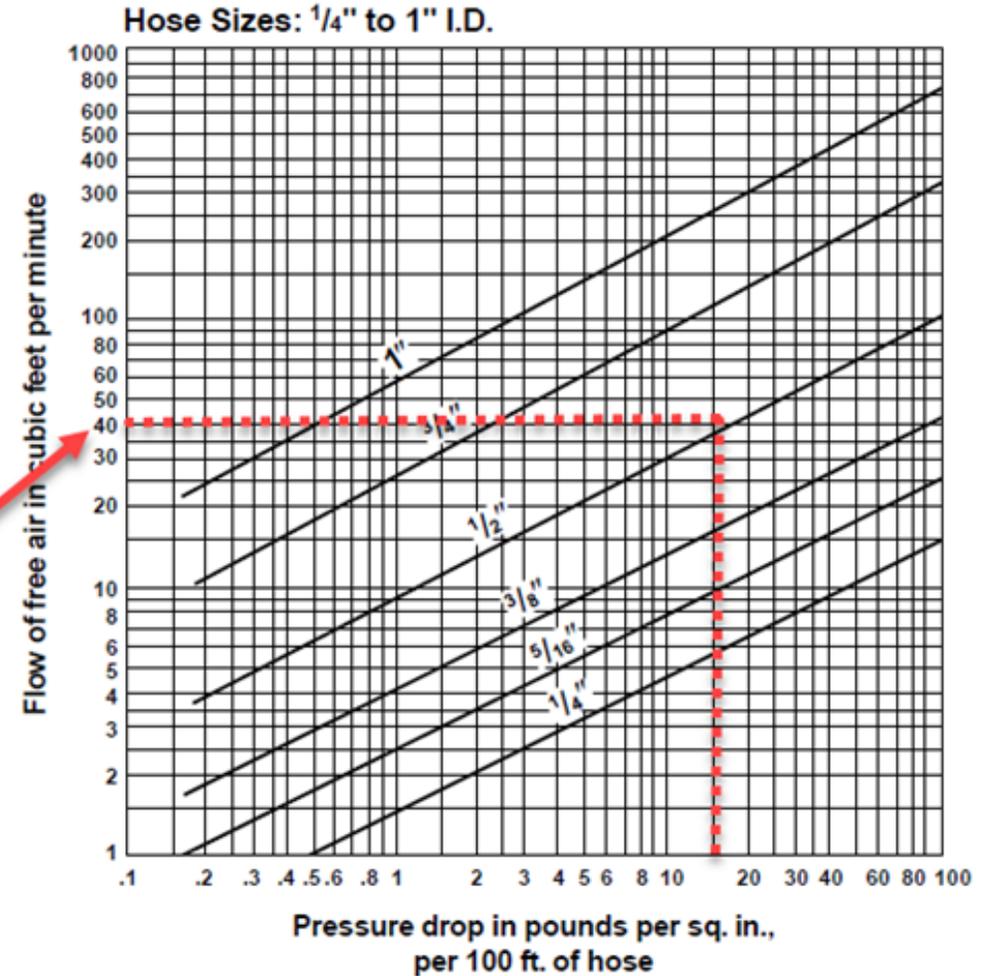## Air Flow Through Hose

Hose Sizes: 1/4" to 1" I.D.

This chart is for approximating and should serve only as a guide in sizing air hose. Pressure drops are directly proportional to hose lengths, i.e. if hose length doubles, pressure drop doubles.

Example:

- 100' x 1/2" I.D. hose at 40 CFM has a pressure loss of 17 1/2 psi.
- 200' x 1/2" I.D. will lose 35 psi.
- 50' x 1/2" I.D. will lose between 8 to 9 psi.

Formula to determine pressure drops for hose lengths other than 100':

$$(\text{Pressure Drop per Chart Figure}) \times \frac{(\text{Ft. of Hose})}{100} = \frac{\text{Pressure drop for}}{\text{hose used}}$$

Hose Sizes: 1/4" to 1" I.D.

Flow of free air in cubic feet per minute

Pressure drop in pounds per sq. in., per 100 ft. of hose

Pressure Drop

Hose Sizes: ¼" to 1" I.D.

Flow of free air in cubic feet per minute

Pressure drop in pounds per sq. in., per 100 ft. of hose
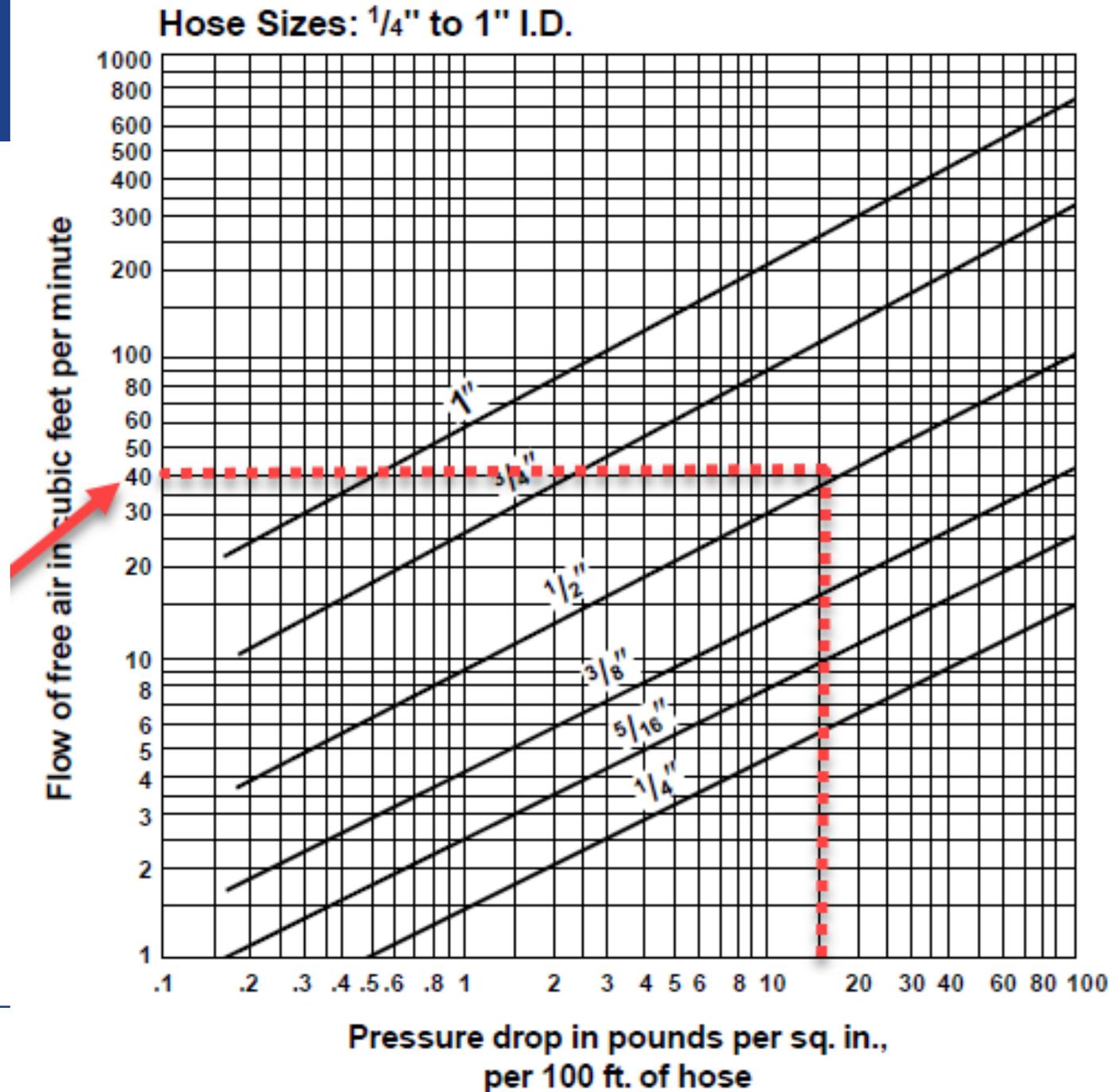
Restriction

- Any type of obstruction, restriction or roughness in the system will cause resistance to air flow and cause pressure drop.

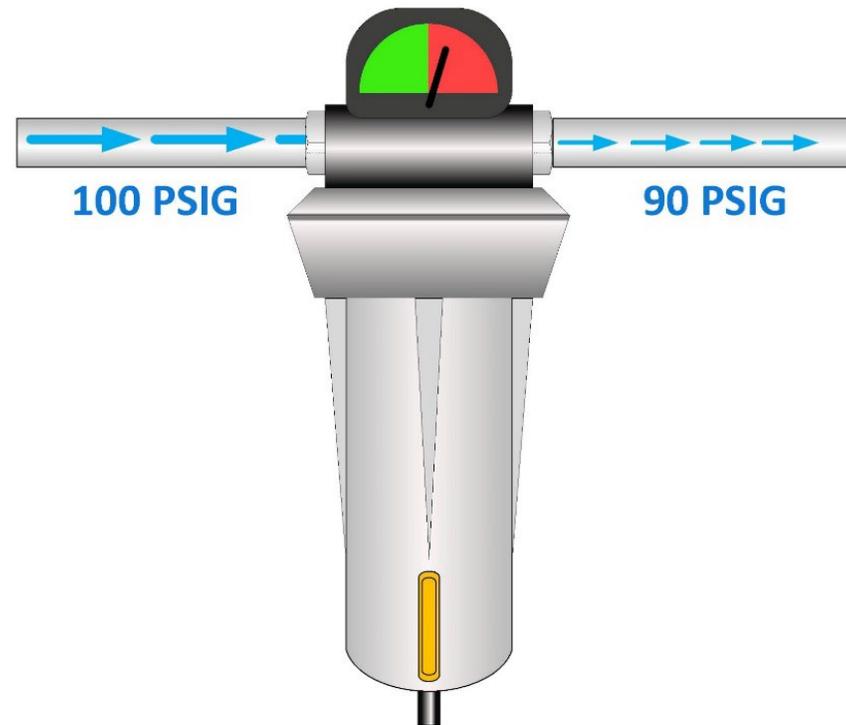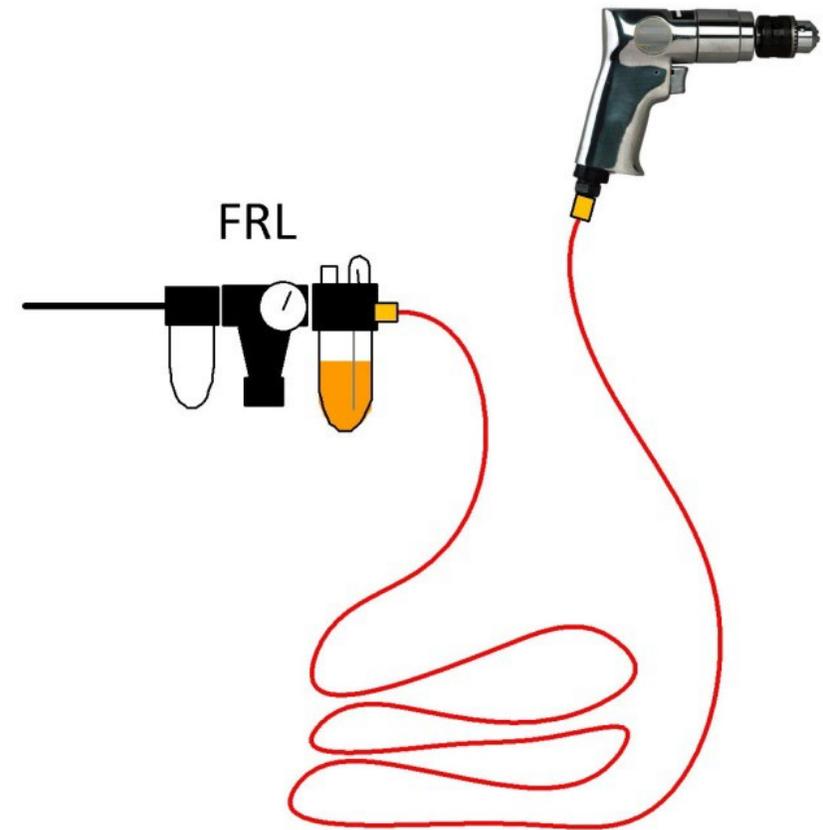- Highest pressure drops usually are found at the points of use including undersized or leaking hoses, plastic tubing, disconnects, filters, regulators and lubricators.

FRL

Pressure Drop

- Production engineers often specify end-use equipment to operate at an average system pressure.

- This results in higher system operating costs.

- For applications that use a significant amount of compressed air, such as large air cylinders, it is wise to specify a brand or model that operates at lower pressures.

- Necessary equipment such as hoses, pressure regulators and filters should be purchased with the goal of minimal pressure loss.

- The added cost of the components should be recouped quickly from the resulting energy savings.
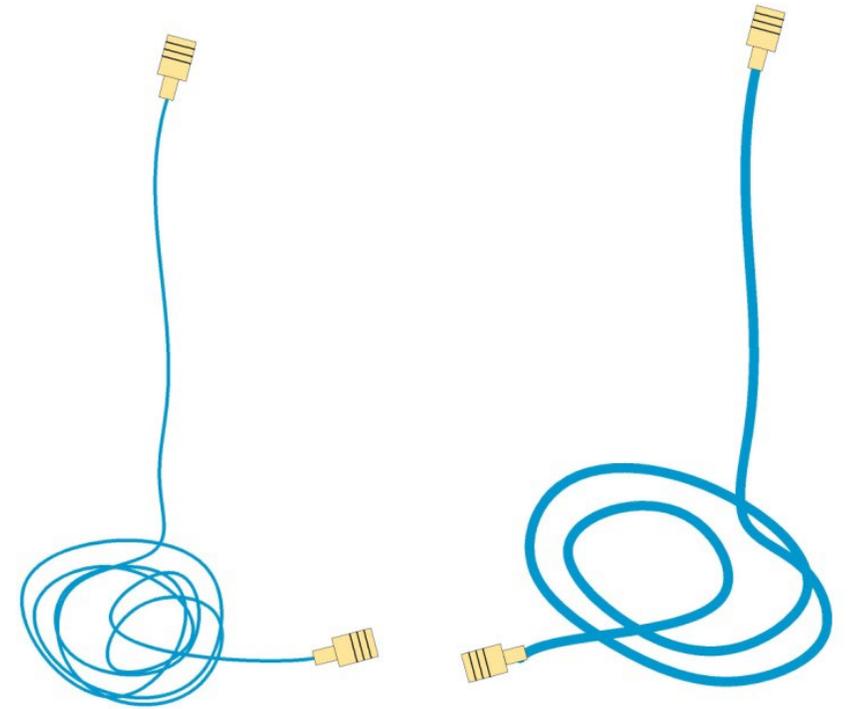
Reducing Pressure Drops Throughout the System

- Sometimes reducing pressure drops throughout the system can help solve problems with the applications in the system that require the highest pressures.

- Pressure drop is a term used to characterize the reduction in air pressure from the compressor discharge to the actual point of use.

- Pressure drop occurs as the compressed air travels through the treatment and distribution system.

- The velocity of compressed air in a header should not exceed 20ft/sec and in distribution piping should not exceed 30ft/sec to minimize the pressure drop.

- Pressure drop increases as the square of the rate of flow.

- If a second compressor is brought online and doubles the flow rate, the pressure drop will increase by a factor of 4.

- The actual pressure at the point of use may not be increased!

Reducing Pressure Drops Throughout the System

- **The following equation is for calculating Velocity:**

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

- 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

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

- Let's try 500 cfm in 3-inch pipe (ID = 3.068)

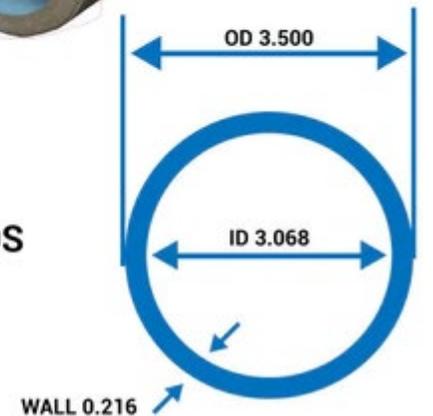$$V_{fps} = \frac{cfm \times P_a}{60 \times a \times (P_2 + P_a)}$$

$$a = .051311$$

$$V_{fps} = \frac{500 \times 14.5}{60 \times .051311 \times 114.5}$$

$$V_{fps} = 20.56$$

OD 3.500

ID 3.068

3/4 Inch NPS Schedule 40S

WALL 0.216

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

Solve for Diameter *(d)*

- What pipe size for 500 cfm at 100 psig keeping 20fps?

$$a_{sqft} = \frac{144 \times cfm \times P_a}{V_{fps} \times 60 \times (P_2 + P_a)}$$

$$a_{sqft} = \frac{144 \times 500 \times 14.5}{20_{fps} \times 60 \times 114.5}$$

$$d = \sqrt{\frac{a \times 4}{\Pi}}$$

$$a_{sqft} = 7.5982$$
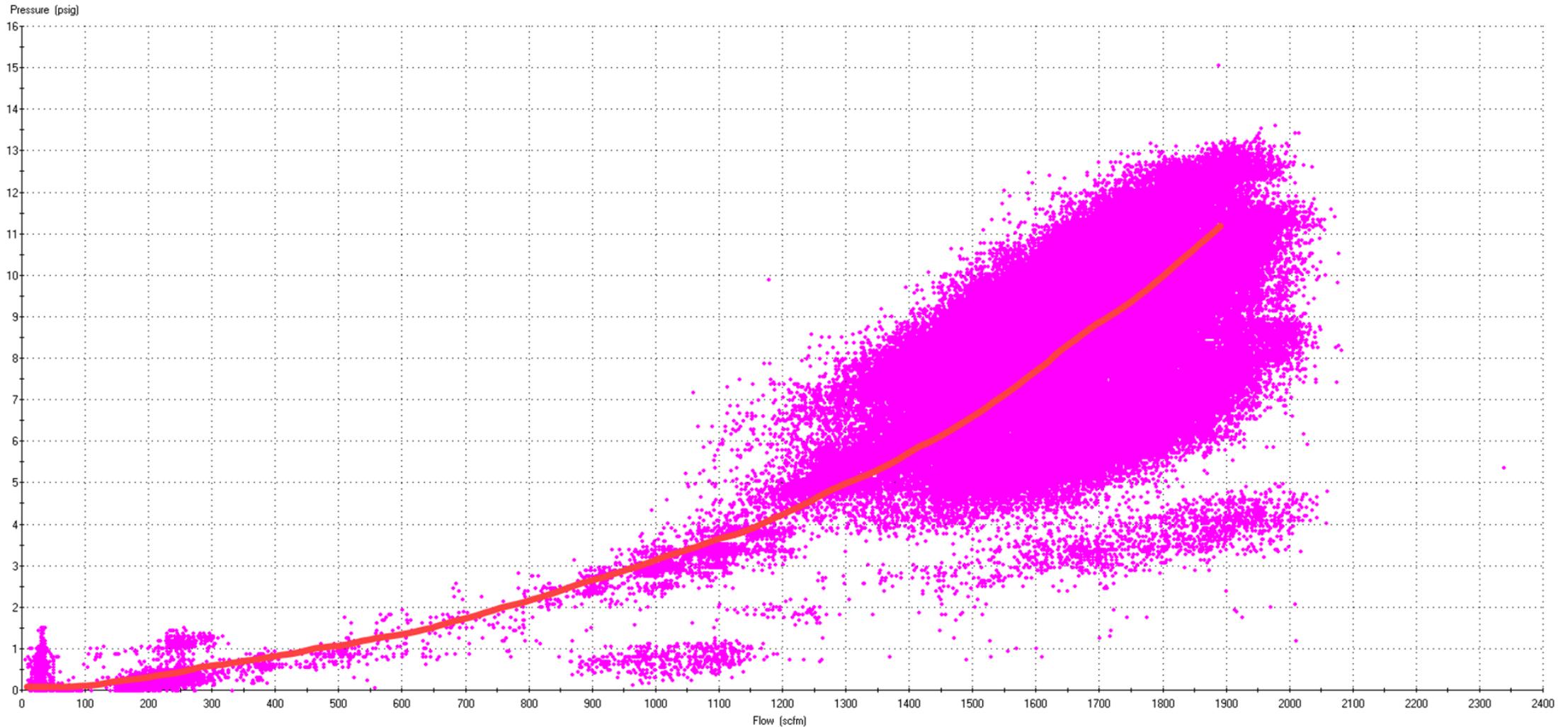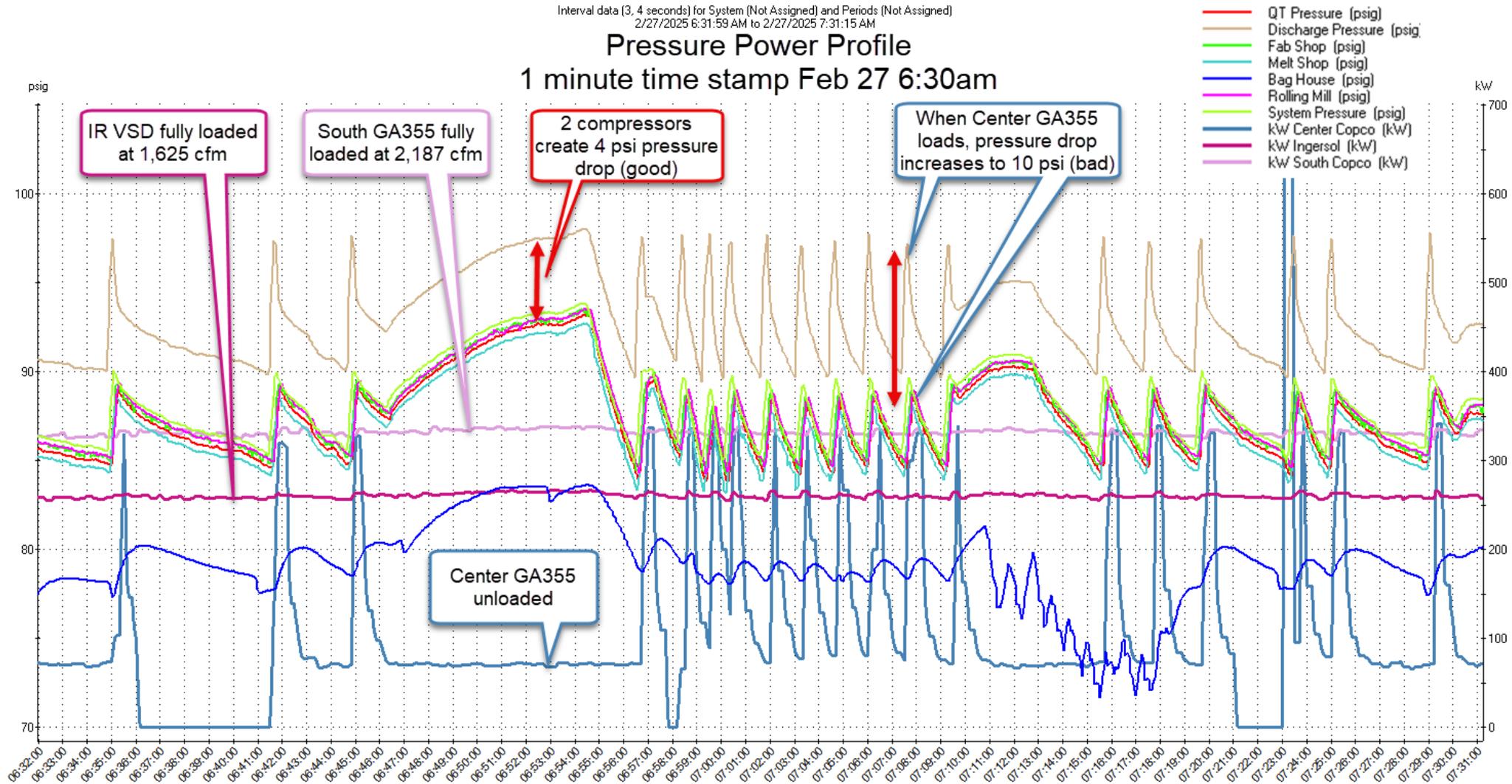
$$d = 3.11$$

An Example of Pressure Drop

- Pressure drop increases as the square of the rate of flow.
- Doubling the flow rate means four times the pressure drop through the same piping.

$$\Delta P_2 = \Delta P_1 \times \left(\frac{Flow_2}{Flow_1} \right)^2$$

An Example of Pressure Drop

An Example of Pressure Drop

An Example of Pressure Drop
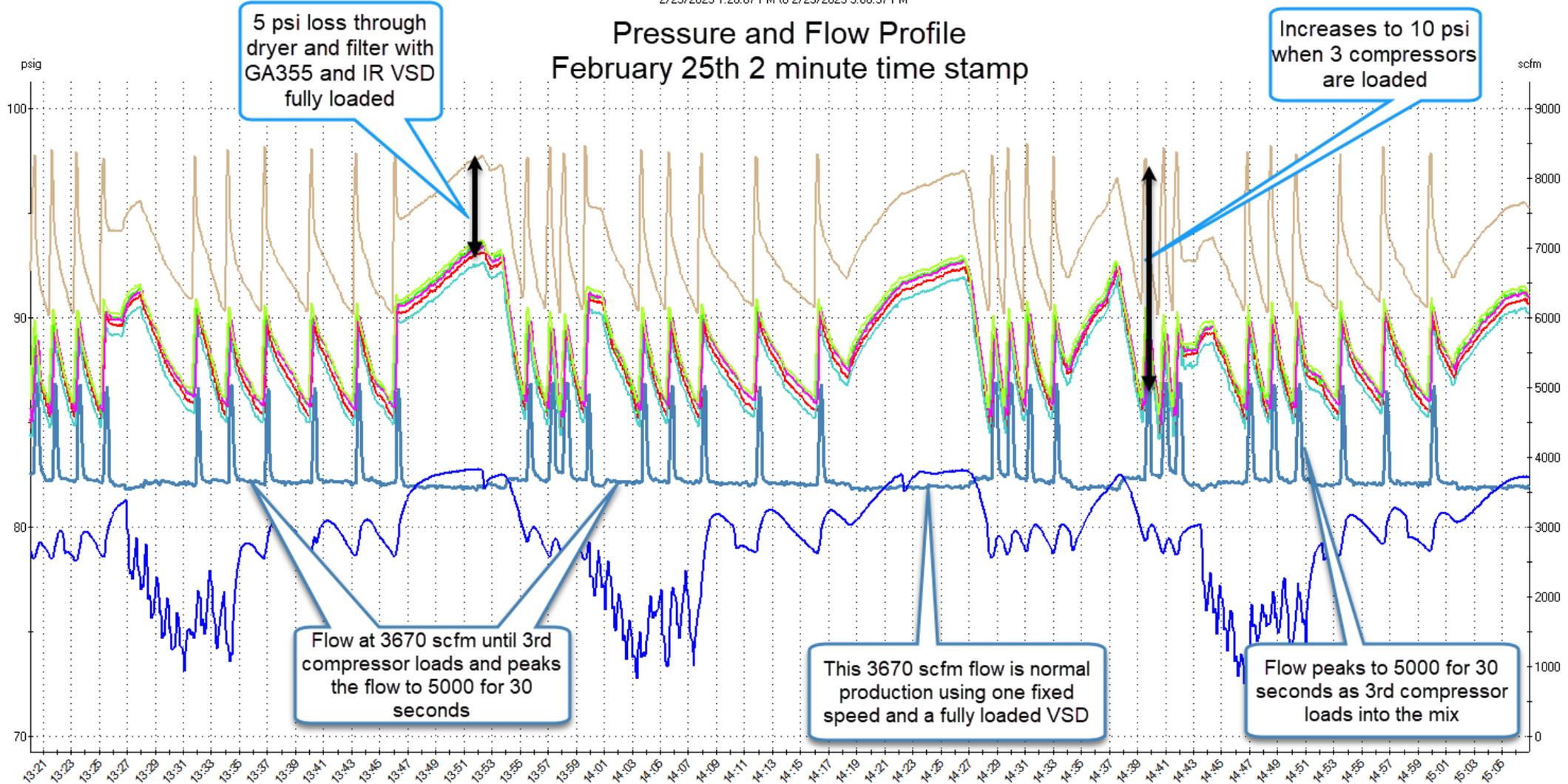
An Example of Pressure Drop
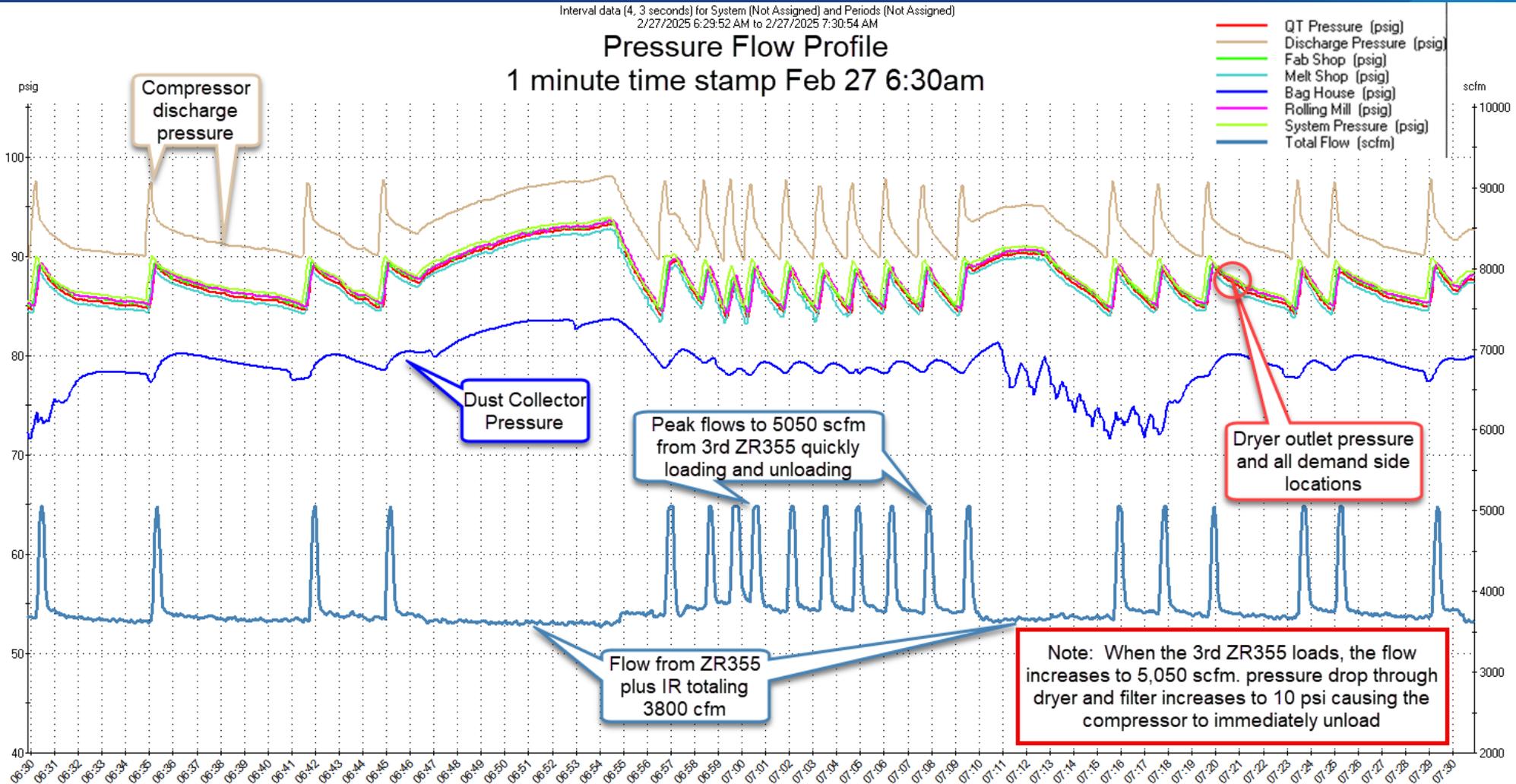
Loss of Air Pressure Due To Friction

Cfm free air	2" ID	3" ID	4" ID
500	19.2	2.34	1.09
600	27.6	3.36	1.56
700	37.7	4.55	2.13

In psi per 1000 feet of pipe, 100 psig inlet pressure. Losses are proportional to length

Air pressure loss due to friction is usually expressed in psi per feet of pipe with a given inlet pressure.

Loss of air pressure due to friction, is a function of cfm, pipe inside diameter, pipe length, and initial pressure.

General Reference Data · CAGI Compressed Air & Gas Institute

Table 8.14 Loss of Air Pressure Due to Friction

Cu ft Free Air Per Min	Equivalent Cu ft Compressed Air Per Min	Nominal Diameter, In. 1/2	3/4	1	1 1/4	1 1/2	2	3	4	6	8	10	12
10	1.28	6.50	.99	0.28									
20	2.56	25.9	3.90	1.11	0.25	0.11							
30	3.84	58.5	9.01	2.51	0.57	0.26							
40	5.12	....	16.0	4.45	1.03	0.46							
50	6.41	....	25.1	9.96	1.61	0.71	0.19						
60	7.68	....	36.2	10.0	2.32	1.02	0.28						
70	8.96	....	49.3	13.7	3.16	1.40	0.37						
80	10.24	....	64.5.	17.8	4.14	1.83	0.49						
90	11.52	....	82.8	22.6	5.23	2.32	0.62						
100	12.81	....	....	27.9	6.47	2.86	0.77						
125	15.82	....	....	48.6	10.2	4.49	1.19						
150	19.23	....	....	62.8	14.6	6.43	1.72	0.21					
175	22.40	....	....	....	19.8	8.72	2.36	0.28					
200	25.62	....	....	....	25.9	11.4	3.06	0.37					
250	31.64	....	....	....	40.4	17.9	4.78	0.58					
300	38.44	....	....	....	58.2	25.8	6.85	0.84	0.20				
350	44.80	....	....	....	....	35.1	9.36	1.14	0.27				
400	51.24	....	....	....	....	45.8	12.1	1.50	0.35				
450	57.65	....	....	....	....	58.0	15.4	1.89	0.46				
500	63.28	....	....	....	....	71.6	19.2	2.34	0.55				
600	76.88	....	....	....	....	....	27.6	3.36	0.79				
700	89.60	....	....	....	....	....	37.7	4.55	1.09				
800	102.5	....	....	....	....	....	49.0	5.89	1.42				
900	115.3	....	....	....	....	....	62.3	7.6	1.80				
1,000	128.1	....	....	....	....	....	76.9	9.3	2.21				
1,500	192.3	....	....	....	....	....	....	21.0	4.9	0.57			

In psi in 1000-ft of pipe, 100-lb gage initial pressure. For longer or shorter lengths of pipe the friction loss is proportional to the length, i.e., for 500 ft, one-half of the above; for 4,000 ft, four times the above, etc.
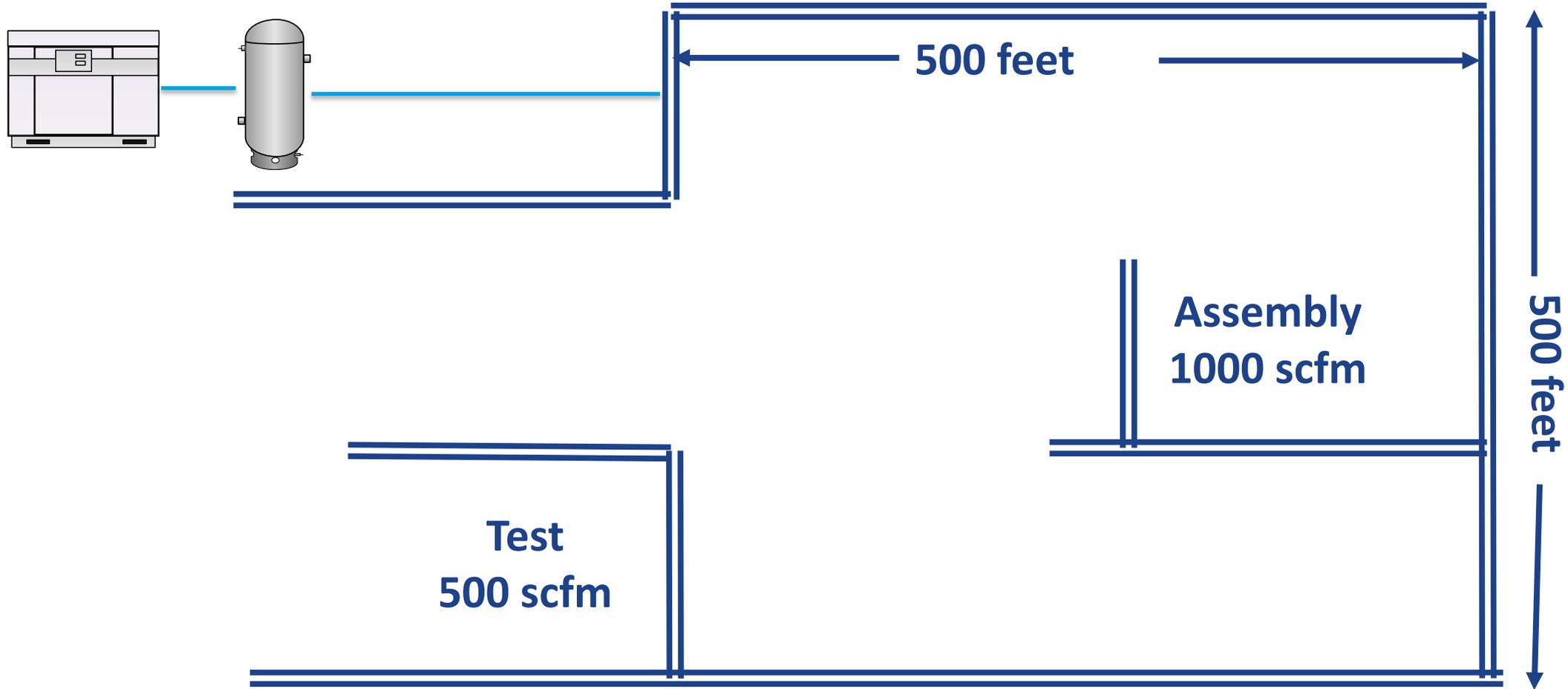
General Reference Data · CAGI Compressed Air & Gas Institute

Table 8.14 Loss of Air Pressure Due to Friction

Cu ft Free Air Per Min	Equivalent Cu ft Compressed Air Per Min	Nominal Diameter, In. 1/2	3/4	1	1 1/4	1 1/2	2	3	4	6	8	10	12
2,000	256.2	....	....	....	....	....	....	37.4	8.8	0.99	0.24		
2,500	316.4	....	....	....	....	....	....	58.4	13.8	1.57	0.37		
3,000	384.6	....	....	....	....	....	....	84.1	20.0	2.26	0.53		
3,500	447.8	....	....	....	....	....	....	....	27.2	3.04	0.70	0.22	
4,000	512.4	....	....	....	....	....	....	....	35.5	4.01	0.94	0.28	
4,500	576.5	....	....	....	....	....	....	....	45.0	5.10	1.19	0.36	
5,000	632.8	....	....	....	....	....	....	....	55.6	6.3	1.47	0.44	0.17
6,000	768.8	....	....	....	....	....	....	....	80.0	9.1	2.11	0.64	0.24
7,000	896.0	....	....	....	....	....	....	....	....	12.2	2.88	0.87	0.33
8,000	1,025	....	....	....	....	....	....	....	....	16.1	3.77	1.12	0.46
9,000	1,153	....	....	....	....	....	....	....	....	20.4	4.77	1.43	0.57
10,000	1,280	....	....	....	....	....	....	....	....	25.1	5.88	1.77	0.69
11,000	1,410	....	....	....	....	....	....	....	....	30.4	7.10	2.14	0.83
12,000	1,540	....	....	....	....	....	....	....	....	36.2	8.5	2.54	0.98
13,000	1,668	....	....	....	....	....	....	....	....	42.6	9.8	2.98	1.15
14,000	1,795	....	....	....	....	....	....	....	....	49.2	11.5	3.46	1.35
15,000	1,923	....	....	....	....	....	....	....	....	56.6	13.2	3.97	1.53
16,000	2,050	....	....	....	....	....	....	....	....	64.5	15.0	4.52	1.75
18,000	2,310	....	....	....	....	....	....	....	....	81.5	19.0	5.72	2.22
20,000	2,560	....	....	....	....	....	....	....	....	....	23.6	7.0	2.74
22,000	2,820	....	....	....	....	....	....	....	....	....	28.5	8.5	3.33
24,000	3,080	....	....	....	....	....	....	....	....	....	33.8	10.0	3.85
26,000	3,338	....	....	....	....	....	....	....	....	....	39.7	11.9	4.65
28,000	3,590	....	....	....	....	....	....	....	....	....	46.2	13.8	5.40
30,000	3,850	....	....	....	....	....	....	....	....	....	53.0	15.9	6.17

In psi in 1000-ft of pipe, 100-lb gage initial pressure. For longer or shorter lengths of pipe the friction loss is proportional to the length, i.e., for 500 ft, one-half of the above; for 4,000 ft, four times the above, etc.

Factors for calculating Loss of Air Pressure Due to Pipe Friction, Applicable for any Initial Pressure Chapter 8 of the CAGI Handbook. Table 8.16 page 719

	PIPE DIAMETER IN INCHES											
Pump cfm free air	1	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8	10	12
80	139.2	14.3	3.8	1.5								
100	217.4	22.3	6.0	2.3								
120	318.0	32.2	8.6	3.3								
150	490.0	50.3	13.4	5.2	1.6							
200	870.0	89.4	23.9	9.3	2.9							
250	163.0	140.0	37.4	14.5	4.6							
300		201.0	53.7	20.9	6.6	3.5						
350			73.2	28.5	9.0	4.2	2.2					
400			94.7	37.1	11.7	5.4	2.7					
450			120.6	46.9	14.8	6.9	3.6					
500			150.0	58.0	18.3	8.5	4.3					
550			181.5	70.2	22.1	10.2	5.2					
600			215.0	83.5	26.3	12.2	6.2					
650			253.0	98.0	30.9	14.3	7.3	2.2				
700			294.0	113.7	35.8	16.6	8.5	2.6				
750			337.0	130.5	41.5	19.0	9.7	2.9				
800			382.0	148.4	46.7	21.7	11.1	3.3				
850			433.0	168.0	52.8	24.4	12.5	3.8				
900			468.0	188.0	59.1	27.4	14.0	4.2				
950			541.0	209.4	65.9	30.5	15.7	4.7				
1000			600.0	232.0	73.0	33.8	17.3	5.2	1.9			
1200			850.0	344.0	105.2	48.8	25.0	7.5	2.8			
1400						66.3	33.9	10.2	3.8			
1600						86.6	44.3	13.4	5.1			
1800						97.8	50.1	16.9	6.4			
2000						135.0	69.3	20.9	7.8	1.8		
2250						173.0	87.6	28.9	10.9	2.5		
2500						229.0	108.2	32.6	12.3	2.9		
2750						256.0	131.0	39.6	14.9	3.5		
3000						305.0	156.0	47.0	17.7	4.1		
4000						488.0	277.0	83.6	31.4	7.3	2.2	
5000							433.0	131.0	49.1	11.5	3.4	
6000								188.0	70.7	16.5	5.0	1.9

Pipe Loss Calculation

The following formula is used to calculate losses in a piping system

$$\frac{\text{Correction factor}}{\text{Compression Ratio*}} \times \frac{\text{Pipe Length}}{1000} = \text{Pipe Loss (psig)}$$

*compression ratio = discharge pressure in psia/inlet pressure psia

example... 120 psig discharge = 134.70/14.7 = 9.16

What pipe size is needed?

To determine the pressure drop in psi, the factor listed in the table for a given capacity and pipe diameter should be divided by the ratio of compression (from free air) at entrance of pipe, multiplied by the actual length of the pipe in feet, and divided by 1000.

Let's try using 3-inch pipe to the assembly area:

$$\frac{CorrectionFactor}{CompressionRatio} \times \frac{PipeLength}{1000}$$

$$\frac{73}{7.8} \times \frac{700}{1000} = 6.55$$

Let's try using 4-inch pipe to the assembly area:

$$\frac{CorrectionFactor}{CompressionRatio} \times \frac{PipeLength}{1000}$$

$$\frac{17.3}{7.8} \times \frac{700}{1000} = 1.55$$

This is a 5-psi difference between the two pipe sizes…Since each 1 psi is a .5% increase of energy,

5 psi will equate to a 2.5 % increase in energy overall

What pipe size is needed?

If this were a 200-horsepower compressor using $ 112,429 annually in electricity… the additional pressure drop would equate to 2.5% times $ 112,429 or:

$ 2,810.73 annually !!!

Enough to have certainly paid for the minimal difference between the 3" and 4" pipe !!!

| 3" SCH 40 (3.50" OD X .216" wall)
A-500 ERW Structural Steel Pipe | 7.58 lb/ft | 10 Ft. | 1 | $189.40 ea. |
| 4" SCH 40 (4.50" OD X .237" wall)
A-500 ERW Structural Steel Pipe | 10.79 lb/ft | 10 Ft. | 1 | $256.20 ea.
IN STOCK
Ships in 1 – 5 Days |

Conclusion:

There are no cost savings associated with reducing material expense in air line systems!!!

The previous charts were from chapter 8 of the CAGI Handbook. Table 8.12 page 715

Factors for calculating Loss of Air Pressure Due to Pipe Friction, Applicable for any Initial Pressure Chapter 8 of the CAGI Handbook. Table 8.16 page 719

Pump cfm free air	PIPE DIAMETER IN INCHES											
	1	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8	10	12
80	139.2	14.3	3.8	1.5								
100	217.4	22.3	6.0	2.3								
120	318.0	32.2	8.6	3.3								
150	490.0	50.3	13.4	5.2	1.6							
200	870.0	89.4	23.9	9.3	2.9							
250	163.0	140.0	37.4	14.5	4.6							
300		201.0	53.7	20.9	6.6	3.5						
350			73.2	28.5	9.0	4.2	2.2					
400			94.7	37.1	11.7	5.4	2.7					
450			120.6	46.9	14.8	6.9	3.6					
500			150.0	58.0	18.3	8.5	4.3					
550			181.5	70.2	22.1	10.2	5.2					
600			215.0	83.5	26.3	12.2	6.2					
650			253.0	98.0	30.9	14.3	7.3	2.2				
700			294.0	113.7	35.8	16.6	8.5	2.6				
750			337.0	130.5	41.5	19.0	9.7	2.9				
800			382.0	148.4	46.7	21.7	11.1	3.3				
850			433.0	168.0	52.8	24.4	12.5	3.8				
900			468.0	188.0	59.1	27.4	14.0	4.2				
950			541.0	209.4	65.9	30.5	15.7	4.7				
1000			600.0	232.0	73.0	33.8	17.3	5.2	1.9			
1200			850.0	344.0	105.2	48.8	25.0	7.5	2.8			
1400						66.3	33.9	10.2	3.8			
1600						86.6	44.3	13.4	5.1			
1800						97.8	50.1	16.9	6.4			
2000						135.0	69.3	20.9	7.8	1.8		
2250						173.0	87.6	28.9	10.9	2.5		
2500						229.0	108.2	32.6	12.3	2.9		
2750						256.0	131.0	39.6	14.9	3.5		
3000						305.0	156.0	47.0	17.7	4.1		
4000						488.0	277.0	83.6	31.4	7.3	2.2	
5000							433.0	131.0	49.1	11.5	3.4	
6000								188.0	70.7	16.5	5.0	1.9

 Pipe Loss Calculation

The following formula is used to calculate losses in a piping system

 Correction factor   x Pipe Length   = Pipe Loss (psig)
Compression Ratio*   1000

*compression ratio = discharge pressure in psia/inlet pressure psia

example... 120 psig discharge = 134.70/14.7 = 9.16

What pipe size is needed?

- The purpose of the friction chart is to make approximate estimations of the pressure loss through piping.
- The estimates do not take into account leaks and other factors affecting the piping system.
- A typical rule of thumb is to keep the line loss below 5%. However, the ultimate decision rests with the customer based upon his system and design requirements.

For every 90-degree pipe elbow multiply pipe diameter by 20 to equal additional pipe length in inches.

For every globe valve multiply pipe diameter by 30 to equal additional pipe length in inches.

For every gate valve multiply pipe diameter by 3 to equal additional pipe length in inches.

For every angle valve multiply pipe diameter by 16 to equal additional pipe length in inches.

For every tee multiply pipe diameter by 6 to equal additional pipe length in inches.

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Frictional Loss in Pipe Example:

A customer has a new installation using 1200 ACFM, at 100 psig and wants to use 4" pipe with a total run of 2000 feet

12 elbows, 2 gate valves and 1 tee.

Assume the facility is at sea level. First cross reference 1200 CFM from the chart to find the FACTOR, which is 25.0. Figure the Compression Ratios, 114.7psia/14.7psia = 7.8 Compression Ratios

11 elbows @ 4" is 4 x 20 x 11 = 880 / 12   = 80 feet additional
2 gate valve is 4 x 3 x 2 = 24 / 12   = 2 feet additional
1 tee is 4 x 6 x 1 = 24 / 12   = 2 feet additional

2000 + 80 + 2 + 2 = 2084 total feet in inlet piping.

Now putting it altogether (25 / 7.8) (2084 / 1000) = 6.67 psi pressure drop

Let's Not Forget Rubber Hose Losses

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								

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Distribution Best Practices

- Piping systems have many variables to take into account.

- These include vibration, pulsations, temperature exposure (internal and external), maximum air pressures, corrosion and chemical resistance.

- In addition, lubricated compressors will always discharge some oil into the air stream, and the compatibility of the discharge piping and other accessories (such as O-rings and seals) with both petroleum and/or synthetic lubricants is critical.

Distribution Best Practices

- It is important that compressed air flow into and out of a wet receiver in such; a way that the air does not stagnate.

- Air flow should go into the bottom of the receiver and come out the top whenever possible.

- If the inlet and discharge are located directly opposite each other, the tendency for the high velocity discharge air would be to go directly from one to the other without circulating through the receiver and dropping out oil and moisture.

- The receiver should always be installed so that the bottom condensate drain can be checked often.

- A zero-air loss drain trap is highly recommended.
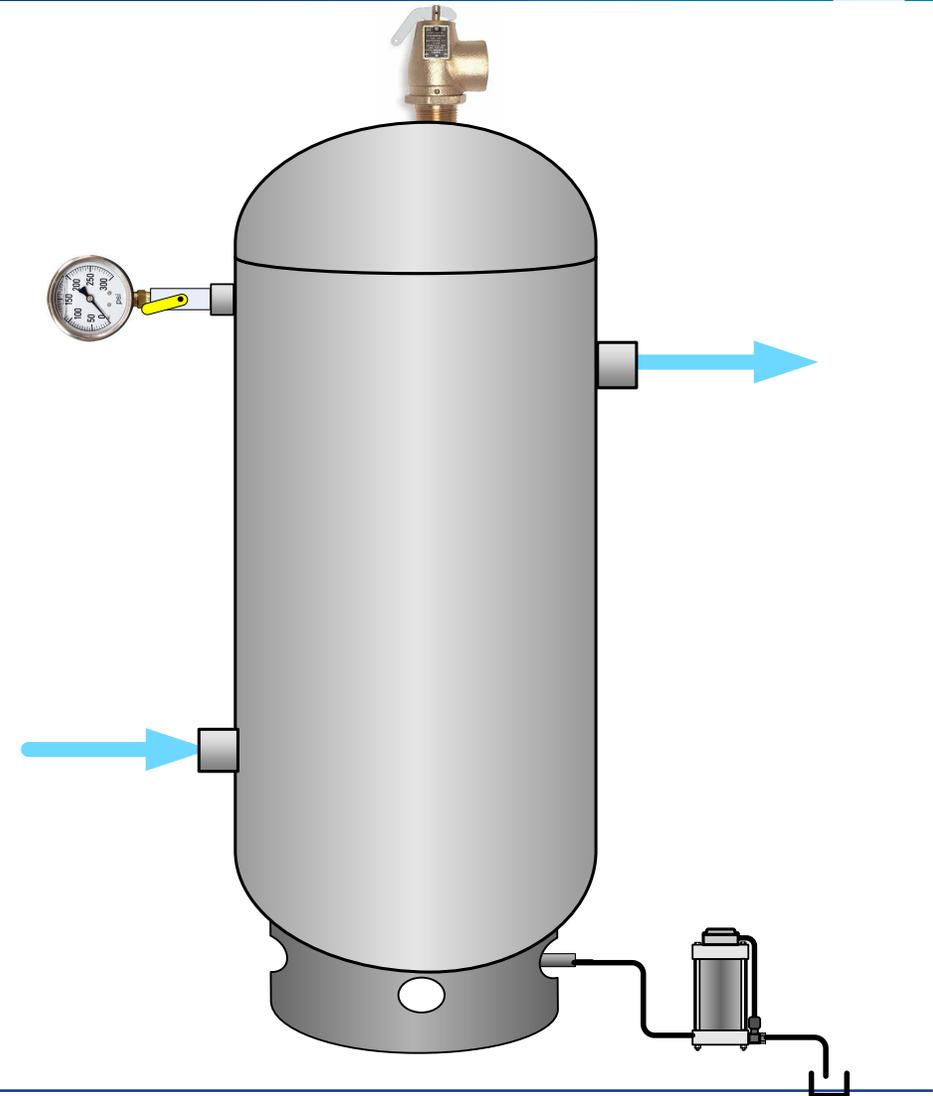
Distribution Best Practices

- Condensation can take place in air piping systems even though after-coolers, dryers, receivers and separators are installed.

- When air lines are exposed, for example, to low ambient temperatures, moisture can condense.

- This is why drip legs should be installed at all low points in the piping system.

- A drain or trap should be installed at the very bottom.
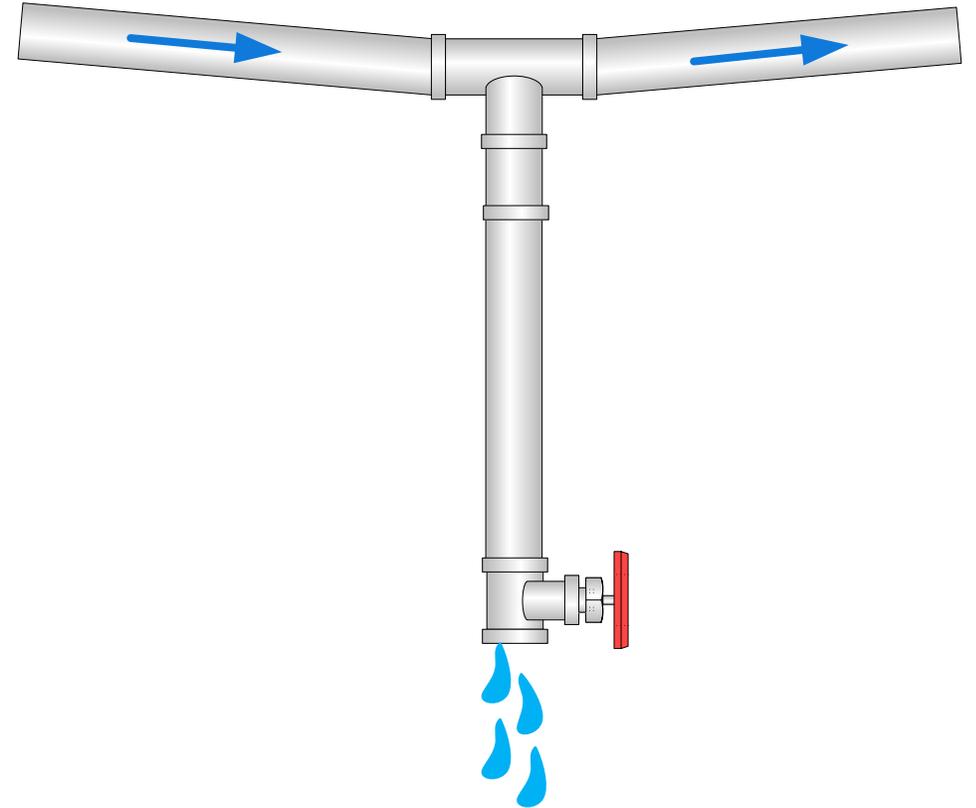
Distribution Best Practices

- A drop leg is a pipe coming from the top, rather than the bottom, of the main air distribution line to feed air to an outlet for tools or an air-operated device.

- The drop leg is taken off the top of the main line so that condensation does not easily flow into the drop leg.

- It should be designed with the tool air outlet coming off the side of the drop leg rather than the bottom so condensation will collect below the tool outlet.

- A drain or trap should be installed at the very bottom.
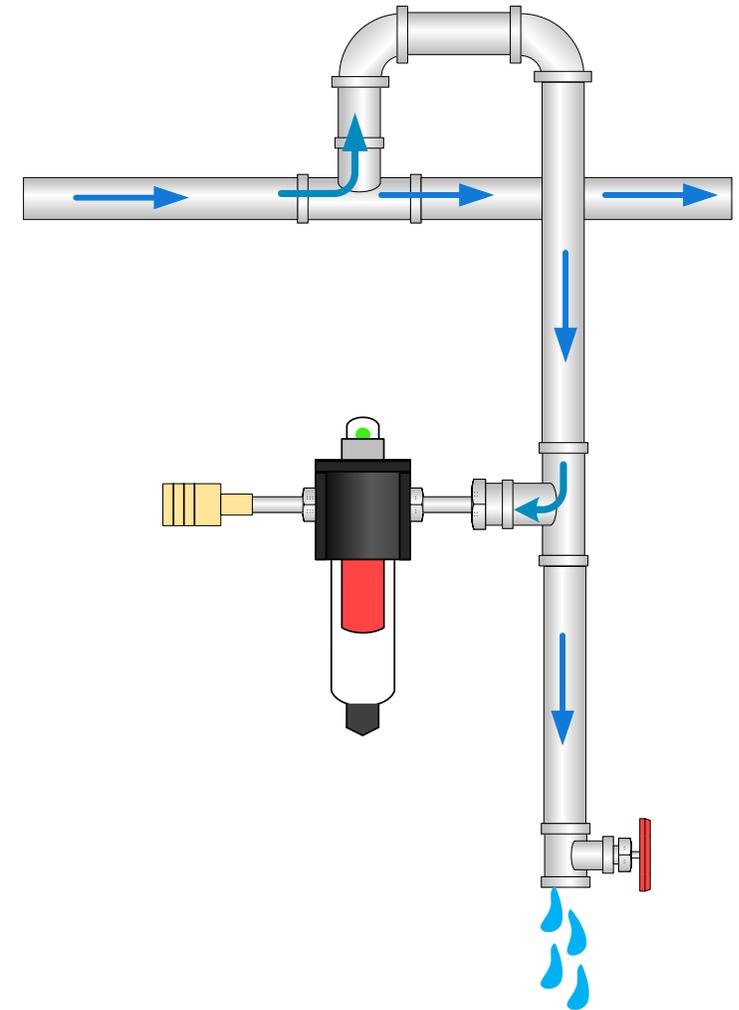
Location

- In some plants, a centralized compressor room can have benefits of a minimum of operators and maintenance requirements.

- The location should be chosen to minimize the distance or distances the compressed air has to travel to the points of use, particularly the larger volume applications.
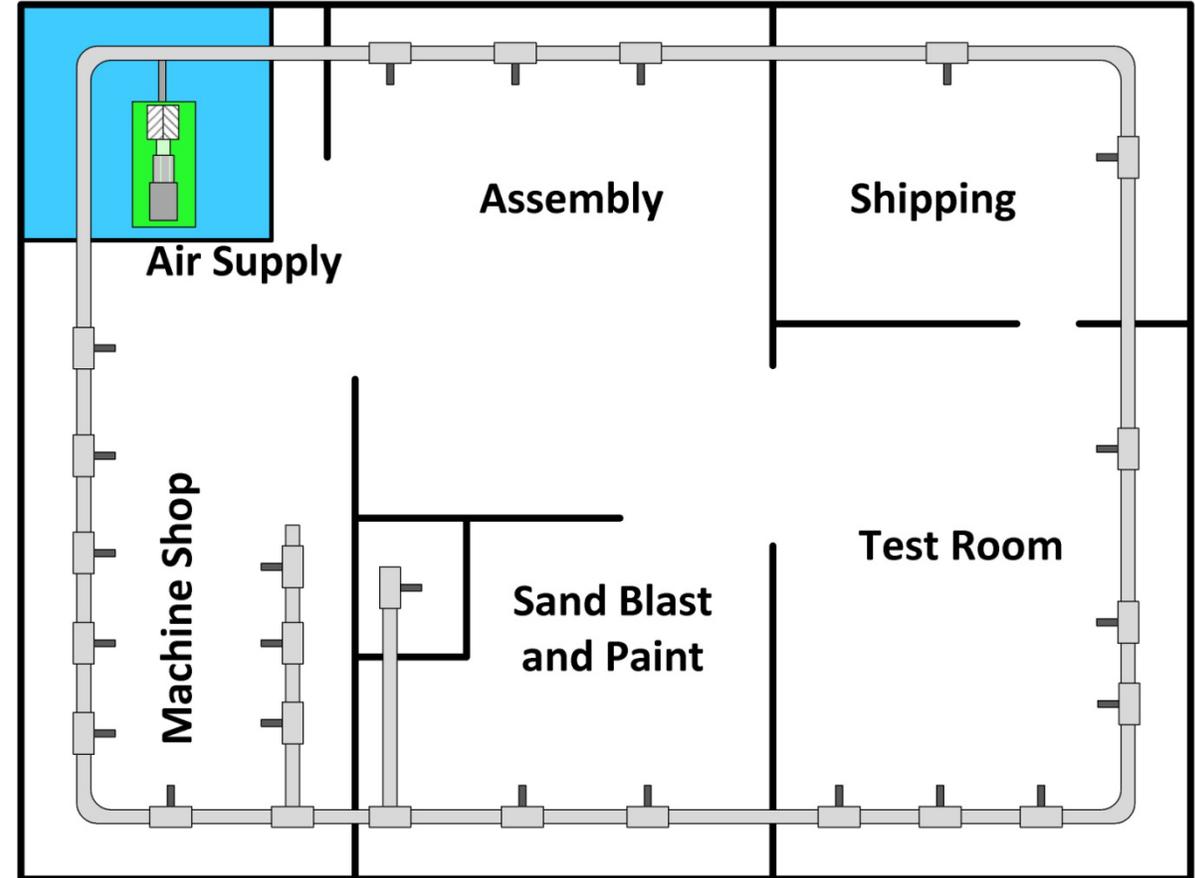
Location

- There may be occasions where a separate, dedicated compressor, booster, amplifier, dedicated storage can be located adjacent to a high volume and or high pressure point of use, avoiding system problems.

- For example, if a facility requires plant air at 90 psig, but has one application that requires air at 120 psig.

- Rather than providing 120 psig air to the whole plant, it would make sense to have a compressor or group of compressors provide plant air at 90 psig.

- One dedicated compressor could provide air to that one high pressure application at 120 psig.

- Another possibility is to modify the high-pressure requirement to run at 90 psig.
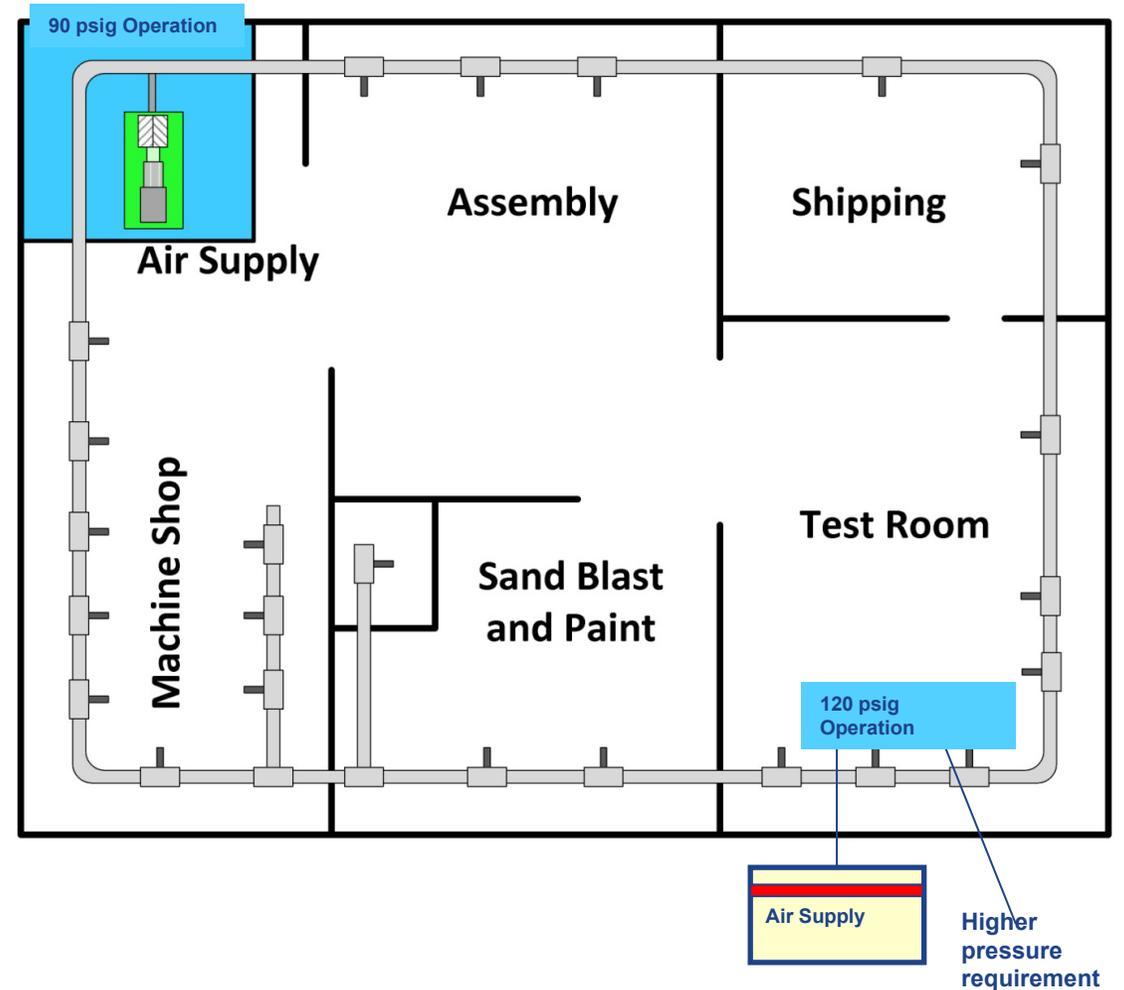
Location

- Using the same example as previous, this diagram shows an alternative of using a booster rather than a dedicated compressor to pressurize to 150 psig.
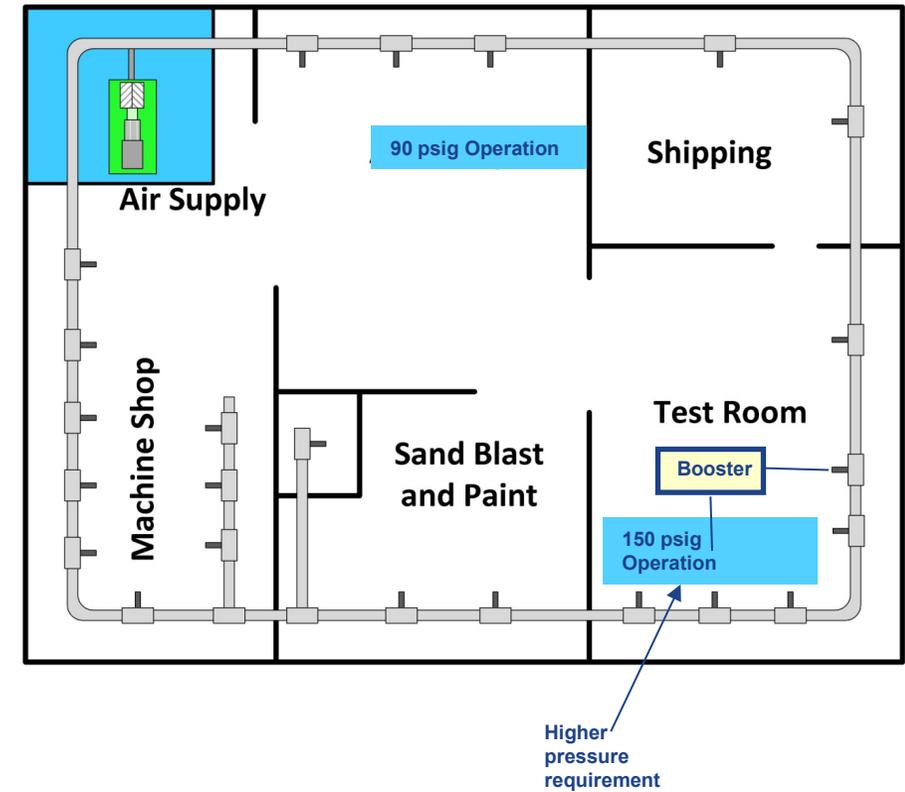
Piping Materials

- ## **Iron**
  - An old favorite, iron piping has been around for decades.
  - One benefit to iron piping is fittings for it can be found at any hardware store and are generally inexpensive.
  - However, tailoring iron piping to your facilities can be challenging and often requires a plumber.
  - Also, because of the condensation that is unavoidable with compressed air systems, iron compressed air piping is prone to corrosion.
  - Corrosion, in turn, leads to rusty debris, blockages, and possibly even leaks that affect the pressure of the compressed air.

Tap image to zoom

Piping Materials

- **Copper**
  - Copper piping is an excellent choice for use with air compressors.
  - Any condensation that builds up in the system will not corrode copper pipes, so the risk of debris entering the system is very low.
  - It also withstands heat well.
  - However, it can be expensive because installing it requires time and skill.
  - Copper pipes require threading and soldering that can require expertise to be properly installed.
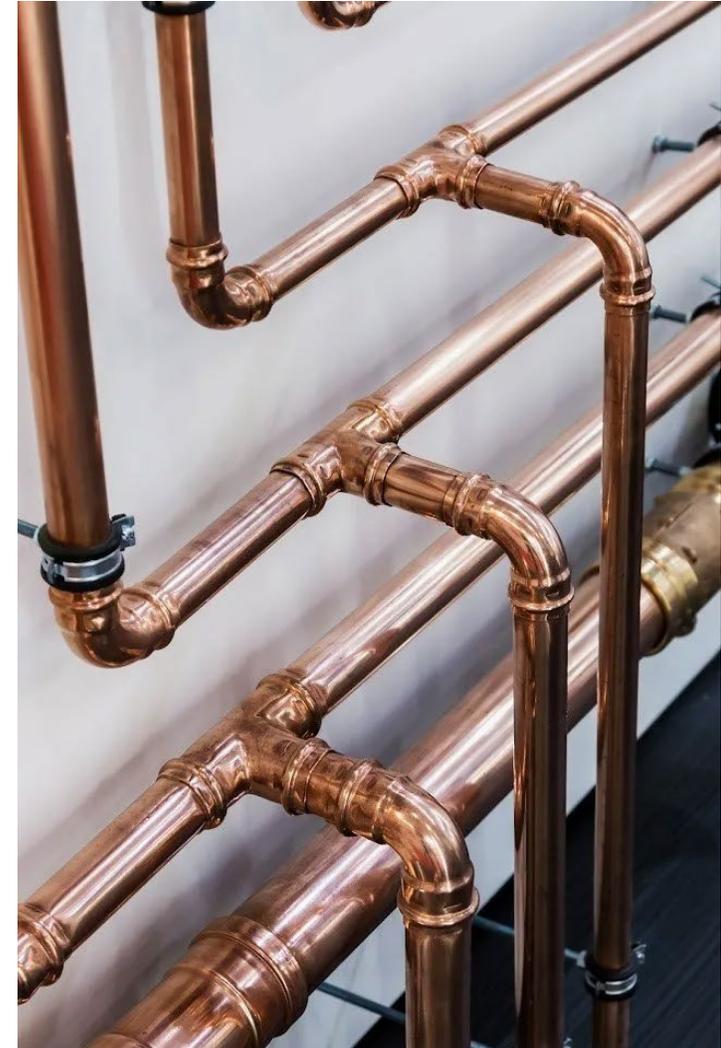
Piping Materials

- **Stainless Steel**
  - A great choice for compressed air piping is stainless steel because it is strong and resists corrosion.
  - Like with copper, corrosion resistance in stainless steel piping produces a cleaner, more consistent less friction factor stream of air.
  - However, also like copper, installing stainless steel piping can be time-consuming since the joints require welding and threading.

Piping Materials

- **Aluminum**
  - The current compressed air piping material of choice is aluminum.
  - Lightweight but durable and resistant to corrosion, it is easier to install and modify than most alternatives.
  - Typically, aluminum piping arrives ready to install and requires few tools to set up.
  - It does not require soldering or threading, and it provides much cleaner air, leading to lower repair costs and a more efficient air stream.
  - The downside is that, like copper, it can be more expensive upfront.
  - However, the easy labor of aluminum pays for itself in the long run.
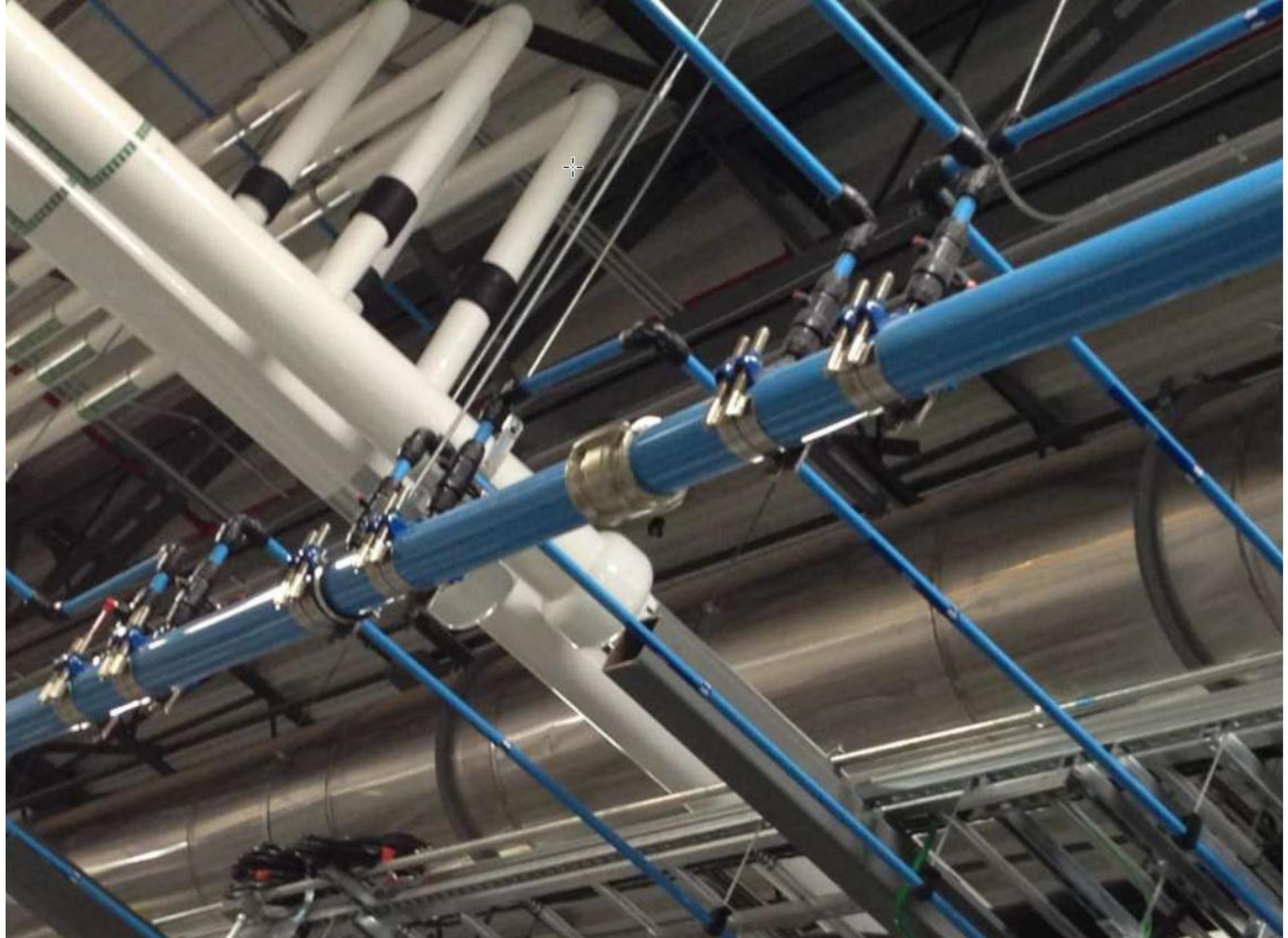
Piping Layout

- Piping layout is just as important as the pipe's diameter in optimizing airflow and reducing potential problems.

- In any system design with multiple drops, equalizing pressure throughout the entire plant is critical for stable use and measurement.

- Using a single piping run along with multiple airdrops will cause users at the end of the line to receive a significant reduction in airflow.

- To combat these issues, users should create a layout of their piping in a loop configuration, forcing evenly distributed airflow throughout the entire plant.

Piping Systems

- ## The dead end or grid system.
    - ### Simplest of the piping systems.
        - Least expensive to install.
    - ### Central main with small feeder lines.
    - ### The mains typically decrease in size away form the main header?
        - Feeder lines are generally of uniform size.
    - ### Only one flow path is available.
        - Workstations near the ends of the system are subject to insufficient air supply (air starvation) when upstream demand is heavy.
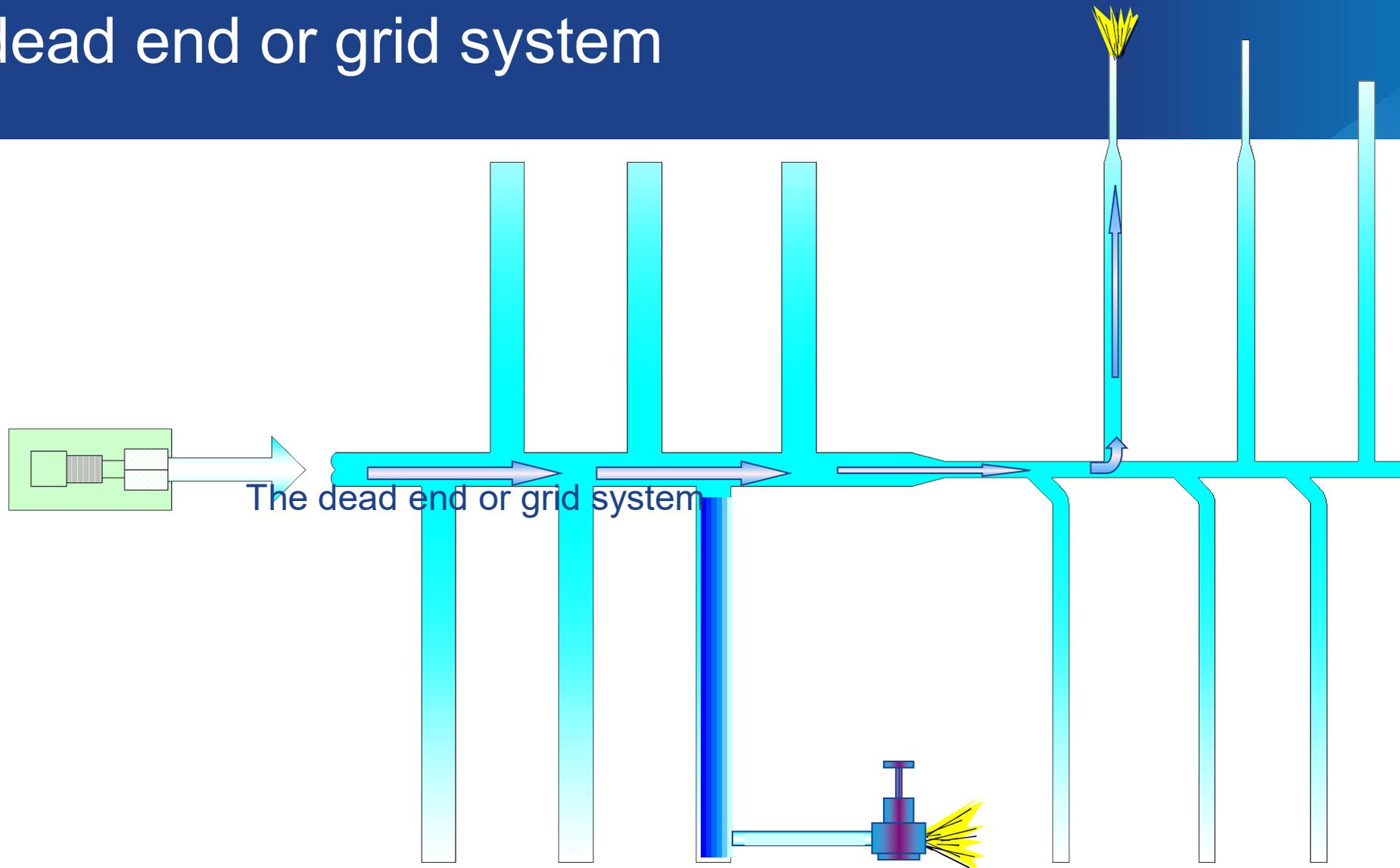
The dead end or grid system

The dead end or grid system
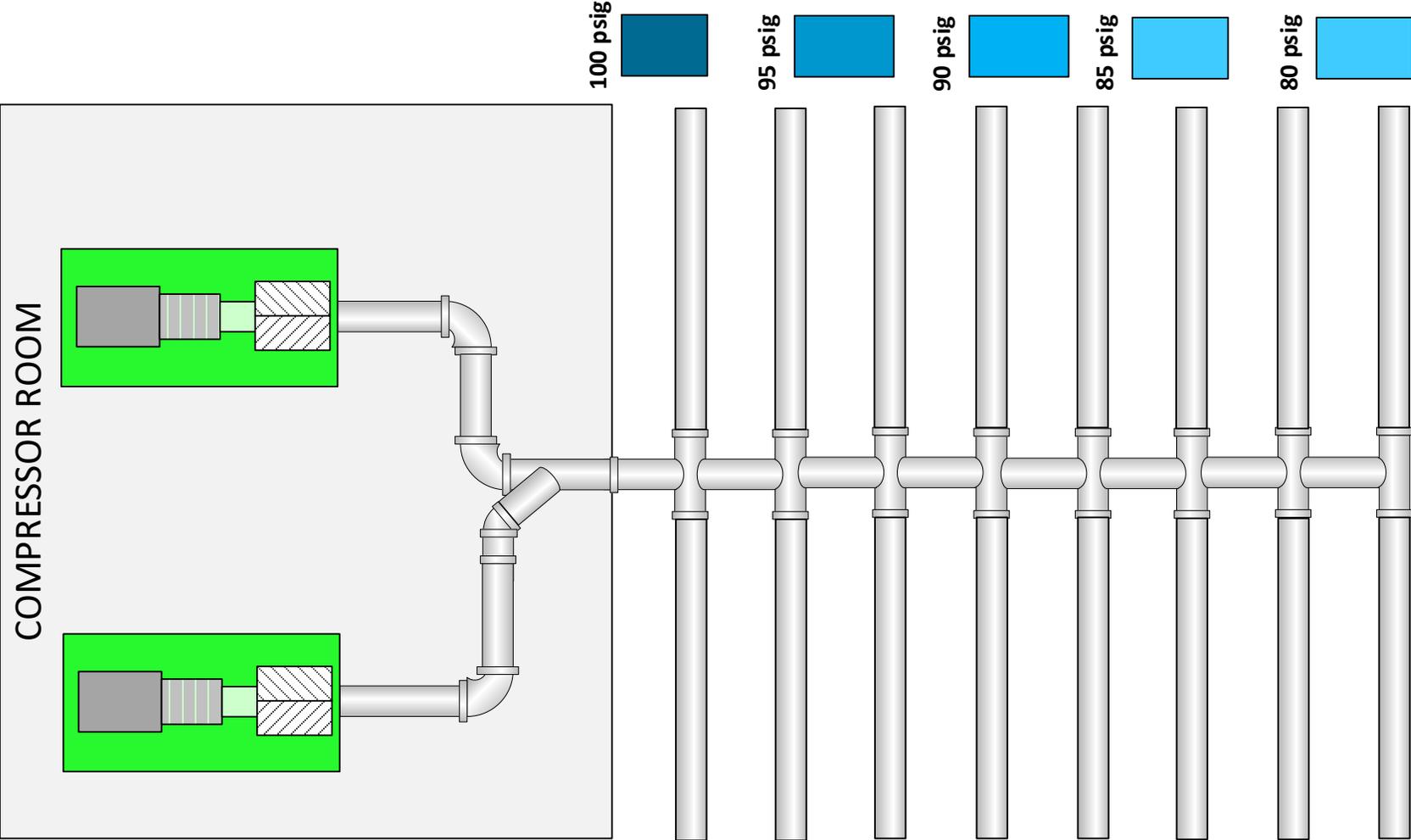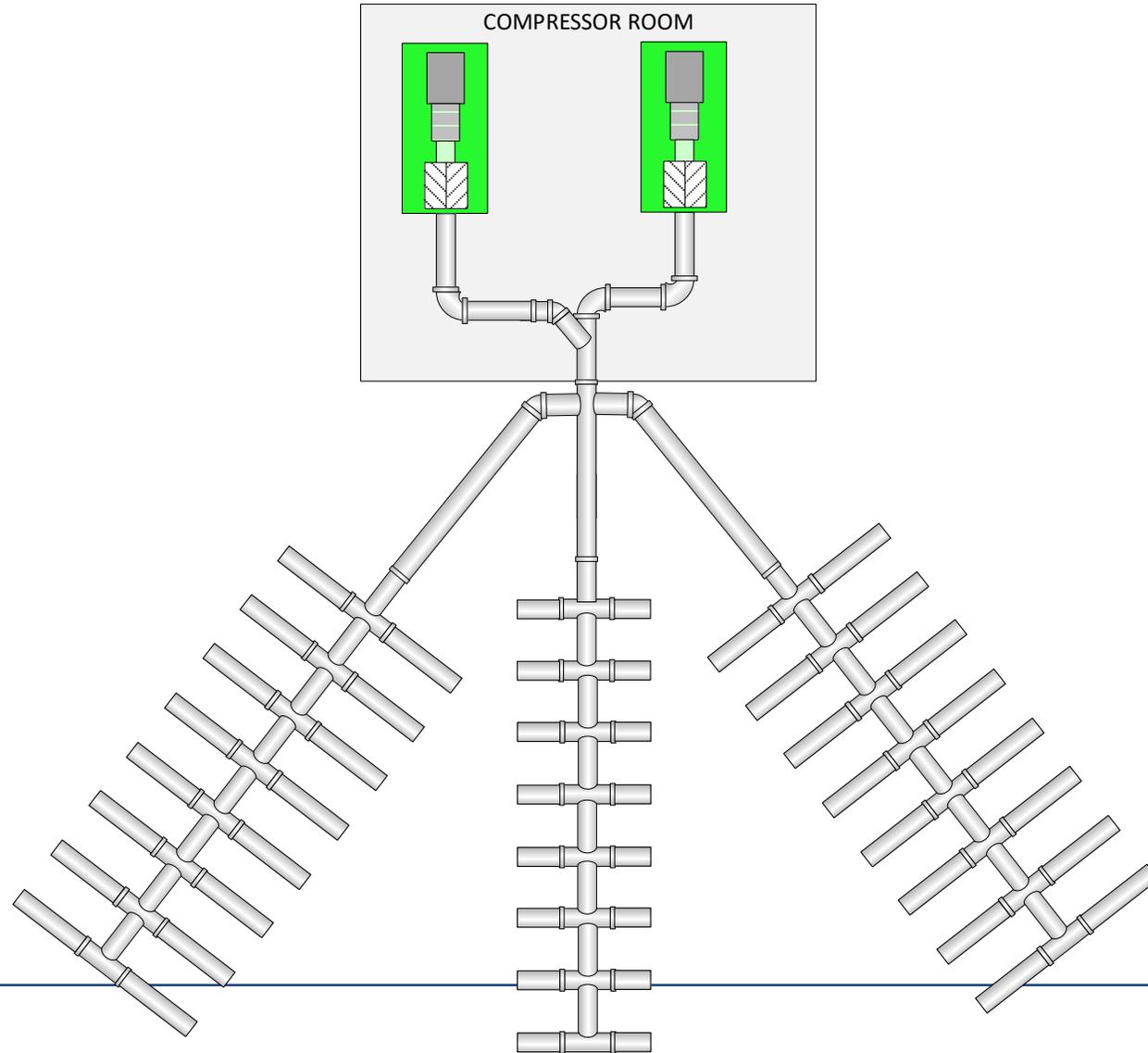
COMPRESSOR ROOM

Piping Systems

- Decentralized system.
  - May consist of two or more grids or loops.
    - Sometimes connected to form one large loop.
    - Each section has its own compressor.
  - Compressors are closer to the system using the air.
    - This allows shorter supply line.
    - Lower pressure drops.
    - Result is more uniform pressure throughout.
  - Very versatile and can easily be changed as needed.

Decentralized system
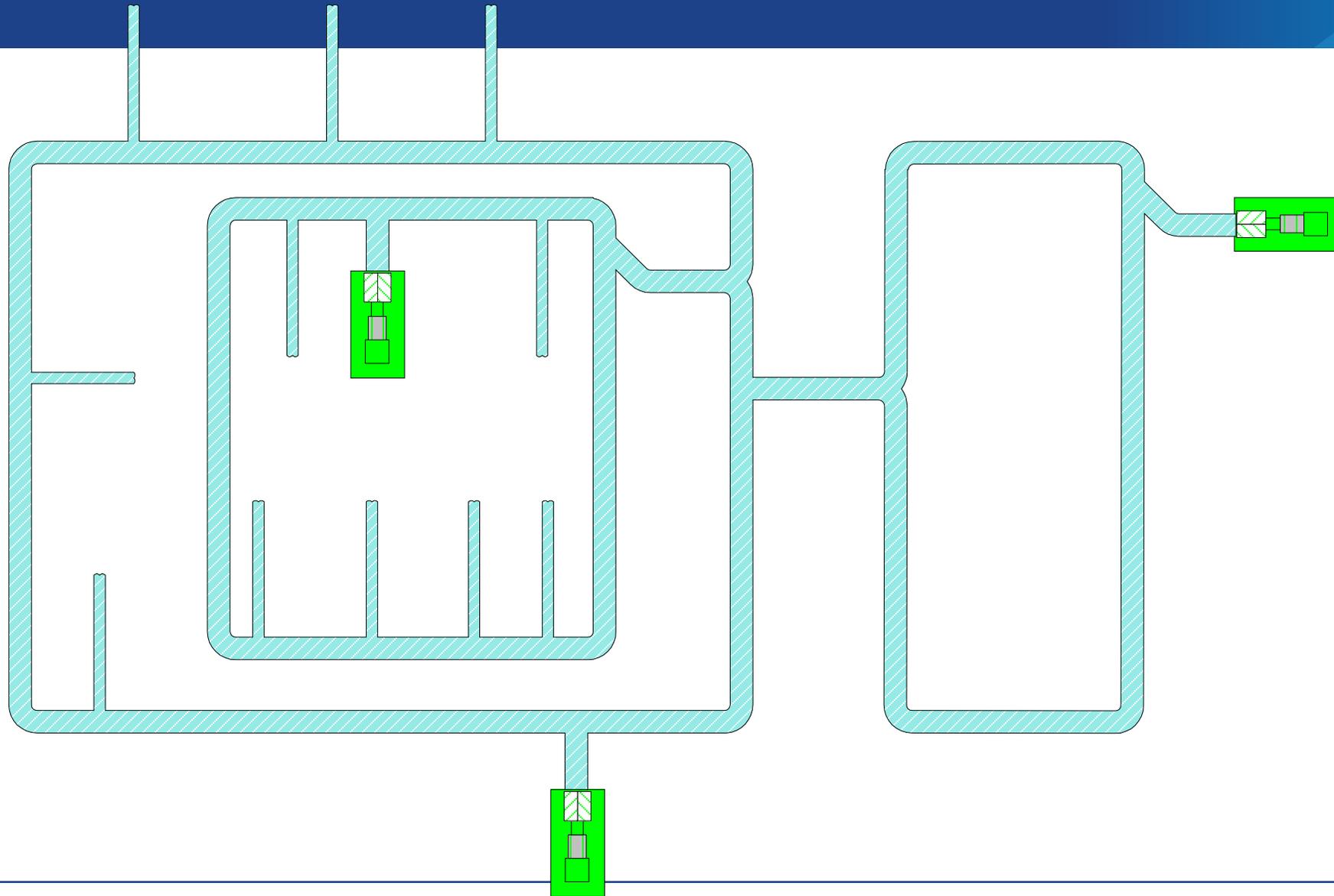
Piping Systems

- Loop system.
  - Highly recommend and most common.
  - Allows the optimum pipe size and assures equal distribution through the plant.
  - At points of heavy momentary demands for air, a receiver can be used to store the energy.

Loop system
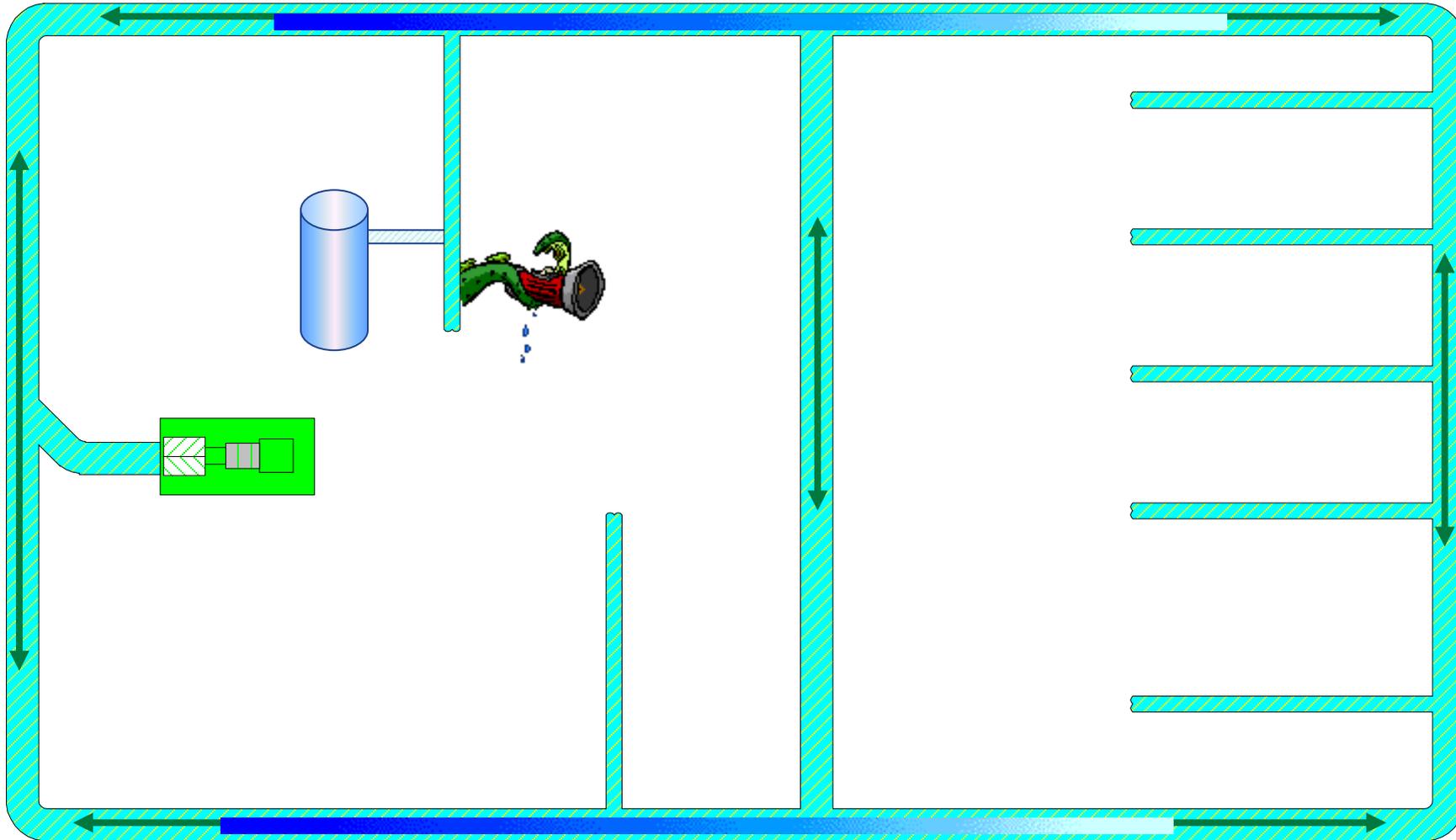
Loop system
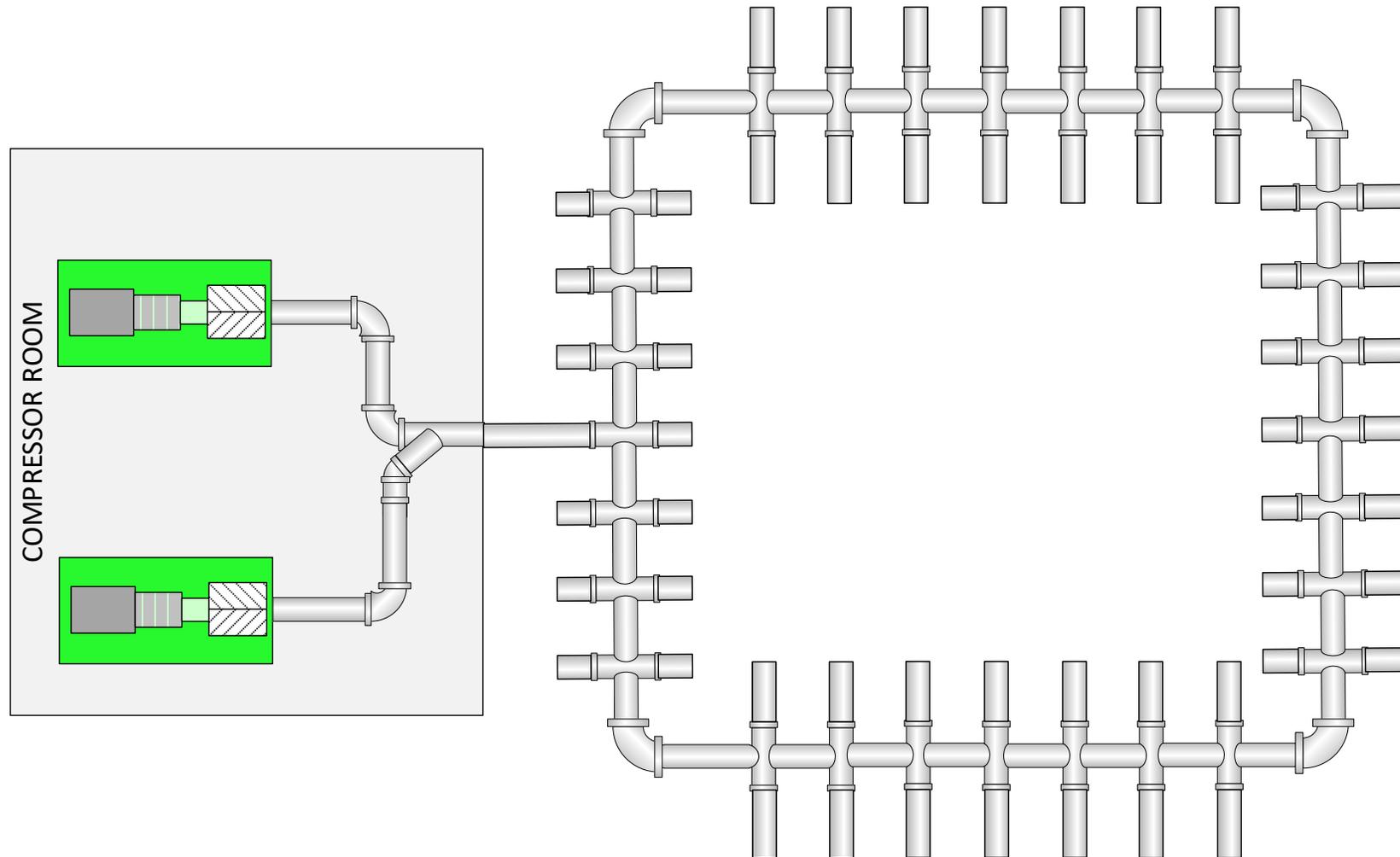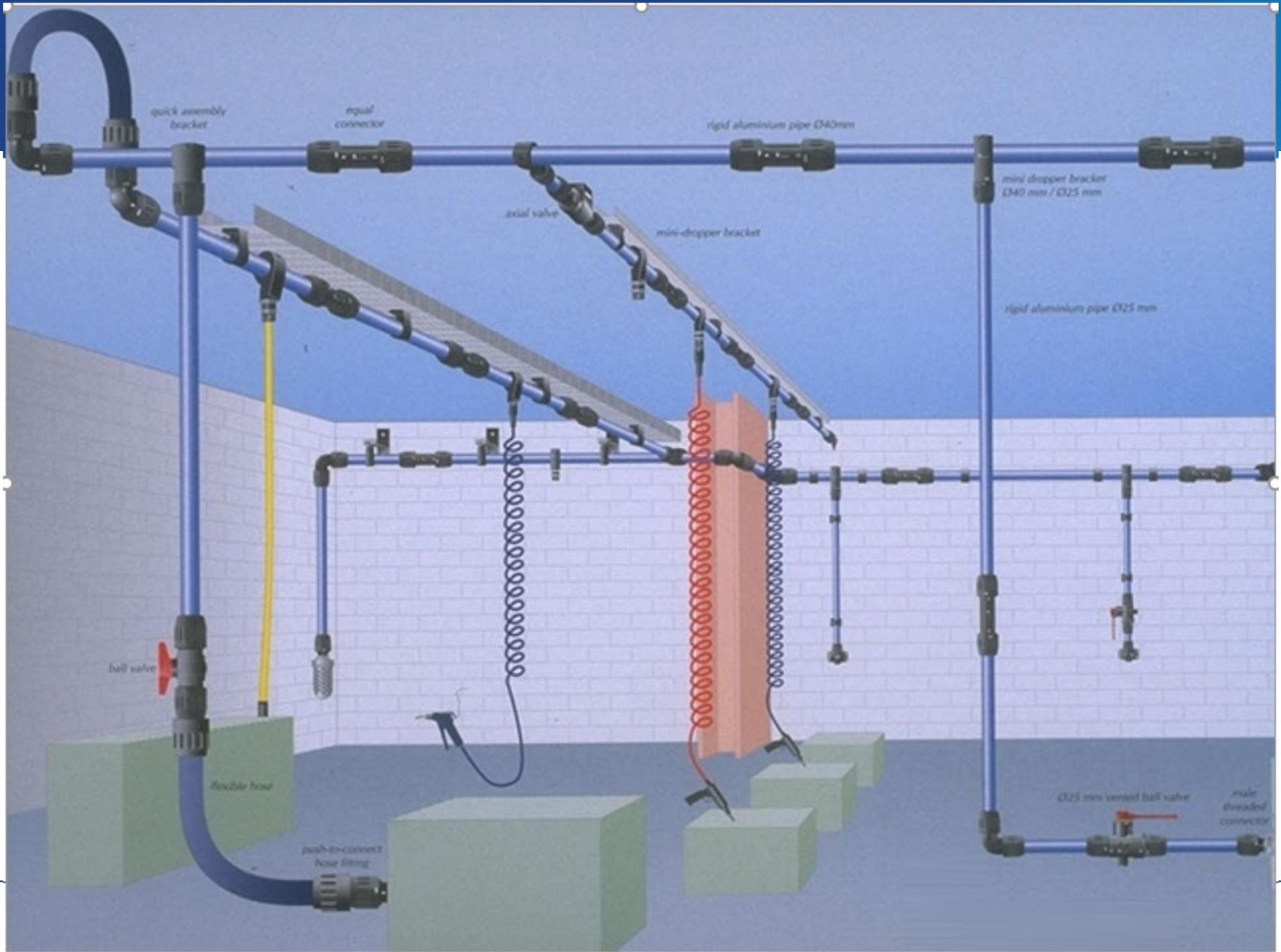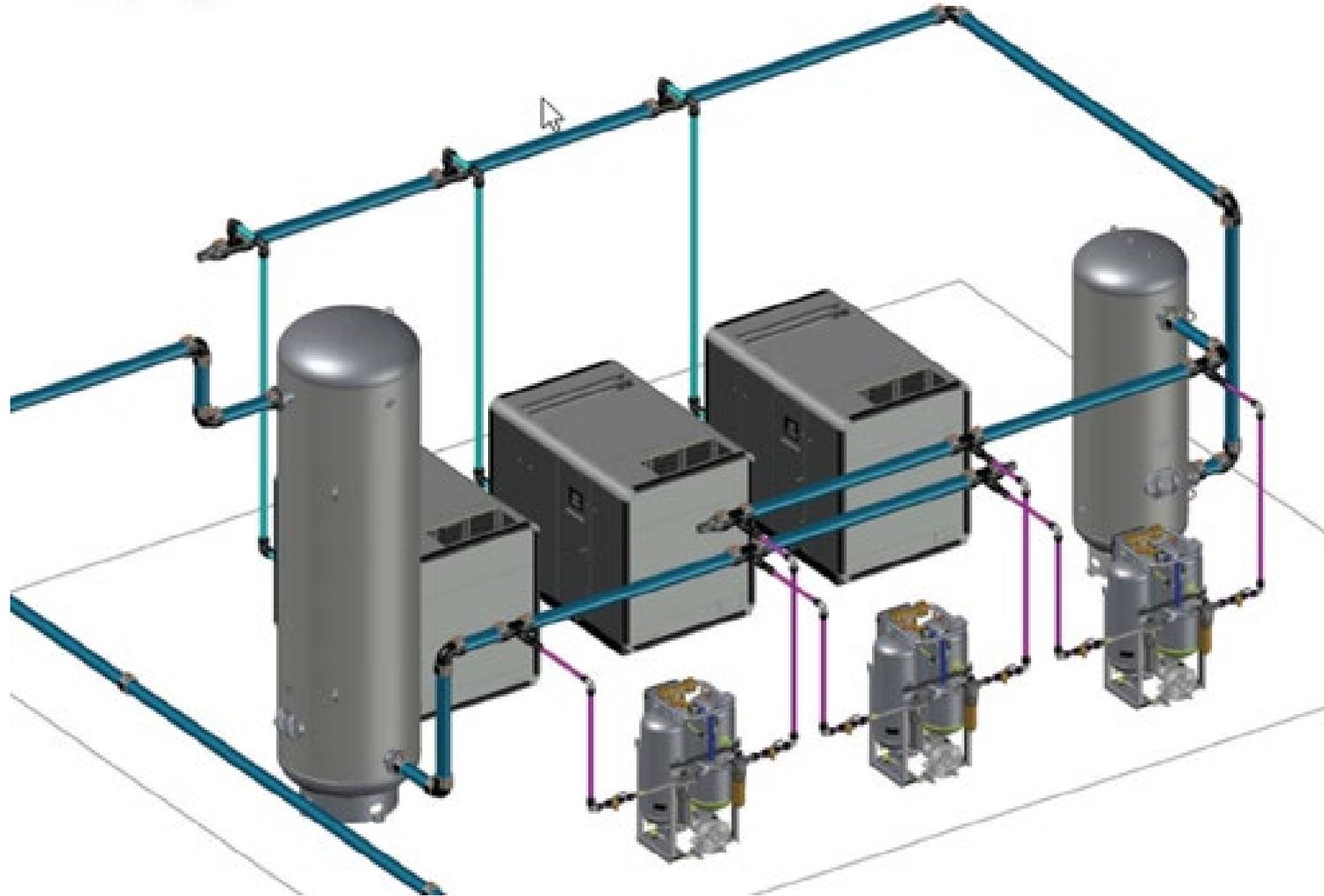
COMPRESSOR ROOM

Piping Systems

- The compressed air may contain small amounts of water having condensed in the piping.
- To eliminate the possibility for this water to drain back down into the compressor, the supply line should always be plumbed into the top of the header.
- This will prevent water or contaminants from draining down into another currently stopped compressor.

General Rules for Compressed Air Distribution System

- Pressure drops between the compressor and points of use are irrecoverable

- Pipe size should be large enough so that pressure drop does not exceed 2-3 % between receiver and point of use

- Design the piping for smooth flow with uniform bends

- Compressor pipe size should always be larger than the discharge connection size of the air compressor.

- Determine the correct pipe size based on system flow, length of pipe, number of bends/valves and acceptable pressure drop.

General Rules for Compressed Air Distribution System

- Arrange piping to avoid the following types of strains:
  - Strains due to the dead weight of the pipe itself
  - Strains due to expansion or contraction of the piping with temperature change
  - Strains due to internal pressure within the piping
- Plan ahead for future emergencies and plan an area for a temporary compressor.
- Consider bypass lines on all items that may require future maintenance.

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Pressure Profiles

- Pressure measurements need to be taken to:
  - Give feedback for control adjustments
  - Determine pressure drops across components
  - Determine system operating pressures
- The following pressure measurements should be taken:
  - Discharge Pressure
  - Loss from filters and dryers
  - Various points in the distribution system

System Pressure Profile

Supply

Demand

110 psig — *Operating Range of Compressors*

100 psig — *Dryer and Filter Pressure Drop*

90 psig —

Distribution System Pressure Drop — *Unregulated End-Use*

85 psig —

FRL, Valve, Hose, and Disconnect Pressure Drop — *Regulated End-Uses*

70 psig —
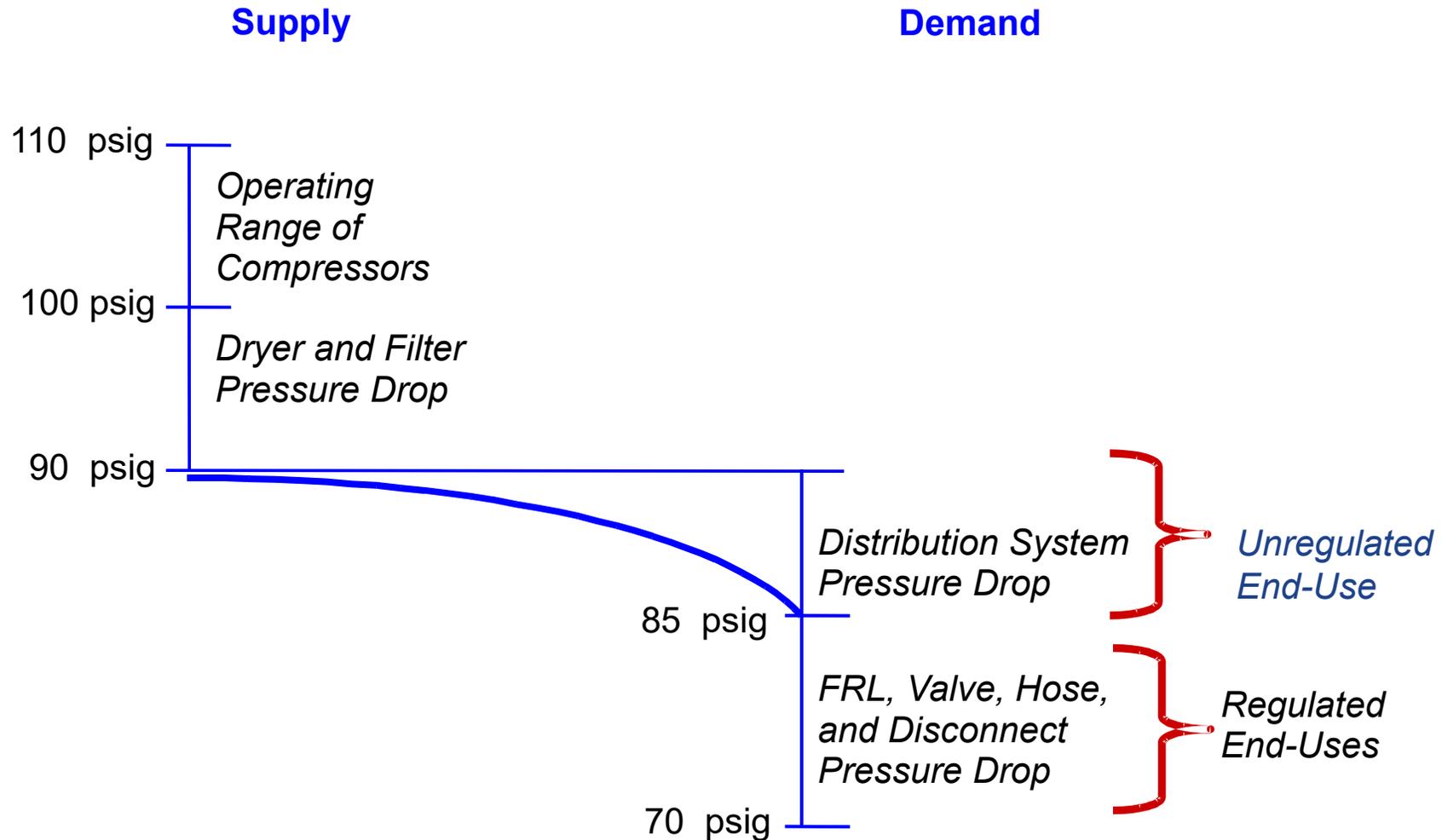
Developing a System Profile
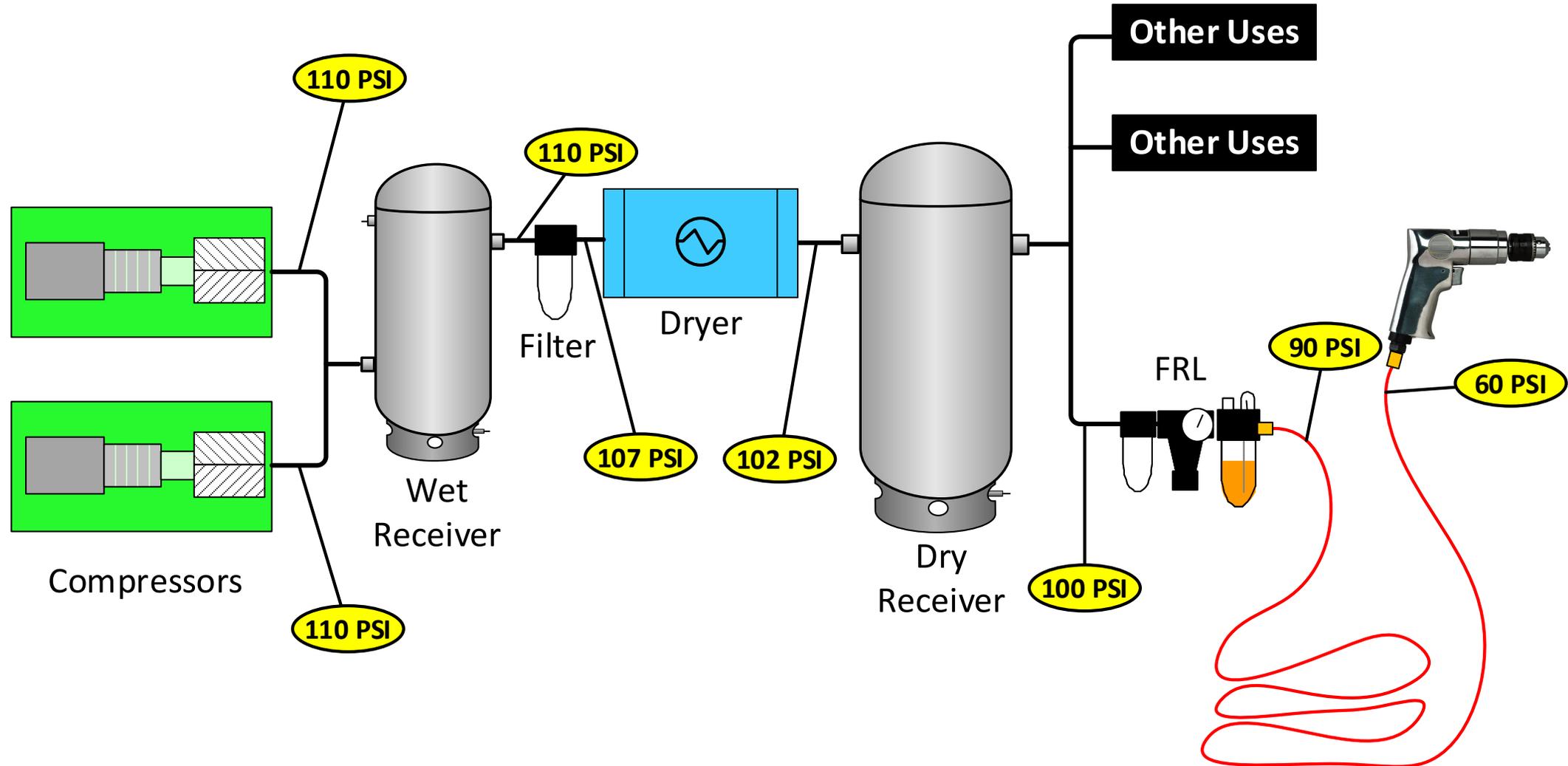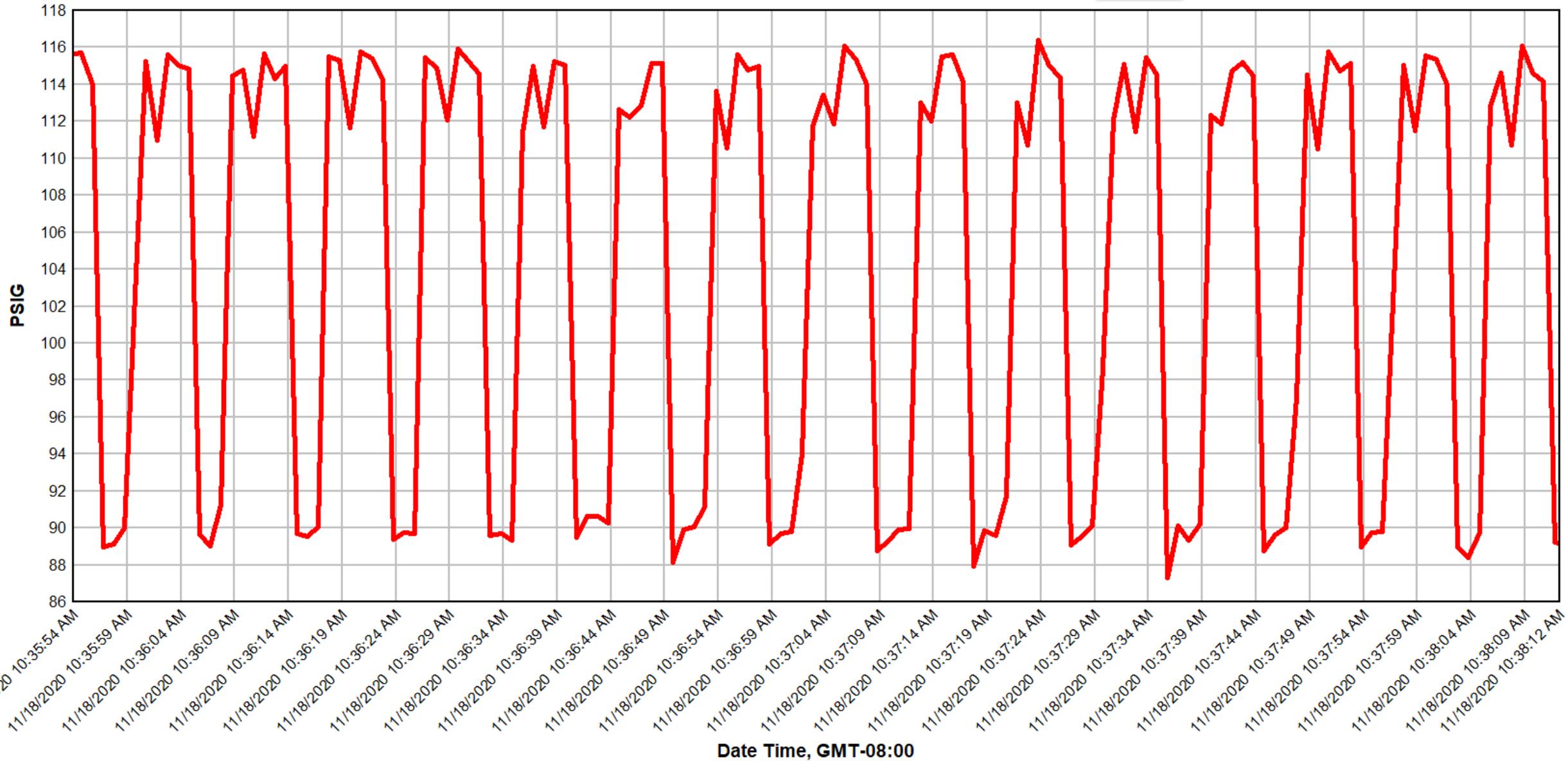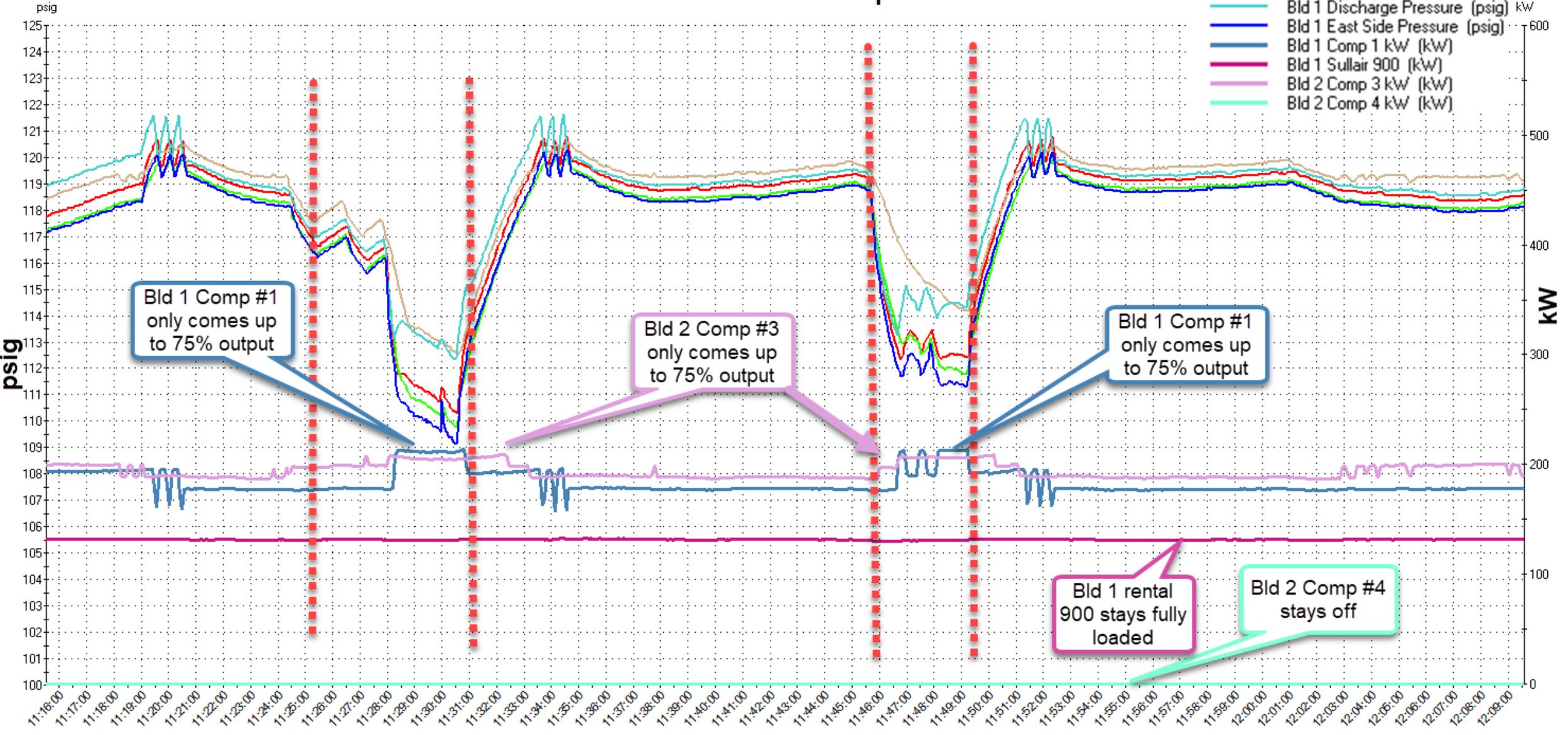
Summary

- The objective of compressed air piping is to deliver compressed air to the end uses without pressure loss and the introduction of contaminants.
- Proper piping material selection and following guidelines for both distribution and compressor discharge piping can help system designers accomplish this goal.
- Larger diameter pipe sizes reduce air velocities (and therefore turbulence) resulting in minimized pressure losses.
- Use a loop piping system, if possible, both around the plant and within each area
- Create the correct size storage by using proper size receivers

Using LogTool - Quick Review

LogTool is Designed To:

- Import data which is exported from different types of data loggers.
- Select logger data channels and modify their properties.
  - e.g., name, type, units, etc.
- View data values for one or more logger channels.
- Display trend plots on one or two Y axis.
- Display scatter plots.
- Display daytype plots in the format that is needed for AIRMaster+
- The previous charts were all created from LogTool

Box Plant Example:

Fully Loaded

250 hp, Air Cooled
Rated 1269 acfm @ 100 psig

Fully Loaded

200 hp, Air Cooled
Rated 1014 acfm @ 100 psig

PT

1020 Gallons

By-Pass Open

3 inch Pipe

3 inch to Plant

PT

Mist Eliminator Filter

Refrigerated Dryer
Rated for 1500 SCFM @ 100 psig

2180 Gallons
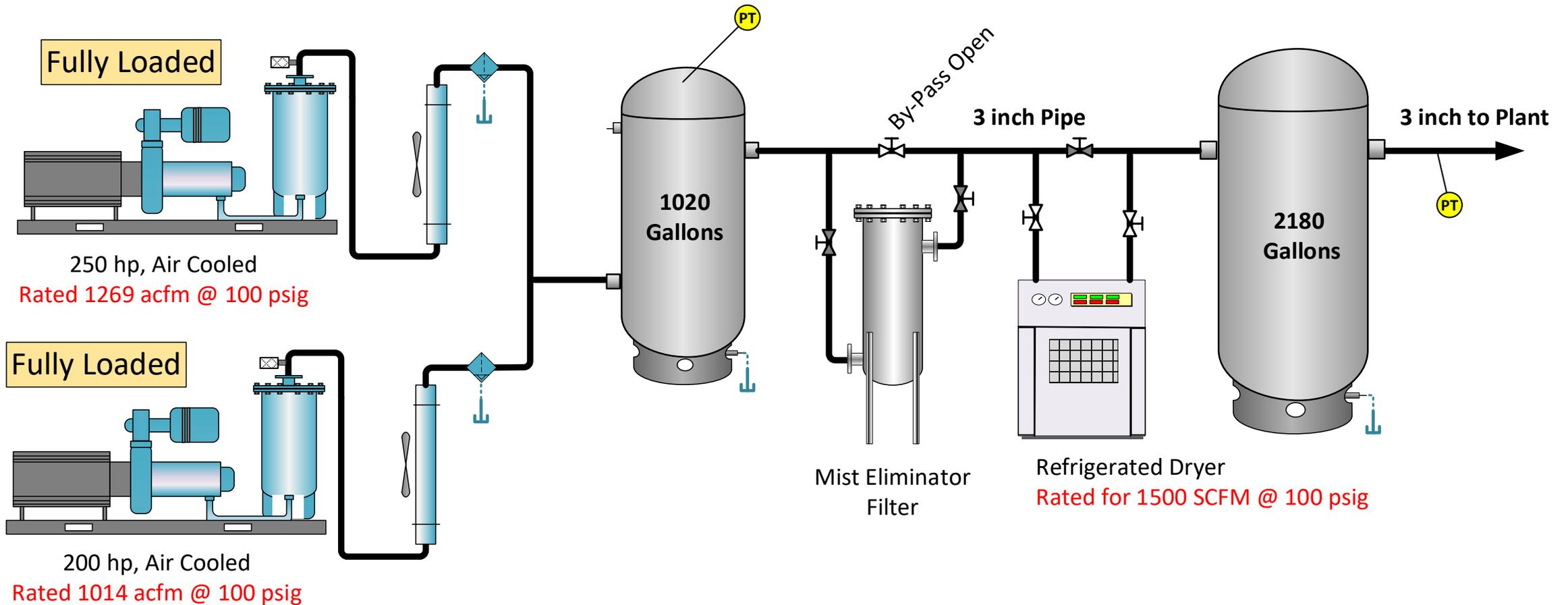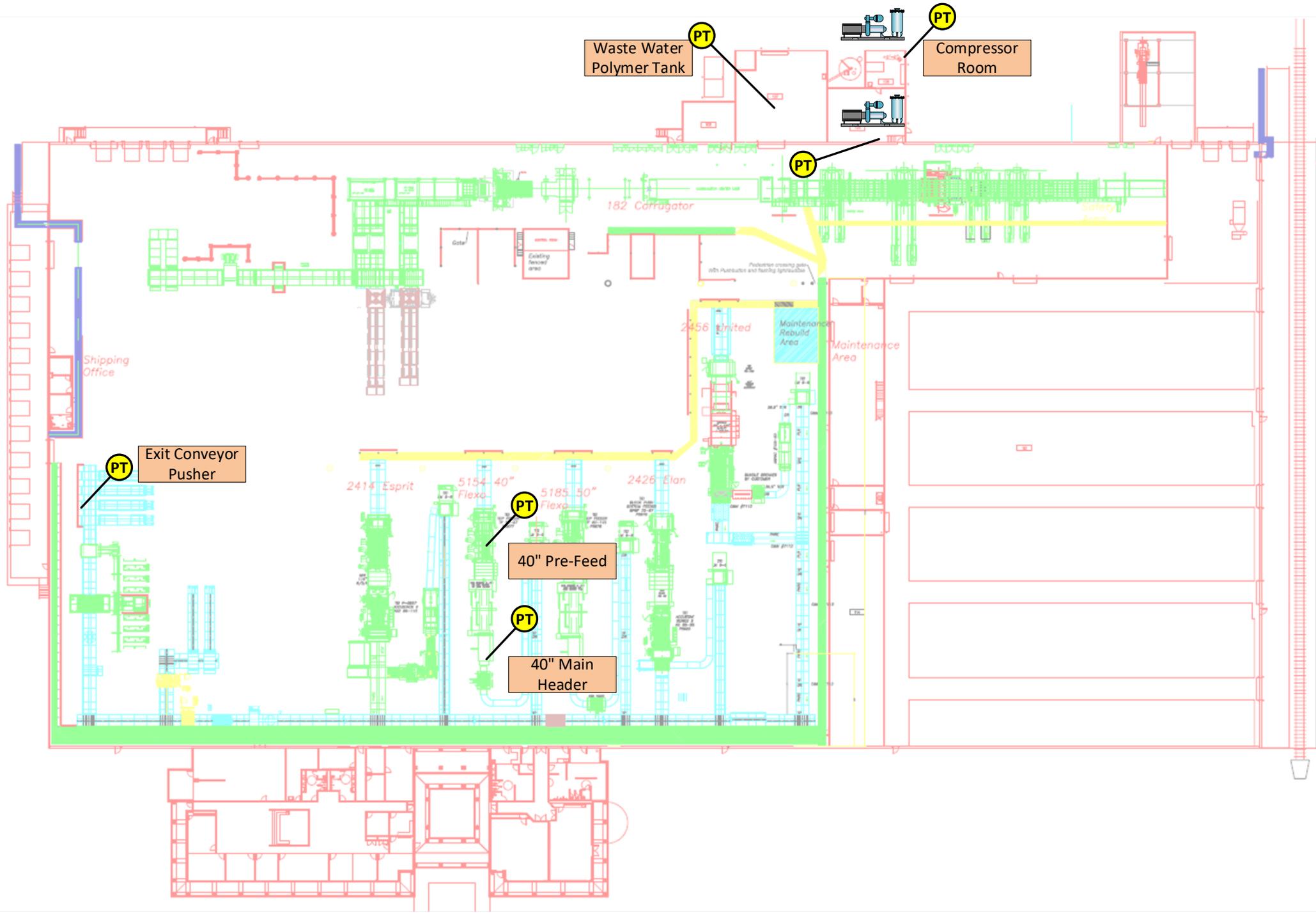
Waste Water Polymer Tank

Compressor Room

Exit Conveyor Pusher

40" Pre-Feed

40" Main Header

Import/Manage Logger Data in: IP LogTool.mdb

Logger File Type

Help

Select Logger Data Files

	Pace Pocket Logger Software
	HOBOware for Windows
	FLUKE Hydra Logger
	DP 3000 Configuration Software
	SULLAIR LogAir Software
	Ranger Pronto For Windows
	Wonderware ActiveFactory
	Unknown Logger Software

Logger Data Files

	Import	File Name	Start	End	Interval (sec.)	File Status

Channels in Files Checked for Import

	Import	File Name	Logger ID	Logger Name	Ch #	Name	Type	Units	Period	System

Import Checked Channels | Check All Channels | Uncheck All Channels

Logger Channels Imported to this MDB File

	Delete	Name	Type	Units	Period	System	Start	End	Interval (sec.)
▶	☐	Wet Tank	Pressure	psig	Not Assigned	Not Assigned	1/11/2018 11:46:51	1/23/2018 14:40:00	3
	☐	Dry Tank	Pressure	psig	Not Assigned	Not Assigned	1/11/2018 11:43:14	1/23/2018 14:36:23	3
	☐	40 inch pre feed	Pressure	psig	Not Assigned	Not Assigned	1/11/2018 12:12:03	1/23/2018 15:05:12	3
	☐	40 inch main header	Pressure	psig	Not Assigned	Not Assigned	1/11/2018 12:15:25	1/23/2018 15:08:34	3
	☐	Exit Conveyor Pushe	Pressure	psig	Not Assigned	Not Assigned	1/11/2018 12:22:10	1/23/2018 15:15:19	3
	☐	Waste Water	Pressure	psig	Not Assigned	Not Assigned	1/11/2018 12:05:48	1/23/2018 14:58:57	3
	☐	200 QNW	Power	kW	Not Assigned	Not Assigned	1/11/2018 11:35:38	1/23/2018 14:29:59	3
	☐	250 QNW	Power	kW	Not Assigned	Not Assigned	1/11/2018 11:31:38	1/23/2018 14:24:47	3

Delete Checked Channels

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LogTool Main Menu

Enter LogTool Data Into AIRMaster

Copy Profiles to a Spreadsheet

DayTypeName	ChannelName	Hr_01	Hr_02	Hr_03	Hr_04	Hr_05	Hr_06	Hr_07	Hr_08	Hr_09	Hr_10	Hr_11	Hr_12	Hr_13	Hr_14	Hr_15	Hr_16	Hr_17	Hr_18	Hr_19	Hr_20	Hr_21	Hr_22	Hr_23	Hr_24
Monday	200 QNW	0.0	0.0	0.0	0.0	84.6	175.9	177.1	181.6	182.2	180.8	177.2	177.7	177.0	178.6	178.7	178.7	176.9	177.0	178.2	177.2	178.7	179.6	180.1	179.3
Monday	250 QNW	0.0	0.0	0.0	0.0	83.8	164.2	163.6	164.5	165.0	166.7	171.6	169.9	168.1	164.9	163.3	162.5	163.6	164.8	165.6	167.1	167.1	167.0	166.2	166.9
Production	200 QNW	178.1	178.3	177.9	177.1	177.7	178.1	178.0	177.9	177.7	178.1	177.3	177.2	177.2	168.0	174.9	175.7	175.7	175.8	177.5	177.4	178.4	179.0	179.1	179.8
Production	250 QNW	166.5	166.8	167.5	168.3	168.5	168.5	168.4	168.0	168.1	167.1	166.4	166.1	165.0	167.1	165.9	164.7	164.5	165.2	165.0	165.8	165.3	164.5	164.2	164.4
Sunday	200 QNW	181.8	180.5	179.2	177.0	154.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sunday	250 QNW	165.6	163.8	162.4	161.8	143.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Date	Day	Day Type
Jan-11-2018	Thu	Excluded Days
Jan-12-2018	Fri	Production
Jan-13-2018	Sat	Production
Jan-14-2018	Sun	Sunday
Jan-15-2018	Mon	Monday
Jan-16-2018	Tue	Production
Jan-17-2018	Wed	Production
Jan-18-2018	Thu	Production
Jan-19-2018	Fri	Production
Jan-20-2018	Sat	Production
Jan-21-2018	Sun	Excluded Days
Jan-22-2018	Mon	Excluded Days
Jan-23-2018	Tue	Excluded Days

DayType Profiles
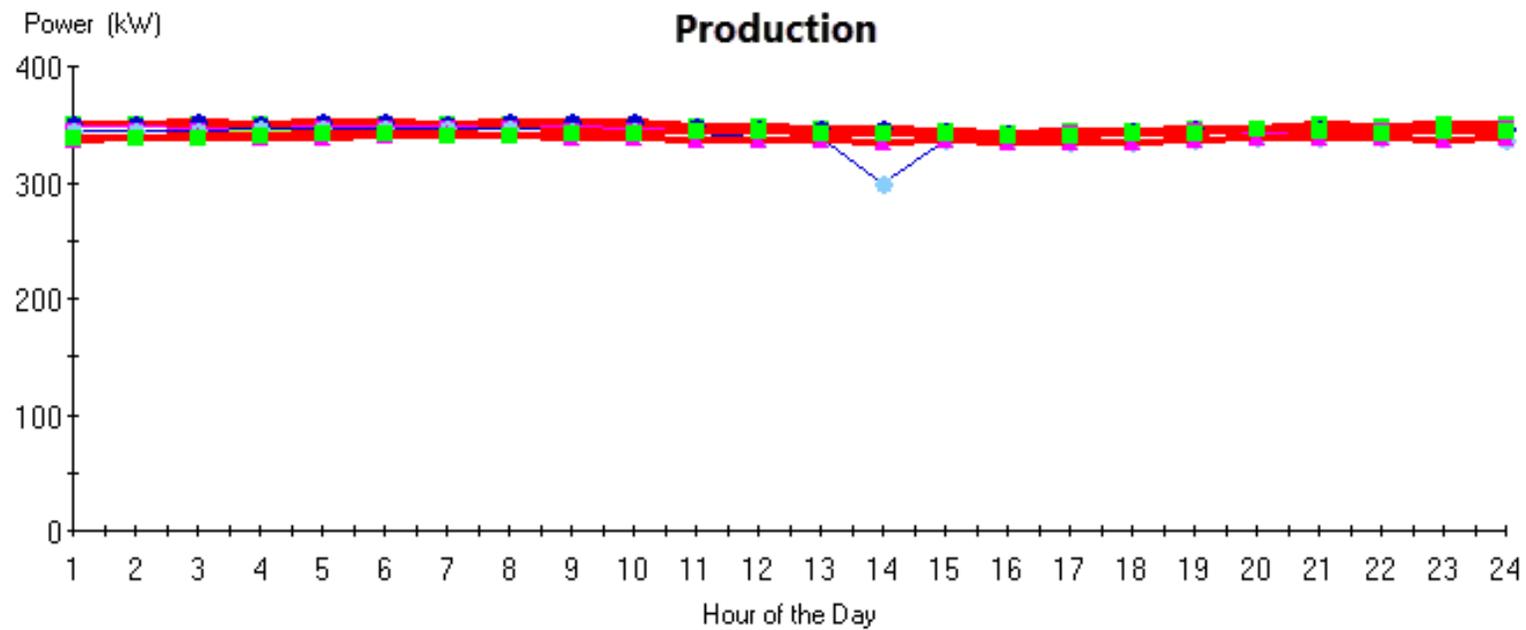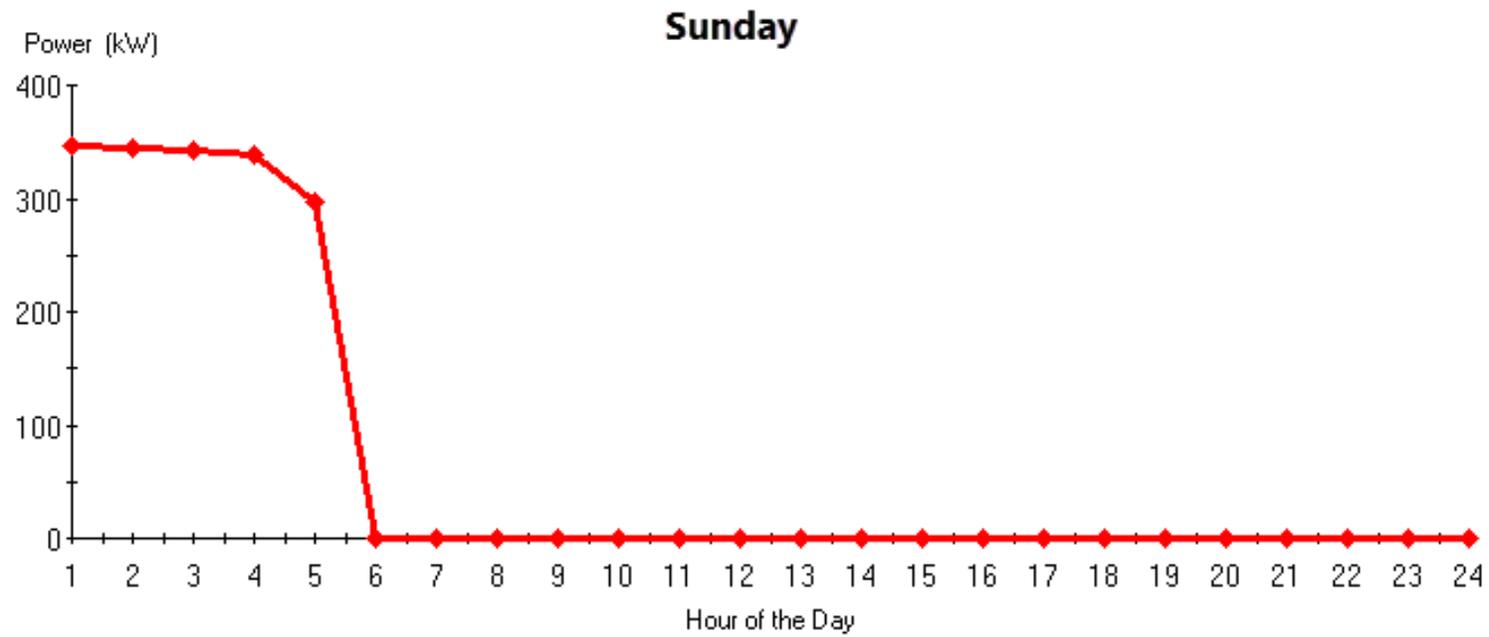
DayType Profiles

DayType Profiles

LogTool Trend Plot

Leakage Losses Example

Leakage Losses Example

SYSTEM CAPACITY

Pipes

Pipe Size (in)	Pipe Length (ft)
1/2	0 ft ✕

Add Pipe

Receiver Tanks

Receiver 1	8500 gal ✕

Add Receiver Tank

Leak Rate Calculator

Normal Operating Pressure	115	psi
Test Pressure	71	psi
Time	6	min
Atmospheric Pressure	14.7	psia

Total Pipe Volume	— —
Total Receiver Volume	8,500 gal (1,136 ft^3)
Total Capacity of Compressed Air System	8,500 gal (1,136 ft^3)

Leak Rate	708.57 acfm

Using MEASUR - Quick Review

Add New ▾

ℹ v1.6.8 Release Notes

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- 🖥 Masonite
- 🖥 Roppe
- 🖥 International Paper
- 🖥 International Paper
- 🖥 Roppe Honeywell
- 🖥 Roppe
- 🖥 Roppe
- 🖥 Roppe Honeywell 2
- 🖥 Roppe Honeywell
- 🖥 Roppe
- 🖥 JSW Lime Dolo
- 🖥 JSW Mill
- 🖥 JSW Caster Spray
- 🖥 Masonite
- 🖥 Masonite
- 🖥 CMC Steel
- 🖥 General Mills Alb
- 🖥 International Paper
- 🖥 International Paper
- 🖥 Coca Cola v2
- 🖥 Coca Cola v2
- 🖥 Coca Cola v2
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- 🖥 Coca Cola

🏭 MEASUR

🏭 **M**anufacturing **E**nergy **A**ssessment **S**oftware for **U**tility **R**eduction

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.
For additional tools and resources, check out ORNL's 📊 Industrial Resources page.

View Assessments

Eq...

🏭 MEASUR

| Pump Assessment | Compressed Air Assessment | Process Heating Assessment | Fan Assessment | Steam Assessment | Treasure Hunt | Wastewater Assessment | Water Assessment *Beta* |

| Motor Inventory | Pump Inventory | Compressed Air Inventory | Data Exploration | Water Diagram *Beta* |

MEASUR Tool

Compressed Air Calculators

Compressed Air Reduction
This calculator is used to quantify the energy savings associated with reducing compressed air usage.

Compressed Air Pressure Reduction
This calculator is used to quantify the energy savings associated with reducing compressed air system pressure.

Actual to Standard Airflow
The calculator converts ACFM (Actual cubic feet per minute) to SCFM (Standard cubic feet per minute) and vice versa for the given conditions using either ASME standard conditions or CAGI/ISO standard conditions.

Leak Loss Estimator - Bag Method
Estimates the leakage losses in a compressed air system using the bag method
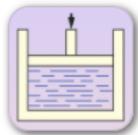
Pneumatic Air Requirement
Estimate the quantity of air required by a specific single acting or a double acting piston cylinder compressor

Compressed Air - Leak Survey
Used to quantify the energy savings associated with reducing compressed air leaks.

MEASUR Tool
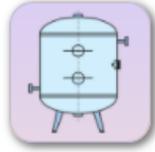
Receiver Tank Sizing
Calculate the required size of the receiver tank
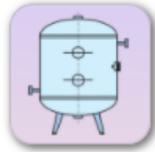
Usable Air Capacity
Estimate the quantity of compressed air that is available for use
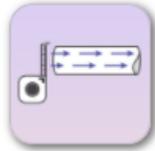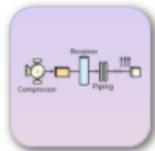
Pipe Sizing
Determine pipe diameter when the volumetric flow velocity, pressure, and design velocity are known
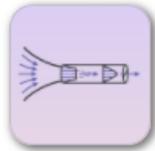
Velocity in the Piping
Estimate the velocity of compressed air throughout system piping

System Capacity
Determine total capacity of compressed air system or specific pipes and receiver tanks

Operation Costs
Estimate the cost of operation of the compressor in both fully and partially loaded instances

MEASUR Tool

Data Exploration

Setup Day Type Analysis Visualization

1 **Import Data** 2 Select Header Row 3 Refine Data 4 Map Date and Time

The Data Exploration module is designed to help users establish Day Types for equipment analysis incorporating multiple operating types (e.g. Compressed Air Assessments). It also provides a robust Data Visualization component to allow users to create scatter plots and histograms of their data.

Import .csv or .xlsx files from your file system.
- The Refine Data and Map Data steps will allow you to modify imported data.
- Timestamps are required for Day Type Analysis and some data visualizations. More Info

Upload Files

Import Existing Data Exploration | Load Example Data

> Timestamp Help

File Upload Preview

International_Paper_Co_inside_200hp_QSI1.csv   Remove

International_Paper_Co_outside_QSI_n250h.csv   Remove

Reset Data

Next

MEASUR Tool

MEASUR Tool

Data Exploration

Setup   Day Type Analysis   Visualization

1 Import Data   **2** Select Header Row   **3** Refine Data   **4** Map Date and Time

Mark the columns to be used for analysis and advance to the next file

☐ Apply my selections for all datasets

| International_Paper_Co_inside_200hp_QSI1.csv | International_Paper_Co_outside_QSI_n250h.csv |

Column Name	Use Column	Alias	Display Unit
Date Time, GMT-07:00	☑	Date Time, GMT-07:00	+Add
200hp QSI1000, kW	☑	200hp QSI1000, kW	+Add

Original Data

Date Time, GMT-07:00	200hp QSI1000, kW
1/11/18 11:35:38 AM	179.256
1/11/18 11:35:41 AM	179.159

Back   Next

MEASUR Tool

MEASUR Tool

Graph Data Table   Data: Total Aggregated Equipment Data ▾

Day Types **Days**   Apply To Assessment

Total Aggregated Equipment Data (Hourly Data Average)

Legend:
- Jan 11, 2018
- Jan 12, 2018
- Jan 13, 2018
- Jan 14, 2018
- Jan 15, 2018
- Jan 16, 2018
- Jan 17, 2018
- Jan 18, 2018
- Jan 19, 2018
- Jan 20, 2018
- Jan 21, 2018
- Jan 22, 2018
- Jan 23, 2018
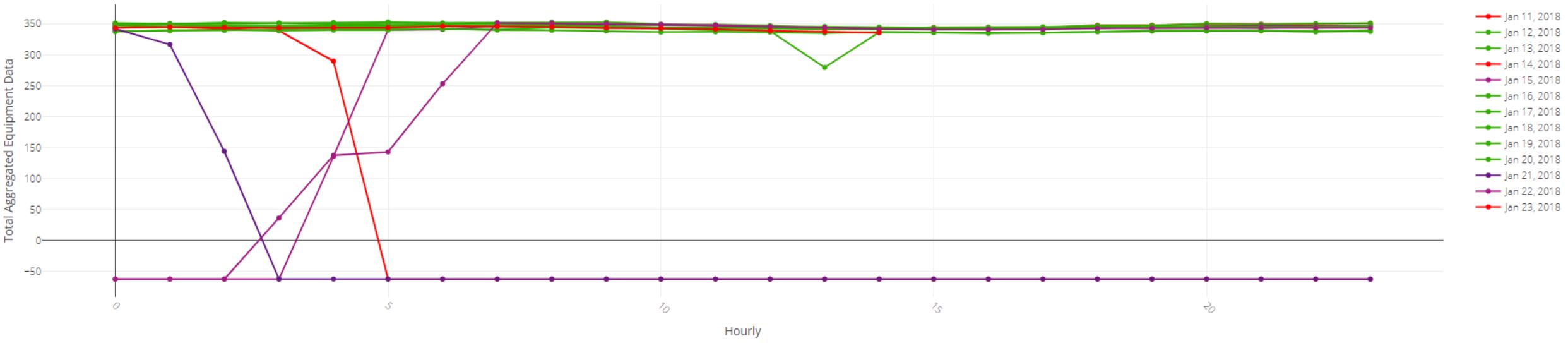
Day Types: Excluded ✖ Production ✖ Sunday ✖ Monday   +Add New | Reset

January 2018

Su	Mo	Tu	We	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			
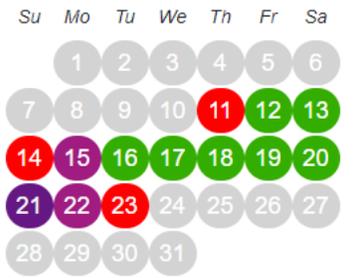
Day Type Average Interval Hourly ▾

Update Analysis

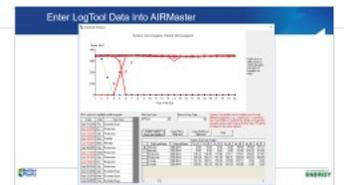**Select Columns for Total Aggregated Equipment Data:**

☐ Apply my selections for all datasets

International_Paper_Co_inside_200hp_QSI1.csv	International_Paper_Co_outside_QSI_n250h.csv

Column Name	Include in Aggregated Data
200hp QSI1000, kW	☑

MEASUR Tool- Main Plant Day Type Analysis

Let's compare to old Log Tool

Harley Davidson
Last modified: Feb 16, 2026

Baseline **Assessment** Diagram Report Sankey Calculators

Explore Opportunities | Profile Summary Table | Profile Summary Graphs

Scenario 1
Selected Scenario

View / Add Scenarios

SELECT POTENTIAL ENERGY EFFICIENCY MEASURES

Select potential energy efficiency measures (EEMs) to explore opportunities to increase efficiency and the effectiveness of your system.

Add New Scenario

Modification Name	Scenario 1
Flow Reallocation Implementation Cost	0

Reduce System Air Pressure | Supply — 1 ∨

Implementation Cost	0	$
Average System Pressure Reduction	10	psig

Reduce Air Leaks | Demand — 2 ∨

Implementation Cost	0	$
Leak Flow	100	acfm
Leak Reduction	50	%

Improve End Use Efficiency | Demand — Off ∨

Reduce Run Time | Supply — Off ∨

MODIFICATION RESULTS | PERFORMANCE PROFILE | HELP | NOTES

All Day Types ∨

	Baseline	Scenario 1
Percent Savings (%)	——	15.2%
Flow Reallocation Energy Savings	——	96,491 kWh
Reduce Air Leaks Energy Savings	——	76,237 kWh
Reduce System Air Pressure Energy Savings	——	201,641 kWh
Peak Demand	**412.76 kW**	**349.78 kW**
Annual Energy	**2,461,562 kWh**	**2,087,194 kWh**
Annual Emission Output Rate	**776 tonne CO_2**	**658 tonne CO_2**
Average Total Flow	**1,340 acfm**	**1,249 acfm**
Peak Air Flow	**1,945 acfm**	**1,805 acfm**
Peak Demand Savings	——	62.98 kW
Annual Energy Savings	——	374,369 kWh
Annual Emission Savings	——	118 tonne CO_2
Flow Reallocation Savings	——	$8,442.94
Reduce Air Leaks Savings	——	$6,670.71
Reduce System Air Pressure Savings	——	$17,643.60
Peak Demand Cost	**$0.00**	**$0.00**
Annual Energy Cost	**$215,386.69**	**$182,629.45**
Annual Cost	**$215,386.69**	**$182,629.45**
Average Total Flow	**1,340 acfm**	**1,249 acfm**
Peak Air Flow	**1,945 acfm**	**1,805 acfm**
Peak Demand Cost Savings	——	$0.00
Annual Energy Cost Savings	——	$32,757.25
Annual Cost Savings	——	$32,757.25

VSD

Selected Scenario

View / Add Scenarios

SELECT POTENTIAL ADJUSTMENT PROJECTS

Select potential adjustment projects to explore opportunities to increase efficiency and the effectiveness of your system.

Add New Scenario

Modification Name: VSD

Reduce Run Time | *Supply*   1 ▾

Implementation Cost: 106700 $

Day Type: Weekday ▾

	Capacity acfm	Shutdown Timer	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
200 hp QNW	933 acfm	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
250 hp QNW	1261 acfm	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
New Compressor	1141 acfm	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Available Airflow			933	933	933	933	933	2,074	2,074	2,074	2,074	2,074	2,074	2,074	2,074
Required Airflow			705	708	709	775	907	1,085	1,347	1,526	1,527	1,524	1,524	1,521	1,513
Power, kW			159.5	159.7	159.8	164.1	172.7	244.1	300.9	357.7	357.8	357.6	357.6	357.4	344.2

Reduce Air Leaks | *Demand*   2 ▾

Implementation Cost: 5000 $

Leak Flow: 600 acfm

Leak Reduction: 50 %

Improve End Use Efficiency | *Demand*   Off ▾

Reduce System Air Pressure | *Supply*   Off ▾

Add Primary Receiver Volume | *Supply*   Off ▾

MODIFICATION RESULTS | PERFORMANCE PROFILE | HELP | NOTES

All Day Types ▾
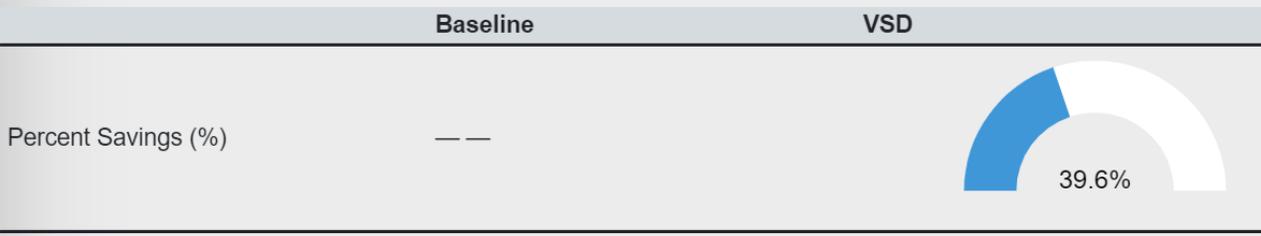
	Baseline	VSD
Percent Savings (%)	— —	39.6%
Flow Reallocation Energy Savings	— —	391,627 kWh
Reduce Air Leaks Energy Savings	— —	585,745 kWh
Reduce Run Time Energy Savings	— —	-233,967 kWh
Peak Demand	346.6 kW	273.86 kW
Annual Energy	2,620,045 kWh	1,876,639 kWh
Annual Emission Output Rate	1,050,821 tonne CO_2	752,664 tonne CO_2
Peak Demand Savings	— —	72.74 kW
Annual Energy Savings	— —	743,405 kWh
Annual Emission Savings	— —	298,158 tonne CO_2
Flow Reallocation Savings	— —	$25,847.38
Reduce Air Leaks Savings	— —	$55,352.94
Reduce Run Time Savings	— —	-$22,109.88
Peak Demand Cost	$0.00	$0.00
Annual Energy Cost	$247,594.21	$177,342.40
Annual Cost	$247,594.21	$177,342.40
Peak Demand Cost Savings	— —	$0.00
Annual Energy Cost Savings	— —	$70,251.80
Annual Cost Savings	— —	$70,251.80
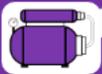
Explore Opportunities Profile Summary Table Profile Summary Graphs

Scenario 1
Selected Scenario

View / Add Scenarios

SELECT POTENTIAL ENERGY EFFICIENCY MEASURES

Select potential energy efficiency measures (EEMs) to explore opportunities to increase efficiency and the effectiveness of your system.

Add New Scenario

Modification Name	Scenario 1
Flow Reallocation Implementation Cost	75000

Reduce Air Leaks | *Demand* [1 ▾]

Implementation Cost	6000	$
Leak Flow	1000	acfm
Leak Reduction	50	%

Improve End Use Efficiency | *Demand* [2 ▾]

▲ Improve End Use Efficiency #1

Implementation Cost	20000	$
Substitute Auxiliary Equipment?	Yes	
Equipment Demand	10	kW
Airflow Reduction Type	◉ Fixed ◯ Variable	
Airflow Reduction	300	acfm

☐ Fill right on change

0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

+Add Efficiency Improvement

Reduce System Air Pressure | *Supply* [Off ▾]

Reduce Run Time | *Supply* [Off ▾]

MODIFICATION RESULTS	PERFORMANCE PROFILE	HELP	NOTES
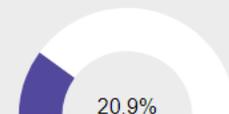
	Baseline	**Scenario 1**
Percent Savings (%)	— —	20.9%
Auxiliary Power Energy Use	— —	87,600 kWh
Flow Reallocation Energy Savings	— —	2,393,011 kWh
Improve End Use Efficiency Energy Savings	— —	343,500 kWh
Reduce Air Leaks Energy Savings	— —	572,498 kWh
Peak Demand	**1,769.48 kW**	**1,404.7 kW**
Annual Energy	**15,417,175 kWh**	**12,195,766 kWh**
Annual Emission Output Rate	**6,778 tonne CO$_2$**	**5,362 tonne CO$_2$**
Average Total Flow	**9,946 acfm**	**9,146 acfm**
Peak Air Flow	**10,041 acfm**	**9,241 acfm**
Peak Demand Savings	**— —**	**364.78 kW**
Annual Energy Savings	**— —**	**3,221,409 kWh**
Annual Emission Savings	**— —**	**1,416 tonne CO$_2$**
Auxiliary Power Cost	— —	-$7,008.00
Flow Reallocation Savings	— —	$191,440.90
Improve End Use Efficiency Savings	— —	$27,480.01
Reduce Air Leaks Savings	— —	$45,799.81
Peak Demand Cost	**$0.00**	**$0.00**
Annual Energy Cost	**$1,233,373.98**	**$975,661.25**
Annual Cost	**$1,233,373.98**	**$975,661.25**
Average Total Flow	**9,946 acfm**	**9,146 acfm**
Peak Air Flow	**10,041 acfm**	**9,241 acfm**
Peak Demand Cost Savings	**— —**	**$0.00**
Annual Energy Cost Savings	**— —**	**$257,712.72**
Annual Cost Savings	**— —**	**$257,712.72**

Baseline System Capacity

Legend: Peak Airflow · Max System Capacity · New 450 hp VSD · Compressor 8 · Compressor 6 (Trim) · Compressor 5 · Compressor 3 · Compressor 2 · Compressor 1

System Capacity (acfm) vs Hour

Scenario 1 System Capacity

Legend: Peak Airflow · Max System Capacity · New 450 hp VSD · Compressor 8 · Compressor 6 (Trim) · Compressor 5 · Compressor 3 · Compressor 2 · Compressor 1

System Capacity (acfm) vs Hour

Baseline System Power

Legend: Peak Power · Max Full Load Power · New 450 hp VSD · Compressor 8 · Compressor 6 (Trim) · Compressor 5 · Compressor 3 · Compressor 2 · Compressor 1

Power (kW) vs Hour

Scenario 1 System Power

Legend: Peak Power · Max Full Load Power · New 450 hp VSD · Compressor 8 · Compressor 6 (Trim) · Compressor 5 · Compressor 3 · Compressor 2 · Compressor 1

Power (kW) vs Hour

Harley Davidson
Last modified: Feb 16, 2026

Baseline | **Assessment** | Diagram | Report | Sankey | Calculators

Scenario 1
Selected Scenario

View / Add Scenarios

Explore Opportunities | Profile Summary Table | Profile Summary Graphs

SELECT POTENTIAL ENERGY EFFICIENCY MEASURES

Select potential energy efficiency measures (EEMs) to explore opportunities to increase efficiency and the effectiveness of your system.

Add New Scenario

Modification Name	Scenario 1
Flow Reallocation Implementation Cost	0

Reduce System Air Pressure | *Supply* — 1 ▾

Implementation Cost	0	$
Average System Pressure Reduction	10	psig

Reduce Air Leaks | *Demand* — 2 ▾

Implementation Cost	0	$
Leak Flow	100	acfm
Leak Reduction	50	%

Improve End Use Efficiency | *Demand* — Off ▾

Reduce Run Time | *Supply* — Off ▾

MODIFICATION RESULTS | PERFORMANCE PROFILE | HELP | NOTES

All Day Types ▾

	Baseline	Scenario 1
Percent Savings (%)	— —	15.2%
Flow Reallocation Energy Savings	— —	96,491 kWh
Reduce Air Leaks Energy Savings	— —	76,237 kWh
Reduce System Air Pressure Energy Savings	— —	201,641 kWh
Peak Demand	**412.76 kW**	**349.78 kW**
Annual Energy	**2,461,562 kWh**	**2,087,194 kWh**
Annual Emission Output Rate	**776 tonne CO₂**	**658 tonne CO₂**
Average Total Flow	**1,340 acfm**	**1,249 acfm**
Peak Air Flow	**1,945 acfm**	**1,805 acfm**
Peak Demand Savings	— —	62.98 kW
Annual Energy Savings	— —	374,369 kWh
Annual Emission Savings	— —	118 tonne CO₂
Flow Reallocation Savings	— —	$8,442.94
Reduce Air Leaks Savings	— —	$6,670.71
Reduce System Air Pressure Savings	— —	$17,643.60
Peak Demand Cost	**$0.00**	**$0.00**
Annual Energy Cost	**$215,386.69**	**$182,629.45**
Annual Cost	**$215,386.69**	**$182,629.45**
Average Total Flow	**1,340 acfm**	**1,249 acfm**
Peak Air Flow	**1,945 acfm**	**1,805 acfm**
Peak Demand Cost Savings	— —	$0.00
Annual Energy Cost Savings	— —	$32,757.25
Annual Cost Savings	— —	$32,757.25

MEASUR Tool- Data Analysis
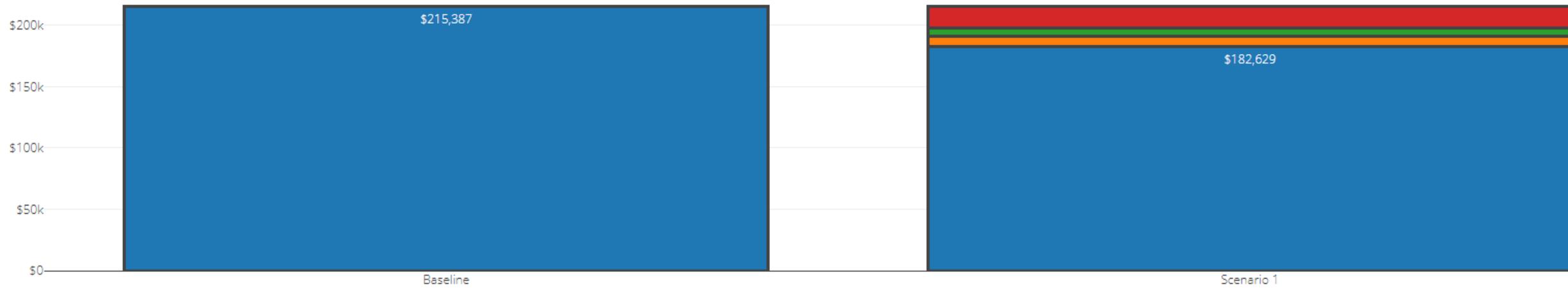
MEASUR Tool- Data Analysis
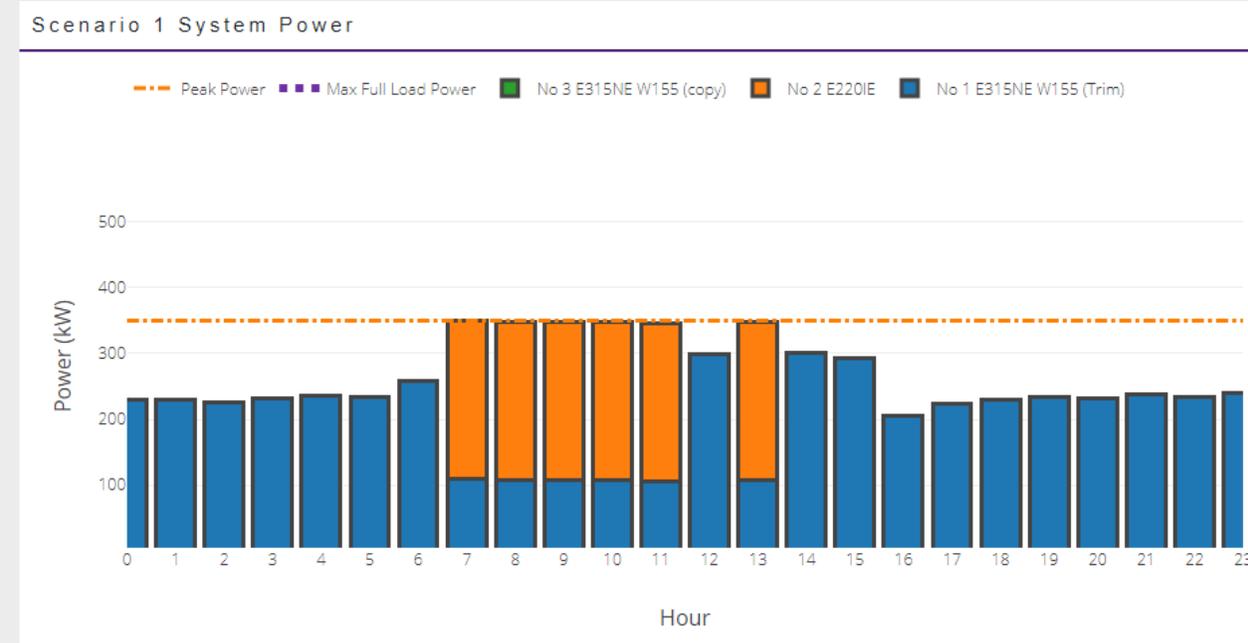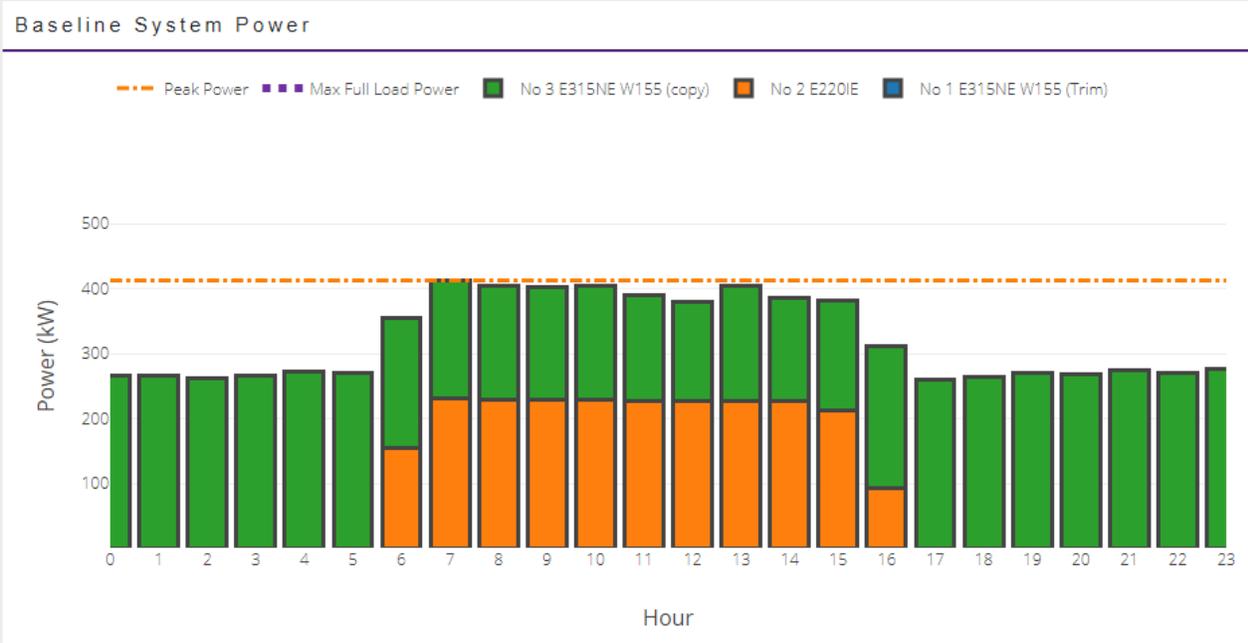
Next Week - The Demand Side

- Typically, only 50% of the air produced in supply gets to productive used in demand.

- 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?

- In many cases, misapplication of compressed air at the end-use causes systems to perform poorly.
- Please fill out (sample below) which Jennifer will send you via email

What is the pressure going into the main header?
Pressure: _____ psig

What is the end-use pressure required for typical applications in the plant?
Pressure: _____ psig

List any applications that require higher than typical pressure:

Application	Approximate End-Use Pressure Req'd
_____	_____ psig
_____	_____ psig
_____	_____ psig
_____	_____ psig

List any applications that require lower than typical pressure:

Application	Approximate End-Use Pressure Req'd
_____	_____ psig
_____	_____ psig
_____	_____ psig
_____	_____ psig

List any applications where users complain about low pressure:

Application	Approximate End-Use Pressure Req'd
_____	_____ psig
_____	_____ psig
_____	_____ psig
_____	_____ psig

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

Comments:_____

Questions?