Better Plants
U.S. DEPARTMENT OF ENERGY

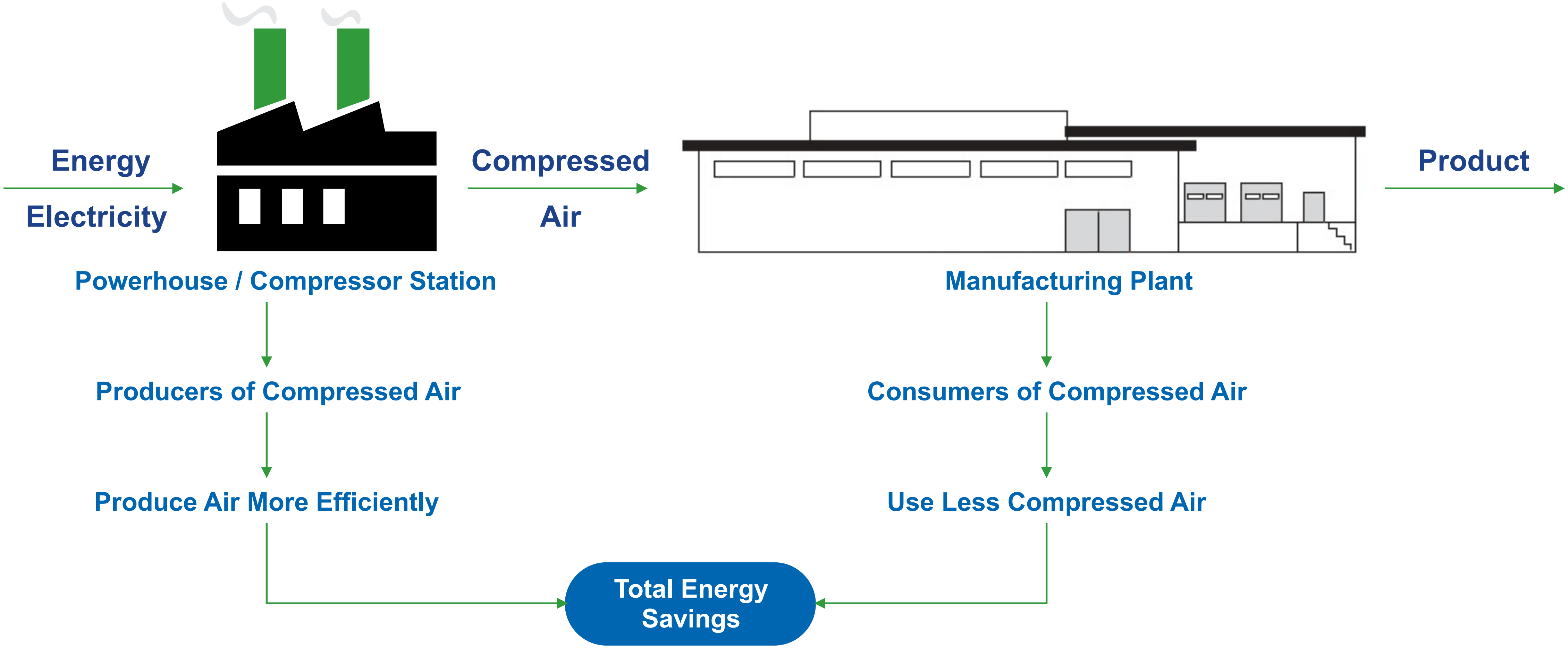
In-Plant Trainings

8 – Session Virtual Platform
Session 5 Distribution

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.



Session 2 we reviewed:

Compressor Types
Maintenance
Compressor Room Best Practices and Ventilation

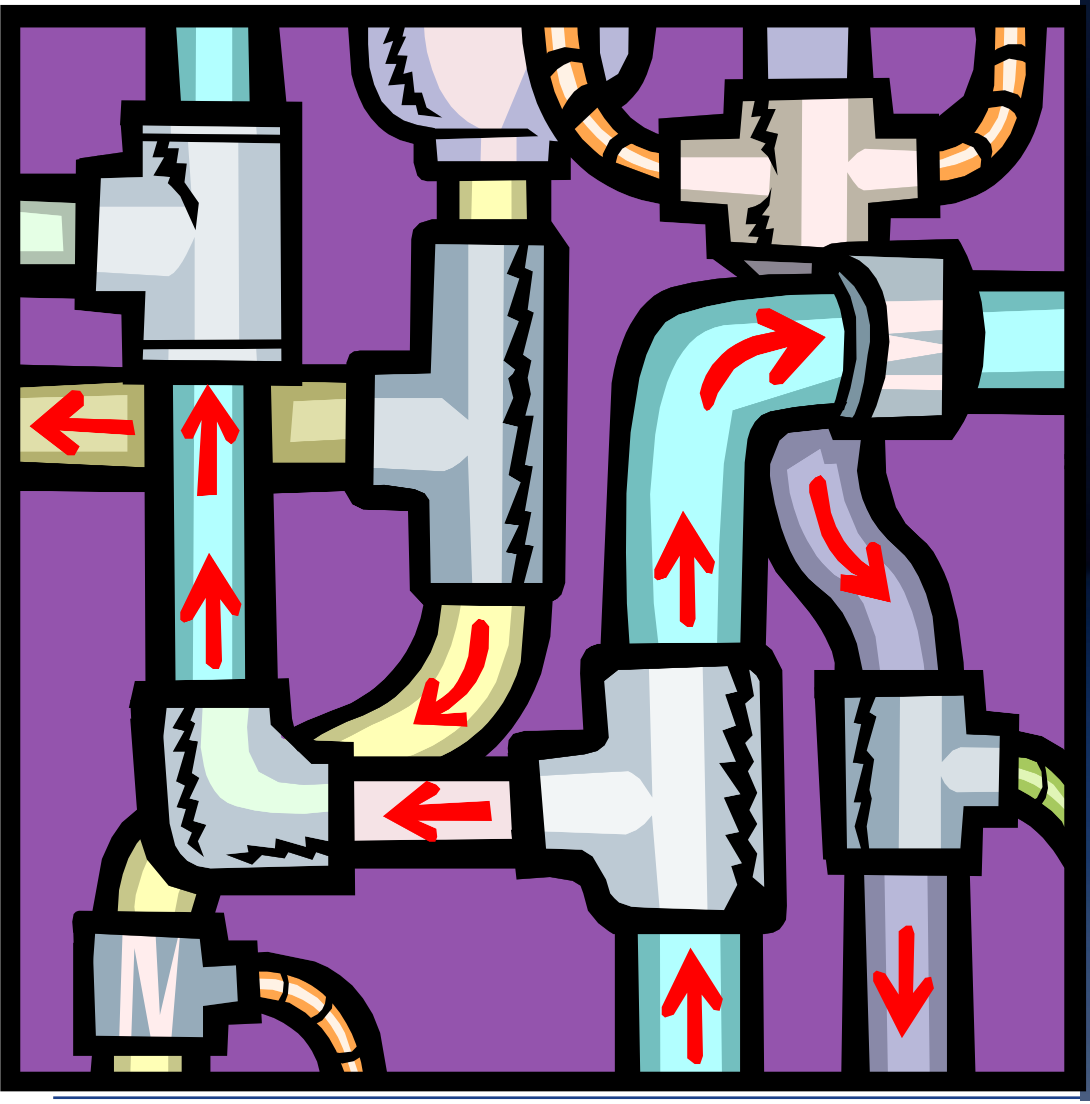
Session 3 we reviewed:

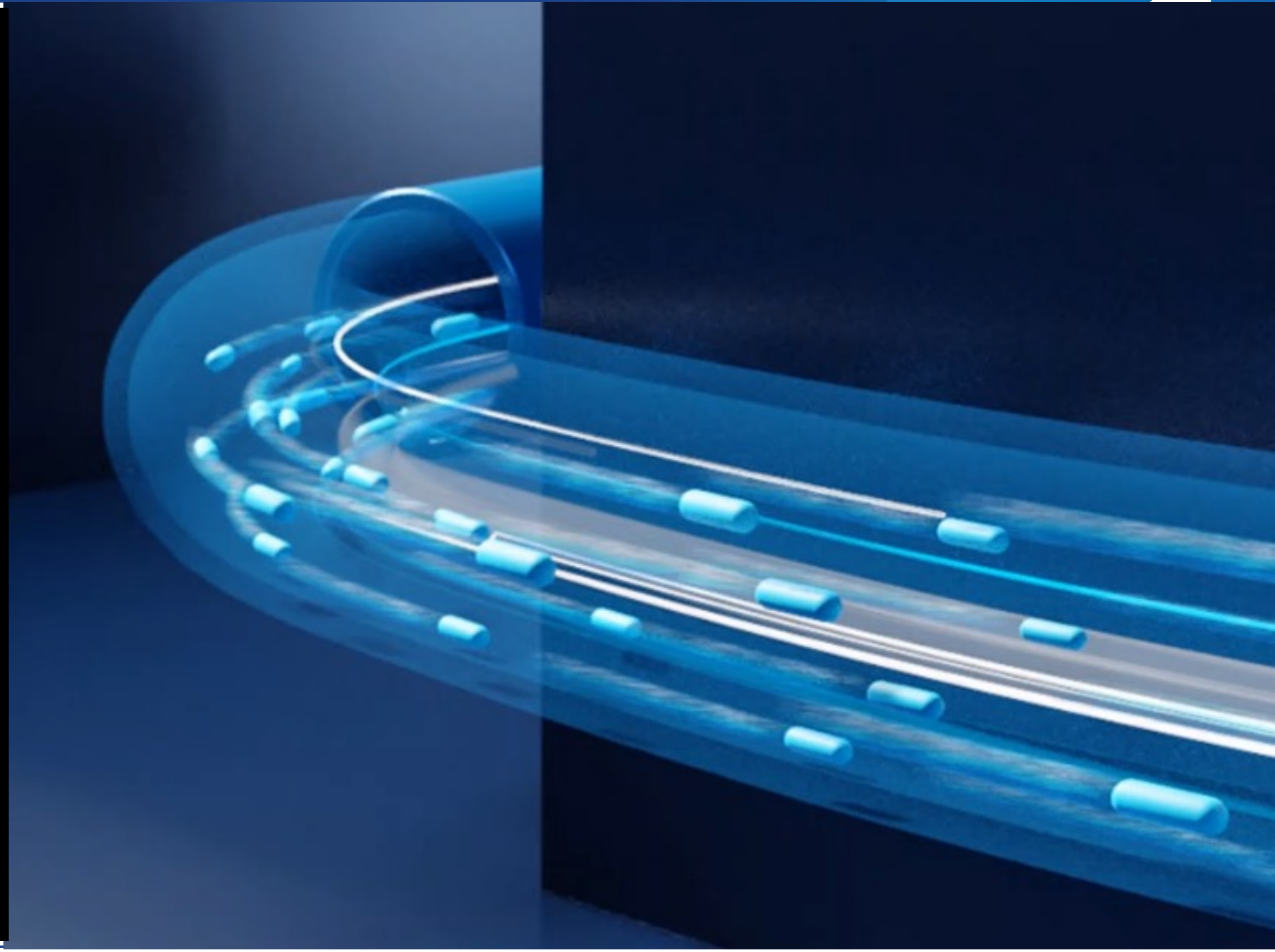
Compressor Controls
Intro to Airmaster+
Intro to LogTool
Intro to MEASUR

Last Week Session 4

Air Treatment

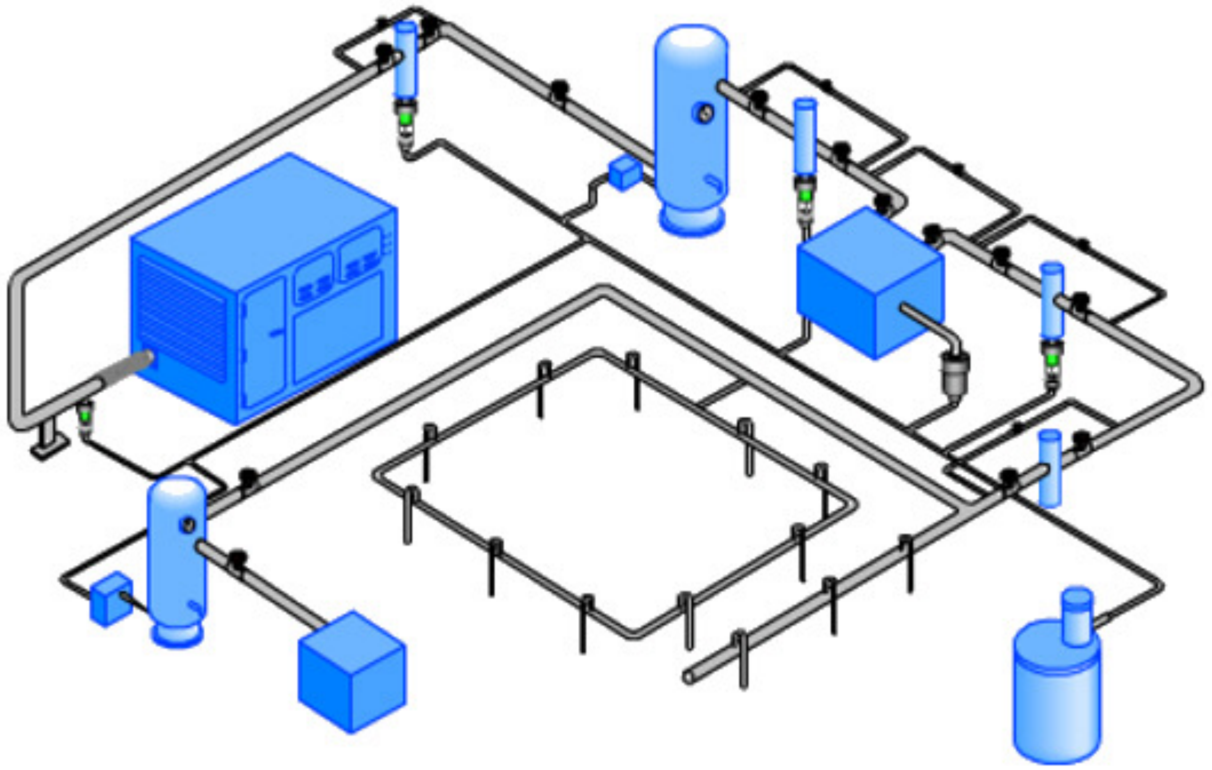
Session 5 Distribution System





Distribution System

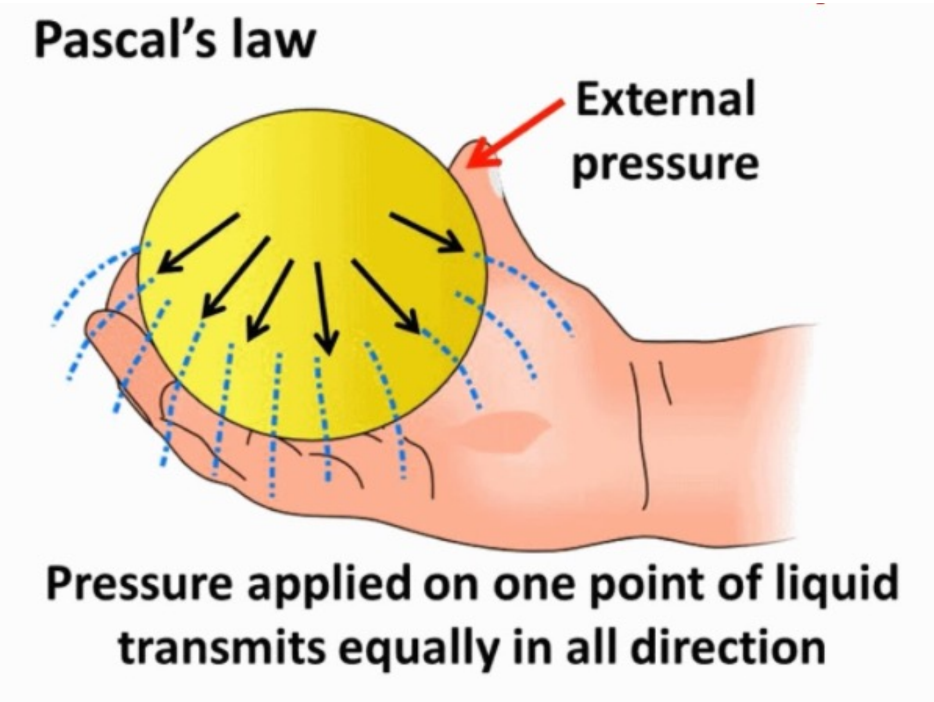
- The purpose of the distribution system is to ensure the right rate of flow of compressed air, at the right pressure, temperature and quality, for each end use application.

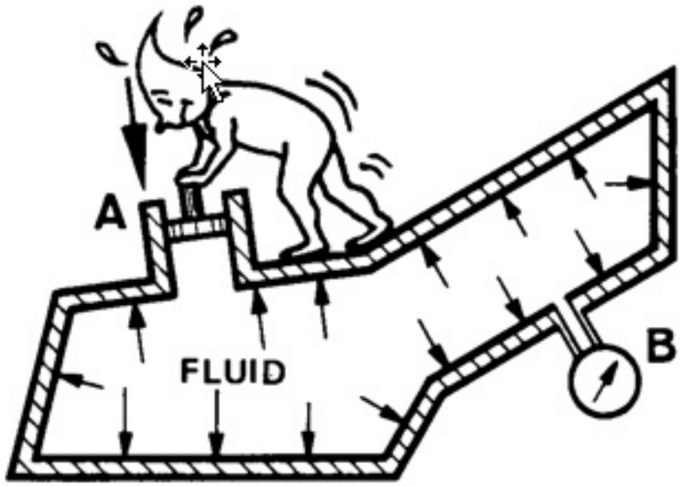


Pascal's Law

His principle of Hydrostatics is stated as follows:

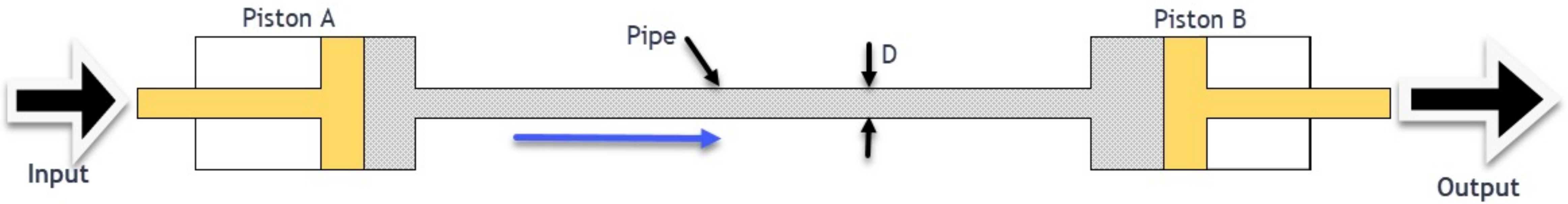
"pressure set up in a confined body of fluid acts equally in all directions and always at right angles to the containing surfaces"





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

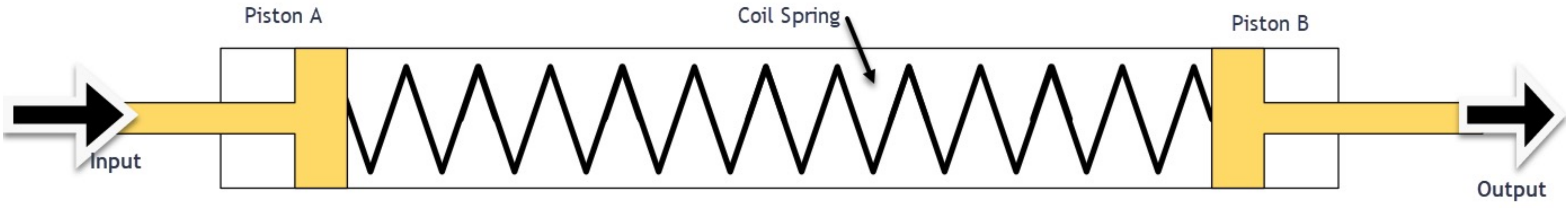
Transmission of Force Through Fluids



How large in diameter must this connecting pipe be?

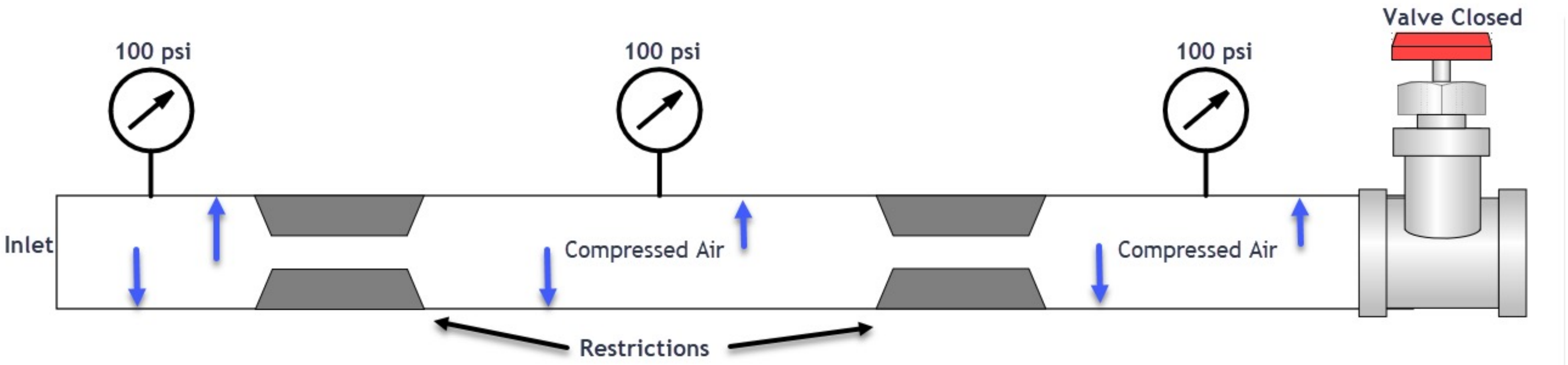
- If pistons A and B are used simply to transmit force with no movement of the pistons, they will do equally well no matter how small the diameter of the connecting pipe. PASCAL's law still applies.
- If the fluid must move through the pipe for transmitting work or power, the pipe diameter should be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



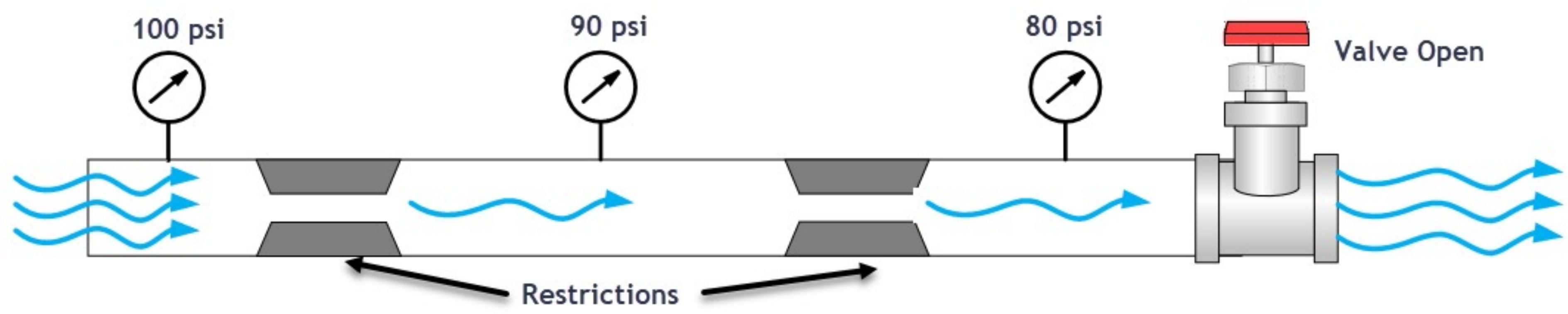
- Transmitting force through compressed air is like transmitting force through a spring.
- Force applied on piston A will produce a force output on piston B although the spring will compress to some extent while transmitting the force.
- While compressed air is an excellent medium for transmitting power,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



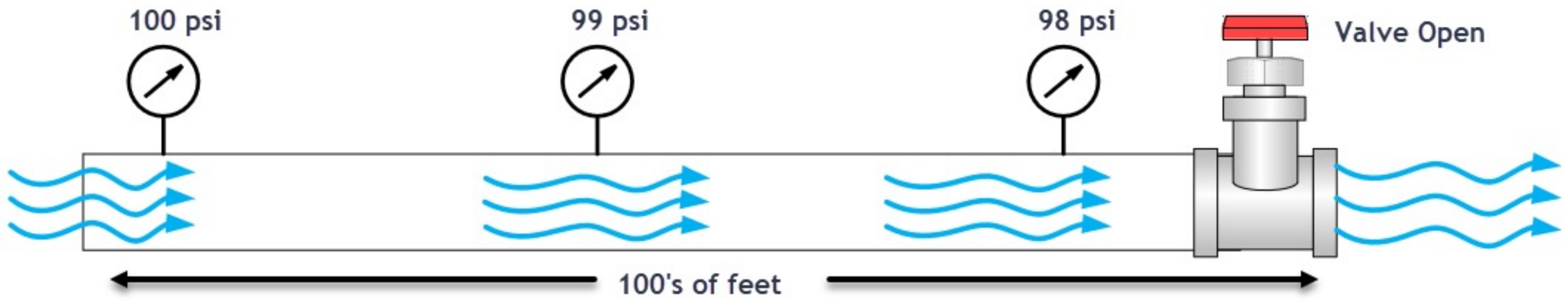
- A very important point to remember about pressure loss is that it only appears when fluid starts to flow.
- As long as the fluid is static, (non-moving) there is no pressure loss.
- Pure force without movement of compressed air can be transmitted through extremely long piping systems.
- This is analogous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

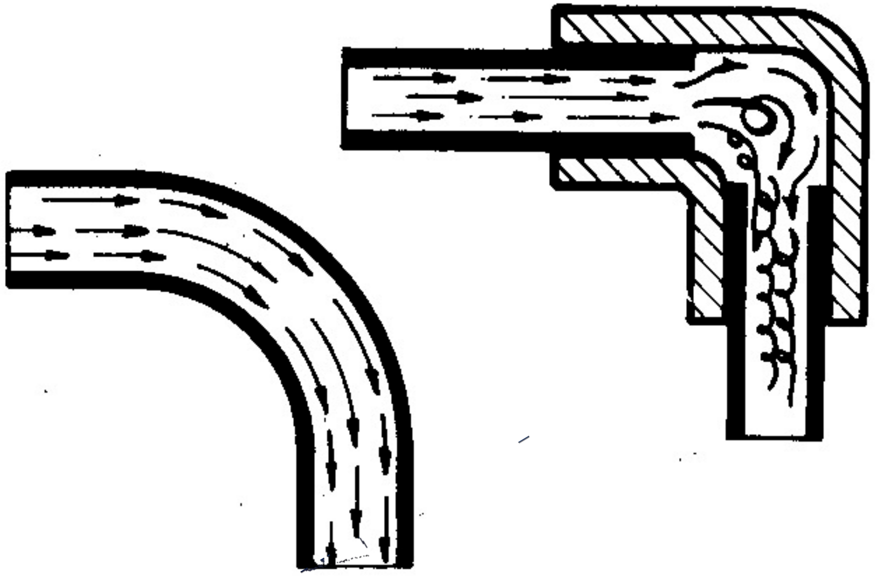
Reducing Pressure Drops Throughout the System

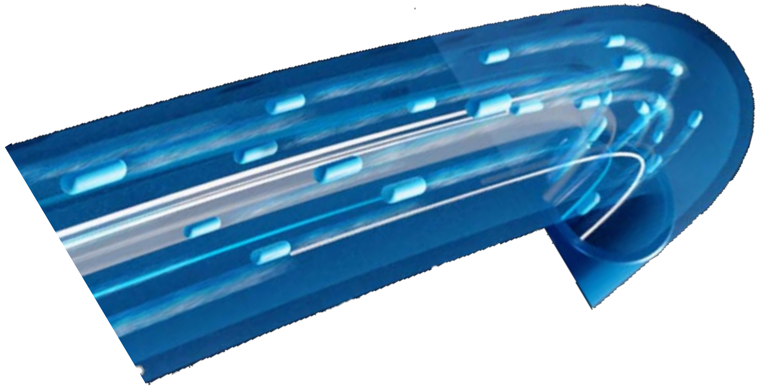


- When major restrictions are removed and the pipe is made sufficiently large to carry the flow, a relatively small proportion of inlet pressure will be sacrificed to flow losses.

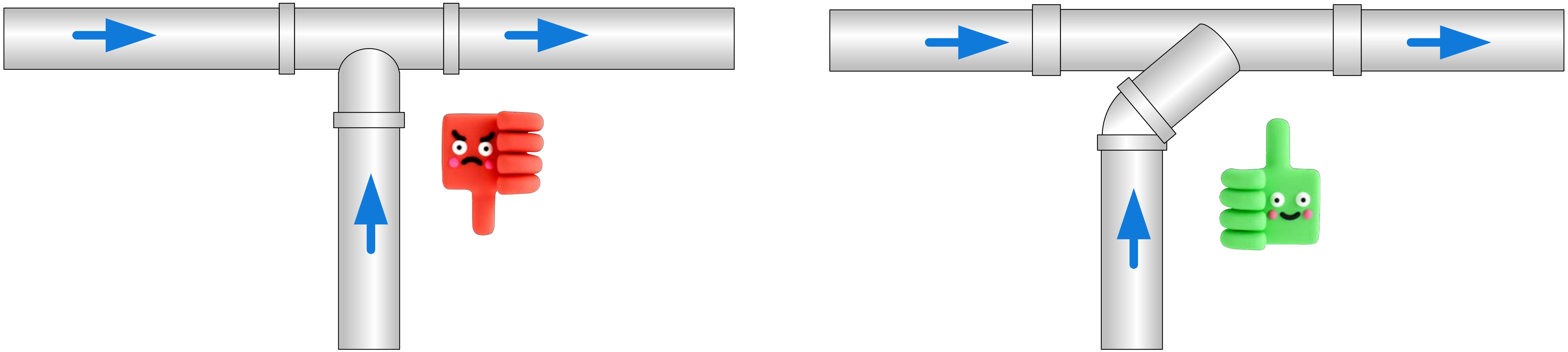
Pipe Fittings

- 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



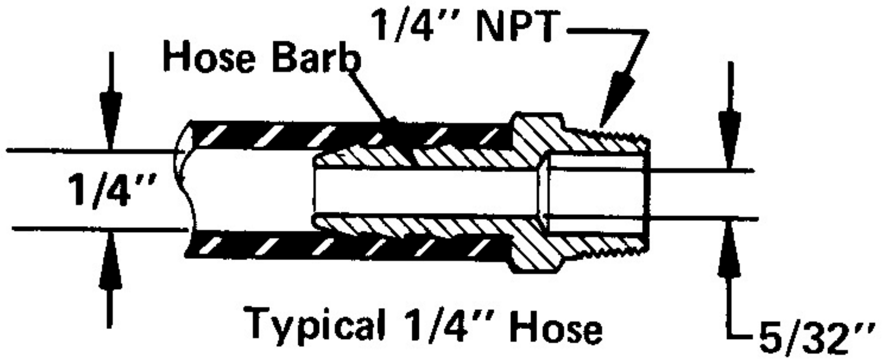


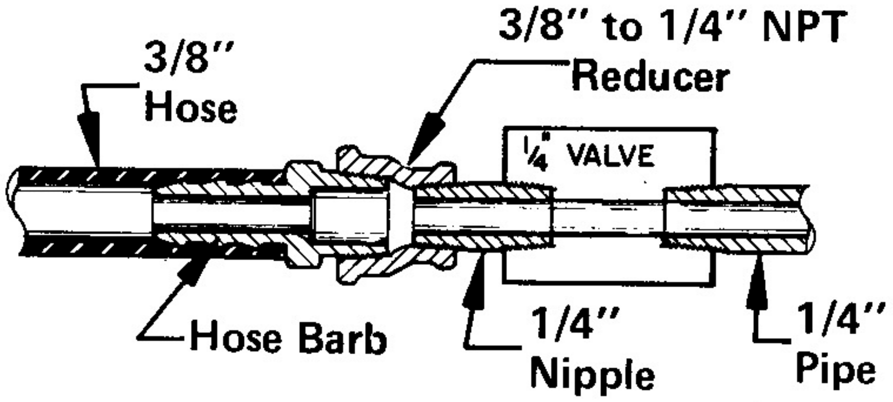
Piping Systems



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



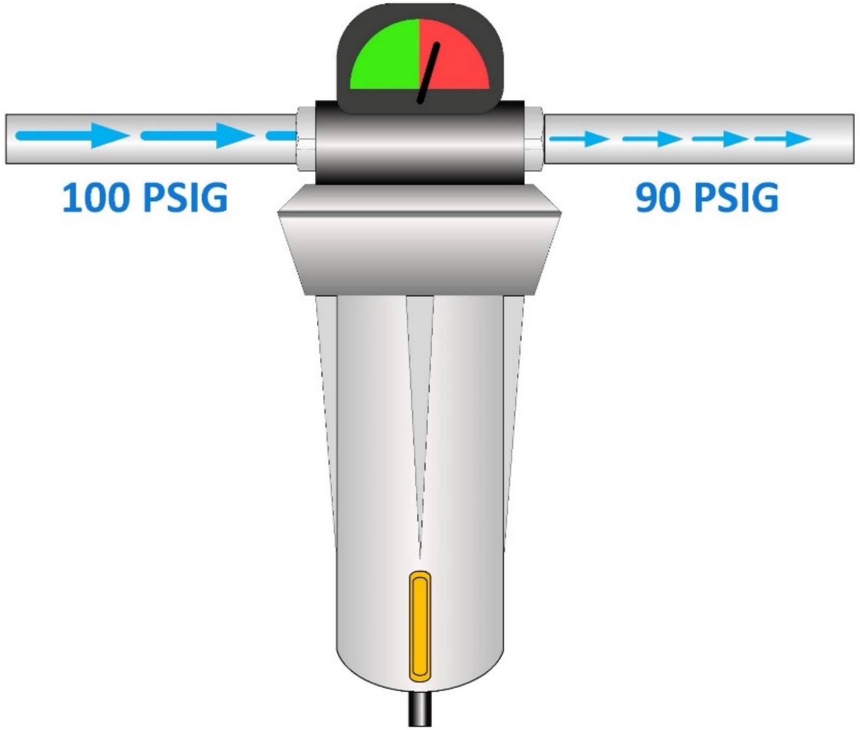


Rubber Hose Losses Without the Fittings

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								

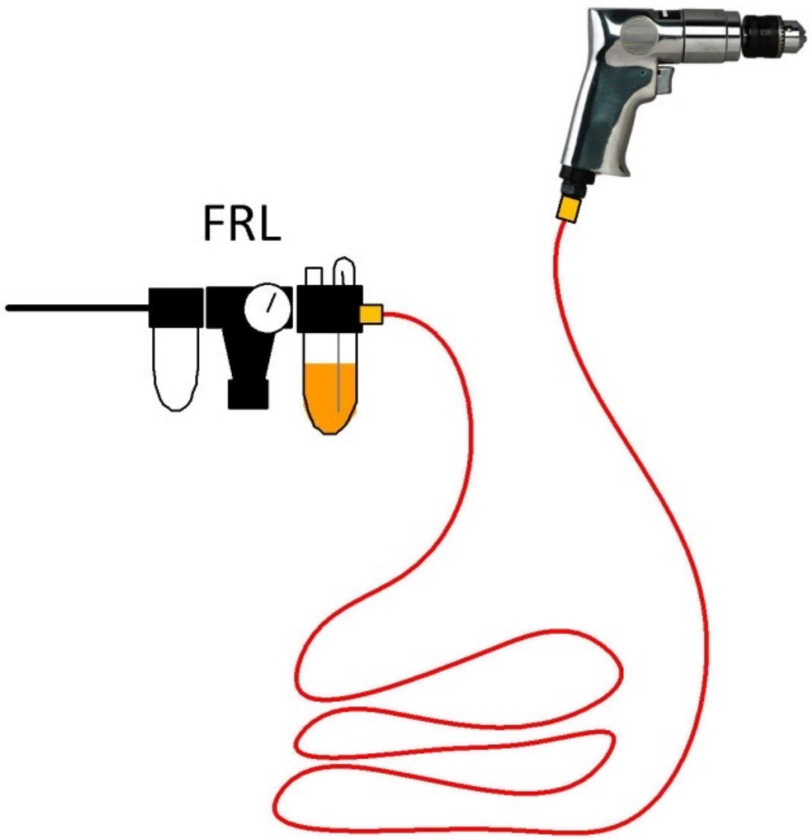
Restriction

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



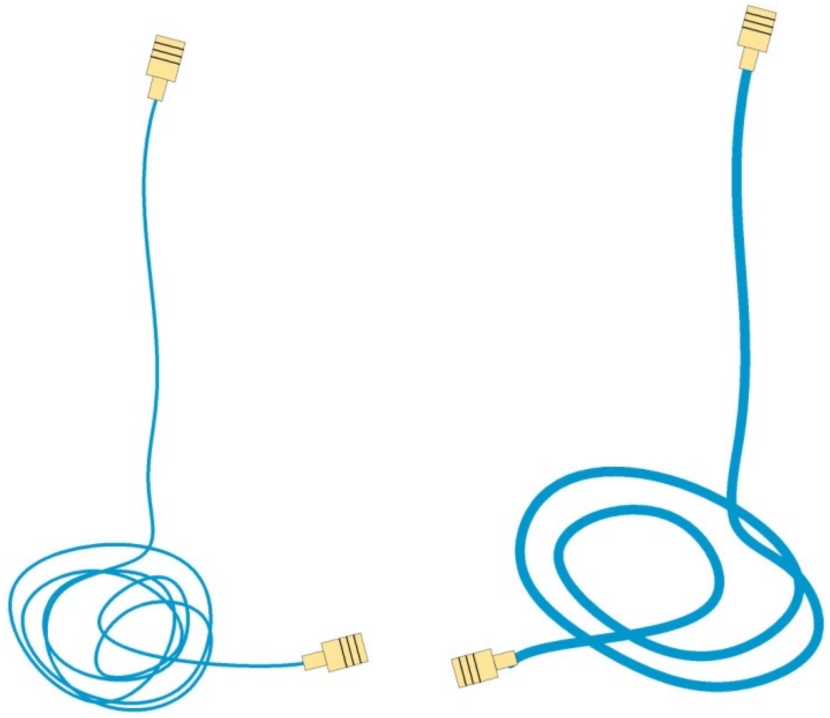
Pressure Drop

- 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!

Reducing Pressure Drops Throughout the System

- The following equation is for calculating Velocity:

$$V = \frac{cfm \times P_a}{60 \times a \times (p_2 + 14.7)}$$

  - 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

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

Solve for Diameter *(d)*

- The following equation is for calculating Velocity:

$$a = \frac{144 \times cfm \times P_a}{V \times 60 \times (P_d + P_a)}$$

$$a_{sq.in} = \frac{\Pi \times d^2}{4}$$

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

Loss of Air Pressure Due To Friction

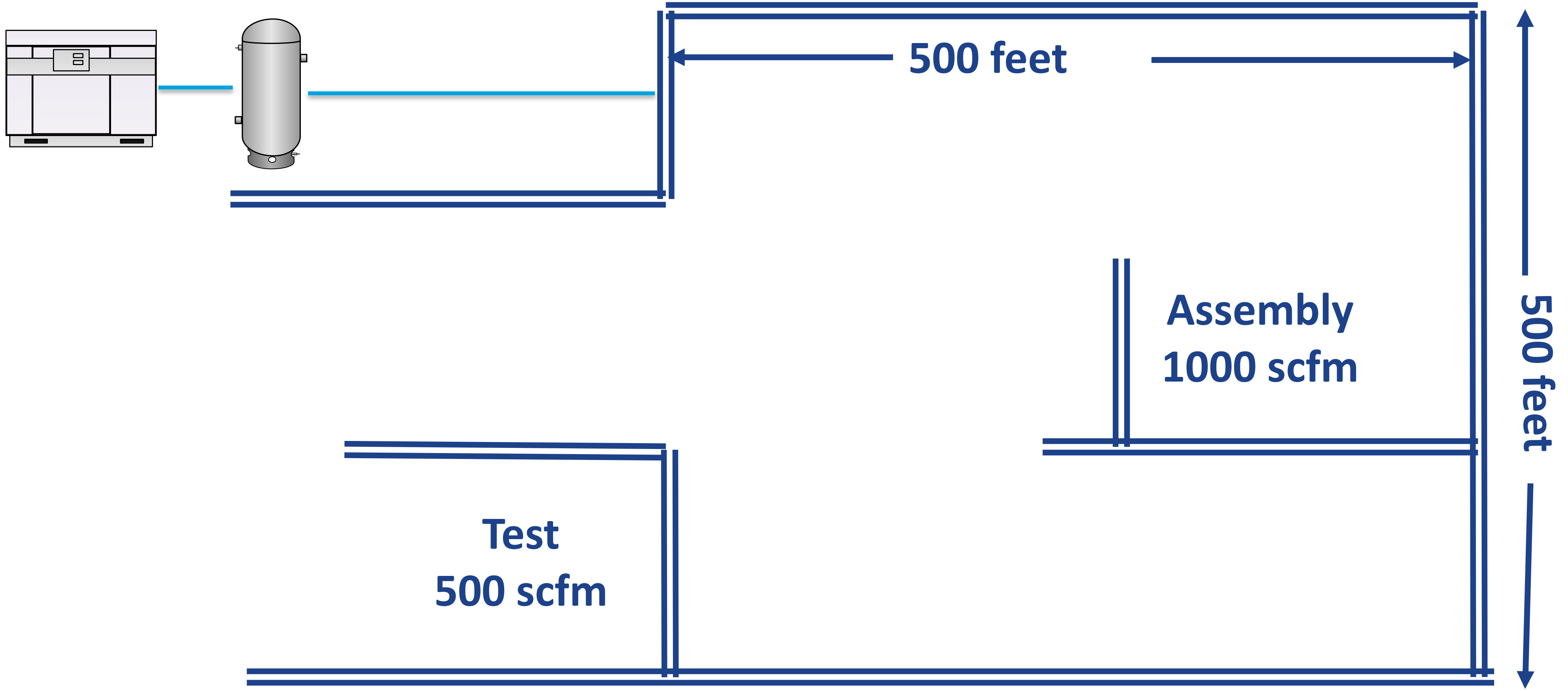
Cfm free air	2'' ID	3'' ID	4'' ID
500	19.2	2.34	1.09
600	27.6	3.36	1.56
700	37.7	4.55	2.13

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.

WHAT PIPE SIZE IS NEEDED



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!!!

CAGI:

The following charts are from chapter 4 of the CAGI Handbook.

Table 4.7 Loss of Air Pressure Due to Friction @ 100 psig

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					

Table 4.7 Loss of Air Pressure Due to Friction @ 100 psig

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
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			
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

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								
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150	490.0	50.3	13.4	5.2	1.6							
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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?

- 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

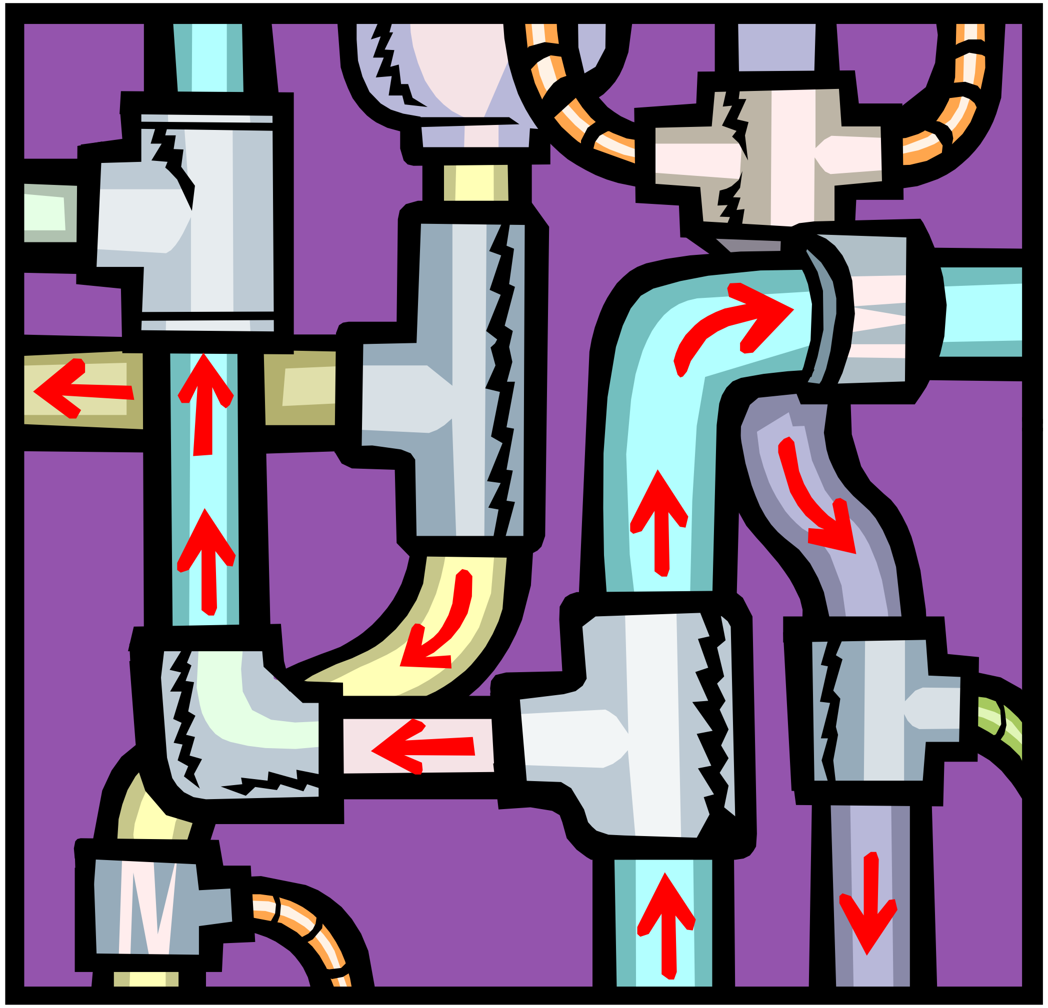
2000 + 80 + 2 + 2 = 2084 total feet in inlet piping.

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

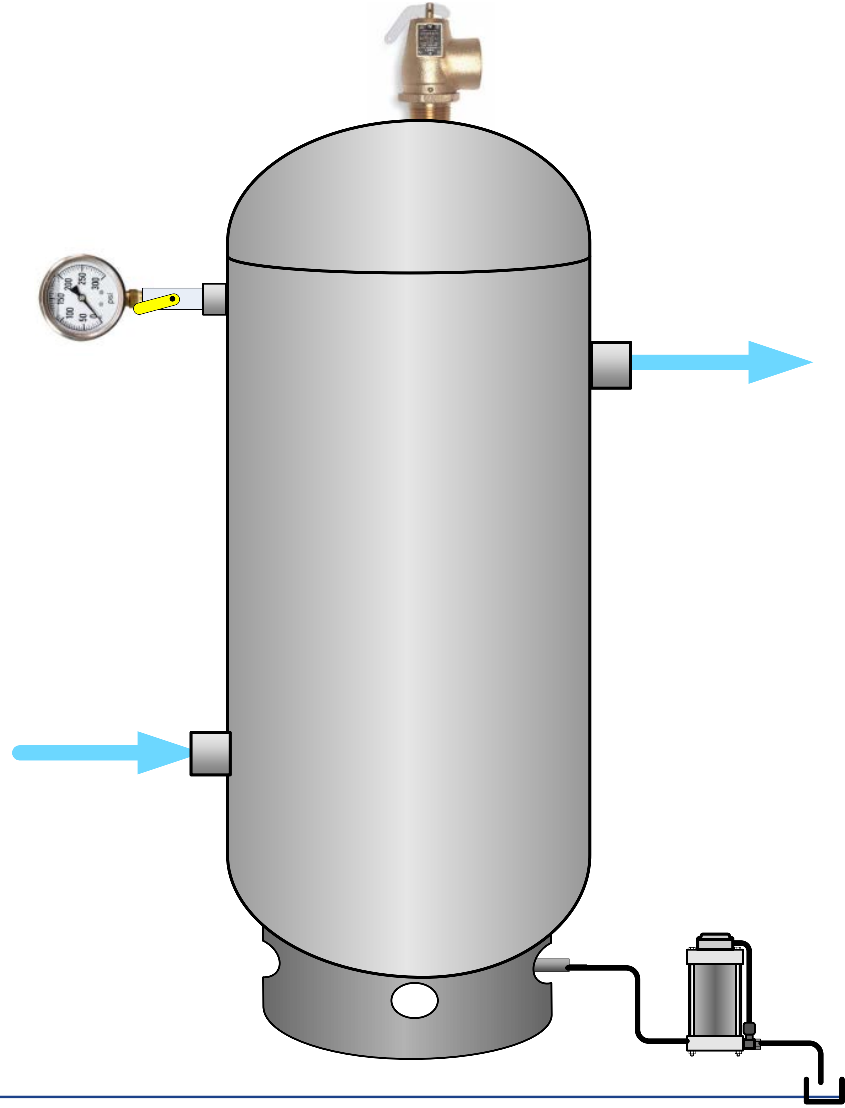


Distribution Best Practices

- 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.

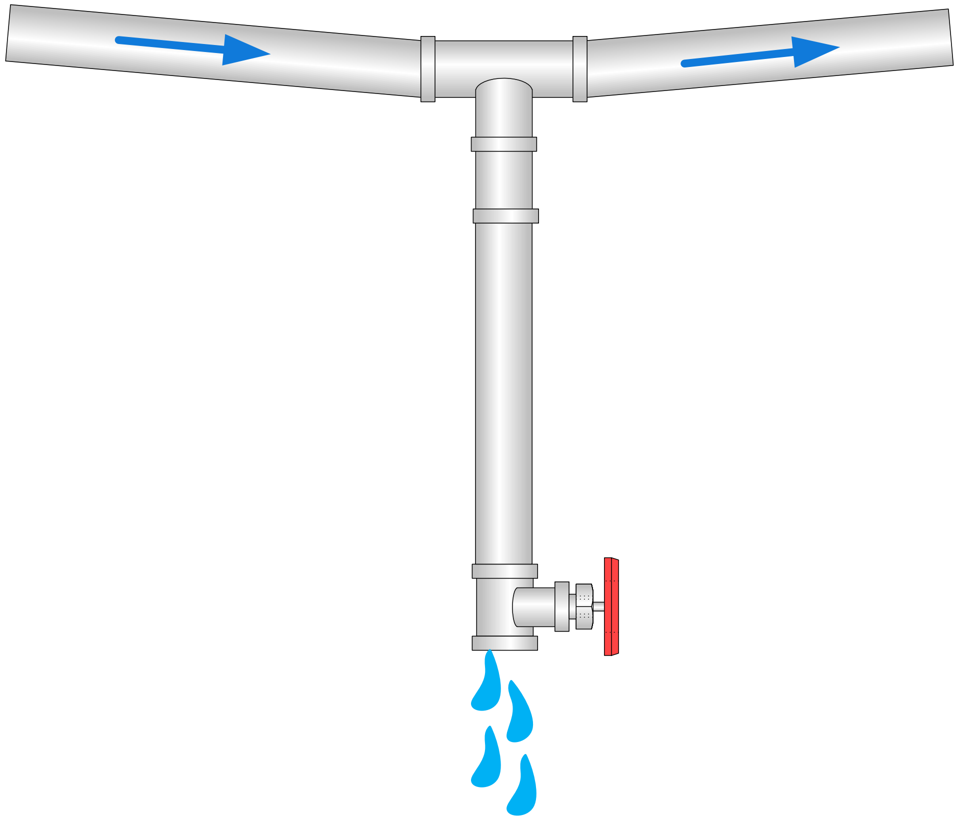
Distribution Best Practices

- 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.



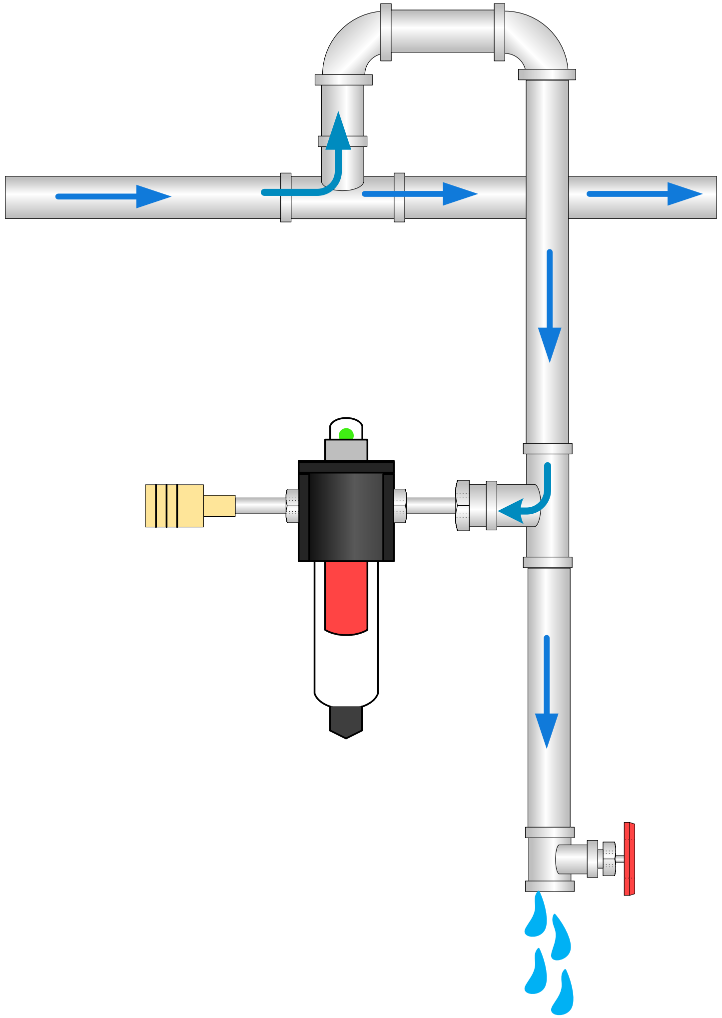
Distribution Best Practices

- 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.



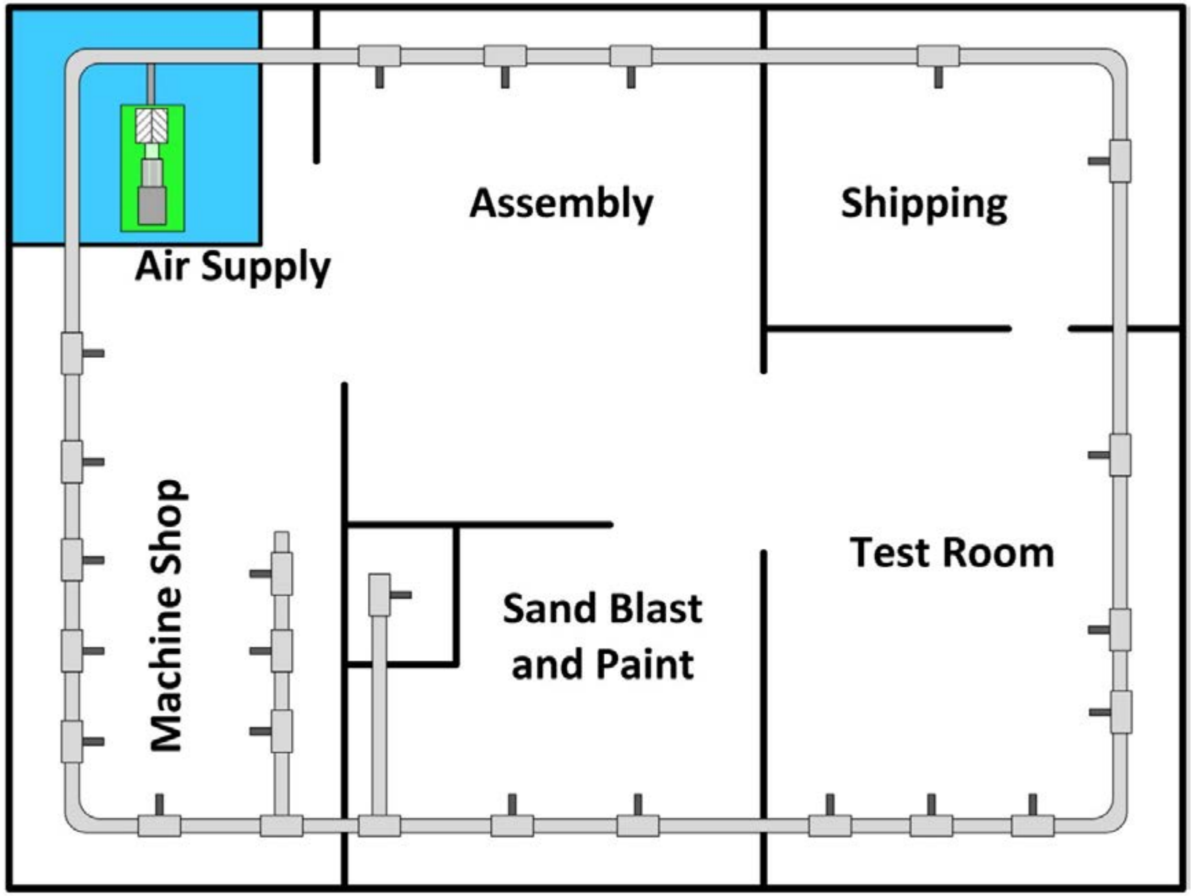
Distribution Best Practices

- 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.



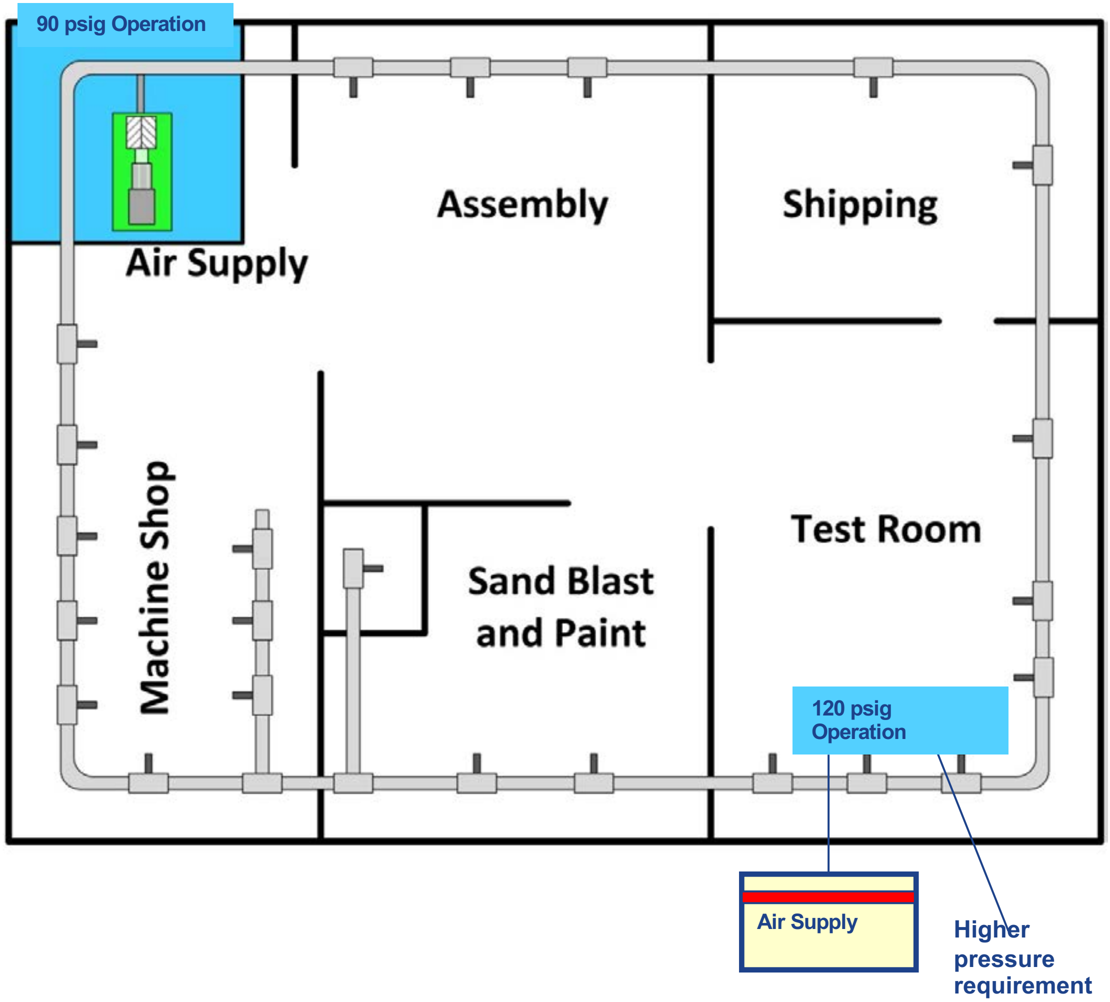
Location

- 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.



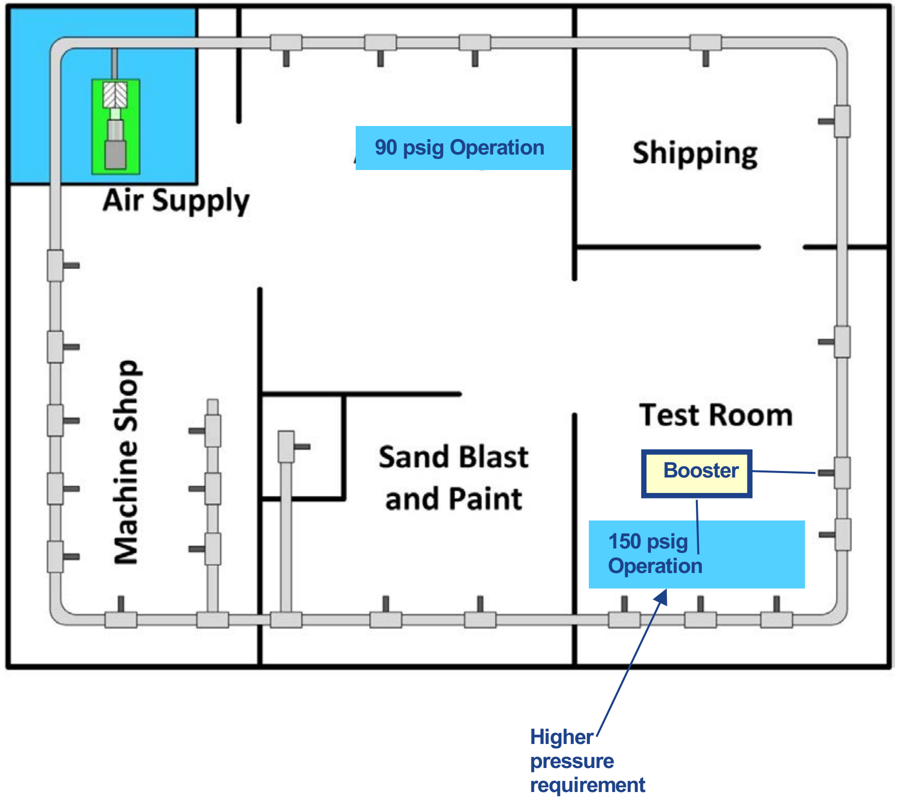
Location

- 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.



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.

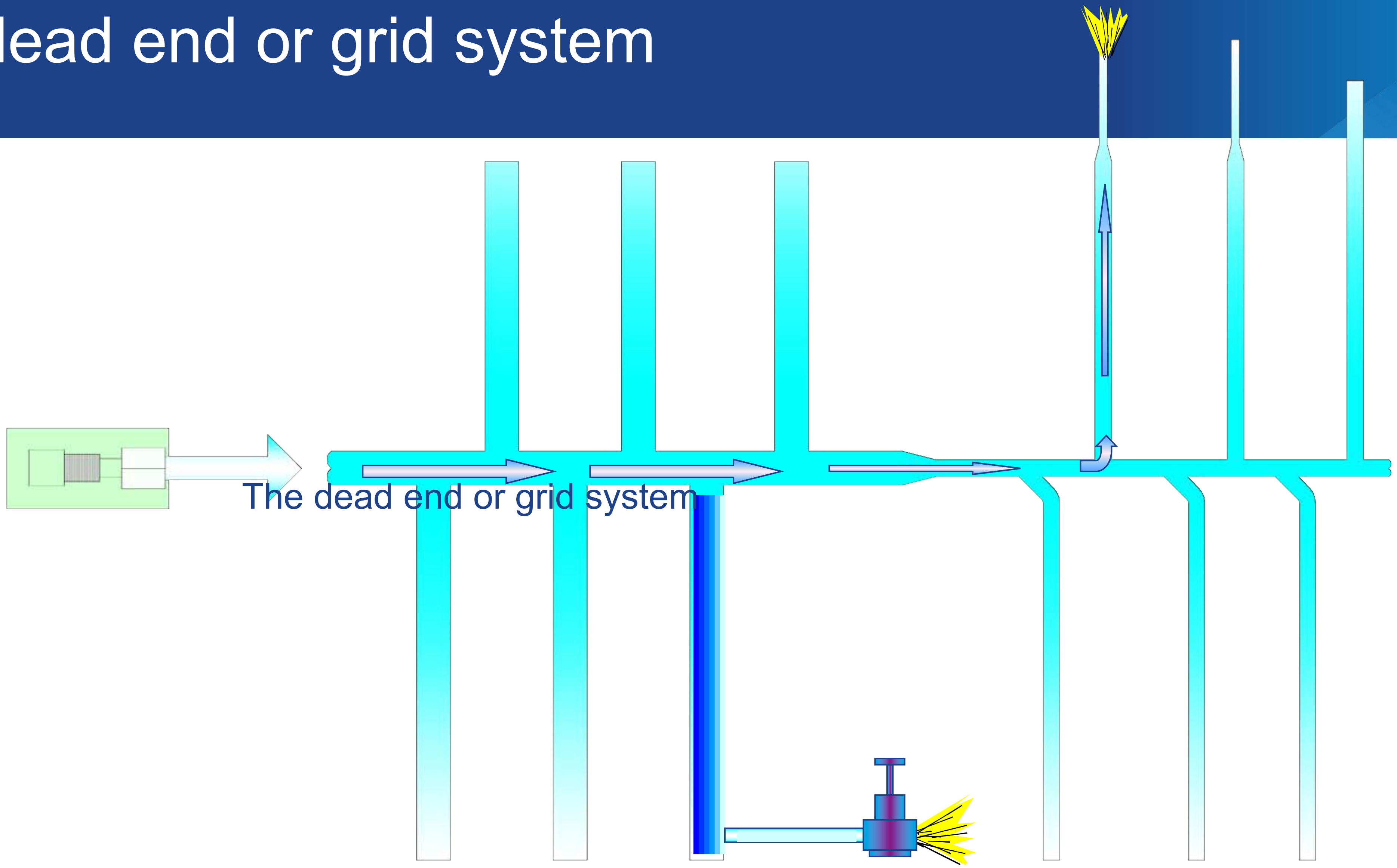
Piping Layout

- 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.

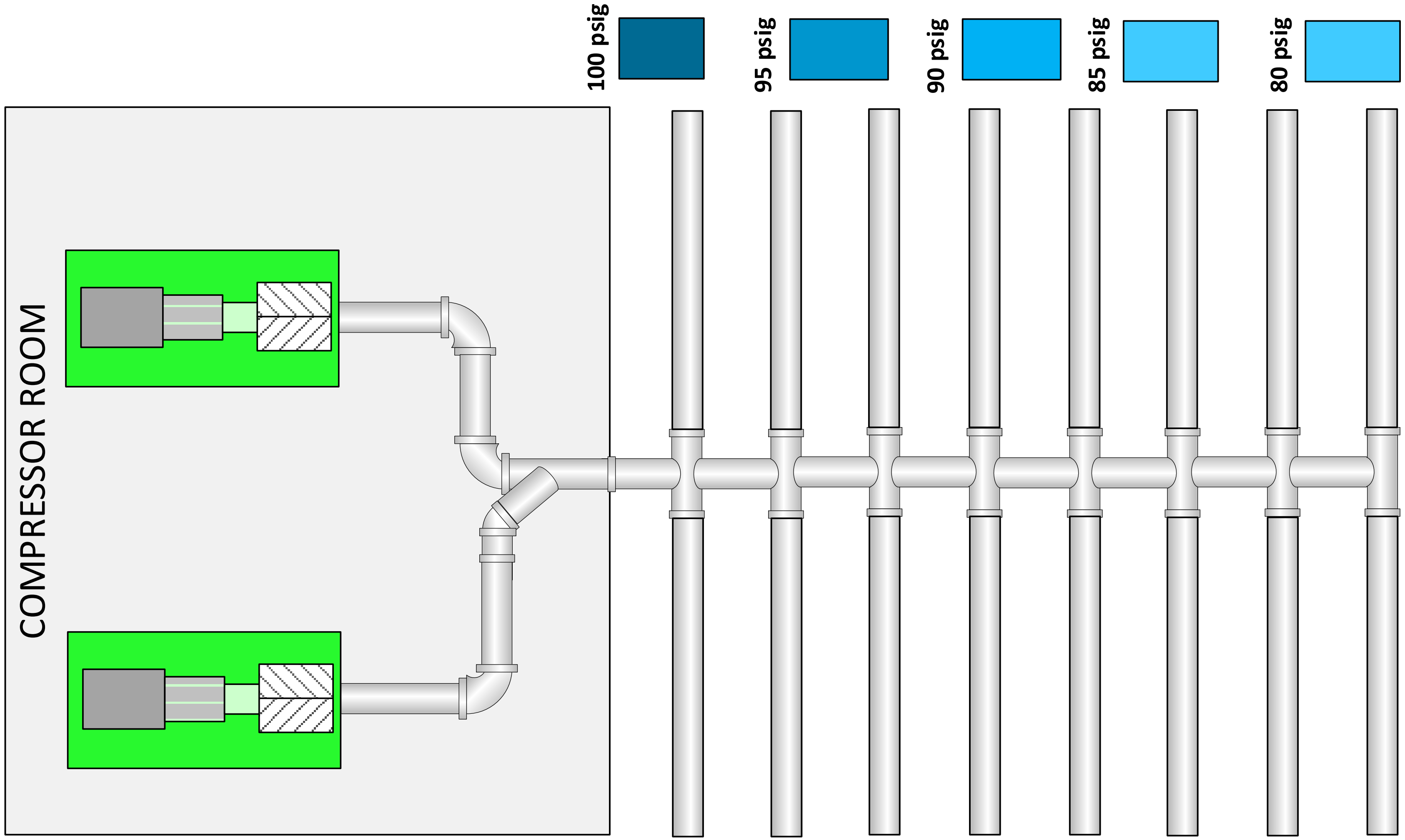
Piping Systems

- 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.

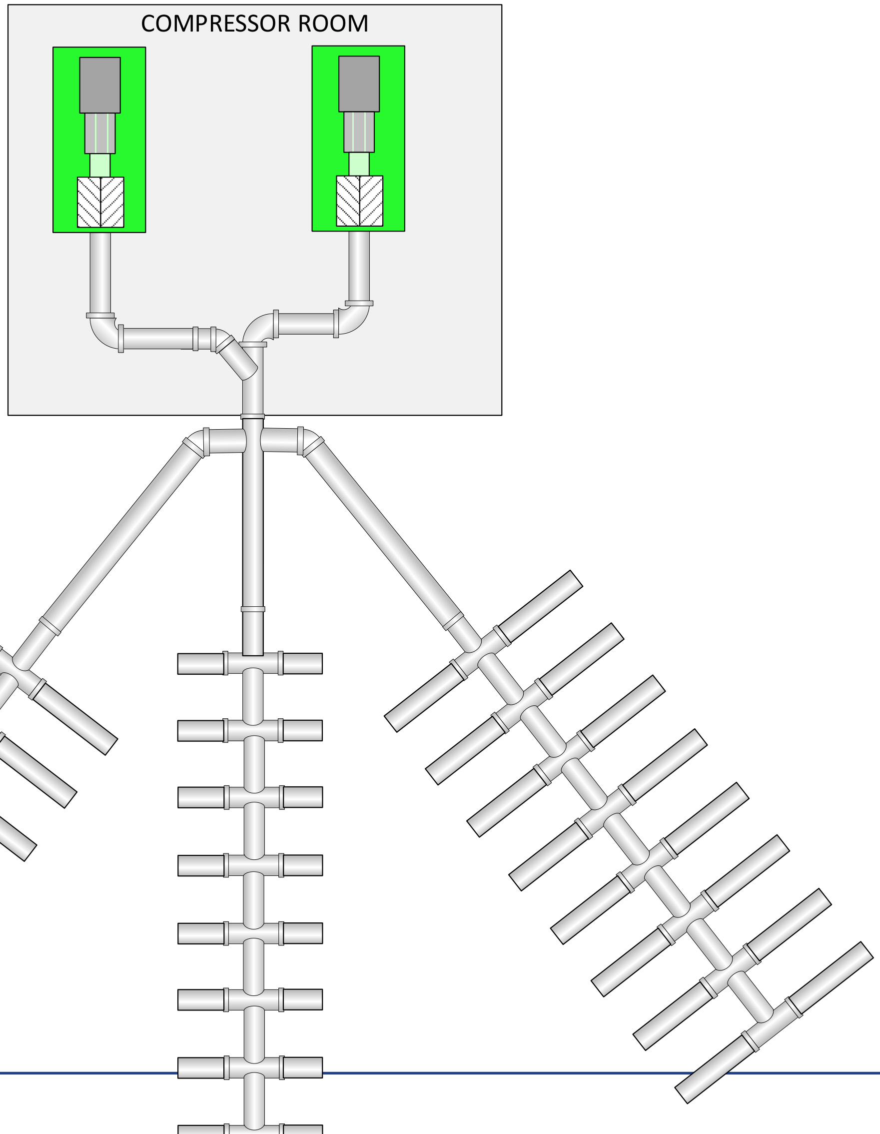
The dead end or grid system



The dead end or grid system



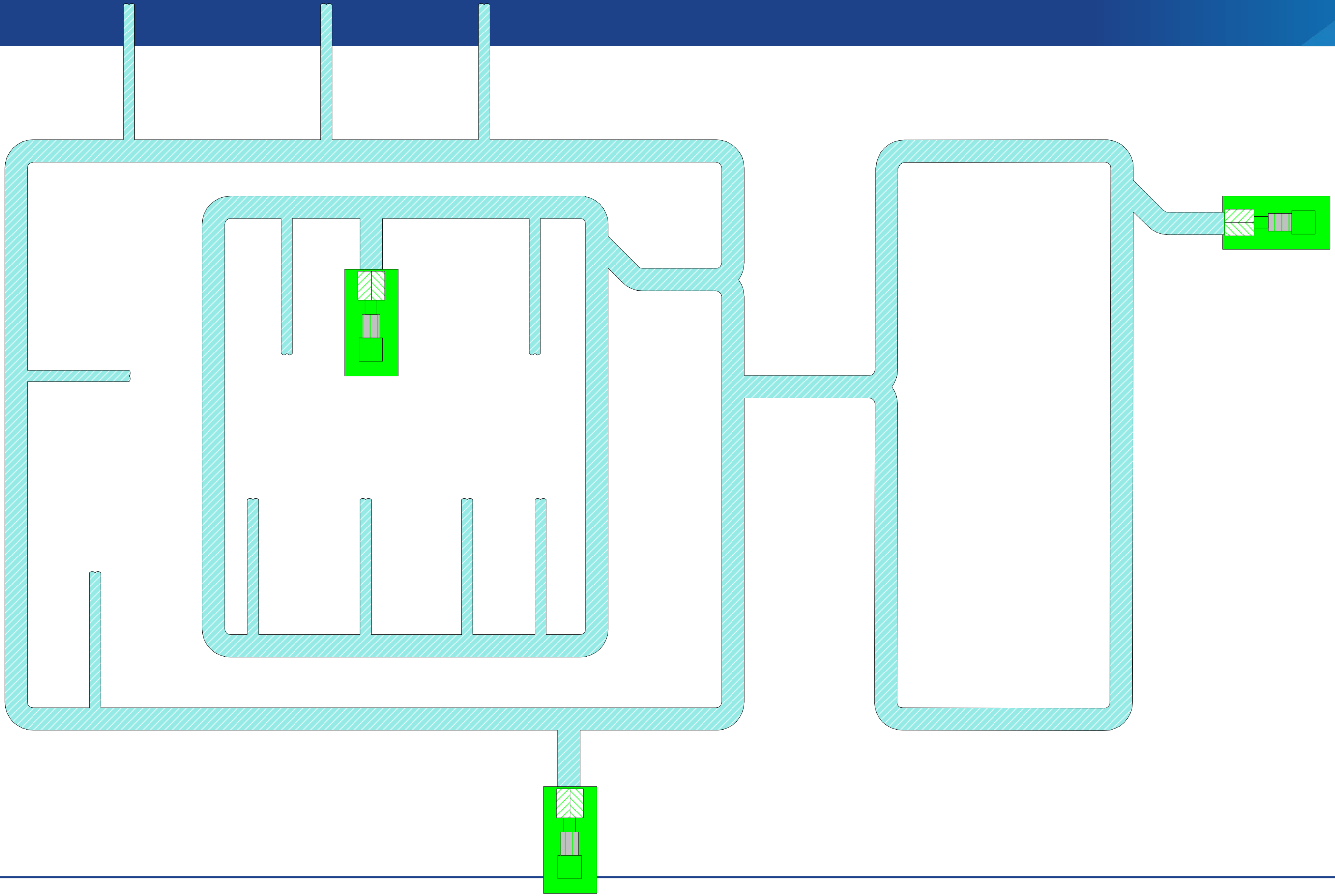
The dead end or grid system



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.

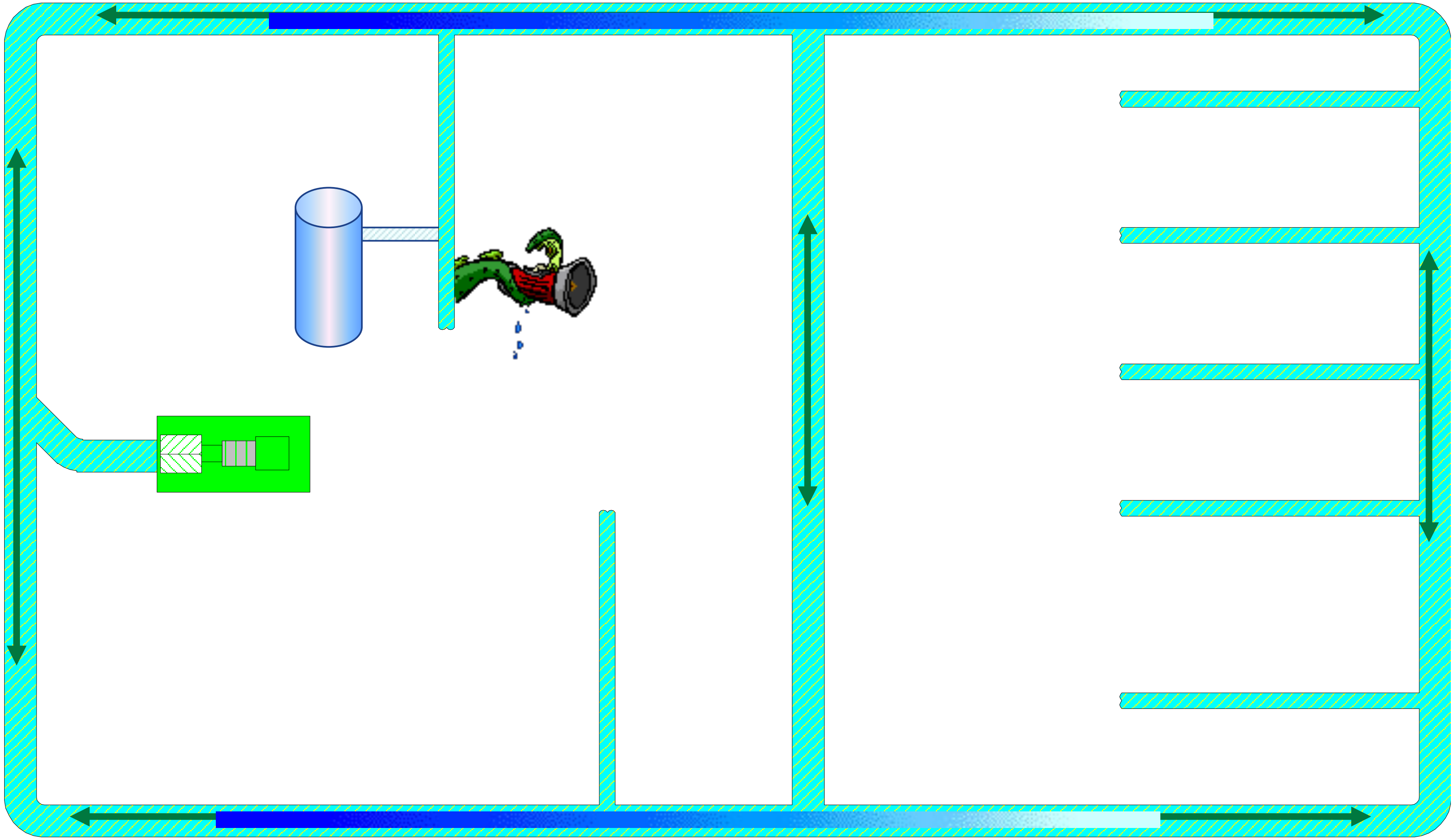
Decentralized system



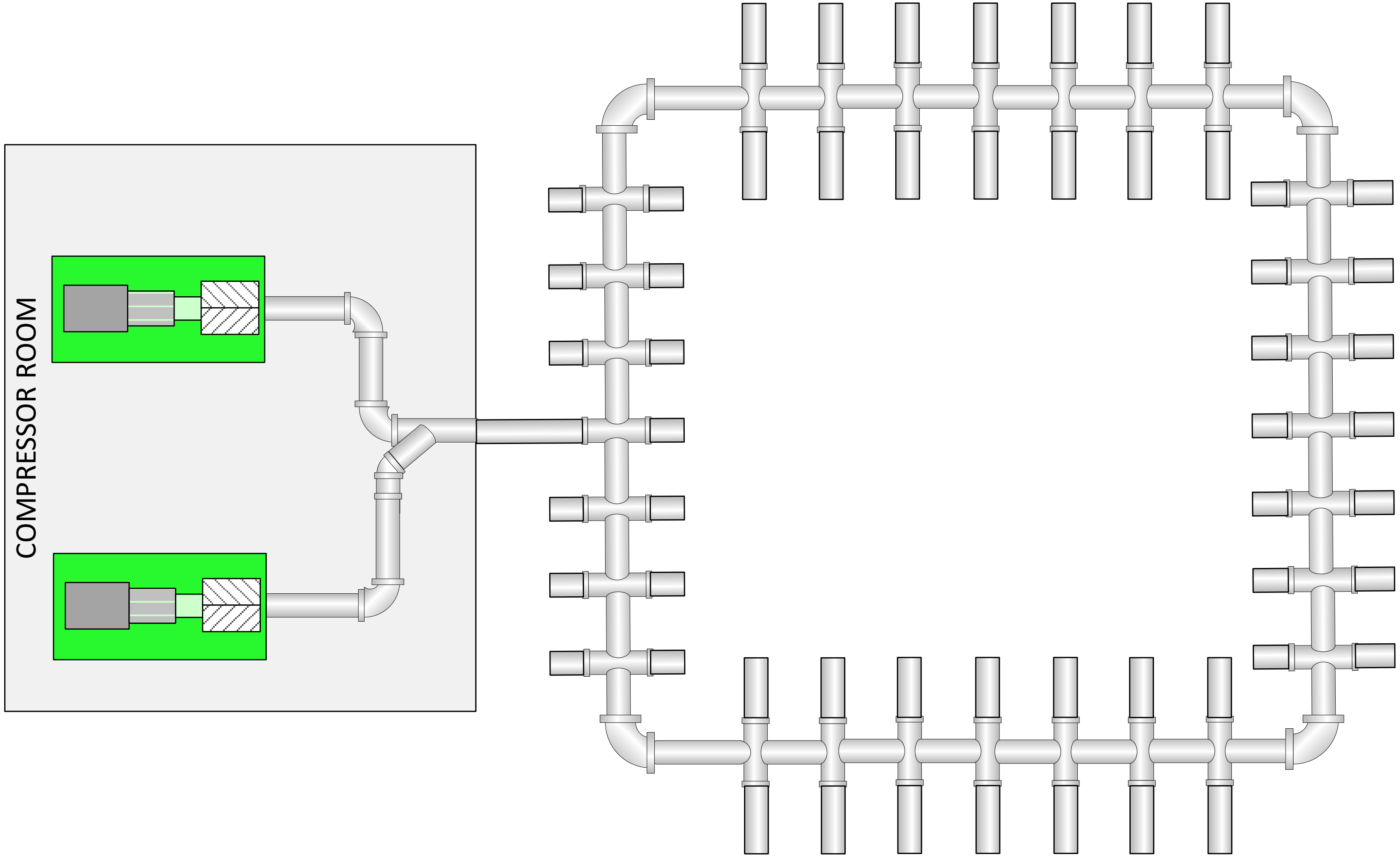
Piping Systems

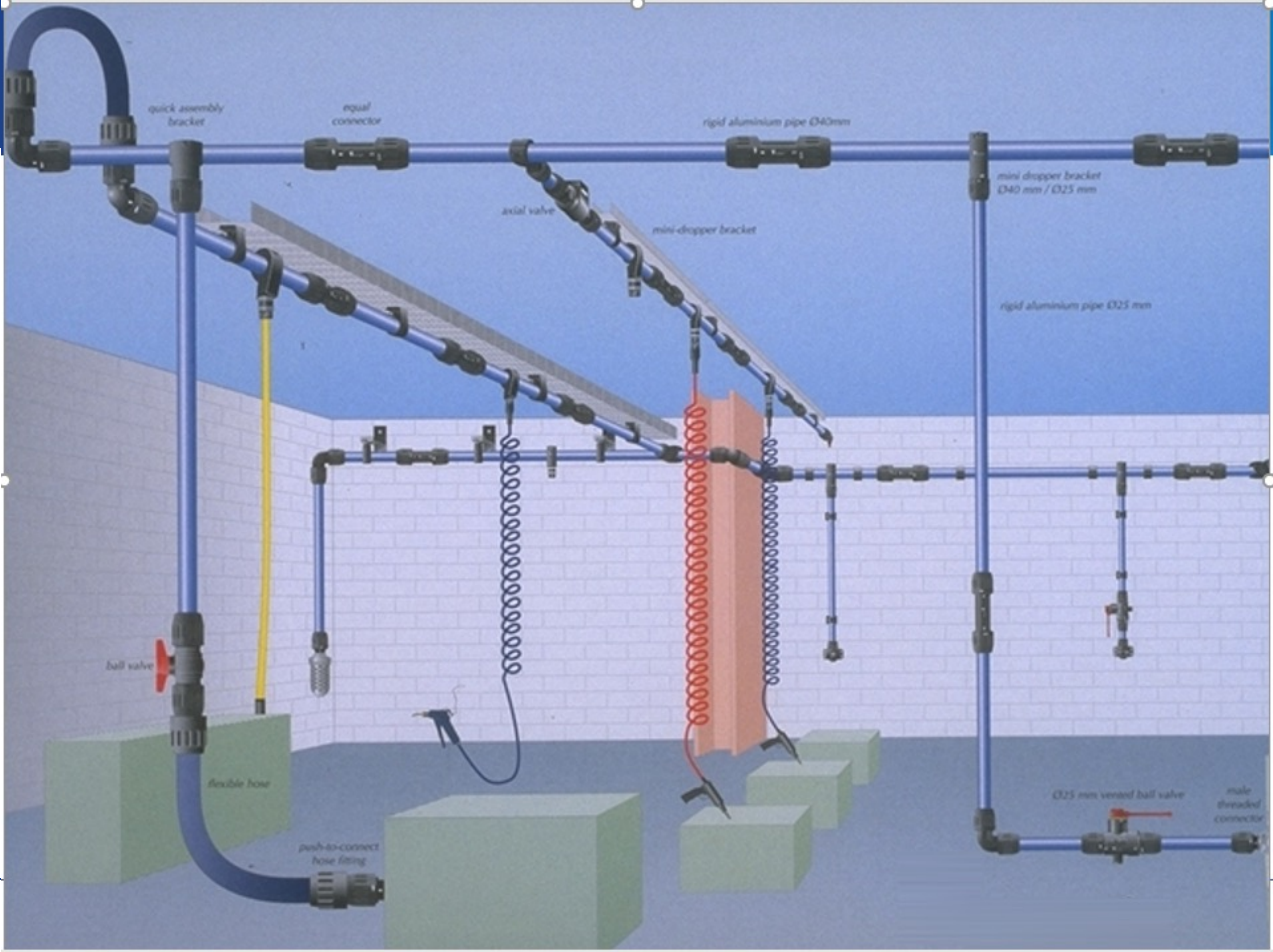
- Loop system.
  - Highly recommend and most common.
  - Allows the optimum pipe size and assures equal distribution through the plant.
  - At points of heavy momentary demands for air, a receiver can be used to store the energy.

Loop system

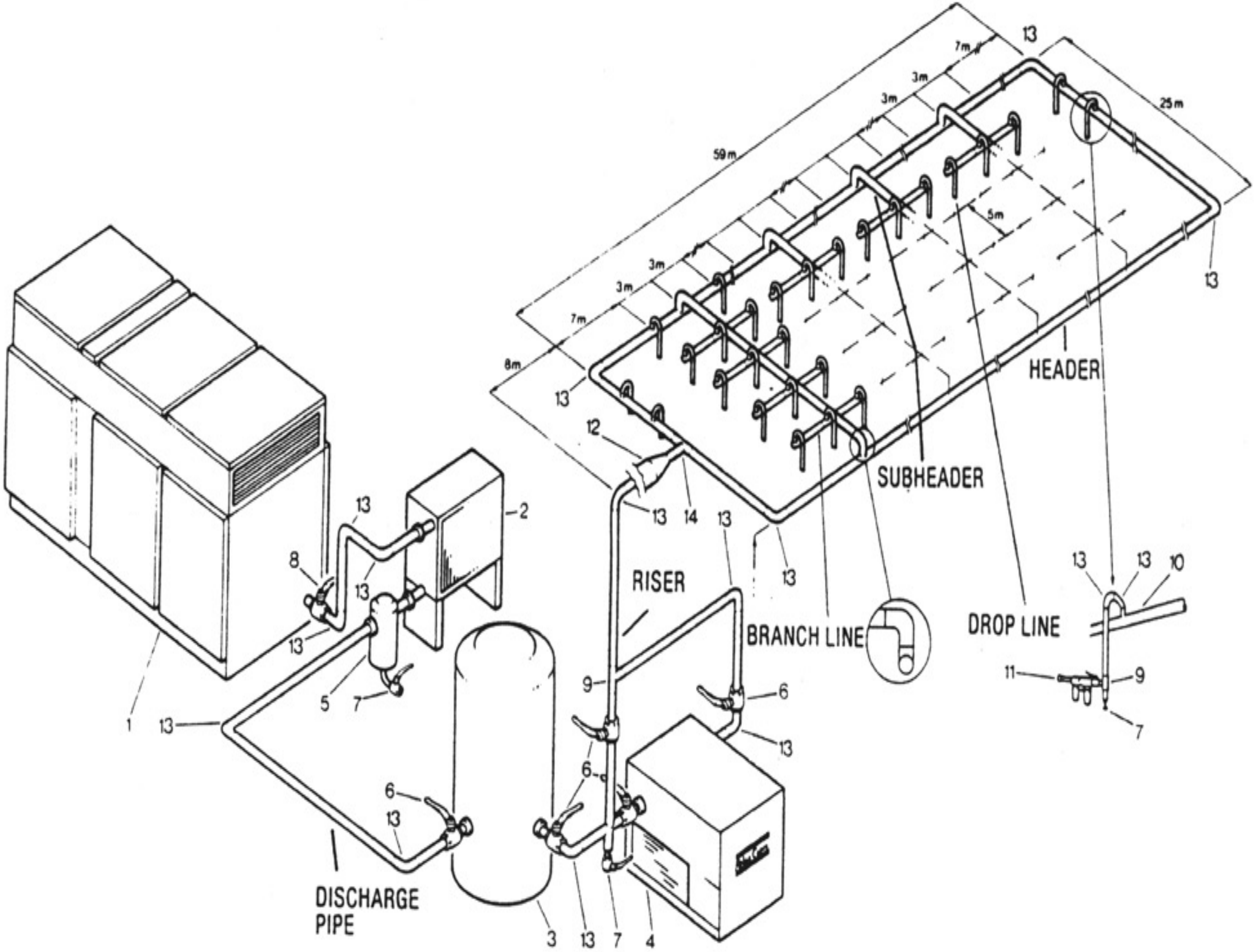


Loop system

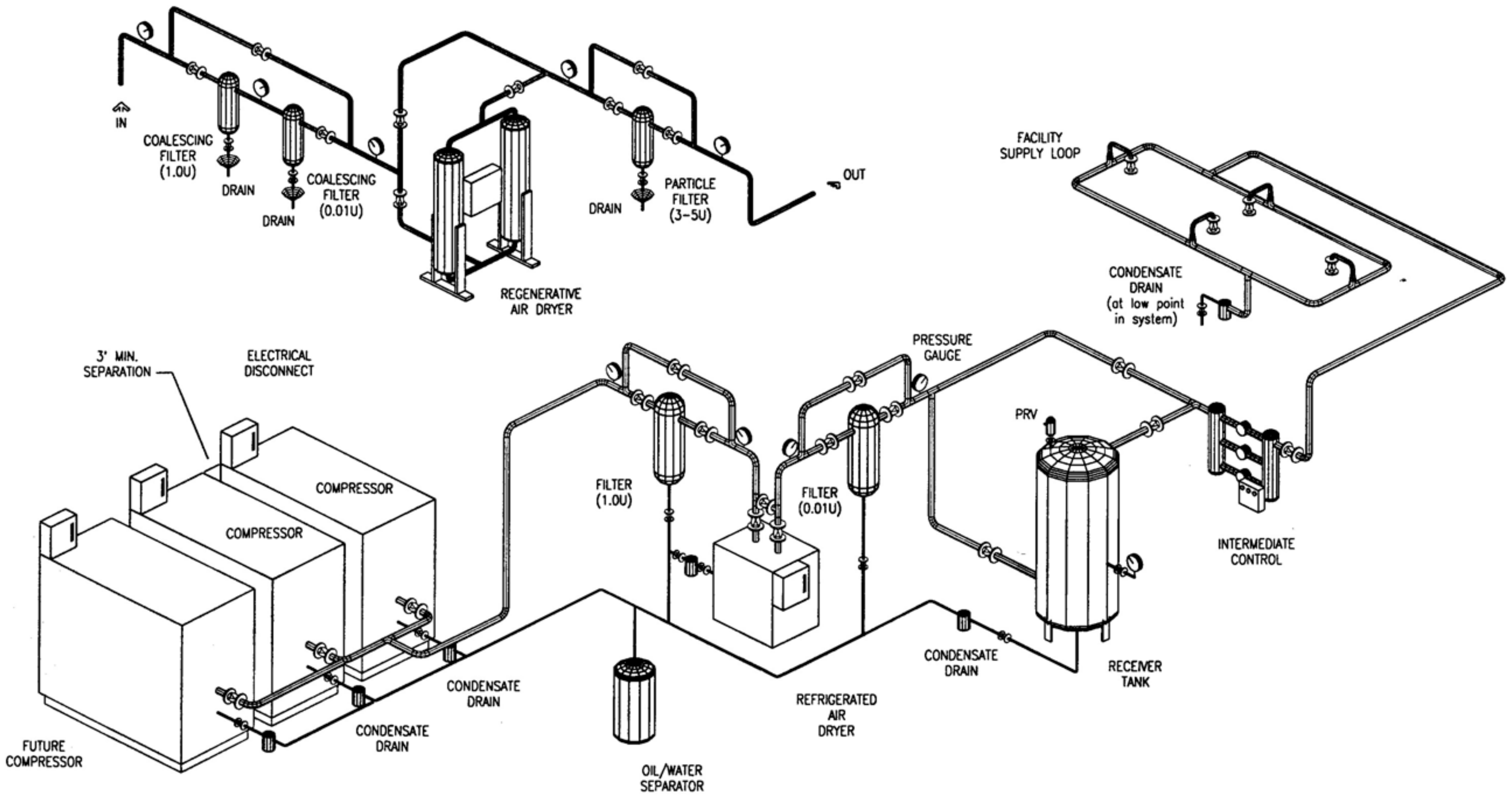




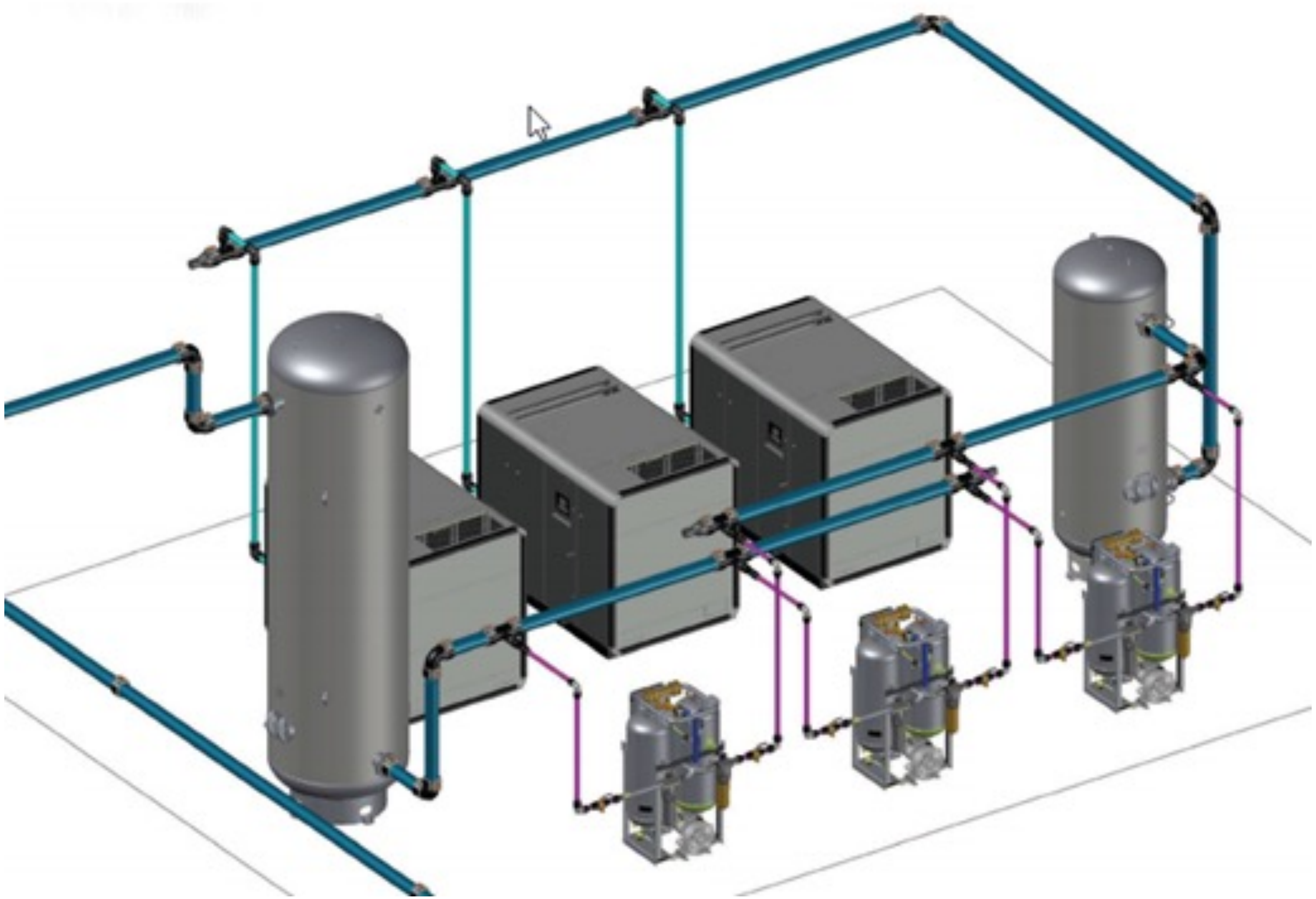
quick assembly bracket
equal connector
rigid aluminium pipe Ø40mm
mini dropper bracket Ø40 mm / Ø25 mm
axial valve
mini-dropper bracket
rigid aluminium pipe Ø25 mm
ball valve
flexible hose
push-to-connect hose fitting
Ø25 mm vented ball valve
male threaded connector


59 m
7 m
3 m
3 m
3 m
3 m
7 m
8 m
25 m
5 m
13
HEADER
SUBHEADER
DROP LINE
BRANCH LINE
RISER
DISCHARGE PIPE
1
2
3
4
5
6
7
8
9
10
11
12
14

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.

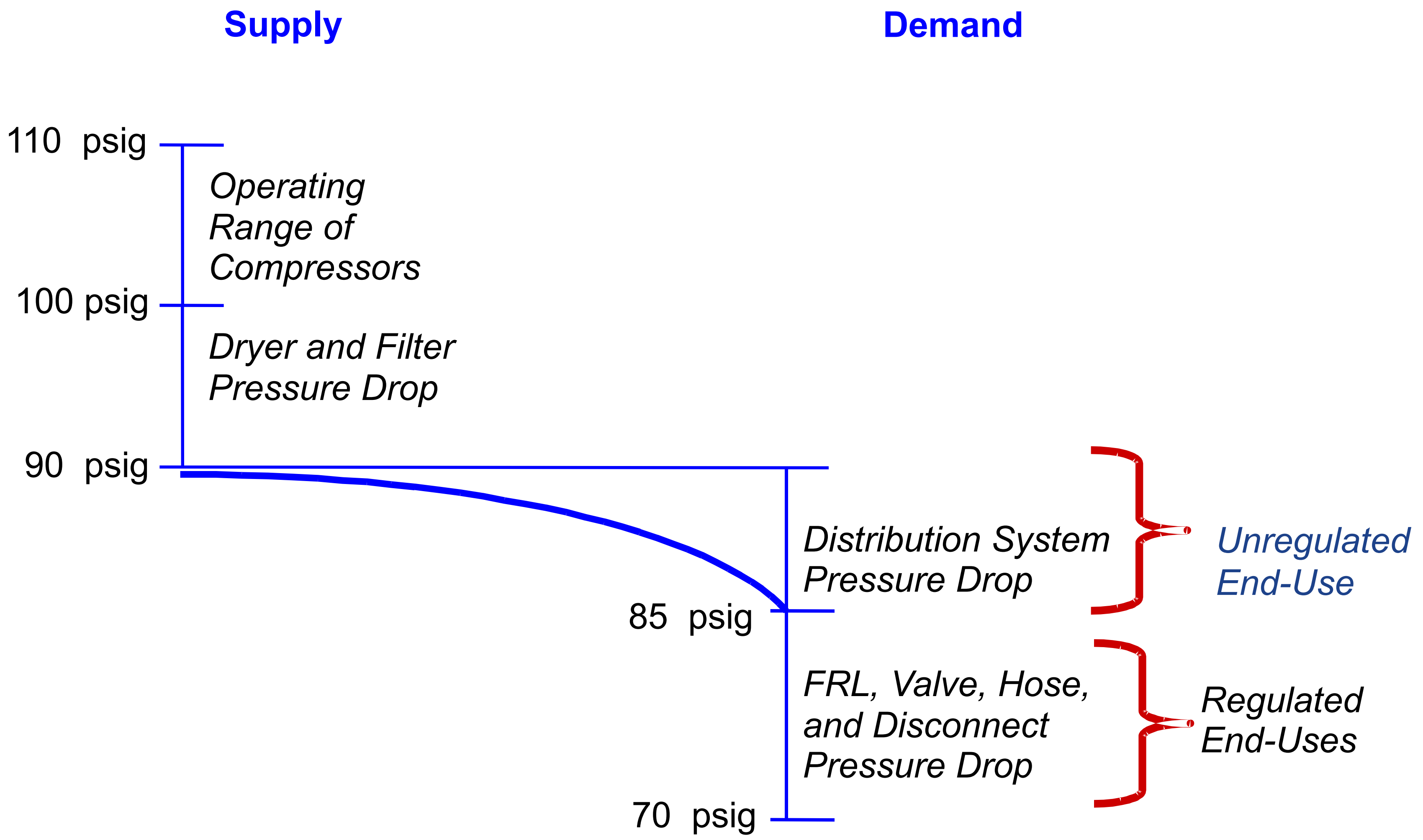
What's Wrong Here?

What's Wrong Here?

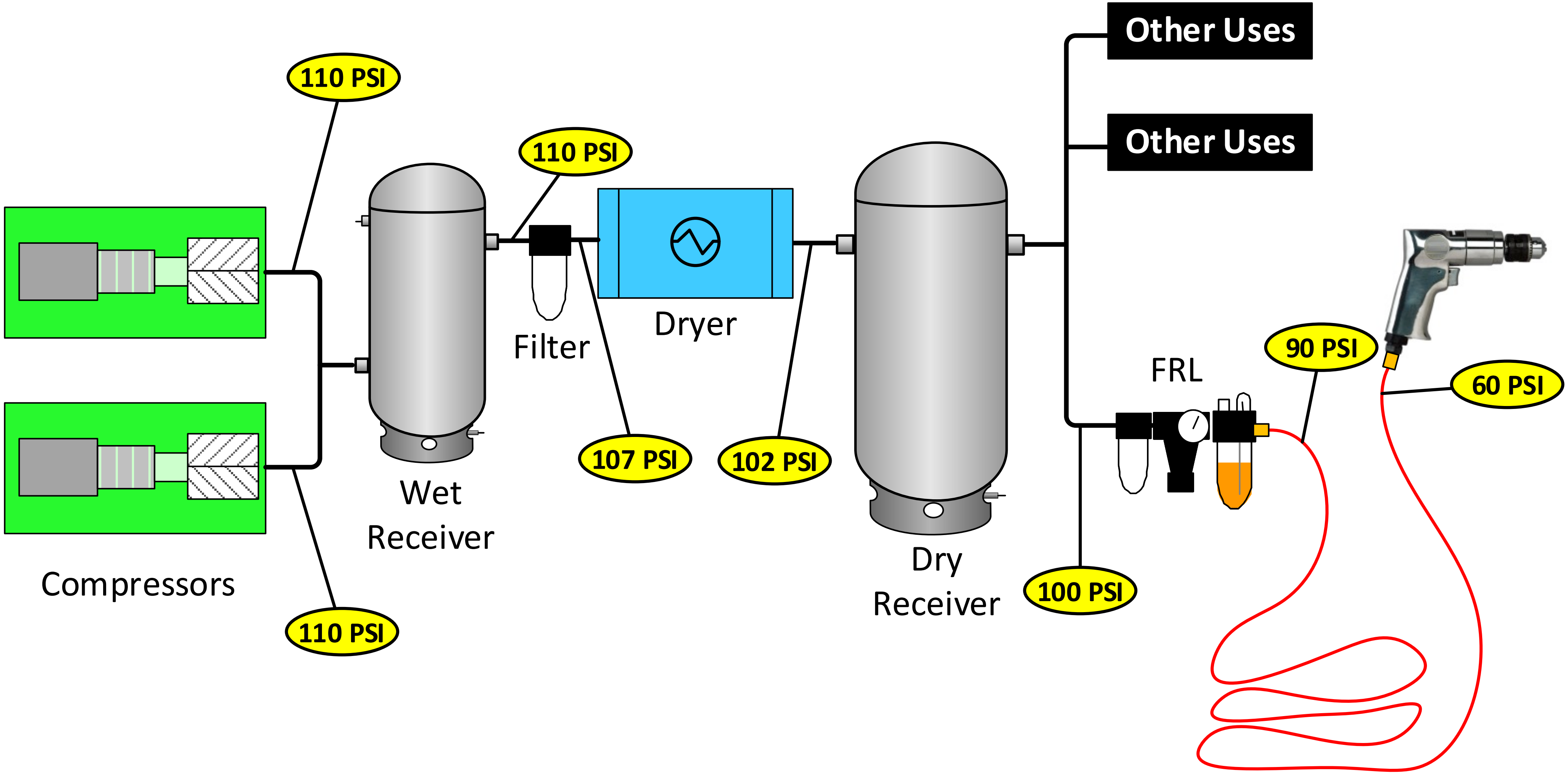
Pressure Profiles

- 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:
  - Inlet to compressor
  - Air/lubricant separator (if applicable)
  - Interstage on multi stage compressors
  - Aftercooler, air treatment equipment
  - Various points in the distribution system

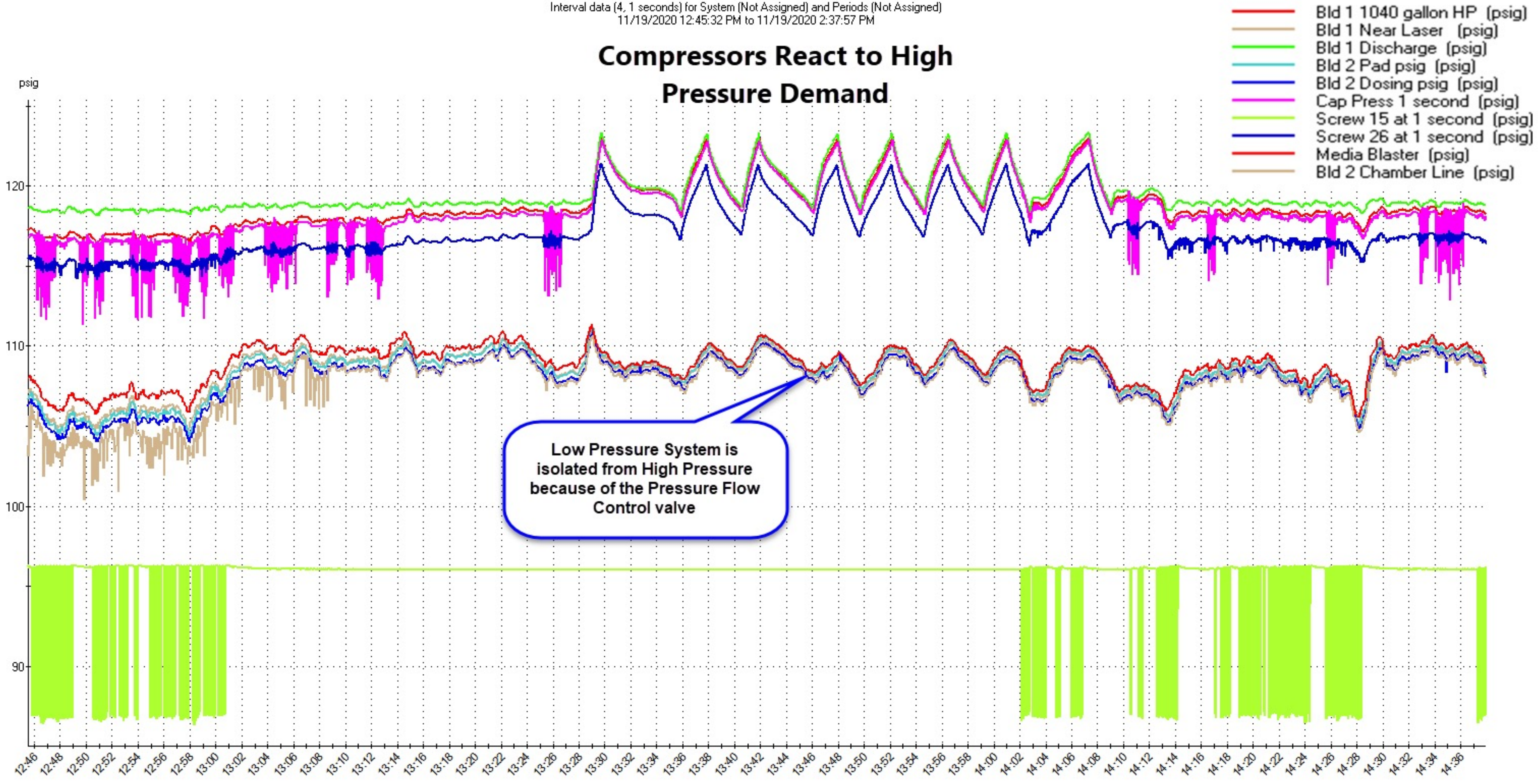
System Pressure Profile

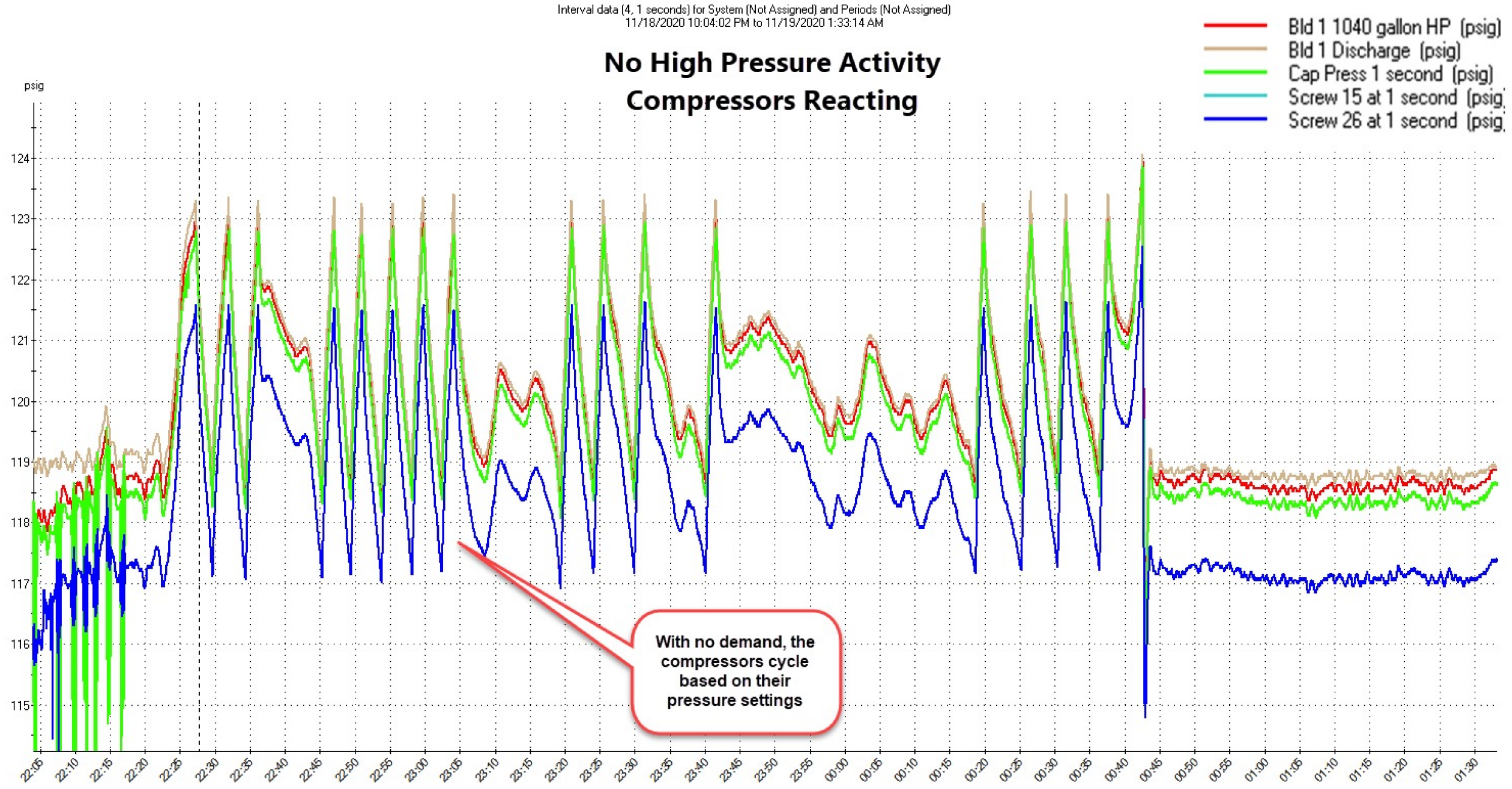


Developing a System Profile

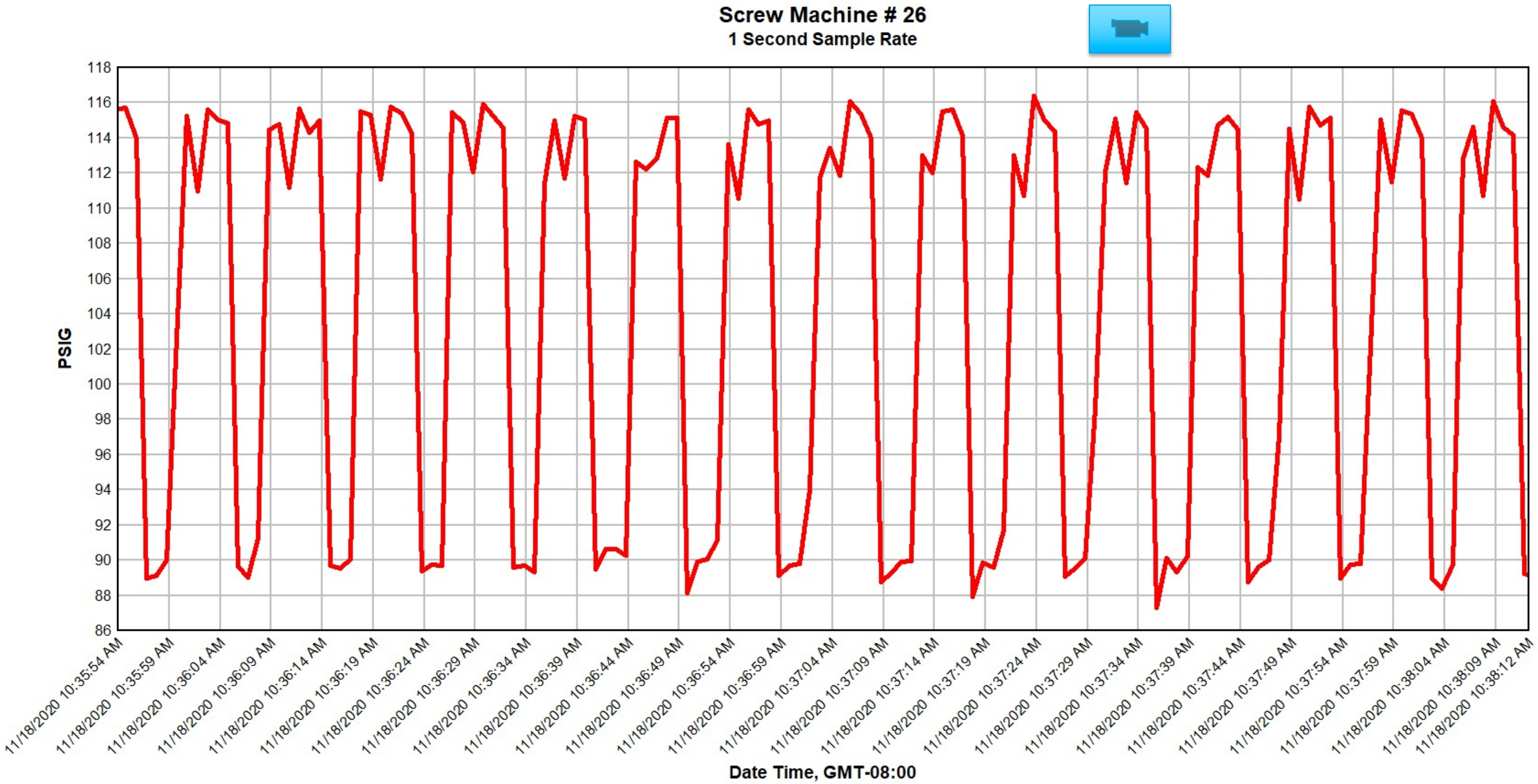


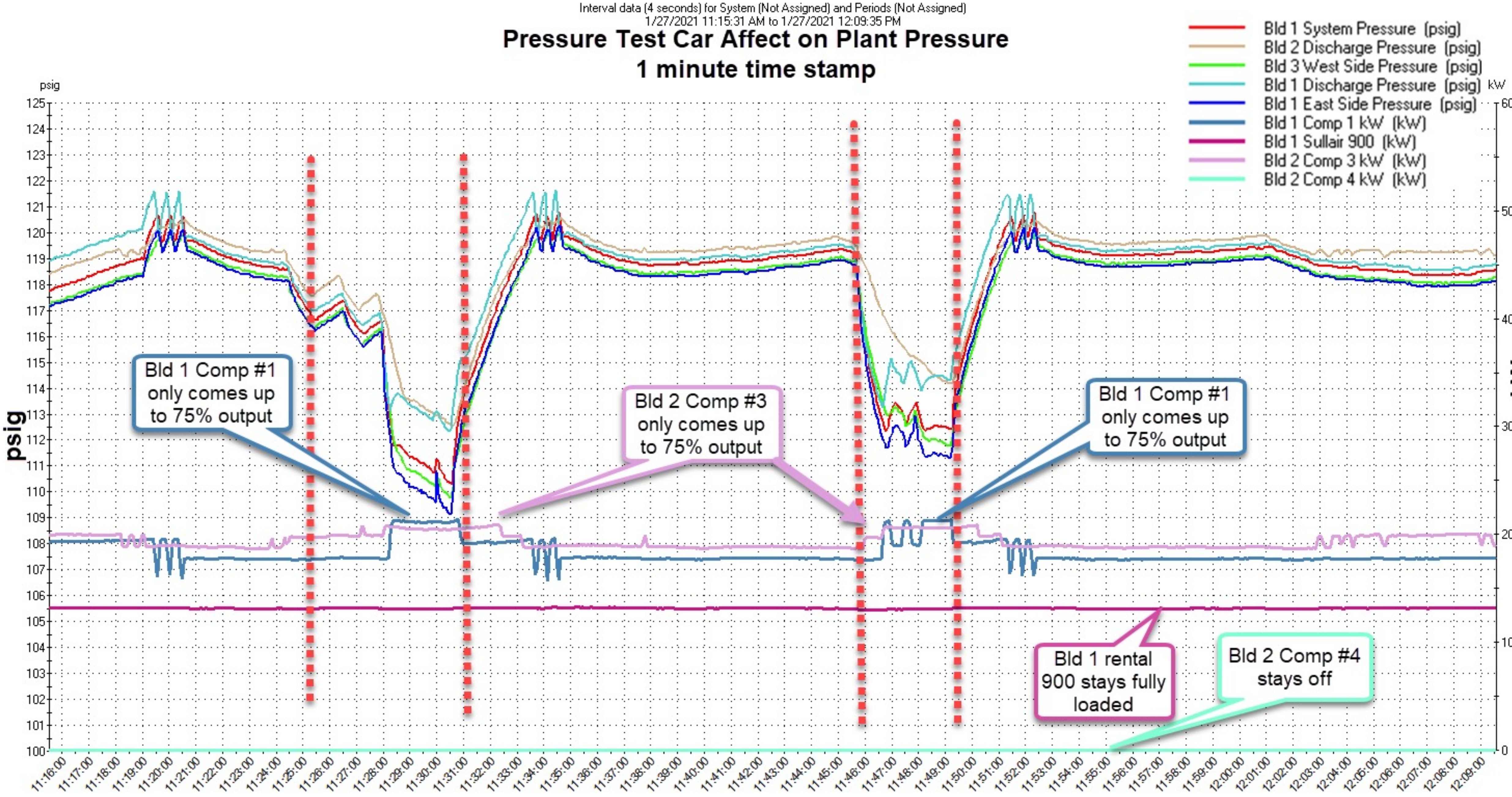
Compressors React to High Pressure Demand

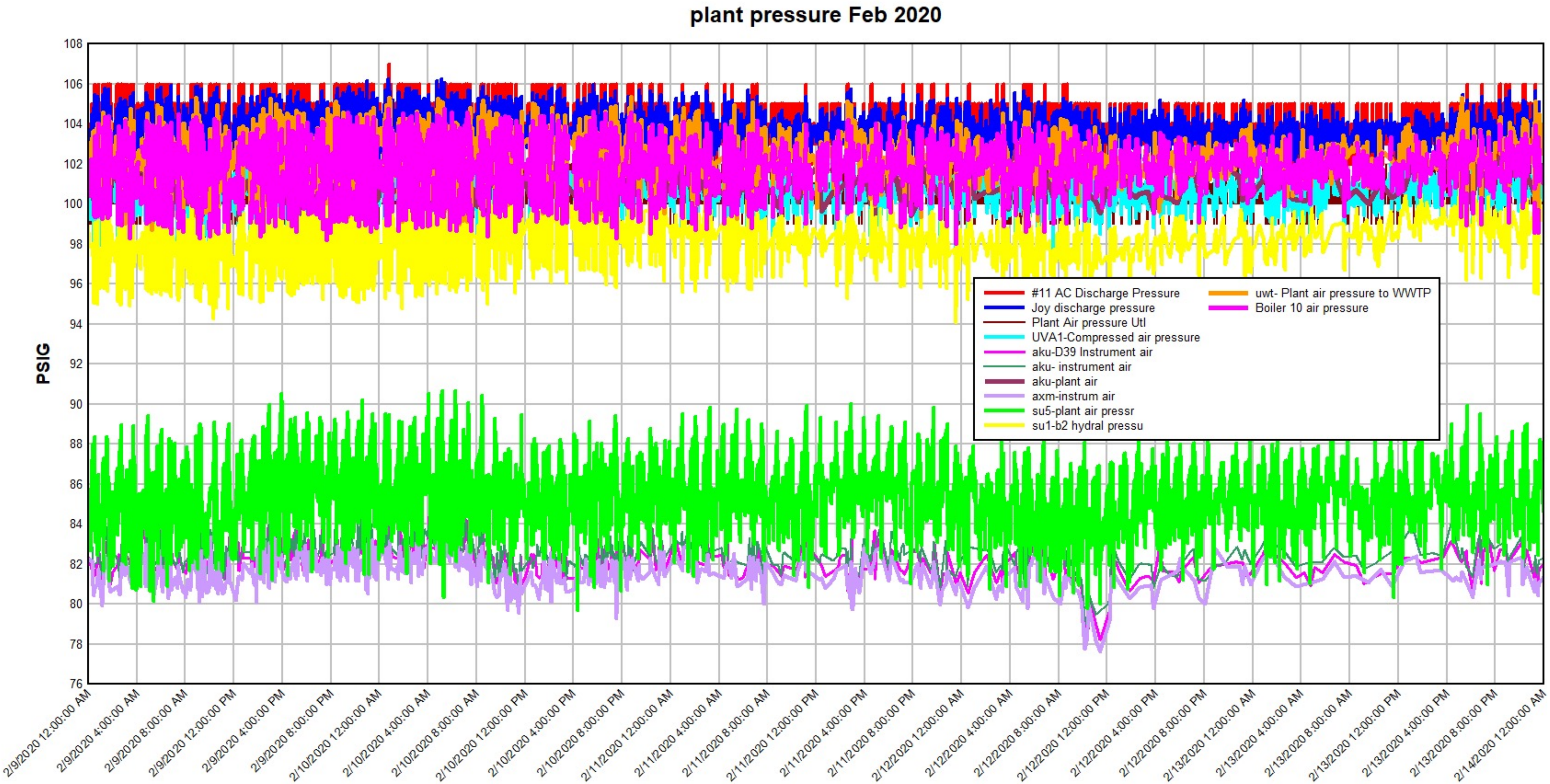




Interval data (4, 1 seconds) for System (Not Assigned) and Periods (Not Assigned)
11/18/2020 10:04:02 PM to 11/19/2020 1:33:14 AM
No High Pressure Activity
Compressors Reacting
psig
Bld 1 1040 gallon HP (psig)
Bld 1 Discharge (psig)
Cap Press 1 second (psig)
Screw 15 at 1 second (psig)
Screw 26 at 1 second (psig)
With no demand, the compressors cycle based on their pressure settings


Screw Machine # 26
1 Second Sample Rate
PSIG
Date Time, GMT-08:00
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


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
psig
kW
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)
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



plant pressure Feb 2020
PSIG
108
106
104
102
100
98
96
94
92
90
88
86
84
82
80
78
76
#11 AC Discharge Pressure
Joy discharge pressure
Plant Air pressure Utl
UVA1-Compressed air pressure
aku-D39 Instrument air
aku- instrument air
aku-plant air
axm-instrum air
su5-plant air pressr
su1-b2 hydral pressu
uwt- Plant air pressure to WWTP
Boiler 10 air pressure
2/9/2020 12:00:00 AM
2/9/2020 4:00:00 AM
2/9/2020 8:00:00 AM
2/9/2020 12:00:00 PM
2/9/2020 4:00:00 PM
2/9/2020 8:00:00 PM
2/10/2020 12:00:00 AM
2/10/2020 4:00:00 AM
2/10/2020 8:00:00 AM
2/10/2020 12:00:00 PM
2/10/2020 4:00:00 PM
2/10/2020 8:00:00 PM
2/11/2020 12:00:00 AM
2/11/2020 4:00:00 AM
2/11/2020 8:00:00 AM
2/11/2020 12:00:00 PM
2/11/2020 4:00:00 PM
2/11/2020 8:00:00 PM
2/12/2020 12:00:00 AM
2/12/2020 4:00:00 AM
2/12/2020 8:00:00 AM
2/12/2020 12:00:00 PM
2/12/2020 4:00:00 PM
2/12/2020 8:00:00 PM
2/13/2020 12:00:00 AM
2/13/2020 4:00:00 AM
2/13/2020 8:00:00 AM
2/13/2020 12:00:00 PM
2/13/2020 4:00:00 PM
2/13/2020 8:00:00 PM
2/14/2020 12:00:00 AM

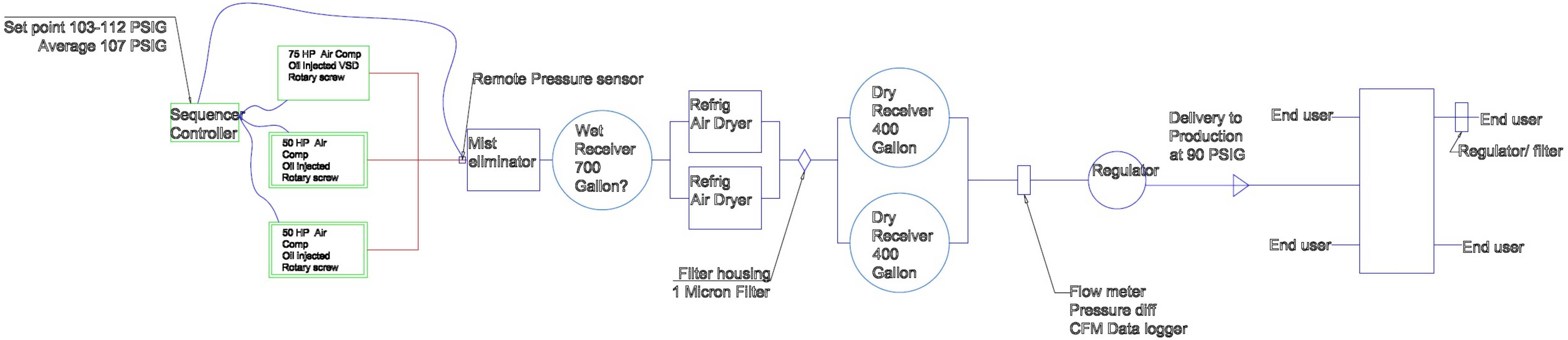
Summary

- 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

Block Diagrams



Next Week - The Demand Side

- 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?