Better Plants
U.S. DEPARTMENT OF ENERGY

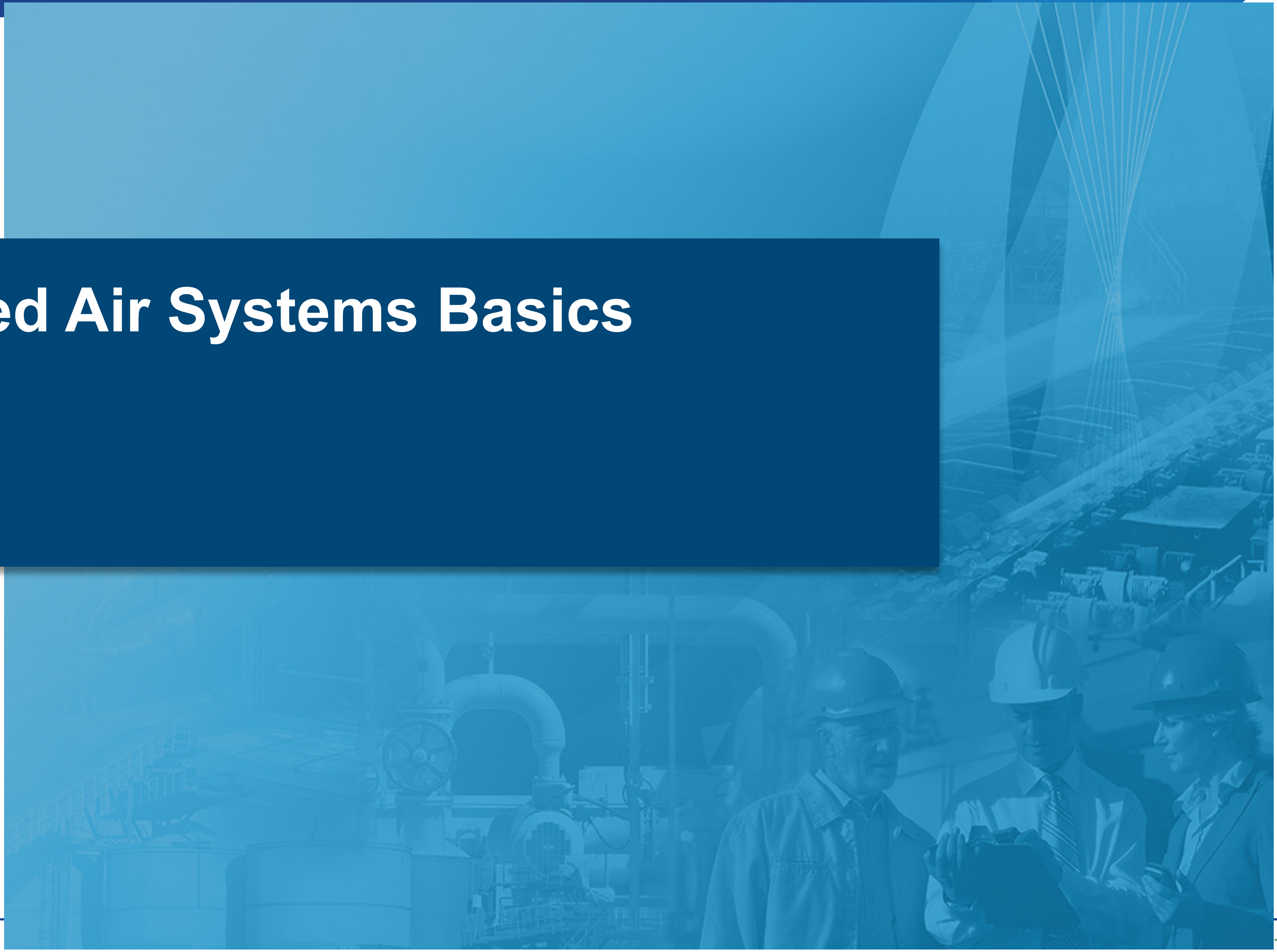
In-Plant Trainings

8 – Session Virtual Platform

U.S. DEPARTMENT OF ENERGY

Week 1

Compressed Air Systems Basics



What is an In-Plant Training?

- In-Plant Trainings (INPLTs) are system-specific workshops led by Better Plants experts that train participants on how to identify, implement, and replicate energy-saving projects.
- The goal is to help manufacturing plants reduce energy consumption and become more efficient.
- During Pre-Covid days, Better Plant partners hosted an on-site, three-day training at one of their facilities, and invited others to attend.
- Due to the challenges from Covid, we will conduct this Training virtually, requiring eight (8) 2-hour online training sessions.
- Through Better Plants:
  - Industrial organizations commit to efficiency goals
  - Receive technical assistance and national recognition for their achievements

The Facilitator

- Frank Moskowitz – Draw Professional Services
  - Compressed Air Challenge Instructor for Fundamentals & Advanced Workshop as well as an Instructor for AIRMaster+ Qualified Specialist Workshop
  - DOE Compressed Air System Energy Expert
    - In-Plant Training & Save Energy Now Assessments
  - CAGI – Certified Compressed Air System Specialist
  - Co-Vice Chair ASME EA-4 Energy Assessment for Compressed Air Systems
  - International Standards Organization (ISO) Technical Advisory Group Member
    - Air compressors and compressed air systems energy manageme
  - Contact Information:
    - fmoskowitz@drawproservices.com
    - 602-809-4195

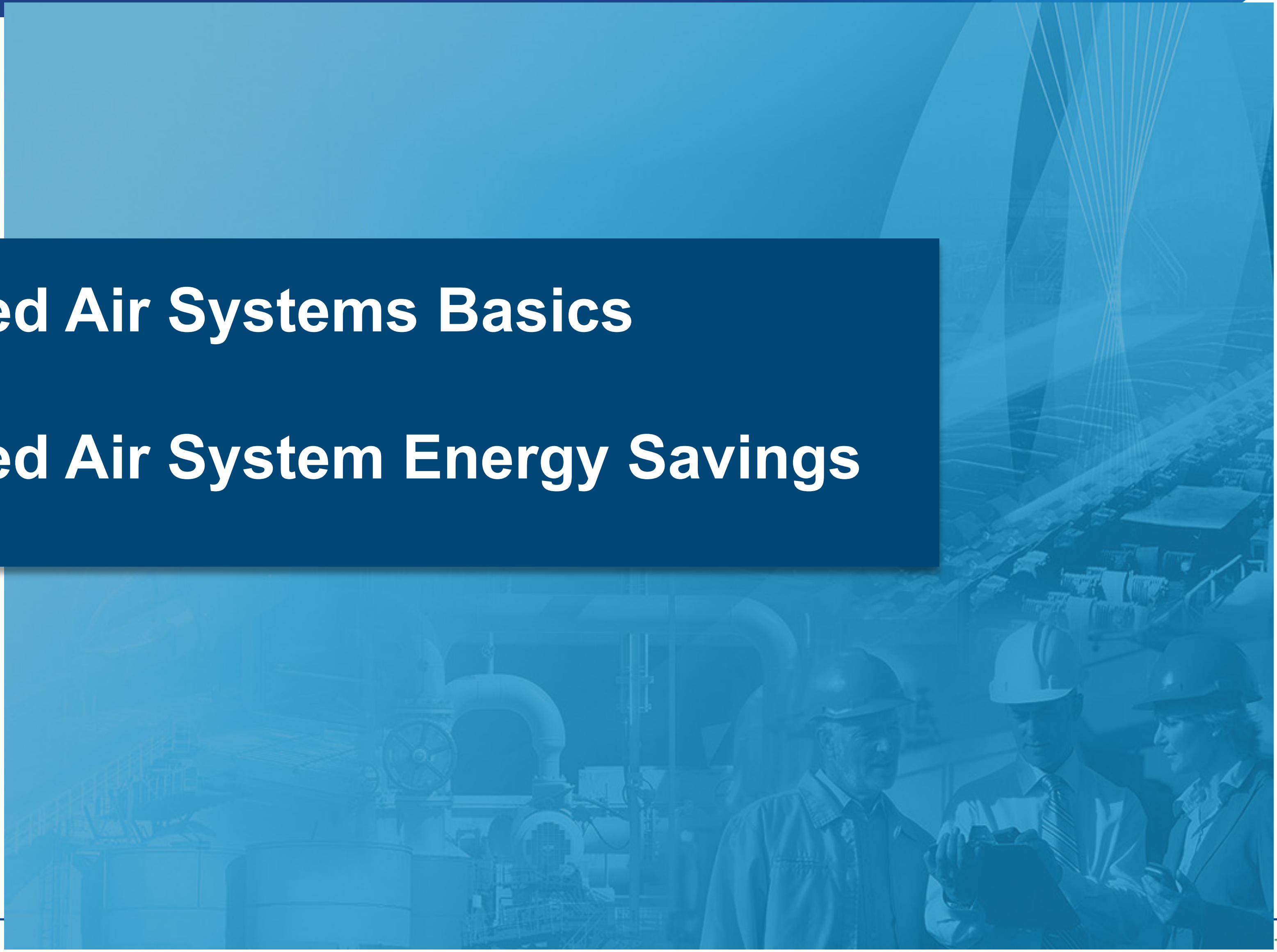
Assessment Process

- **Prepare**
  - Learn how to gather information
- **Participate**
  - Find out what to expect and how to make the most of the assessment through examples, quizzes, homework.
- **Implement**
  - Take action on the opportunities identified in this training and start saving energy.
- **Communicate**
  - Share the success from your assessment with other plants and multiply benefits throughout your company

Agenda

- Week 1 – Compressed Air Systems Basics
  - Pre-screening process for an Assessment
  - Conducting an Assessment
- Week 2 – Compressor Types
  - Maintenance
  - Compressor Room Ventilation
- Week 3 – Compressor Controls
  - DOE Software Tools
- Week 4 - Distribution System
  - Pipe Sizing
  - Proper Layout
- Week 5 – Demand Side
  - Waste or Productive?
- Week 6 - System Volume vs Storage
  - Math behind correct sizing
- Week 7 – Air Treatment
  - Dryer Types
- Week 8 – Wrap-up
  - What are your savings?

Week 1

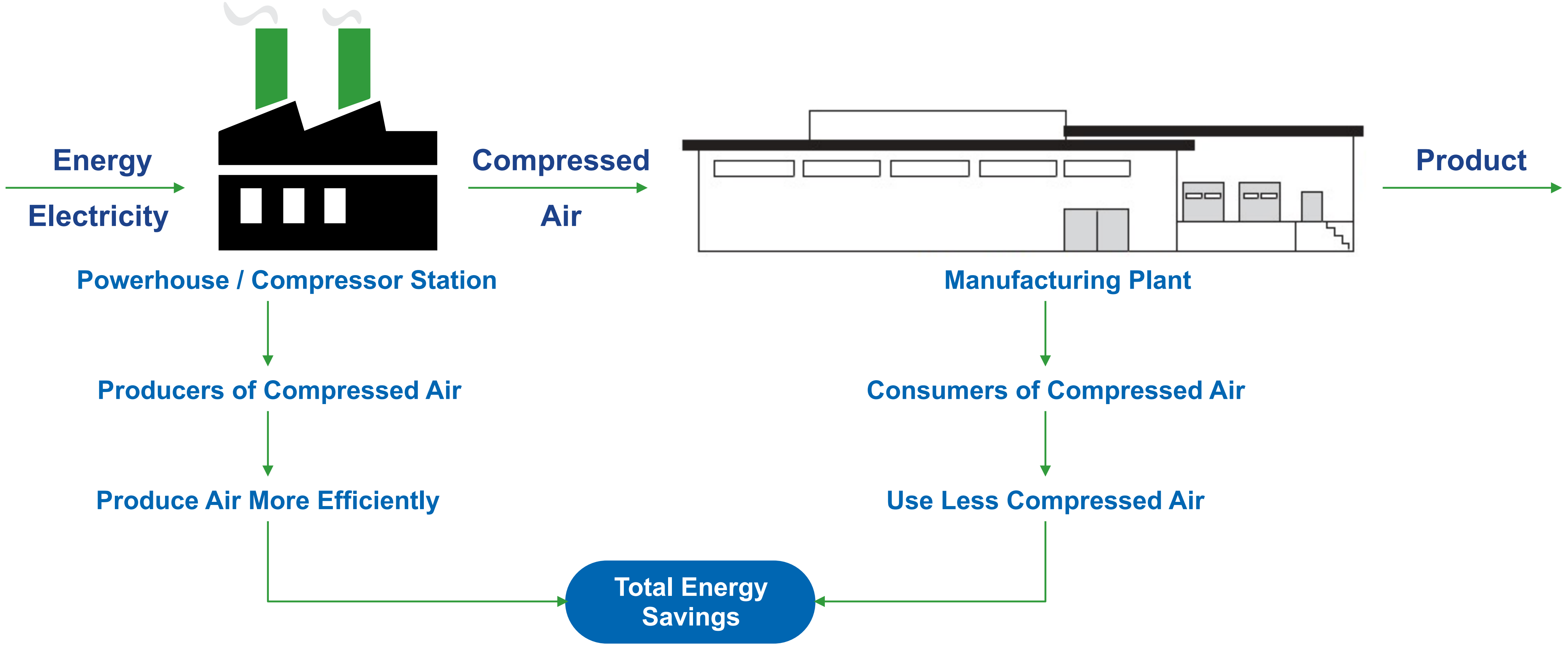


Compressed Air Systems Basics

Compressed Air System Energy Savings

Compressed Air Systems Approach
plant efficiency: energy >> product

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.



Look from the System Level Approach

Market research continues to make it clear that the majority of compressed air systems in use today are inefficient and because of this, often limit their own productivity.

The value trapped in poorly designed and operated air systems in the U.S. markets alone are estimated to range from a low of $1 billion to as much $3.2 billion in energy costs alone.

What Are My Goals?

Produce more efficiently

- Improve Compressor Control
- Discharge Pressure?

Use less compressed air

- Reduce Air Demand (Leaks, Inappropriate Uses, etc…)
- What is the Pressure at End Uses
- How does compressed air support production?

Understanding how compressed air is used is the single most important step to effective management.

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.

Why Should You be Interested in Optimizing?

- Because compressed air optimization will have a huge impact on your bottom line.
- Compressed Air accounts for 10%-15% (at a minimum) of a company's electrical costs.

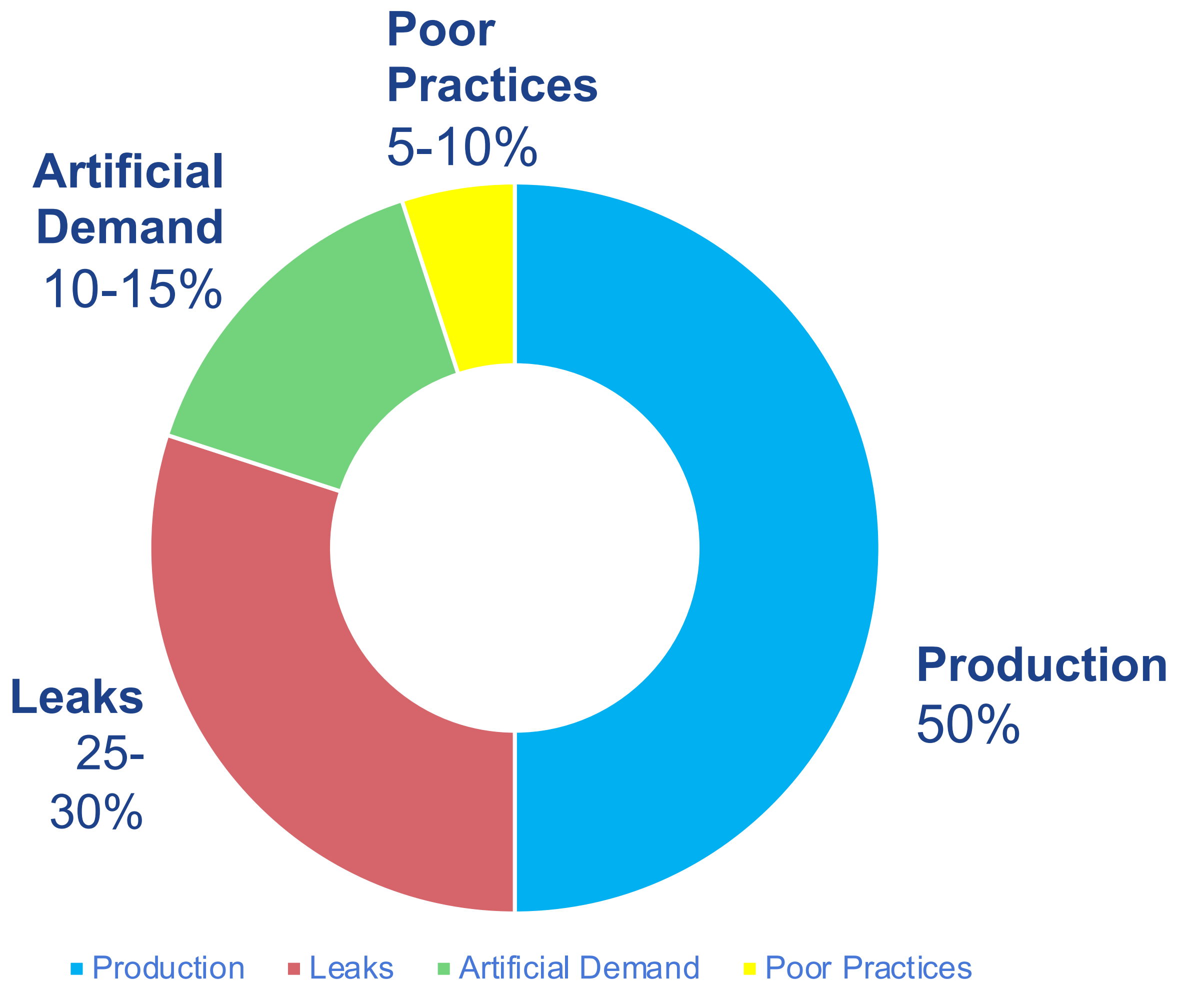
Compressed Air Versus Other Energy Sources

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

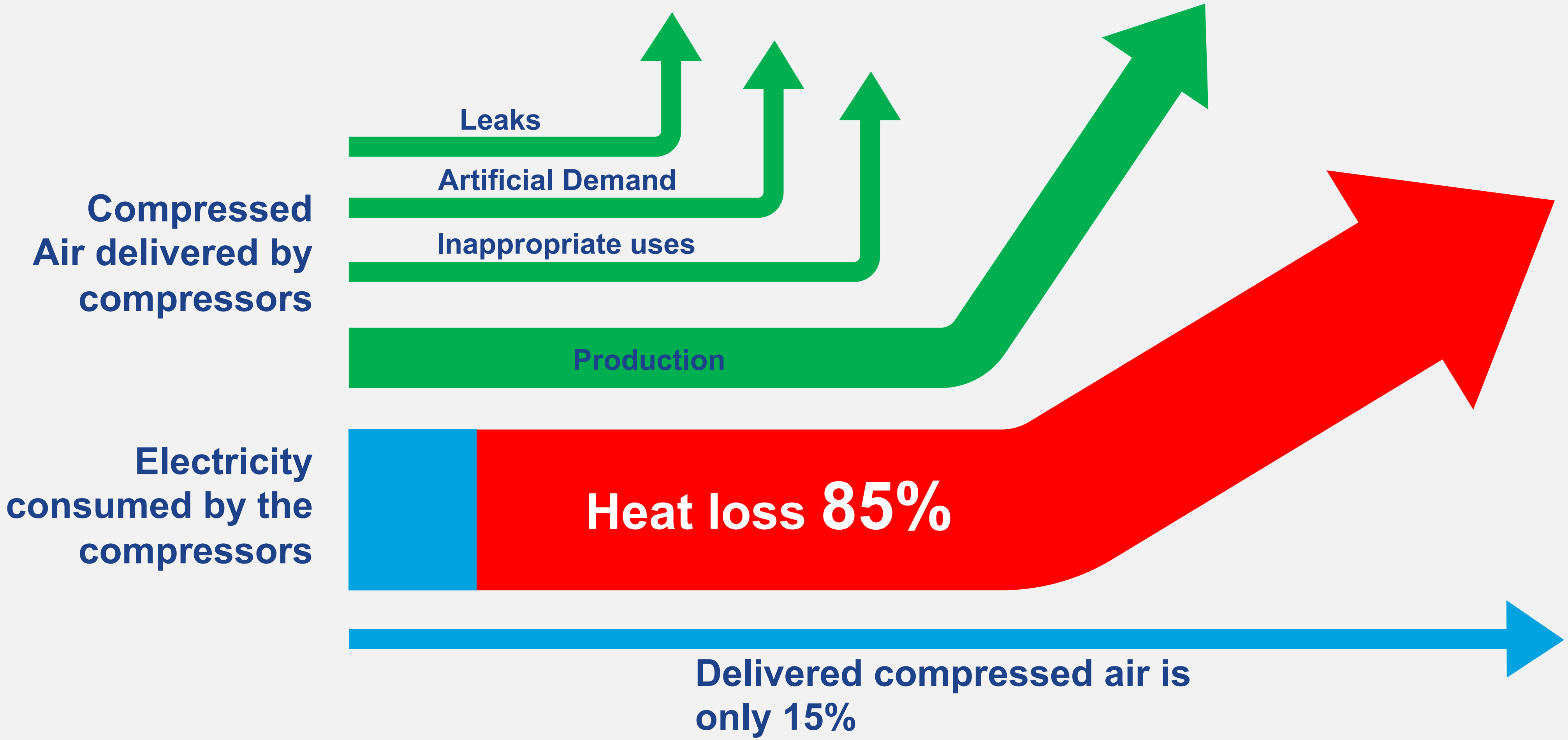
- You may be surprised, in most industrial plants, only 50% of the compressed air generated supplies productive air use.
- The other 50% is consumed by various losses.
- The losses are

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

Where does the air go?



Not very efficient!



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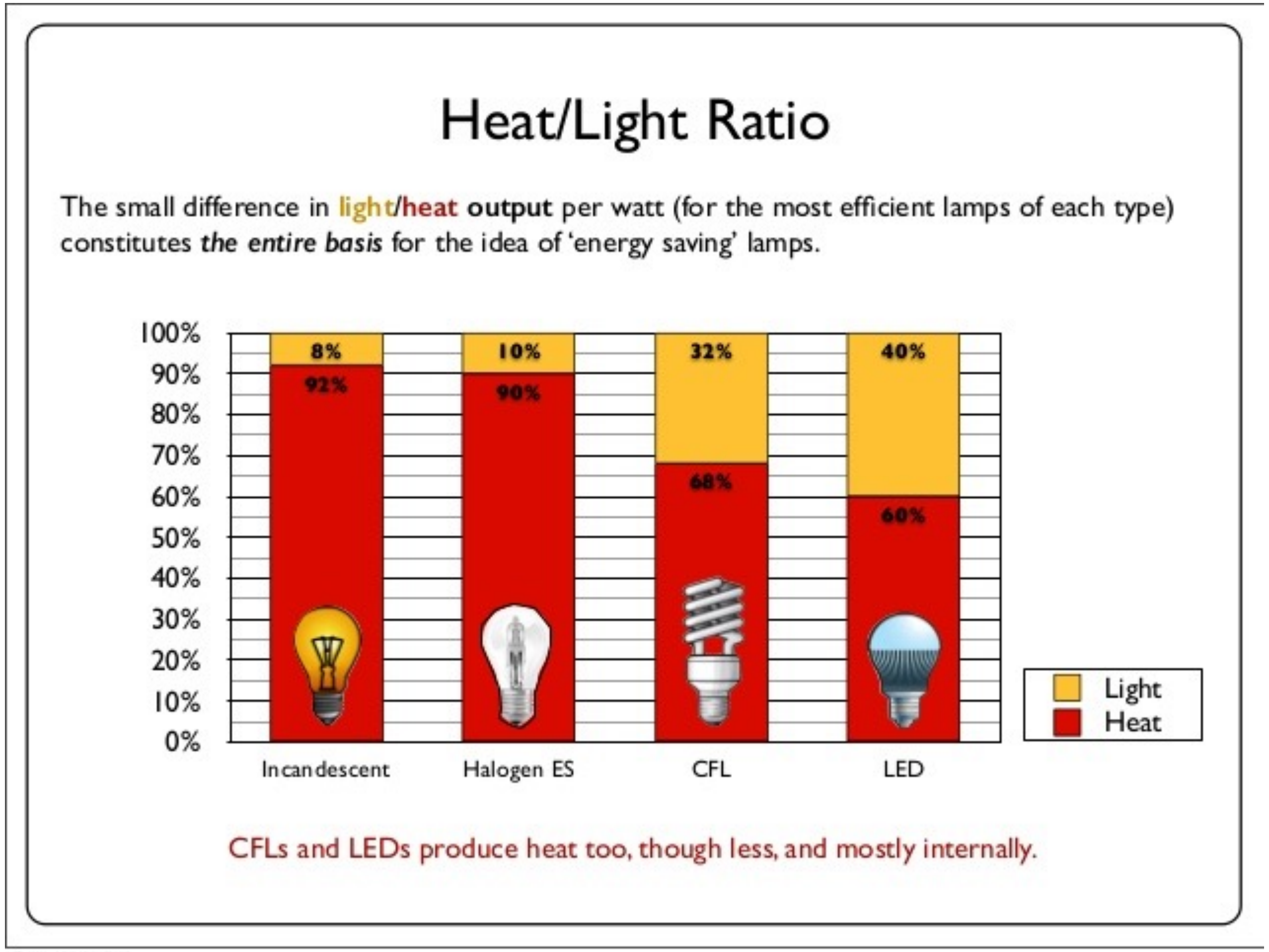

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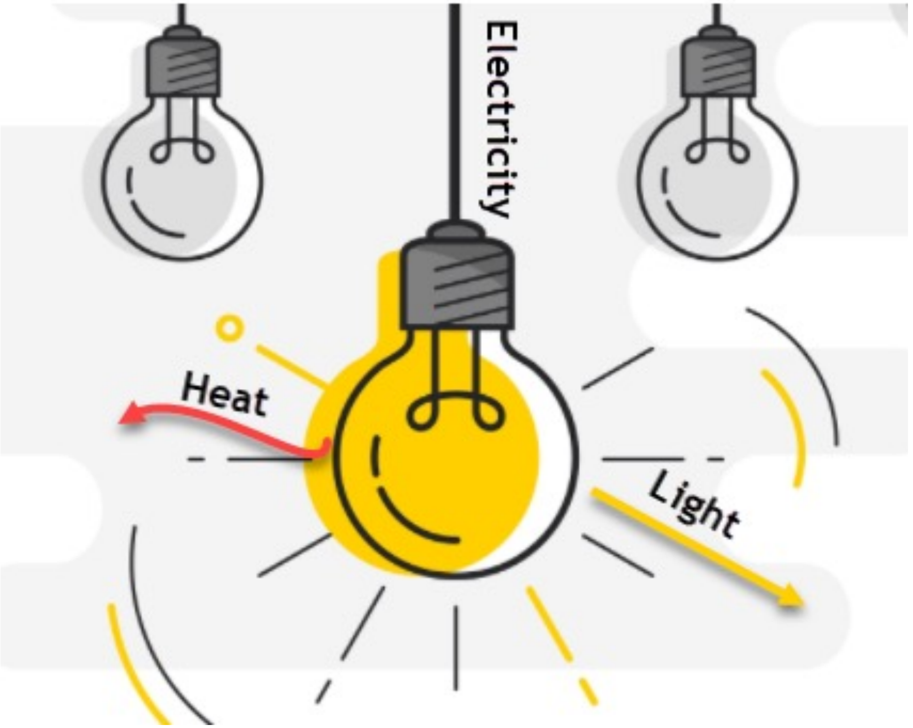
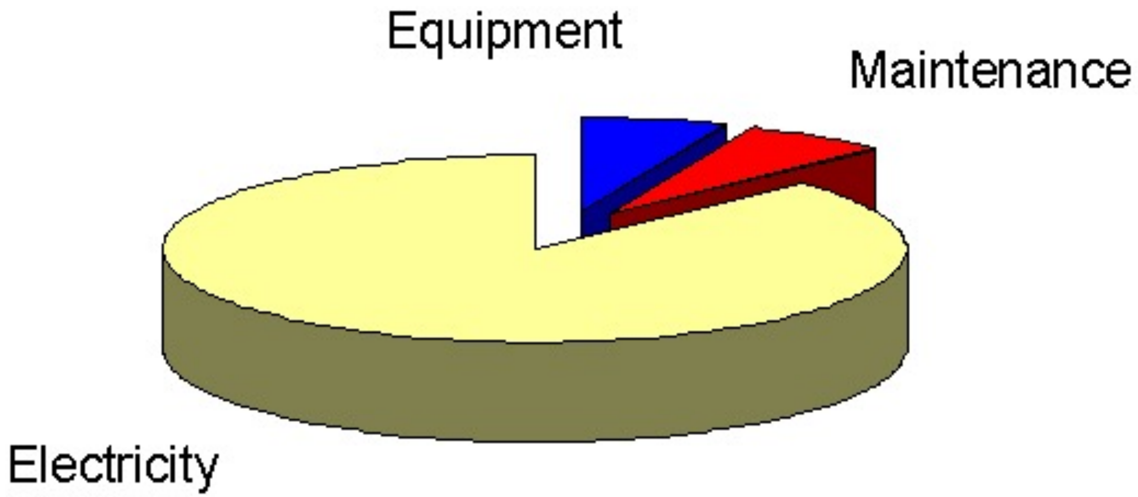


Compressed Air Systems
Total Cost of Ownership

Equipment cost and maintenance cost represent only a small part of the total cost of operating a compressed air system.

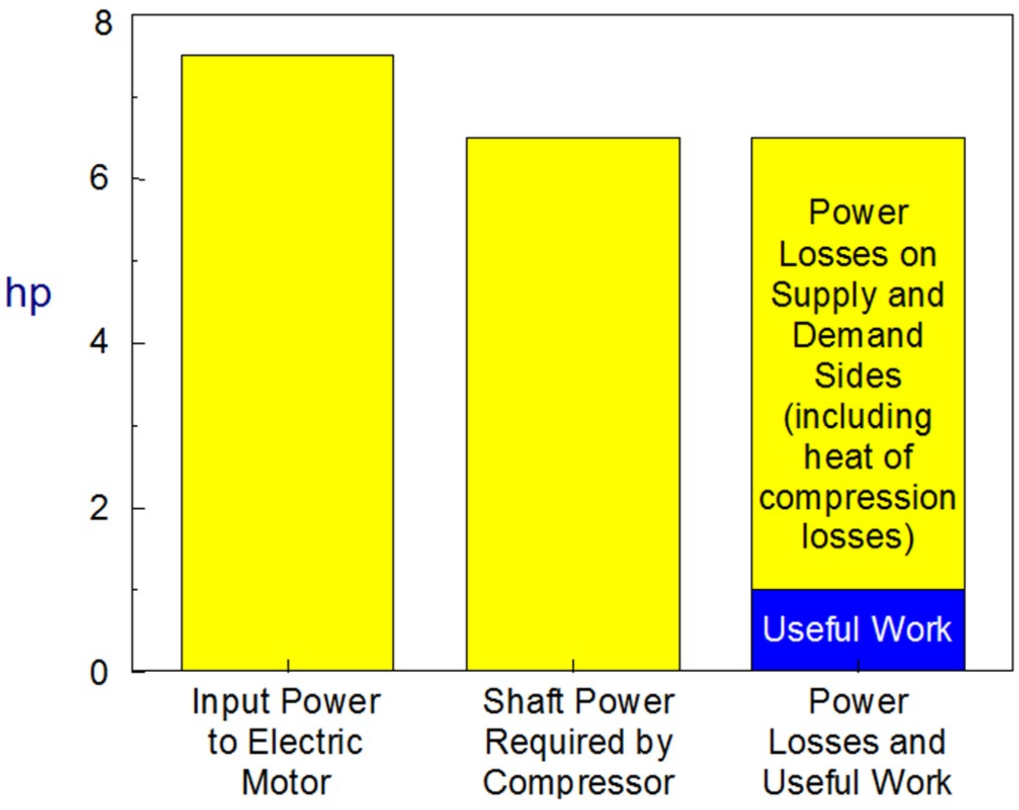
Electrical cost usually exceeds 75% of the total operating expense.



Source: Compressed Air Challenge®

Compressed Air Versus Other Energy Sources

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



What Measurements Should I Record?

- Produce more efficiently
  - Improve Compressor Control
  - Discharge Pressure?
- Use less compressed air
  - Reduce Air Demand (Leaks, Inappropriate Uses, etc…)
  - What is the Pressure at End Uses
  - How does compressed air support production?
    - Understanding how compressed air is used is the single most important step to effective management.

Are these some of your problems?

- ❑ We need to improve the reliability of the compressed air system in supporting manufacturing operations.
  - ❑ Yes 84% No 16%
- ❑ Production interruptions occur which are a result of poor compressed air system performance; we need to minimize production downtime.
  - ❑ Yes 53% No 47%
- ❑ Product quality is being affected by poor compressed air system performance; we need to reduce our scrap rate.
  - ❑ Yes 32% No 68%

Are these some of your problems?

- ❑ Our automated equipment which is operated by compressed air will not achieve its full capacity throughput: we need to know if this is a compressed air related issue.
  - ❑ Yes 53% No 47%
- ❑ We are expanding our production facility and consequently need to expand our existing compressed air system to accommodate the new flows; we want to know if our existing compressors can handle it.
  - ❑ Yes 42% No 58%
- ❑ We need to reduce air leakage and air demand to lower energy costs of operating our compressed air system.
  - ❑ Yes 100%

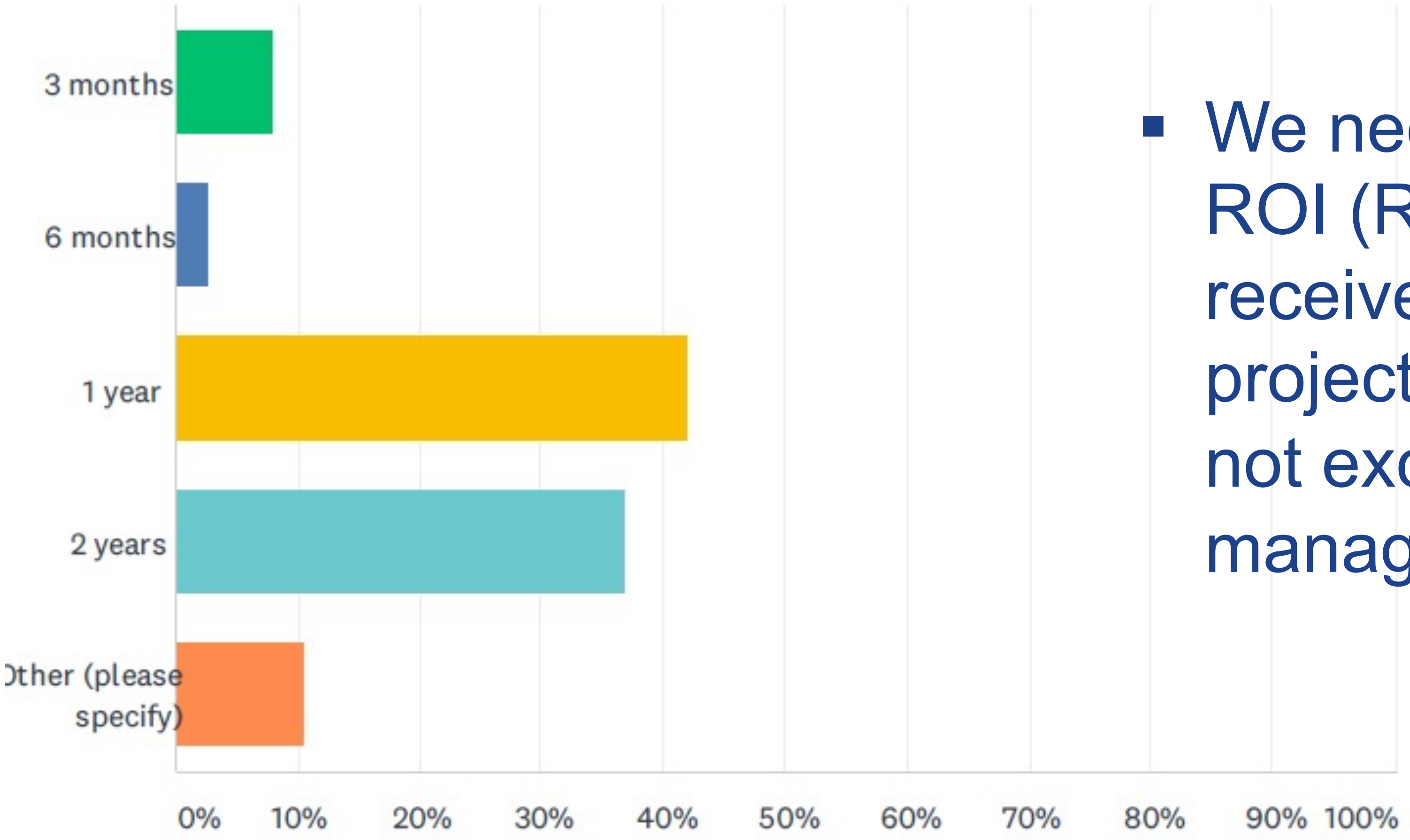
Are these some of your problems?

- We are replacing older compressors and want to investigate new more efficient type of compressors.
  - Yes 68% No 32%
- We have recently eliminated production equipment which used compressed air but the compressors are still using the same energy as before: we need to reduce the compressed air demand.
  - Yes 45% No 55%
- Low pressure occurs on a system wide basis and occasionally impacts production.
  - Yes 37% No 63%
- Low pressure occurs on a localized basis (point of use).
  - Yes 29% No 71%

Are these some of your problems?

- Pressure fluctuations frequently occur; we need to maintain more stable air pressure.
  - Yes 29% No 71%
- We have water in the compressed air lines; we need to maintain acceptable compressed air quality delivered to our end uses.
  - Yes 50% No 50%
- Oil in the compressed air lines is contaminating our end product.
  - Yes 16% No 84%

Final Question on ROI

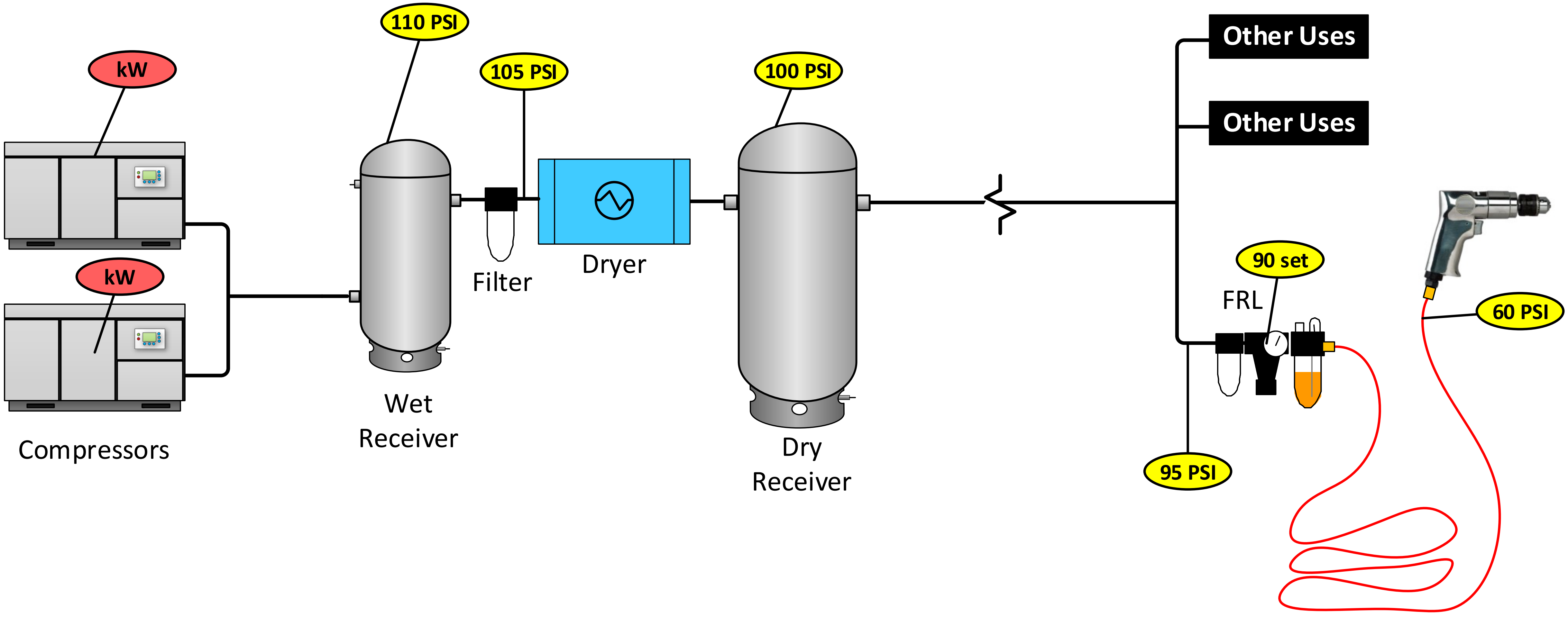


- We need to maintain effective ROI (Return On Investment) to receive funding for capital projects. Simple payback must not exceed _____ months for managements approval.

Assessment Check List

- The compressed air audit will include analysis of both the demand and supply side of the compressed air system. The assessment should include, but is not limited to the following:
  - Draw a Block Diagram which identifies components of the supply side, including age, type, and condition of compressors, filters, treatment equipment, drains, and compressor or system controls.
  - Determine major uses of compressed air.
  - Identify inappropriate use of compressed air and make recommendations for alternatives.
  - Identify usage reduction opportunities from leak management.
  - Identify any air quality problems.
  - Determine highest point of use pressure requirements and likelihood of whether requirements are valid.
  - Determine highest volume point of use and ability of existing system to respond.
  - Determine effectiveness of control strategies in meeting demand and make recommendations for improvement.

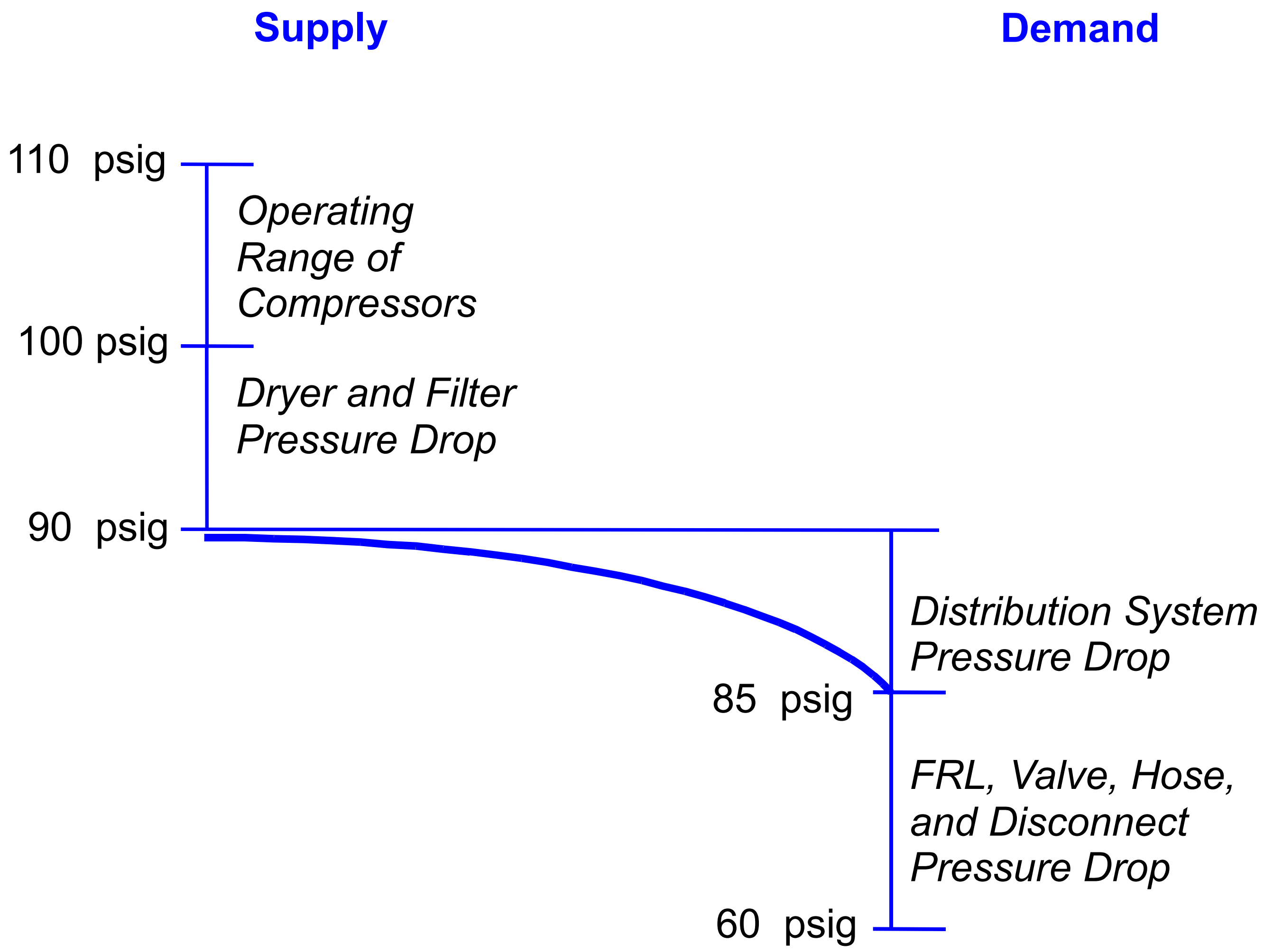
What Measurements Should I Record?



End Use Demand

End –use	Minimum Load	Average Load	Peak Load
Baghouses	0	15	300
Packing Lines	40	60	80
Transport 1	0	48	482
Transport 2	0	67	670
Transport 3	0	90	900
Crushing	160	150	160
Miscellaneous	150	150	150
Open Drainage	50	50	50
Artificial Demand	150	150	150
Leaks	850	850	850
Total	1,400	1,640	3,792

System Pressure Profile



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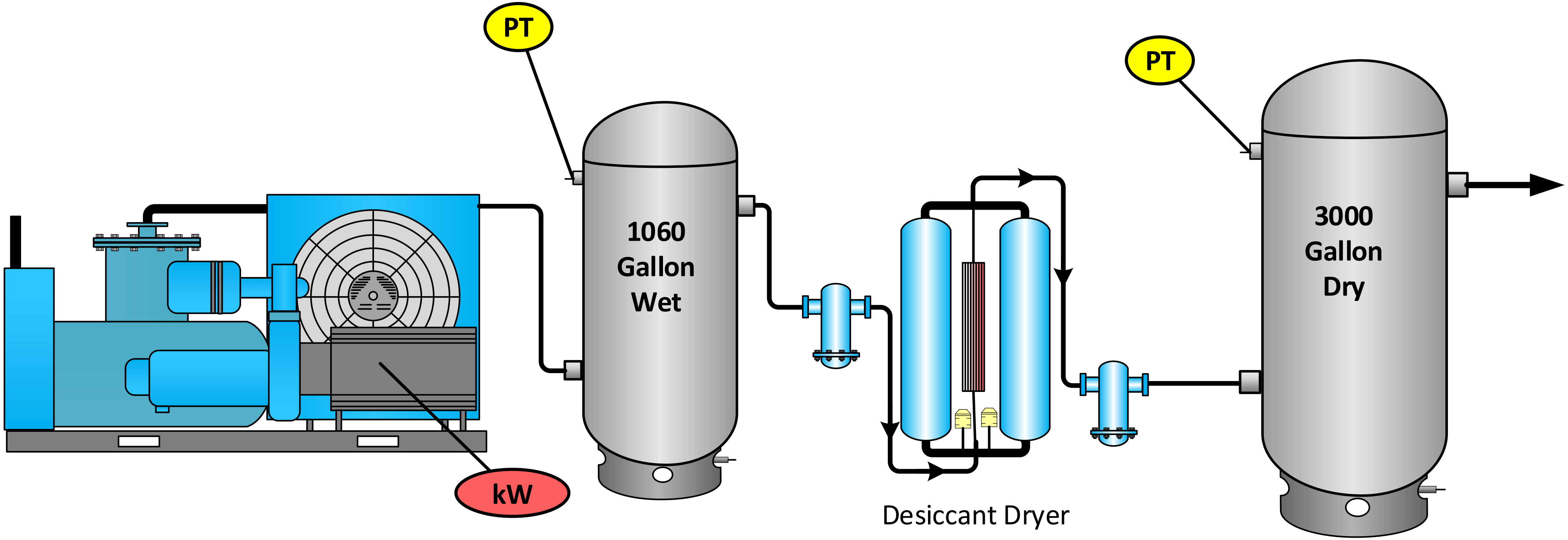

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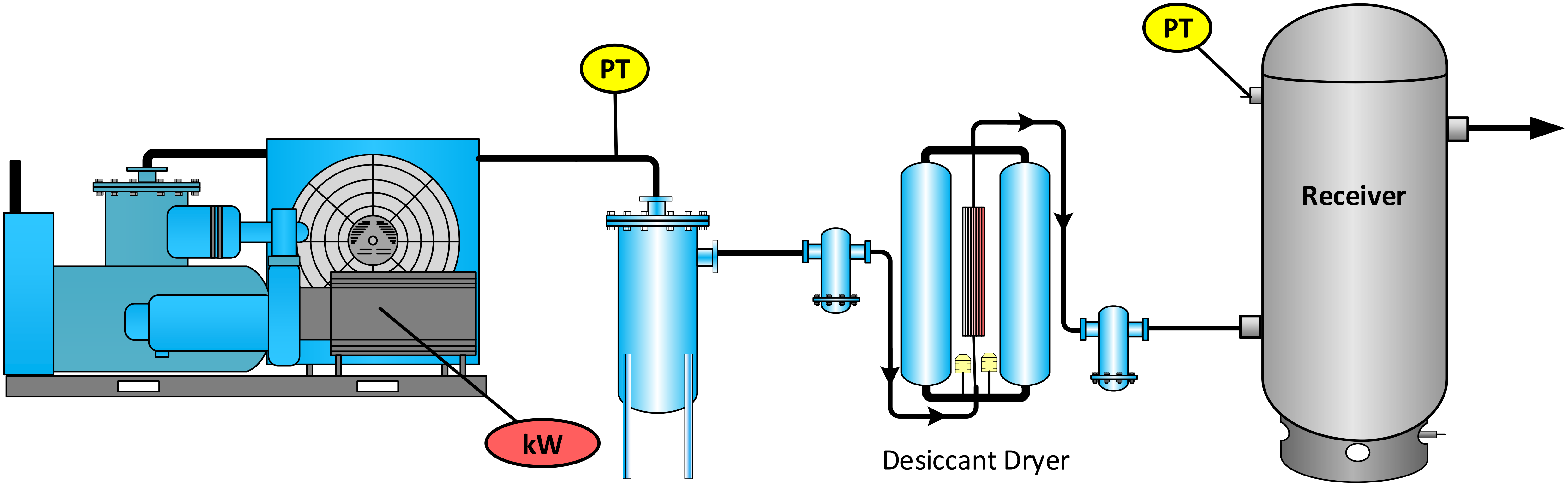

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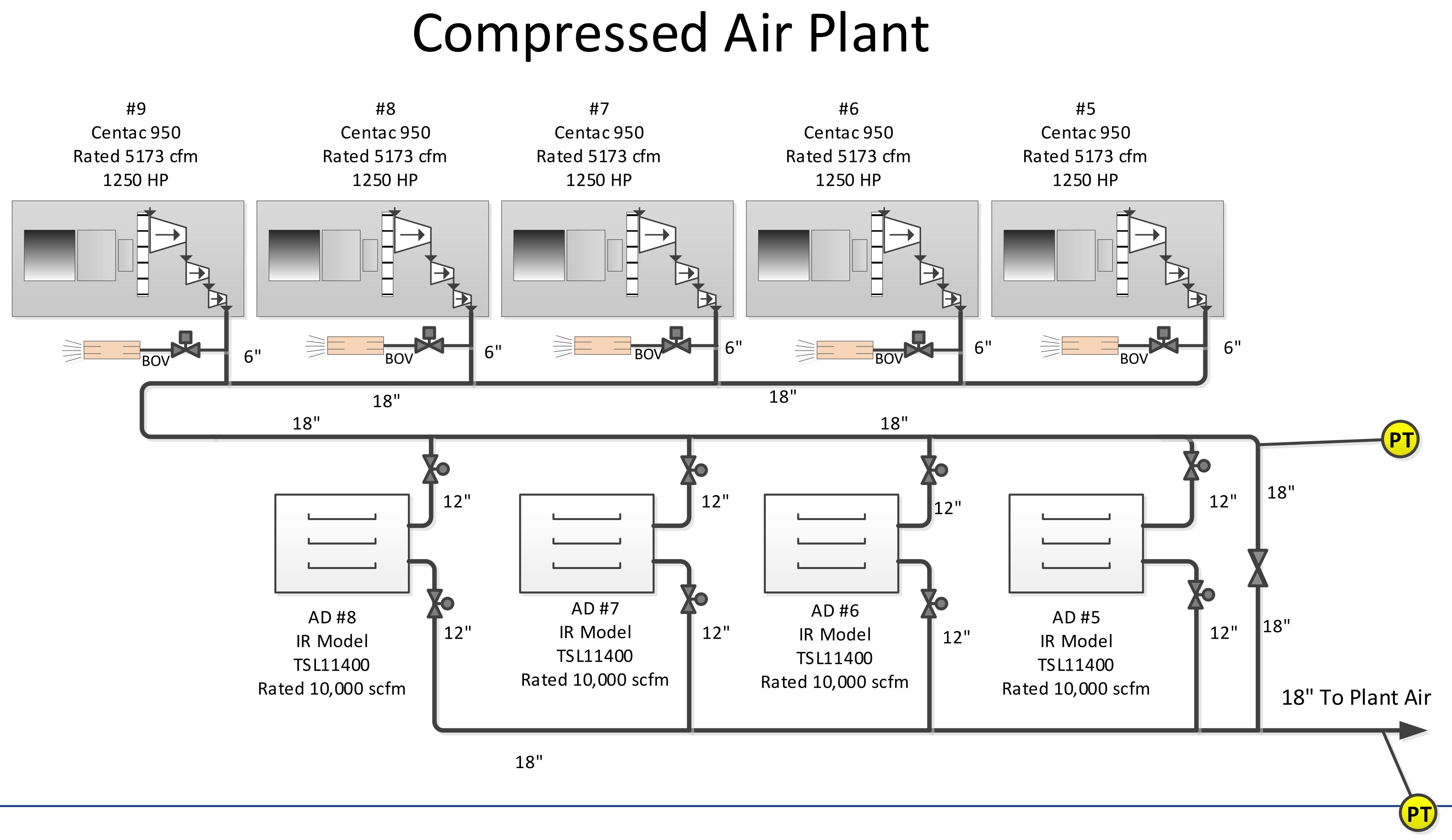

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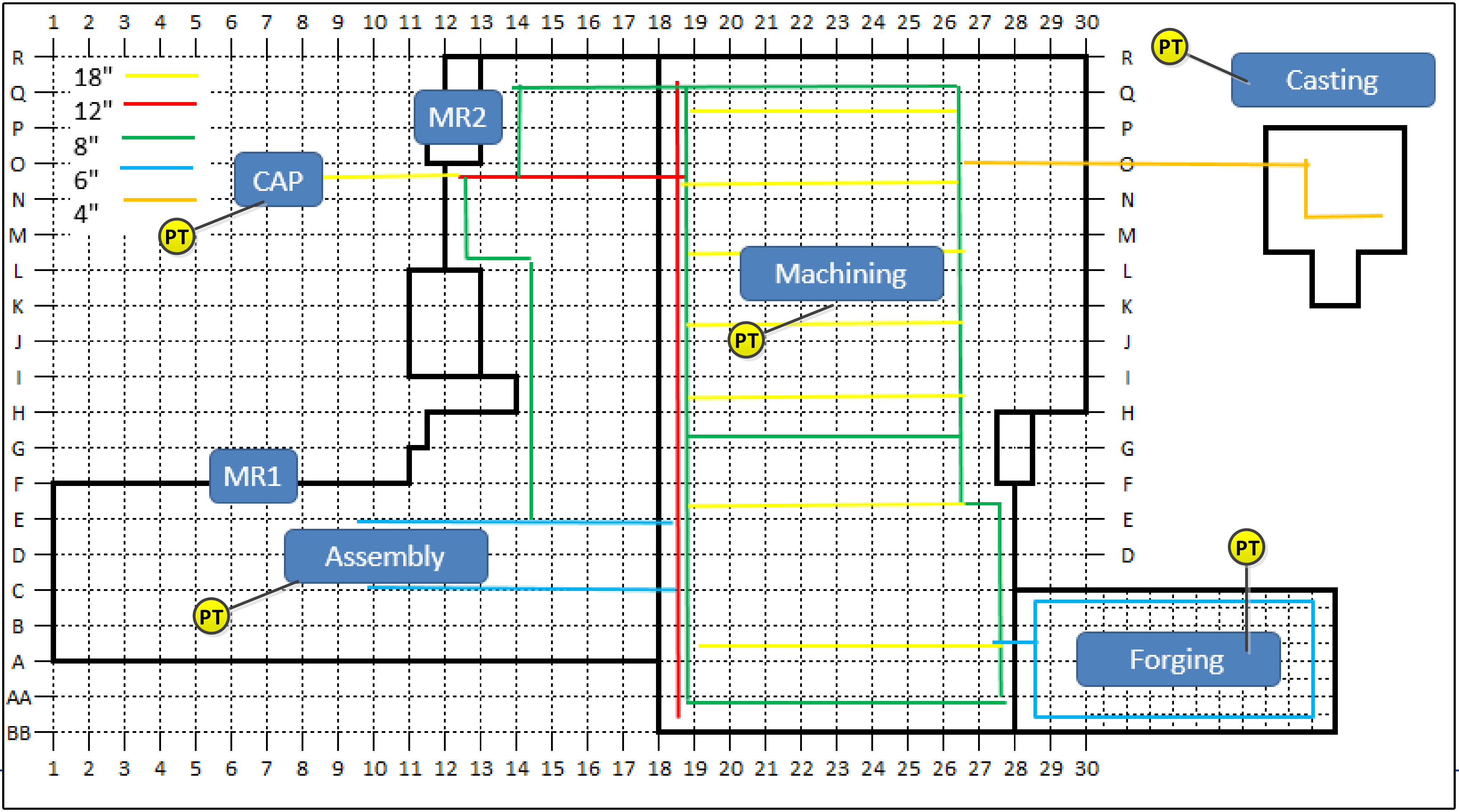
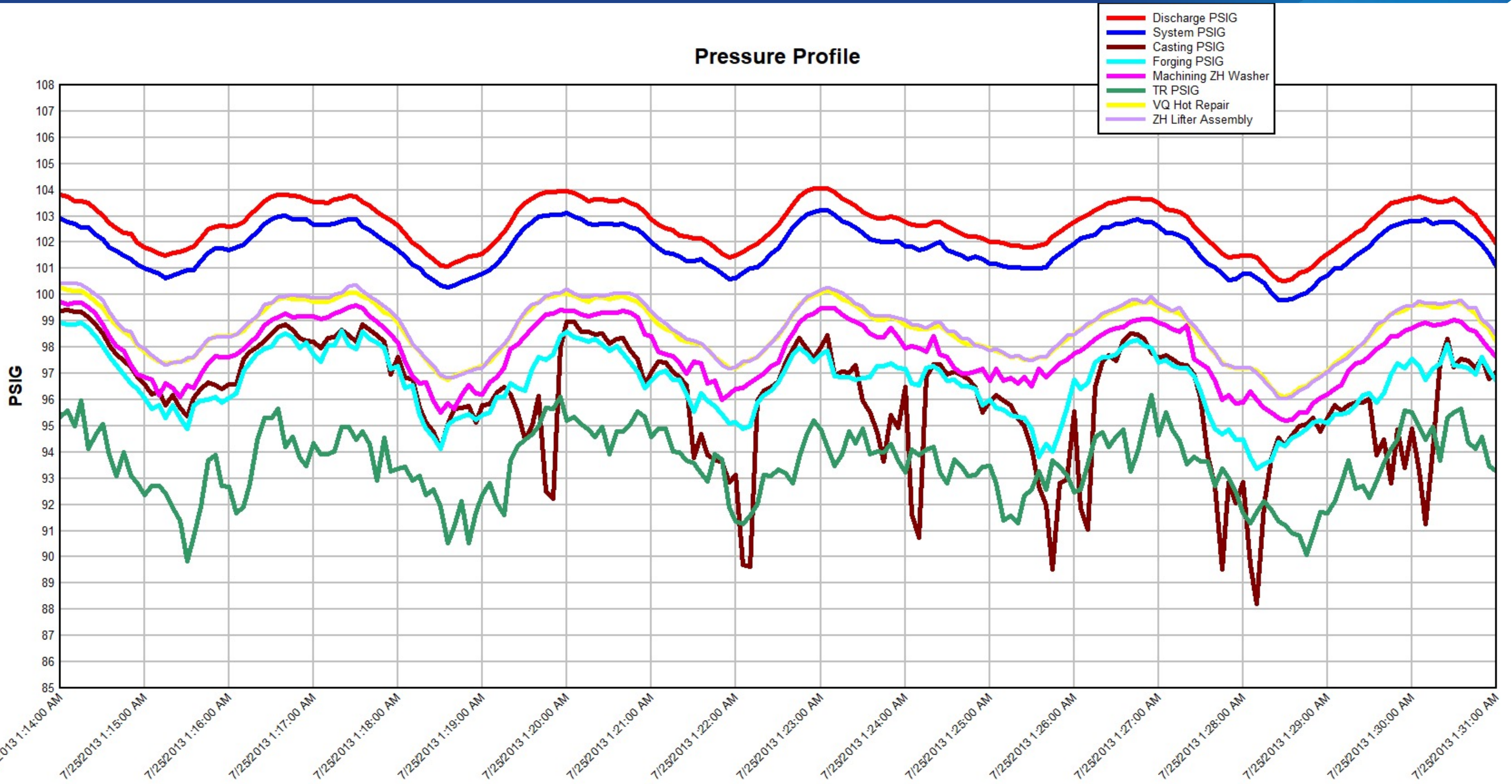
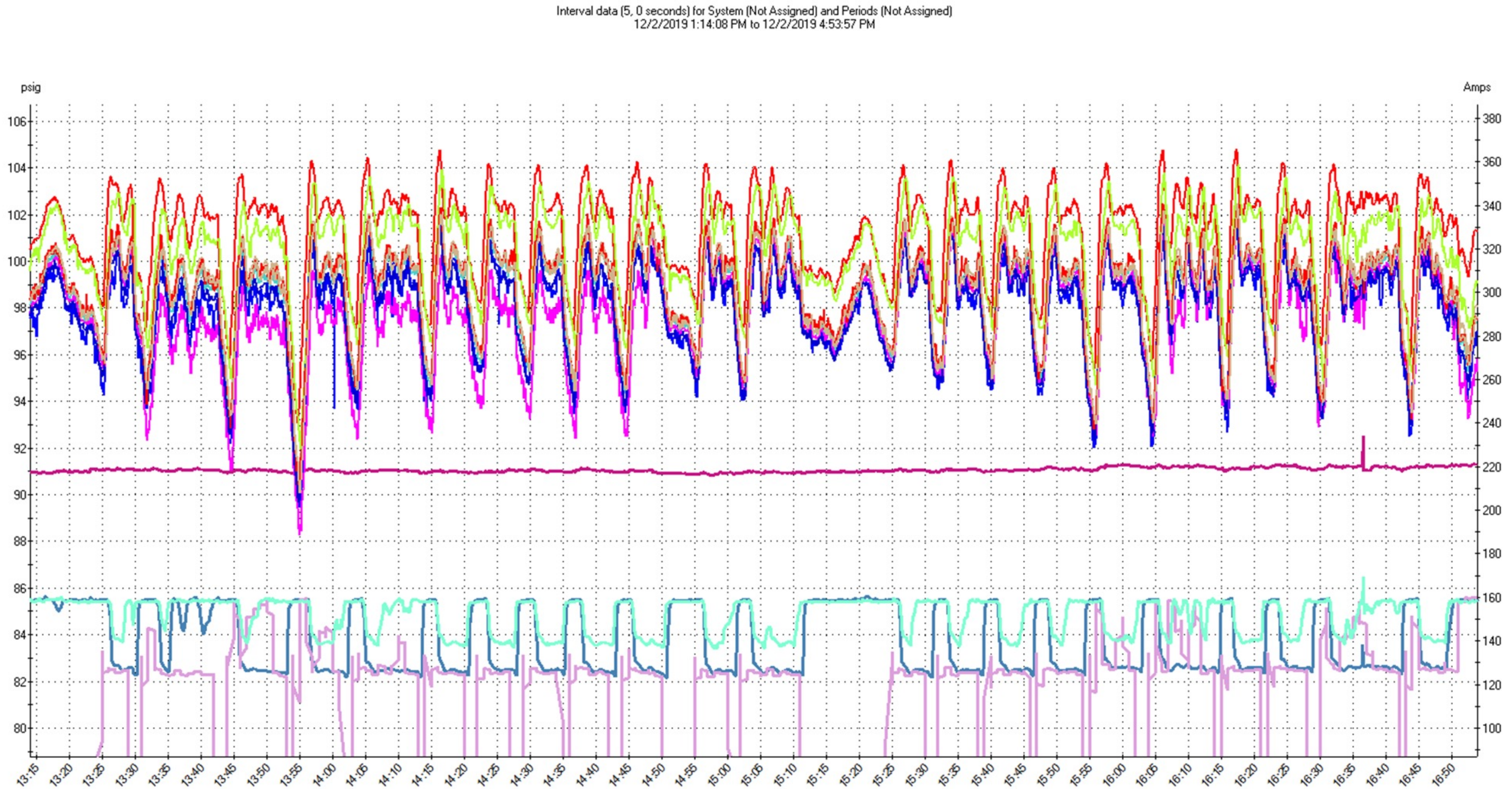


Data Collection Can Be Interpreted

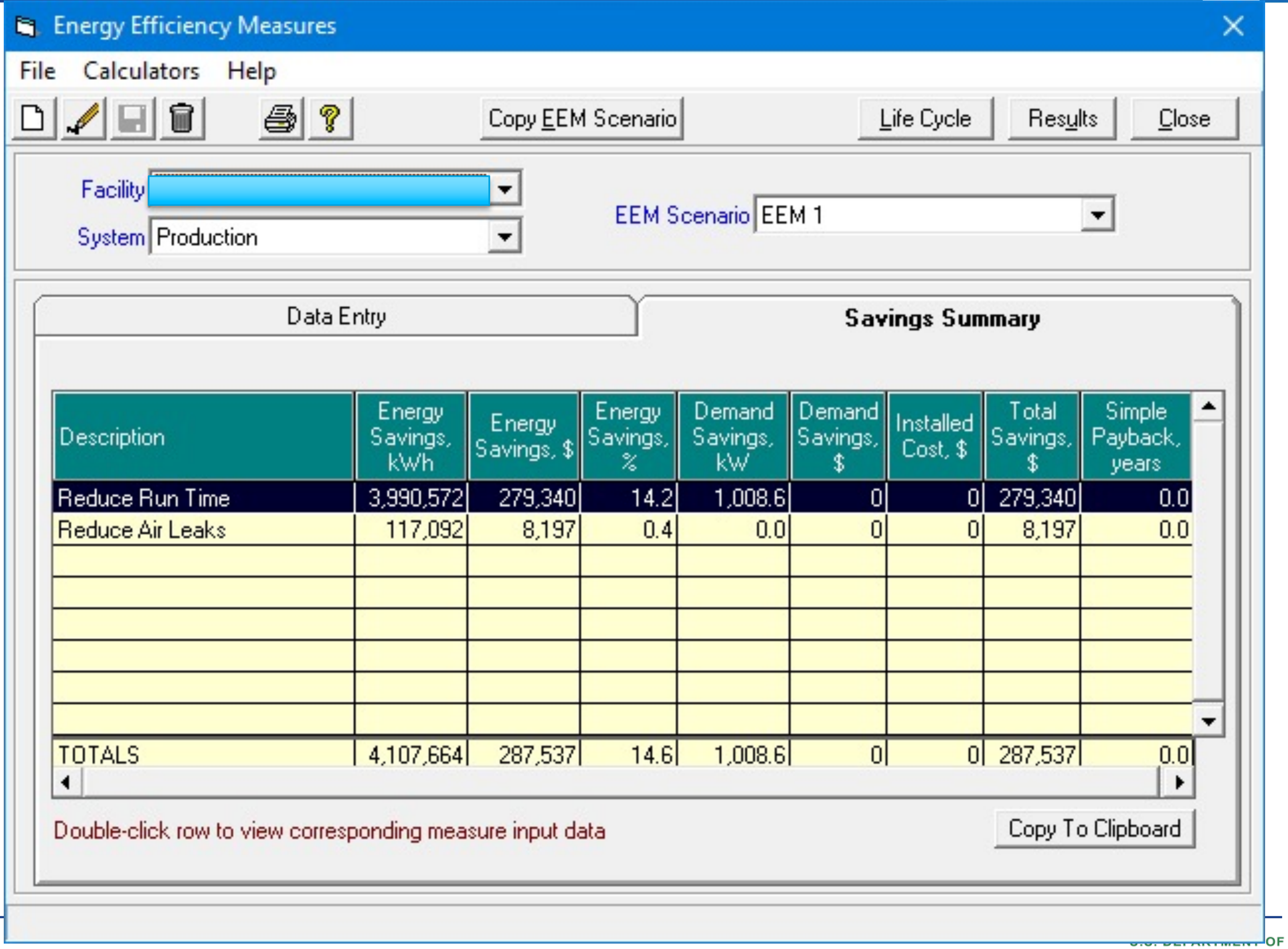


Comparing Pressure and Power



AIRMaster+ Energy Efficiency Measures

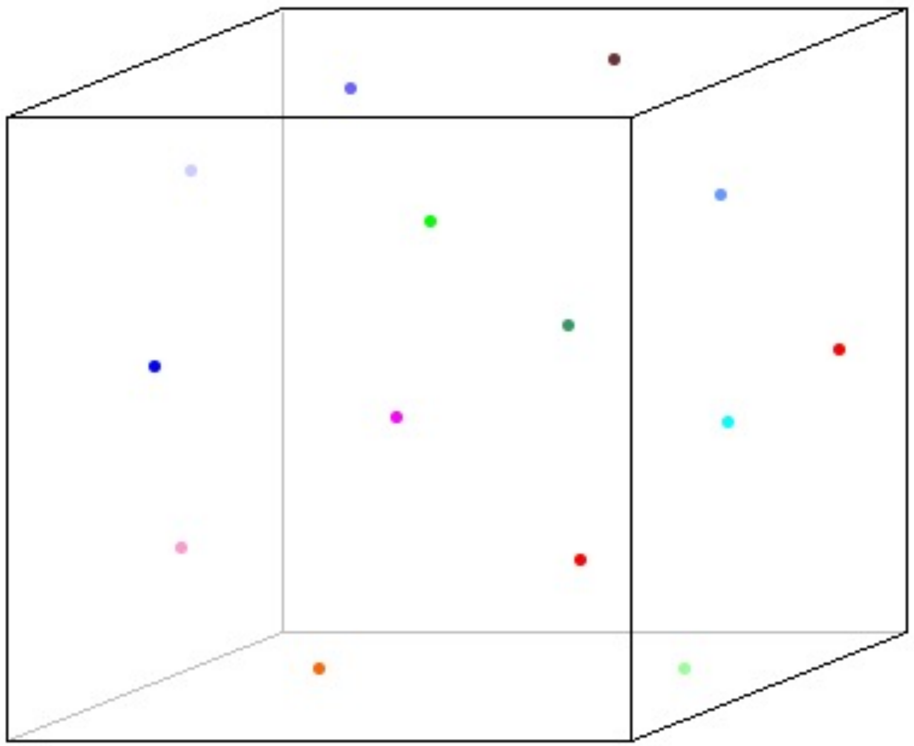
1. Reduce Air Leaks
2. Improve End Use Efficiency
3. Reduce System Air Pressure
4. Use Unloading Controls
5. Adjust Cascading Set Points
6. Use Automatic Sequencer
7. Reduce Run Time
8. Add Primary Receiver Volume



Description	Energy Savings, kWh	Energy Savings, $	Energy Savings, %	Demand Savings, kW	Demand Savings, $	Installed Cost, $	Total Savings, $	Simple Payback, years
Reduce Run Time	3,990,572	279,340	14.2	1,008.6	0	0	279,340	0.0
Reduce Air Leaks	117,092	8,197	0.4	0.0	0	0	8,197	0.0
TOTALS	4,107,664	287,537	14.6	1,008.6	0	0	287,537	0.0

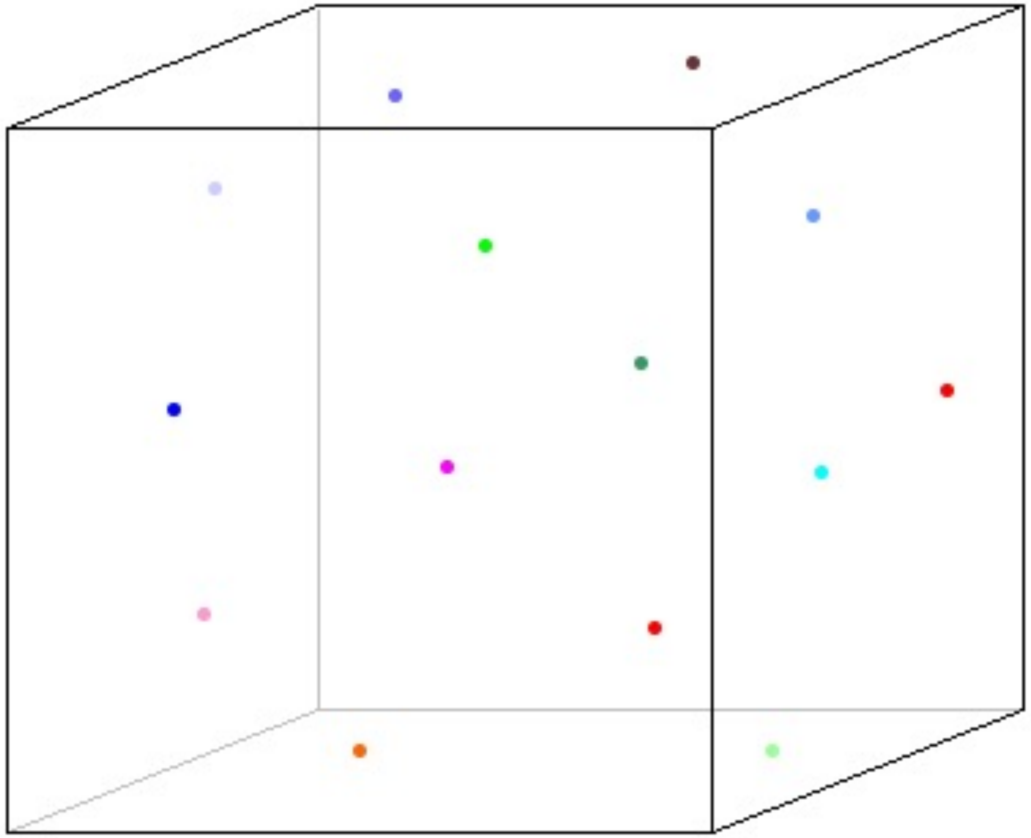
Compressed Air Fundamentals

Pressure?



- Imagine a closed container with air inside.
- Air, as a gas, is composed of molecules that you can imagine as round elastic balls.
- Molecules move in straight lines until they collide with neighboring molecules or the container wall.
- Molecules of gas hitting the wall impose a force on the wall.
- The amount of this impact force per area of the container inner walls is called pressure.

Gas Theory



On a square inch of surface there are over two sextillion molecular impacts per second....that's 2 followed by 21 zeros!!!

ALL THIS TRANSLATES TO PRESSURE. AT SEA LEVEL THIS PRESSURE WOULD BE -- 14.69 PSIA; 29.92"HgA; 1013mBar; or 760 Torr

Compressed Air Fundamentals

- At sea level, atmospheric pressure is 14.7 psia
- psia stands for pounds per square inch (Absolute)

Compressed Air Fundamentals

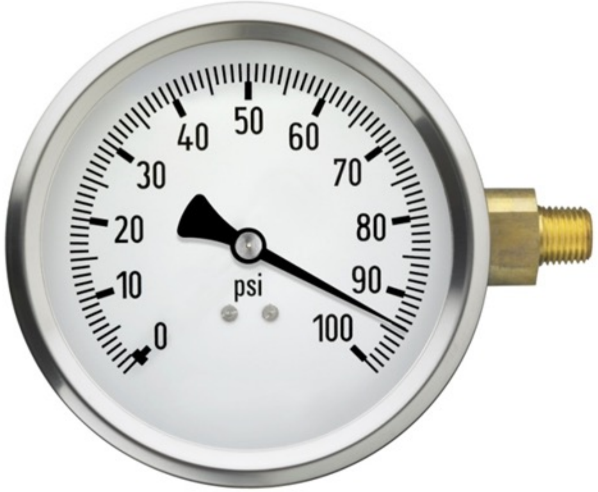
- In Death Valley, which is 500 feet below sea level, The air pressure is 14.94 psia

Compressed Air Fundamentals

- On top of a 5,000-foot mountain, air pressure is only 12.2 psia
- Mount Everest is 29,000 feet above sea level, and the air pressure is 4.56 psia

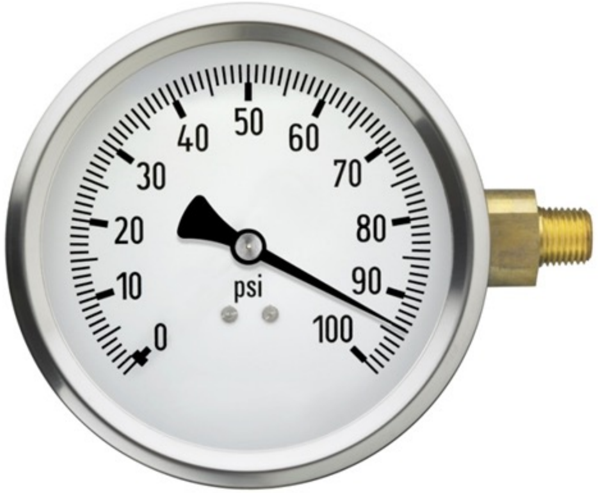
Pressure Terms

- **psig** is pounds per square inch gauge - the pressure on the gauge or digital readout of the compressor's controller.
- At zero gauge, the pressure is at atmospheric pressure. If the gauge reads 100 psig, then that means the pressure is 100 pounds above ambient atmospheric pressure.
- **psia** is pounds per square inch absolute. This is the sum of the existing gauge pressure plus the atmospheric pressure. At sea level, a gauge showing 95 psig would have an absolute pressure of 109.5 psia.
- 14.5 + 95 = 109.5 psia



Pressure Terms

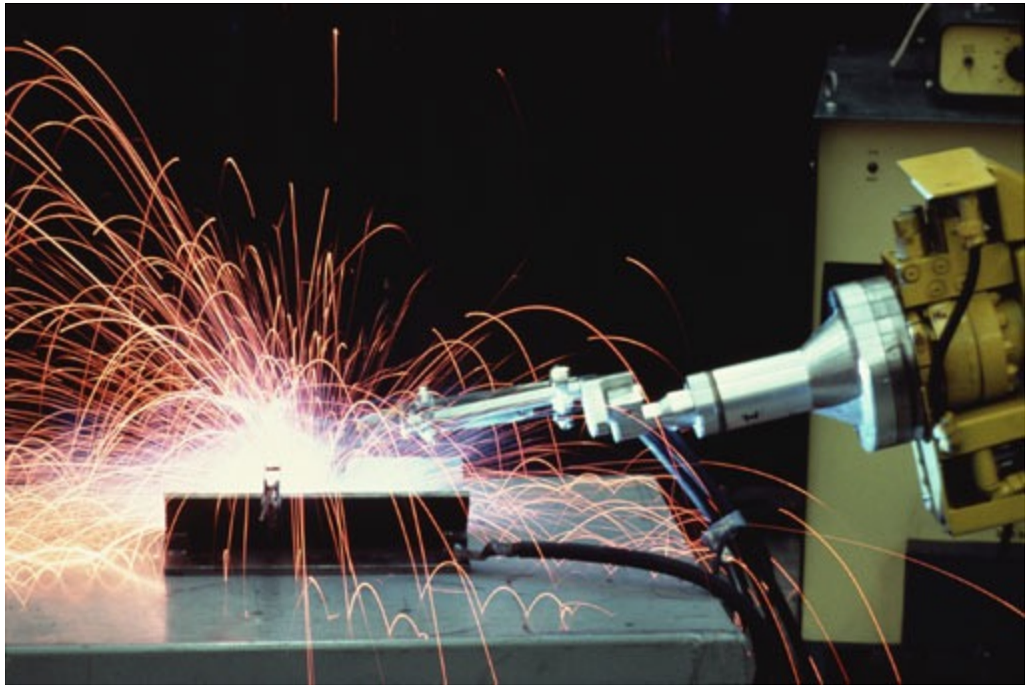
Micron	Torr/ mmHG	mbar	psia	inches Hg absolute	inches Hg gauge	atm	% vacuum
760,000	760	1013	14.696	29.92	0	1	0
750,000	750	1000 (1 bar)	14.5	29.5	0.42	0.987	1.3
735,600	735.6	981	14.2	28.9	1.02	0.968	1.9
700,000	700	934	13.5	27.6	2.32	0.921	7.9
600,000	600	800	11.6	23.6	6.32	0.789	21
500,000	500	667	9.7	19.7	10.22	0.658	34
400,000	400	533	7.7	15.7	14.22	0.526	47
380,000	380	507	7.3	15	14.92	0.5	50
300,000	300	400	5.8	11.8	18.12	0.395	61
200,000	200	267	3.9	7.85	22.07	0.264	74
100,000	100	133.3	1.93	3.94	25.98	0.132	87
90,000	90	120	1.74	3.54	26.38	0.118	88
80,000	80	106.8	1.55	3.15	26.77	0.105	89.5
70,000	70	93.4	1.35	2.76	27.16	0.0921	90.8
60,000	60	80	1.16	2.36	27.56	0.0789	92.1
51,700	51.7	68.8	1	2.03	27.89	0.068	93
50,000	50	66.7	0.97	1.97	27.95	0.0658	93.5
40,000	40	53.3	0.77	1.57	28.35	0.0526	94.8
30,000	30	40	0.58	1.18	28.74	0.0395	96.1
25,400	25.4	33.8	0.4912	1	28.92	0.034	96.6
20,000	20	26.7	0.39	0.785	29.135	0.0264	97.4
10,000	10	13.33	0.193	0.394	29.526	0.0132	98.7
7,600	7.6	10.13	0.147	0.299	29.621	0.01	99
1,000	1	1.33	0.01934	0.03937	29.88063	0.00132	99.9
750	0.75	1	0.0145	0.0295	29.8905	0.000987	99.9
100	0.1	0.133	0.00193	0.00394	29.91606	0.000132	99.99
10	0.01	0.0133	0.000193	0.000394	29.919606	0.0000132	99.999
1	0.001	0.00133	0.0000193	0.0000394	29.919961	0.0000132	99.999999
0.1	0.0001	0.000133	0.00000193	0.00000394	29.919996	0.000000132	99.999999



Compressed Air Fundamentals

- Compress: To press together or force into a smaller space; condense
- Air: A colorless, odorless, tasteless gaseous mixture, mainly nitrogen (78%) and oxygen (21%)
- When controlled, compressed air can be used to perform work.

Compressed Air Fundamentals



- Energy from compressed air is used to power pneumatic production equipment.
  - E.G.--air motors, actuators, instrumentation, tools, etc.
- To cool components or parts during fabrication
- To blow off waste material

Compressed Air Fundamentals

- Process Air
- Compressed air is an integral part of a process, and/or comes in contact with product.
  - Chemicals
  - Pharmaceuticals
  - Food & Beverage
  - Aeration and agitation
  - Semiconductor & Electronics
  - Medical Breathing Air
- CDA Quality--means Clean, Dry, Air

Capacity Ratings and Corrections

- Before beginning a discussion of compressor ratings, a couple of often misused terms need to be understood.
- SCFM - Standard Cubic Feet per Minute
  - A standard cubic foot of air is the amount of air in one cubic foot of volume when the air is at standard conditions of pressure, temperature and relative humidity.
  - There are a number of different standards:
  - The most common is air at sea level (14.5 PSIA)
  - 68° F and a relative humidity of 0%

Ratings

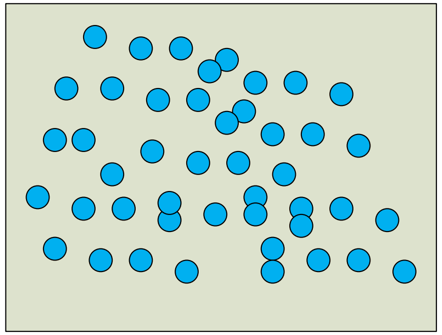
- In the industry, there are four different capacity definitions for CFM.
  - Free Air Delivery (FAD CFM)
  - Actual Cubic Feet per Minute (ACFM)
  - Inlet Cubic Feet per Minute (ICFM)
  - Standard Cubic Feet per Minute (SCFM)

Definitions and Formulas

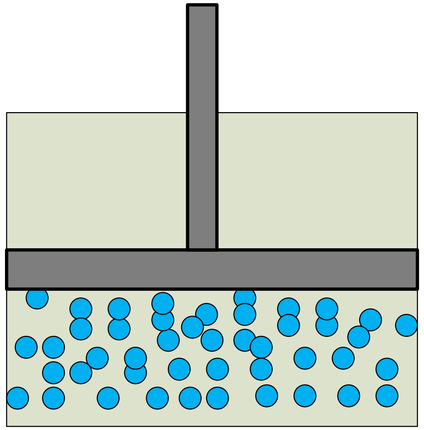
- Capacity calculations (Positive-Displacement)
  - **Golden rule**: FAD, ACFM, and ICFM are fixed volume flow rates which do not change with respect to atmospheric conditions.
  - In other words, a given compressor, when operating at rated speed and discharge pressure will essentially deliver the same volume flow rate regardless of inlet conditions.
  - **SCFM delivery** of an air compressor is calculated from the unit's FAD volume flow rate.
  - SCFM delivery will vary, depending on how the actual atmospheric conditions deviate from the "standard" reference set of conditions.
  - In winter, the SCFM delivery of a given air compressor is greater than during the summer, and vice versa.

Definitions and Formulas

- If we opened a 1 cubic foot box when the conditions were 68°F, 36% RH and at sea level (14.7 psia), then closed the lid, we would have 1 Standard Cubic Foot of Air.
- If we were to push the lid of the box to compress ½ way down without letting any air escape, the volume of air in the box would now be 1/2 of an Actual Cubic Foot.
- The volume of air in the box, however, is still 1 Standard Cubic Foot. The difference is now that same gas has 1/2 of the actual volume it had, and the pressure and temperature have increased.
- The only time the Actual Cubic Foot and Standard Cubic Foot measurements for a gas will be the same is when the ambient conditions are 68°F and 14.7 PSI.

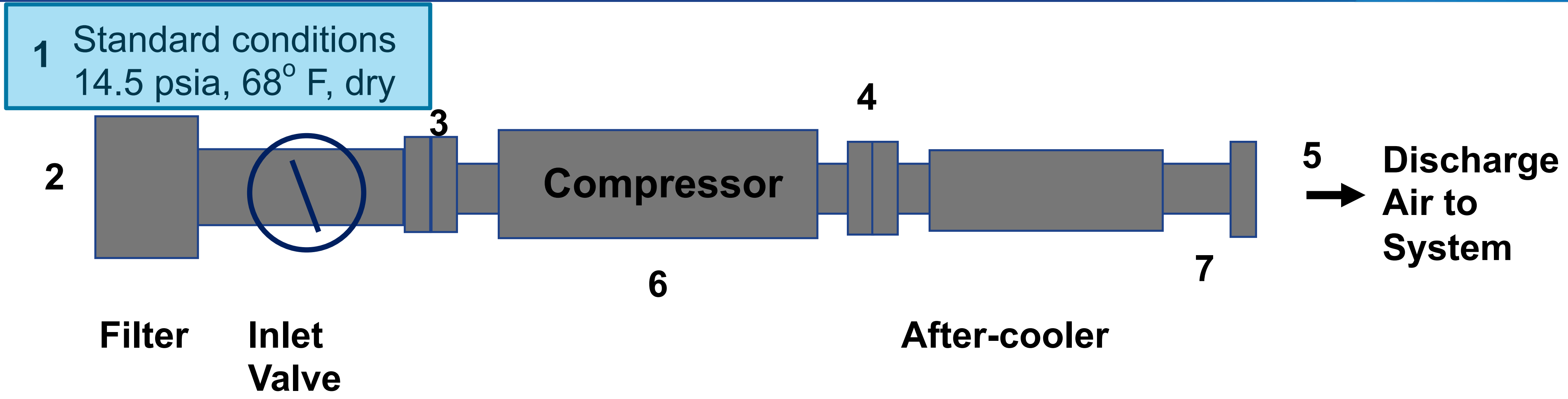


1 Standard Cubic Foot
68°F, 36% RH, 14.7 psia



Now is ½ of Actual Cubic Foot
But still is 1 Standard Cubic Foot

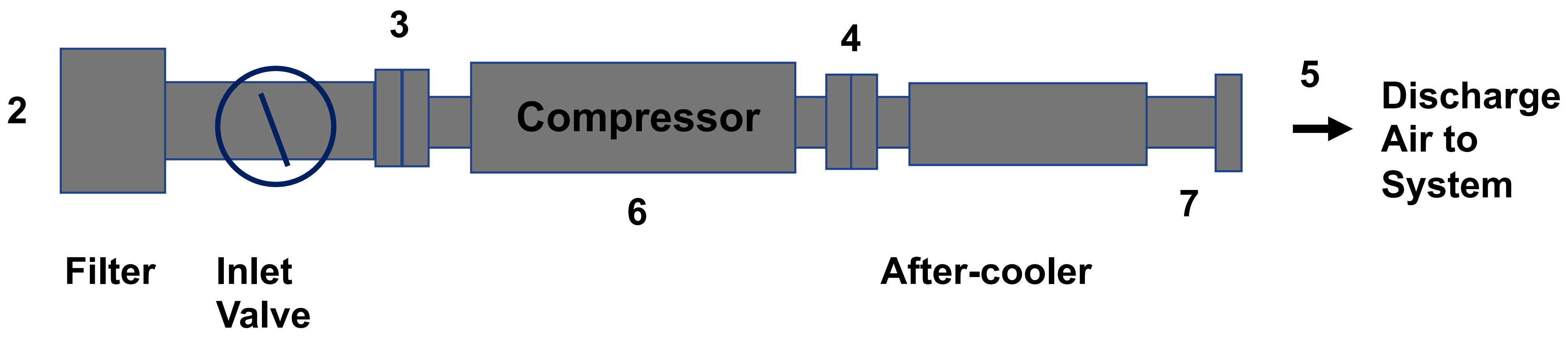
Definitions



1 = Standard conditions 14.5 psia, 68° F, dry
2 = Ambient conditions, example 14.5 psia, 95° F, 90% RH
3 = Inlet flange of compressor
4 = Discharge flange of compressor
5 = Compressed air to system
6 = Seal losses
7 = Condensate losses from intercoolers and after-cooler separators

Definitions

1 Standard conditions
14.5 psia, 68° F, dry



F.A.D.	=	amount of compressed air measured at 5 referred back to ambient conditions 2
SCFM	=	amount at 5 referred back to standard conditions 1
ACFM	=	amount at 5 referred back to inlet flange 3
ICFM	=	amount of air flowing by inlet flange, 3 (used primarily by dynamic compressors, centrifugal)

Formulas

- To convert the required scfm to the flow that will be required at a specific geographic location with acfm, the formula below can be used.

$$acfm = scfm \times \frac{P_s}{\left[P_a - \left(PP_{wv} \times rh\right)\right]} \times \frac{\left(T_a + 460\right)}{\left(T_s + 460\right)}$$

  - Where:
    - P_s = standard pressure, psia
    - P_a = Atmospheric pressure, psia
    - PP_{wv} = Partial Pressure water vapor at ambient temperature
    - Rh = Relative Humidify
    - T_a = Ambient Temperature, °F
    - T_s = Standard Temperature,°F

Formulas

Partial Pressure of Moisture at Various Temperatures

Temp. °F	Ambient Pressure Lb/Sq.In.	Temp. °F	Ambient Pressure Lb/Sq.In.	Temp. °F	Ambient Pressure Lb/Sq.In.	Temp. °F	Ambient Pressure Lb/Sq.In.	Temp. °F	Ambient Pressure Lb/Sq.In.	Temp. °F	Ambient Pressure Lb/Sq.In.
32	0.008854	49	0.1716	67	0.3276	85	0.5959	103	1.0382	121	1.7400
33	0.0922	50	0.1781	68	0.3390	86	0.6152	104	1.0695	122	1.7888
34	0.0960	51	0.1849	69	0.3509	87	0.6351	105	1.1016	123	1.8387
35	0.1000	52	0.1918	70	0.3631	88	0.6556	106	1.1345	124	1.8897
36	0.1040	53	0.1990	71	0.3756	89	0.6766	107	1.1683	125	1.9420
37	0.1082	54	0.2064	72	0.3886	90	0.6982	108	1.2029	126	1.9955
38	0.1126	55	0.2141	73	0.4019	91	0.7204	109	1.2384	127	2.0503
39	0.1171	56	0.2220	74	0.4156	92	0.7432	110	1.2748	128	2.1064
40	0.1217	57	0.2302	75	0.4298	93	0.7666	111	1.3121	129	2.1638
41	0.1265	58	0.2386	76	0.4443	94	0.7906	112	1.3504	130	2.2225
42	0.1315	59	0.2473	77	0.4593	95	0.8153	113	1.3896	131	2.2826
43	0.1367	60	0.2563	78	0.4747	96	0.8407	114	1.4298	132	2.3440
44	0.1420	61	0.2655	79	0.4906	97	0.8668	115	1.4709	133	2.4069
45	0.1475	62	0.2751	80	0.5069	98	0.8935	116	1.5130	134	2.4712
46	0.1532	63	0.2850	81	0.5237	99	0.9210	117	1.5563	135	2.5370
47	0.1591	64	0.2951	82	0.5410	100	0.9492	118	1.6006	136	2.6042
48	0.1653	65	0.3056	83	0.5588	101	0.9781	119	1.6459	137	2.6729
		66	0.3160	84	0.5771	102	1.0078	120	1.6924		

Example

- Requirement.
  - 1000 scfm using ISO standard (68°F, 0% RH, 14.5 psig (1 bar))
  - Altitude 5000 ft above sea level
  - Maximum ambient temperature 100°F
  - Maximum Relative Humidity 50%

  - Ambient pressure at 5000 ft. = 12.2 psia
  - Partial pressure of moisture at 100°F from vapor pressure chart = 0.95 psia
  - Partial pressure at 50% RH = 0.95 x 0.50

$$acfm = scfm \times \frac{P_s}{\left[P_a - \left(PP_{wv} \times rh\right)\right]} \times \frac{\left(T_a + 460\right)}{\left(T_s + 460\right)}$$

$$acfm = 1000\, scfm \times \frac{\left(14.5 - 0rh\right)}{\left[12.2 - \left(0.95 \times .50\right)\right]} \times \frac{\left(100 + 460\right)}{\left(68 + 460\right)}$$

$$acfm = \frac{14.5}{11.725} \times \frac{560}{528} = 1312\, acfm$$

Example using the MEASUR Tool

SCFM ⬆⬇ ACFM

ACTUAL TO STANDARD AIRFLOW

Convert to Standard Airflow | Convert to Actual Airflow

Actual Atmospheric Pressure Auto Calculate From Elevation	12.2	psia
Actual Ambient Temperature	100	°F
Actual Relative Humidity	50	%
Standard Atmospheric Pressure	14.5	psia
Standard Ambient Temperature	68	°F
Standard Relative Humidity	0	%
Standard Airflow	1000	scfm

Results

Airflow **1,311.7 acfm**

MEASUR

Formulas

- The example on the previous page demonstrates the need for accurate requirement specifications.
- In this case, the actual compressor capacity required at the prevalent ambient conditions is one-third greater than the stated scfm.
- Consideration also must be given to the fact that the temperature at this site will not always be as high as 100 degrees Fahrenheit, and relative humidity also may be lower.
- Some geographic locations have wide changes in ambient temperature from day to night and from season to season.
- This will result in less volume being required from the compressor.
- The right compressor with the proper controls will help to manage the supply for these various demands.

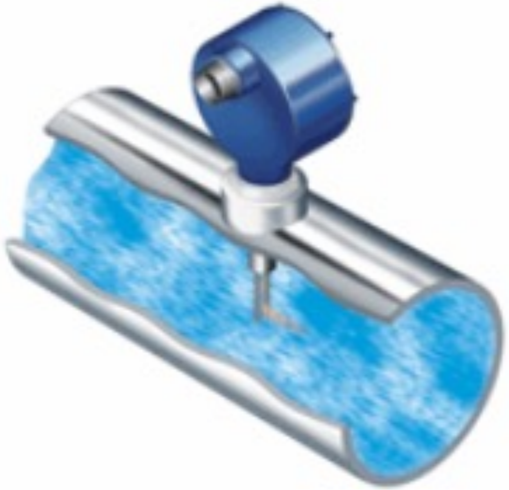
Week 1

Taking Measurements

The Need to Make Measurements

- Flow (cfm)
- Pressure (psi)
- Power (kW)
- Energy (kWh)
- Dollars ($)

Measurement Tools



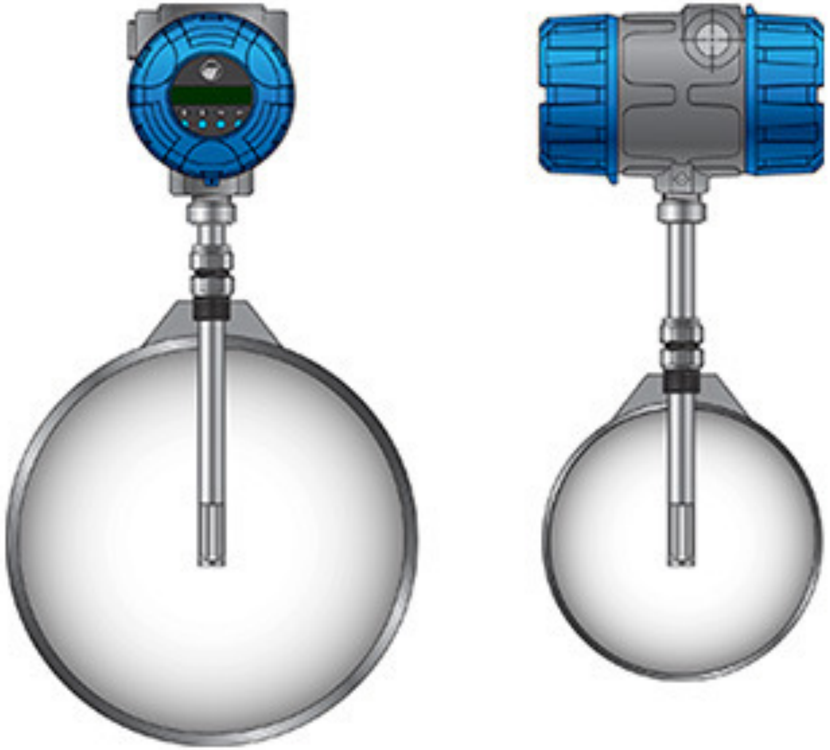
Measurement Tools

Taking Measurements

- Money spent on energy is calculated by converting kWh to dollars.
- Dollars can be estimated using average $/kWh rates, or more complicated calculations can be made using actual electricity rates.
- You need to understand your electricity rate structure, your electricity bill, and how the compressed air system is impacting the bill.
- Calculations on how much is spent on compressed air should always be tied back into production by calculating dollars spent on compressed air per unit of production

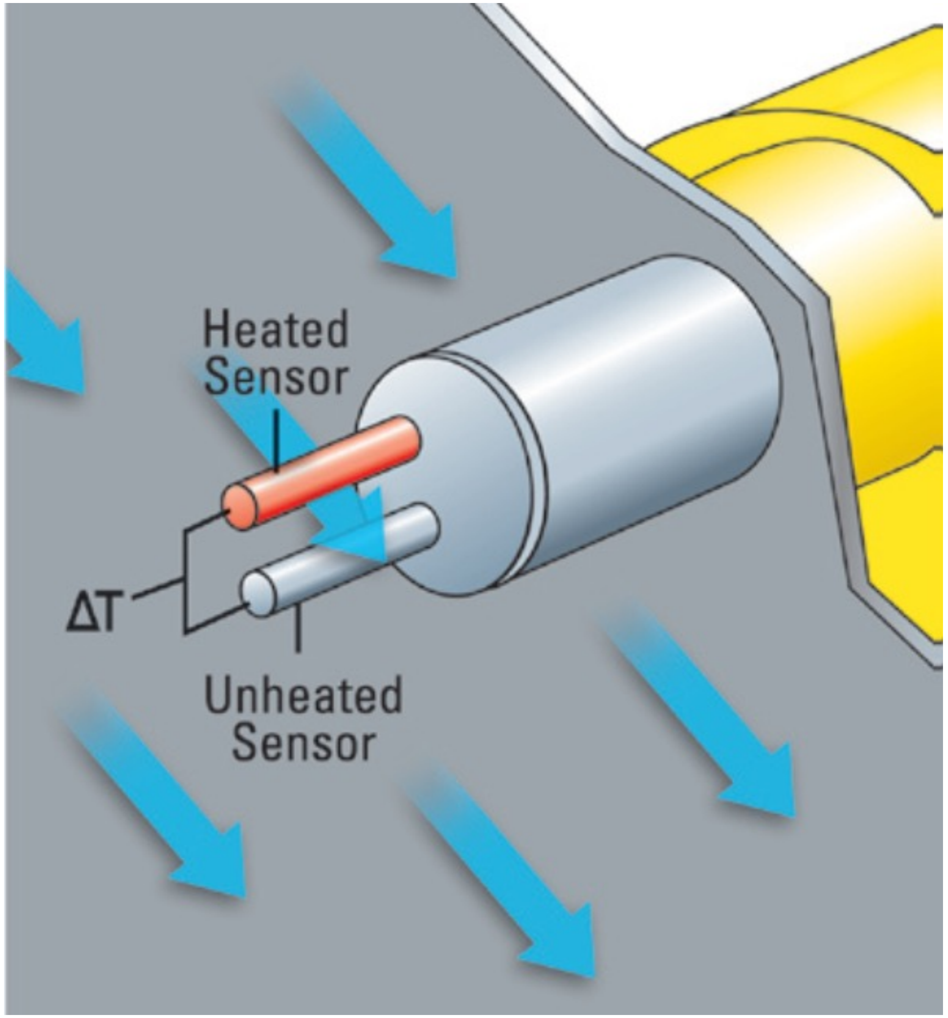
Thermal Mass Flow Meters

- The best choice for measuring air flow is a thermal mass flow meter.
- It consists simply of a relatively small probe inserted into the pipe.
- It effectively measures the velocity of air blowing over it and converts it to standard air volume with no pressure drop.



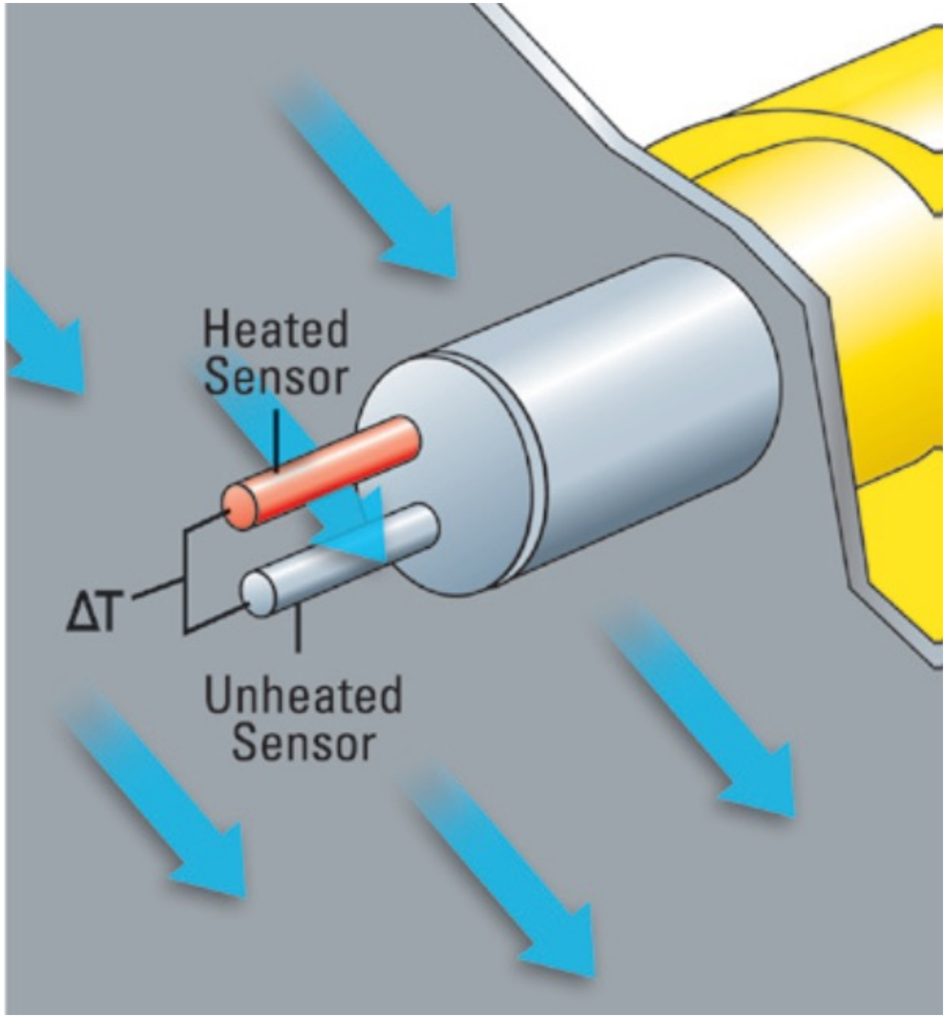
Thermal Mass Flow Meters

- Thermal mass flow meters provide a gas flow measuring solution that is accurate, repeatable, easy to install and requires virtually no maintenance.
- Thermal dispersion mass flow measurement technology places two thermowell protected platinum RTD temperature sensors in the process stream.
- One RTD is heated while the other senses the actual process temperature.
- The temperature differential between these two sensors is measured and is directly proportional to the mass flow rate of the fluid.



Thermal Mass Flow Meters

- Proper installation of the thermal mass flowmeter is very important in assuring accurate measurement of your gas flow.
- The thermal mass flow meter must be installed at a location where the gas is dry or above the dew point temperature.
- Installations which allow large droplets of water to condense out and come in contact with the sensing element must be avoided.
- Such contact could cause sporadic “spikes” in the thermal mass flowmeter’s readings due to the dramatic cooling effect of the denser liquid.



How Do I install an insertion type flow meter?

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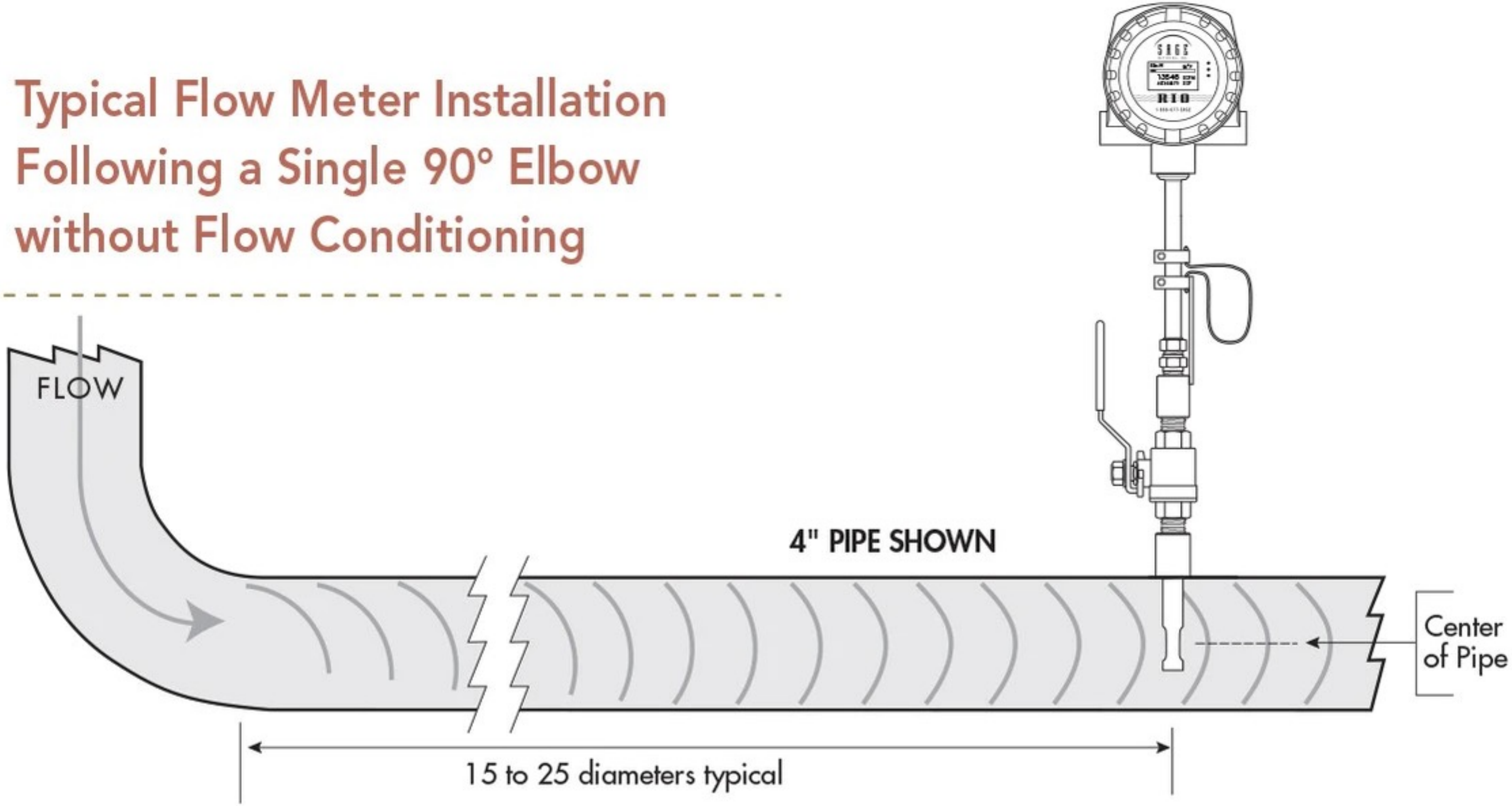
LB
"Apollo"


"Apollo"

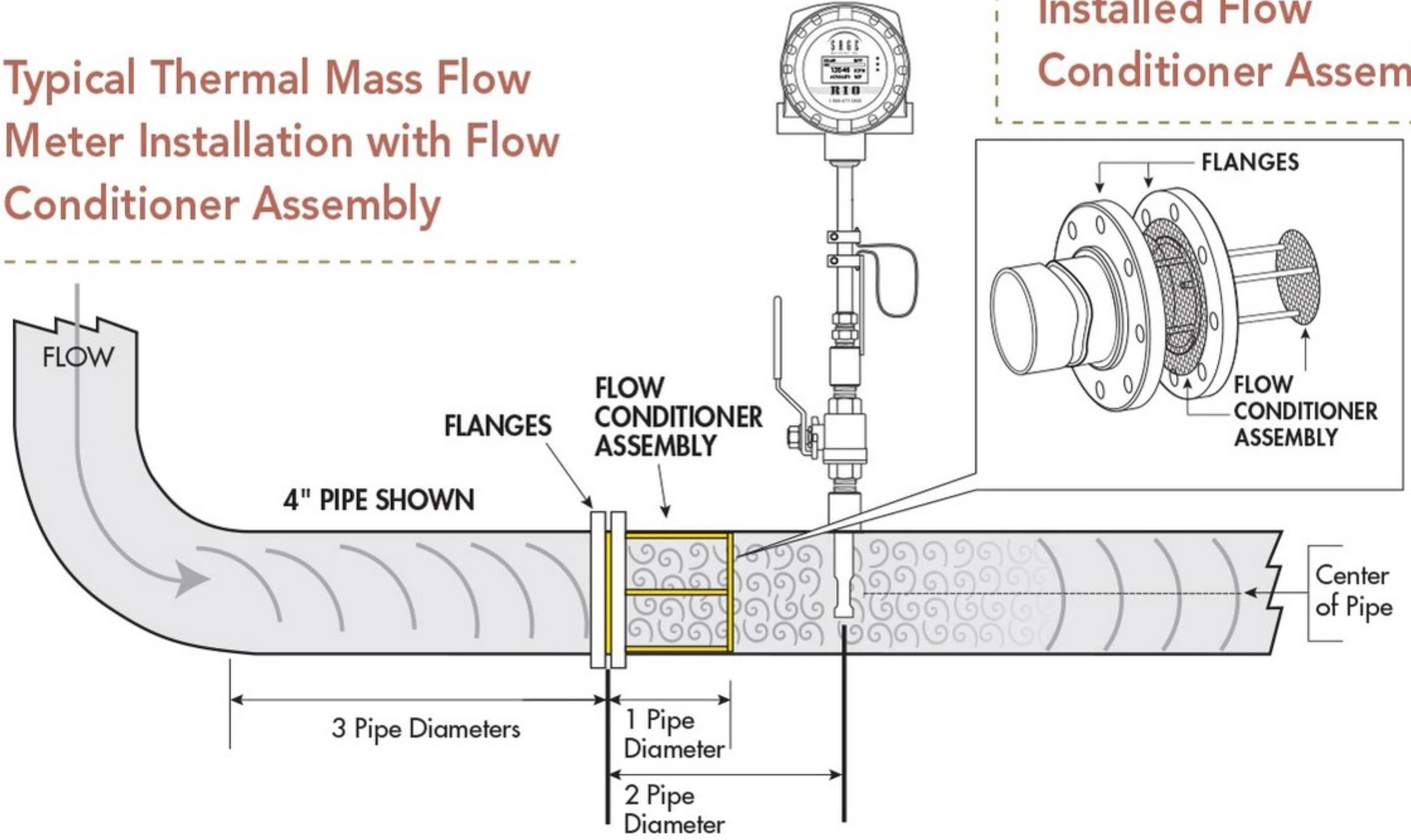
FLOW CONDITIONING

Typical Flow Meter Installation Following a Single 90° Elbow without Flow Conditioning

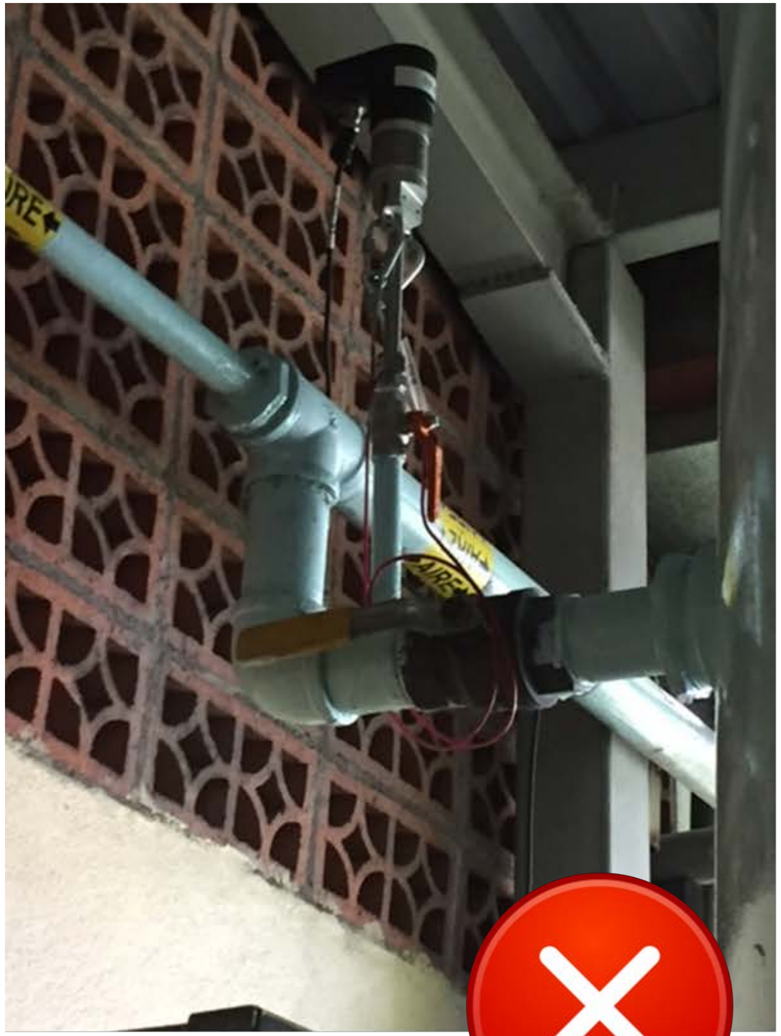


Typical Thermal Mass Flow Meter Installation with Flow Conditioner Assembly

Installed Flow Conditioner Assembly

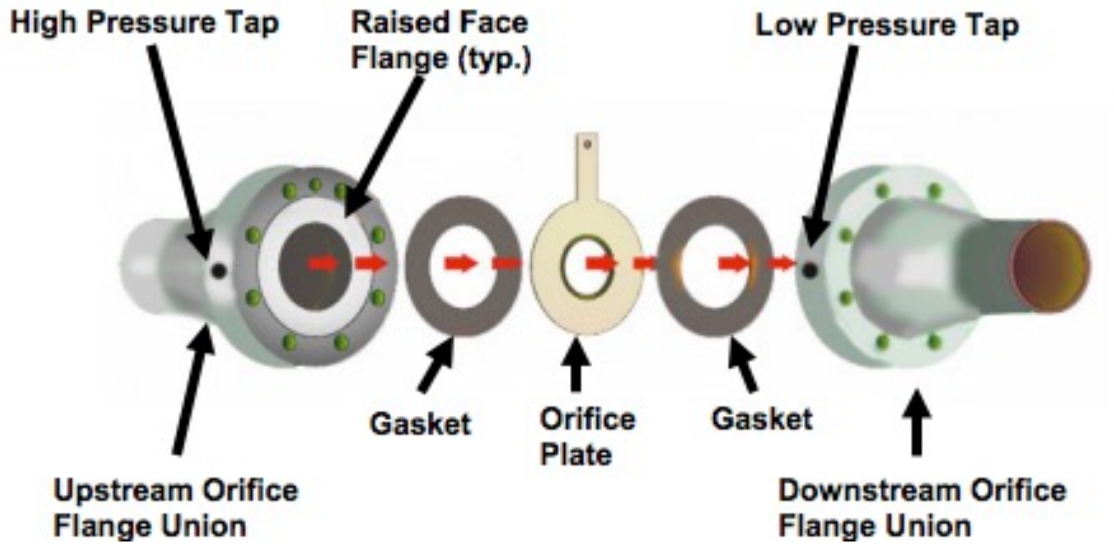


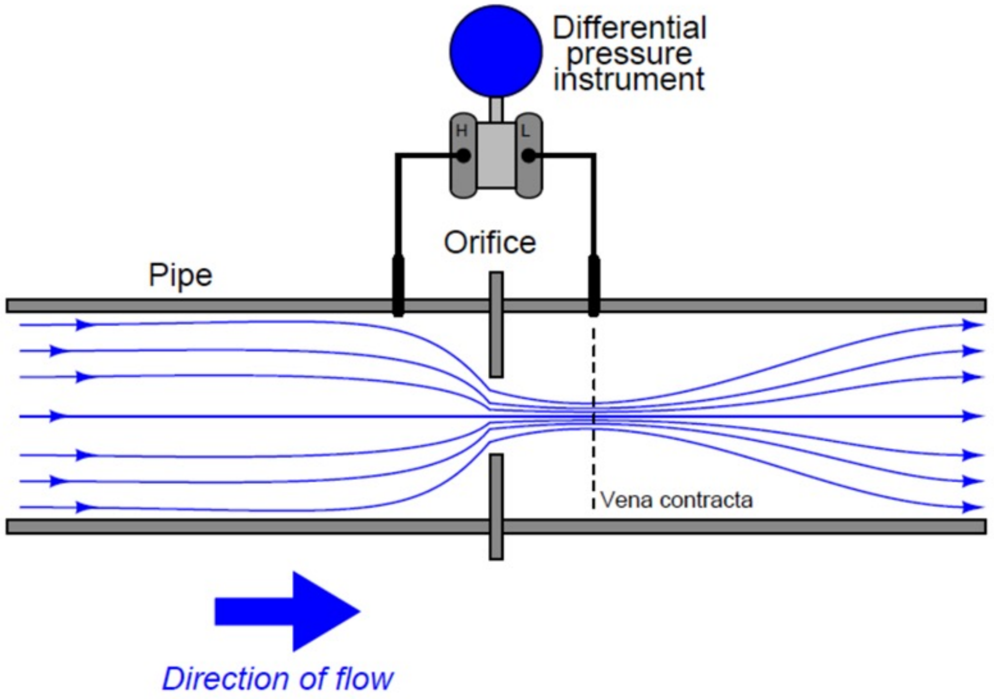
Location and Orientation



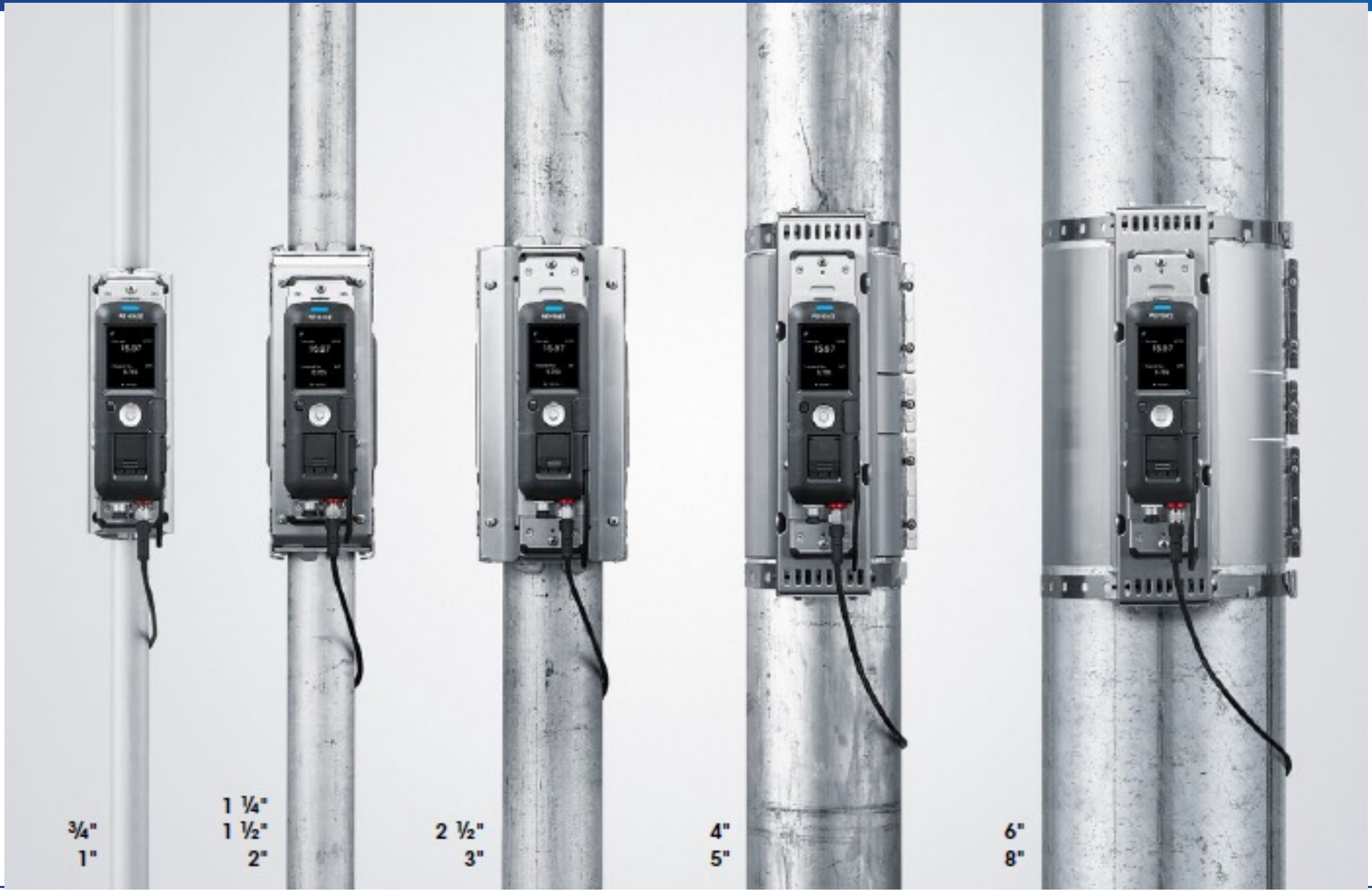
Orifice Plate Flow Meters

- These meters are a carry over from fluid engineering.
- They operate on the physics of a pressure drop being created as a medium flows through an undersized orifice.
- The problem with these meters is just that; they, themselves are a pressure drop.





Other Flow Meters (Ultrasonic)

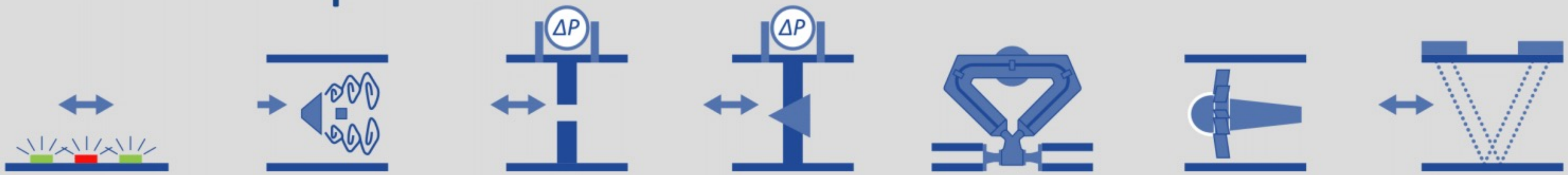


Other Flow Meters

- DP Insertion Meters
- Coriolis Mass Flow Meters
- Vortex Shedding Flow Meters
- Pitot Tubes

- Gas is compressible. The gas volume changes under pressure and temperature fluctuations.
- For this reason, orifice plates, venturi meters and other Delta-P (differential pressure) devices, as well as turbine meters, rotary gas meters and vortex meters, require additional instruments to measure the temperature and pressure and then mathematically convert the volume to mass.
- A TMFM does not need separate temperature or pressure transmitters as it directly measures mass flow

Principles compared



	Thermal	Vortex	DP – Orifice plate	DP – Cone meter	Coriolis	Turbine/ rotary displacement	Clamp on ultrasonic
Mass flow	Yes	Optional	Optional	Optional	Yes	Optional	Optional
Meter run	20D	15D	15D	5D	0D	10D	20D
Pressure loss	Low	Medium/high	high	high	Low	Low	Low
Dirty air	Fouling	OK	Clogging	Clogging	Internal fouling	Faillure	OK
Wet Air	Spikes	OK, spikes	OK	OK, orientation	Yes, but affects reading	Faillure	Spikes
Range	1:250	1:10	1:0	1:10	1:100	1:100	1:100
Accuracy	2%	2%	2%	2%	0.5 .. 1%	0.5...1 %	1%
Purchase price	$	$	$	$	$$$$	$$	$$$
Maintenance	Medium	Low	Medium	Medium	Low	High	Low

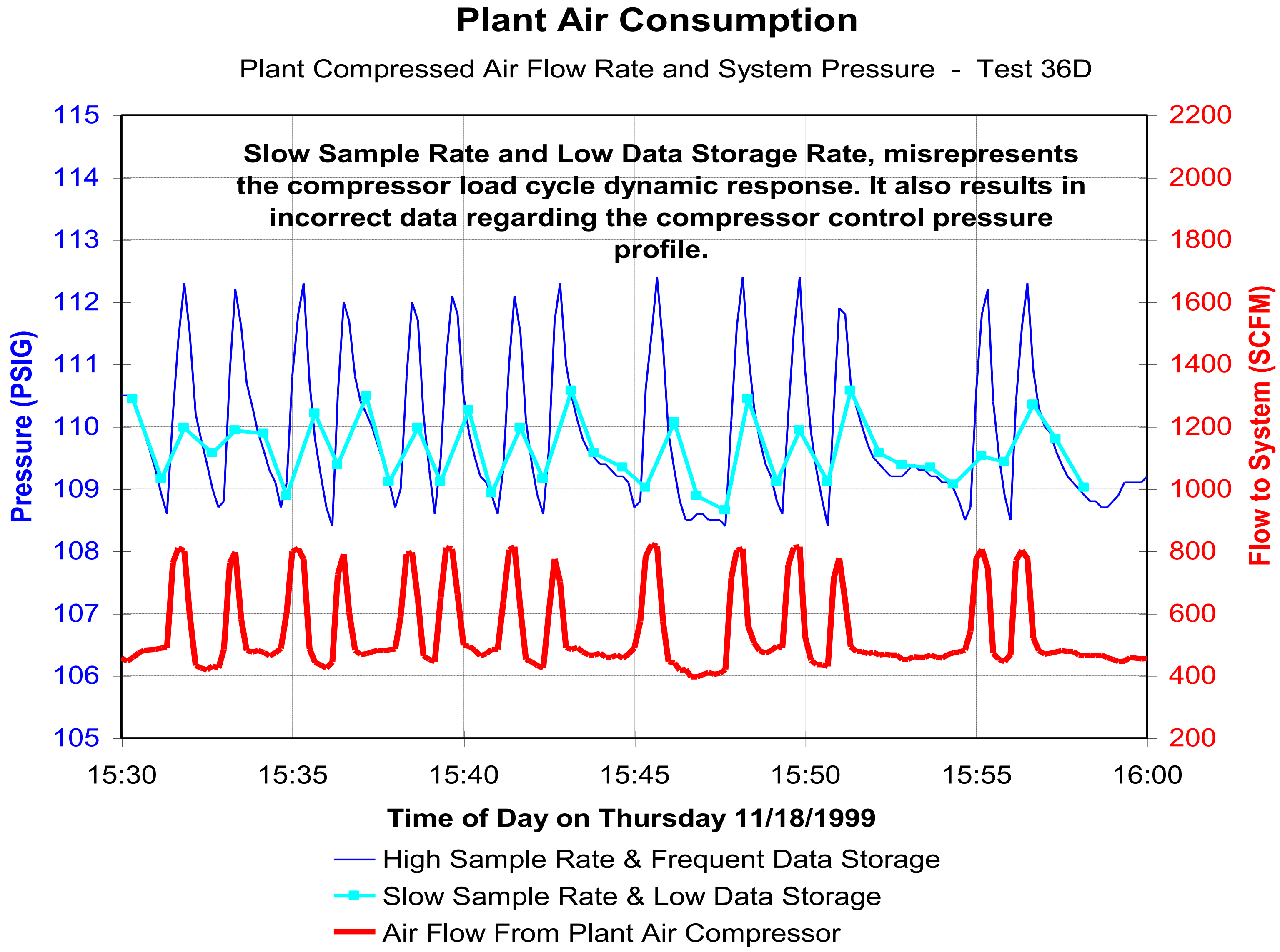
Measurements – A Snapshot Versus a Movie

- Taking data at a single point, or even during various shifts can provide some answers, but not the complete picture.
- The use of data logers is important in determining how a system operates over time.
- When data logging system performance sample rate (reading transducer signals), and data storage interval are critical.
- Sample rate, data reduction averaging methods, and data storage interval must be consistent with system dynamics.

Measurements – A Snapshot Versus a Movie

- This data chart shows a comparison of different sampling rates and data intervals.
- The inappropriate data collection leads to a misrepresentation of compressor load cycles.

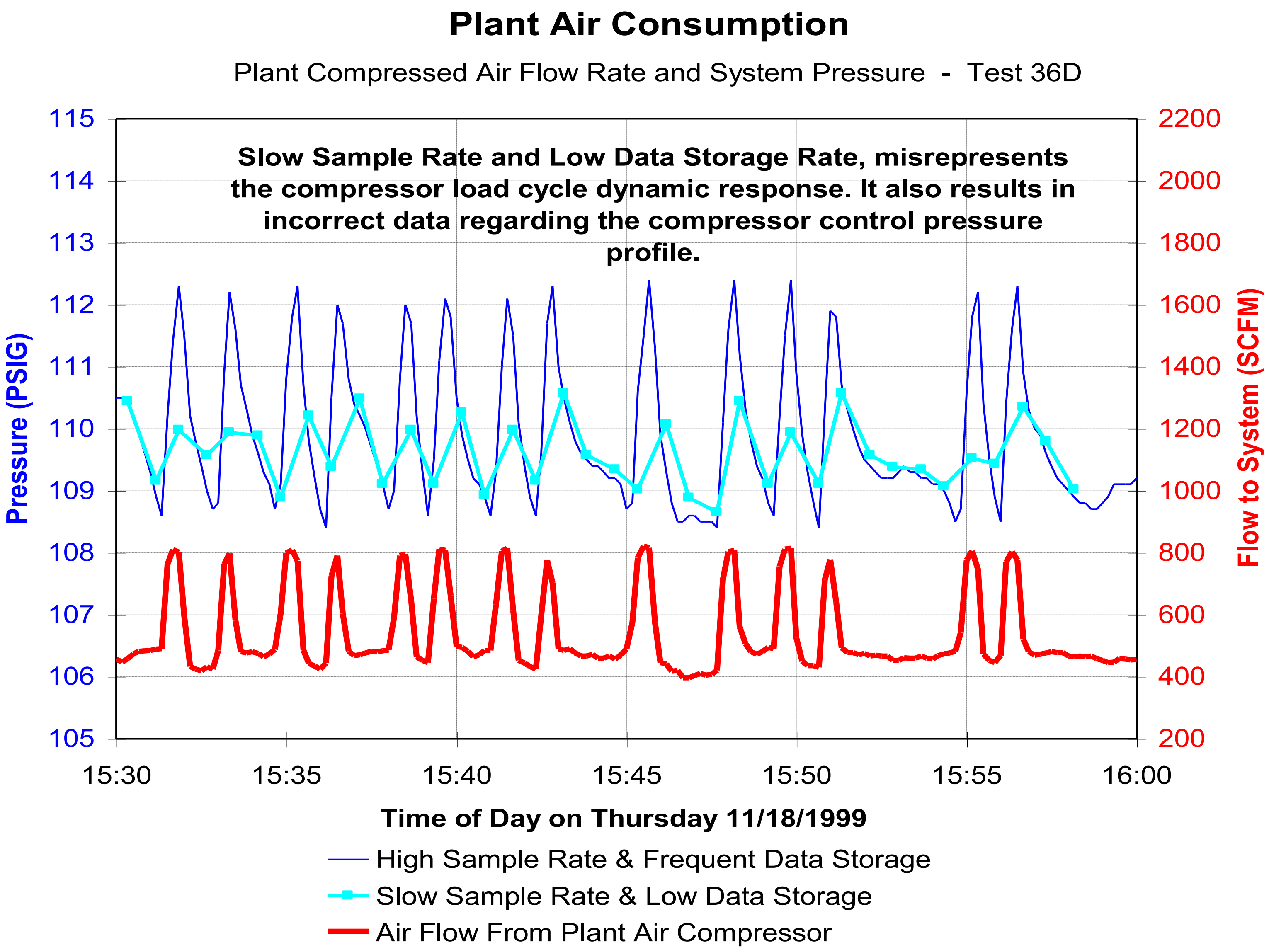
	High Rate	Slow Rate
Sample Rate	1 sample per 1 second	1 sample per 3 seconds
Data Averaging	10 samples	15 samples
Data Interval	10 seconds	45 seconds



Measurements – A Snapshot Versus a Movie

- Signal aliasing in the data tracing above could easily lead to misinterpretation of the recorded system dynamics.
- The 350 scfm swing in flow to the system is NOT a demand event.
- The true wave forms, collected at the high sample rate, clearly show a direct correlation of increasing flow with increasing pressure.

	High Rate	Slow Rate
Sample Rate	1 sample per 1 second	1 sample per 3 seconds
Data Averaging	10 samples	15 samples
Data Interval	10 seconds	45 seconds



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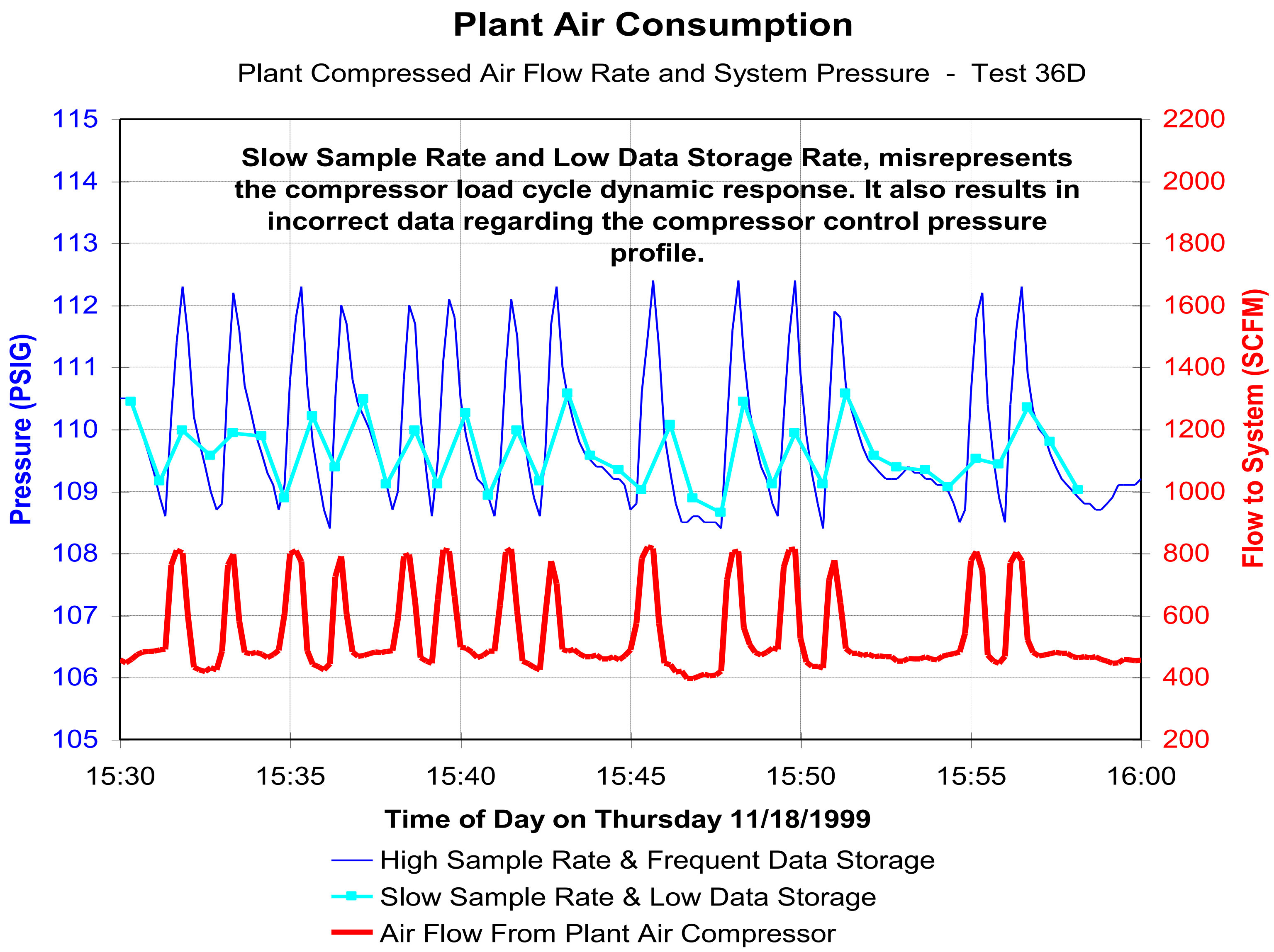
Measurements – A Snapshot Versus a Movie

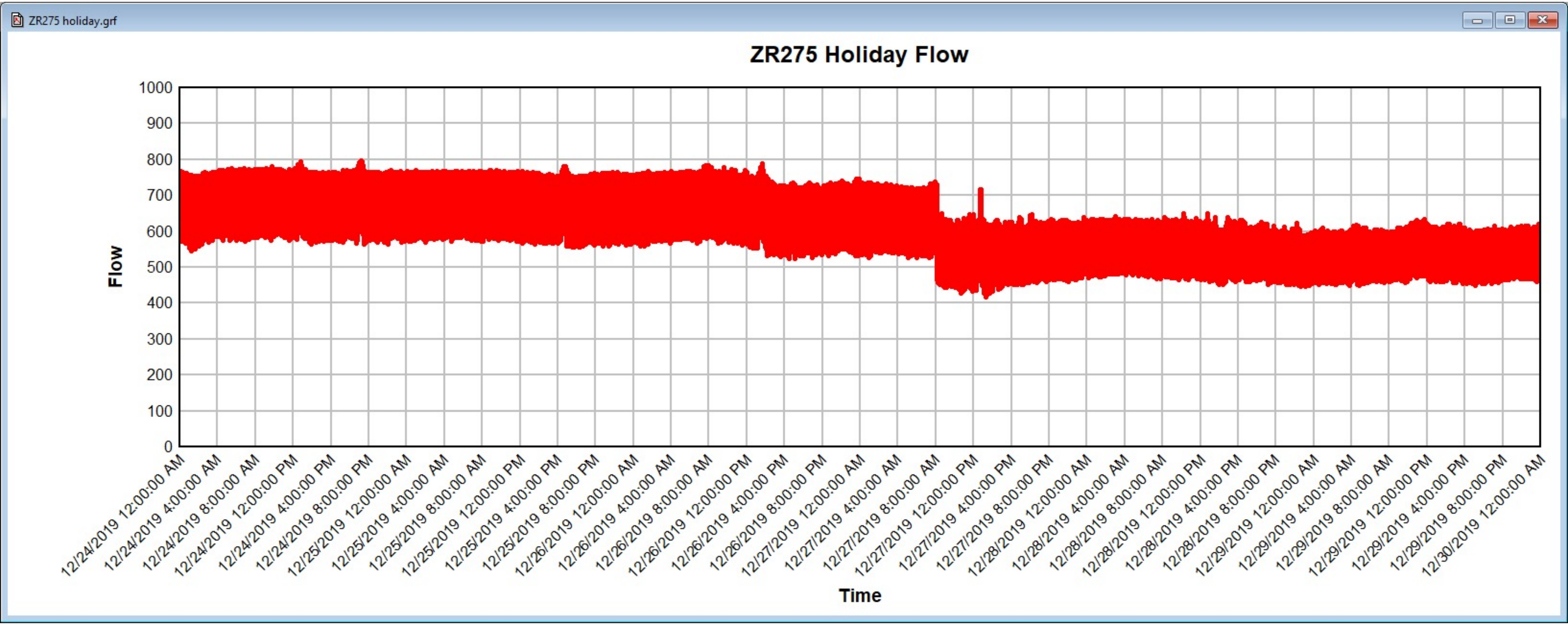
- The aliased pressure tracing between 15:30 hours and 15:35 hours might be interpreted to show increasing flow with decreasing pressure, or no change in pressure.
- The slow sample rate and alias pressure tracing could lead to the conclusion that the flow increase is a demand event.
- **Increasing flow with decreasing, or no pressure change, is due to a demand event.**



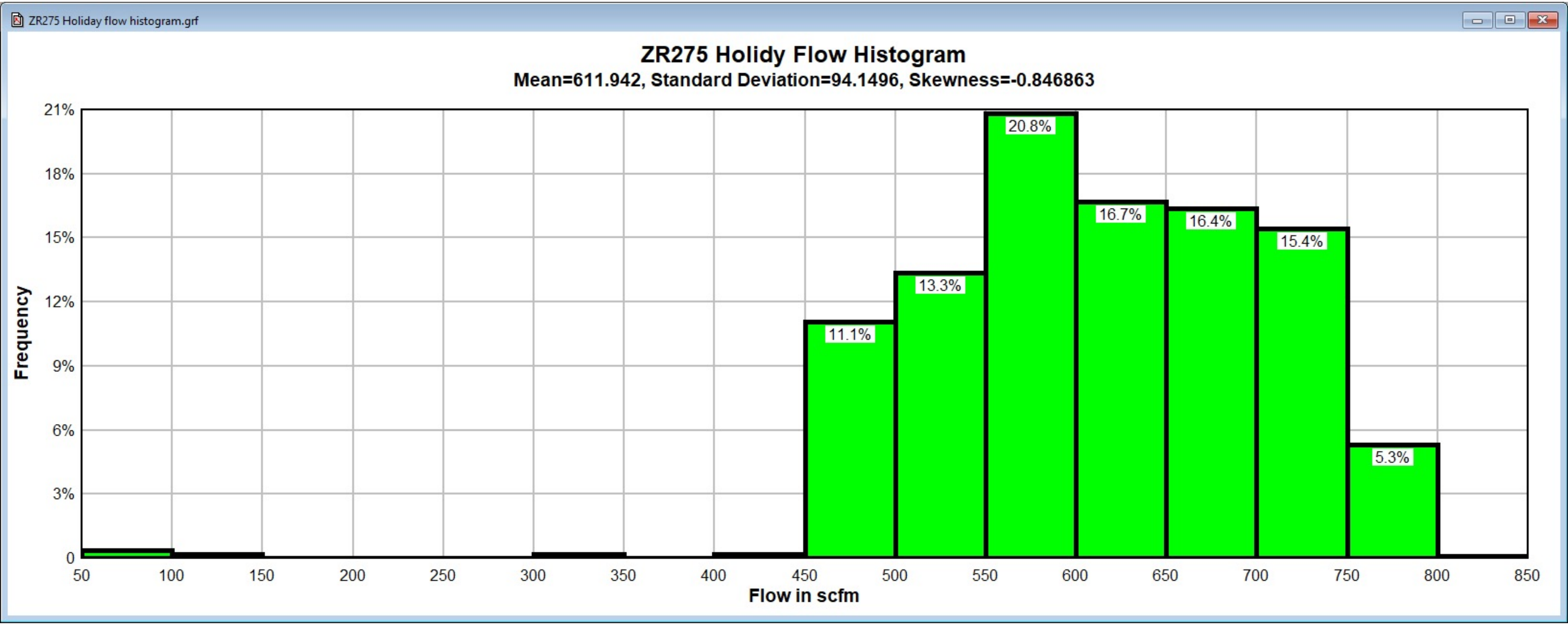
Using Measurements

- Measurements take the "vital signs" of a compressed air system to see how it is operating and how efficient the system is.
- Once the system baseline is established, it can be tracked over time to monitor improvements or degradation in the system’s performance.
- This information is then converted into dollars and communicated to management.

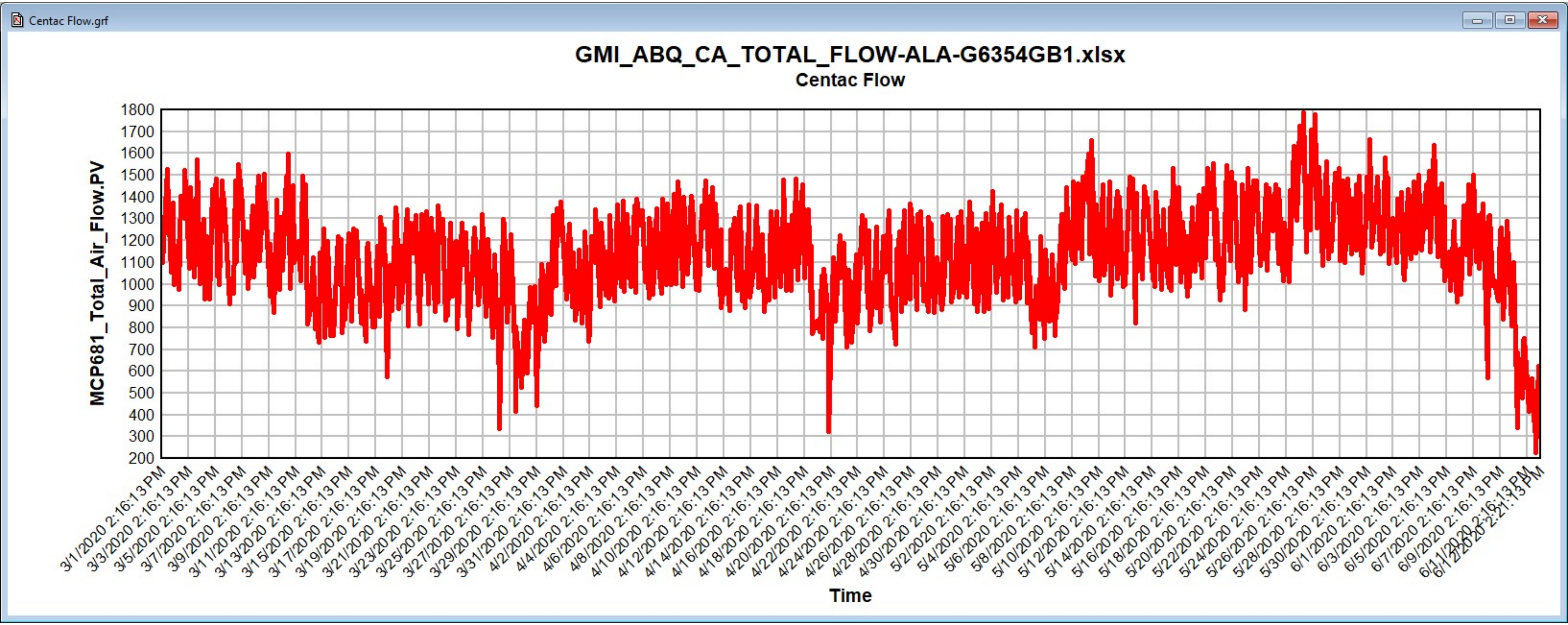
Using Measurements



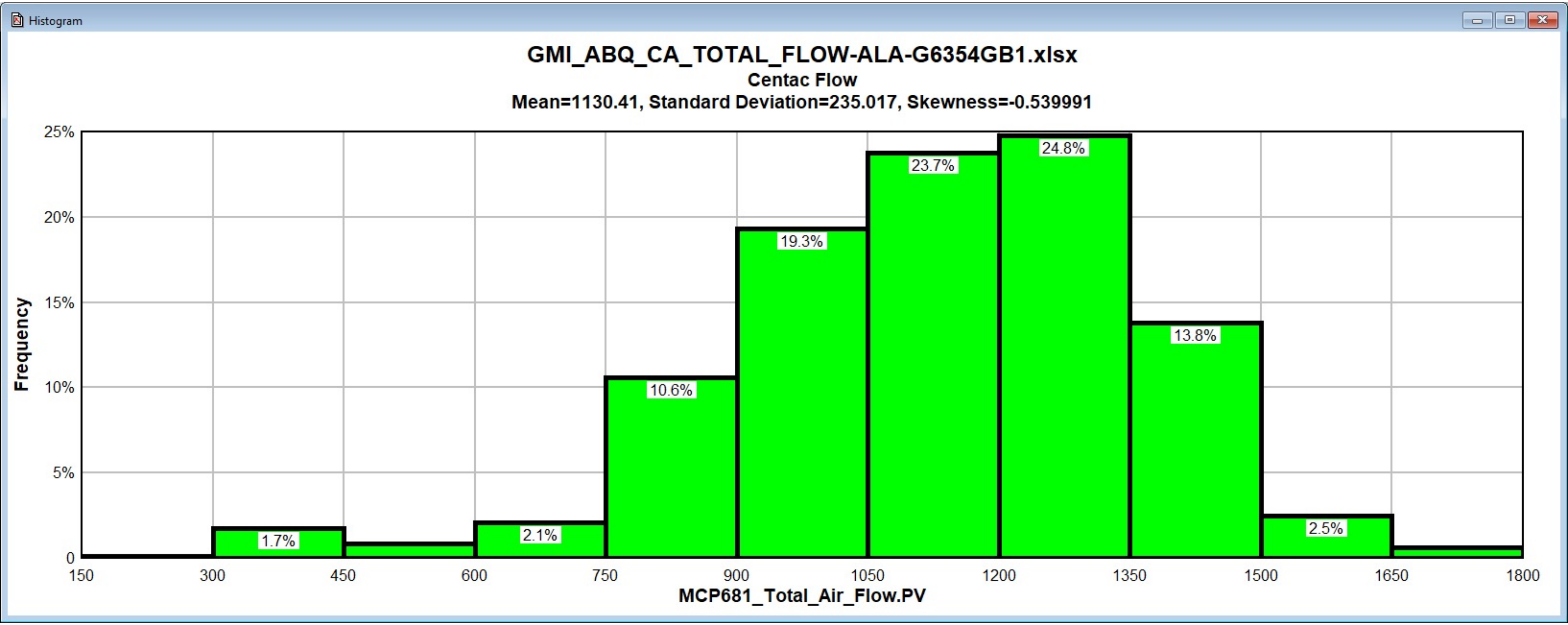
Using Measurements

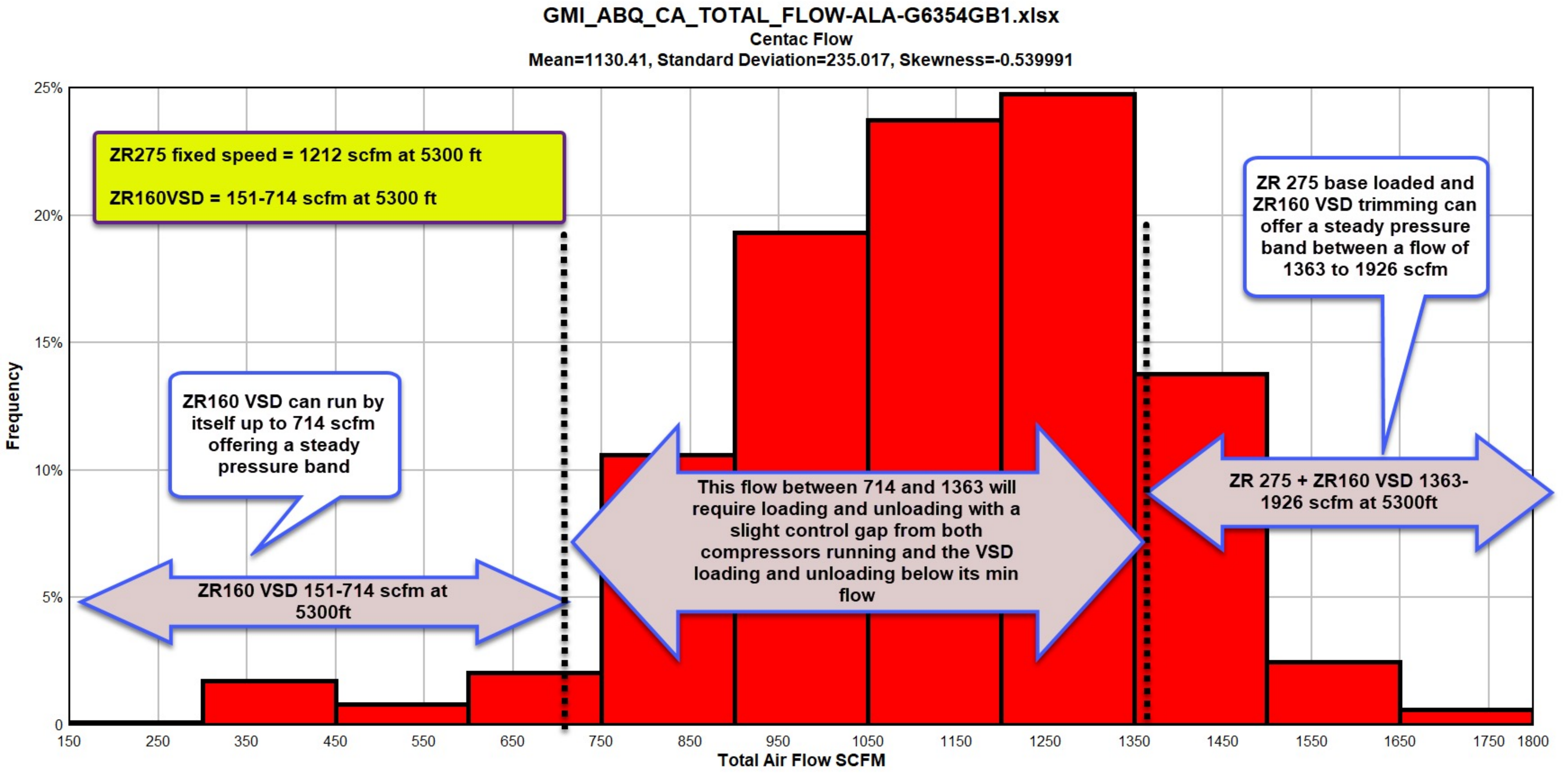


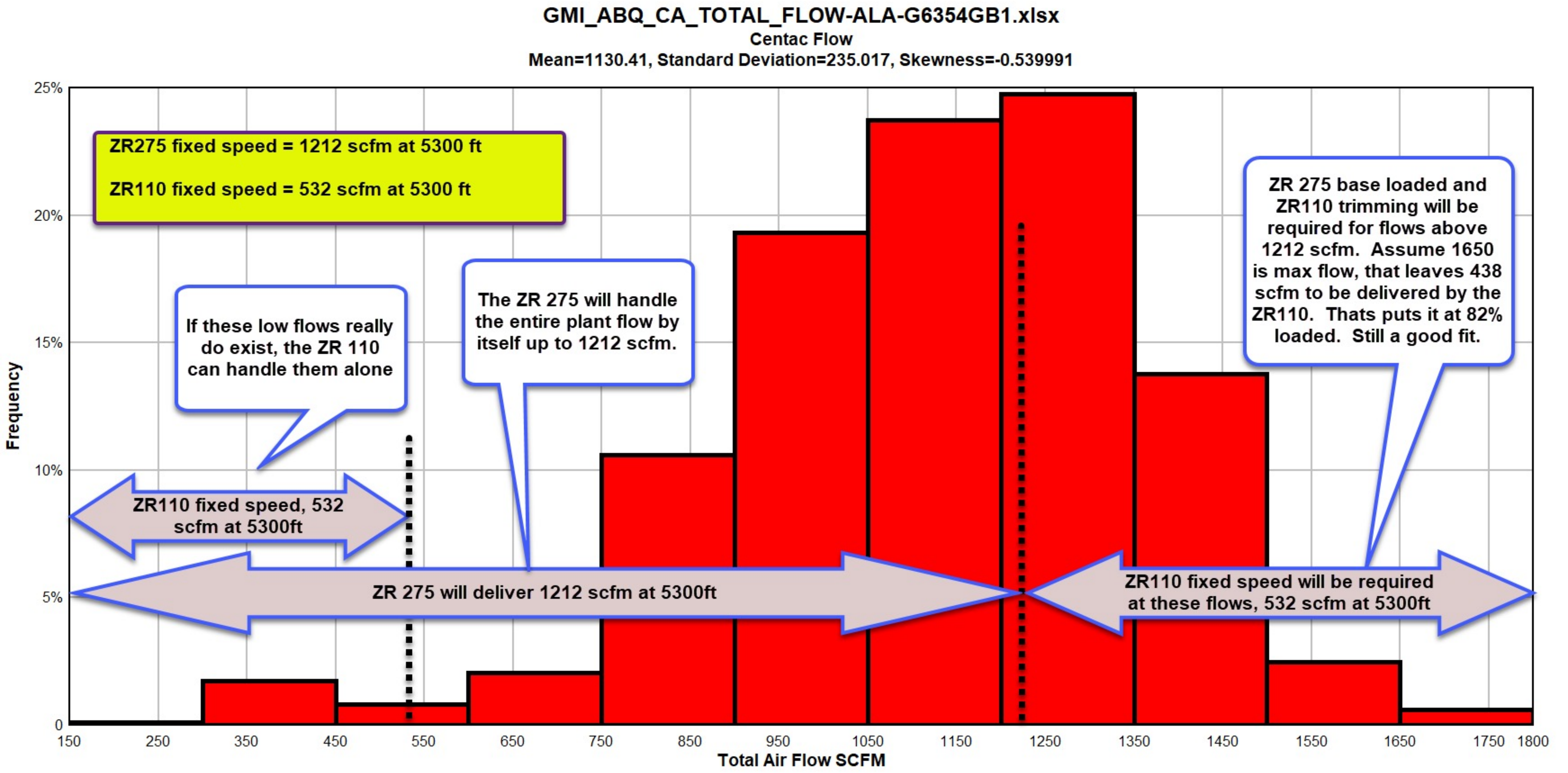
Using Measurements



Using Measurements

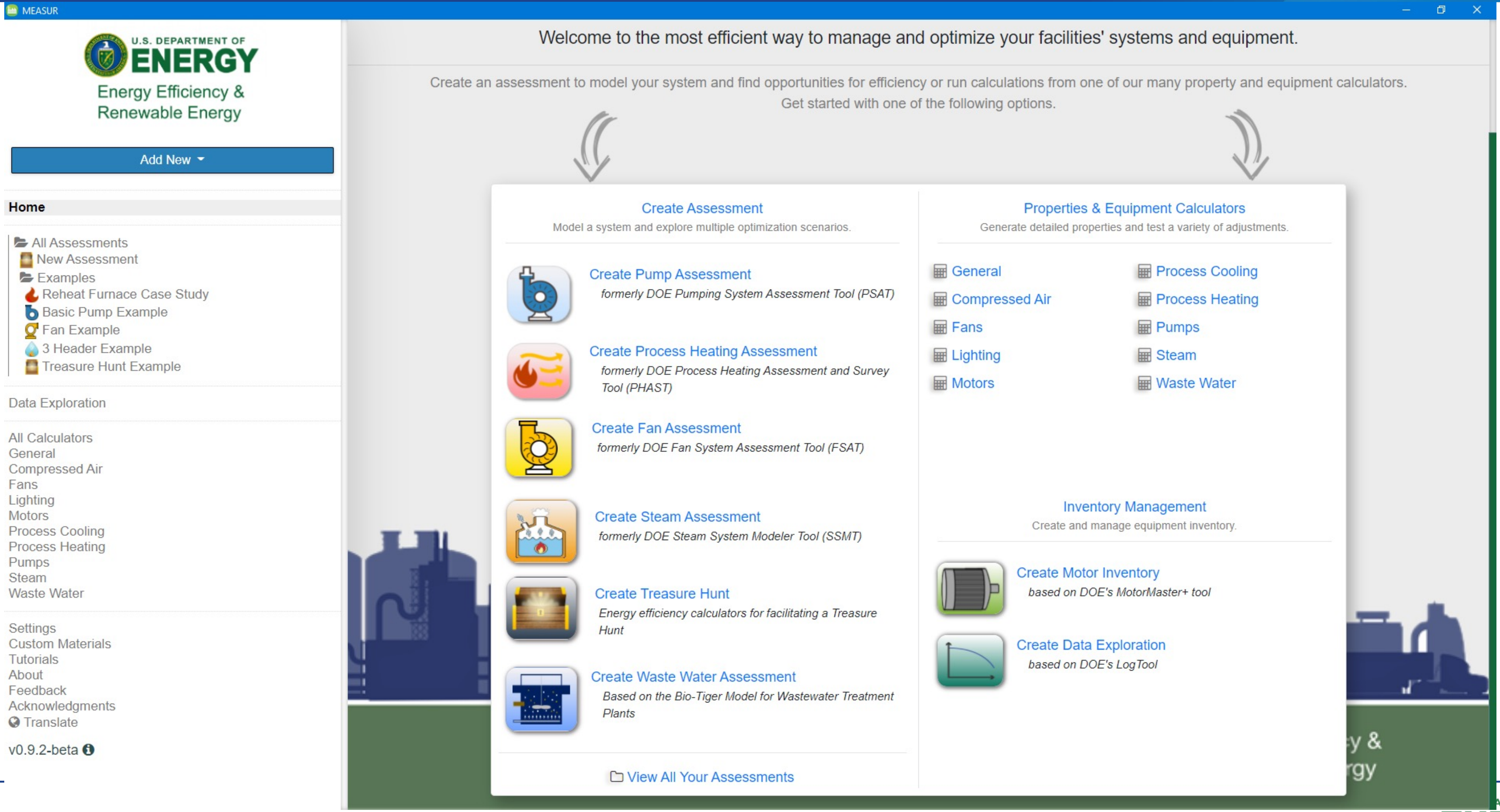



GMI_ABQ_CA_TOTAL_FLOW-ALA-G6354GB1.xlsx
Centac Flow
Mean=1130.41, Standard Deviation=235.017, Skewness=-0.539991
ZR275 fixed speed = 1212 scfm at 5300 ft
ZR160VSD = 151-714 scfm at 5300 ft
ZR 275 base loaded and ZR160 VSD trimming can offer a steady pressure band between a flow of 1363 to 1926 scfm
ZR160 VSD can run by itself up to 714 scfm offering a steady pressure band
This flow between 714 and 1363 will require loading and unloading with a slight control gap from both compressors running and the VSD loading and unloading below its min flow
ZR 275 + ZR160 VSD 1363-1926 scfm at 5300ft
ZR160 VSD 151-714 scfm at 5300ft
Frequency
25%
20%
15%
10%
5%
0
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1800
Total Air Flow SCFM


GMI_ABQ_CA_TOTAL_FLOW-ALA-G6354GB1.xlsx
Centac Flow
Mean=1130.41, Standard Deviation=235.017, Skewness=-0.539991
ZR275 fixed speed = 1212 scfm at 5300 ft
ZR110 fixed speed = 532 scfm at 5300 ft
If these low flows really do exist, the ZR 110 can handle them alone
The ZR 275 will handle the entire plant flow by itself up to 1212 scfm.
ZR 275 base loaded and ZR110 trimming will be required for flows above 1212 scfm. Assume 1650 is max flow, that leaves 438 scfm to be delivered by the ZR110. Thats puts it at 82% loaded. Still a good fit.
ZR110 fixed speed, 532 scfm at 5300ft
ZR 275 will deliver 1212 scfm at 5300ft
ZR110 fixed speed will be required at these flows, 532 scfm at 5300ft
Frequency
25%
20%
15%
10%
5%
0
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1800
Total Air Flow SCFM

AIRMaster+ Main Menu

MEASUR Tool


MEASUR
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Energy Efficiency & Renewable Energy
Add New
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All Assessments
New Assessment
Examples
Reheat Furnace Case Study
Basic Pump Example
Fan Example
3 Header Example
Treasure Hunt Example
Data Exploration
All Calculators
General
Compressed Air
Fans
Lighting
Motors
Process Cooling
Process Heating
Pumps
Steam
Waste Water
Settings
Custom Materials
Tutorials
About
Feedback
Acknowledgments
Translate
v0.9.2-beta
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.
Create Assessment
Model a system and explore multiple optimization scenarios.
Create Pump Assessment
formerly DOE Pumping System Assessment Tool (PSAT)
Create Process Heating Assessment
formerly DOE Process Heating Assessment and Survey Tool (PHAST)
Create Fan Assessment
formerly DOE Fan System Assessment Tool (FSAT)
Create Steam Assessment
formerly DOE Steam System Modeler Tool (SSMT)
Create Treasure Hunt
Energy efficiency calculators for facilitating a Treasure Hunt
Create Waste Water Assessment
Based on the Bio-Tiger Model for Wastewater Treatment Plants
View All Your Assessments
Properties & Equipment Calculators
Generate detailed properties and test a variety of adjustments.
General
Compressed Air
Fans
Lighting
Motors
Process Cooling
Process Heating
Pumps
Steam
Waste Water
Inventory Management
Create and manage equipment inventory.
Create Motor Inventory
based on DOE's MotorMaster+ tool
Create Data Exploration
based on DOE's LogTool

Summary

- Measurements need to be taken to understand how a compressed air system is operating
- Measurements can help you adjust and optimize your system
- Data logging can help you better understand and optimize the system, although sometimes substantial improvements can be made without them
- Care needs to be taken to ensure that you have the right tools for the job, know how to use them, know their limitations, and know how to interpret the data being produced
- Understanding the difference between accuracy and repeatability is important when taking measurements
- Measurements will help you understand how much you are spending on compressed air on a per unit of production basis