Better Plants
U.S. DEPARTMENT OF ENERGY

In-Plant Trainings

Virtual Platform
Session 5 Distribution

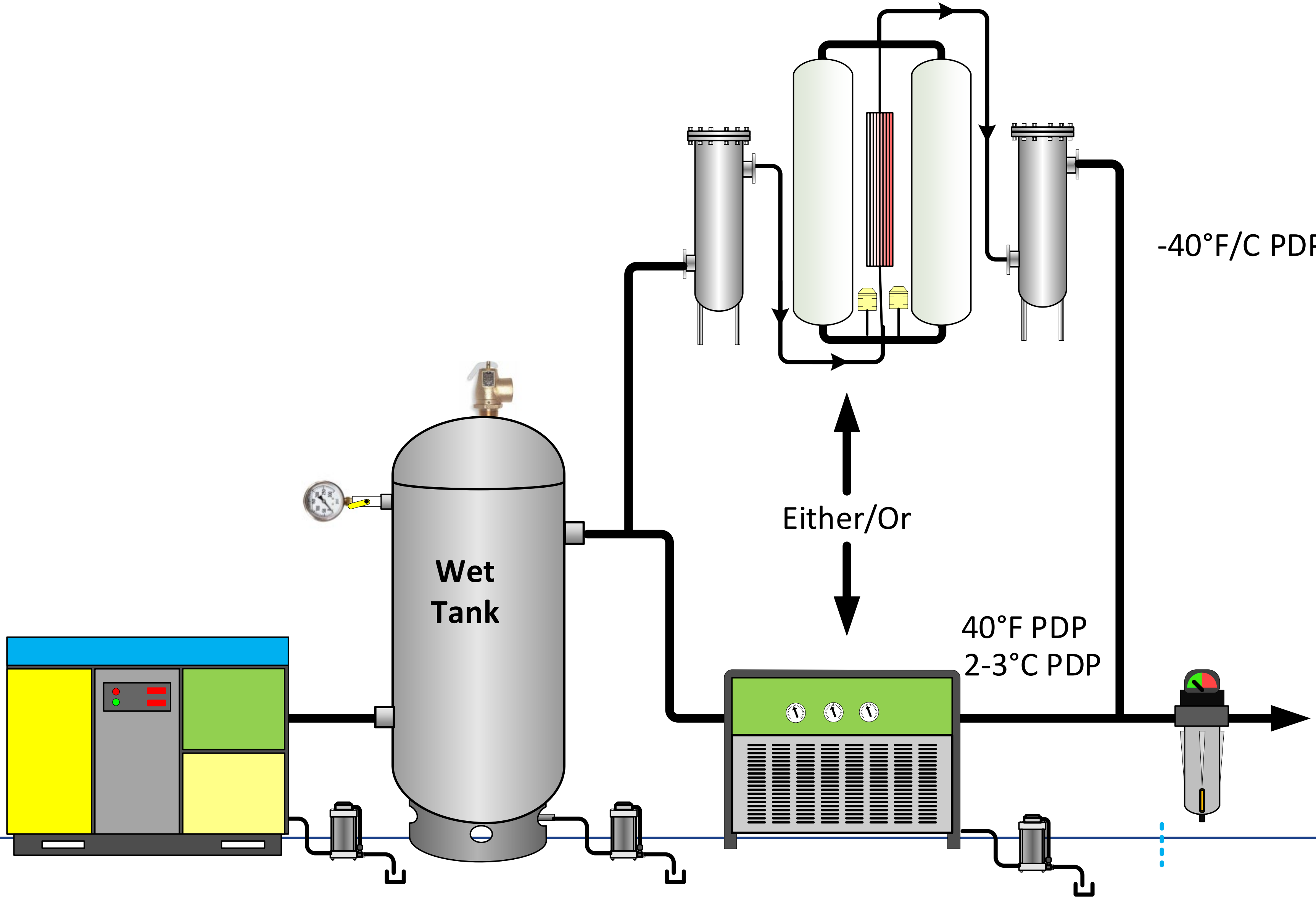
Homework 4 Review:

Homework for Week 3 – Air Quality

- 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?

- Refrigerated Dryer
  - Temperature will not drop below the Pressure Dew Point of the dryer which should be around 40 degrees F (4.4C)

Homework for Week 3 – Air Quality

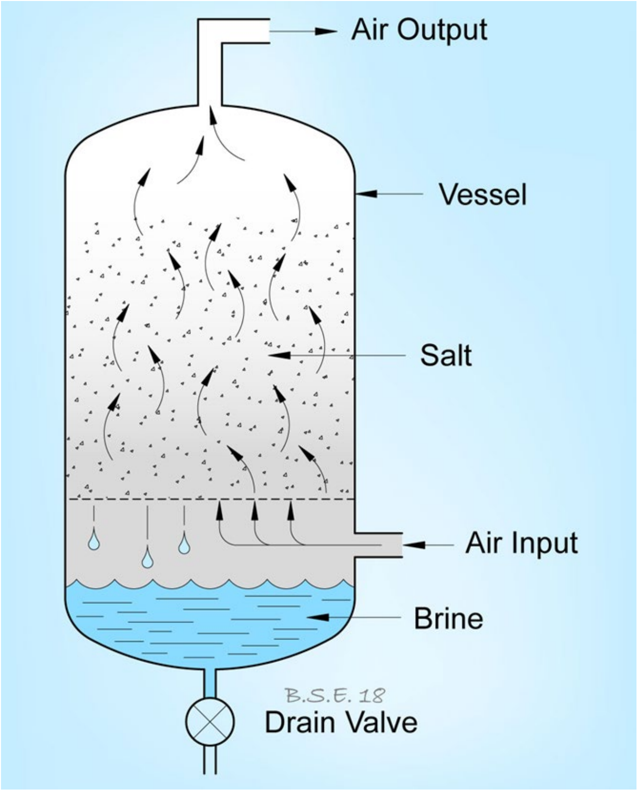


Homework for Week 3 – Air Quality

- What type of dryer uses a porous material that adsorbs the moisture with compressed air or heat reactivation?
- Desiccant Dryer

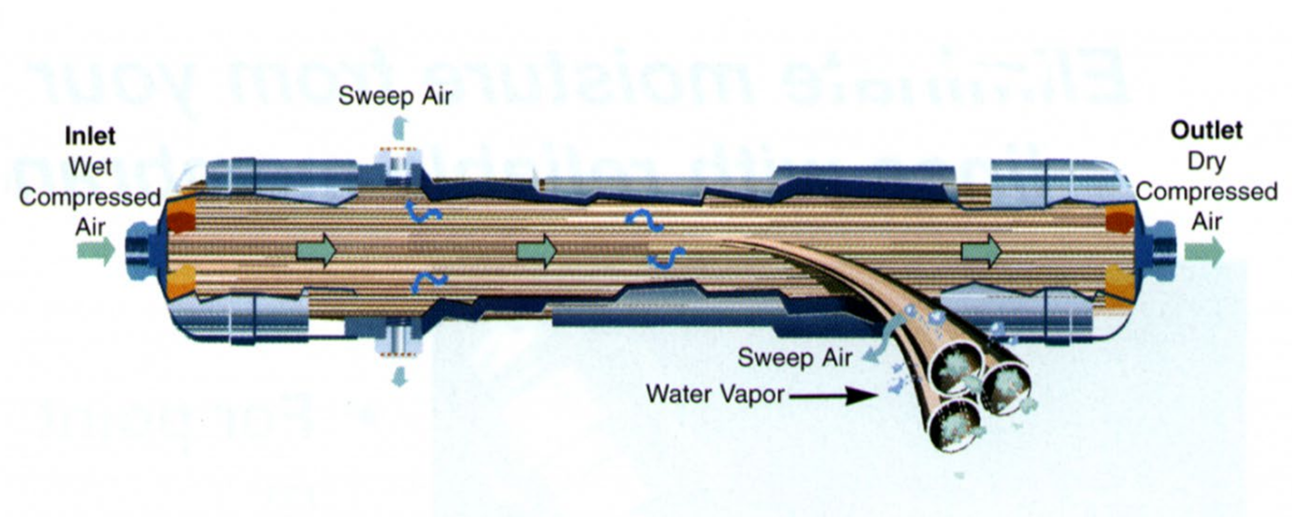
Homework for Week 3 – Air Quality

- What type of dryer uses a drying medium that absorbs the moisture in compressed air?
- Deliquescent Dryer



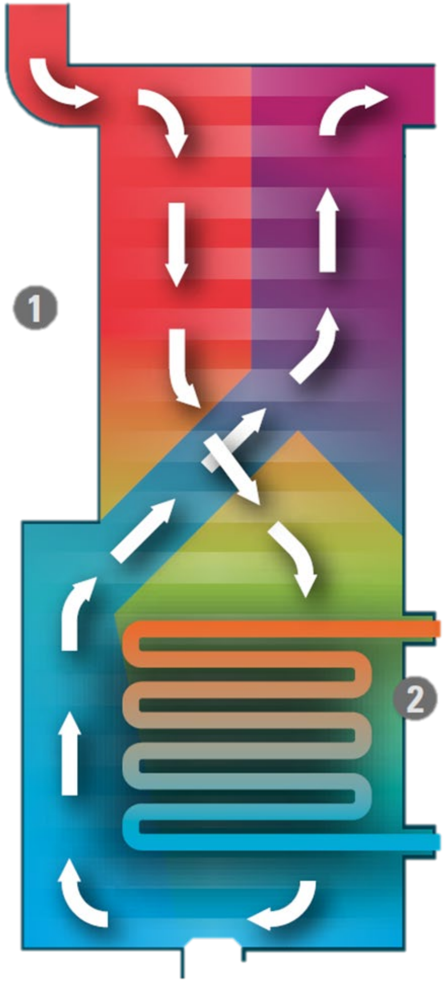
Homework for Week 3 – Air Quality

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



Homework for Week 3 – Air Quality

- What type of dryer cools the air to remove the condensed moisture before the air is reheated and discharged?
- Refrigerated Dryer



Homework for Week 3 – Air Quality

- 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 temperature conditions an air-cooled refrigerated dryer is rated for?
- 100 psig inlet pressure
- 100°F inlet temperature
- 100°F ambient temperature (air cooled only)
- 37.8 C

3-100 Rule

C_1 – Inlet Air Pressure Correction Factor

Pressure (PSIG)	40	60	80	100	120	140	150	180	200
C_1	.67	.83	.94	1.00	1.03	1.05	1.08	1.09	1.11

C_2 – Inlet Air Temperature Correction Factor

Temp °F	60	70	80	90	100	110	120
C_2	2.73	1.94	1.50	1.21	1.00	0.84	0.69

C_3 – Ambient Air Temperature Correction Factor (air cooled unit only)

Temp °F	60	70	80	90	100	110
C_3	1.34	1.24	1.15	1.07	1.00	0.91

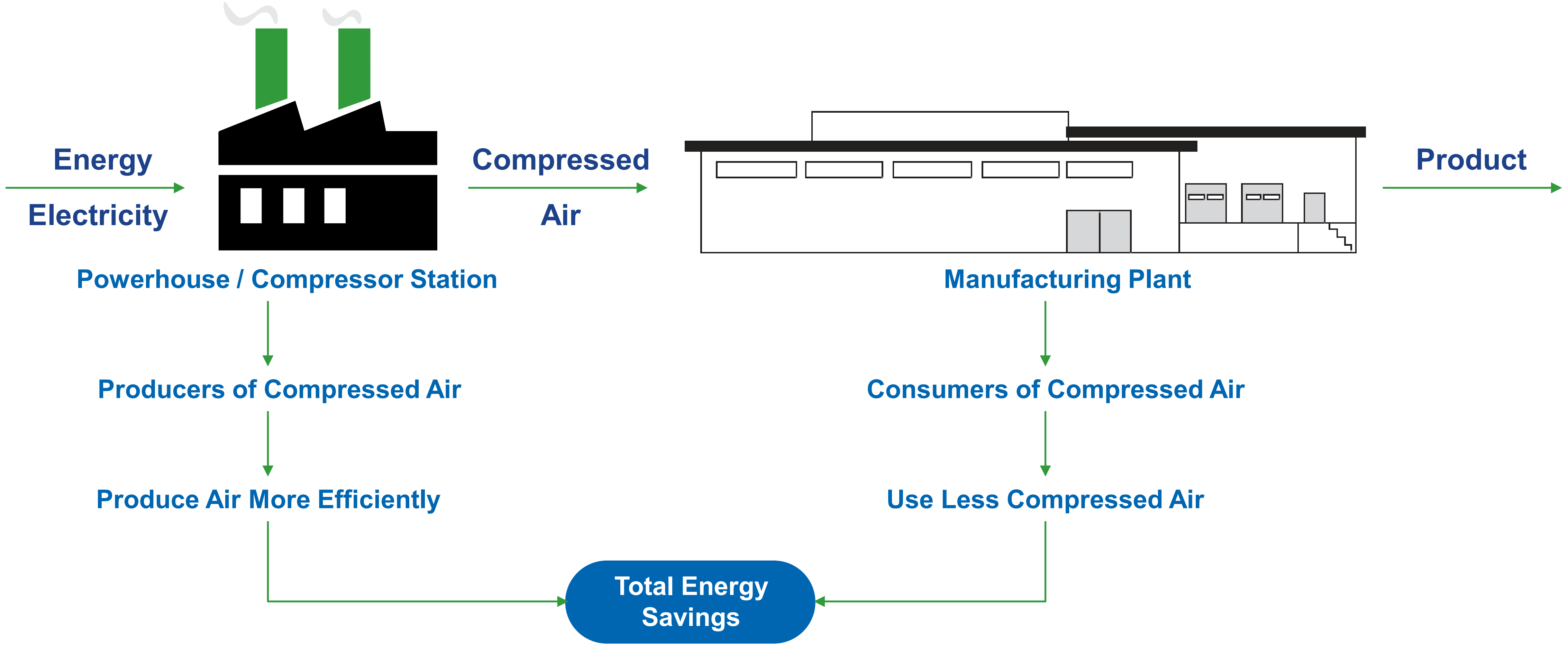
Homework for Week 3 – Air Quality

- What type of filter can remove oil aerosols?
- Coalescing Filter

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.



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.

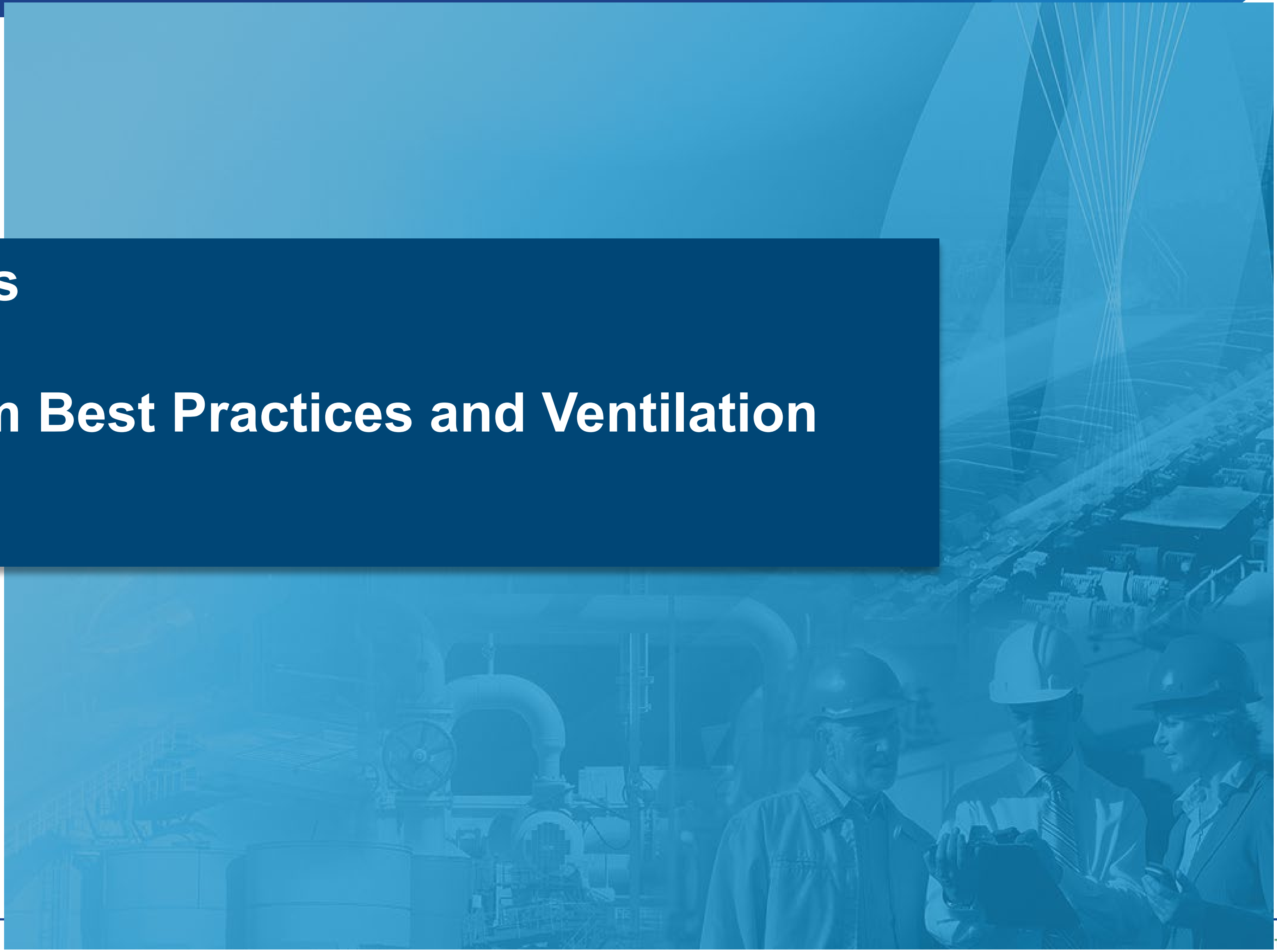
Compressed Air Versus Other Energy Sources

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%)

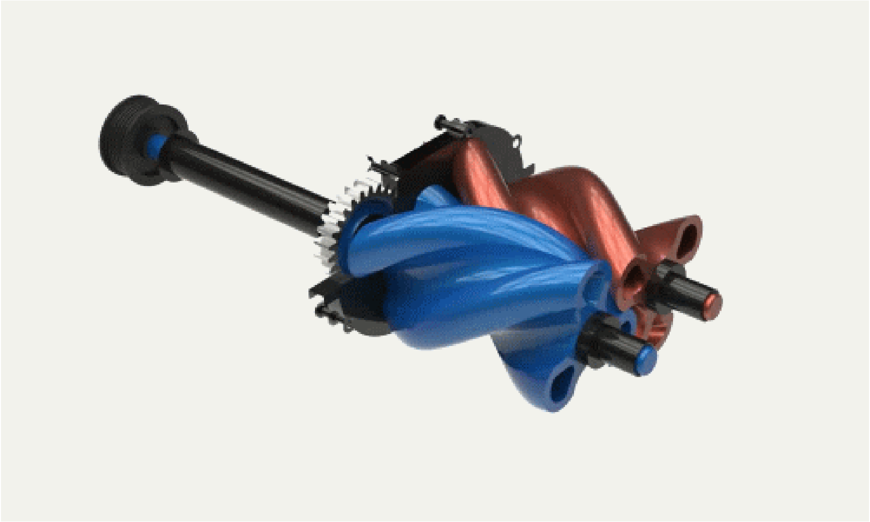
Session 2 we reviewed:



Compressor Types
Maintenance
Compressor Room Best Practices and Ventilation

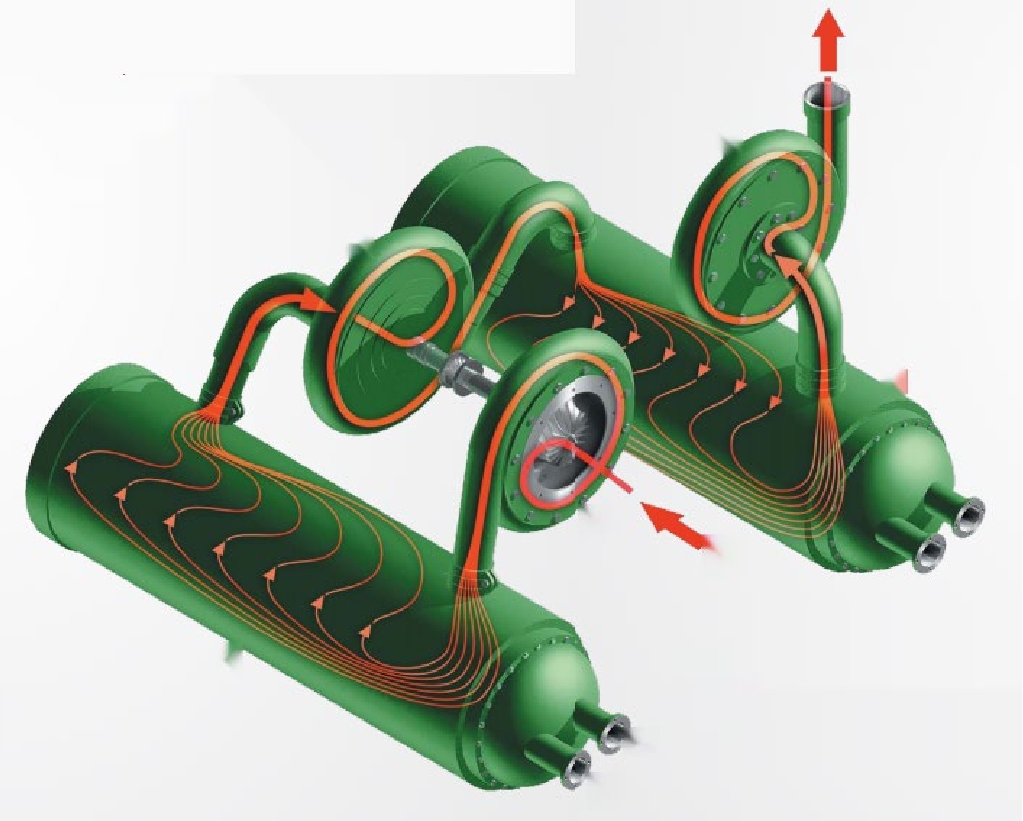
Compressor Types

- Positive displacement compressors can be reciprocating or rotary.
- Reciprocating Compressor   Rotary Compressor

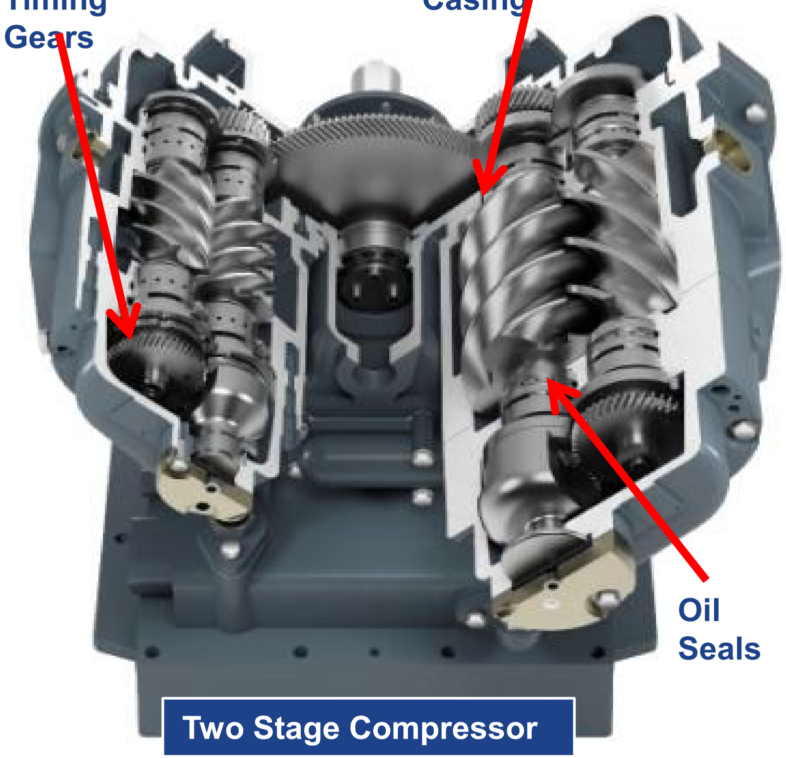


Compressor Types

- Centrifugal Compressor

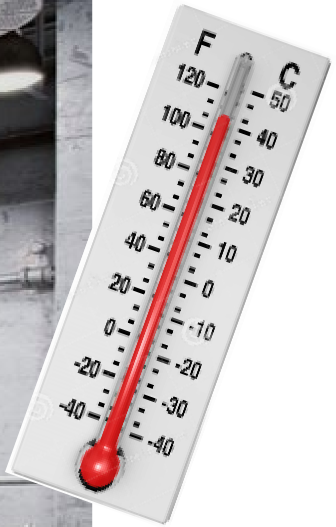


Oil Free Rotary Compressor



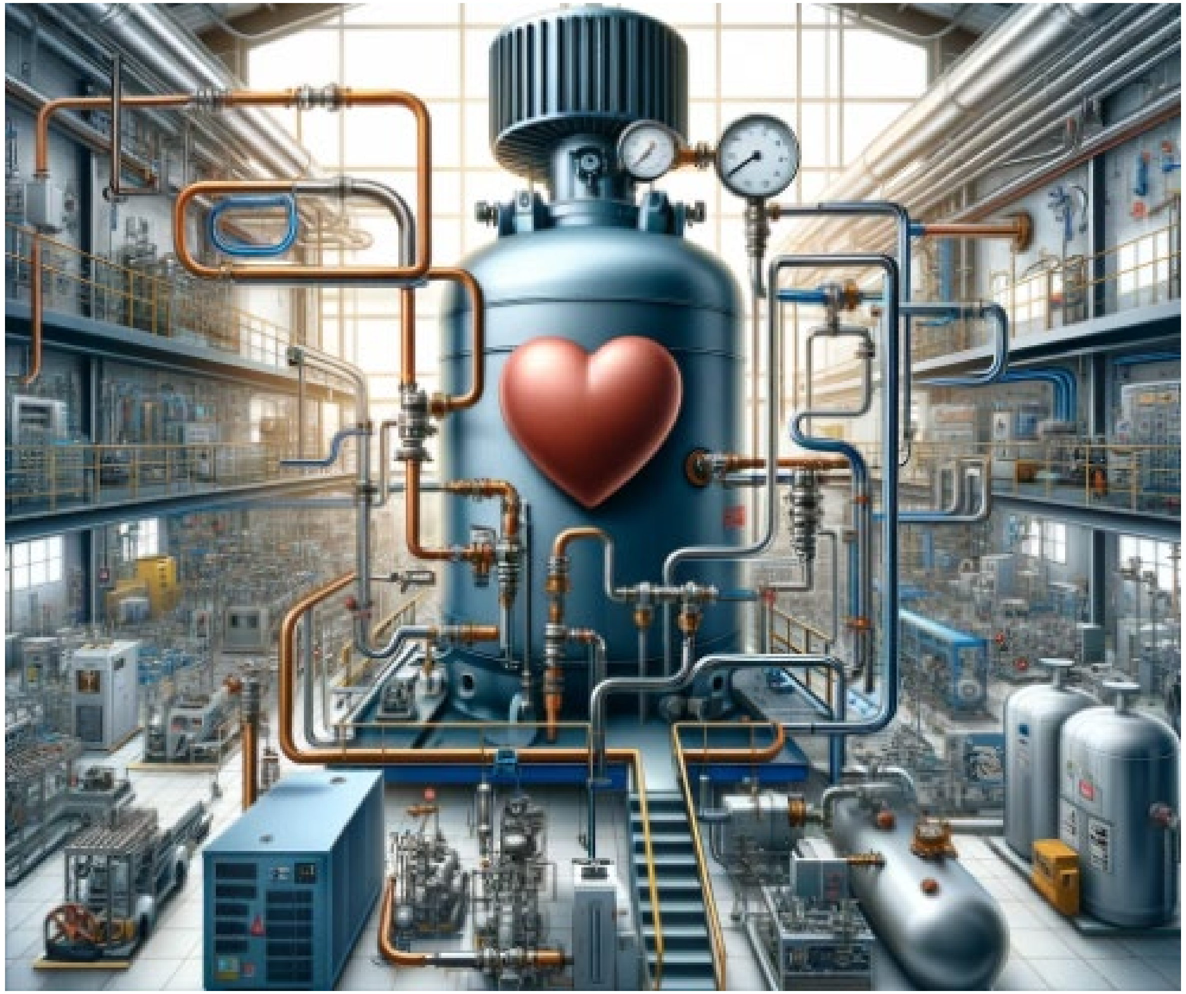
Ventilation

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



The Compressed Air System is the heart of the plant

- A failed system takes down the whole plant and stops production
- Impending failure usually has warning signs
- Frequent failure is often caused by lack of maintenance



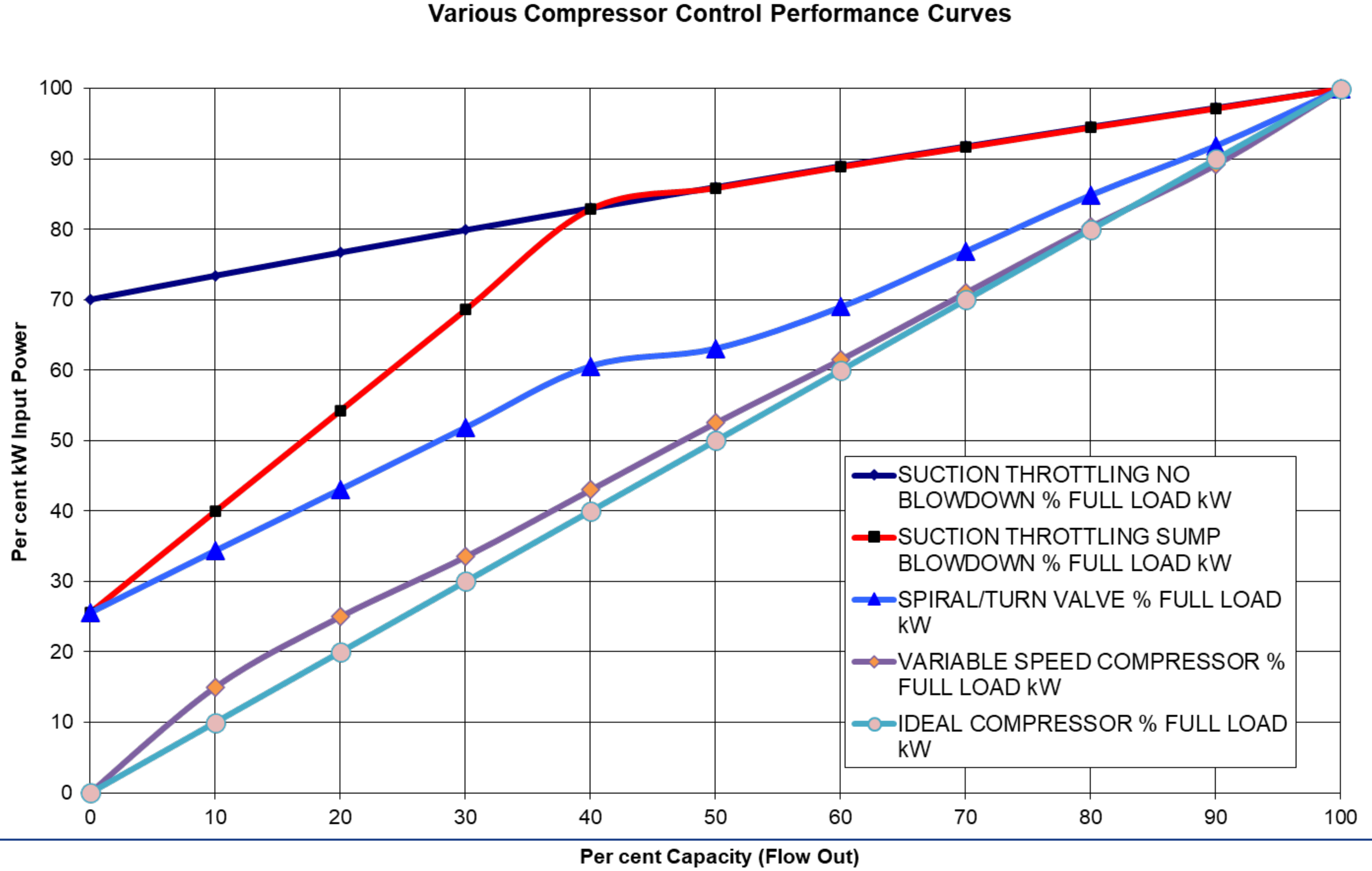
Six Common Maintenance Mistakes

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

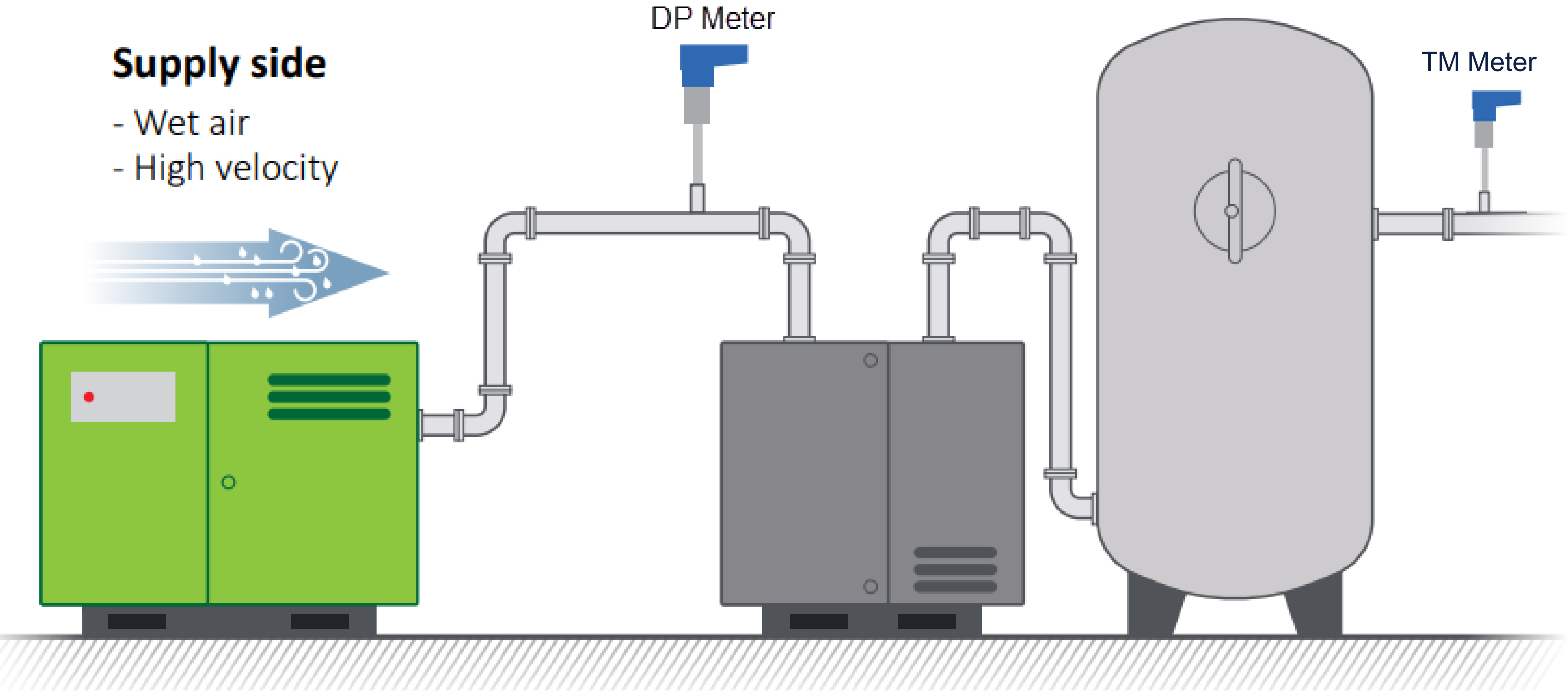
Session 3 we reviewed:

Compressor Controls

Performance Curves

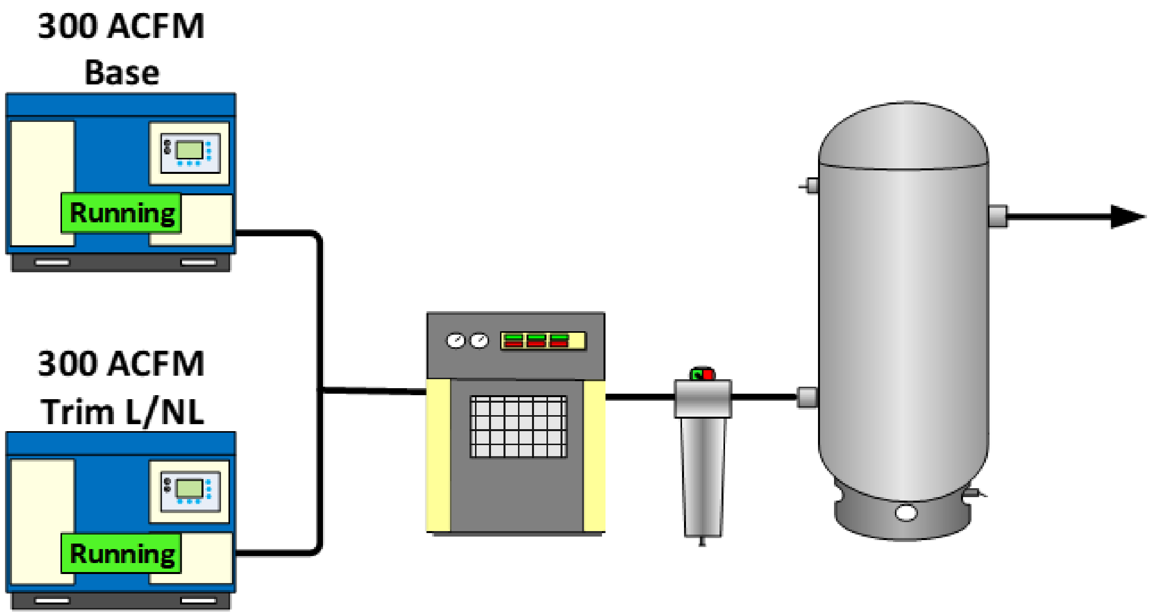


Flow Meters



Calculating Flow on Load/Unload Compressor

Compressor Control

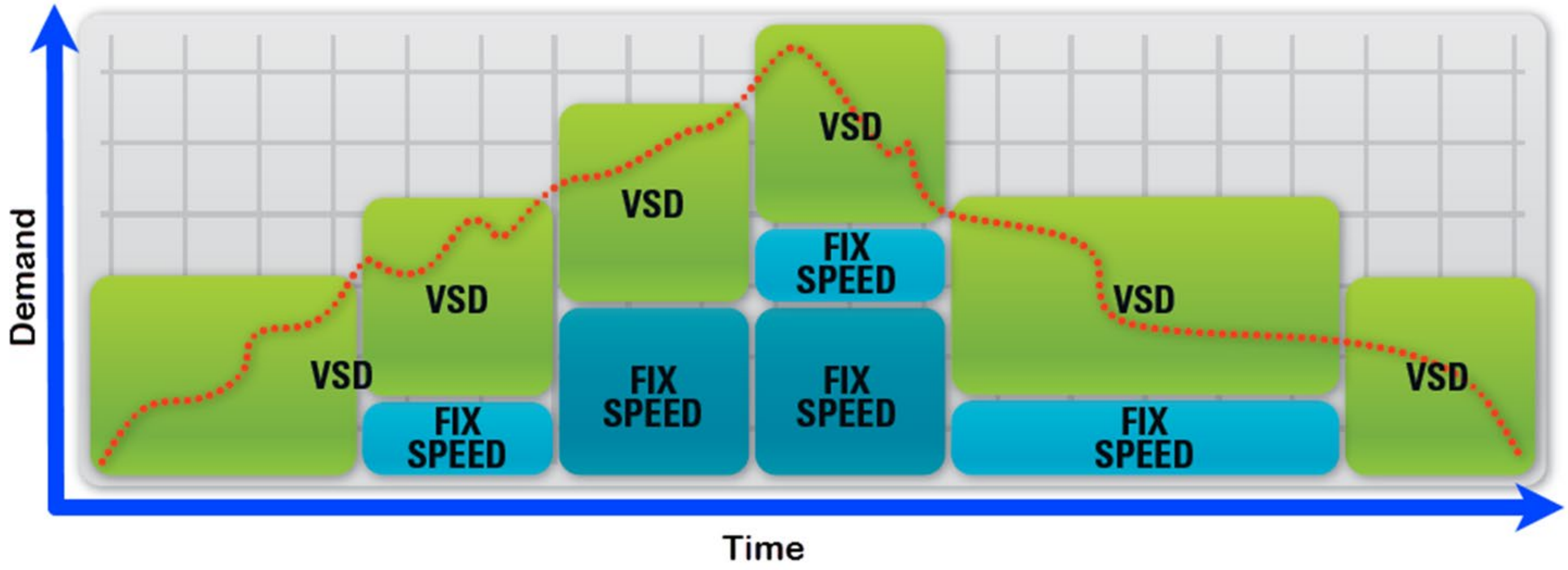


- 100 ft of 6" pipe, 80 ft of 4" pipe 100 ft of 3" pipe and 600-gallon receiver.
- #1 running base load and #2 running trim
  - **40 seconds load @ 100 psig**
  - **25 seconds unload @ 110 psig**
- What is the load supplied by the trim compressor?

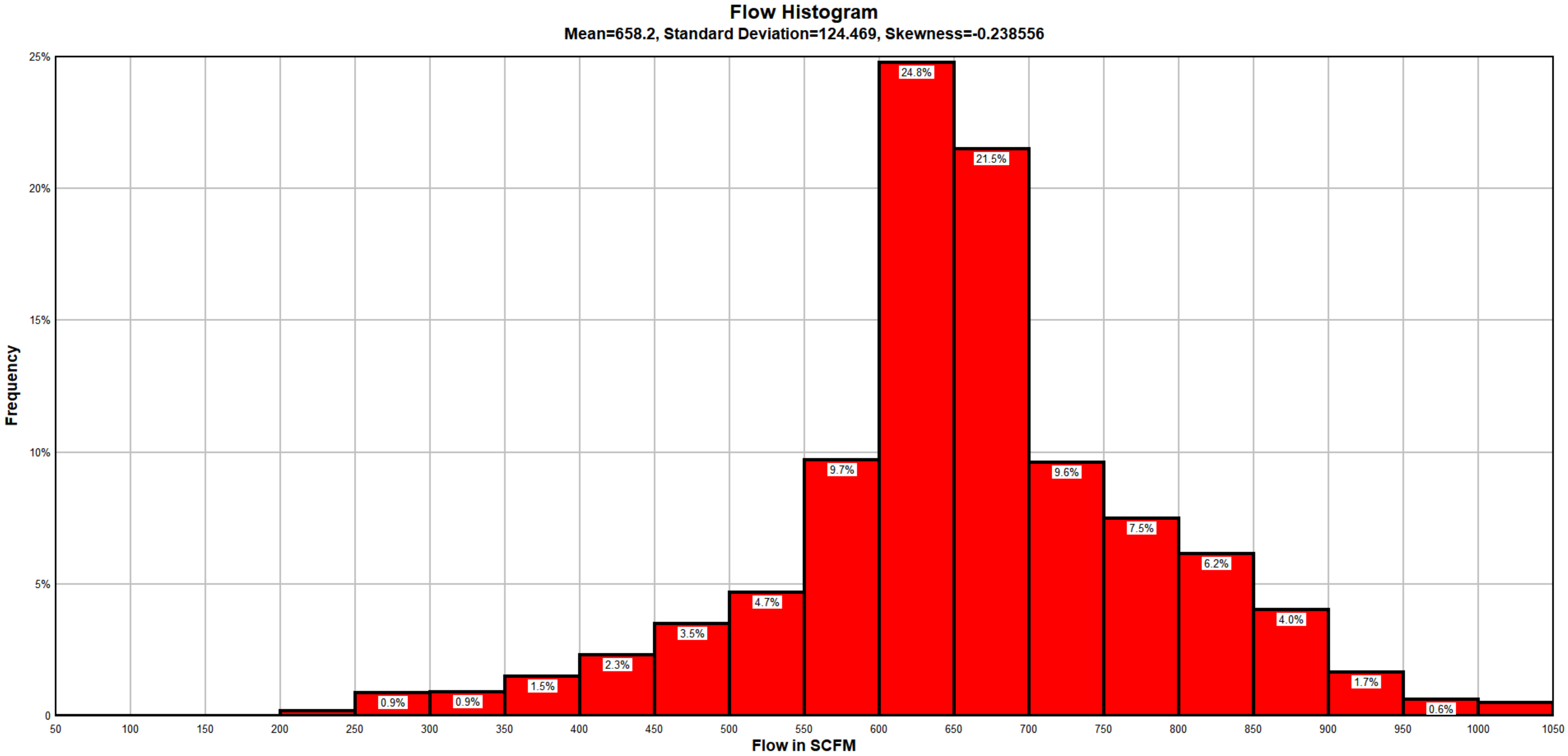
$$Flow\% = \frac{T}{T+t} \times 100$$

Variable Speed Compressors

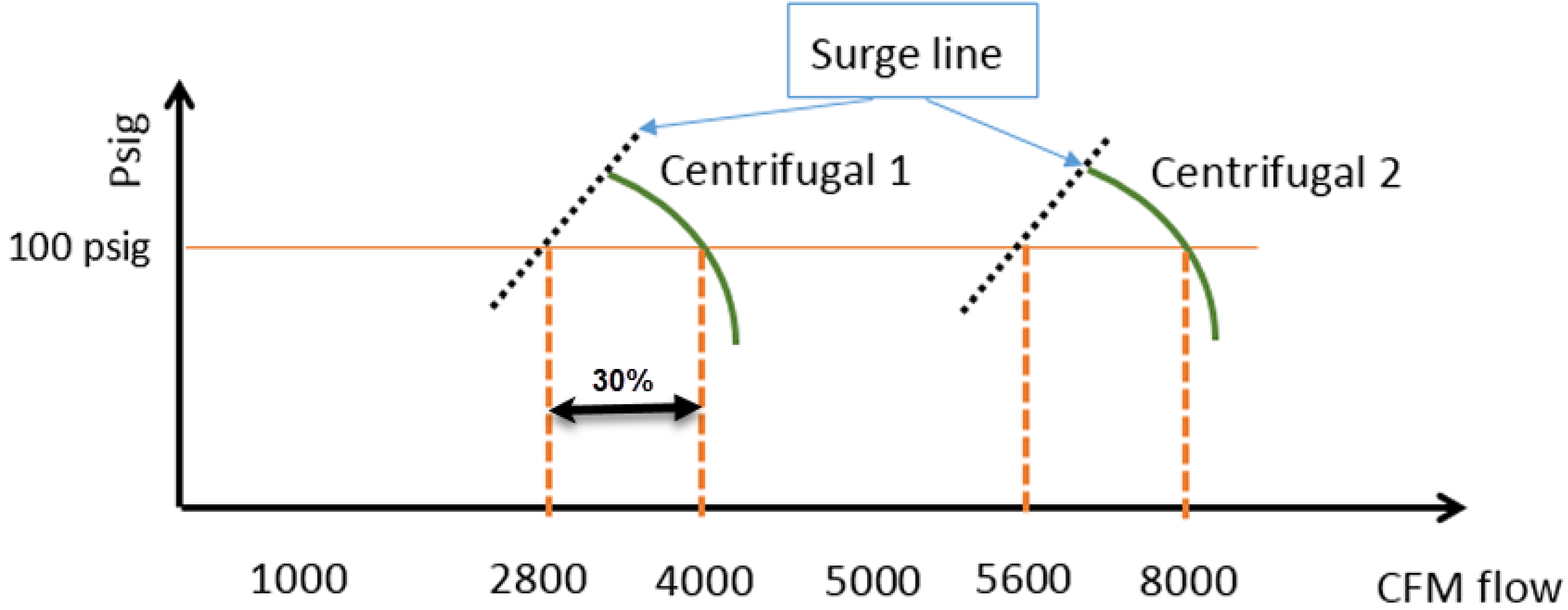
- In order to provide efficient VSD regulation over the complete range of the customer's air profile, the range of the VSD from min to max needs to be sized greater than the load/no load machine



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

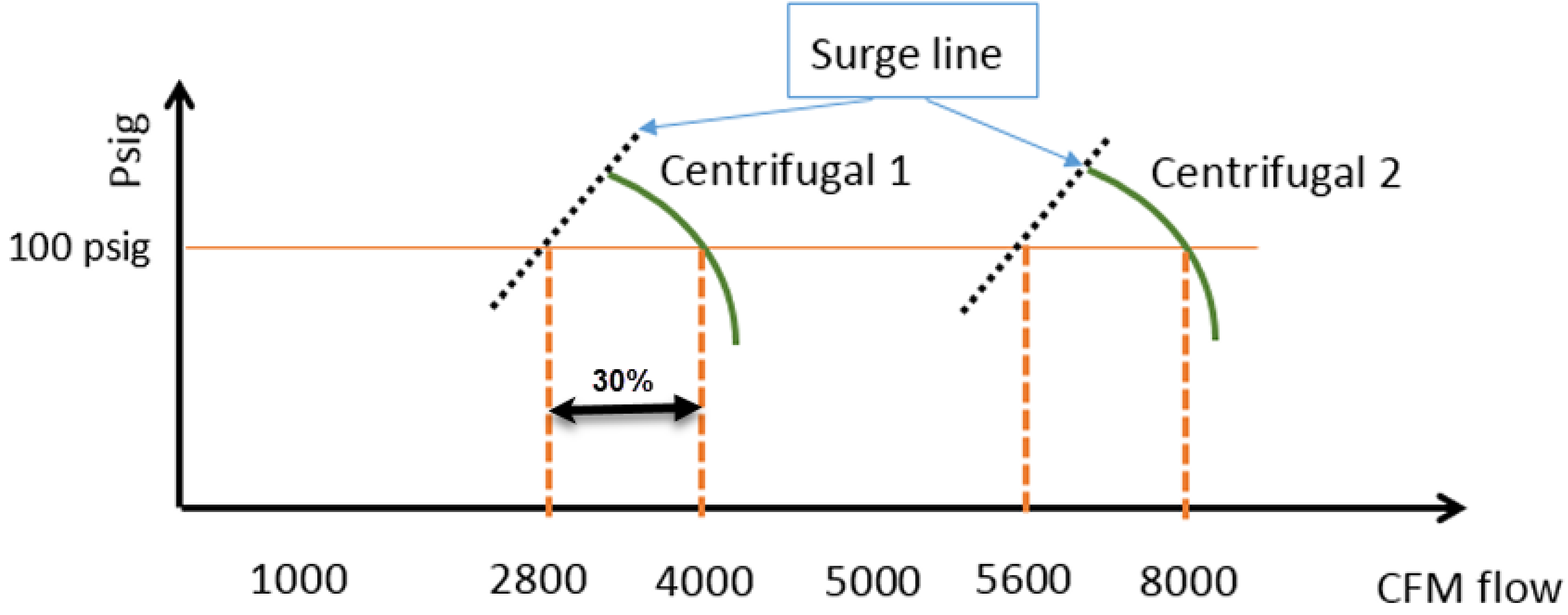


How do I know how to size Centrifugal to my flow Patterns?



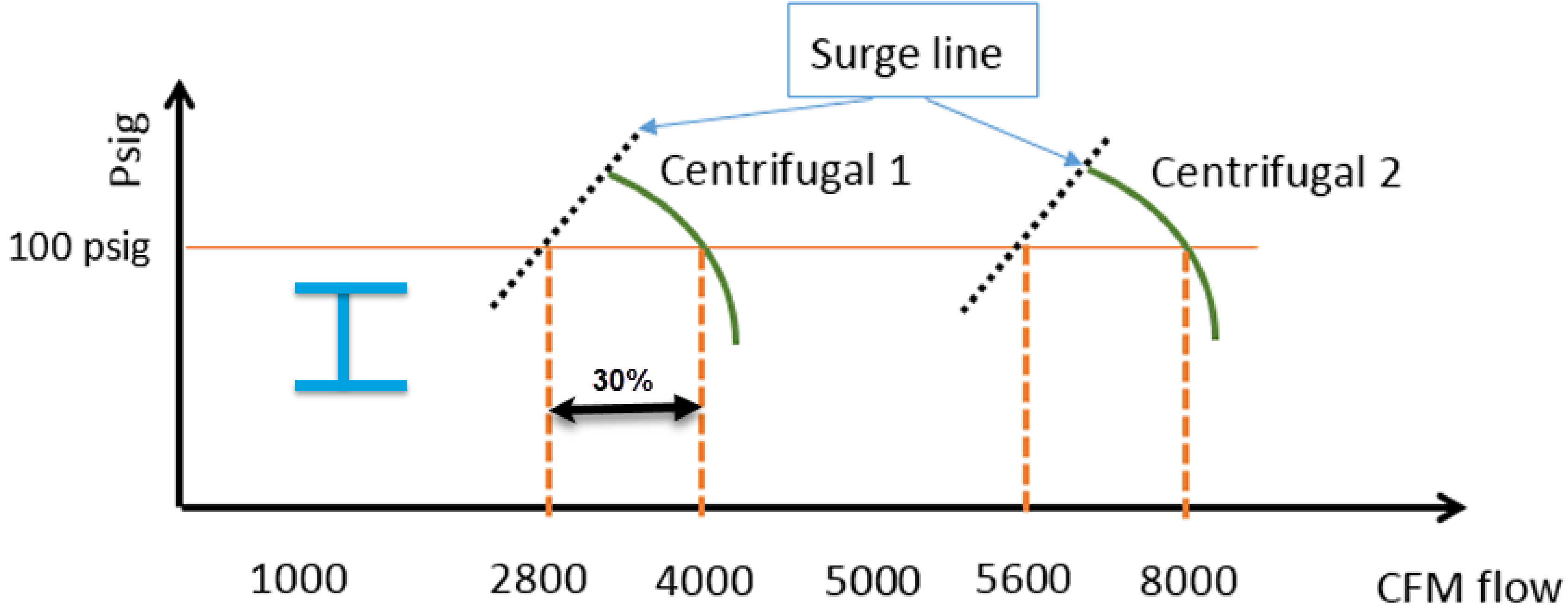
- Plant has 8000 cfm peak demand, 5800 cfm average demand, and 3000 cfm minimum demand during weekends at operating pressure of 100 psig.
- Two 4000 cfm centrifugals with a 30% turndown to 2800 cfm

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?

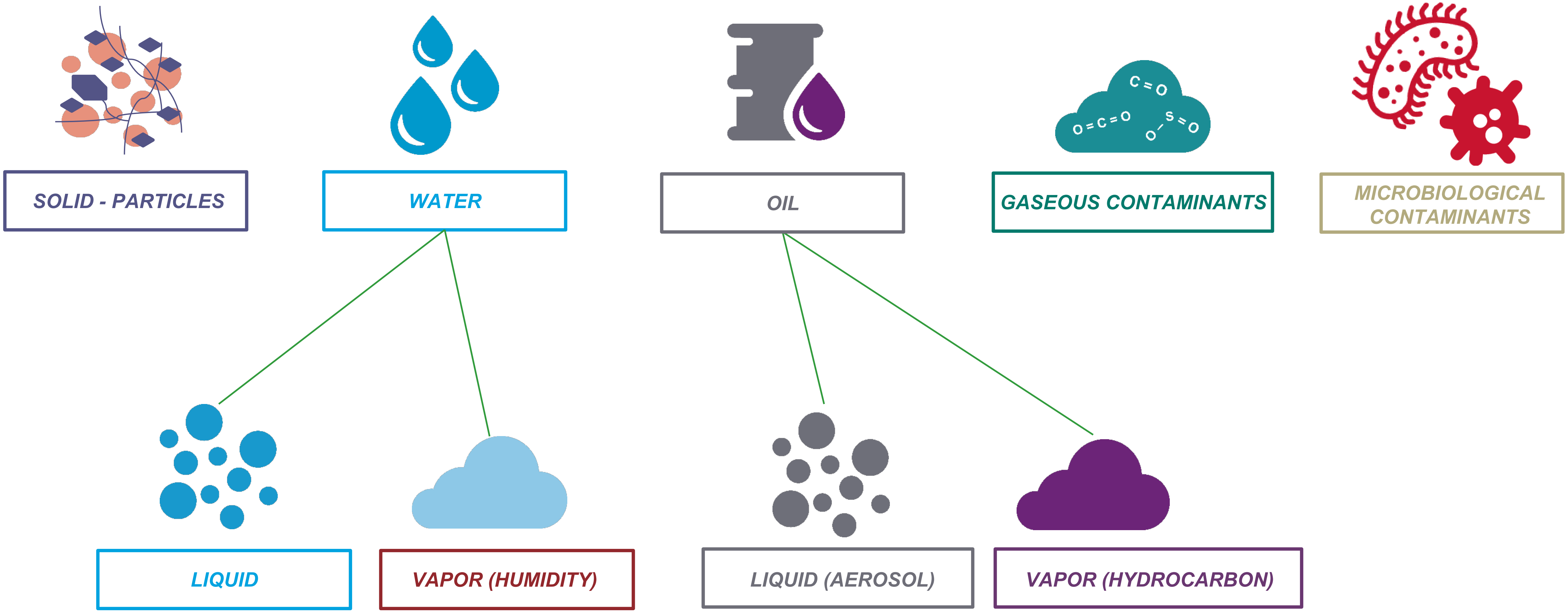


- During the weekend, when the demand reaches to minimum flow of 3000 cfm, one centrifugal compressor will stop and only one compressor will run in its turndown range.
- With this combination, the centrifugal compressors will work most efficiently and save a plant significant energy.
- If flow drops 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.

Last Week Session 4

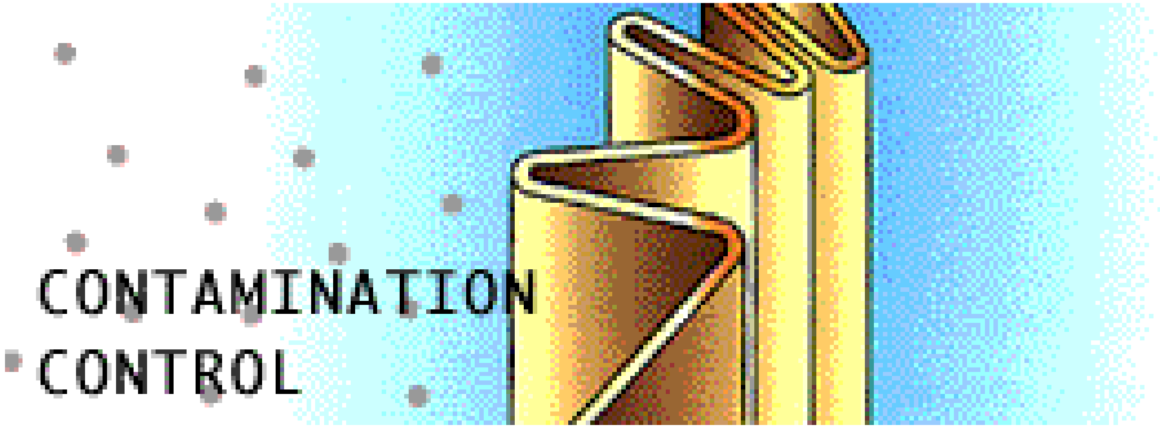
Air Treatment

Which Contaminants do we find in compressed air?



Compressed Air Filters

- Compressed Air Filters
  - Particulate
  - Coalescing
  - Adsorption



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.

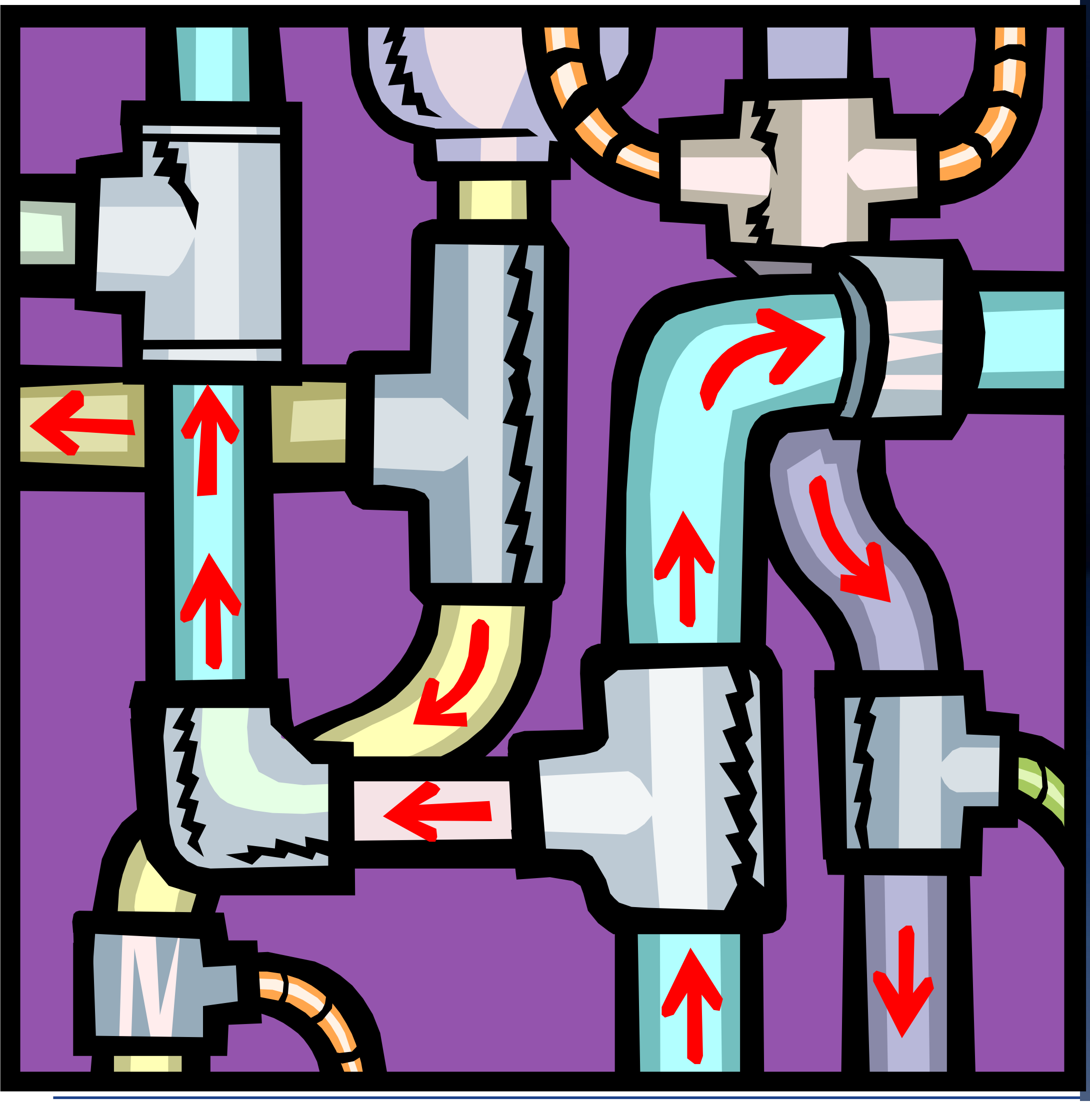
Specifying the Right Dryer

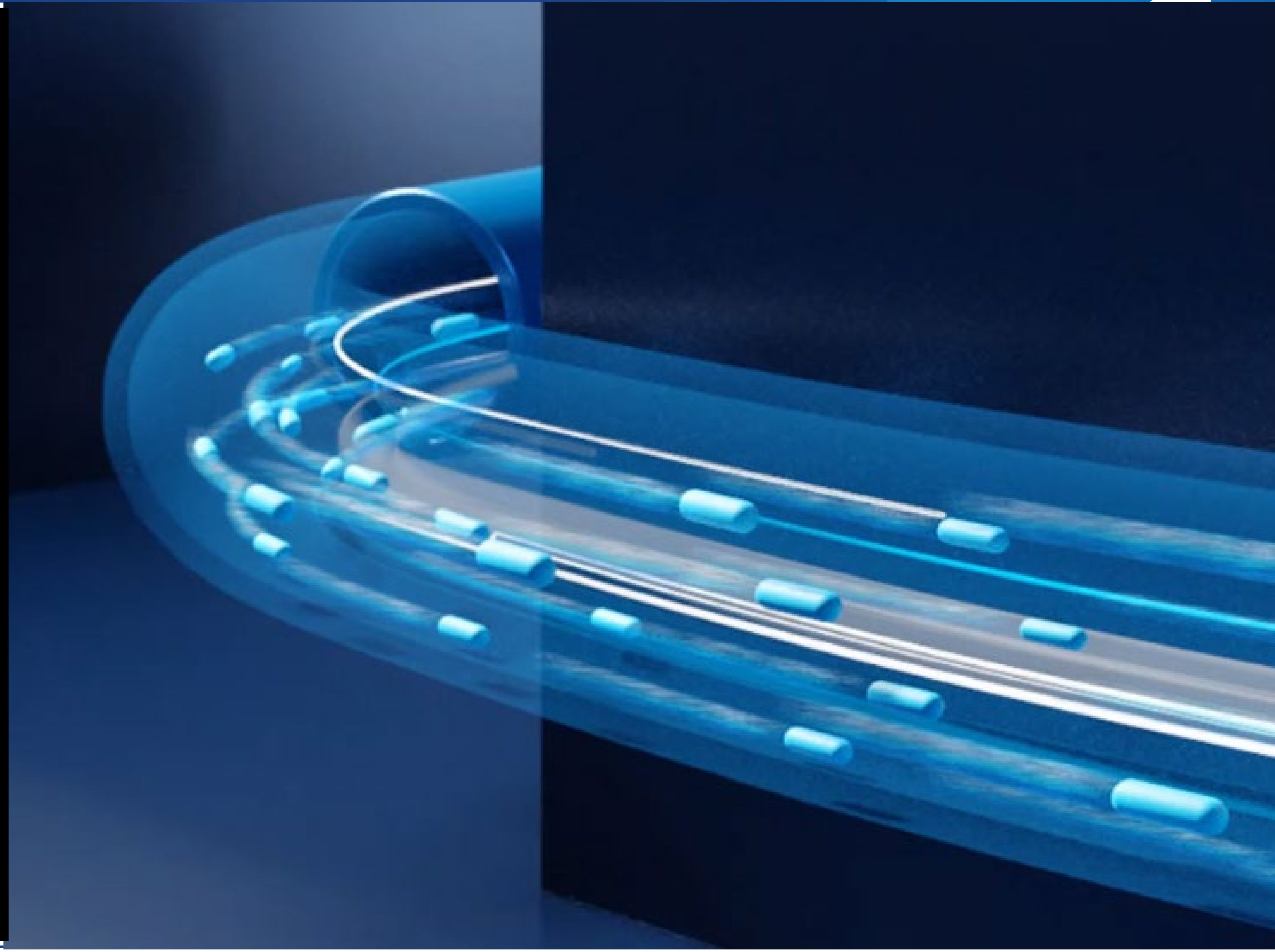
versus

- 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.

Session 5

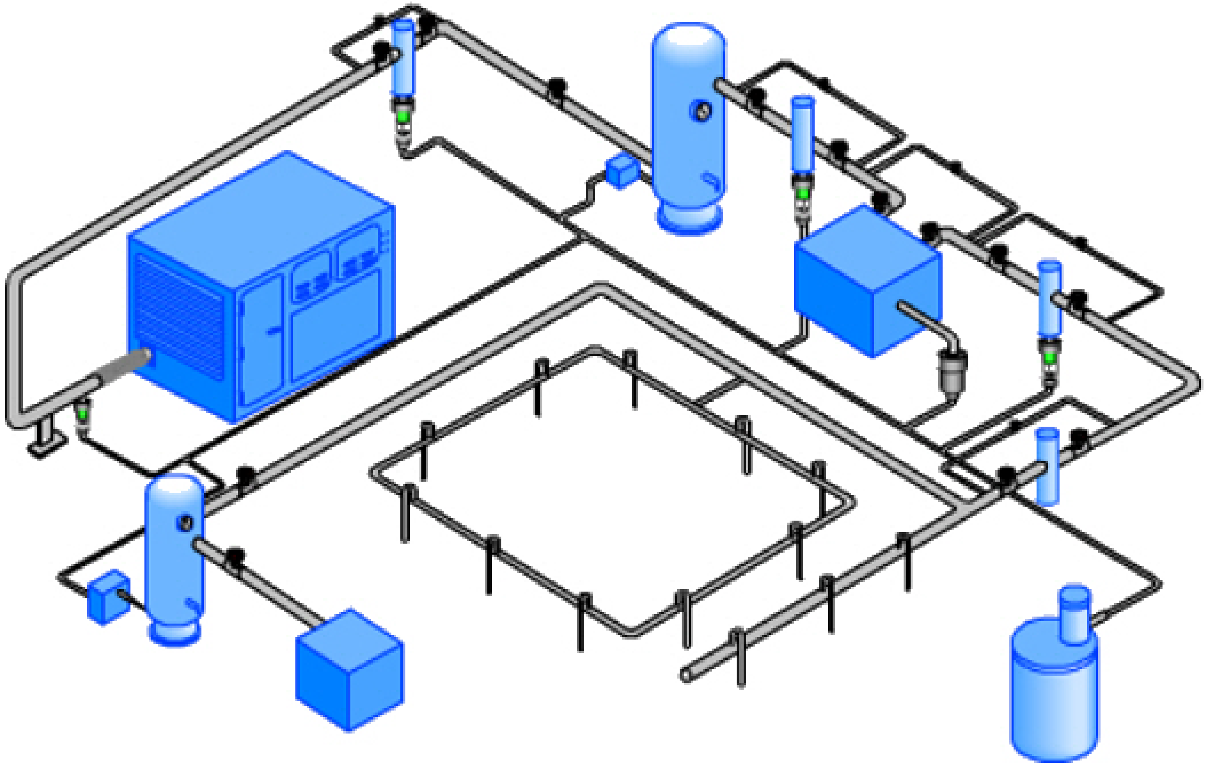
Todays Session is on the Distribution System





Distribution System

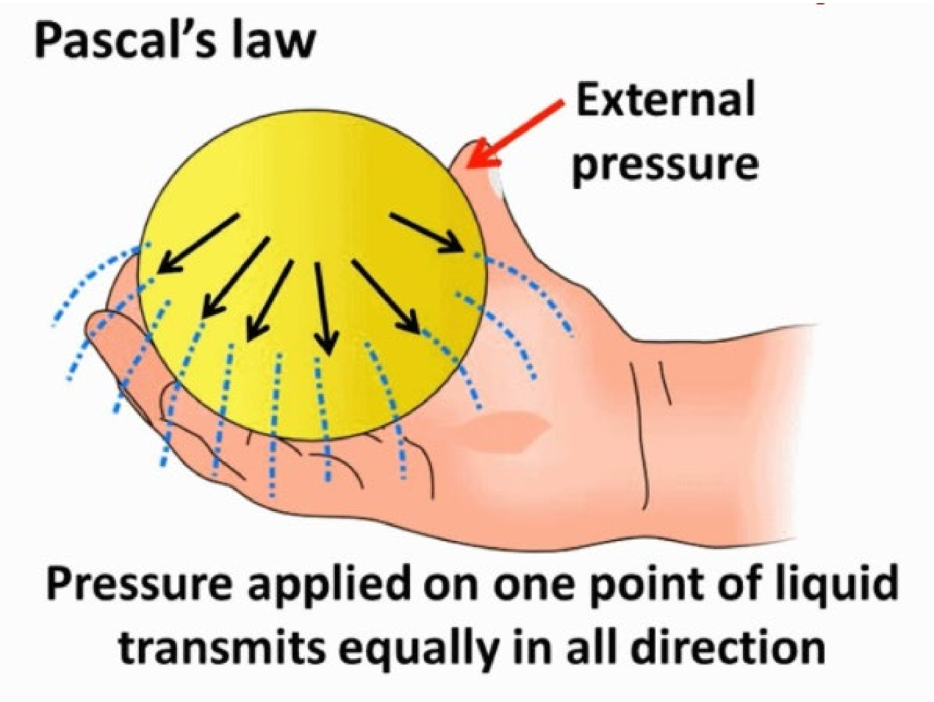
- The purpose of the distribution system is to ensure the right rate of flow of compressed air, at the right pressure, temperature and quality, for each end use application.

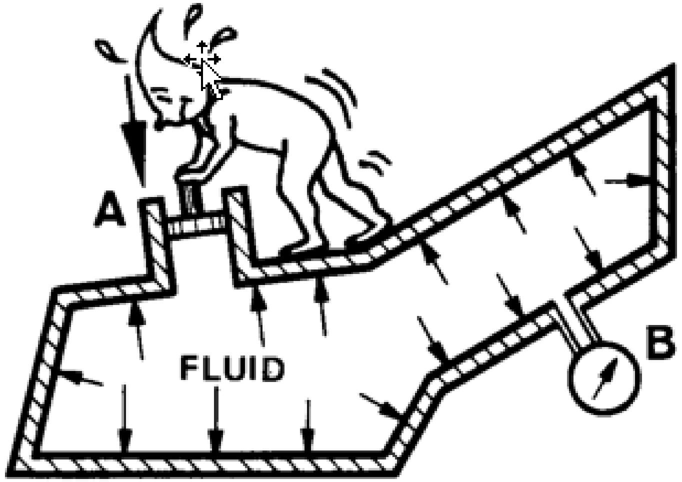


Pascal's Law

His principle of Hydrostatics is stated as follows:

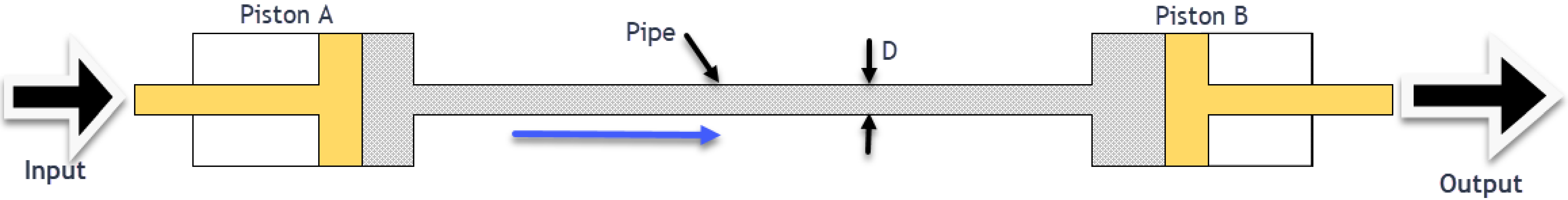
"pressure set up in a confined body of fluid acts equally in all directions and always at right angles to the containing surfaces"





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

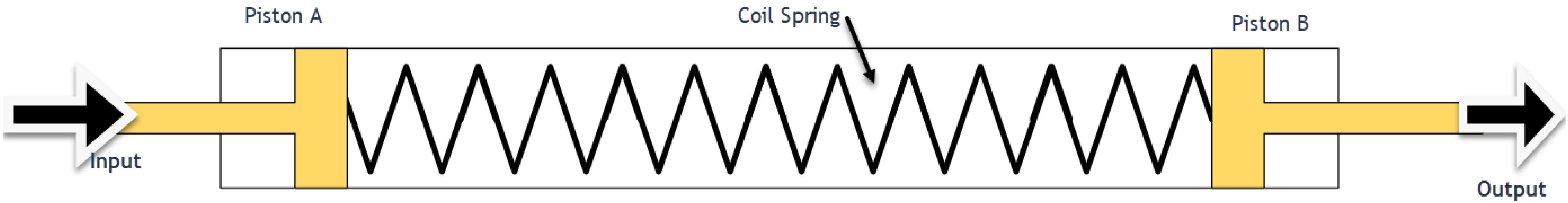
Transmission of Force Through Fluids



How large in diameter must this connecting pipe be?

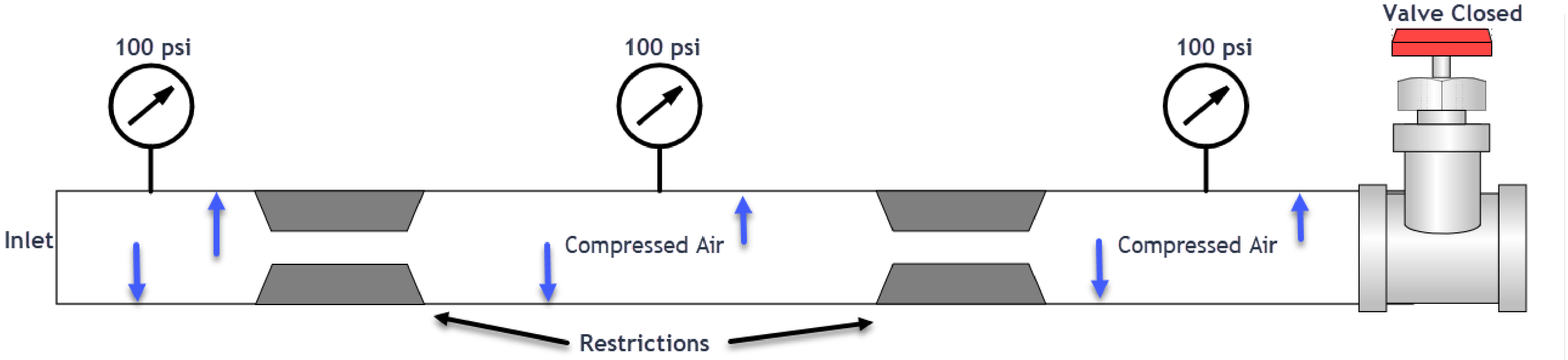
- If pistons A and B are used simply to transmit force with no movement of the pistons, they will do equally well no matter how small the diameter of the connecting pipe. PASCAL's law still applies.
- If the fluid must move through the pipe for transmitting work or power, the pipe diameter should be 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



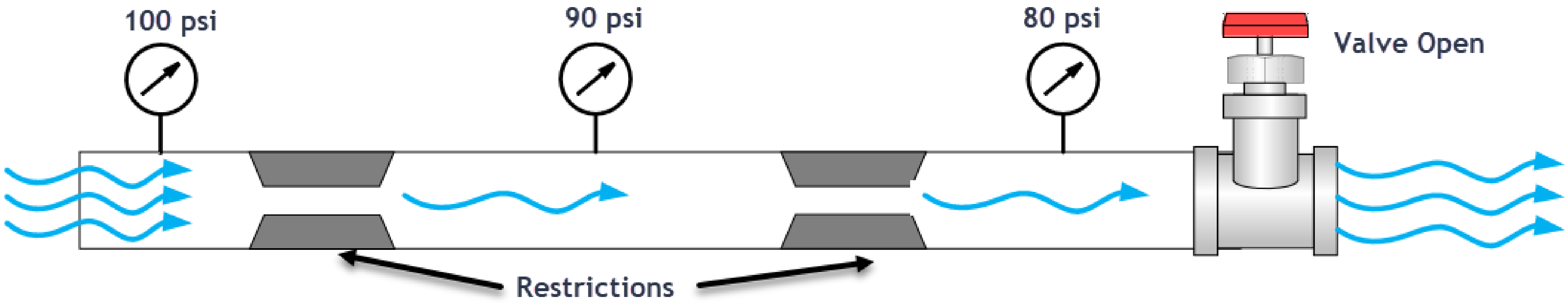
- Transmitting force through compressed air is like transmitting force through a spring.
- Force applied on piston A will produce a force output on piston B although the spring will compress to some extent while transmitting the force.
- While compressed air is an excellent medium for transmitting power, 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



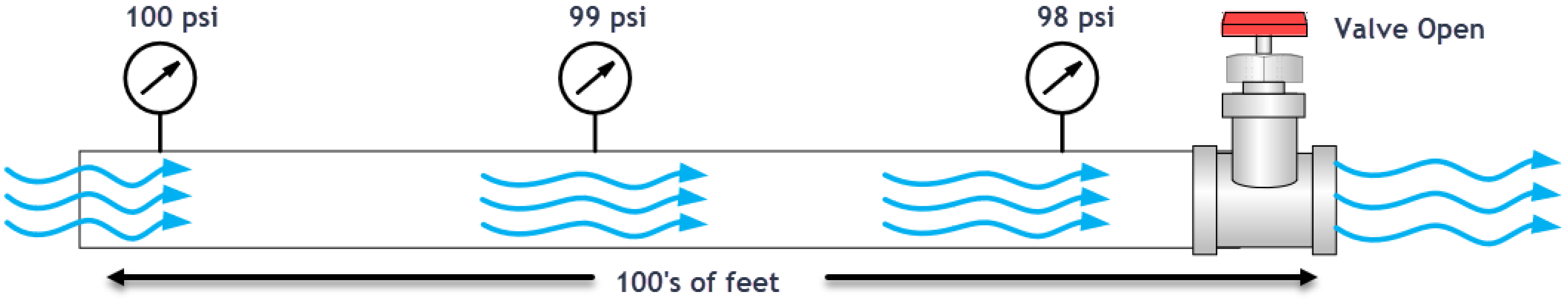
- A very important point to remember about pressure loss is that it only appears when fluid starts to flow.
- As long as the fluid is static, (non-moving) there is no pressure loss.
- Pure force without movement of compressed air can be transmitted through extremely long piping systems.
- This is analogous 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

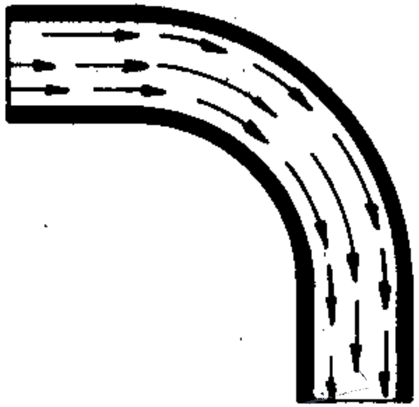
Reducing Pressure Drops Throughout the System

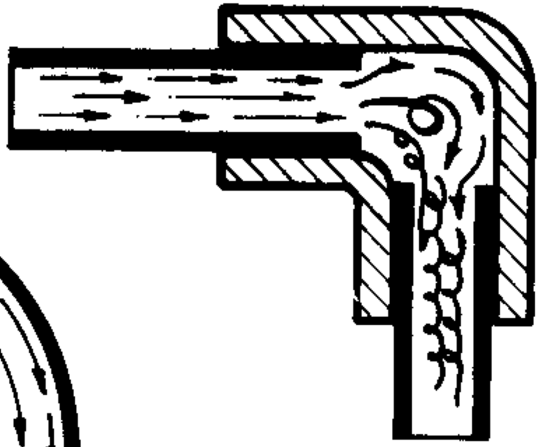


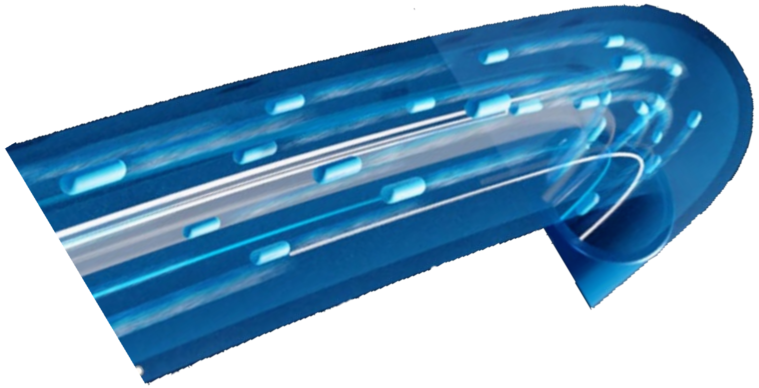
- When major restrictions are removed and the pipe is made sufficiently large to carry the flow, a relatively small proportion of inlet pressure will be sacrificed to flow losses.

Pipe Fittings

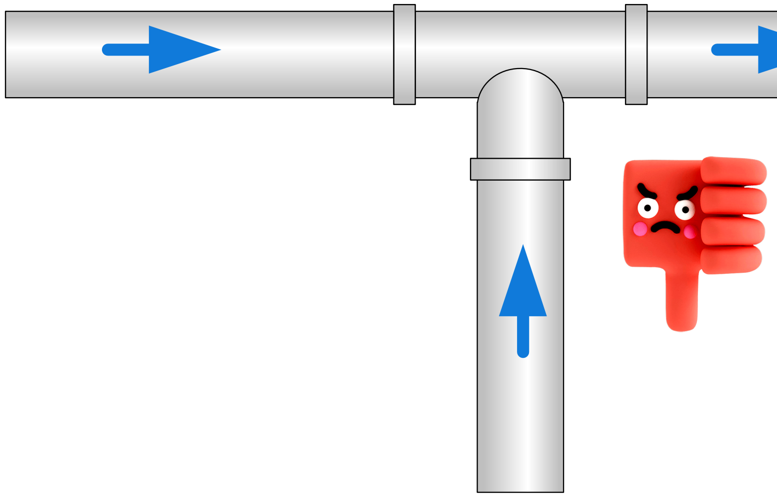
- Every fitting adds its share to the overall power loss in the system
- A certain amount of energy is lost every time the fluid changes direction
- It must decelerate to zero velocity, in the direction it was going, then accelerate back up to speed in the new direction
- The kinetic energy lost in changing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

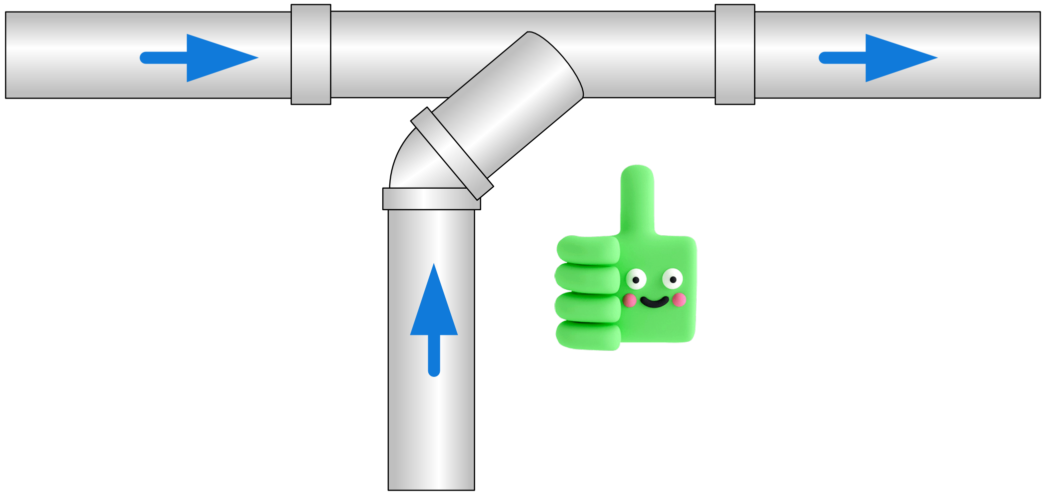




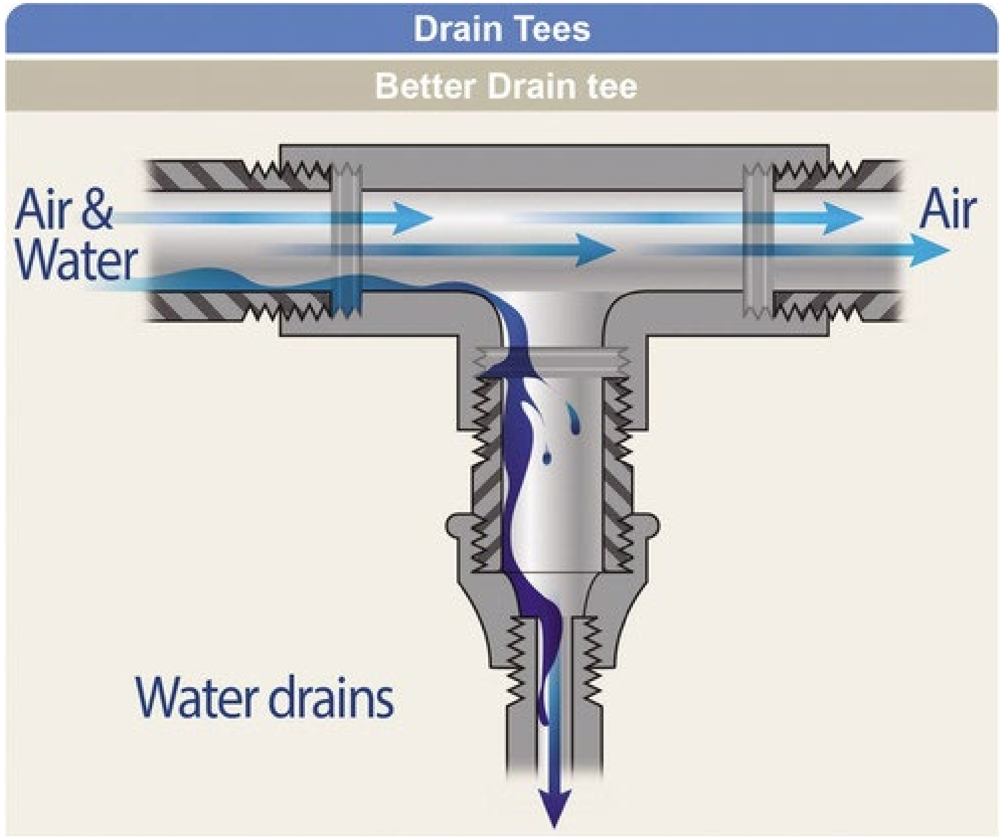


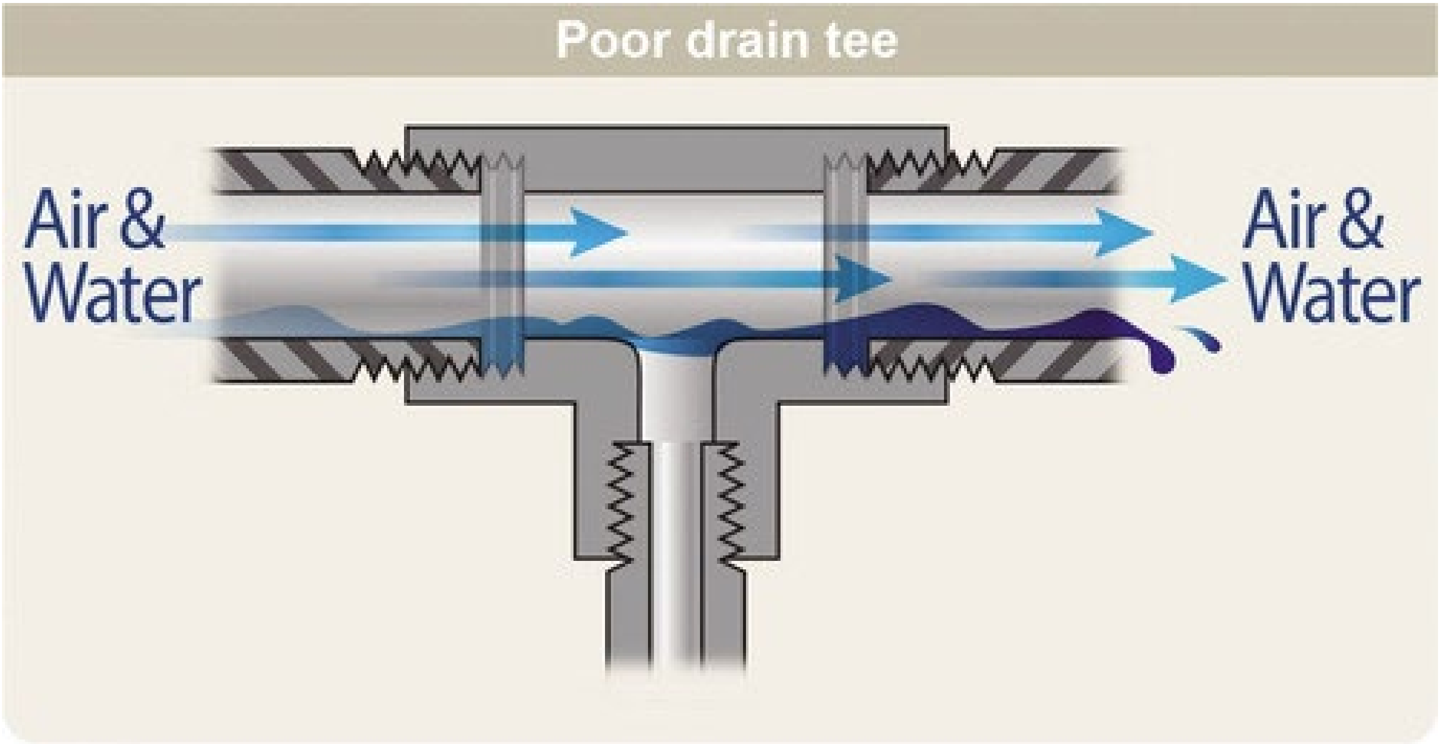
Piping Systems



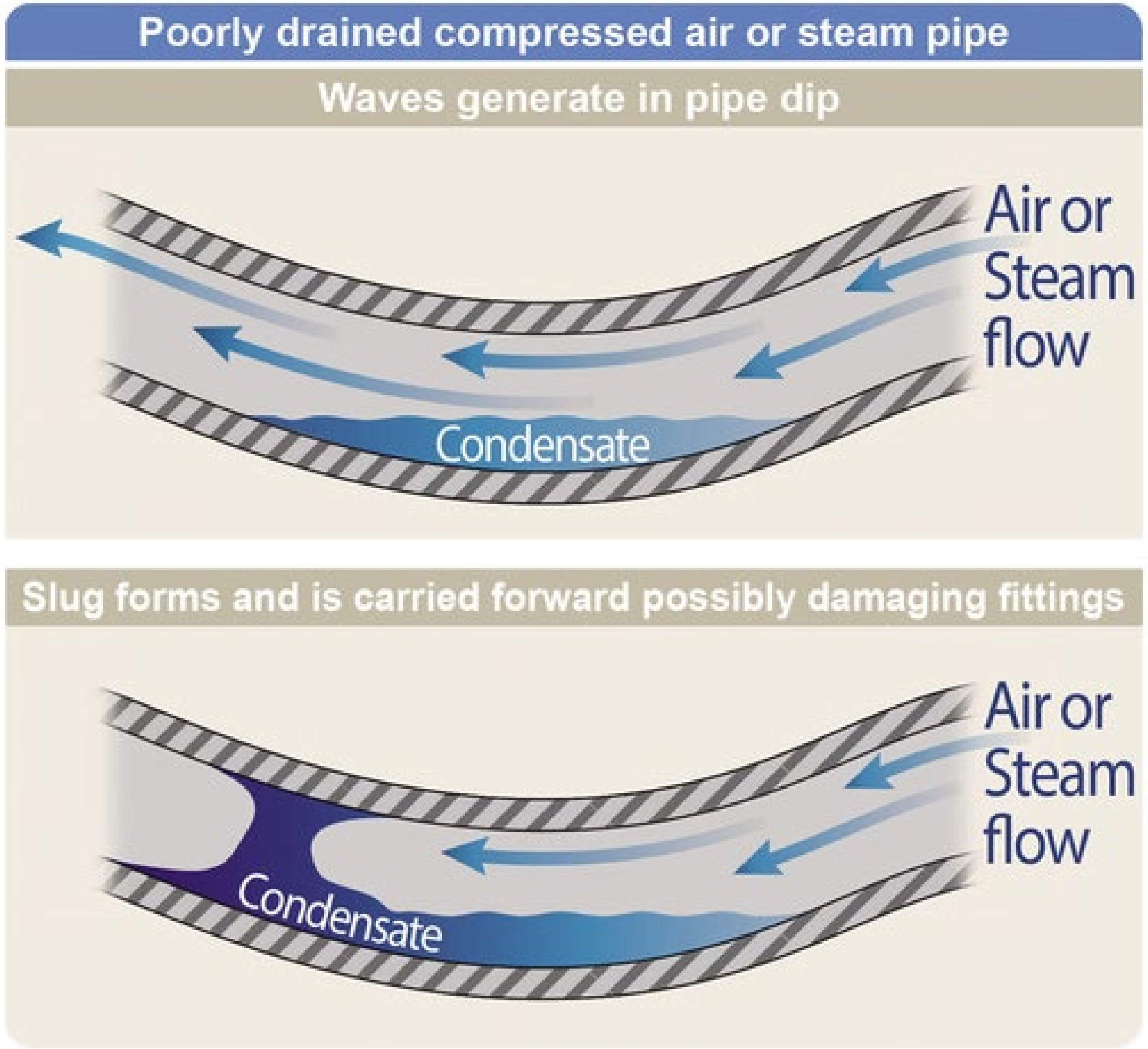


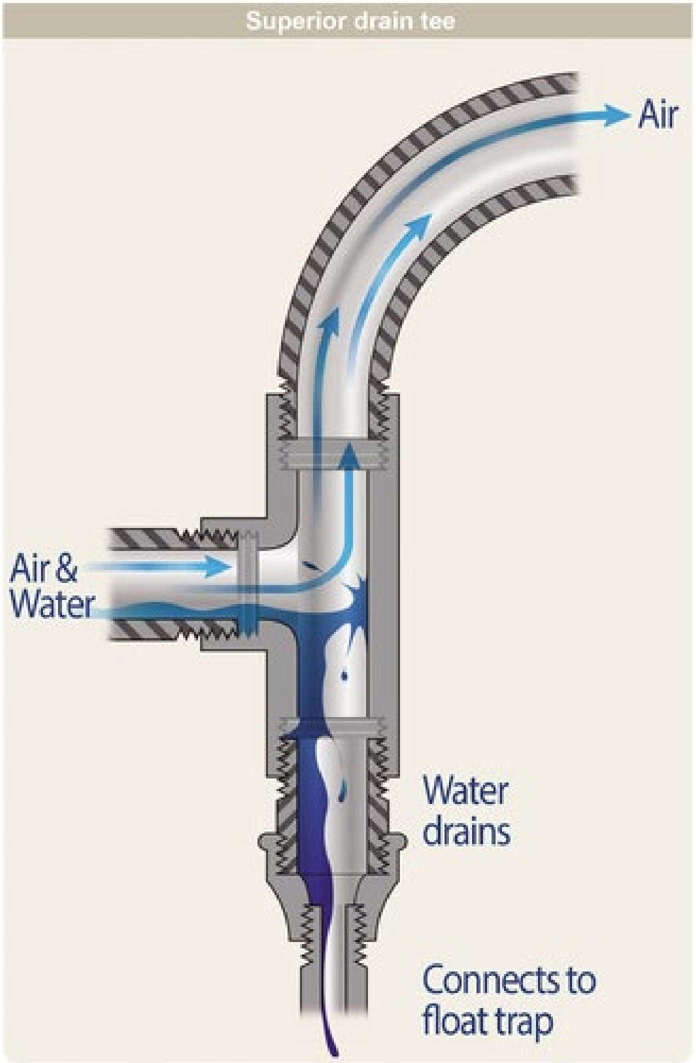
Condensate Removal





Condensate Removal





Rubber Hose Losses Without the Fittings

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

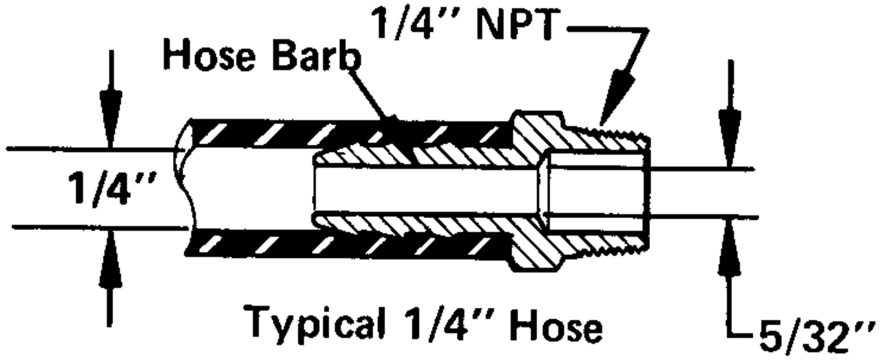
Rubber Hose

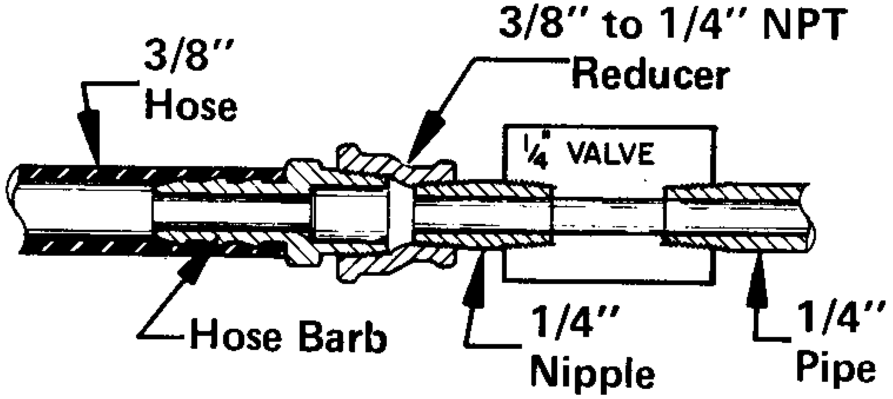
Air Flow CFM	Air Pres				
	1/4" x 10'	5/16" x 8'	3/8" x 10'	1/2" x 12 1/2	1/ 2
10 - 11	5.0	0.9			
11 - 12	5.9	1.0			
12 - 13	6.8	1.2	0.4		
13 - 14	8.0	1.4	0.5		
14 - 15	9.3	1.3	0.6		
15 - 16	11.0	1.9	0.7		
16 - 18	14.0	2.4	0.8		
18 - 20	19.6	3.0	1.0		
20 - 25		4.3	1.4	0.7	1

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

Hose Fittings

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





Pressure Drop

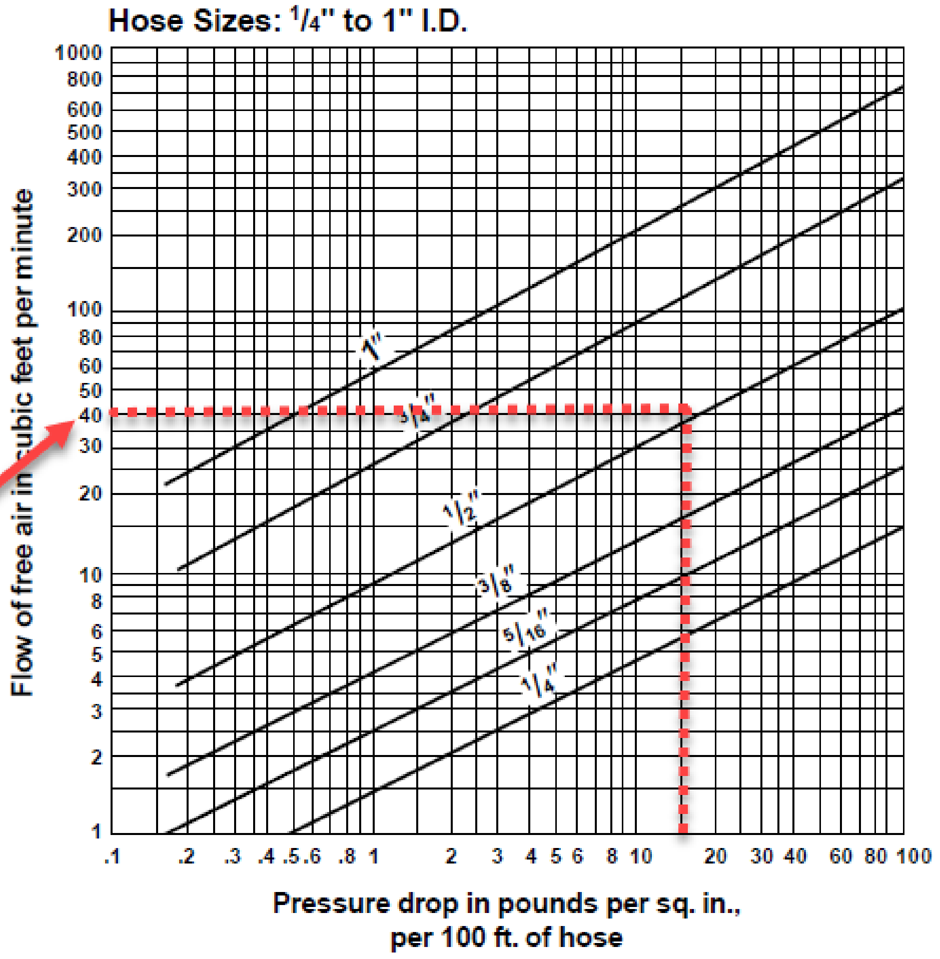
Air Flow Through Hose

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:

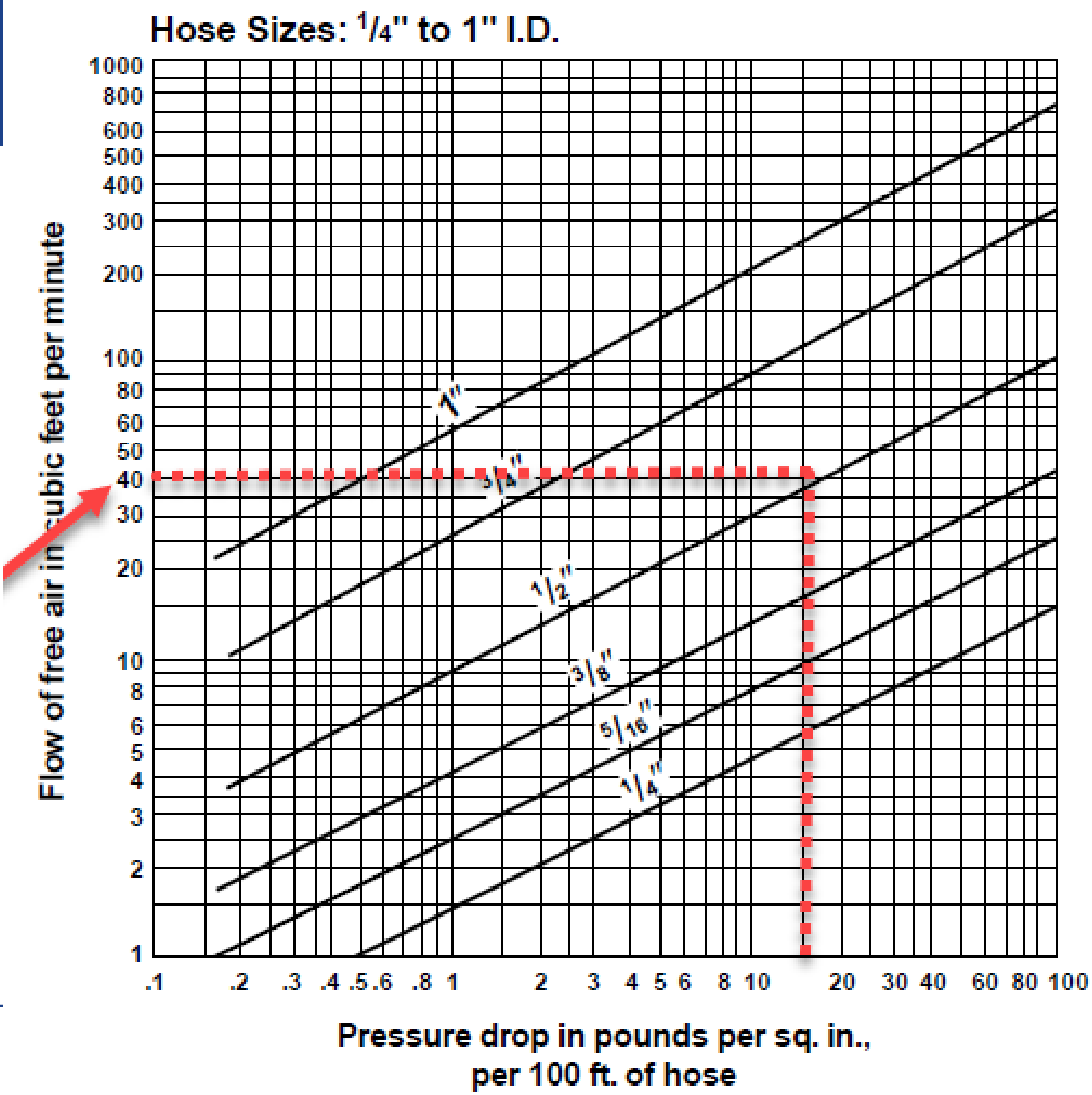
- 100' x 1/2" I.D. hose at 40 CFM has a pressure loss of 17 1/2 psi.
- 200' x 1/2" I.D. will lose 35 psi.
- 50' x 1/2" I.D. will lose between 8 to 9 psi.



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

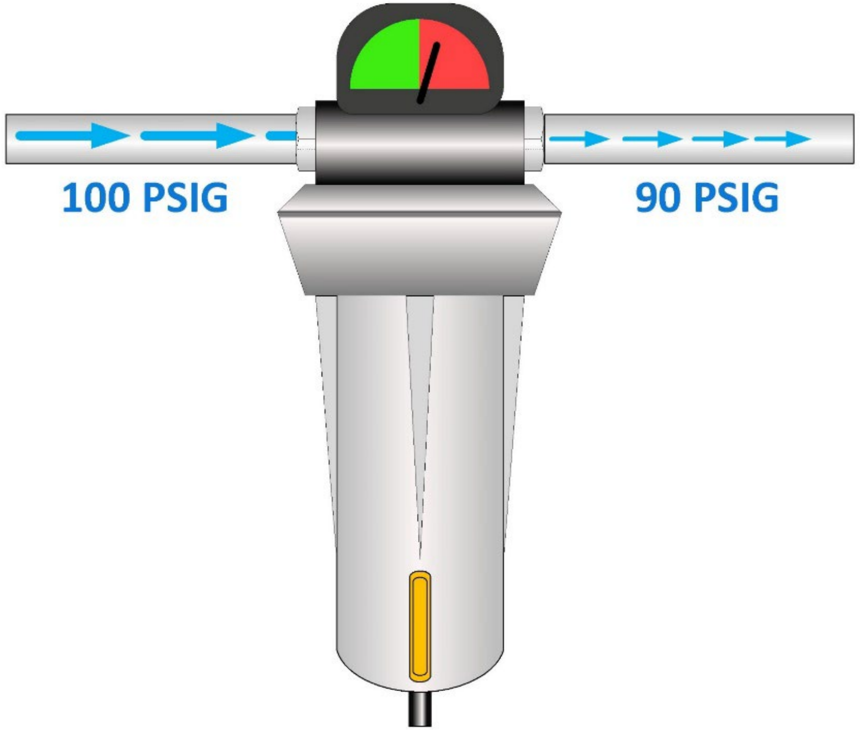
$$(\text{Pressure Drop per Chart Figure}) \times \frac{(\text{Ft. of Hose})}{100} = \text{Pressure drop for hose used}$$

Pressure Drop



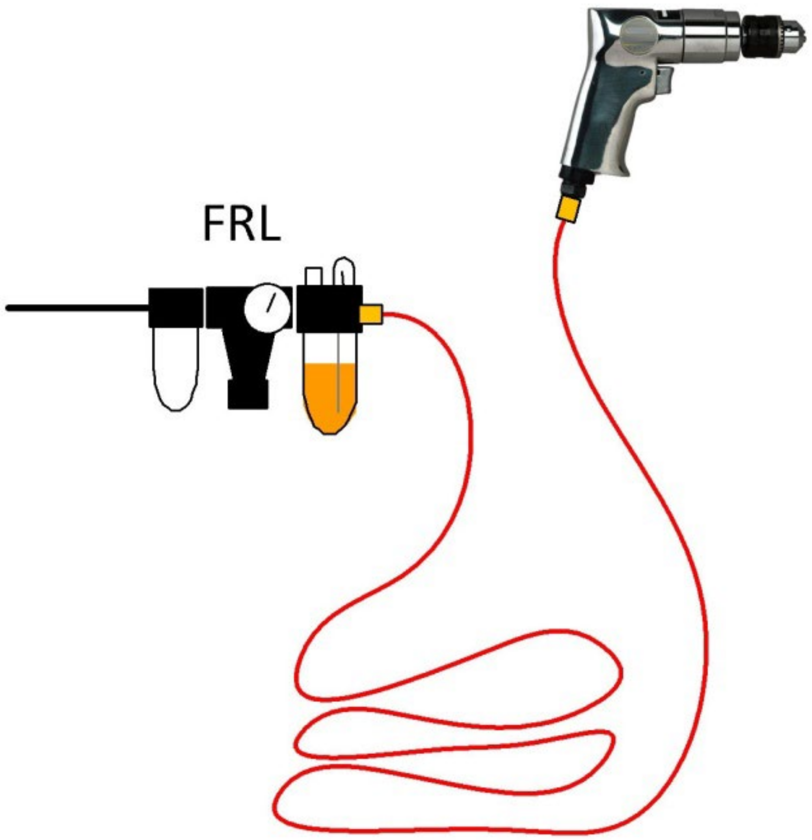
Restriction

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



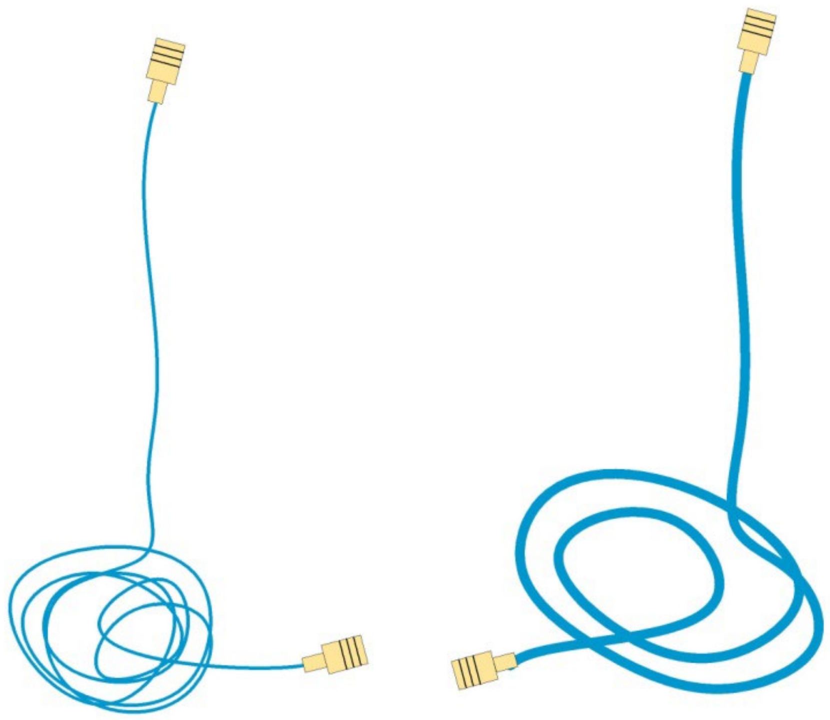
Pressure Drop

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



Pressure Drop

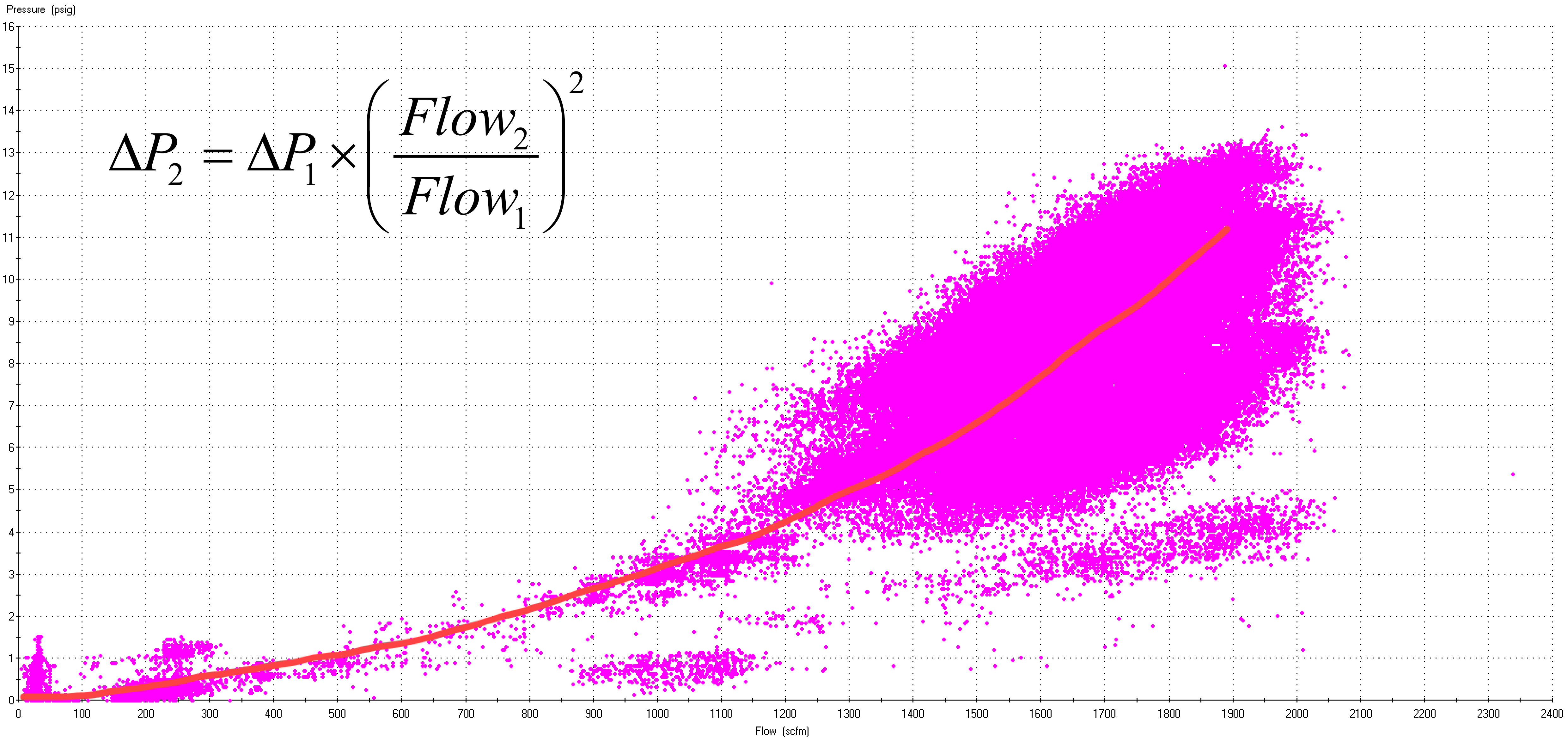
- Production engineers often specify end-use equipment to operate at an average system pressure.
- This results in higher system operating costs.
- For applications that use a significant amount of compressed air, such as large air cylinders, it is wise to specify a brand or model that operates at lower 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!

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



Reducing Pressure Drops Throughout the System

- The following equation is for calculating Velocity:

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

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

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

Reducing Pressure Drops Throughout the System

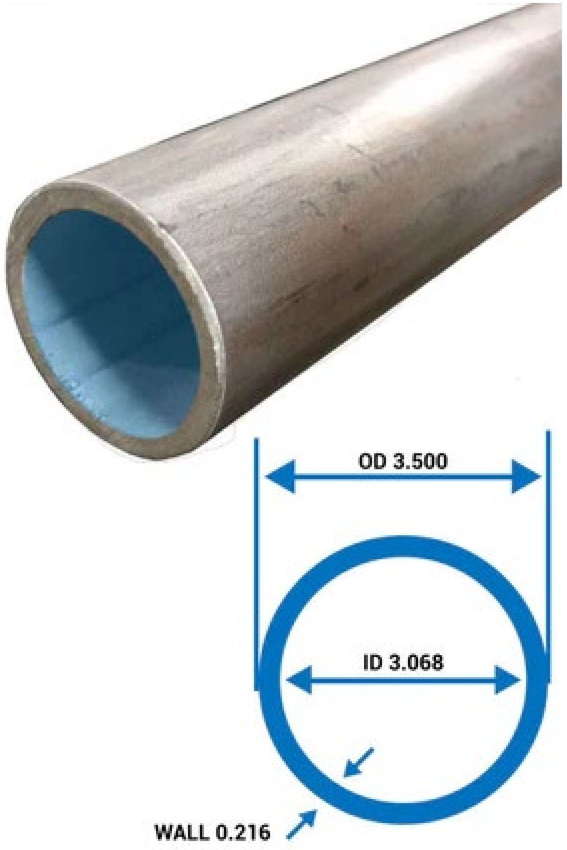
- Let's try 500 cfm in 3-inch pipe (ID = 3.068)

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

$$a = .051311$$

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

$$V_{fps} = 20.56$$



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?

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

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

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

$$a_{sqft} = 7.5982$$

$$d = 3.11$$

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.

Pressure Drop – Loss at 100 psig

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

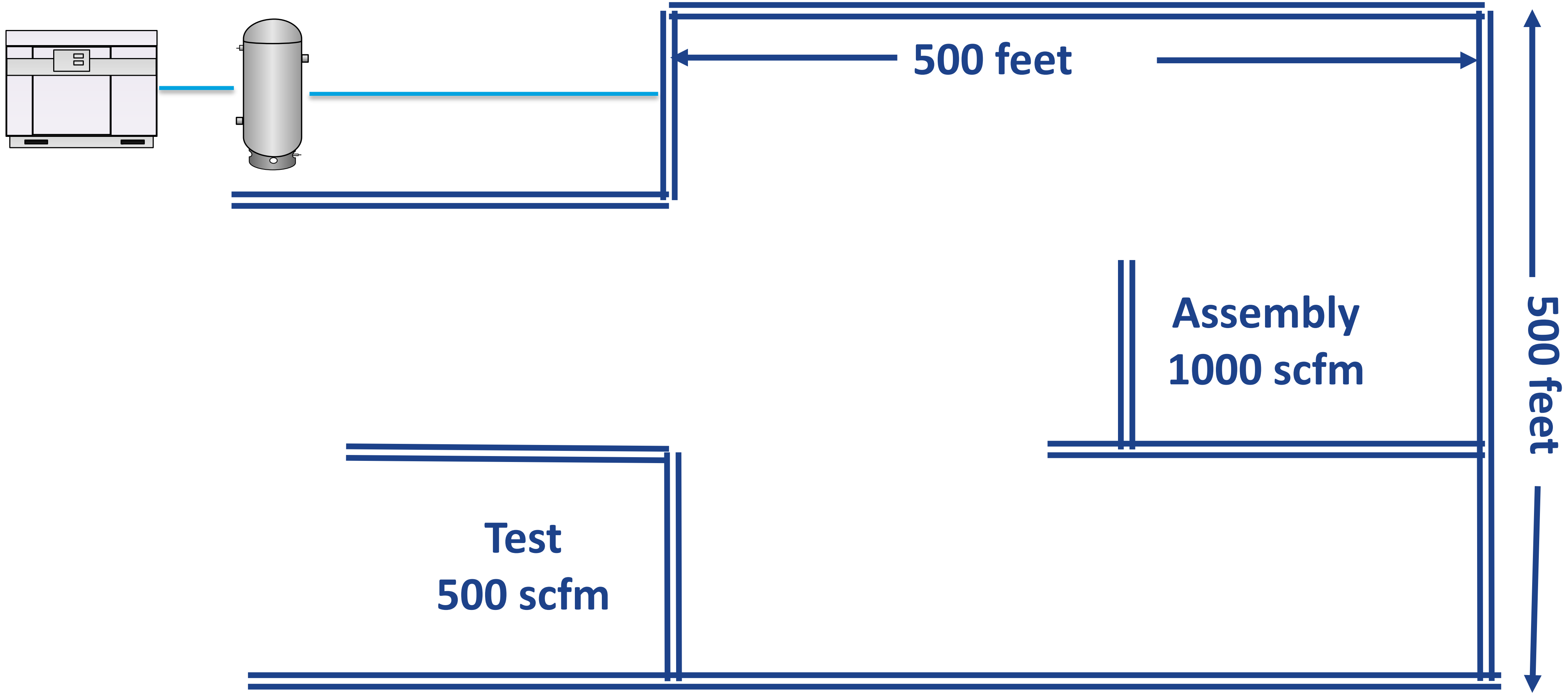
CAGI Compressed Air & Gas Institute

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.

WHAT PIPE SIZE IS NEEDED



Factors for calculating Loss of Air Pressure Due to Pipe Friction, Applicable for any Initial Pressure Chapter 4 of the CAGI Handbook. Table 4.9 page 16

	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” BIP costs $ 3.25/ft

4” BIP costs $ 4.75/ft

Conclusion:

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

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.

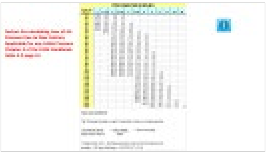
Frictional Loss in Pipe Example:

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



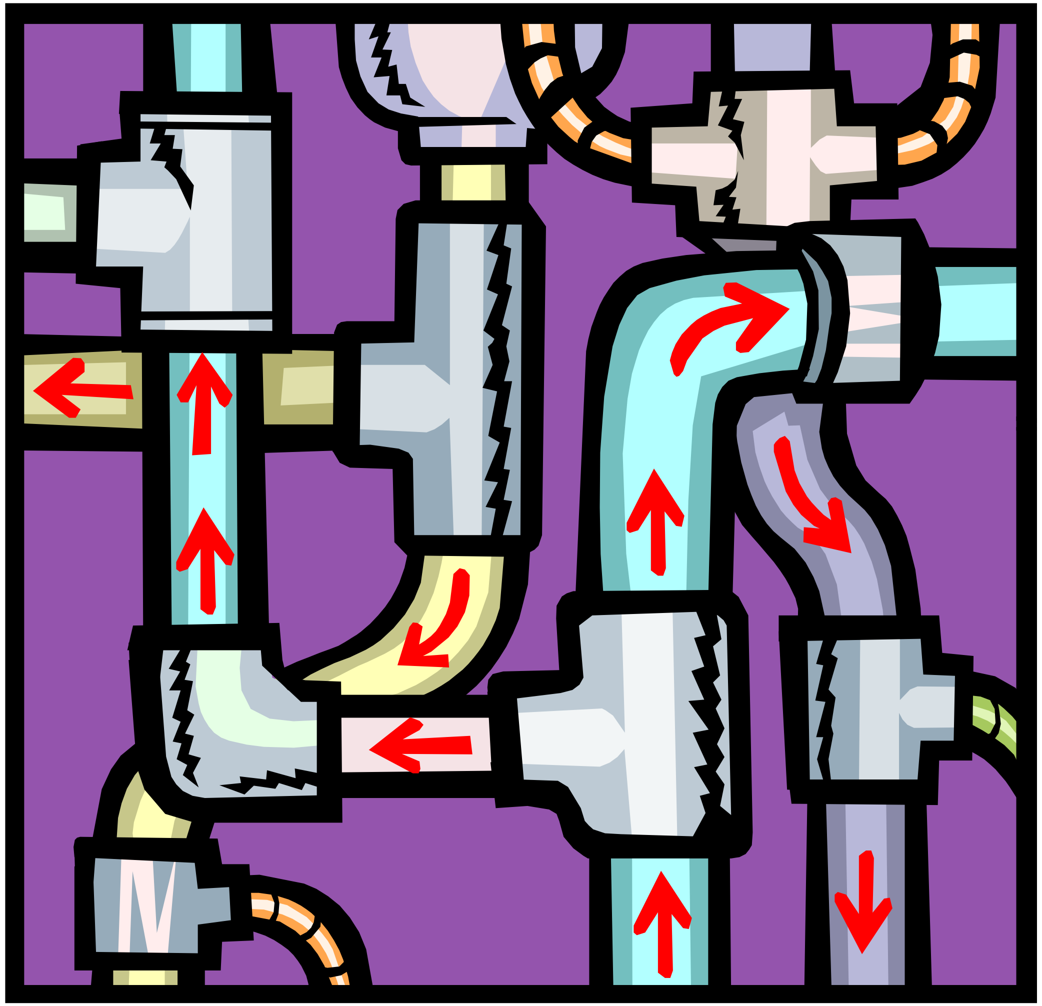
2000 + 80 + 2 + 2 = 2084 total feet in inlet piping.

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								

General Rules for Compressed Air Distribution System

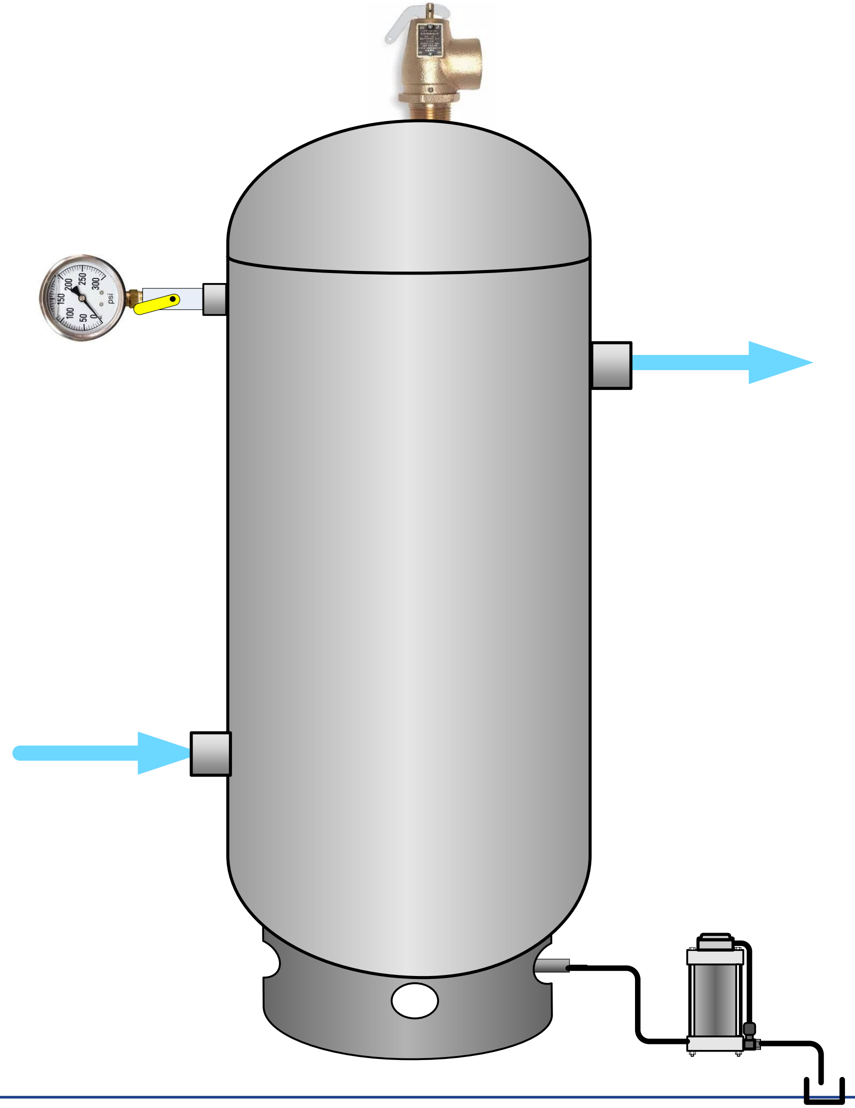


Distribution Best Practices

- 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.

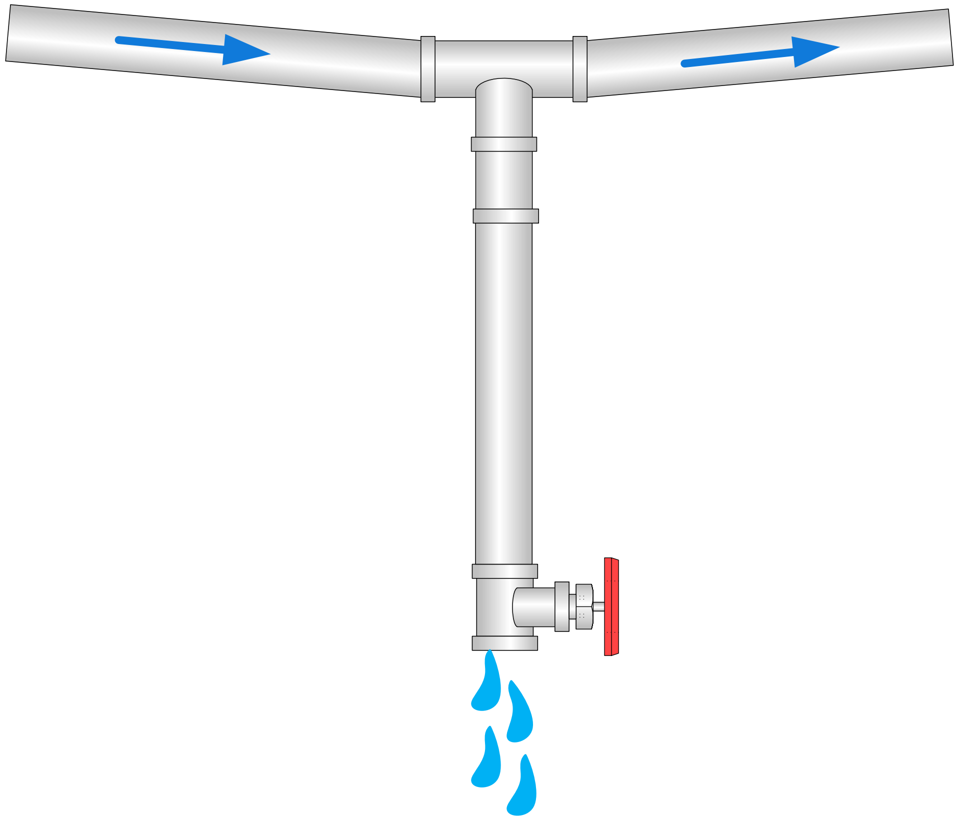
Distribution Best Practices

- 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.



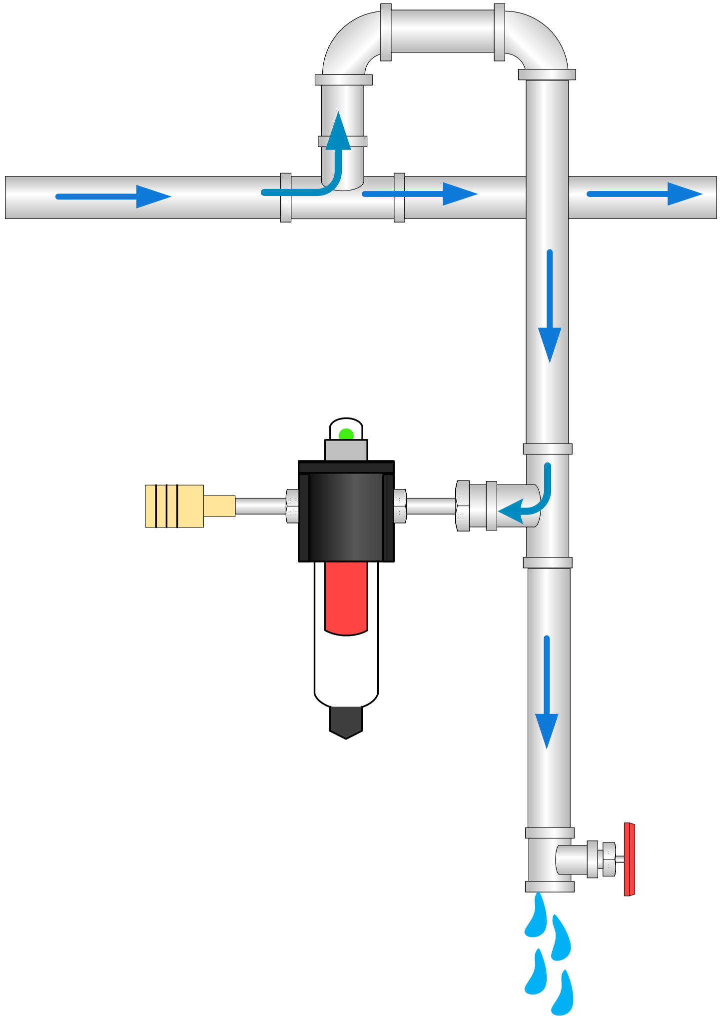
Distribution Best Practices

- 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.



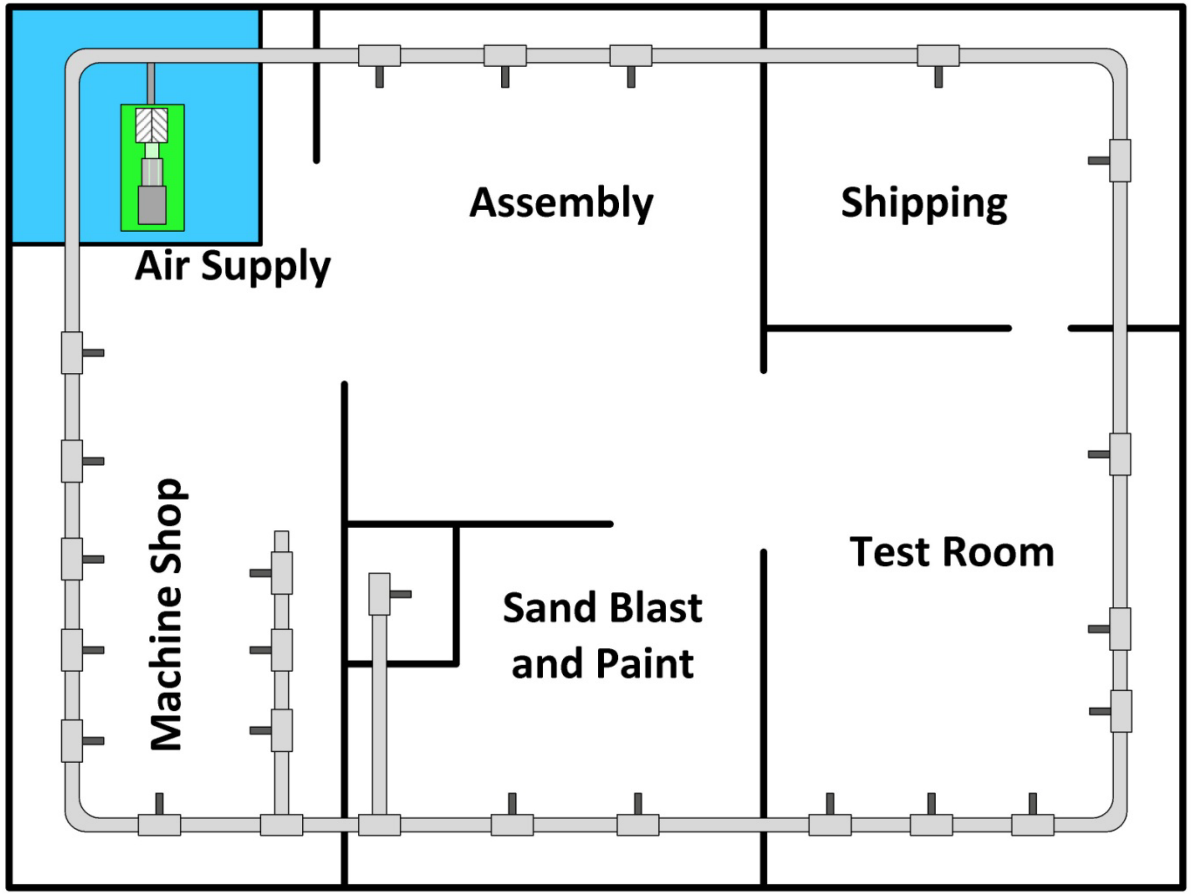
Distribution Best Practices

- 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.



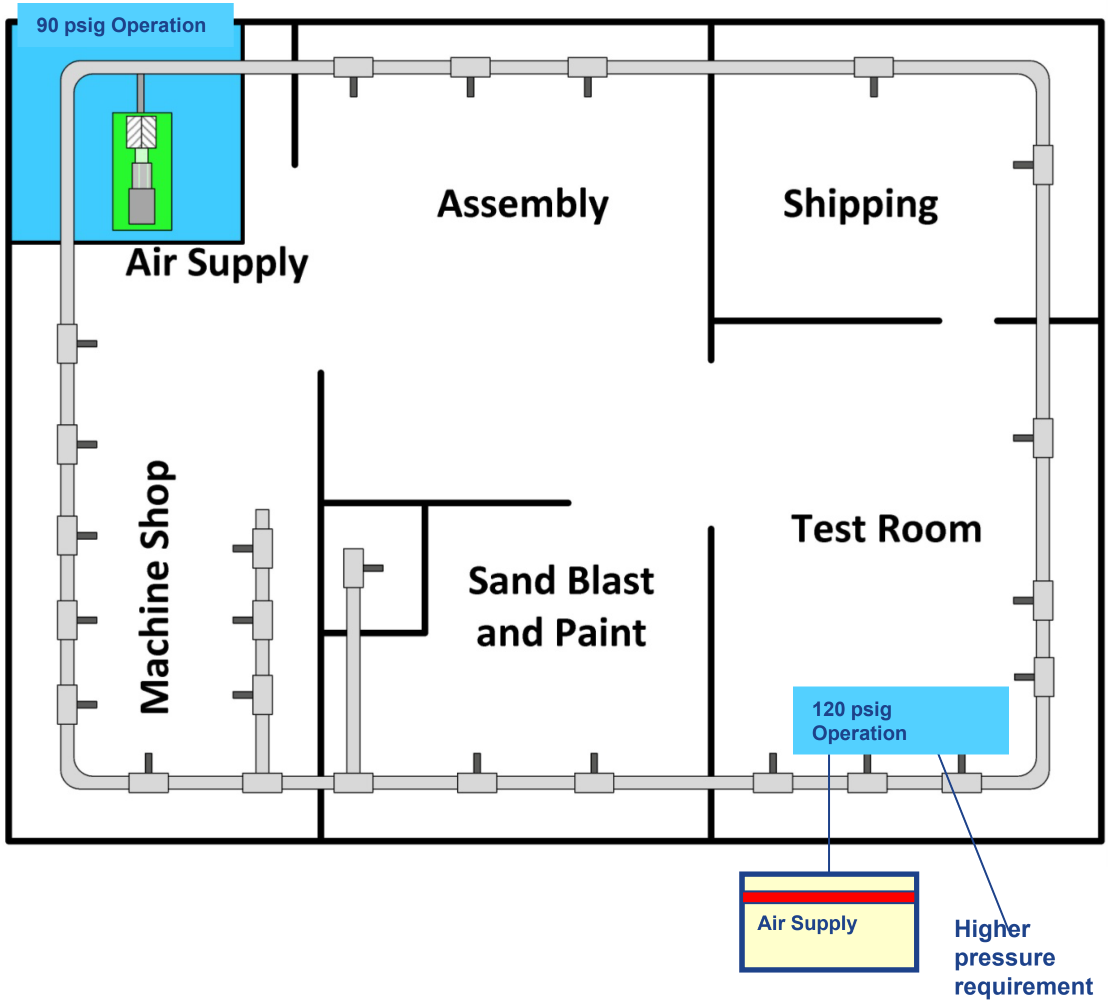
Location

- 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.



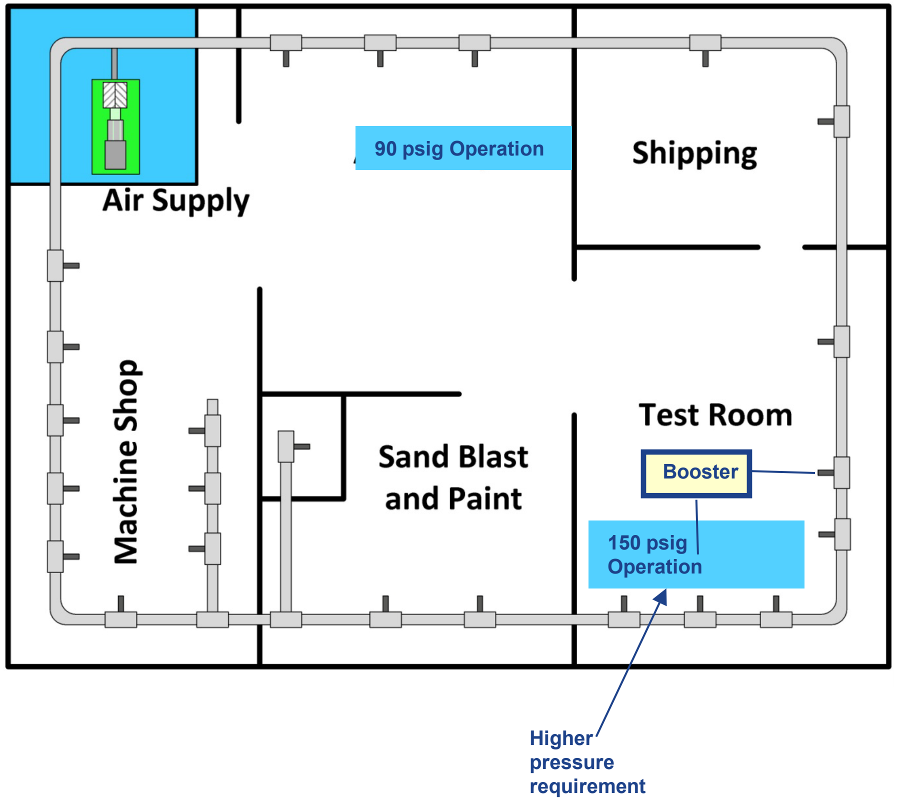
Location

- 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.

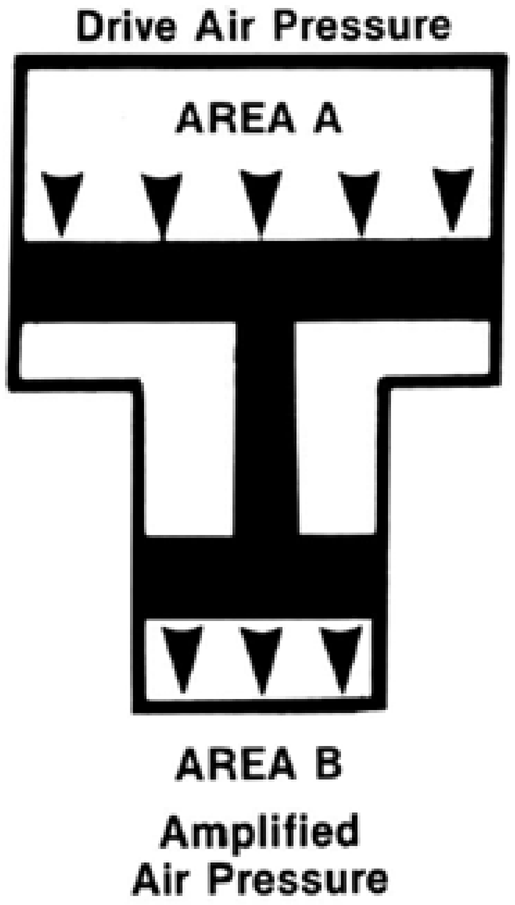


Location

- 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.



Amplifier



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.

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.

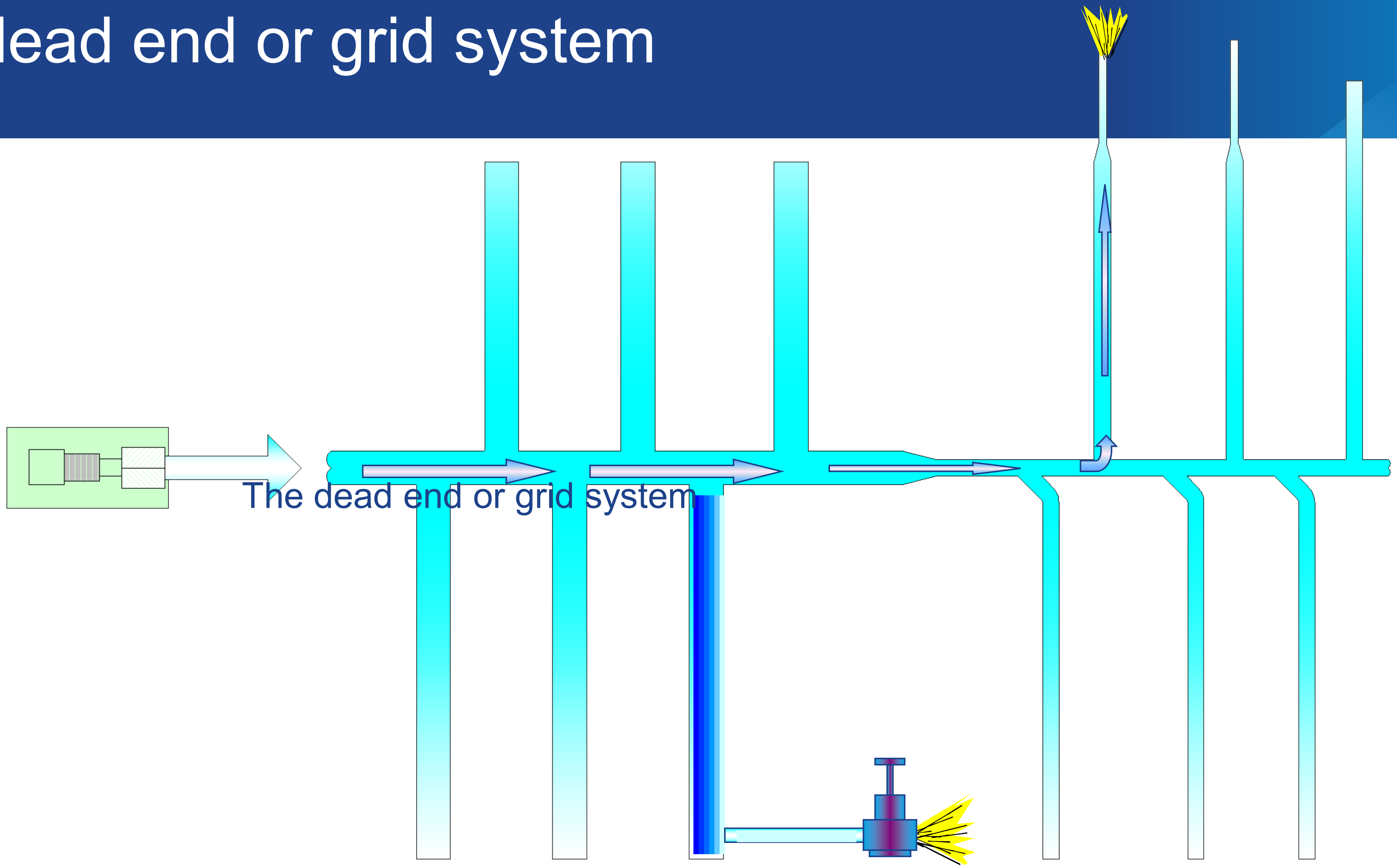
Piping Layout

- 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.

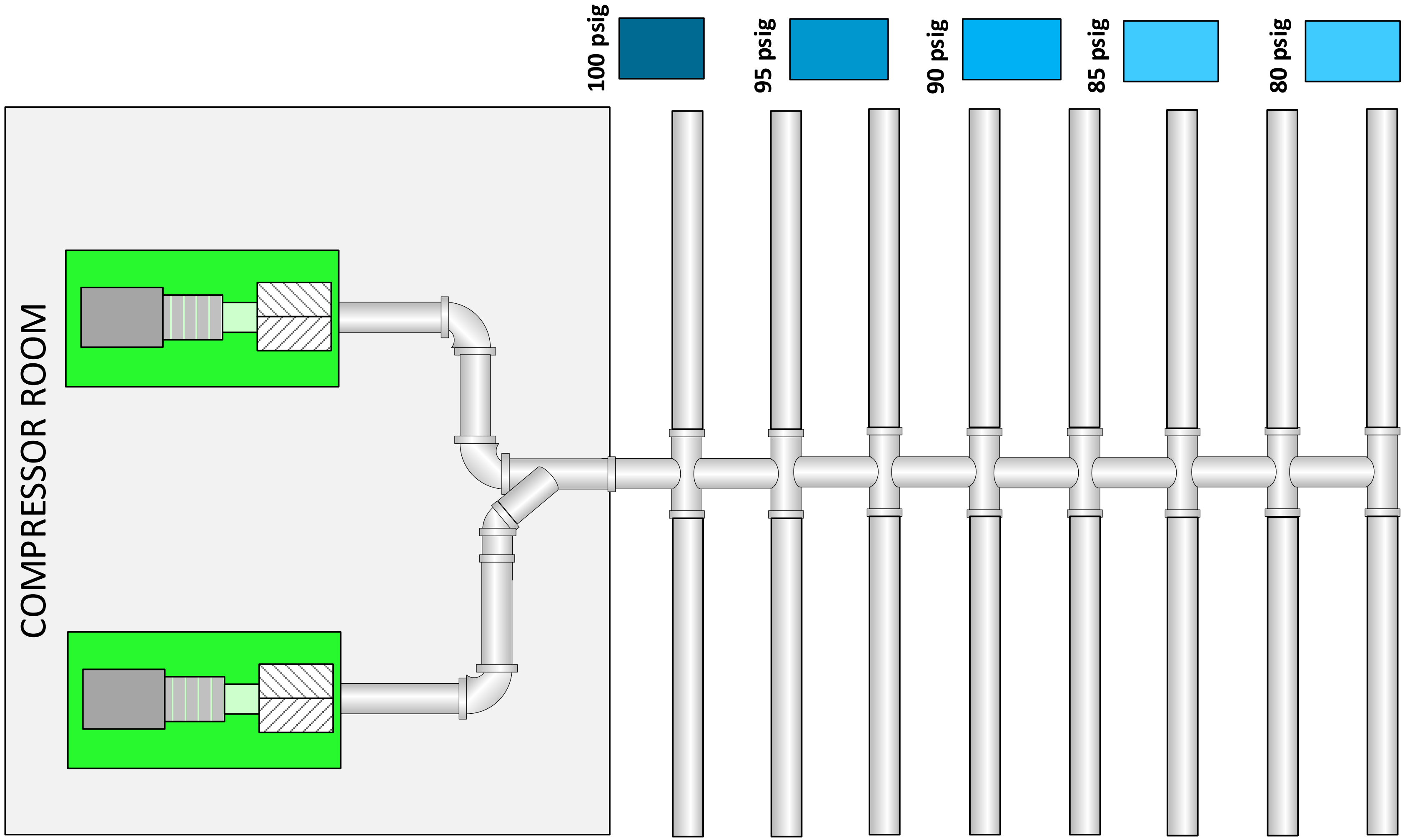
Piping Systems

- 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.
    - Work stations near the ends of the system are subject to insufficient air supply (air starvation) when upstream demand is heavy.

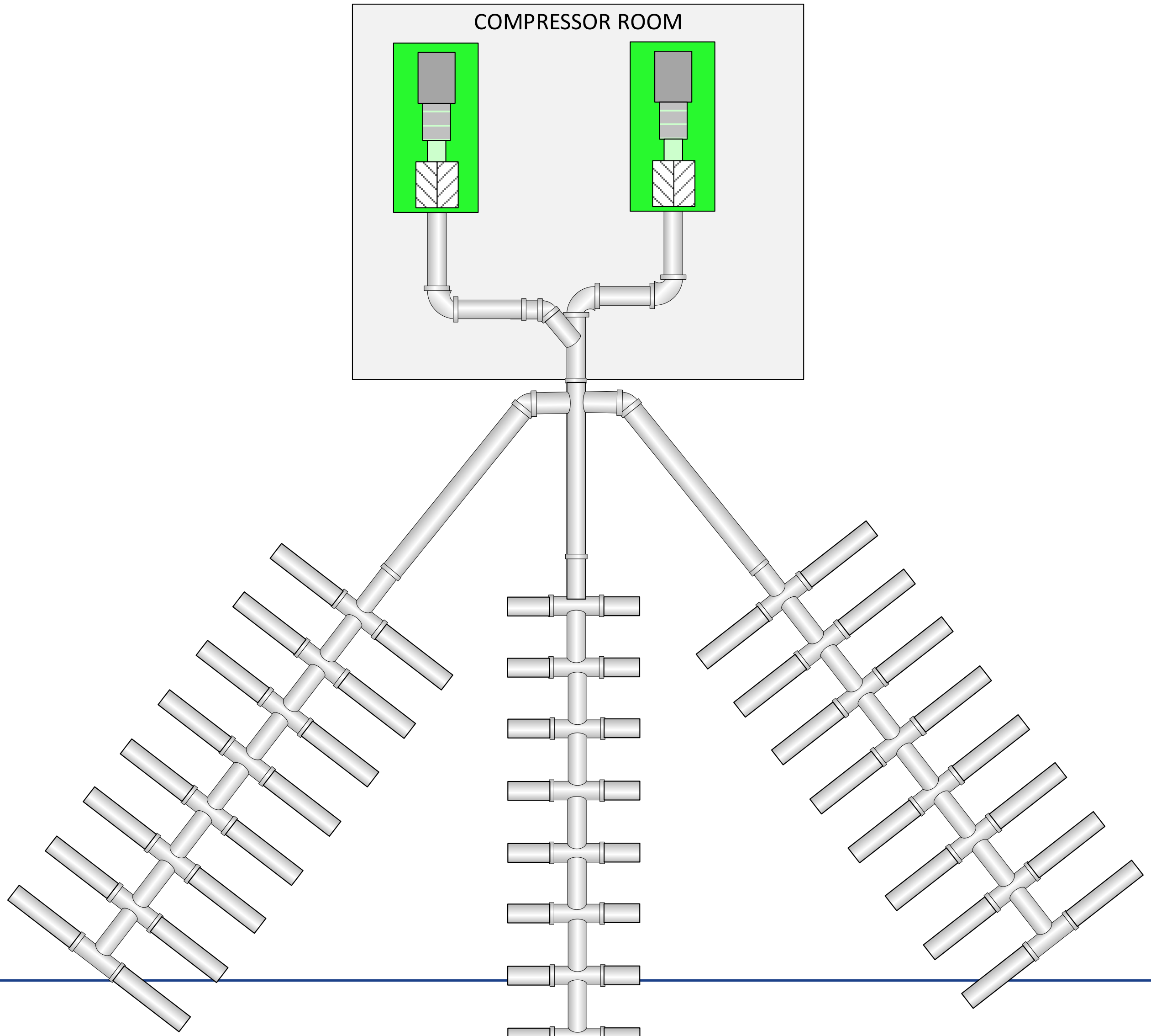
The dead end or grid system



The dead end or grid system



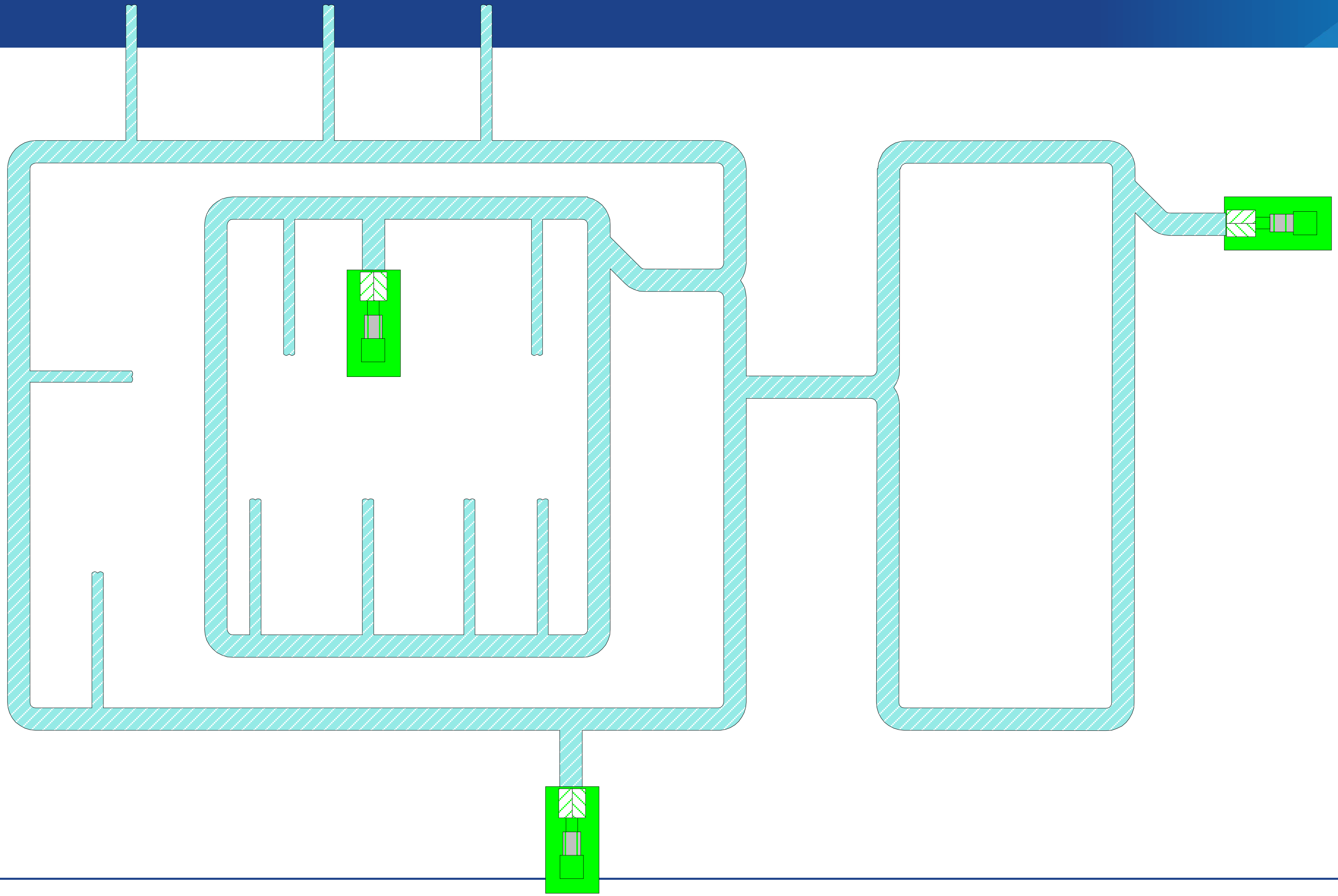
The dead end or grid system



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.

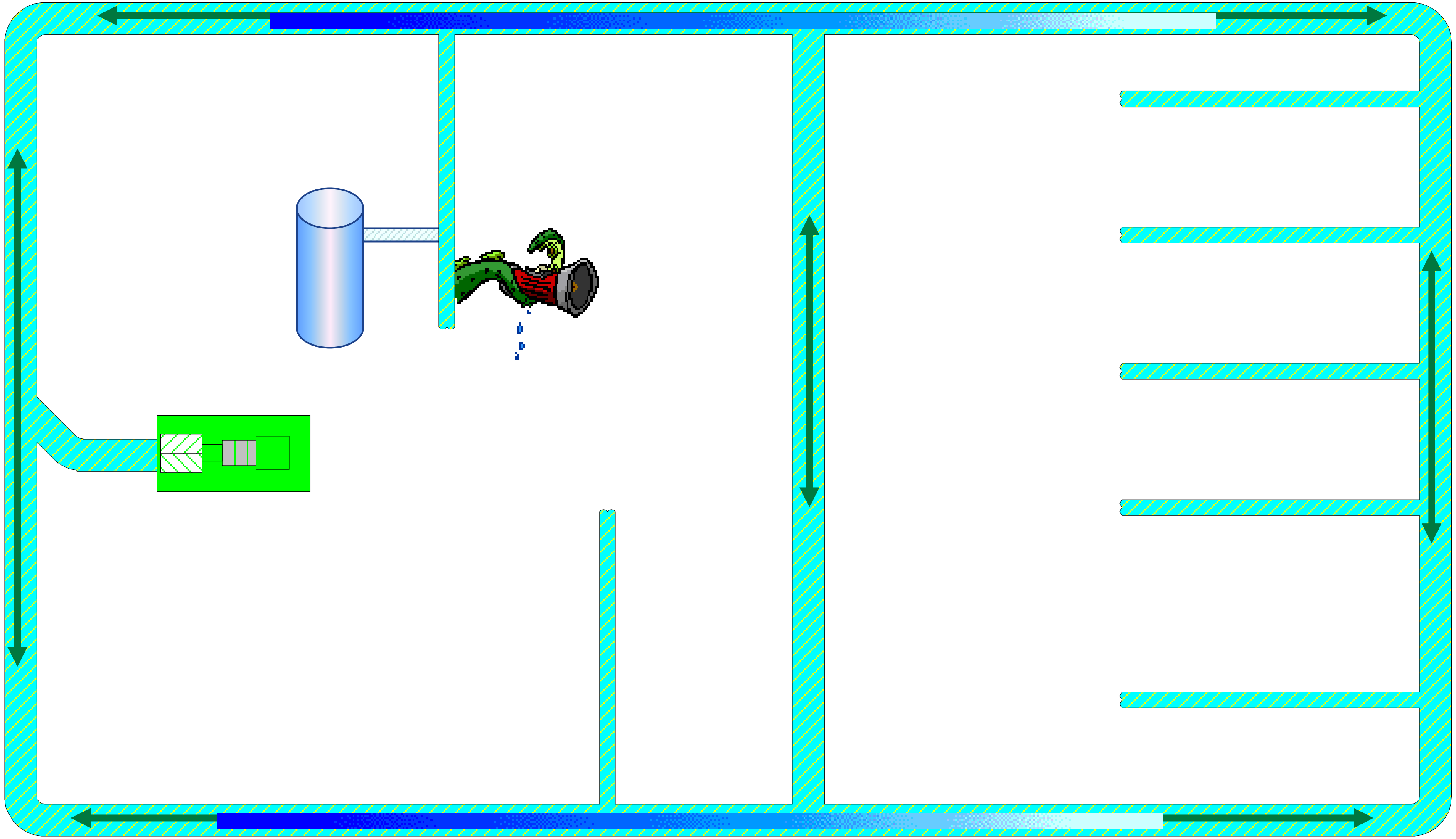
Decentralized system



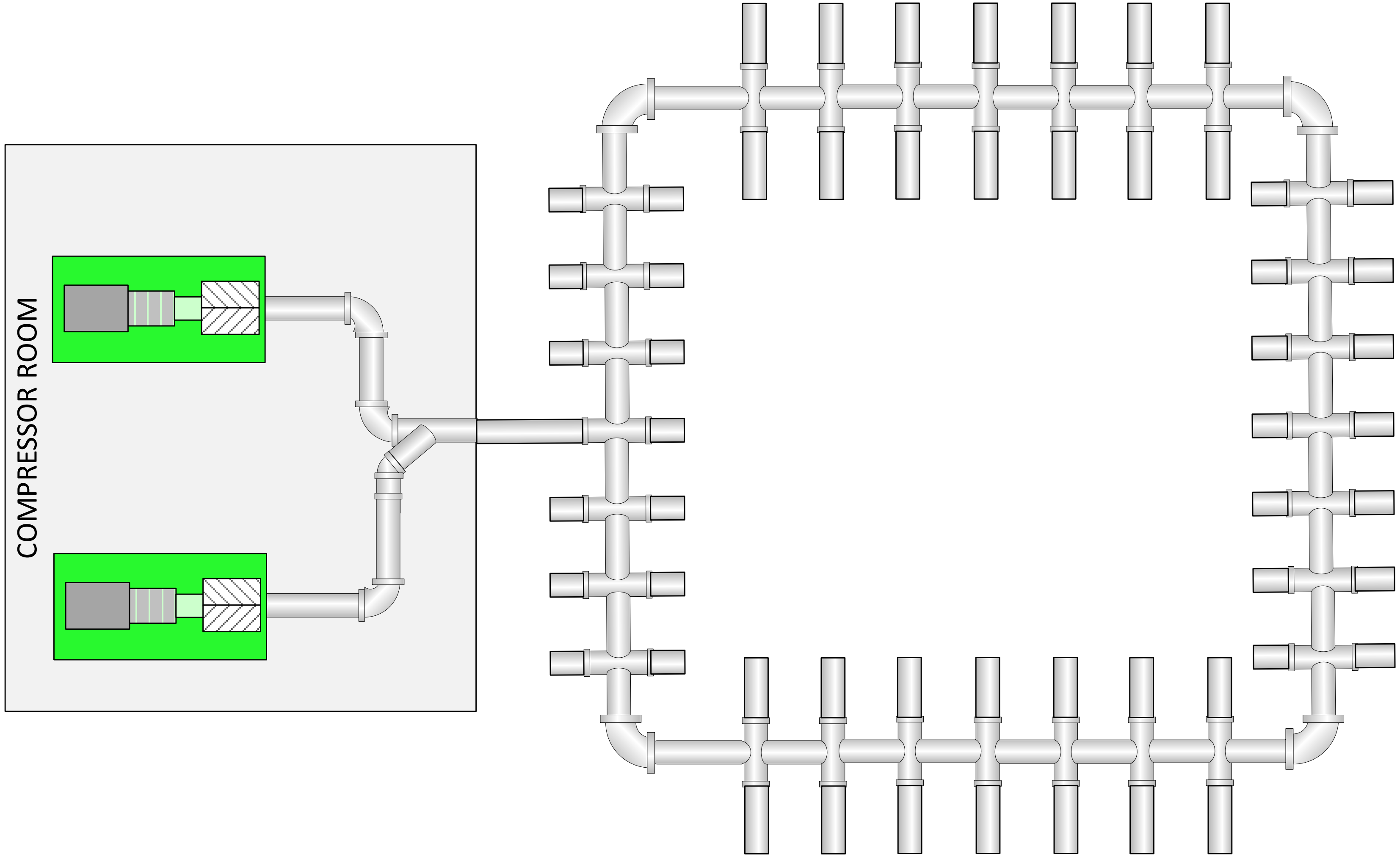
Piping Systems

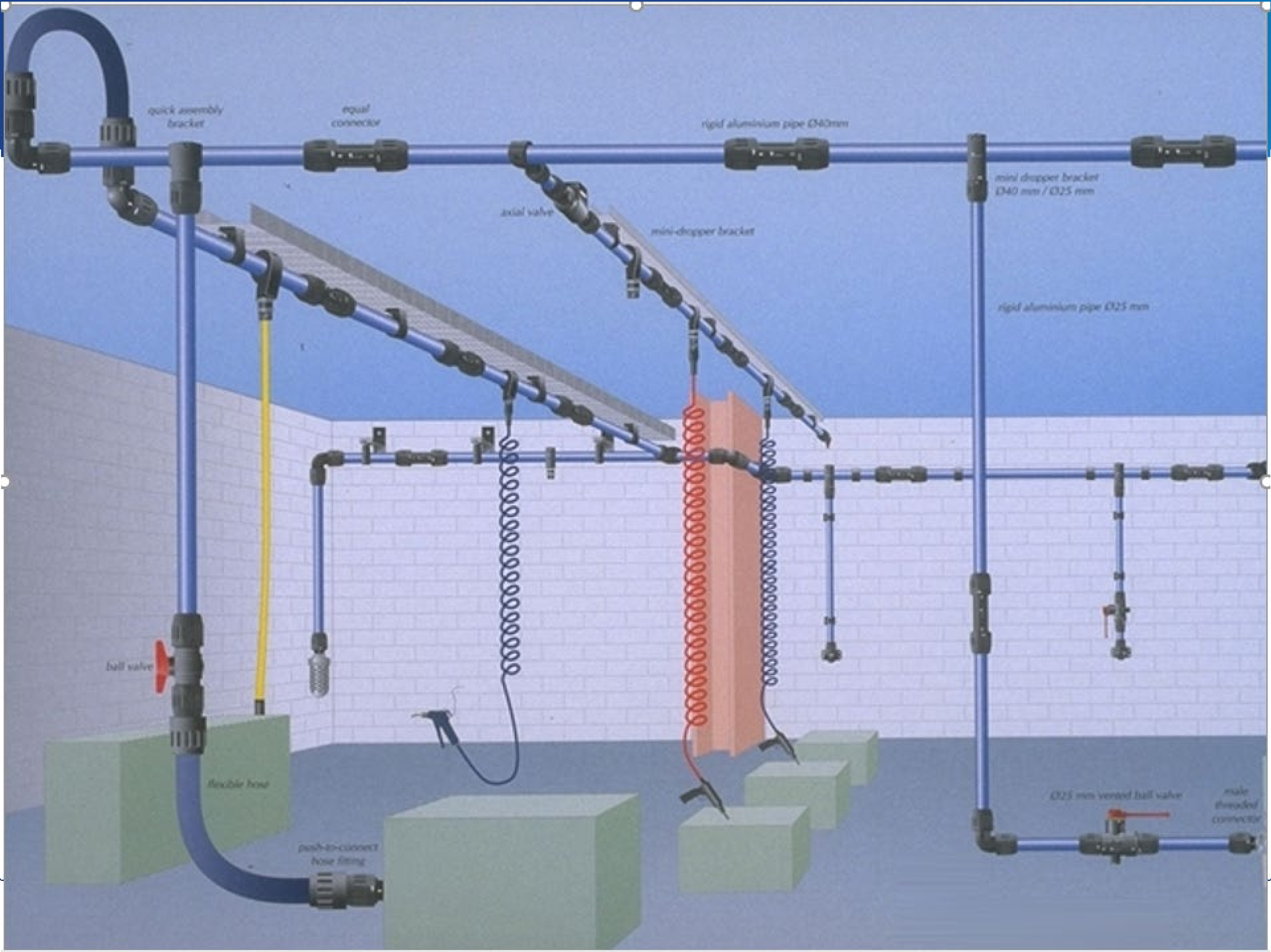
- Loop system.
  - Highly recommend and most common.
  - Allows the optimum pipe size and assures equal distribution through the plant.
  - At points of heavy momentary demands for air, a receiver can be used to store the energy.

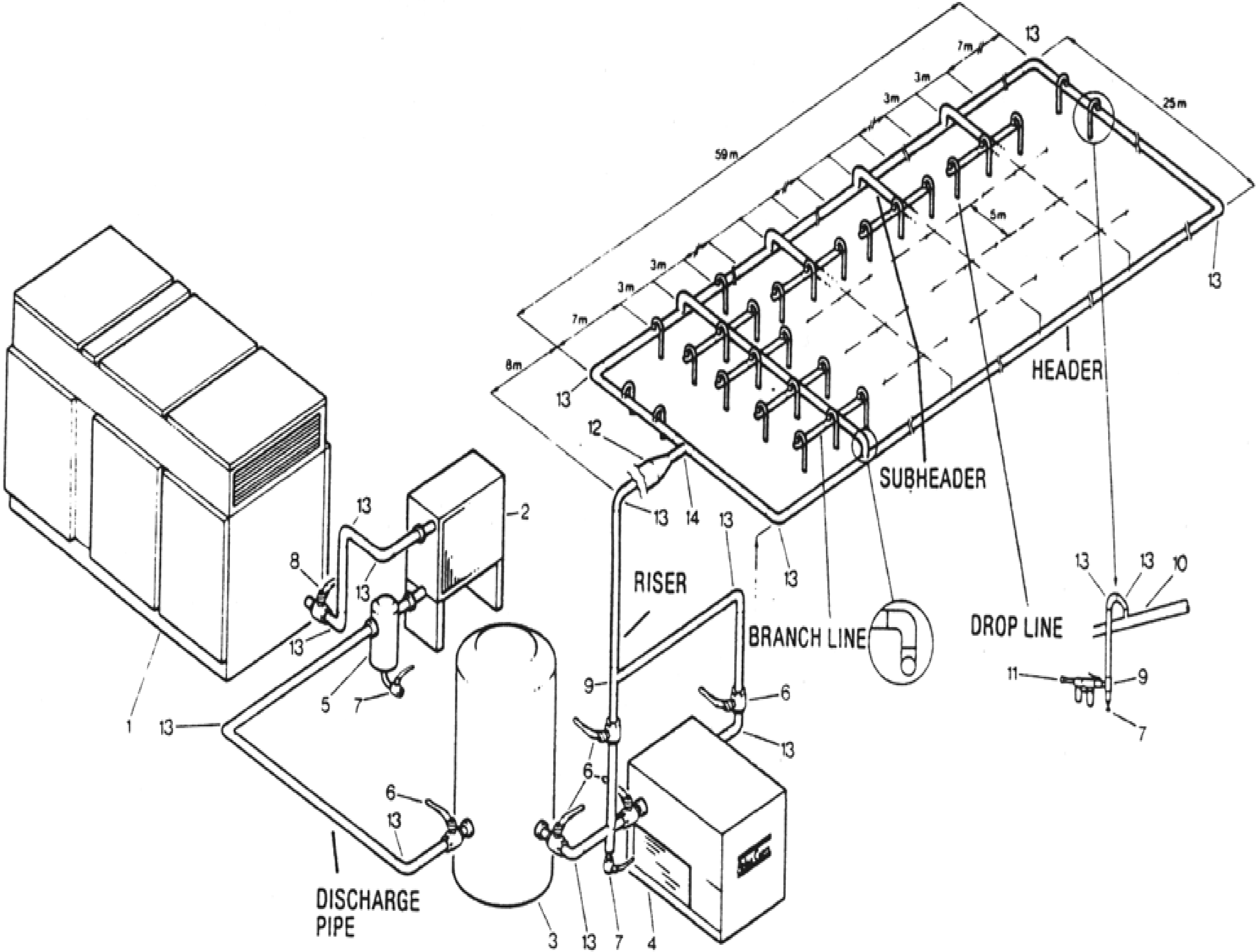
Loop system



Loop system

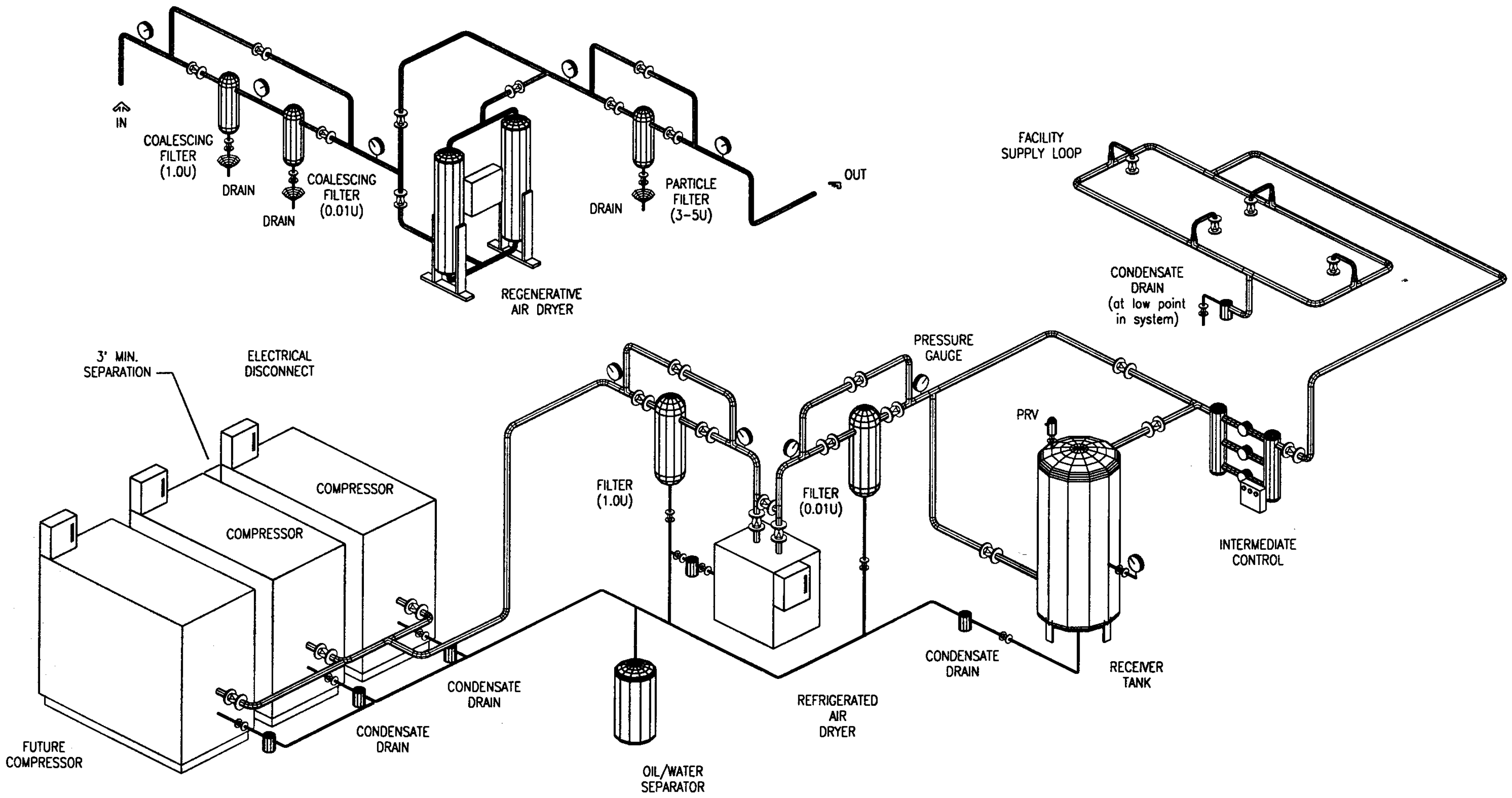



quick assembly bracket
equal connector
rigid aluminium pipe Ø40mm
mini dropper bracket Ø40 mm / Ø25 mm
axial valve
mini-dropper bracket
rigid aluminium pipe Ø25 mm
ball valve
flexible hose
push-to-connect hose fitting
Ø25 mm vented ball valve
male threaded connector

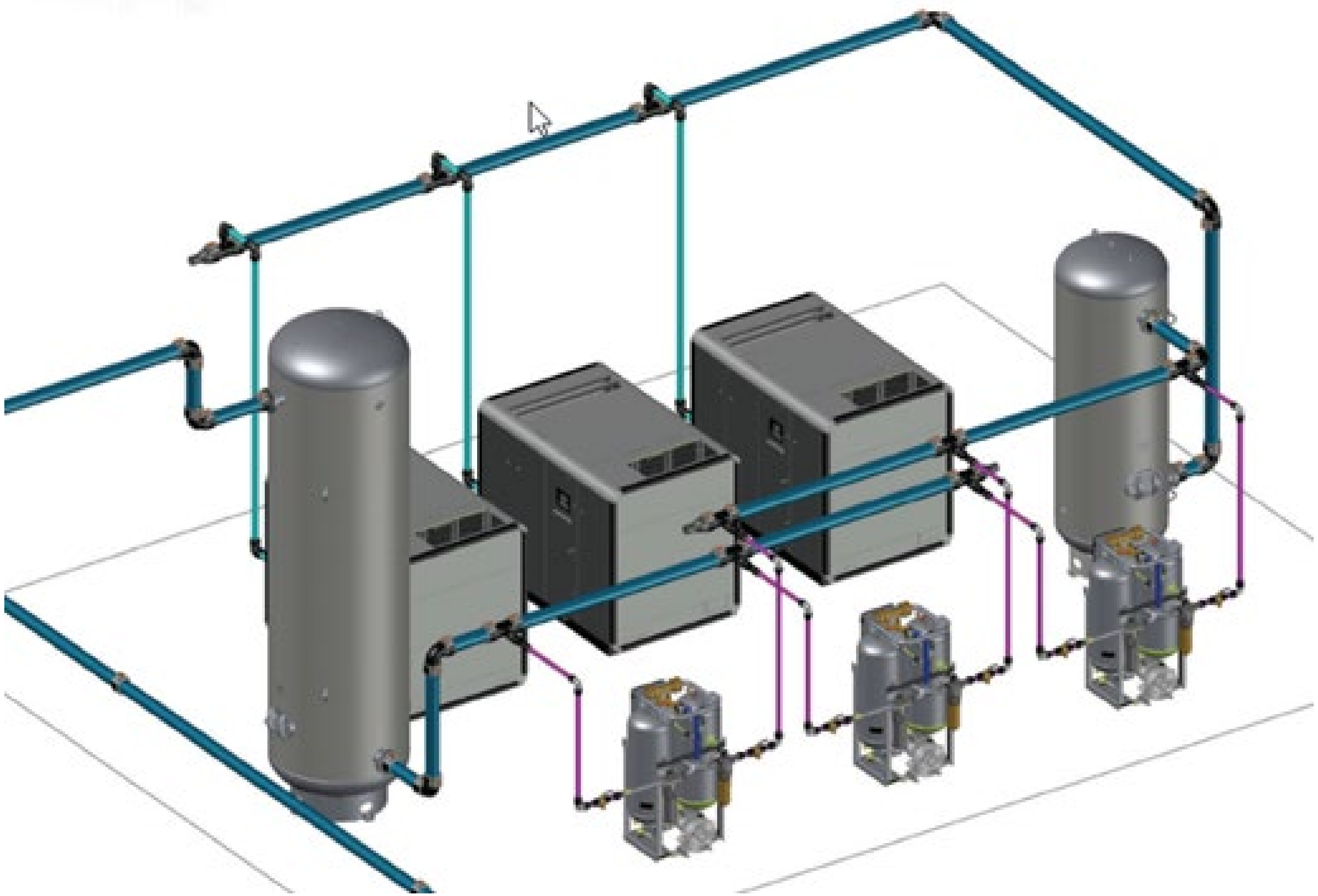


HEADER
SUBHEADER
BRANCH LINE
DROP LINE
RISER
DISCHARGE PIPE
59m
25m
7m
3m
3m
3m
3m
3m
7m
8m
5m

Piping Systems



Piping Systems



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.

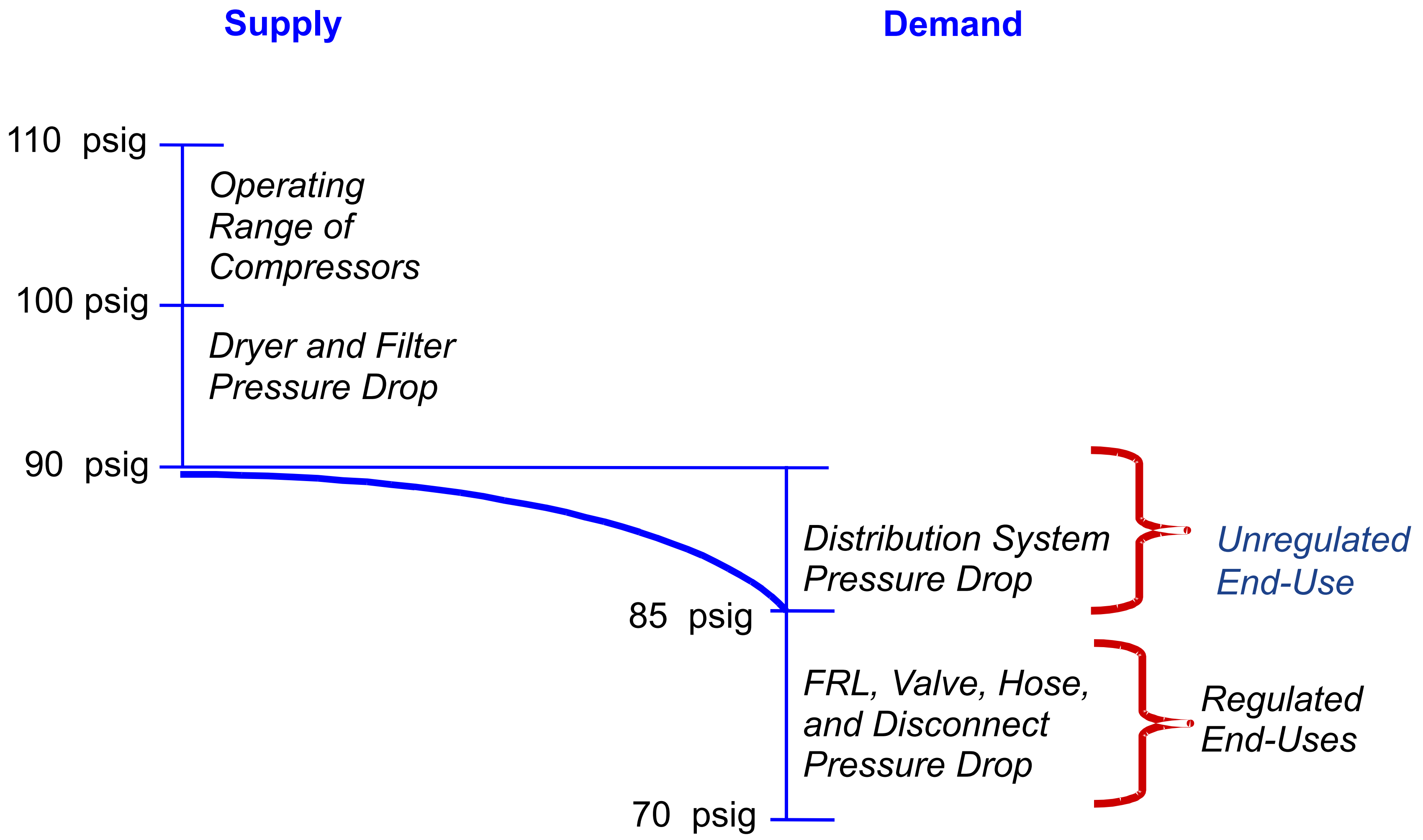
What's Wrong Here?

What's Wrong Here?

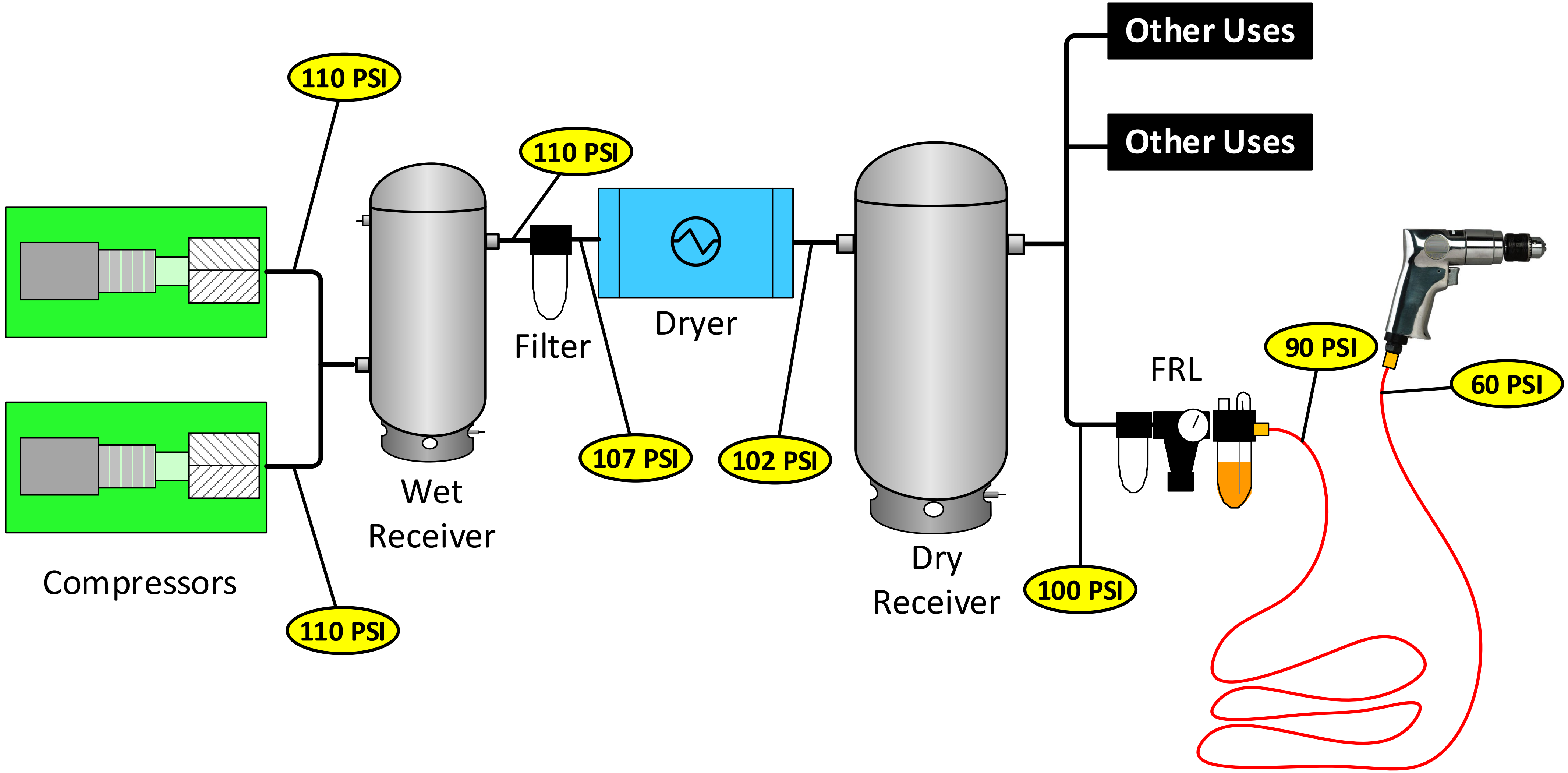
Pressure Profiles

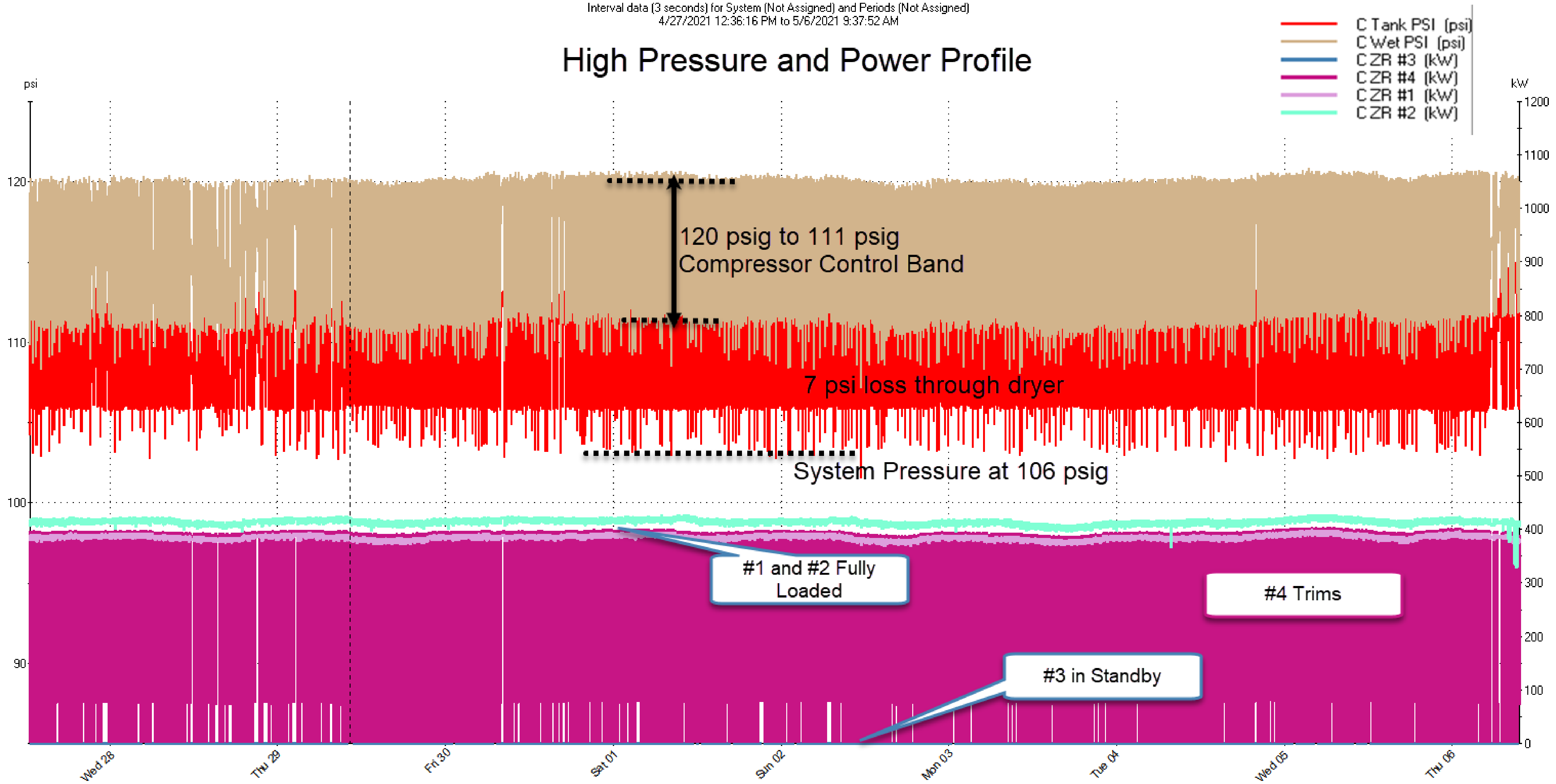
- Pressure measurements need to be taken to:
  - Give feedback for control adjustments
  - Determine pressure drops across components
  - Determine system operating pressures
- The following pressure measurements should be taken:
  - Discharge Pressure
  - Loss from filters and dryers
  - Various points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

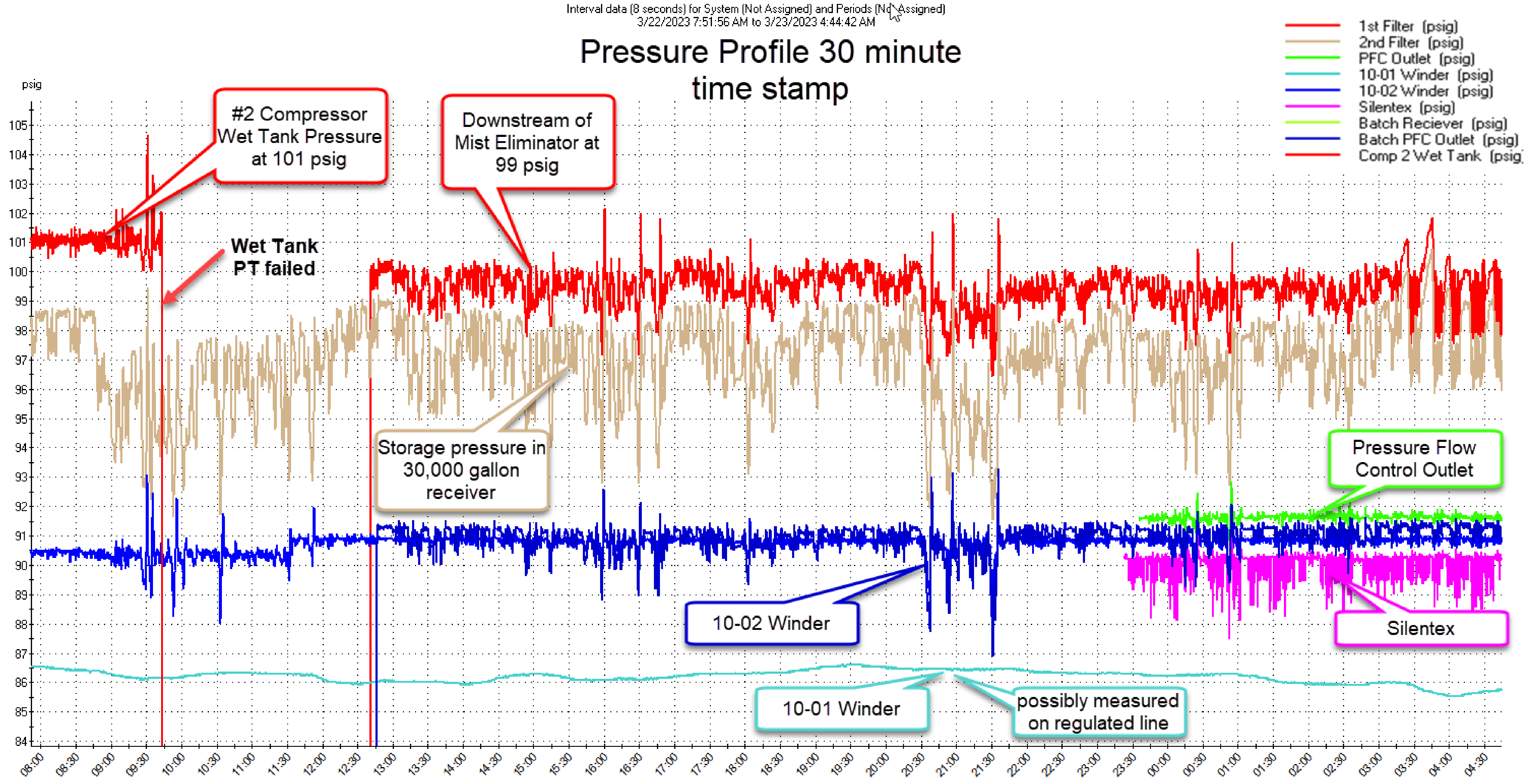
System Pressure Profile



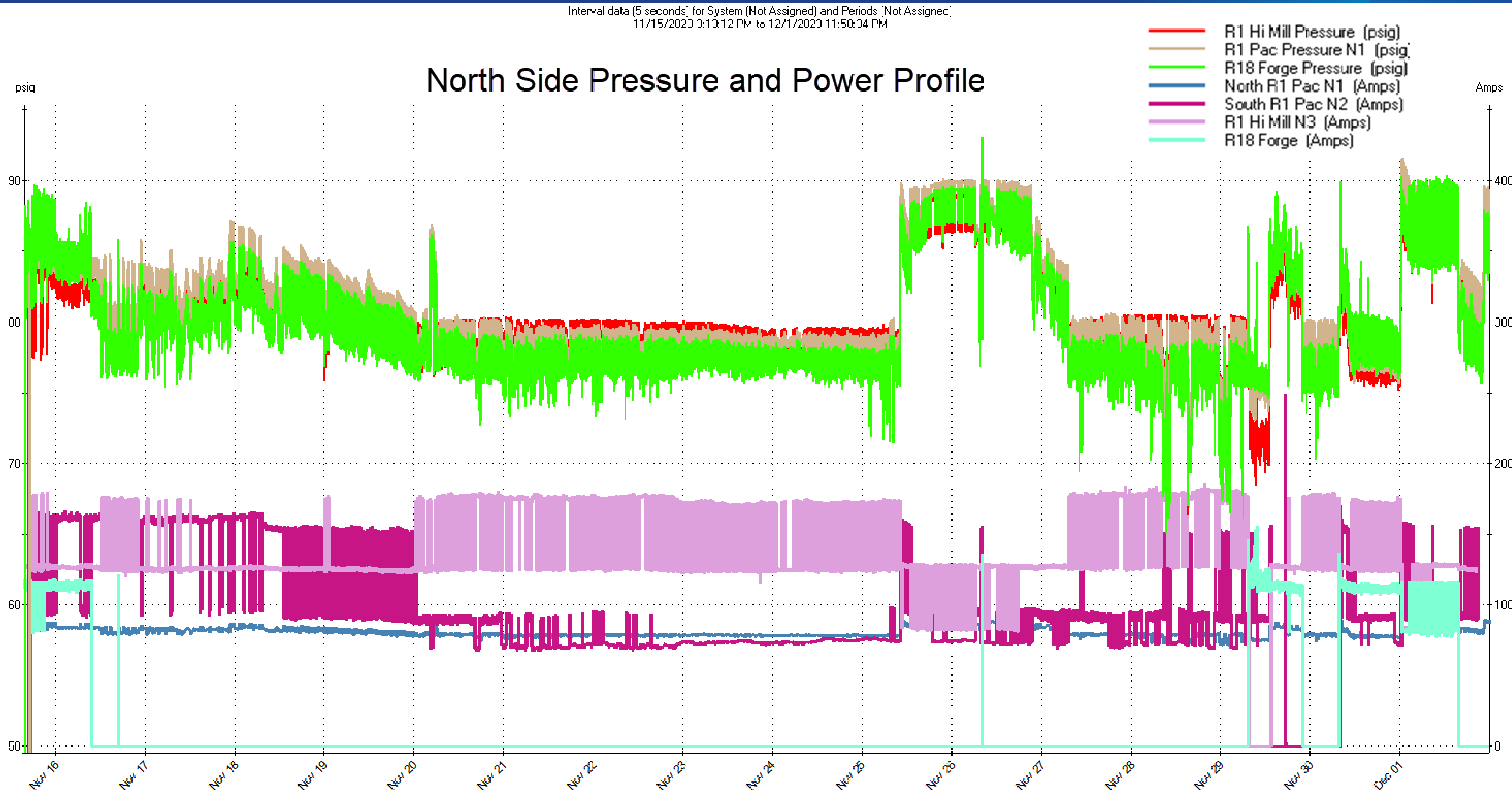
Developing a System Profile

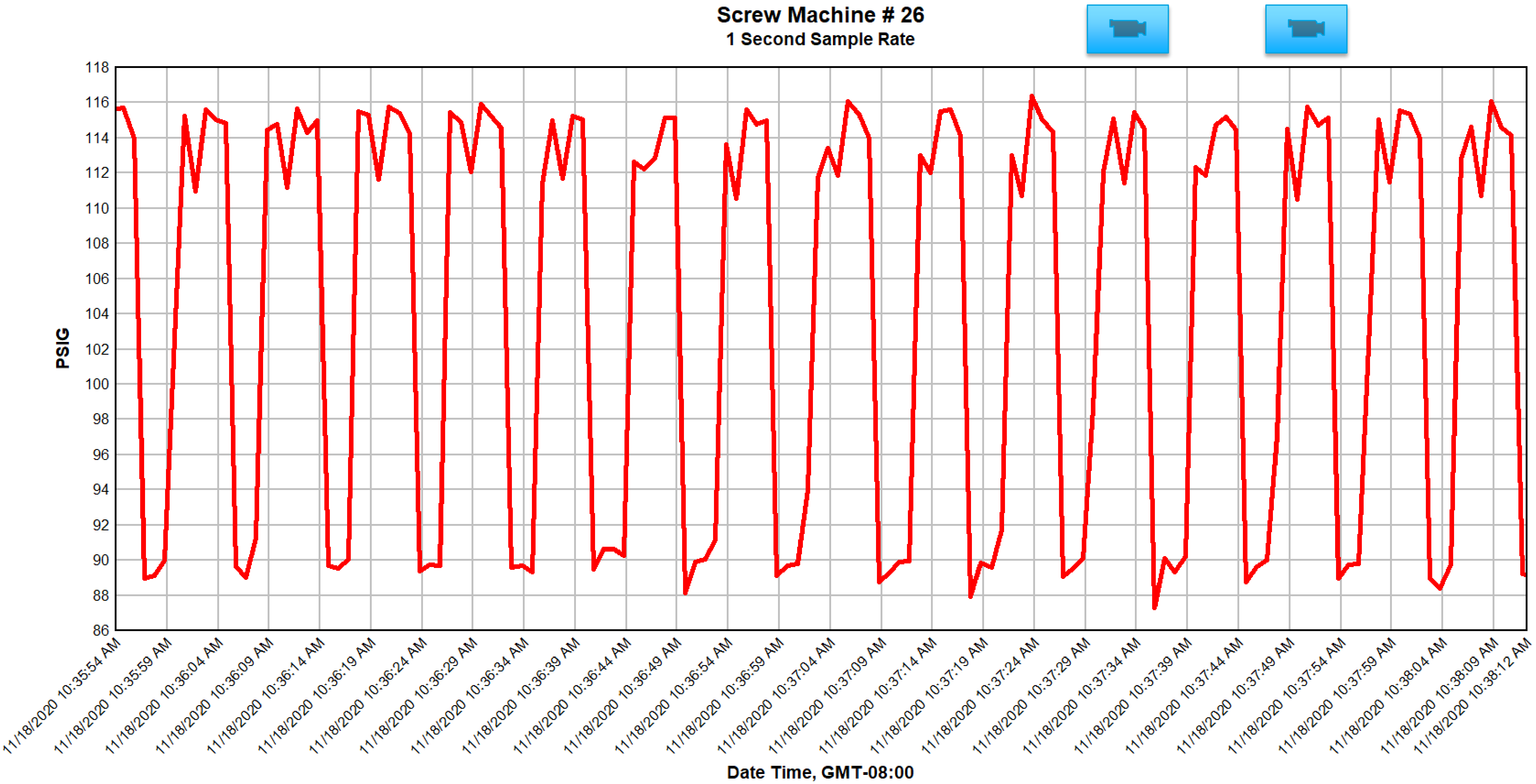


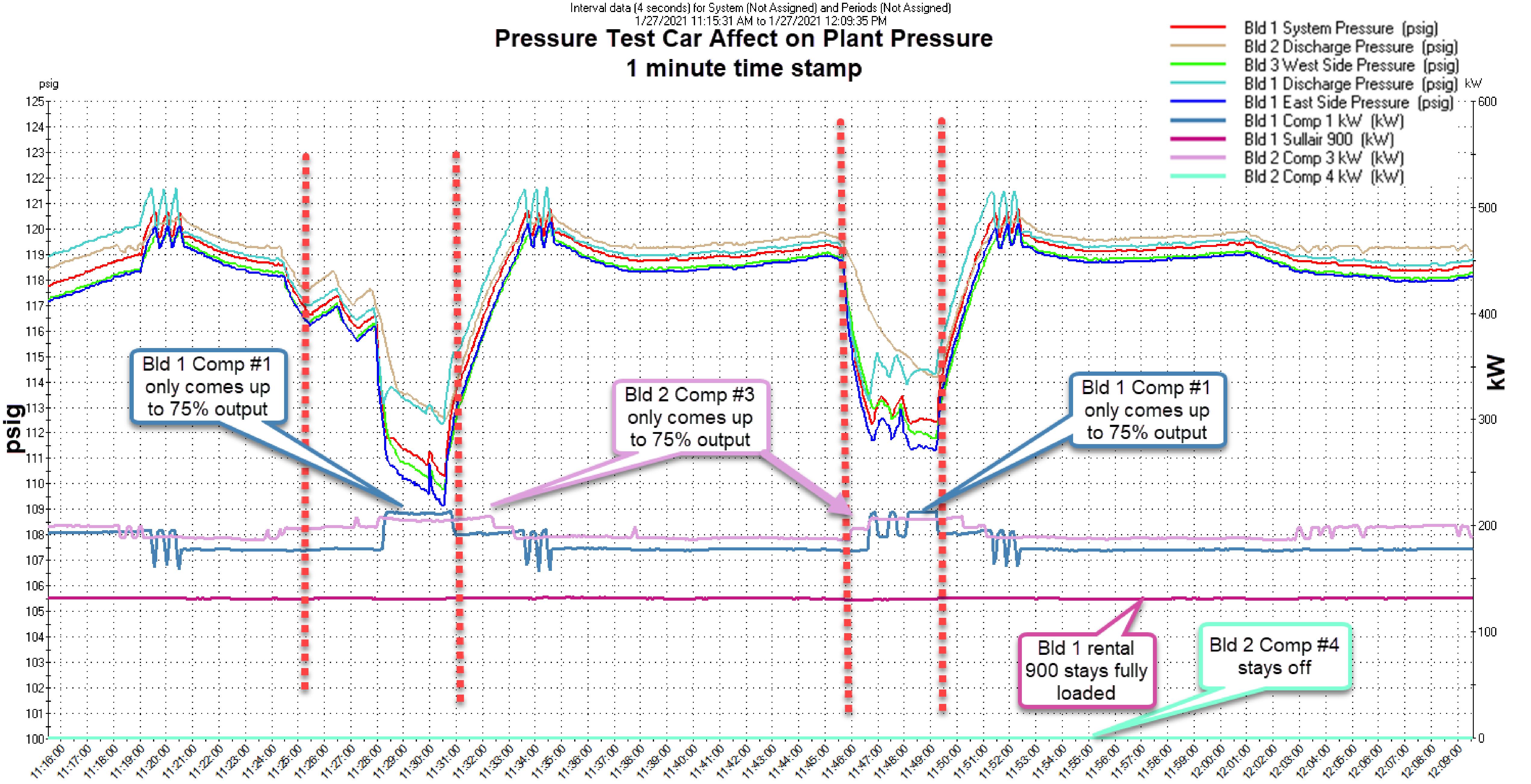

Interval data (3 seconds) for System (Not Assigned) and Periods (Not Assigned)
4/27/2021 12:36:16 PM to 5/6/2021 9:37:52 AM
High Pressure and Power Profile
C Tank PSI (psi)
C Wet PSI (psi)
C ZR #3 (kW)
C ZR #4 (kW)
C ZR #1 (kW)
C ZR #2 (kW)
psi
kW
120
110
100
90
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
120 psig to 111 psig
Compressor Control Band
7 psi loss through dryer
System Pressure at 106 psig
#1 and #2 Fully Loaded
#4 Trims
#3 in Standby
Wed 28
Thu 29
Fri 30
Sat 01
Sun 02
Mon 03
Tue 04
Wed 05
Thu 06



Interval data (8 seconds) for System (Not Assigned) and Periods (Not Assigned)
3/22/2023 7:51:56 AM to 3/23/2023 4:44:42 AM
Pressure Profile 30 minute time stamp
psig
1st Filter (psig)
2nd Filter (psig)
PFC Outlet (psig)
10-01 Winder (psig)
10-02 Winder (psig)
Silentex (psig)
Batch Reciever (psig)
Batch PFC Outlet (psig)
Comp 2 Wet Tank (psig)
#2 Compressor Wet Tank Pressure at 101 psig
Downstream of Mist Eliminator at 99 psig
Wet Tank PT failed
Storage pressure in 30,000 gallon receiver
Pressure Flow Control Outlet
10-02 Winder
Silentex
10-01 Winder
possibly measured on regulated line


Interval data (5 seconds) for System (Not Assigned) and Periods (Not Assigned)
11/15/2023 3:13:12 PM to 12/1/2023 11:58:34 PM
North Side Pressure and Power Profile
psig
Amps
R1 Hi Mill Pressure (psig)
R1 Pac Pressure N1 (psig)
R18 Forge Pressure (psig)
North R1 Pac N1 (Amps)
South R1 Pac N2 (Amps)
R1 Hi Mill N3 (Amps)
R18 Forge (Amps)
90
80
70
60
50
400
300
200
100
0
Nov 16
Nov 17
Nov 18
Nov 19
Nov 20
Nov 21
Nov 22
Nov 23
Nov 24
Nov 25
Nov 26
Nov 27
Nov 28
Nov 29
Nov 30
Dec 01


Screw Machine # 26
1 Second Sample Rate
PSIG
118
116
114
112
110
108
106
104
102
100
98
96
94
92
90
88
86
11/18/2020 10:35:54 AM
11/18/2020 10:35:59 AM
11/18/2020 10:36:04 AM
11/18/2020 10:36:09 AM
11/18/2020 10:36:14 AM
11/18/2020 10:36:19 AM
11/18/2020 10:36:24 AM
11/18/2020 10:36:29 AM
11/18/2020 10:36:34 AM
11/18/2020 10:36:39 AM
11/18/2020 10:36:44 AM
11/18/2020 10:36:49 AM
11/18/2020 10:36:54 AM
11/18/2020 10:36:59 AM
11/18/2020 10:37:04 AM
11/18/2020 10:37:09 AM
11/18/2020 10:37:14 AM
11/18/2020 10:37:19 AM
11/18/2020 10:37:24 AM
11/18/2020 10:37:29 AM
11/18/2020 10:37:34 AM
11/18/2020 10:37:39 AM
11/18/2020 10:37:44 AM
11/18/2020 10:37:49 AM
11/18/2020 10:37:54 AM
11/18/2020 10:37:59 AM
11/18/2020 10:38:04 AM
11/18/2020 10:38:09 AM
11/18/2020 10:38:12 AM
Date Time, GMT-08:00



Interval data (4 seconds) for System (Not Assigned) and Periods (Not Assigned)
1/27/2021 11:15:31 AM to 1/27/2021 12:09:35 PM
Pressure Test Car Affect on Plant Pressure
1 minute time stamp
Bld 1 System Pressure (psig)
Bld 2 Discharge Pressure (psig)
Bld 3 West Side Pressure (psig)
Bld 1 Discharge Pressure (psig)
Bld 1 East Side Pressure (psig)
Bld 1 Comp 1 kW (kW)
Bld 1 Sullair 900 (kW)
Bld 2 Comp 3 kW (kW)
Bld 2 Comp 4 kW (kW)
psig
kW
Bld 1 Comp #1 only comes up to 75% output
Bld 2 Comp #3 only comes up to 75% output
Bld 1 Comp #1 only comes up to 75% output
Bld 1 rental 900 stays fully loaded
Bld 2 Comp #4 stays off

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

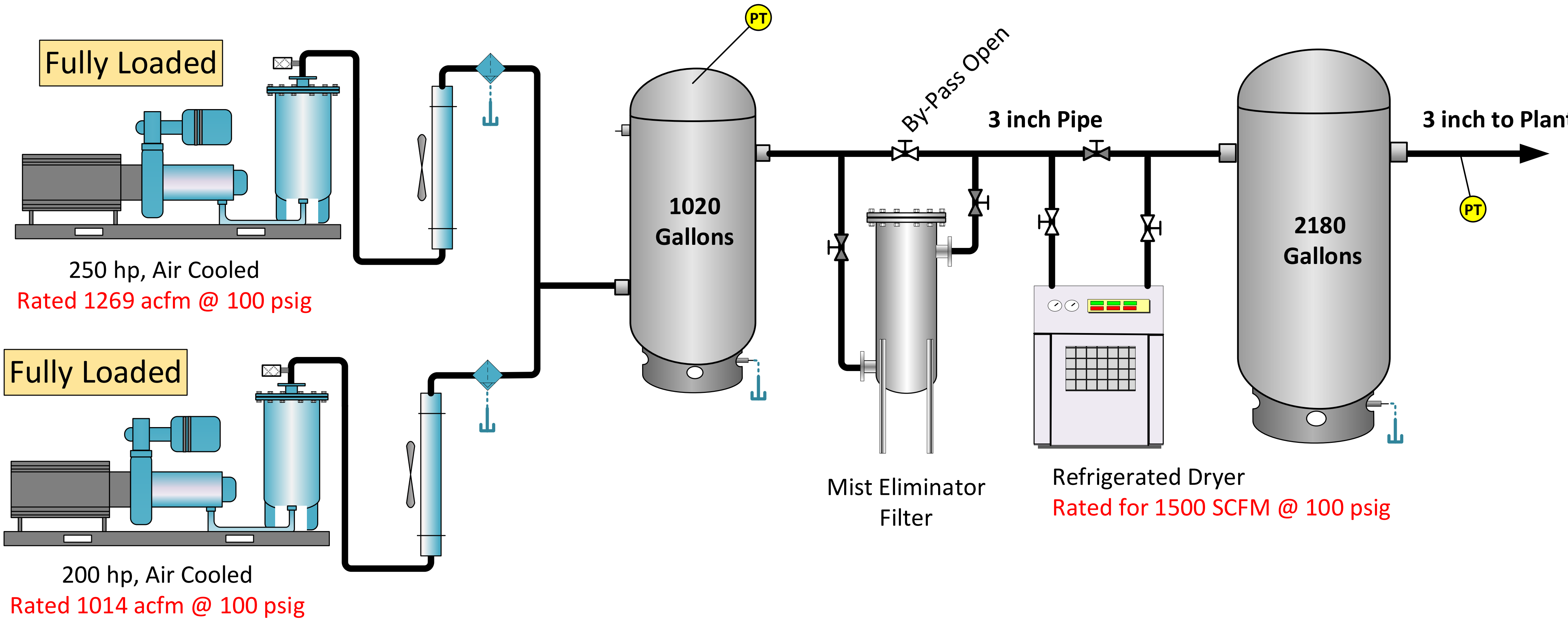
Using LogTool - Quick Review

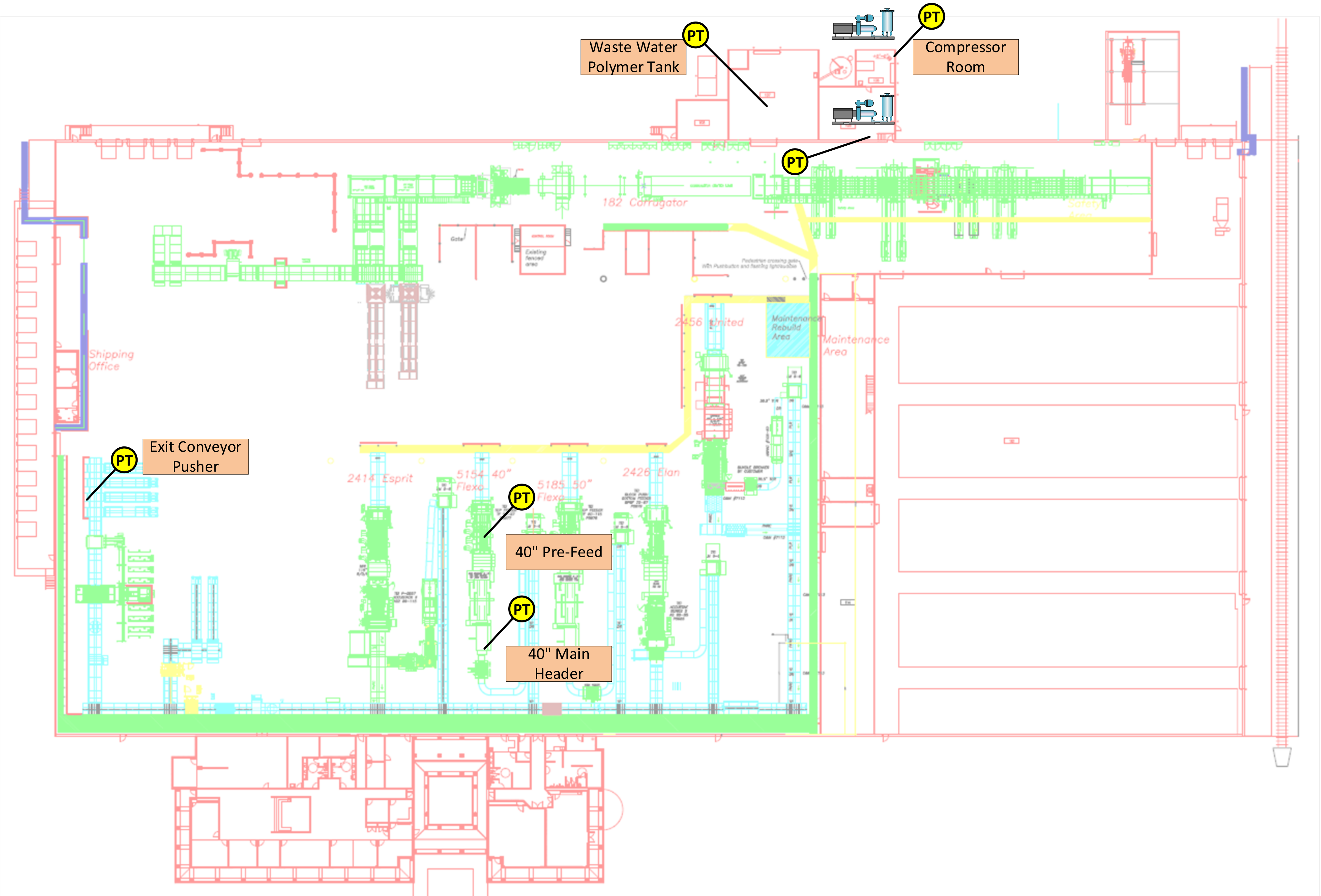
U.S. DEPARTMENT OF ENERGY

LogTool is Designed To:

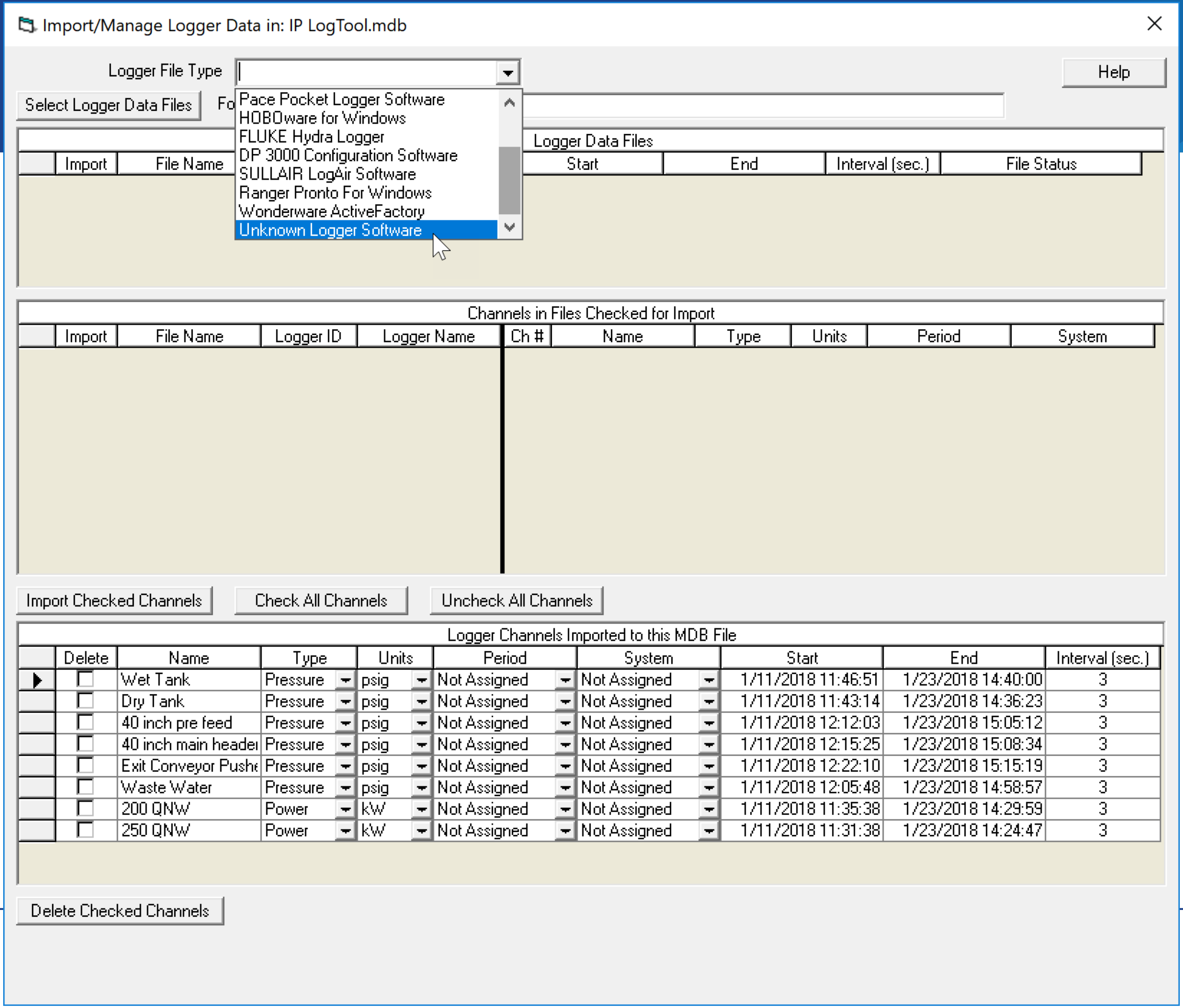
- Import data which is exported from different types of data loggers.
- Select logger data channels and modify their properties.
  - e.g., name, type, units, etc.
- View data values for one or more logger channels.
- Display trend plots on one or two Y axis.
- Display scatter plots.
- Display daytype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

Box Plant Example:

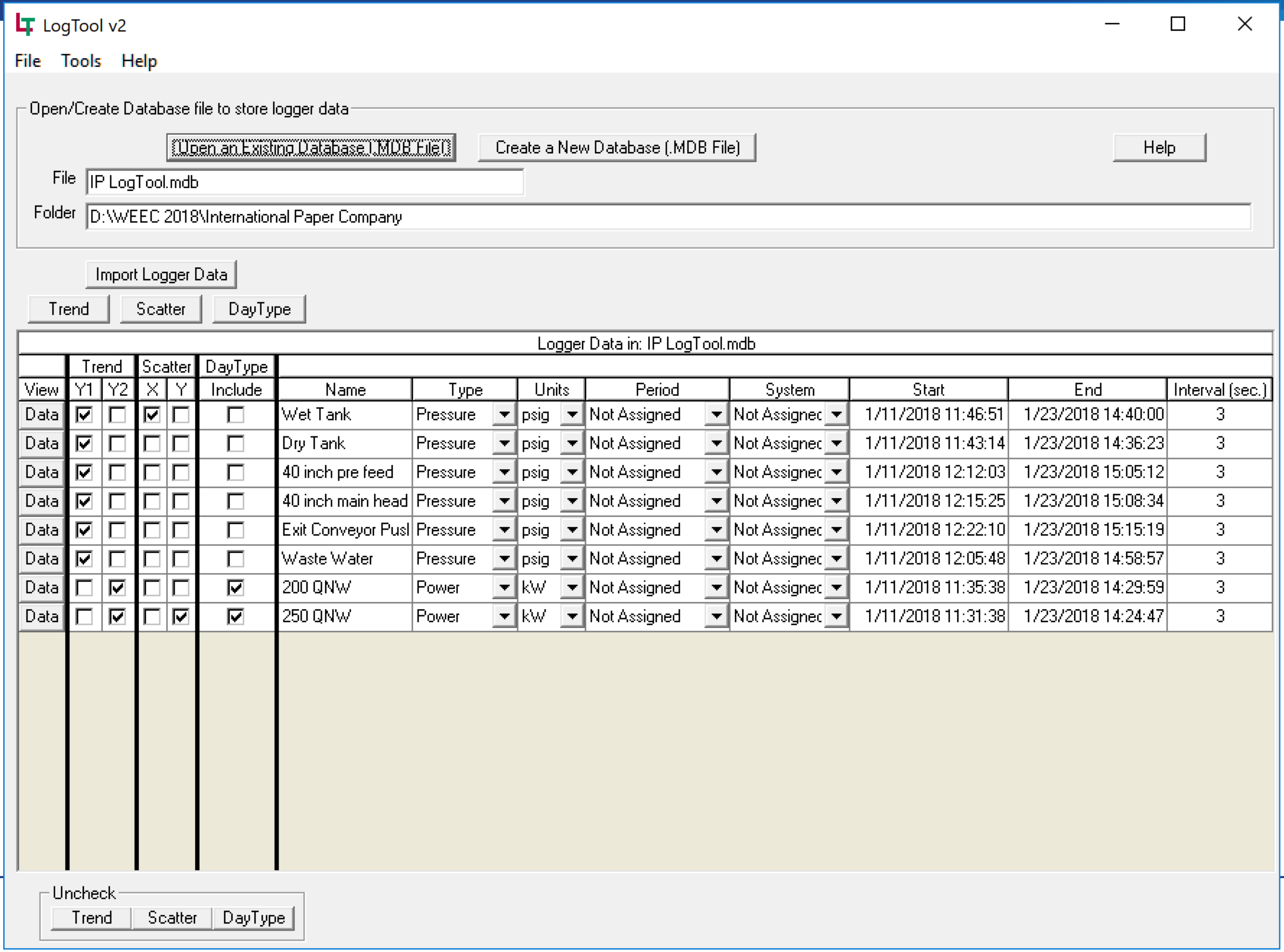




Waste Water Polymer Tank
PT
Compressor Room
PT
PT
182 Corrugator
Shipping Office
2456 United
Maintenance Rebuild Area
Maintenance Area
Exit Conveyor Pusher
PT
2414 Esprit
5154 40" Flexo
5185 50" Flexo
2426 Elan
PT
40" Pre-Feed
PT
40" Main Header


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 Push 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

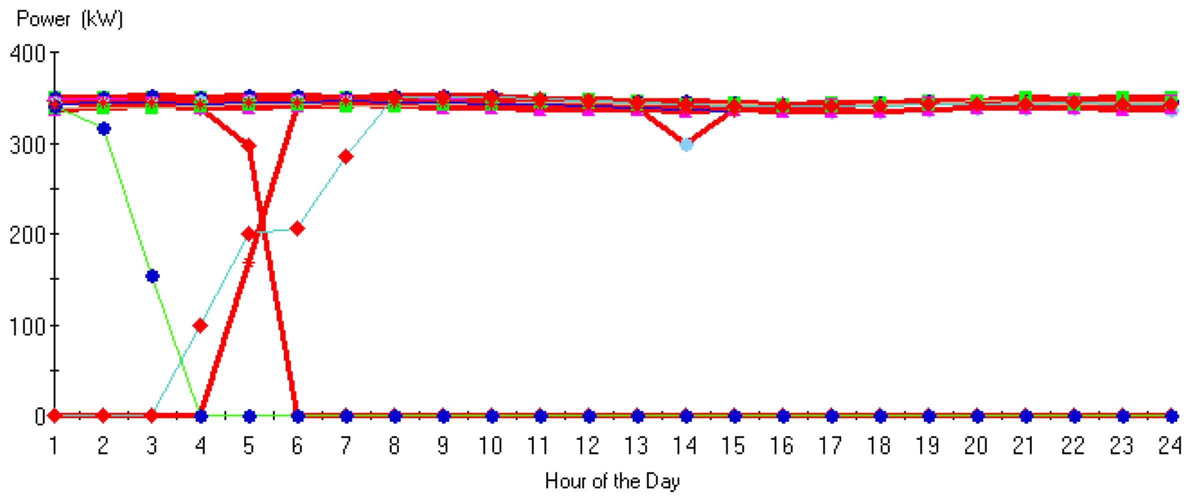
LogTool Main Menu



Enter LogTool Data Into AIRMaster

DayType Analysis

System: Not Assigned, Period: Not Assigned



Right click on data points to select day type. Left click to highlight the trace.

Click a date to highlight profile in graph.

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

Plot Day Type ...

All Days

Remove Day Type...

Caution: Day profiles can be similar even though different equipment, e.g., compressors, is operating. Use Trend Plots to examine the details of equipment operation before determining whether days should be assigned to the same daytype.

Create System DayType Profiles | Copy Plot to ClipBoard | Copy Profiles to ClipBoard | Help

System DayType Profiles

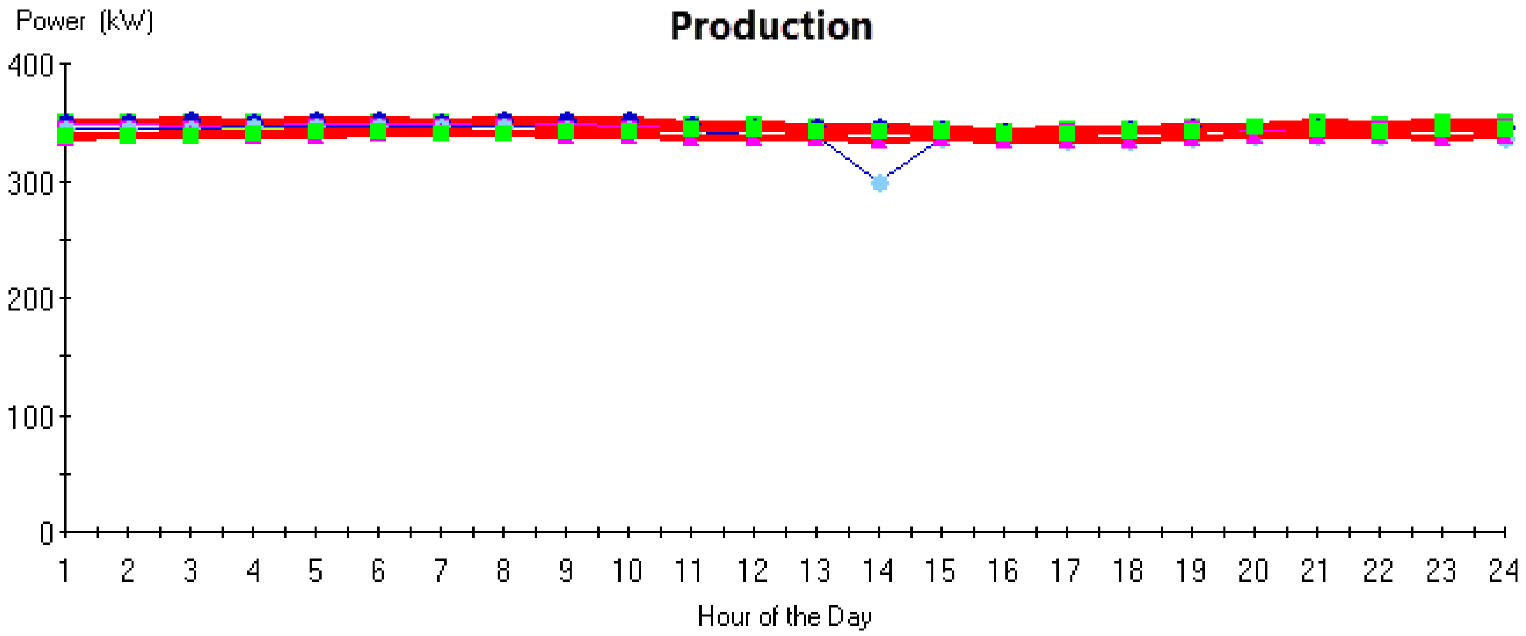
DayTypeName	ChannelName	Hr_01	Hr_02	Hr_03	Hr_04	Hr_05	Hr_06	Hr_07
Monday	200 QNW	0.00	0.00	0.00	0.00	84.55	175.88	177.13
Monday	250 QNW	0.00	0.00	0.00	0.00	83.80	164.18	163.56
Production	200 QNW	178.12	178.25	177.86	177.11	177.67	178.09	177.97
Production	250 QNW	166.54	166.81	167.49	168.31	168.50	168.50	168.40
Sunday	200 QNW	181.76	180.51	179.20	176.98	154.17	0.00	0.00
Sunday	250 QNW	165.56	163.78	162.43	161.83	143.08	0.00	0.00

Copy Profiles to a Spreadsheet

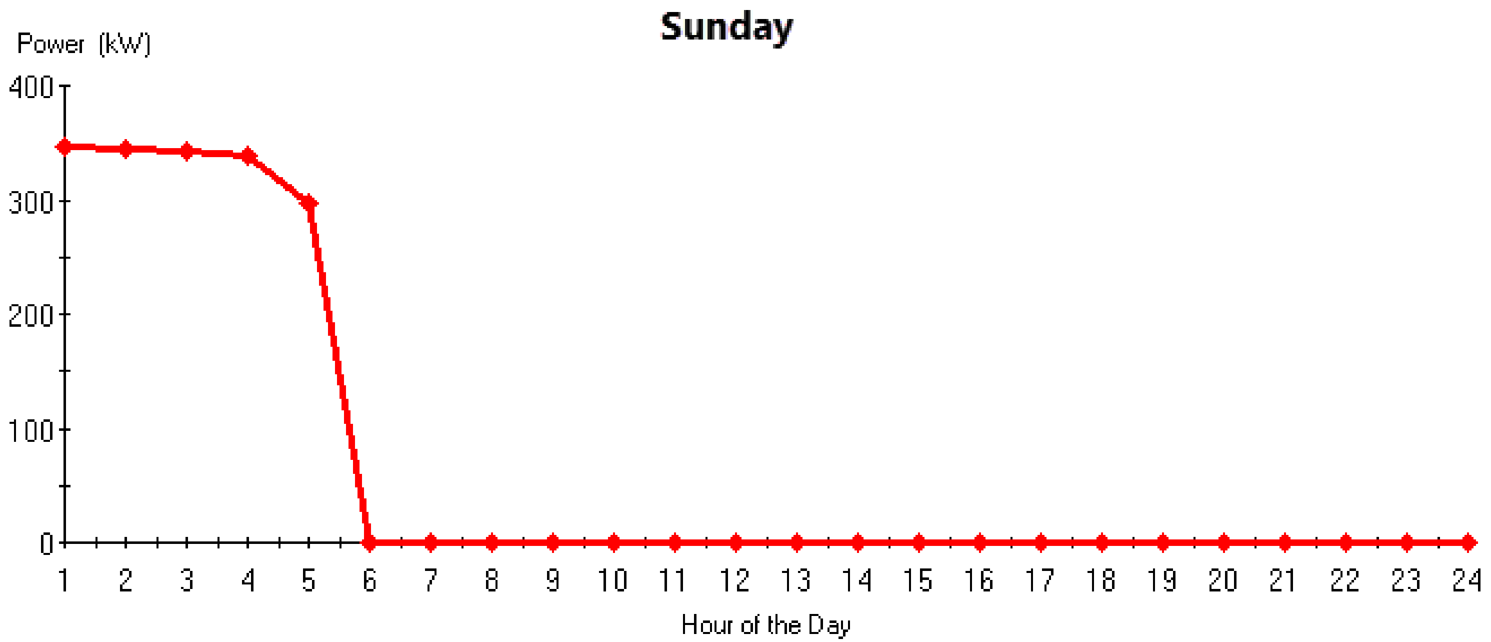
DayTypeName	ChannelName	Hr_01	Hr_02	Hr_03	Hr_04	Hr_05	Hr_06	Hr_07	Hr_08	Hr_09	Hr_10	Hr_11	Hr_12	Hr_13	Hr_14	Hr_15	Hr_16	Hr_17	Hr_18	Hr_19	Hr_20	Hr_21	Hr_22	Hr_23	Hr_24
Monday	200 QNW	0.0	0.0	0.0	0.0	84.6	175.9	177.1	181.6	182.2	180.8	177.2	177.7	177.0	178.6	178.7	178.7	176.9	177.0	178.2	177.2	178.7	179.6	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

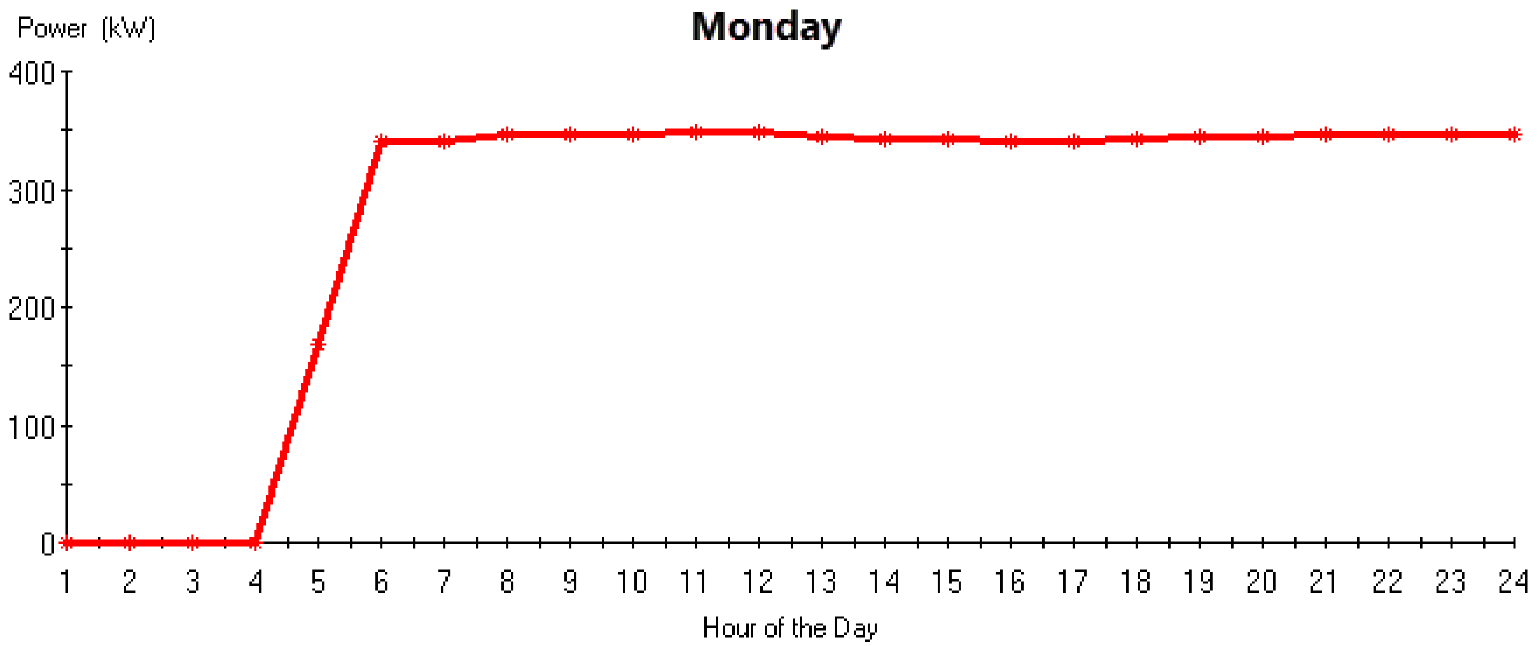
DayType Profiles



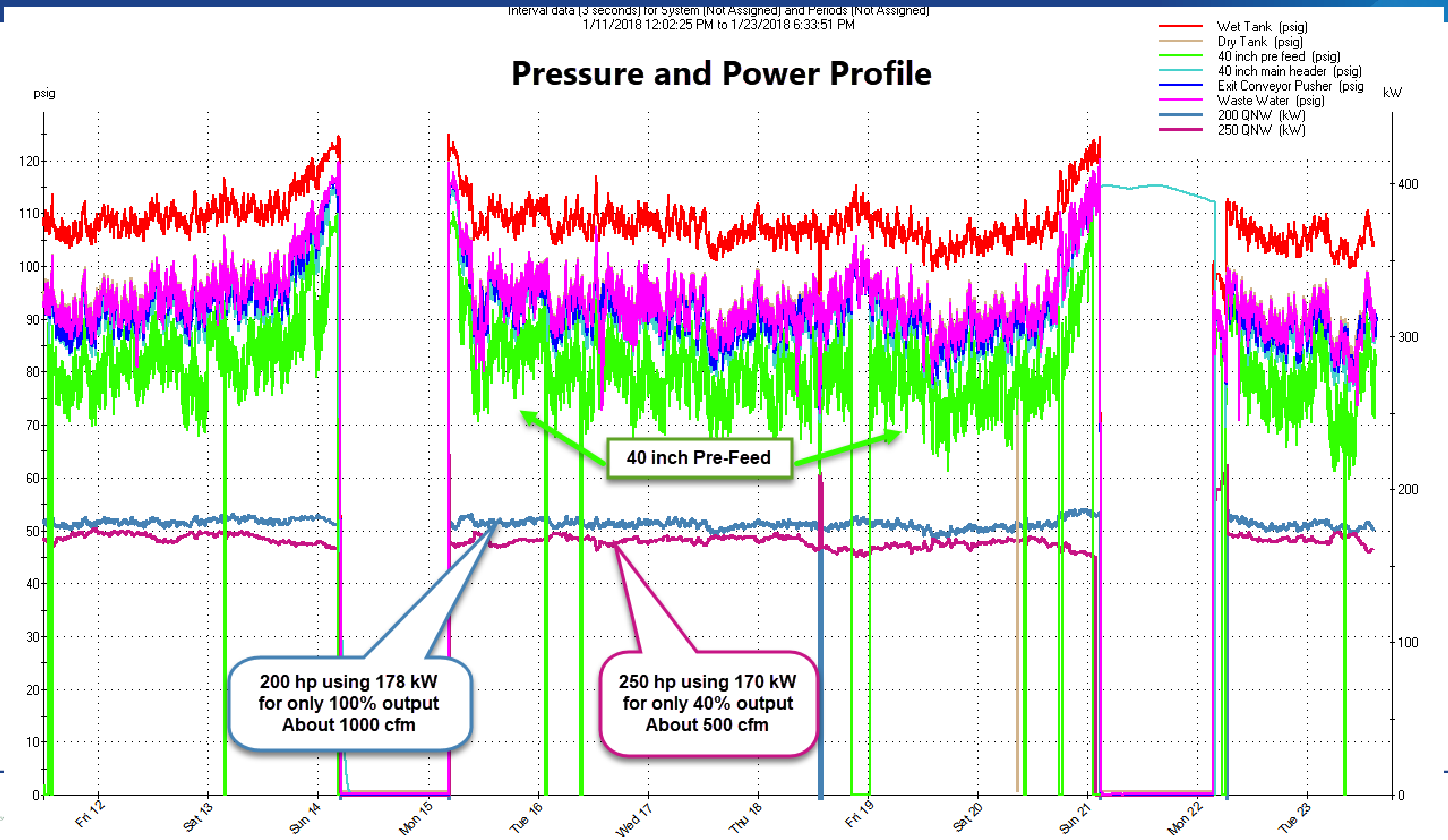
DayType Profiles



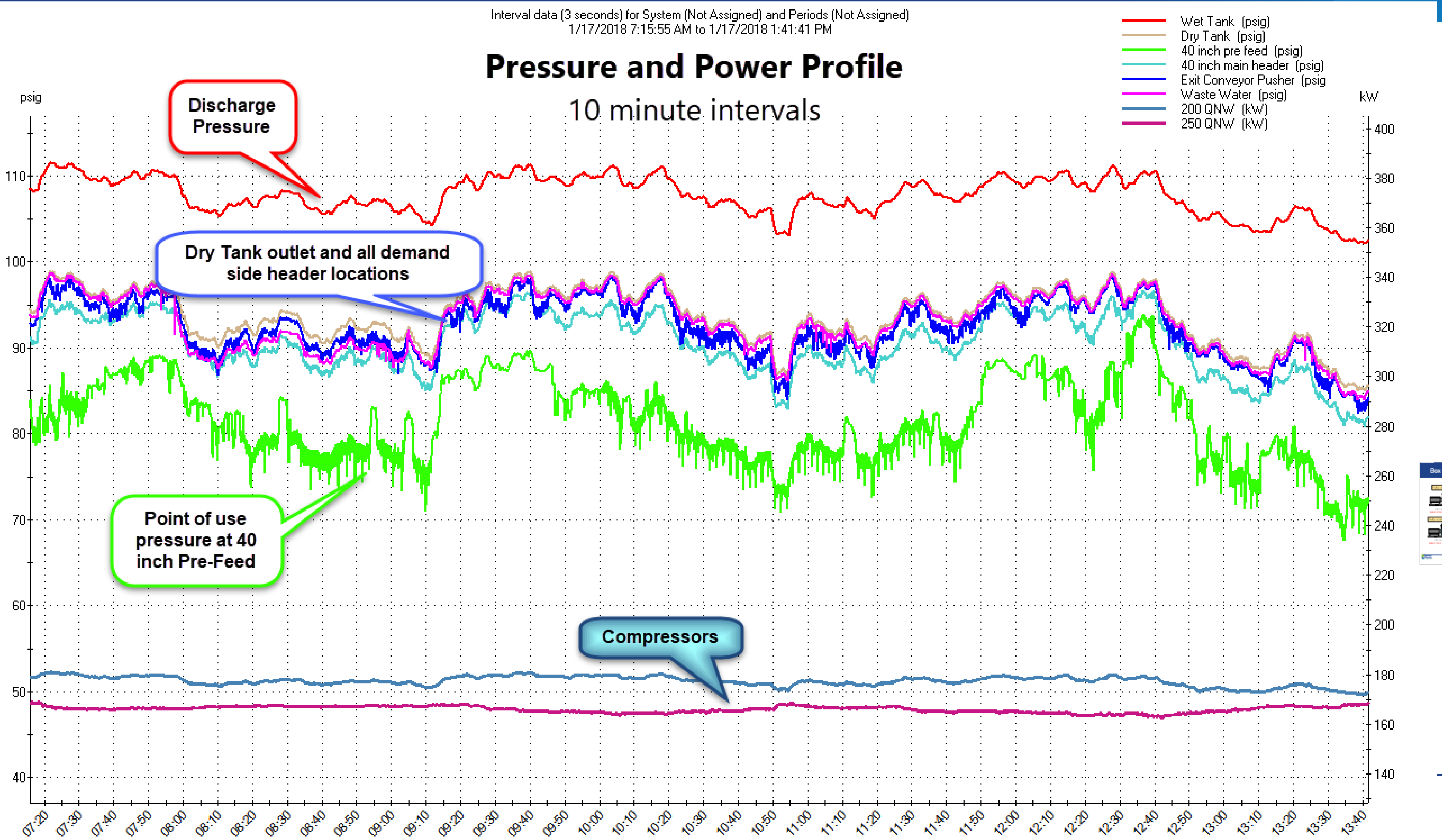
DayType Profiles

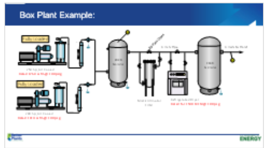


LogTool Trend Plot



LogTool Trend Plot



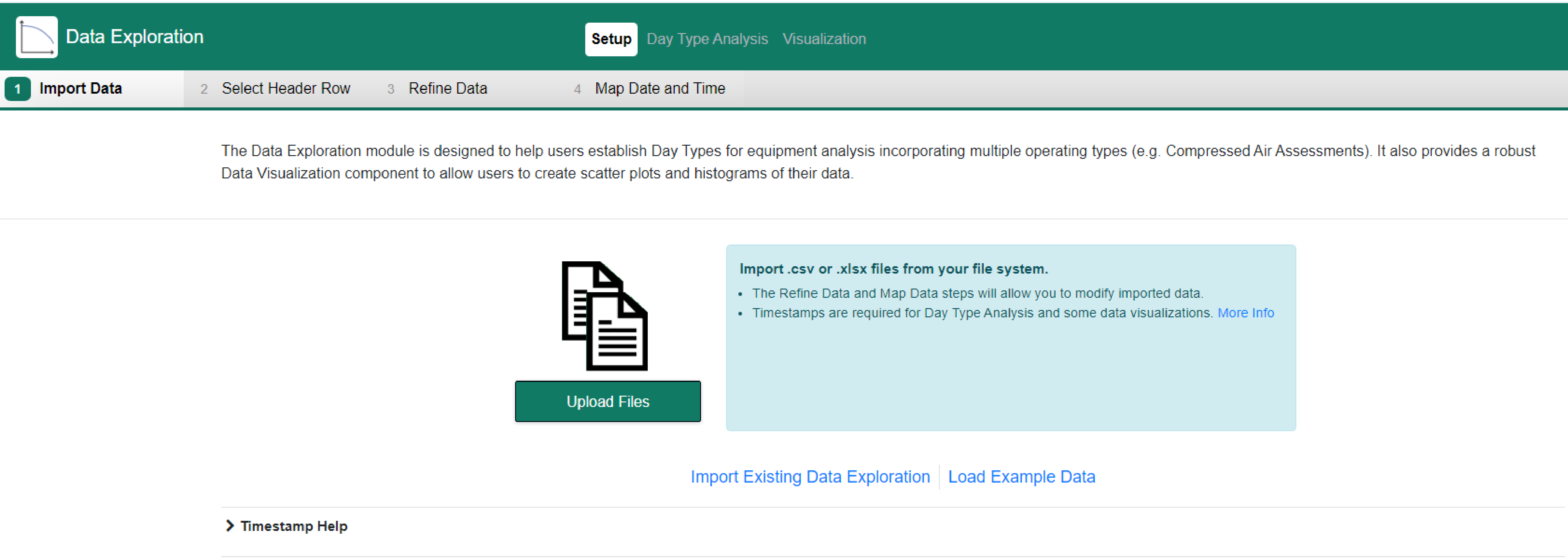


Using MEASUR - Quick Review

U.S. DEPARTMENT OF
ENERGY


Fuji New
International Paper
Hon
Fujifilm
Fuji
Corning Inc
Corning Inc
SRP
Examples
Compressed Air Example
Waste Water Example
Treasure Hunt Example
Steam Example
Fan Example
Pump Example
Process Heating - Fuel E…
Toy Factory
Data Exploration
All Calculators
General
Compressed Air
Fans
Lighting
Motors
Process Cooling
Process Heating
Pumps
Steam
Wastewater
Settings
Custom Materials
User Manuals
About
Feedback
Privacy Notice
Acknowledgments
v1.4.0
MEASUR
Welcome to the most efficient way to manage and optimize your facilities' systems and equipment.
Create an assessment to model your system and find opportunities for efficiency or run calculations from one of our many property and equipment calculators.
Get started with one of the following options.
If you need help at any point along the way, click on a User Manual icon.
View Assessments
Equipment Calculators
Pump Assessment
Compressed Air Assessment
Process Heating Assessment
Fan Assessment
Steam Assessment
Treasure Hunt
Wastewater Assessment
Motor Inventory
Pump Inventory
Data Exploration
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

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.
Upload Files
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
Import Existing Data Exploration
Load Example Data
Timestamp Help

MEASUR Tool

Upload Files

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

Import Existing Data Exploration | Load Example Data

> Timestamp Help

File Upload Preview

International_Paper_Co_inside_200hp_QSI1.csv

International_Paper_Co_outside_QSI_n250h.csv

MEASUR Tool

Data Exploration

Setup Day Type Analysis Visualization

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

Select a header row and advance to the next file

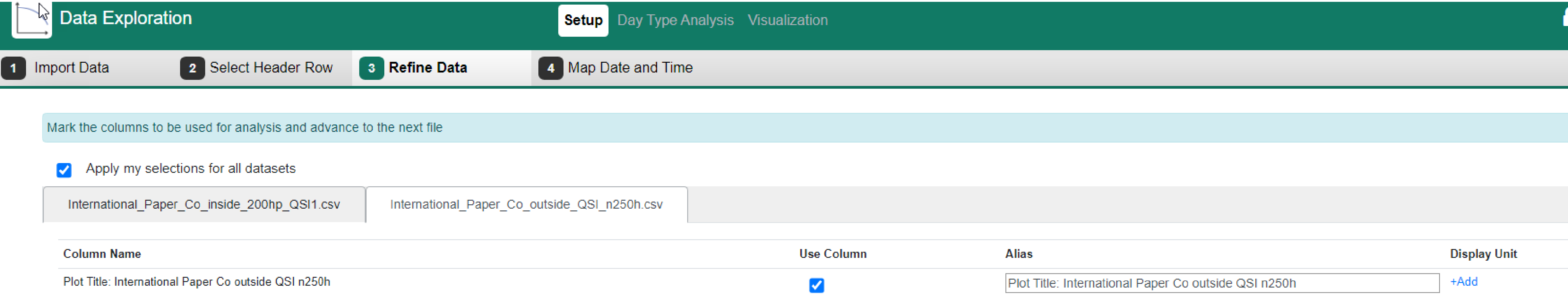
☑ Apply my selections for all datasets

International_Paper_Co_inside_200hp_QSI1.csv | International_Paper_Co_outside_QSI_n250h.csv

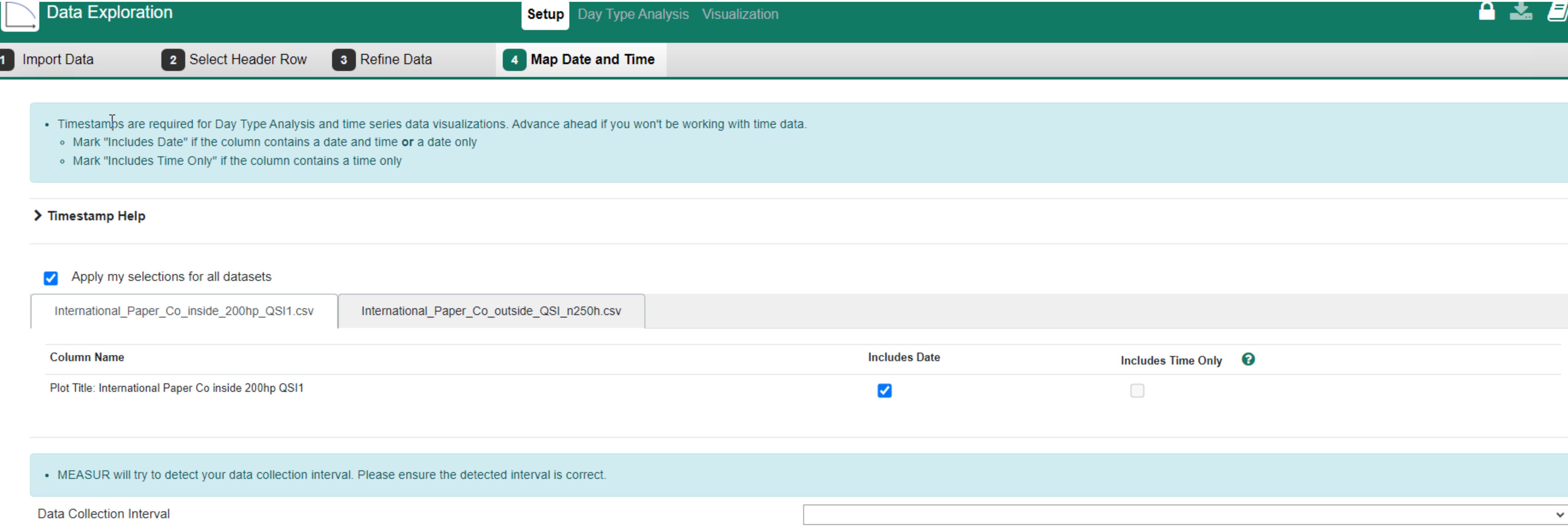
Select Header Row

◉	Plot Title: International Paper Co inside 200hp QSI1		
○	#	Date Time, GMT-07:00	200hp QSI1000, kW
○	1	01/11/18 11:35:38 AM	179.256
○	2	01/11/18 11:35:41 AM	179.159
○	3	01/11/18 11:35:44 AM	179.061
○	4	01/11/18 11:35:47 AM	178.964
○	5	01/11/18 11:35:50 AM	179.159
○	6	01/11/18 11:35:53 AM	179.256
○	7	01/11/18 11:35:56 AM	179.451
○	8	01/11/18 11:35:59 AM	179.354
○	9	01/11/18 11:36:02 AM	179.451

MEASUR Tool

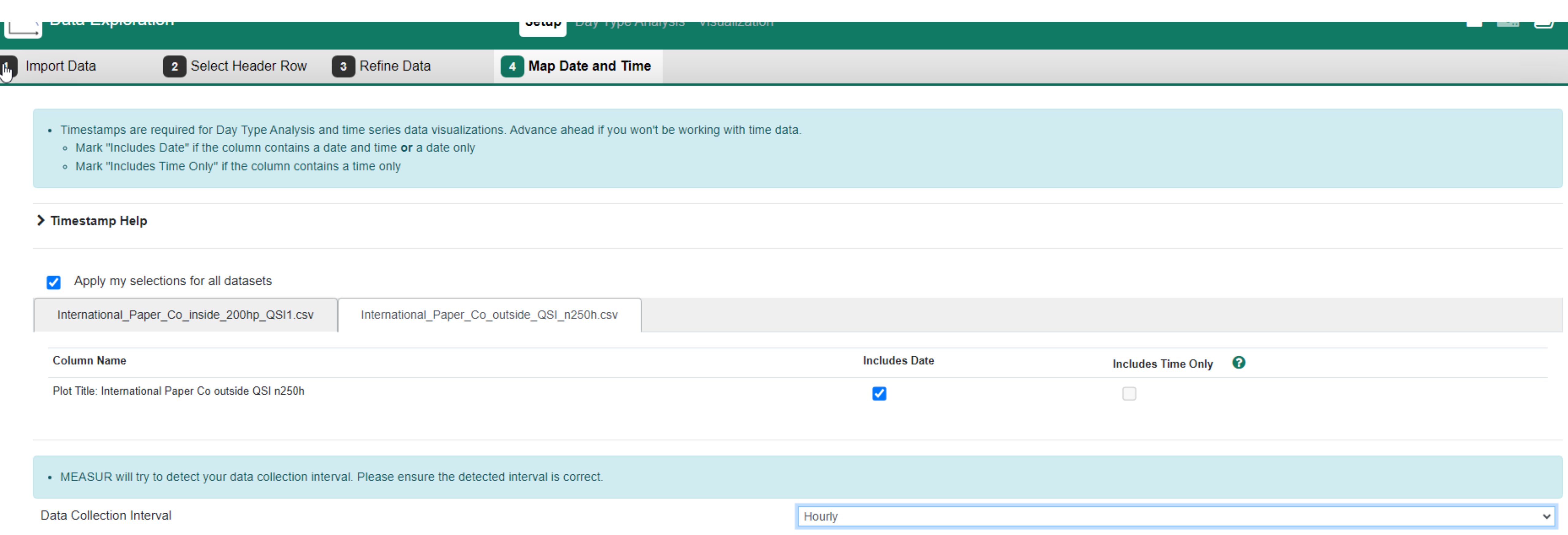

Data Exploration
Setup
Day Type Analysis
Visualization
1 Import Data
2 Select Header Row
3 Refine Data
4 Map Date and Time
Mark the columns to be used for analysis and advance to the next file
Apply my selections for all datasets
International_Paper_Co_inside_200hp_QSI1.csv
International_Paper_Co_outside_QSI_n250h.csv
Column Name
Use Column
Alias
Display Unit
Plot Title: International Paper Co outside QSI n250h
Plot Title: International Paper Co outside QSI n250h
+Add

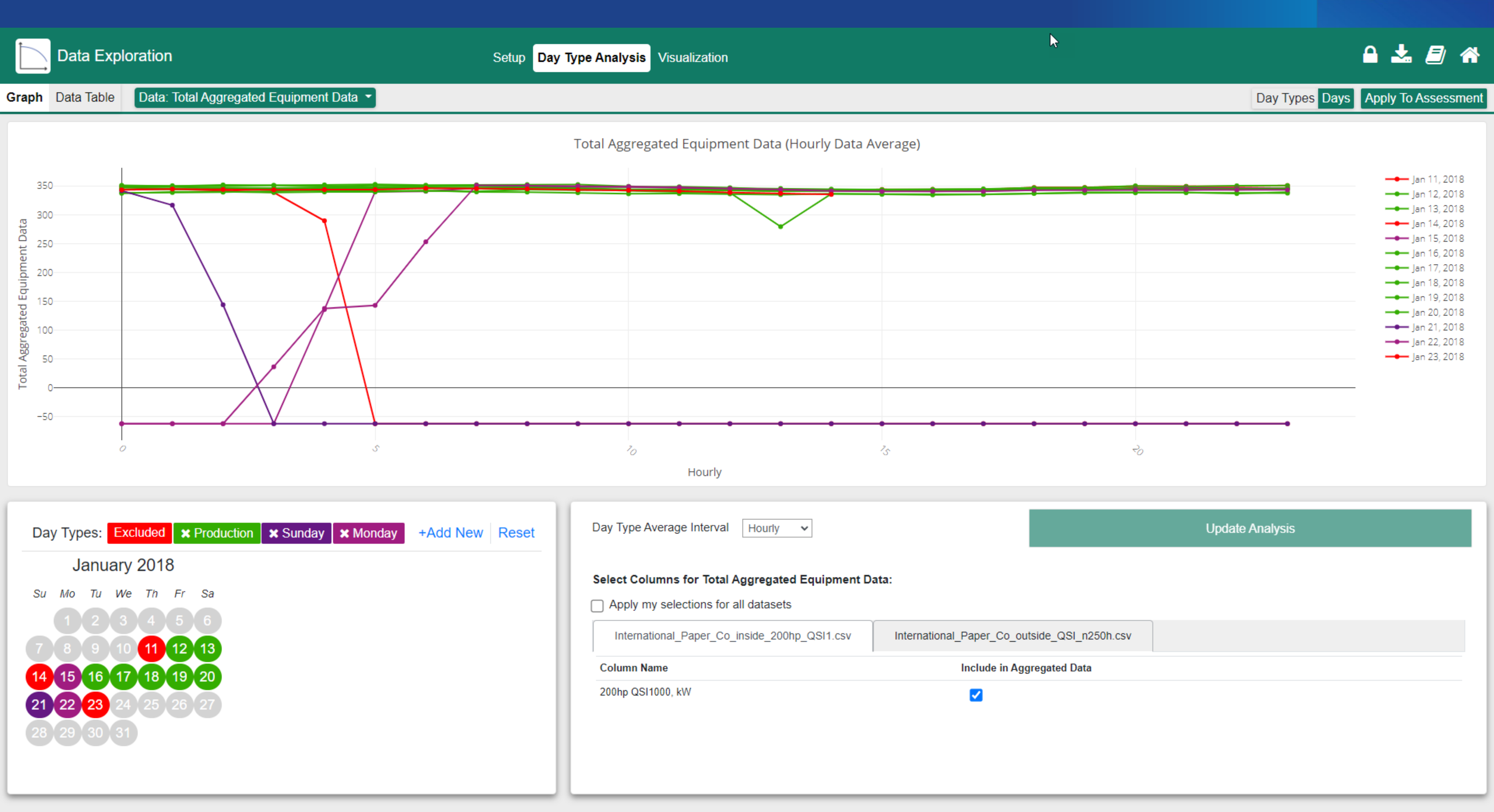
MEASUR Tool



Data Exploration
Setup
Day Type Analysis
Visualization
1 Import Data
2 Select Header Row
3 Refine Data
4 Map Date and Time
Timestamps are required for Day Type Analysis and time series data visualizations. Advance ahead if you won't be working with time data.
Mark "Includes Date" if the column contains a date and time or a date only
Mark "Includes Time Only" if the column contains a time only
Timestamp Help
Apply my selections for all datasets
International_Paper_Co_inside_200hp_QSI1.csv
International_Paper_Co_outside_QSI_n250h.csv
Column Name
Includes Date
Includes Time Only
Plot Title: International Paper Co inside 200hp QSI1
MEASUR will try to detect your data collection interval. Please ensure the detected interval is correct.
Data Collection Interval

MEASUR Tool


Import Data
2 Select Header Row
3 Refine Data
4 Map Date and Time
Timestamps are required for Day Type Analysis and time series data visualizations. Advance ahead if you won't be working with time data.
Mark "Includes Date" if the column contains a date and time or a date only
Mark "Includes Time Only" if the column contains a time only
Timestamp Help
Apply my selections for all datasets
International_Paper_Co_inside_200hp_QSI1.csv
International_Paper_Co_outside_QSI_n250h.csv
Column Name
Includes Date
Includes Time Only
Plot Title: International Paper Co outside QSI n250h
MEASUR will try to detect your data collection interval. Please ensure the detected interval is correct.
Data Collection Interval
Hourly


Data Exploration
Setup
Day Type Analysis
Visualization
Graph
Data Table
Data: Total Aggregated Equipment Data
Day Types
Days
Apply To Assessment
Total Aggregated Equipment Data (Hourly Data Average)
Total Aggregated Equipment Data
Hourly
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
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

Data Exploration

Setup | **Day Type Analysis** | Visualization

Graph | **Data Table** | Data: Total Aggregated Equipment Data

Display Selected | Display All | Day Types | Days | Apply To Assessment

Day Type Summaries (Total Aggregated Equipment Data)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Excluded	345.233	344.441	342.737	341.011	316.626	140.599	141.751	141.474	141.22	140.354	140.009	208.291	207.075	206.017	205.018	140.7	140.813	140.648	142.405	142.431	143.513	143.433	143.463	144.12
Production	344.656	345.067	345.346	345.418	346.18	346.584	346.363	345.848	345.827	345.186	343.719	343.299	342.132	332.419	340.844	340.385	340.169	340.974	342.559	343.259	343.725	343.441	343.333	344.144
Sunday	341.5	316.585	143.837	-62.476	-62.479	-62.478	-62.478	-62.48	-62.48	-62.478	-62.48	-62.48	-62.477	-62.479	-62.481	-62.48	-62.481	-62.478	-62.479	-62.48	-62.476	-62.48	-62.479	-62.48
Monday	-62.479	-62.48	-62.48	-13.16	136.523	241.439	296.894	348.648	349.049	348.693	348.558	347.426	345.133	343.489	341.657	340.832	340.753	341.281	343.225	343.56	344.614	345.199	344.928	344.662

Copy Table

Day Summaries (Total Aggregated Equipment Data)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Excluded																								
Jan 11, 2018												346.218	345.07	343.465	342.276	343.887	344.11	343.776	347.291	347.341	349.506	349.346	349.406	350.719
Jan 23, 2018	343.151	344.6	343.84	343.205	343.652	343.678	345.983	345.427	344.92	343.188	342.499	341.135	338.636	337.064	335.257									
Jan 14, 2018	347.315	344.282	341.634	338.817	289.6	-62.48	-62.481	-62.479	-62.48	-62.48	-62.482	-62.481	-62.48	-62.48	-62.48	-62.488	-62.483	-62.48	-62.48	-62.479	-62.479	-62.48	-62.48	-62.48
Production																								
Jan 12, 2018	350.503	350.457	349.767	350.922	349.444	350.735	350.126	349.697	348.726	347.911	348.143	348.613	346.908	343.422	343.798	343.359	343.994	344.688	346.835	347.03	350.133	349.088	350.24	350.696
Jan 13, 2018	351.026	349.585	351.782	351.001	351.894	352.74	351.297	351.961	352.383	352.372	349.311	346.937	345.905	345.548	344.381	343.145	343.407	344.375	346.107	344.937	346.216	345.54	345.22	346.343
Jan 16, 2018	347.61	347.97	347.122	346.248	347.541	347.869	347.655	346.948	347.811	345.907	343.795	343.826	342.966	340.637	341.396	342.32	341.424	341.937	343.92	343.374	343.997	345.062	343.421	344.827
Jan 17, 2018	344.128	344.633	344.586	344.258	346.296	347.187	345.95	346.432	344.017	345.032	342.959	343.33	341.718	340.763	341.098	341.488	341.749	342.284	344.047	344.131	344.641	344.578	344.717	345.682
Jan 18, 2018	344.129	344.662	345.205	345.692	346.339	346.123	346.506	345.632	345.089	344.363	341.707	339.446	338.237	279.357	336.221	335.939	335.253	335.215	337.038	338.875	338.816	338.304	338.122	337.499
Jan 19, 2018	337.229	339.573	339.789	338.727	339.595	339.627	341.793	339.637	339.3	338.219	336.391	336.754	336.199	334.947	336.405	335.468	334.589	335.592	337.082	337.984	338.112	338.727	336.751	339.25
Jan 20, 2018	337.969	338.586	339.17	341.079	342.147	341.811	341.216	340.627	343.462	342.497	343.729	344.185	342.992	342.259	342.607	340.974	340.766	342.729	342.885	346.484	344.162	342.792	344.86	344.712
Sunday																								
Jan 21, 2018	341.5	316.585	143.837	-62.476	-62.479	-62.478	-62.478	-62.48	-62.48	-62.478	-62.48	-62.48	-62.477	-62.479	-62.481	-62.48	-62.481	-62.478	-62.479	-62.48	-62.476	-62.48	-62.479	-62.48
Monday																								
Jan 15, 2018	-62.48	-62.481	-62.479	-62.48	135.607	340.068	340.692	346.157	347.243	347.519	348.732	347.609	345.048	343.513	341.95	341.139	340.554	341.815	343.719	344.359	345.83	346.652	346.369	346.135
Jan 22, 2018	-62.479	-62.48	-62.48	36.16	137.439	142.81	253.096	351.139	350.856	349.867	348.384	347.243	345.219	343.466	341.363	340.524	340.952	340.747	342.73	342.761	343.397	343.746	343.488	343.188

Copy Table

Day Types: Excluded | ✖ Production | ✖ Sunday | ✖ Monday | +Add New | Reset

Day Type Average Interval: Hourly

Update Analysis

MEASUR Tool Energy Efficiency Measures

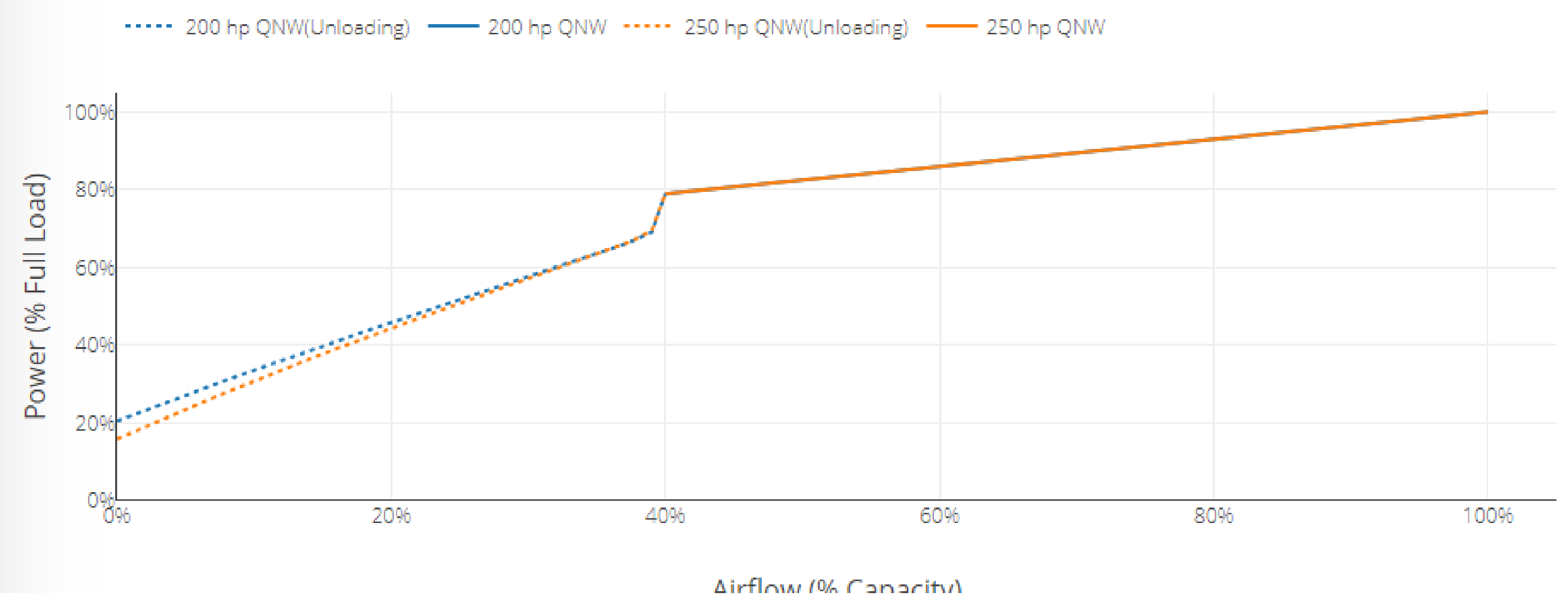
CURRENT INVENTORY | HELP

Name	Compressor Type	Control Type	Pressure Range
200 hp QNW	Single stage lubricant-injected rotary screw	Inlet modulation with unloading	110 - 120 psig
250 hp QNW	Single stage lubricant-injected rotary screw	Inlet modulation with unloading	105 - 115 psig

+Add New Compressor

Performance Profile

☑ Graph All Compressors ☐ Graph Average Operating Points



MEASUR Tool Energy Efficiency Measures

Fuji
Last modified: Aug 3, 2022

System Basics | **Assessment** | Diagram | Report | Sankey | Calculators

Setup Profile | Profile Summary Table | Profile Summary Graphs

Scenario 4
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: Scenario 4

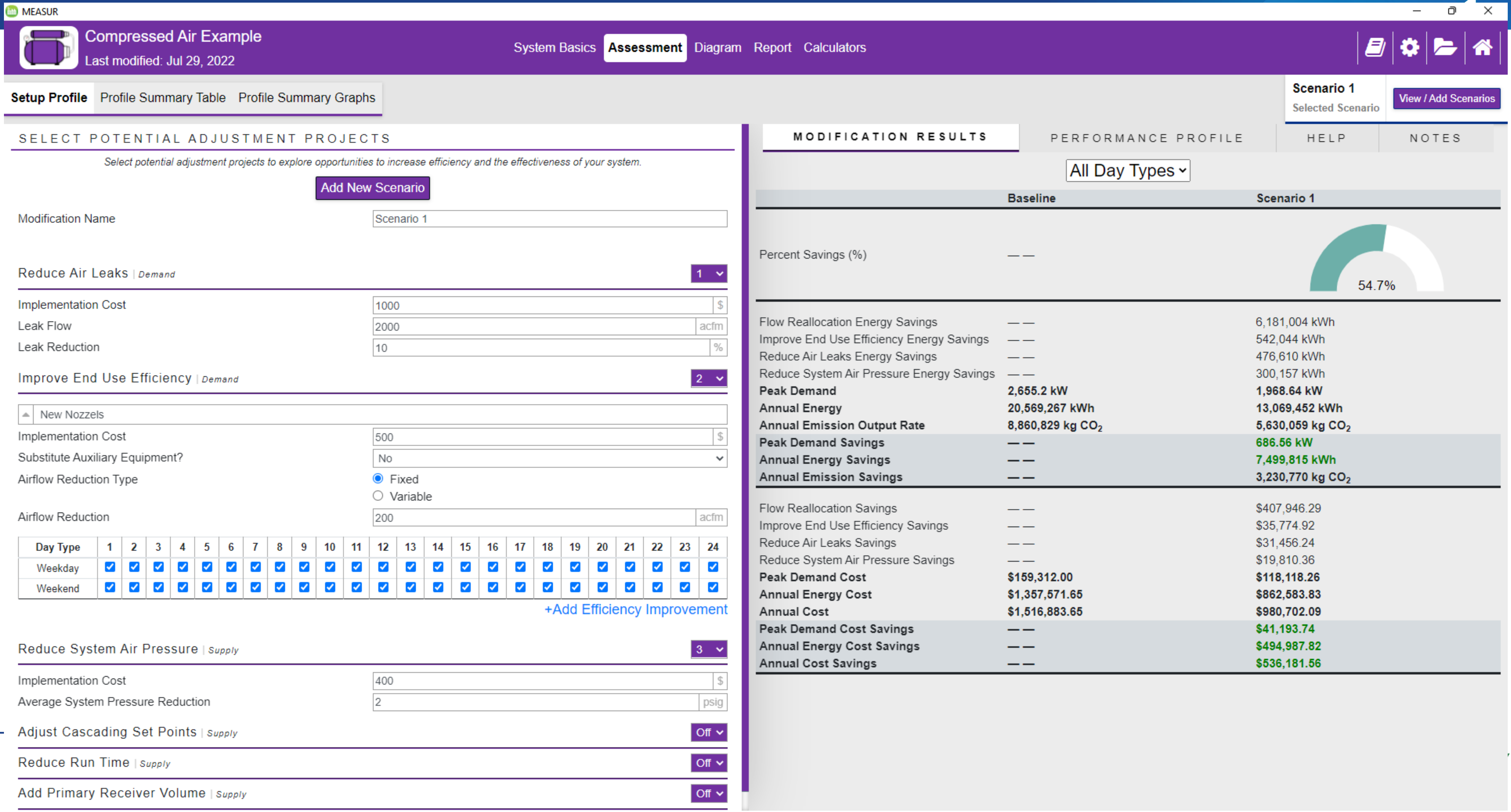
Project	Setting
Reduce Air Leaks *Demand*	Off
Improve End Use Efficiency *Demand*	Off
Reduce System Air Pressure *Supply*	Off
Adjust Cascading Set Points *Supply*	Off
Use Automatic Sequencer *Supply*	Off
Reduce Run Time *Supply*	Off

MODIFICATION RESULTS | PERFORMANCE PROFILE | HELP | NOTES

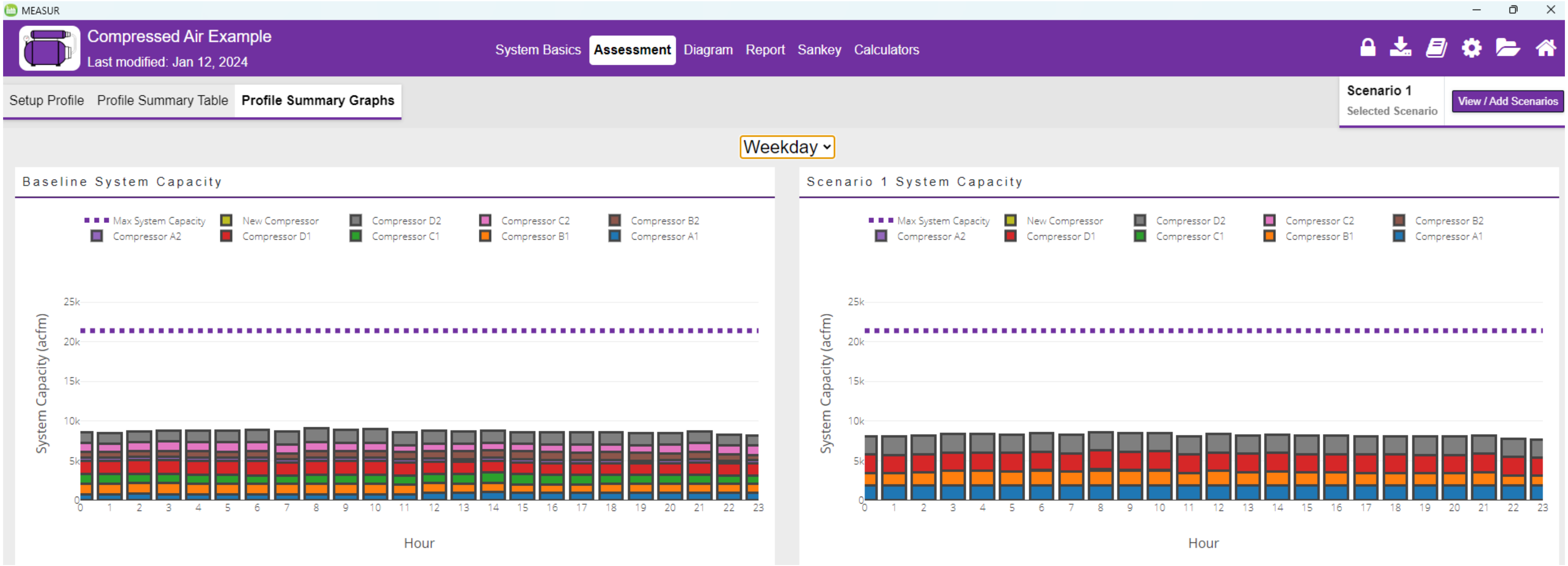
All Day Types

	Baseline	Scenario 4
Percent Savings (%)	— —	11.4%
Flow Reallocation Energy Savings	— —	148,744 kWh
Peak Demand	177.9 kW	161.05 kW
Annual Energy	1,432,803 kWh	1,284,059 kWh
Annual Emission Output Rate	kg CO_2	kg CO_2
Peak Demand Savings	— —	16.85 kW
Annual Energy Savings	— —	148,744 kWh
Annual Emission Savings	— —	kg CO_2
Flow Reallocation Savings	— —	$9,817.09
Peak Demand Cost	$34,156.80	$30,920.83
Annual Energy Cost	$136,689.40	$122,499.24
Annual Cost	$170,846.20	$153,420.06
Peak Demand Cost Savings	— —	$3,235.97
Annual Energy Cost Savings	— —	$14,190.16
Annual Cost Savings	— —	$17,426.14

MEASUR Tool


MEASUR
Compressed Air Example
Last modified: Jul 29, 2022
System Basics
Assessment
Diagram
Report
Calculators
Setup Profile
Profile Summary Table
Profile Summary Graphs
Scenario 1
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
Scenario 1
Reduce Air Leaks | Demand
1
Implementation Cost
1000 $
Leak Flow
2000 acfm
Leak Reduction
10 %
Improve End Use Efficiency | Demand
2
New Nozzels
Implementation Cost
500 $
Substitute Auxiliary Equipment?
No
Airflow Reduction Type
Fixed
Variable
Airflow Reduction
200 acfm
Day Type
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Weekday
Weekend
+Add Efficiency Improvement
Reduce System Air Pressure | Supply
3
Implementation Cost
400 $
Average System Pressure Reduction
2 psig
Adjust Cascading Set Points | Supply
Off
Reduce Run Time | Supply
Off
Add Primary Receiver Volume | Supply
Off
MODIFICATION RESULTS
PERFORMANCE PROFILE
HELP
NOTES
All Day Types
Baseline
Scenario 1
Percent Savings (%) — — 54.7%
Flow Reallocation Energy Savings — — 6,181,004 kWh
Improve End Use Efficiency Energy Savings — — 542,044 kWh
Reduce Air Leaks Energy Savings — — 476,610 kWh
Reduce System Air Pressure Energy Savings — — 300,157 kWh
Peak Demand 2,655.2 kW 1,968.64 kW
Annual Energy 20,569,267 kWh 13,069,452 kWh
Annual Emission Output Rate 8,860,829 kg CO2 5,630,059 kg CO2
Peak Demand Savings — — 686.56 kW
Annual Energy Savings — — 7,499,815 kWh
Annual Emission Savings — — 3,230,770 kg CO2
Flow Reallocation Savings — — $407,946.29
Improve End Use Efficiency Savings — — $35,774.92
Reduce Air Leaks Savings — — $31,456.24
Reduce System Air Pressure Savings — — $19,810.36
Peak Demand Cost $159,312.00 $118,118.26
Annual Energy Cost $1,357,571.65 $862,583.83
Annual Cost $1,516,883.65 $980,702.09
Peak Demand Cost Savings — — $41,193.74
Annual Energy Cost Savings — — $494,987.82
Annual Cost Savings — — $536,181.56

MEASUR Tool


MEASUR
Compressed Air Example
Last modified: Jan 12, 2024
System Basics
Assessment
Diagram
Report
Sankey
Calculators
Setup Profile
Profile Summary Table
Profile Summary Graphs
Scenario 1
Selected Scenario
View / Add Scenarios
Weekday
Baseline System Capacity
Max System Capacity
New Compressor
Compressor D2
Compressor C2
Compressor B2
Compressor A2
Compressor D1
Compressor C1
Compressor B1
Compressor A1
System Capacity (acfm)
Hour
Scenario 1 System Capacity
System Capacity (acfm)
Hour

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?

Homework for Week 5 – Distribution

- In many cases, misapplication of compressed air at the end-use causes systems to perform poorly.
- Please fill out the information below

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?