Better Plants
U.S. DEPARTMENT OF ENERGY

In-Plant Trainings

Virtual Platform
Session 1
The Basics

What is an In-Plant Training?

- In-Plant Trainings (INPLTs) are specialized workshops by Better Plants experts that teach participants to identify, implement, and replicate energy-saving projects.
- The aim is to help manufacturing plants enhance efficiency and lower energy usage.
- Before Covid, Better Plant partners conducted three-day on-site training sessions, inviting others to participate.
- In response to Covid challenges, we shifted to eight 2-hour virtual training sessions but have since returned to in-person sessions while still offering virtual options.
- Through Better Plants, industrial organizations set efficiency targets and receive technical support and national recognition for their efforts.

The Facilitator

- 45 years in Industry, primarily in the auditing, consulting, training and system design fields.
- Specialty consists of Compressed Air Systems (oil flooded and oil free), Vacuum Systems, Contaminate Removal, System Design and Energy Management.
- Compressed air challenge instructor Fundamentals, Advanced and AirMaster
- Department of Energy (energy savings) expert on compressed air systems
- Vice-Chair for ASME Standard EA-4-2010 "Energy Assessment for Compressed Air Systems”
- Member of International Standards Organization (ISO) technical committee for Air Compressors and compressed air systems energy management;/SC6/WG4
- CAGI Certified Compressed Air System Specialist

TRAINING • EDUCATION • EFFICIENCY
COMPRESSED AIR CHALLENGE
INSTRUCTOR

COMPRESSED AIR SYSTEM SPECIALIST
CAGI Compressed Air & Gas Institute
CERTIFIED

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 & Software Tools
- Week 2 – Compressor Types and Ventilation
- Week 3 – Compressor Controls
- Week 4 - Air Treatment
- Week 5 – Distribution System
- Week 6 – Demand Side and Inappropriate Uses
- Week 7 – System Volume vs Storage
- Week 8 – Wrap Up Presentations (example, next slides)

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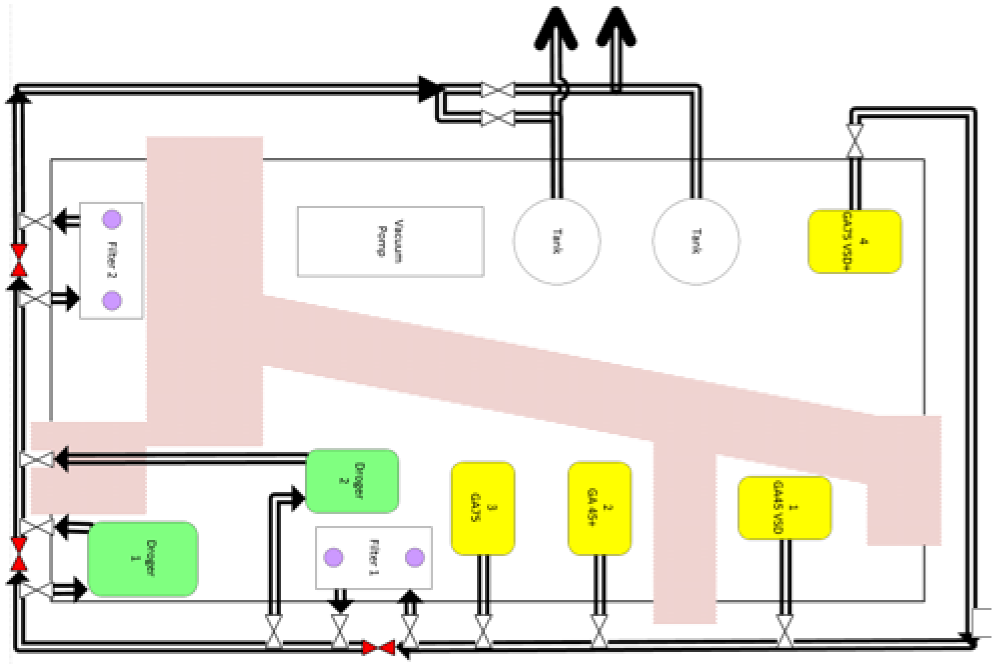
Compressed Air Systems VINPLT: Close out Presentation

Company Name: OwensCorning
Facility Name: OwensCorning Apeldoorn (NL)
Participant Name(s): Hans Berkman

Block Diagram of the Compressed Air System



Nr:	Type	Operating hours	Year	Max pressure	Remakrks remarks	Needed maintanacne Benodigd bijzonder onderhoud
Comp. 1	GA45 VSD	103.000	2010	13 bar	variable	Overhaul needed, replacement recommended by Atlas Copco
Comp. 2	GA45+	85.500	2010	8 bar	Variable	Overhaul needed, replacement recommended by Atlas Copco
Comp. 3	GA75	55.000	2002	8 bar	Back-up	water cooled unreliable , lot of oil leakages
Comp. 4	GA75 VSD	56.000	2016	13 bar	Main	overhaul overdue
dryer 1	FD 450	202.000	2004	14,5 bar		
dryer 2	FD 510 A	54.000	2016	14 bar		
Filter 1	DD 520 F	220.000	2000	16 bar		
Filter 2	PD 520 F	220.000	2000	16 bar		

Savings Opportunities in Compressor Controls

- Install more flow and pressure measurements
- Eliminate peak loads , e.g from pigged lines
- Enlarge buffer capacity for reducing impact of pigged lines
  - Because the piping is quite long it uses a lot of CA in a shirt time , sometimes both line are active at the same time
- Make CA visible in the AspenTech data system
- Limit CA usage of vacuum cleaners as long they are in use

Savings Opportunities in Pressure Setpoints

Lower pressure setpoint for pigged lines , transport will take more time but it’s possible

Lower pressure setpoints for some diaphragm pumps when time is no issue

Limit air usage for camera’s (no restrictions now)

Savings Opportunities in Compressed Air Distribution Systems

We already had a company in for a leakage survey , as soon as the report is available start fixing the leakages

Start restricting new equipment or process driven with CA

Test quantm pump at a position where a diaphragm pump is 24/7 in use

Savings Opportunities in Compressed Air Users

Reduce number of users
Try to reduce simultaneously use
Create a CA cost mindset

Look for alternatives , perhaps there is E driven equipment now

Tips Learned from this Training

- Awareness is very important
- Measuring show you the opportunities
- Start looking for leakages immediately
- Get in control
- Stop seeing CA as a quick and simple energy source
- Make a decent roadmap for improvements
  - Share improvements
  - Secure the improvements

Next Steps or Action Items after the Compressed Air VINPLT

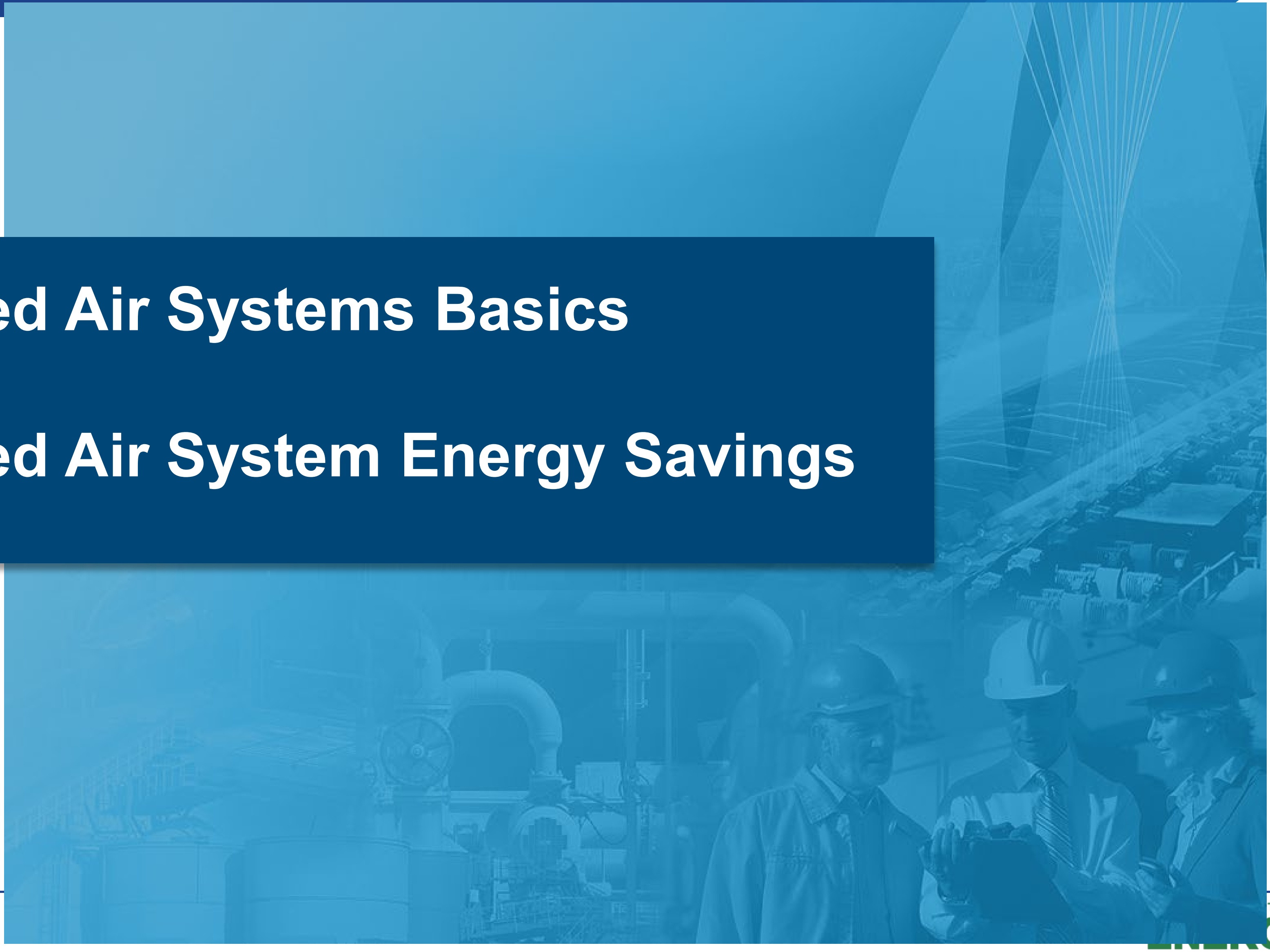
- What are your next steps to implement opportunities?
  - Overhauling of compressed air supply system
  - Switch to quantm pumps if possible
  - Find an other source for the needed air for the pigged lines
- What are you planning to do after the VINPLT?
  - Share learnings with more people in the plant for creating more awareness
  - Set up a compressed air usage dashboard
- Lessons learned?
  - A lot , we have a long way to go , for years there was no focus on CA at all , the motto " was too much is not too little" and when you have not enough you are in trouble

Questions and Answers

- Will there be a follow up session
- Can we share more best practice cases
- It will take time to digest all the shared information
-

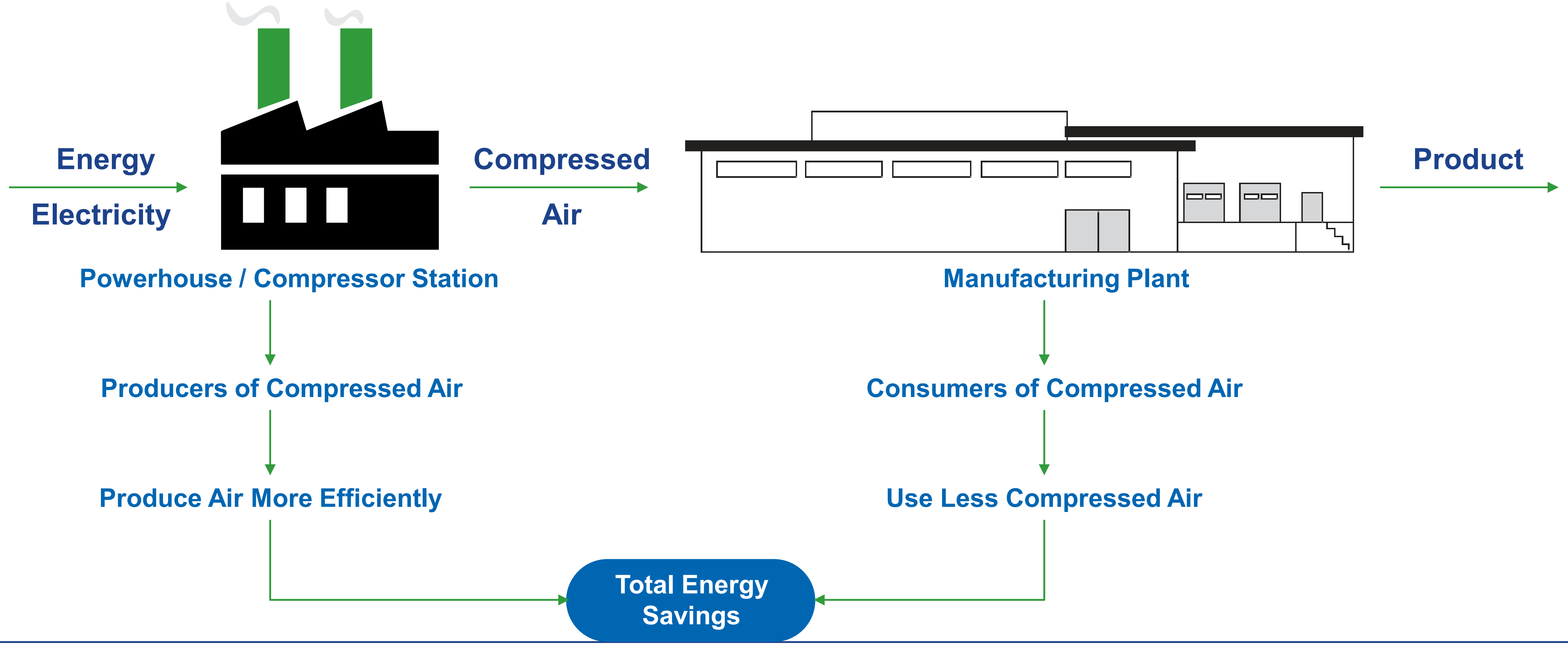
Compressed Air Systems Basics

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.



Treasure Hunt

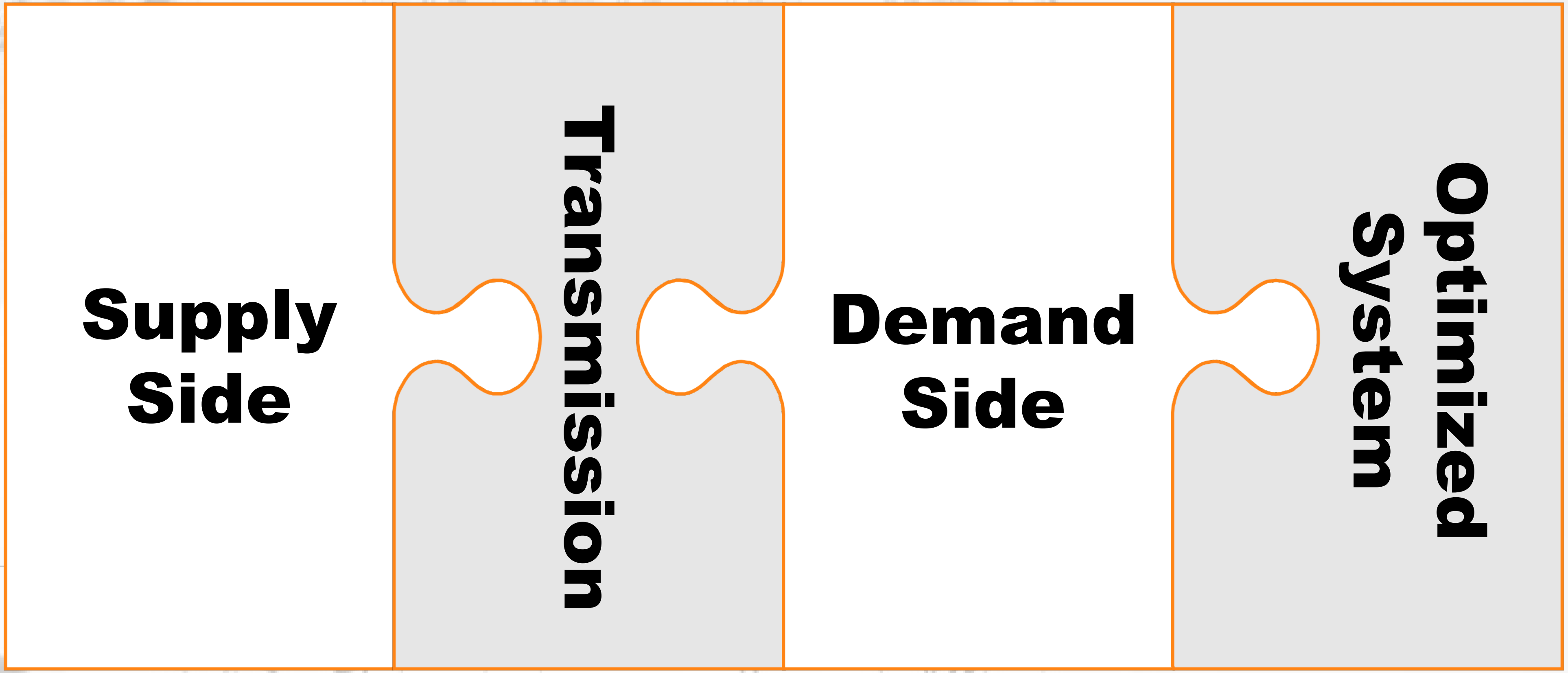
What am I looking for?

Treasure Hunt

The prime consideration for any compressed air system is the ability to generate air with the least amount of energy.

Having done this, the next consideration is to transmit energy from the point of generation to the point of use with the least loss.

The final consideration is to eliminate waste and use the least amount of air for the production process.



Look from the System Level Approach

Compressor manufacturers spend a great deal of money to obtain optimum efficiency of their individual products…….

……only to see much of the energy savings squandered in a poorly designed and managed system.

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.

Look from the System Level Approach

- Improve Compressor Control
- Reduce System Pressure
- Reduce Air Demand

What Do I Look For?

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

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.

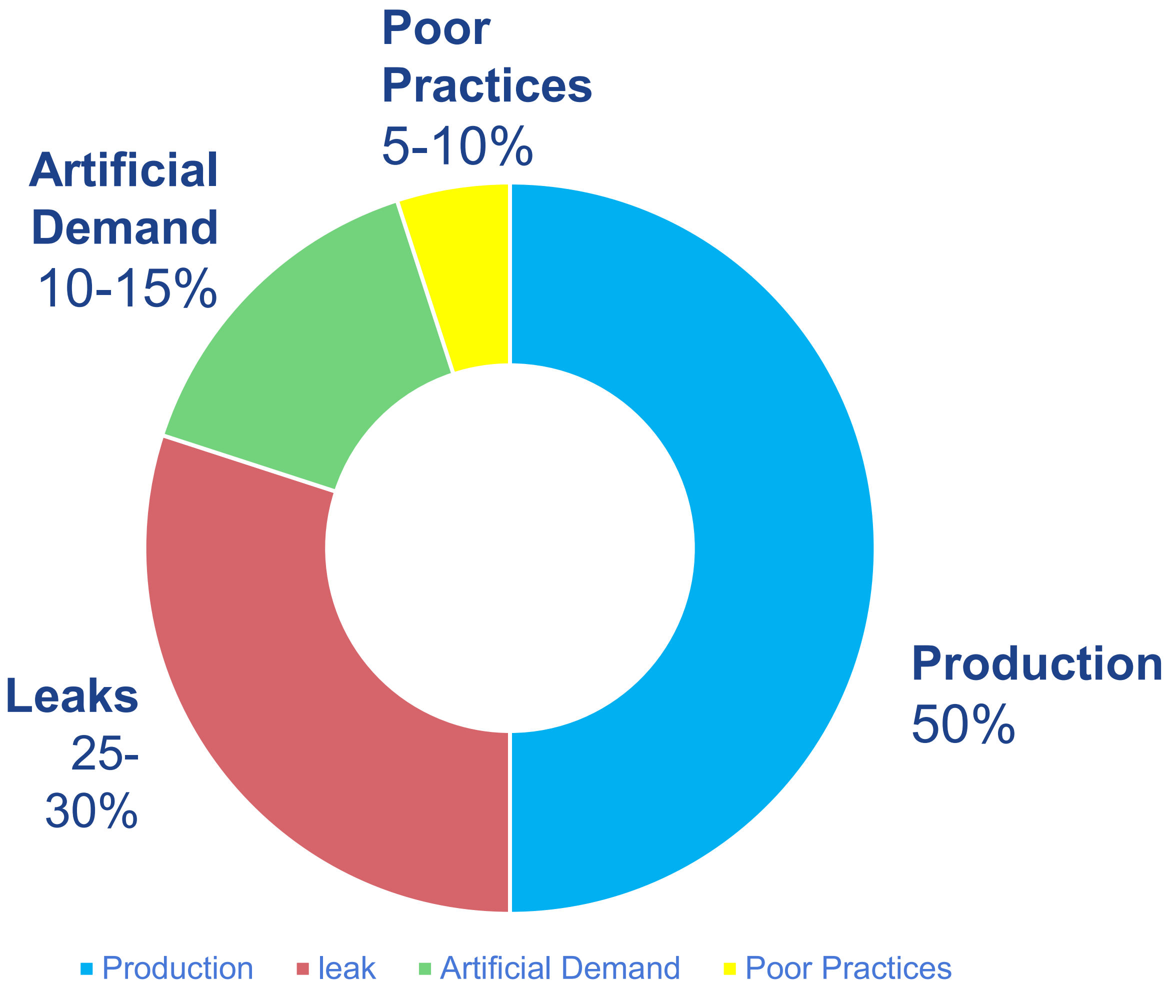
Compressed Air Versus Other Energy Sources

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

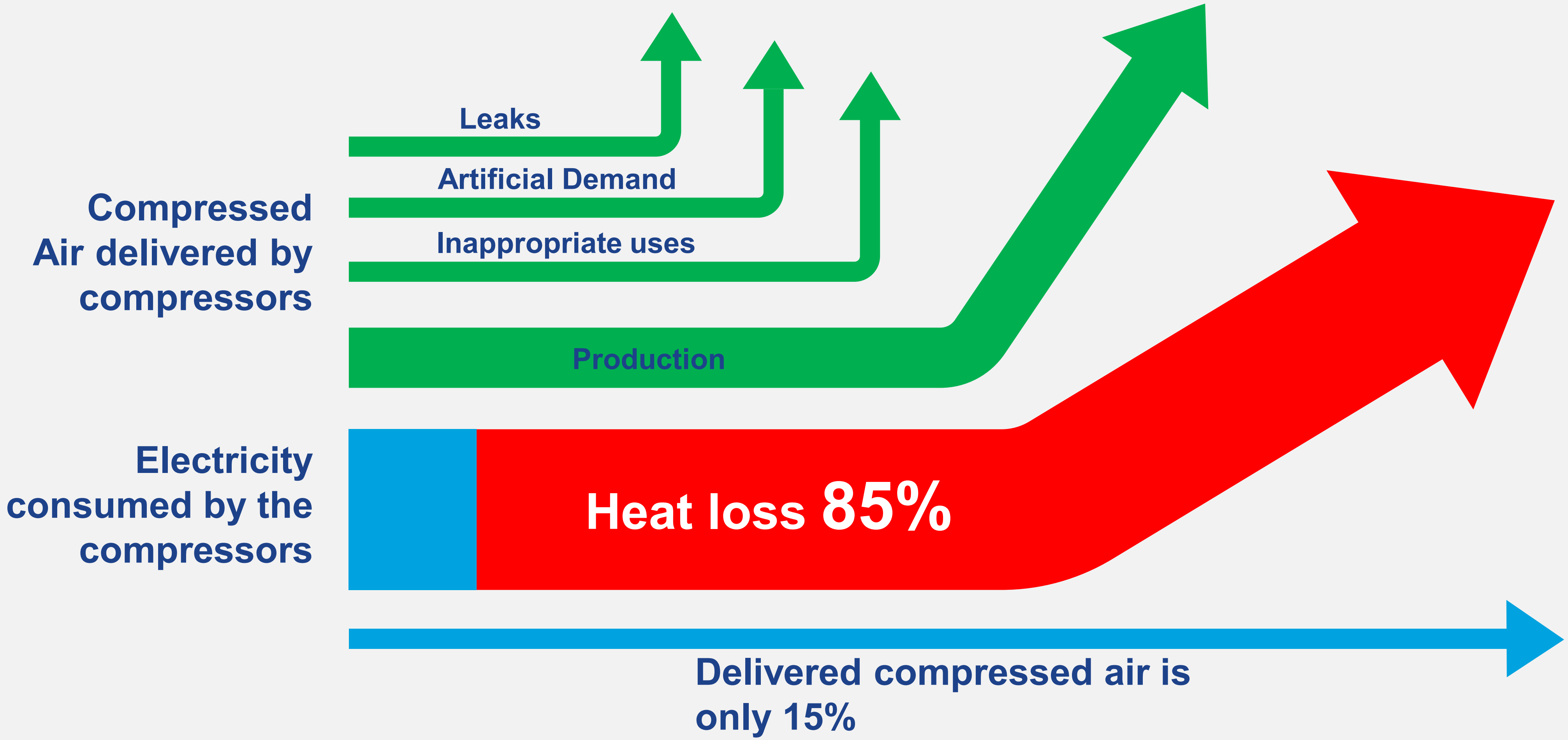
- You may be surprised, in most industrial plants, only 50% of the compressed air generated supplies productive air use.
- The other 50% is consumed by various losses.
- The losses are

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

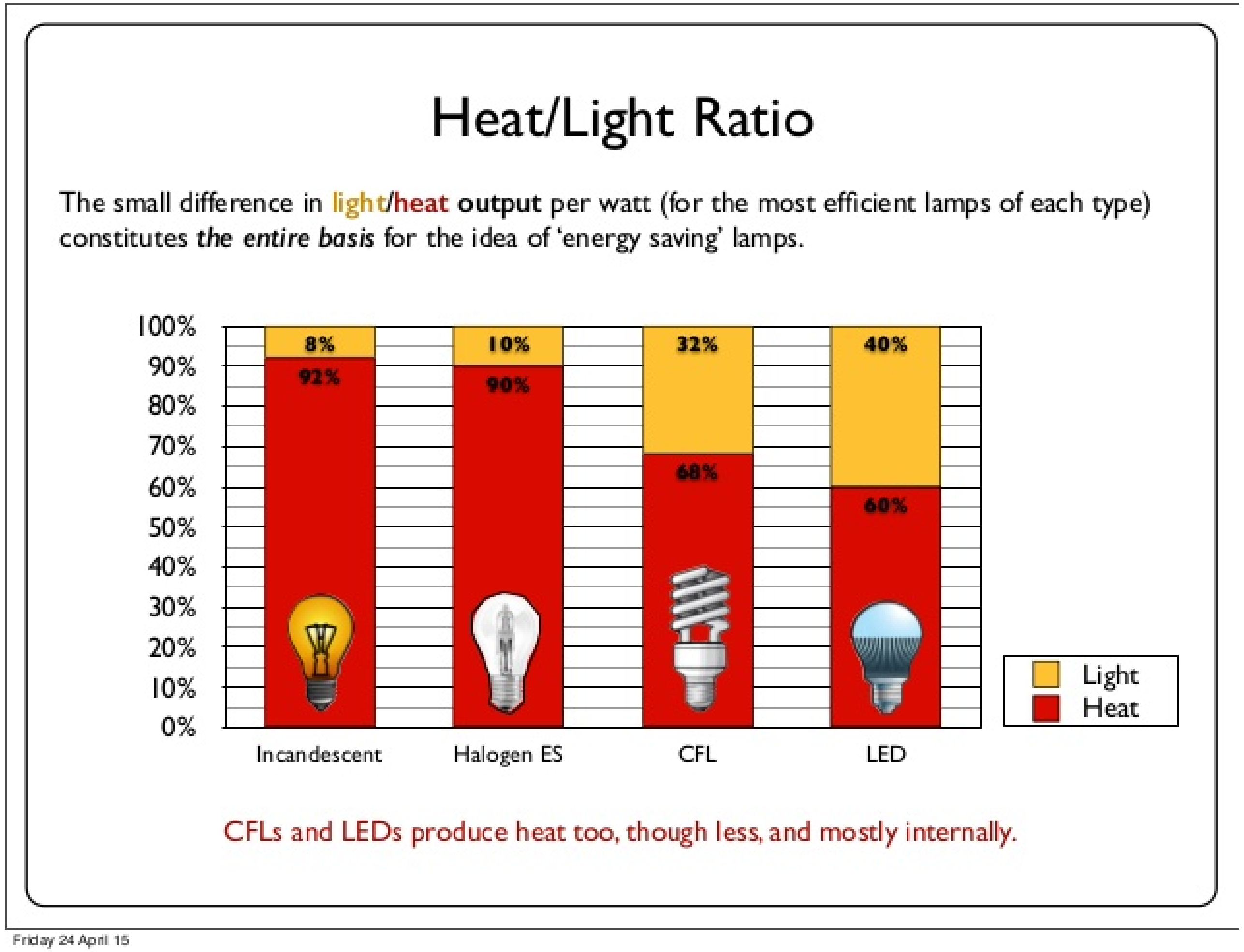
Where does the air go?

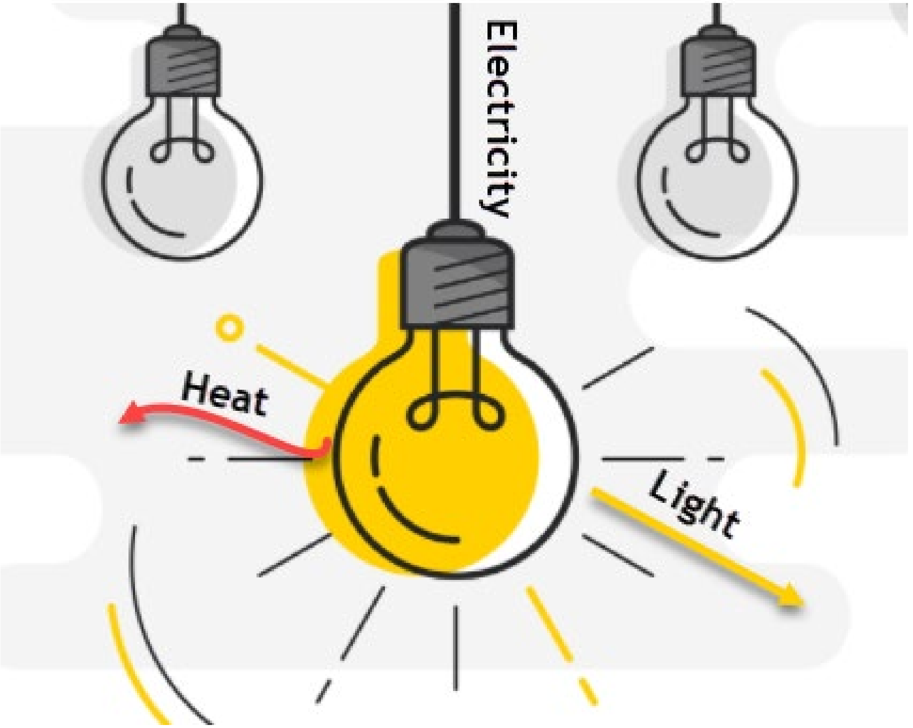


Not very efficient!



Not very efficient!

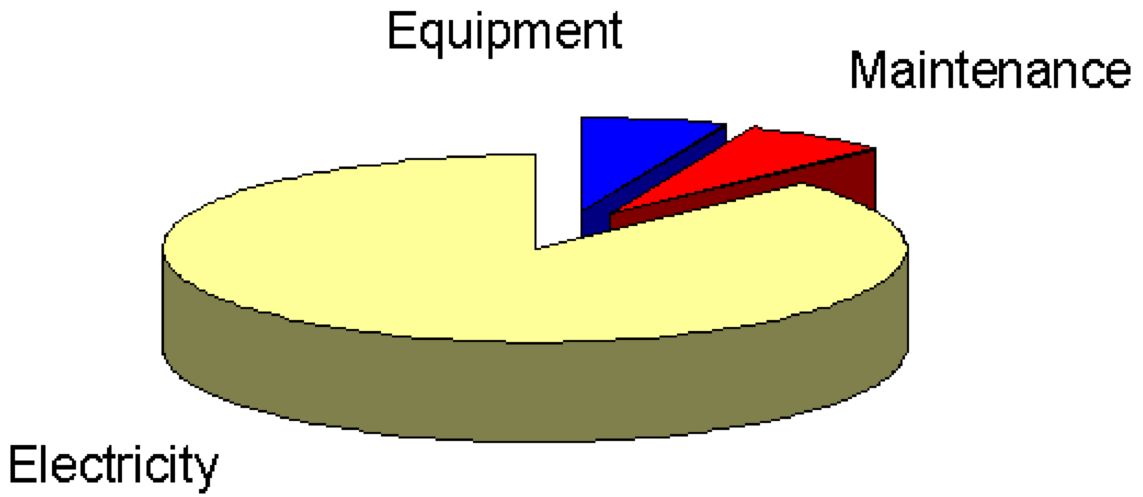




Compressed Air Systems
Total Cost of Ownership

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.



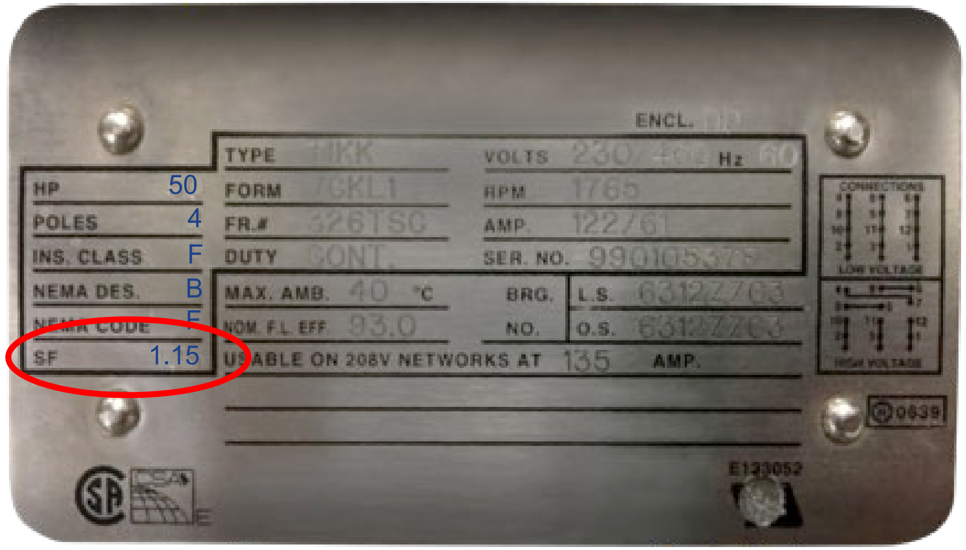
Source: Compressed Air Challenge®

Compressed Air Systems
Total Cost of Ownership

- Kilowatt hours represent the amount billed by the utility company for electricity usage. A business or individual is charged based on the kilowatts consumed each hour.
- Occasionally, the power usage of compressors is Brake Horsepower (BHP) rather than kilowatts (kW). To convert BHP to kW, multiply the BHP value by 0.746. For instance, 100 BHP would equal 100 * 0.746 = 74.6 kW.

Compressed Air Systems
Total Cost of Ownership

- The service factor represents the portion of the horsepower rating that the motor can sustain over time.
- Therefore, a motor with a service factor of 1.15 is able to run continuously at 115% of its rated horsepower.
- For instance, a motor rated at 50 horsepower with a service factor of 1.15 could deliver 57.5 brake horsepower (bhp) continuously, whereas a compressor powered by a 50 hp motor with a 1.30 service factor could operate at 65 brake horsepower continuously.
- Utilizing more brake horsepower will result in higher operational costs.



Compressed Air Systems
Total Cost of Ownership

- The cost of power equals the brake horsepower being used by the compressor times the conversion factor of .746 times the hours the compressor is run times the cost of electricity divided by the motor's efficiency. If it's a 93% efficient motor, you want to plug in .93 into this formula.

$$\frac{BHP \times .746 \times hours \times electricity\ rate}{motor\ efficiency}$$

- For example, let's use a 200 hp compressor running 10% into the SF. The brake horsepower is 220. The compressor runs 8,000 hours in a year. The blended electricity rate is 10 cents per kilowatt hour. And the motor efficiency is 96%.

$$\frac{220 \times .746 \times 8000 \times .10}{.96} = \$136,766$$

Compressed Air Systems
Total Cost of Ownership

Annual Electricity Cost (measurement formula) Much more accurate!

$$\frac{(\text{full load amps}) \times (\text{voltage}) \times (1.732) \times \text{pf} \times \text{hours} \times \text{rate}}{1{,}000}$$

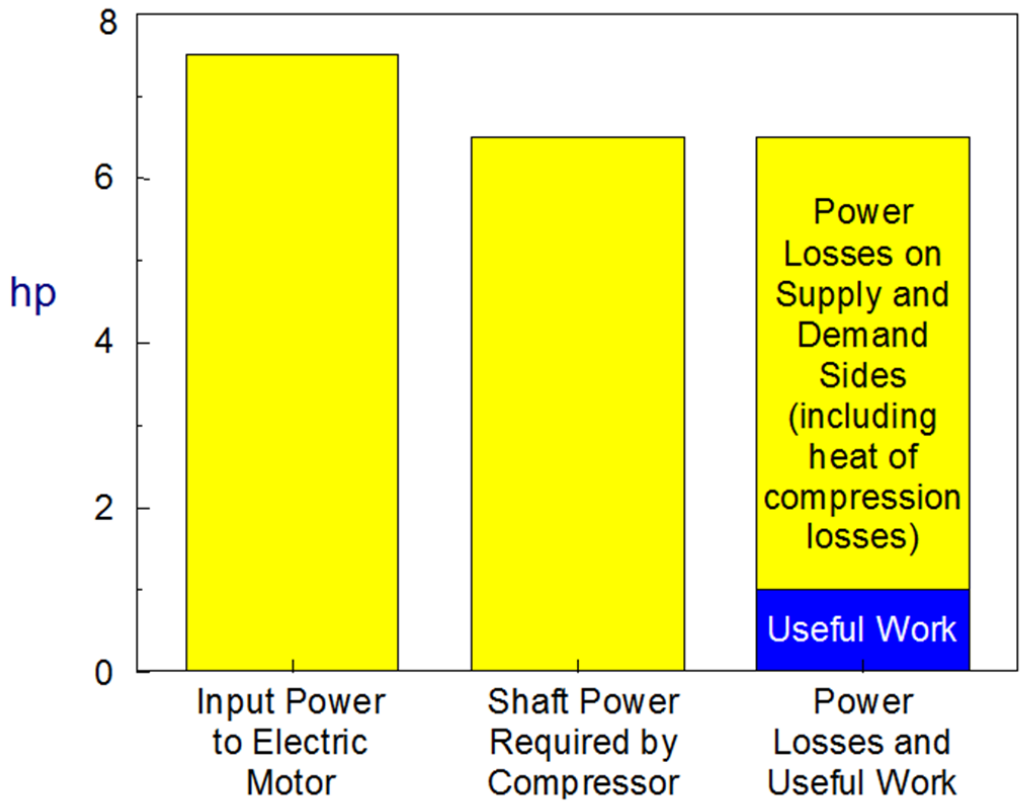
Where:

full load amps	= average of three phases
voltage	= line to line voltage
pf	= power factor (typ .87 full load)
hours	= annual hours of operation
rate	= electricity cost in $/kWh

The full load amps and voltage are the measured values
Get power factor (pf) from motor manufacturer

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**



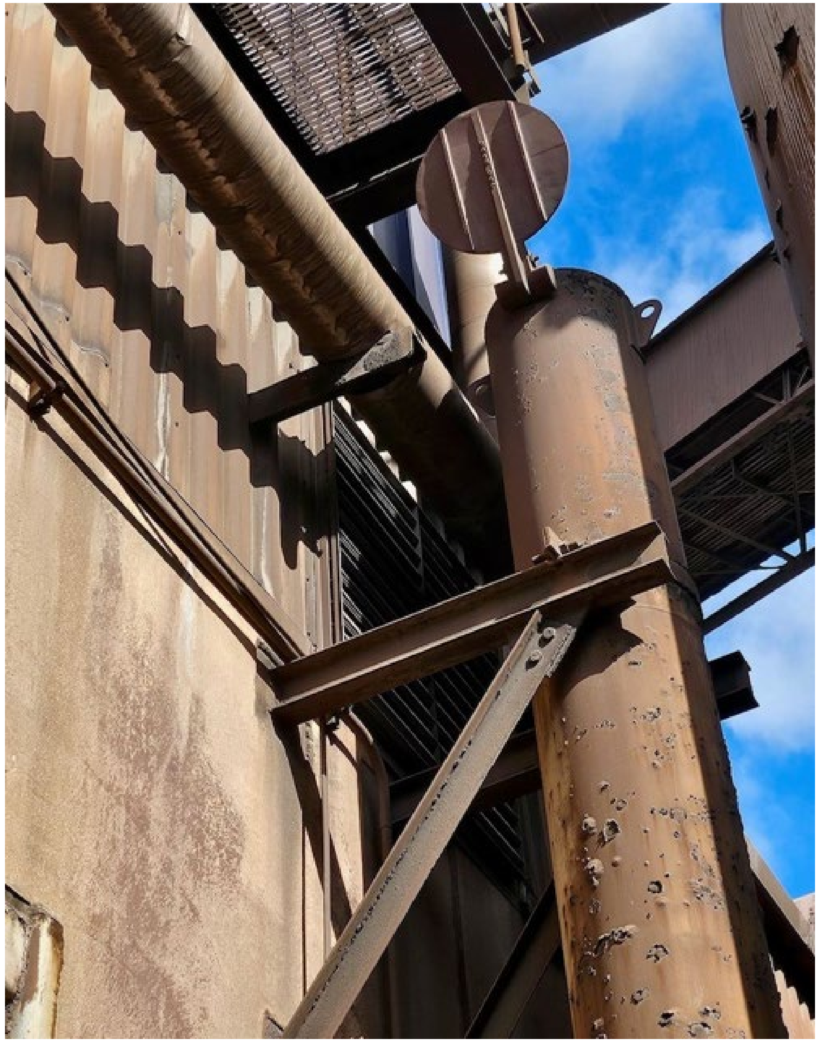
What Measurements Should I Record?

- 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.

Where Do I Start?

First, lets have a look at opportunities in the compressor room……

Centrifugal Controls



Blow off open

Warnings

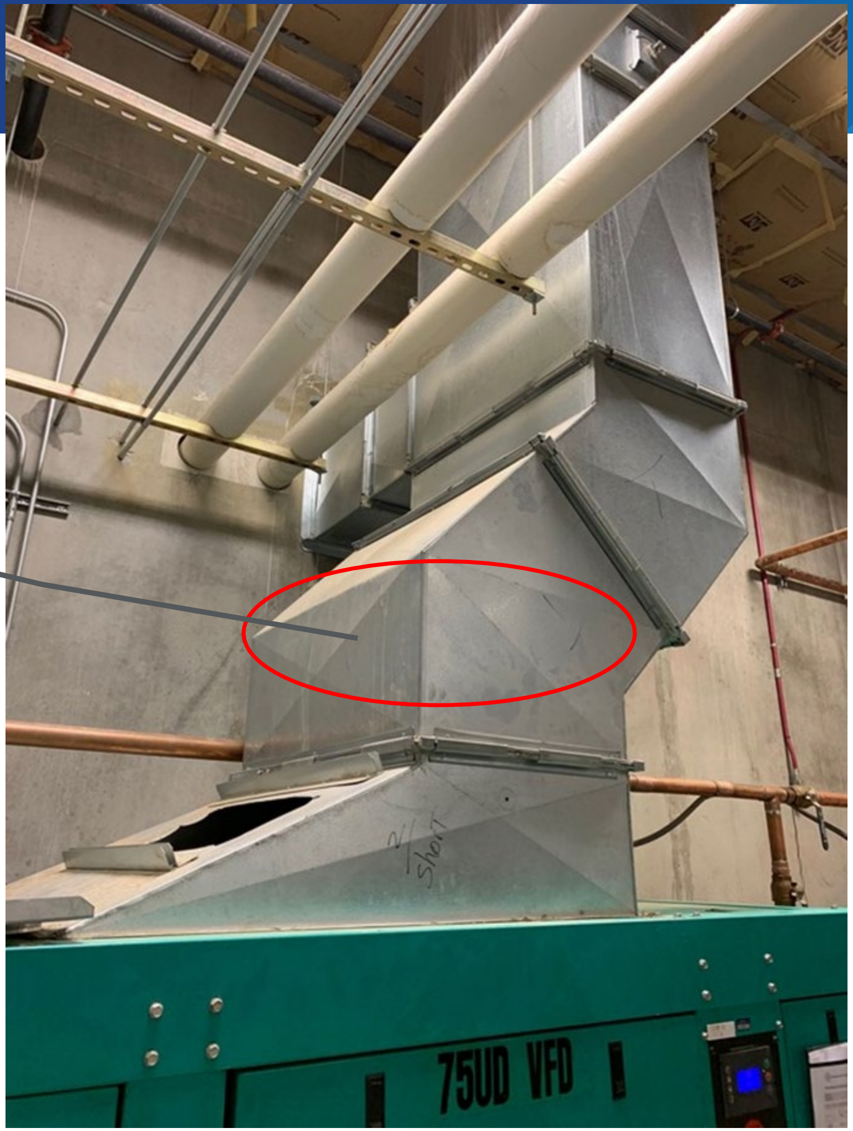
Visual Maintenance Indicators

Warnings

Visual Maintenance Indicators

Proper Ducting

Poor Ducting Design



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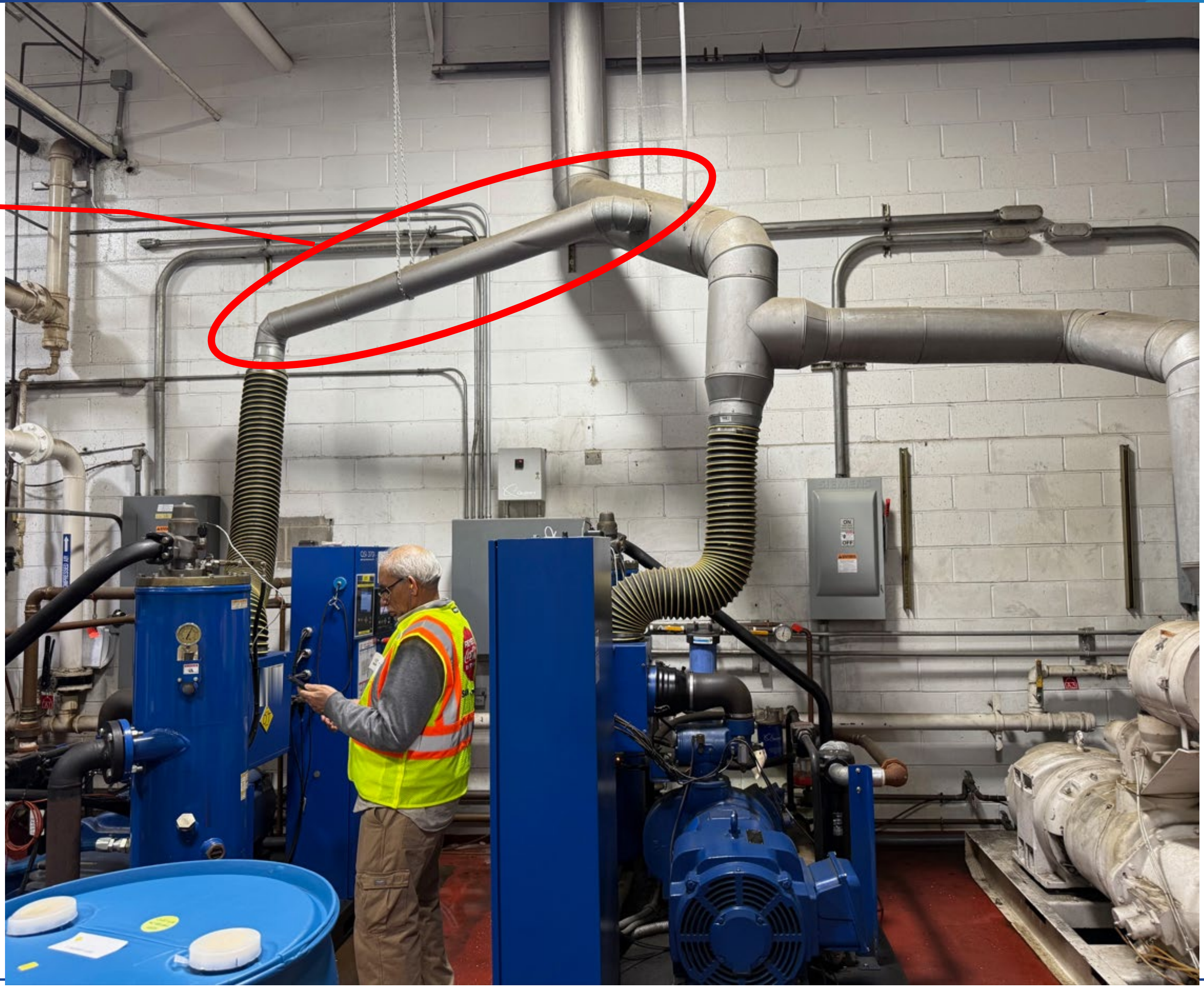
Proper Ducting

Intake Pipe Design



Proper Drainage

Clogged Drain

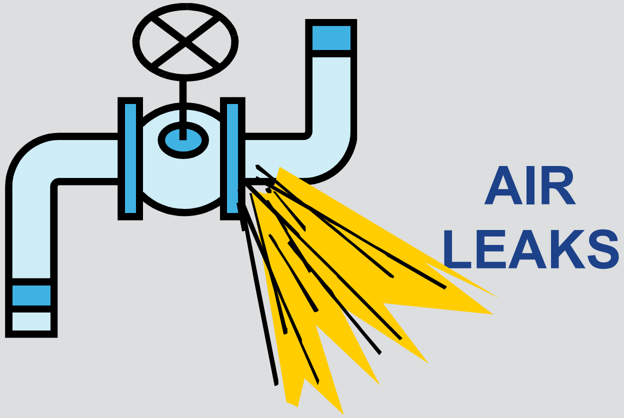
Reduce Pressure at Source

1. Yes, this can be determined visually during a walk through.
2. Every additional 2 psi costs 1% in energy.
3. Check the validity of compressor control settings.
4. Check pressure drops through dryers, filters and piping systems.
5. Artificial Demand is real flow.

Artificial Demand

A 1/16 inch equivalent diameter leak

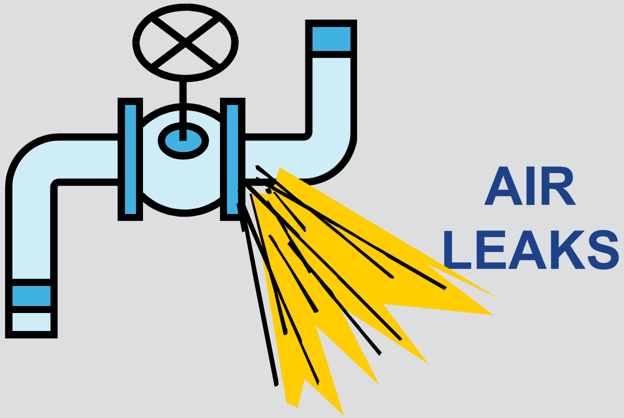
At 120PSIG



7.62 scfm FLOW

A 1/16 inch equivalent diameter leak

At 80PSIG



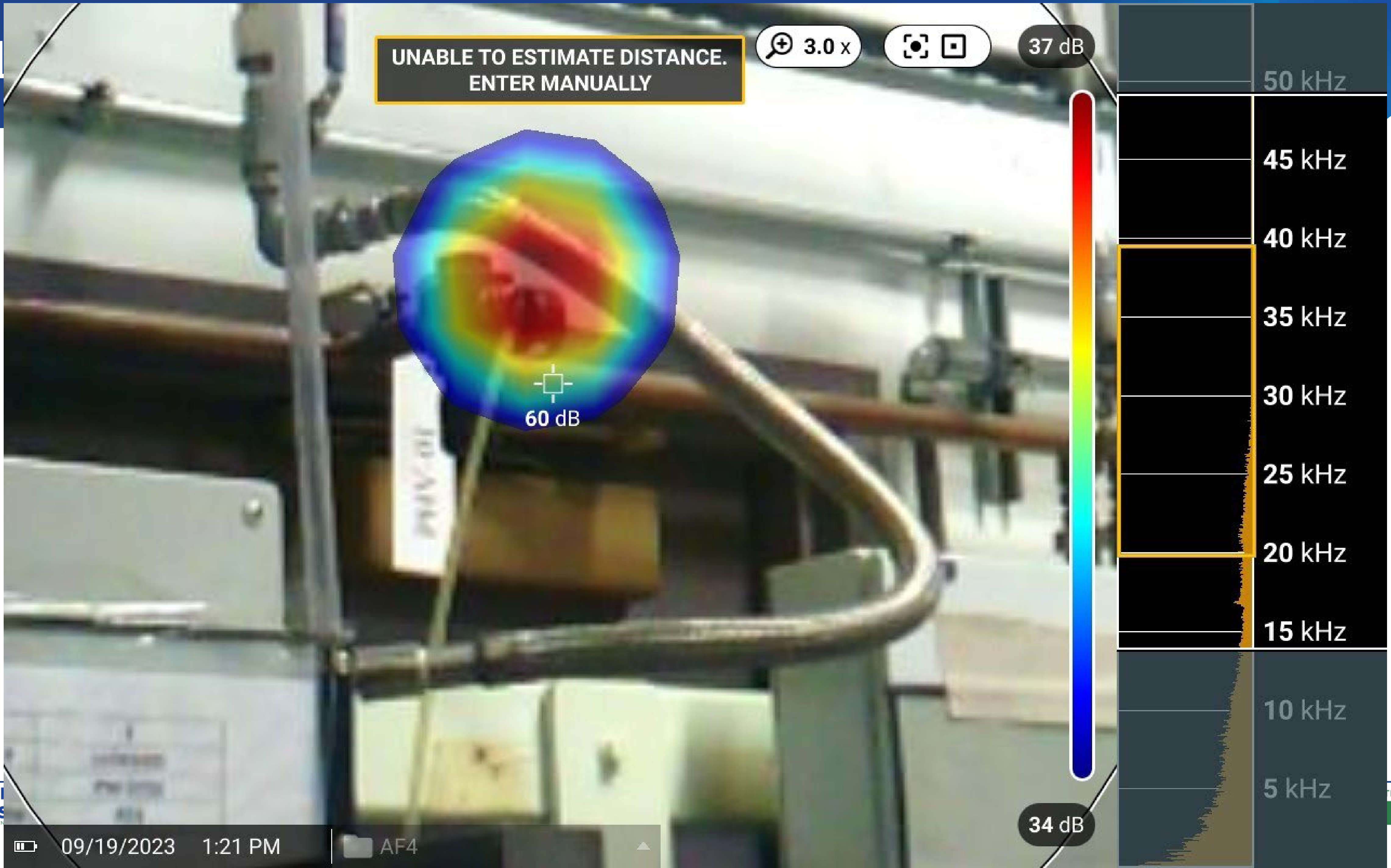
5.36 scfm FLOW

A leak consumes 42% more air at 120 psig than at 80 psig adding to the artificial demand on the system..

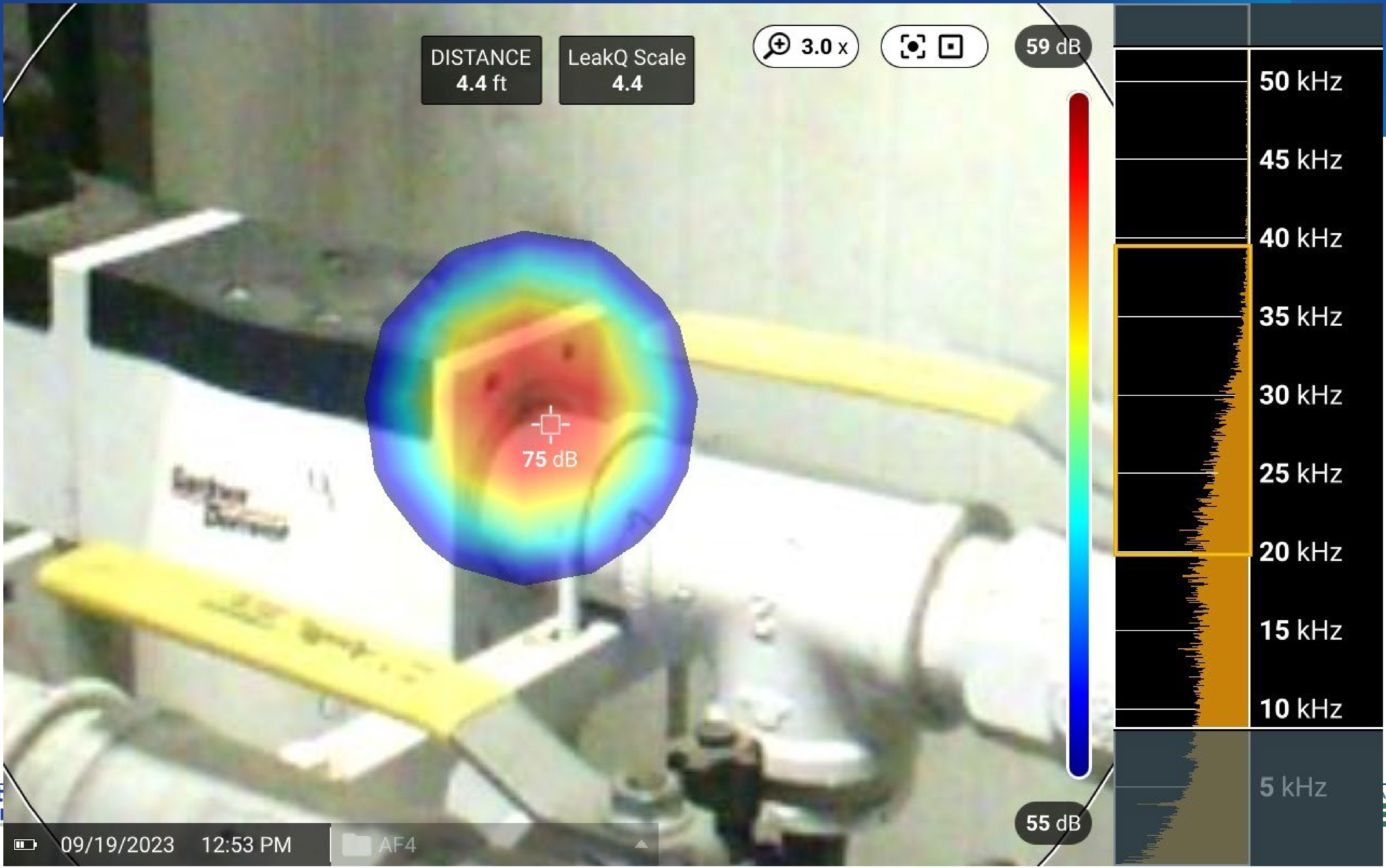
How Acoustic Camera Leak Detection Works

- The acoustic camera uses microphones and sophisticated signal processing and software to identify the loudest source of noise when many sources are present.
- It allows the user to pinpoint sound leaks in walls, doors, and floors and target the leak

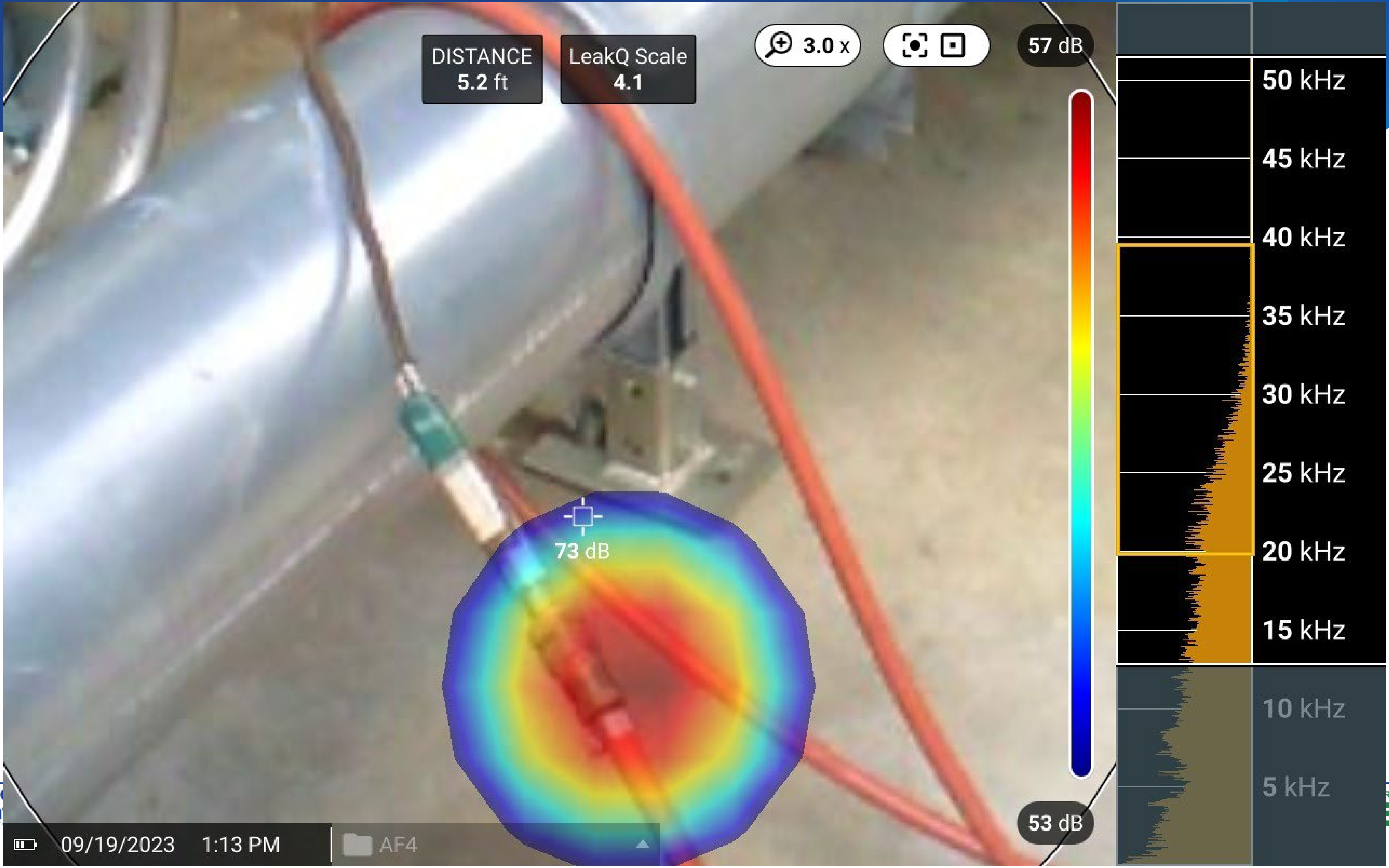

34 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
M_22
0:10
0:00:00



UNABLE TO ESTIMATE DISTANCE.
ENTER MANUALLY
3.0 x
37 dB
60 dB
34 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
09/19/2023
1:21 PM
AF4



DISTANCE
4.4 ft
LeakQ Scale
4.4
3.0 x
59 dB
75 dB
55 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
09/19/2023
12:53 PM
AF4


DISTANCE
5.2 ft
LeakQ Scale
4.1
3.0 x
57 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
73 dB
53 dB
09/19/2023
1:13 PM
AF4


DISTANCE
4.9 ft
LeakQ Scale
2.5
2.9 x
45 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
64 dB
42 dB
09/19/2023
1:33 PM
AF4


51 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
0:00:01
0:00:09
10
30

Imager Vs. Conventional Ultrasonic Leak Detector

- With acoustic imager type, multiple microphones enable the inspection of an expansive area from a distance.
- A conventional Ultrasonic Leak Detector inspects plants point by point looking for leaks in each hose, coupling, trap, drain, valve and gasket.
  - How can I test the accuracy of my leak detector?

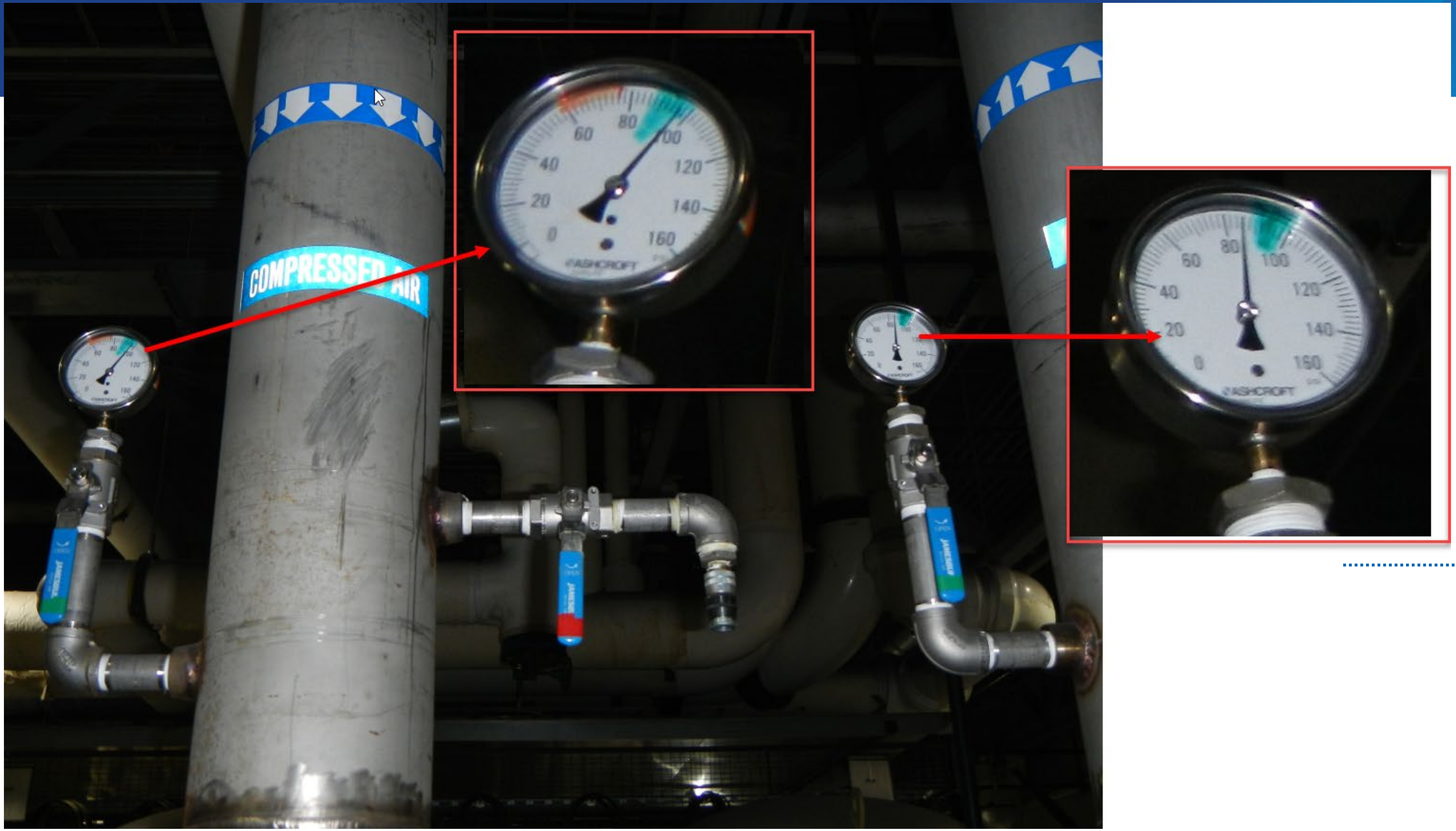
Leakage Losses

gallon size	Time to fill (seconds)	scfm
50	10	40.10695187
50	60	6.684491979
50	120	3.342245989
30	2	120.3208556
50	15	26.73796791
		#DIV/0!

Leak Loss Estimator - Bag Method

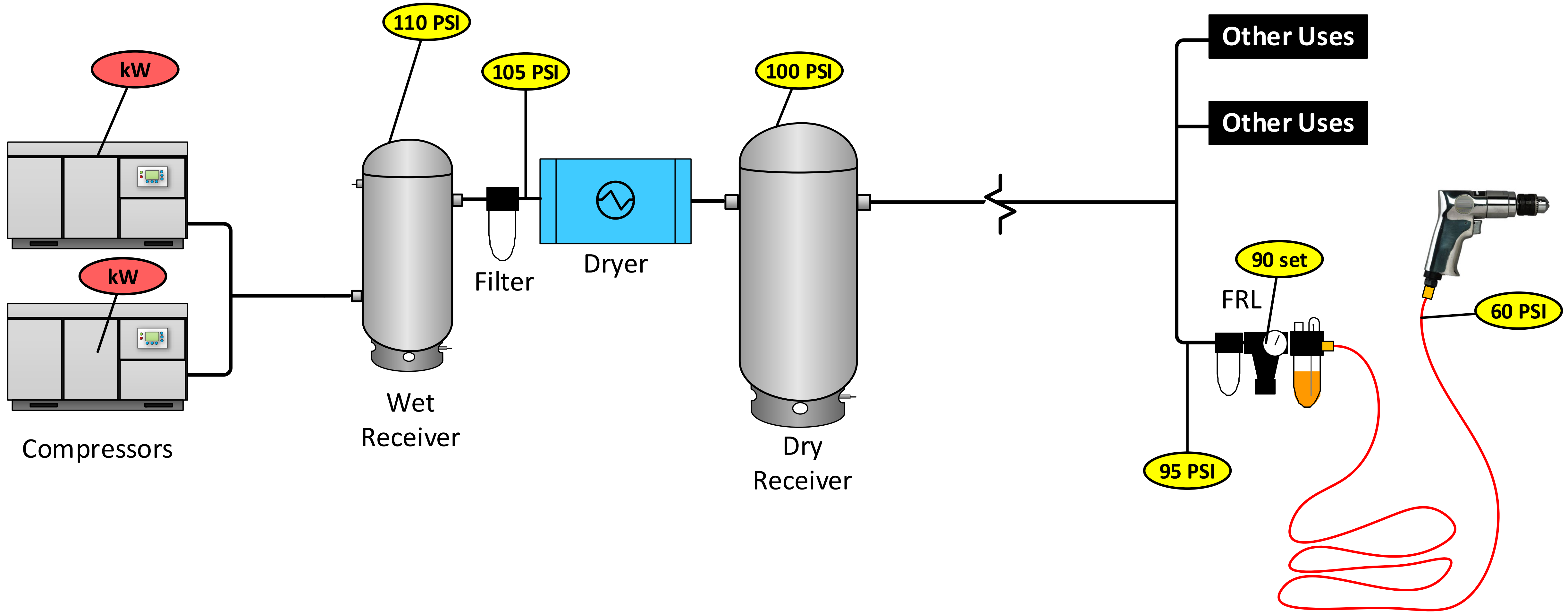
Estimates the leakage losses in a compressed air system using the bag method

Reduce Pressure at Source (Cont'd)

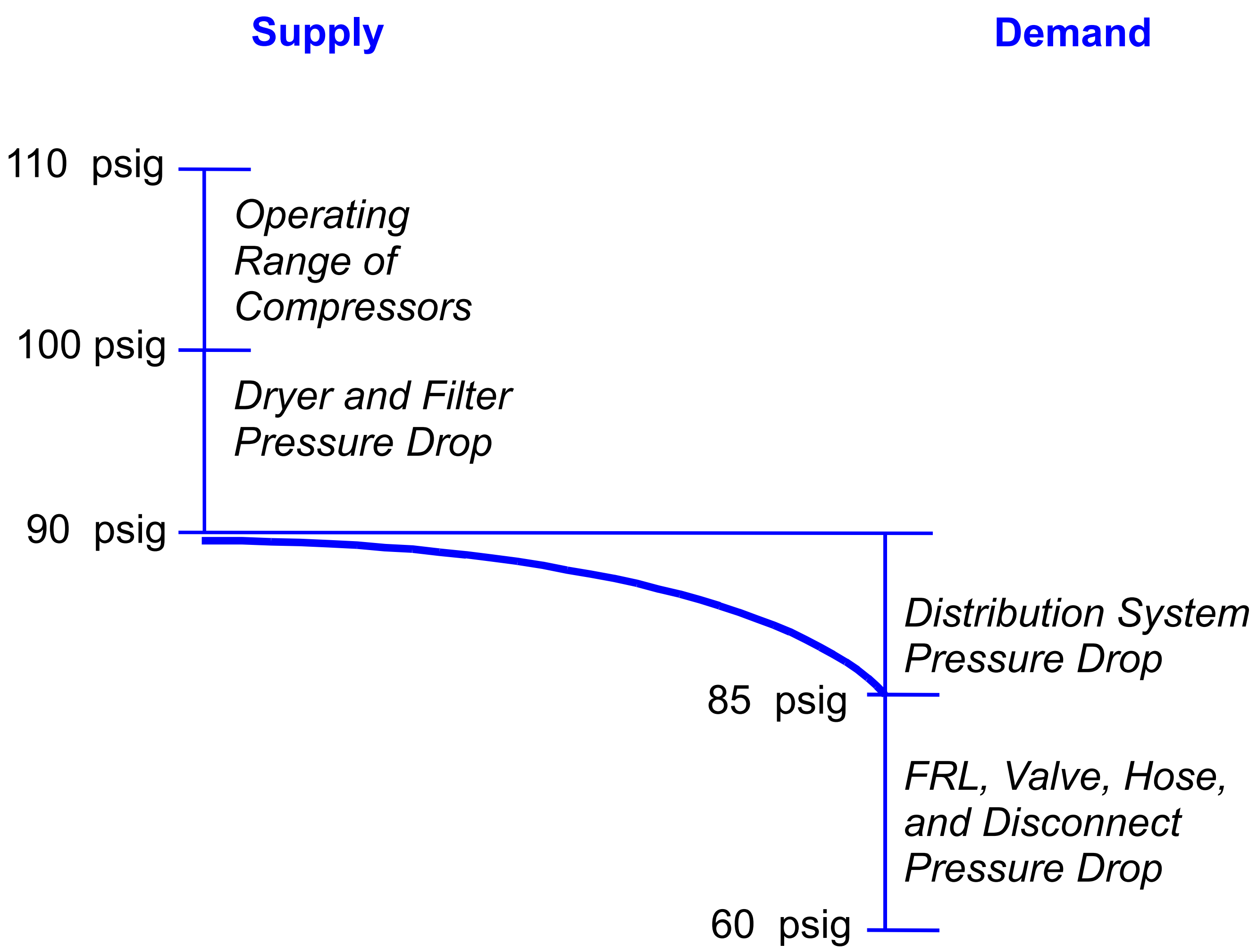

COMPRESSED AIR
0
20
40
60
80
100
120
140
160
ASHCROFT

Reduce Pressure at Source (Cont'd)

What Measurements Should I Record?



System Pressure Profile



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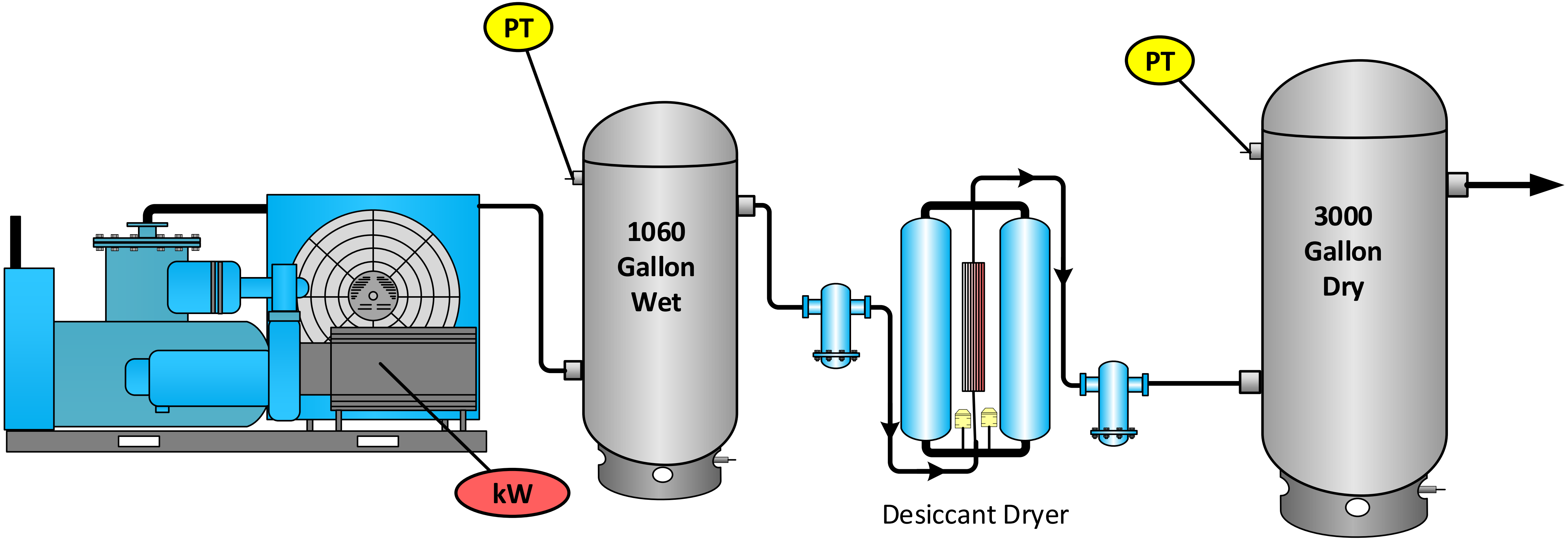

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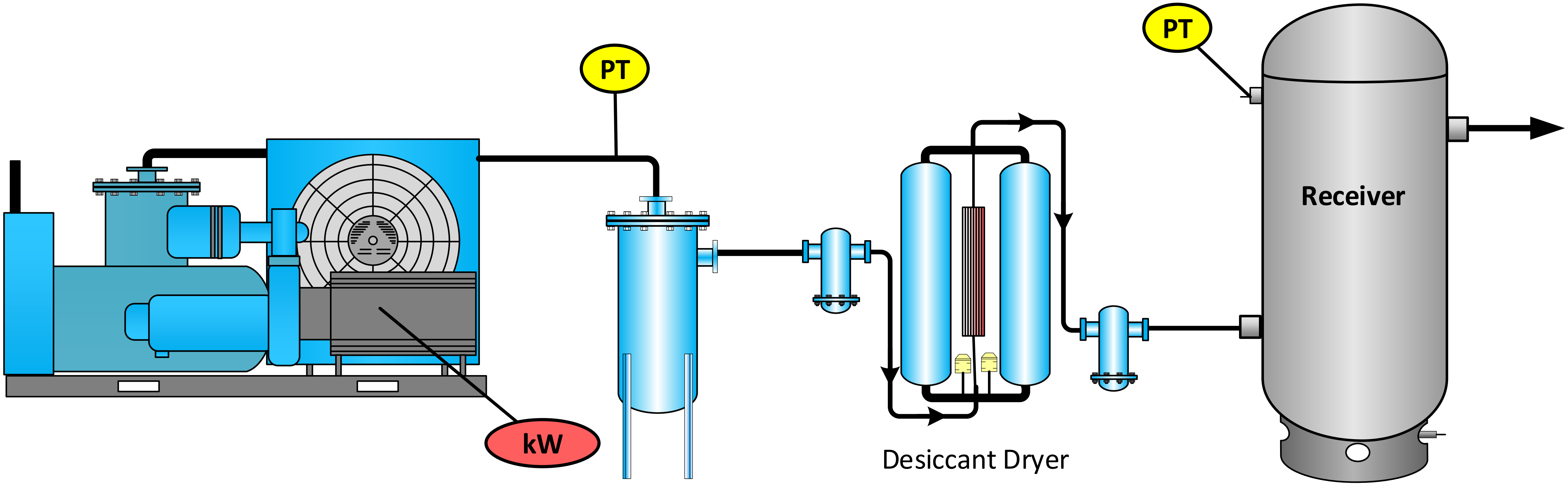
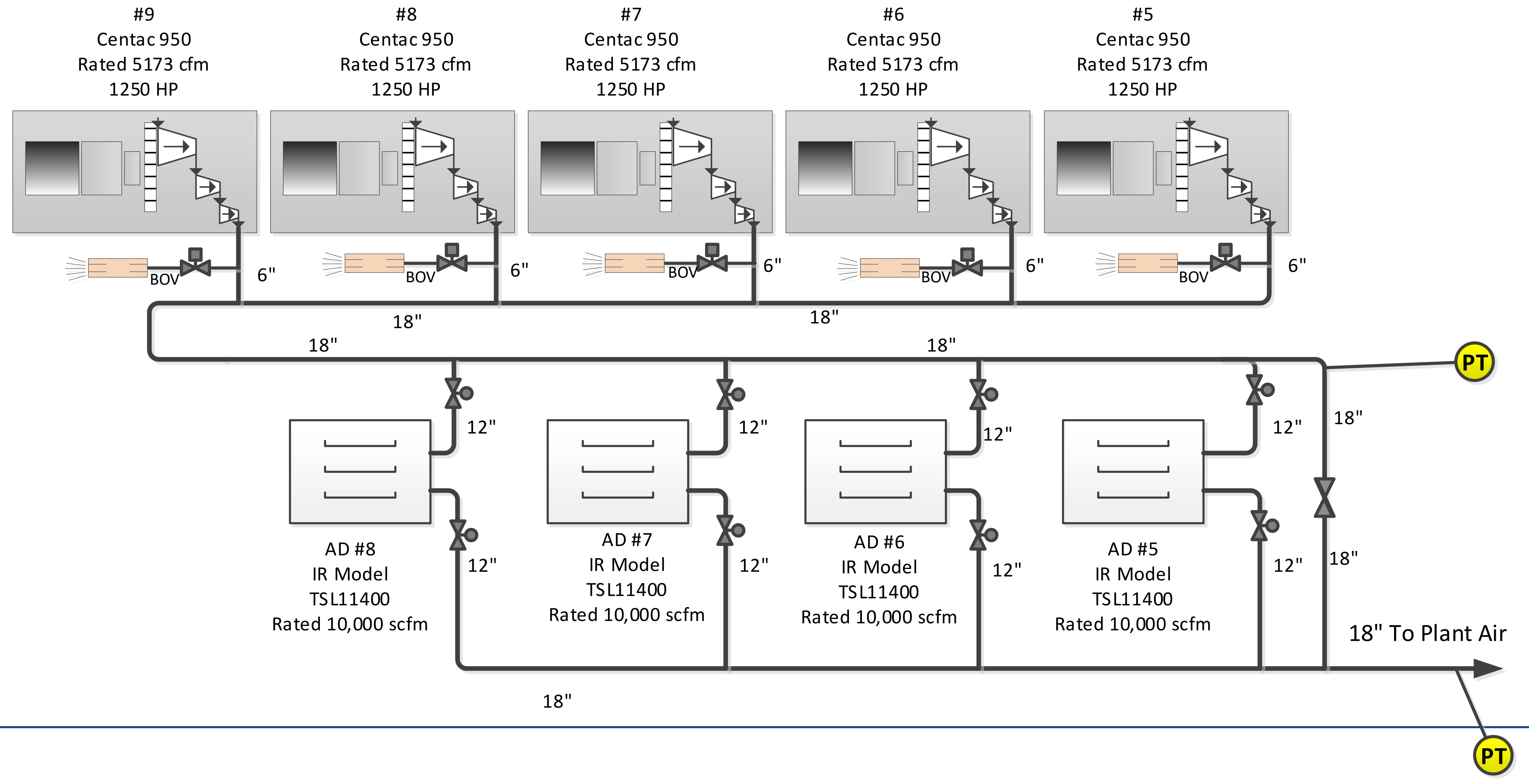
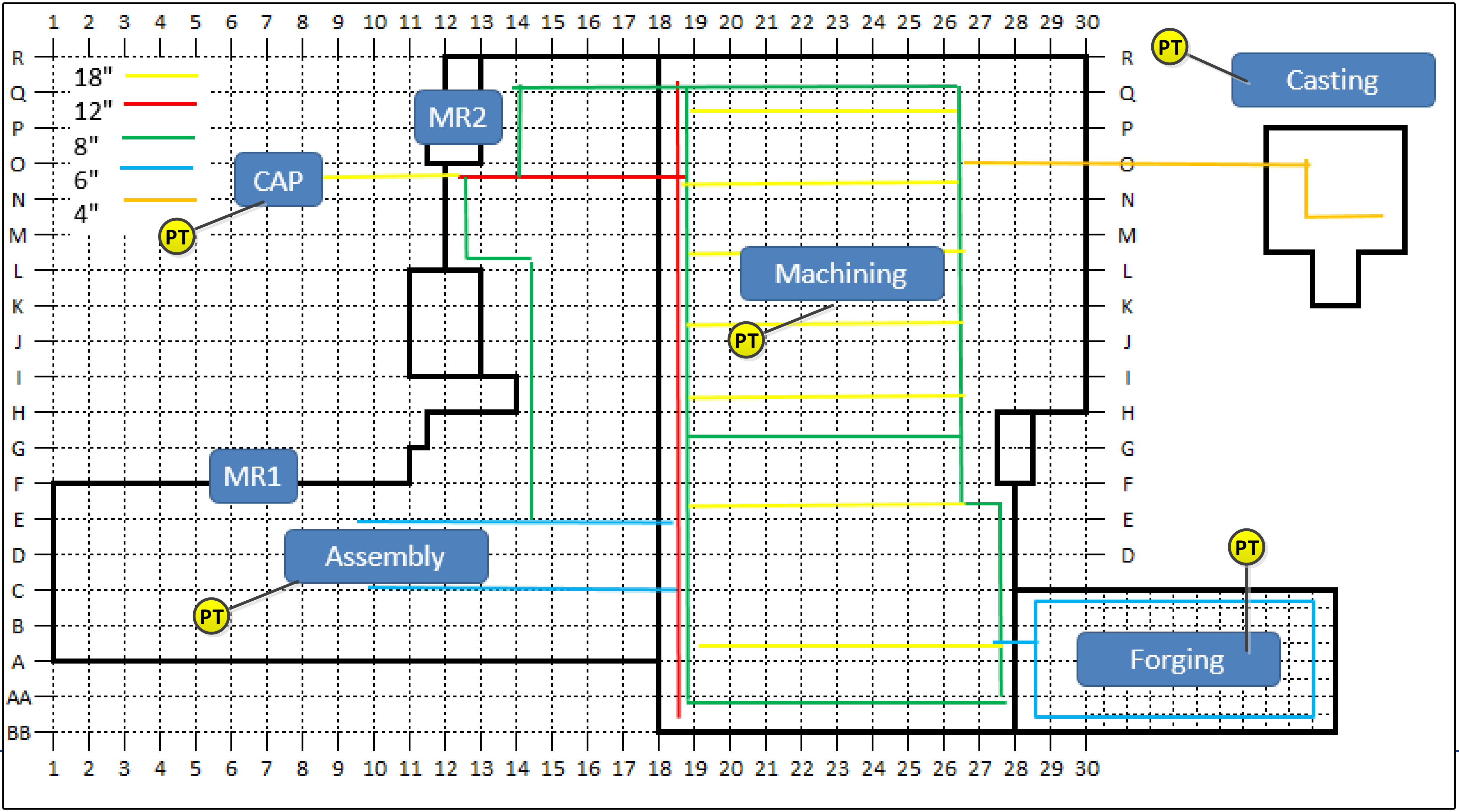


What Measurements Should I Record?

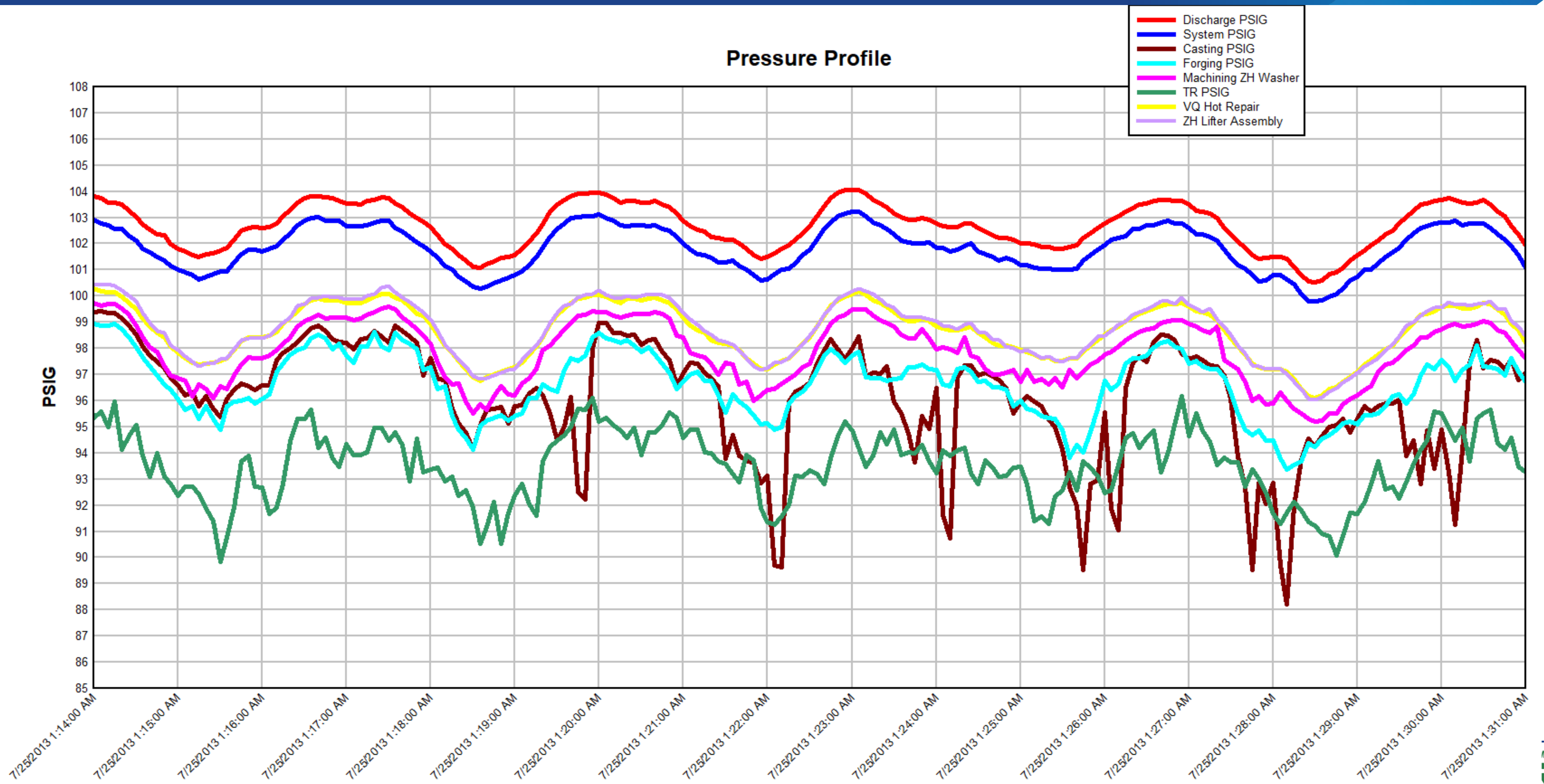
Compressed Air Plant



What Measurements Should I Record?



Data Collection Can Be Interpreted



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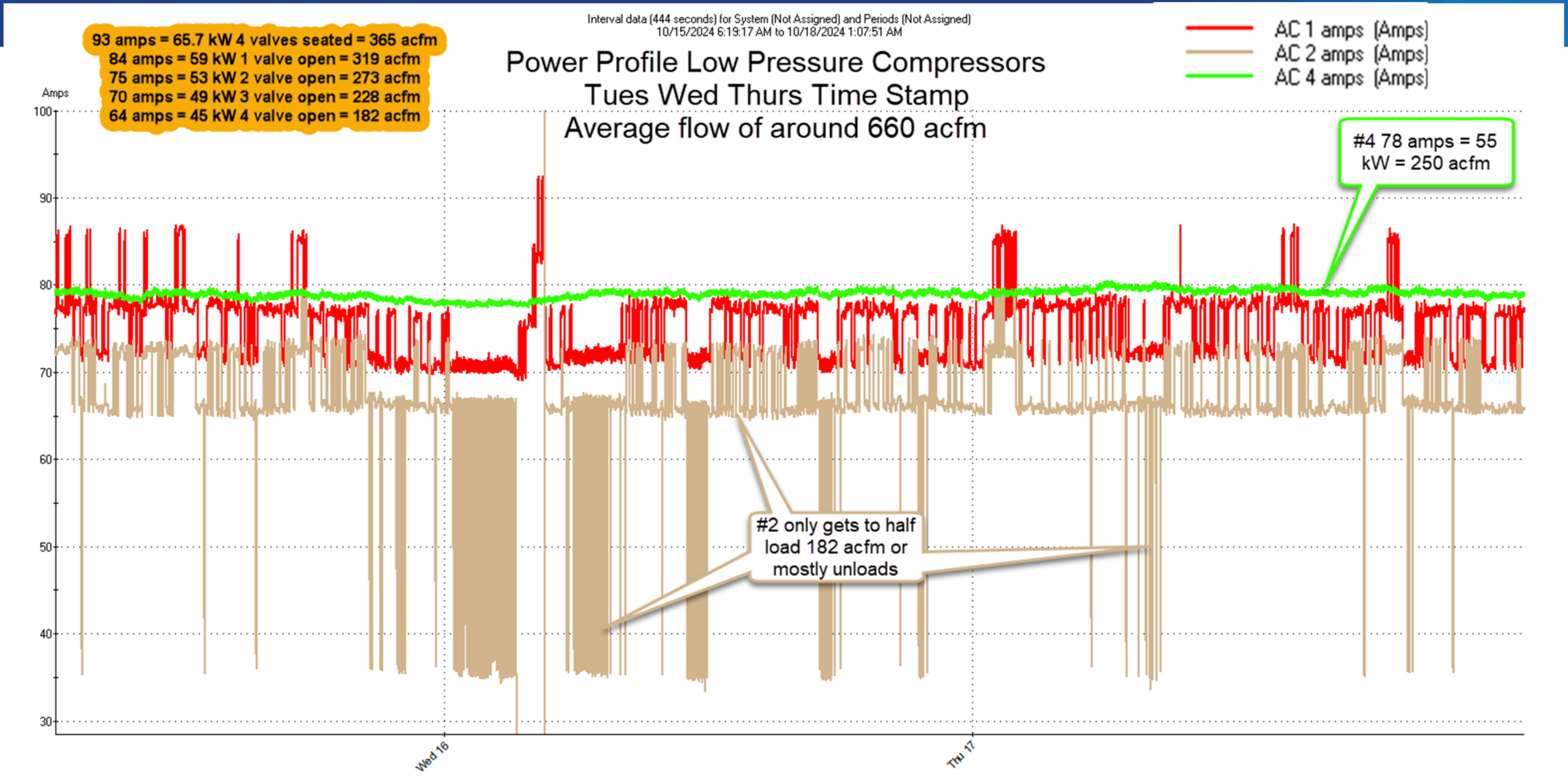

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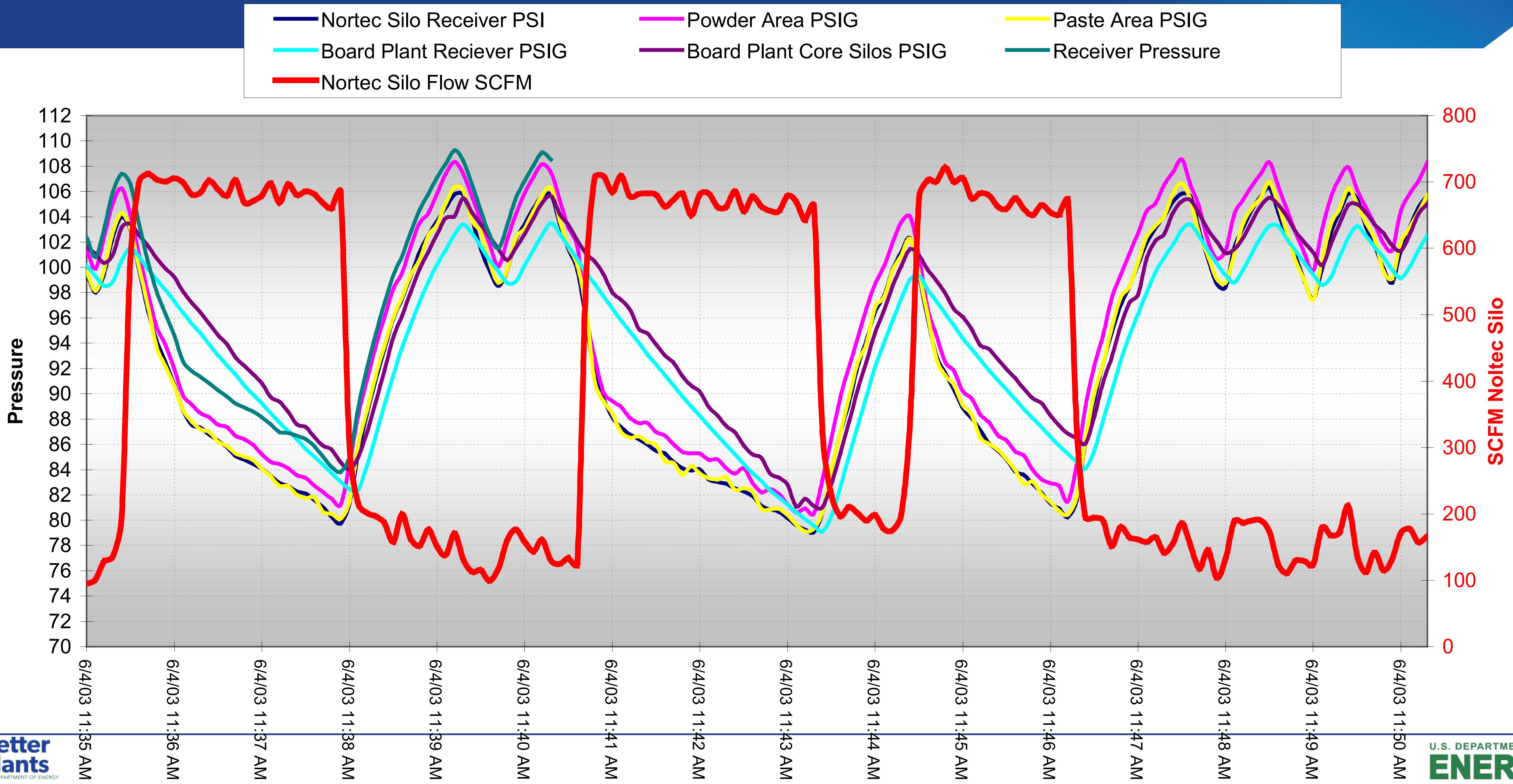
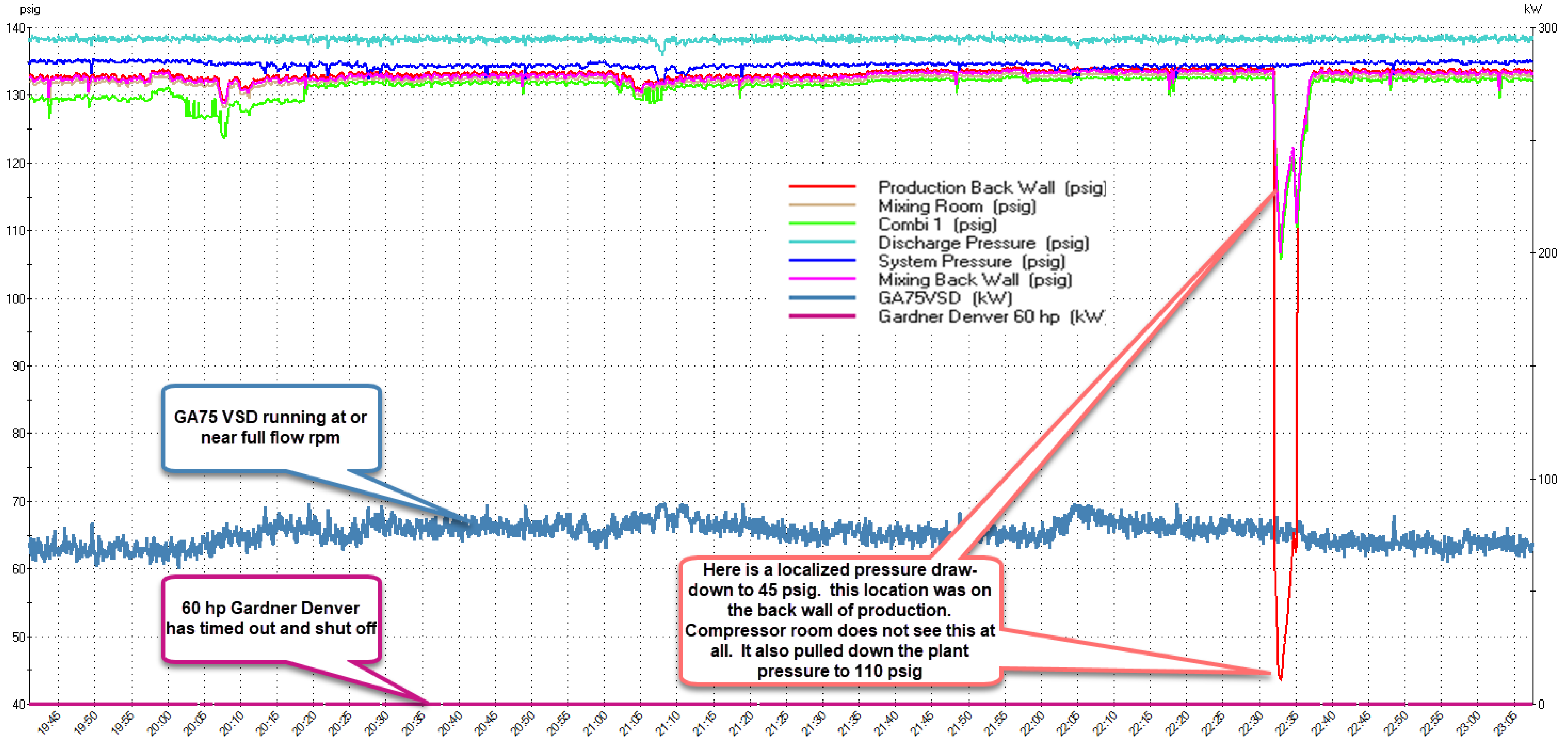
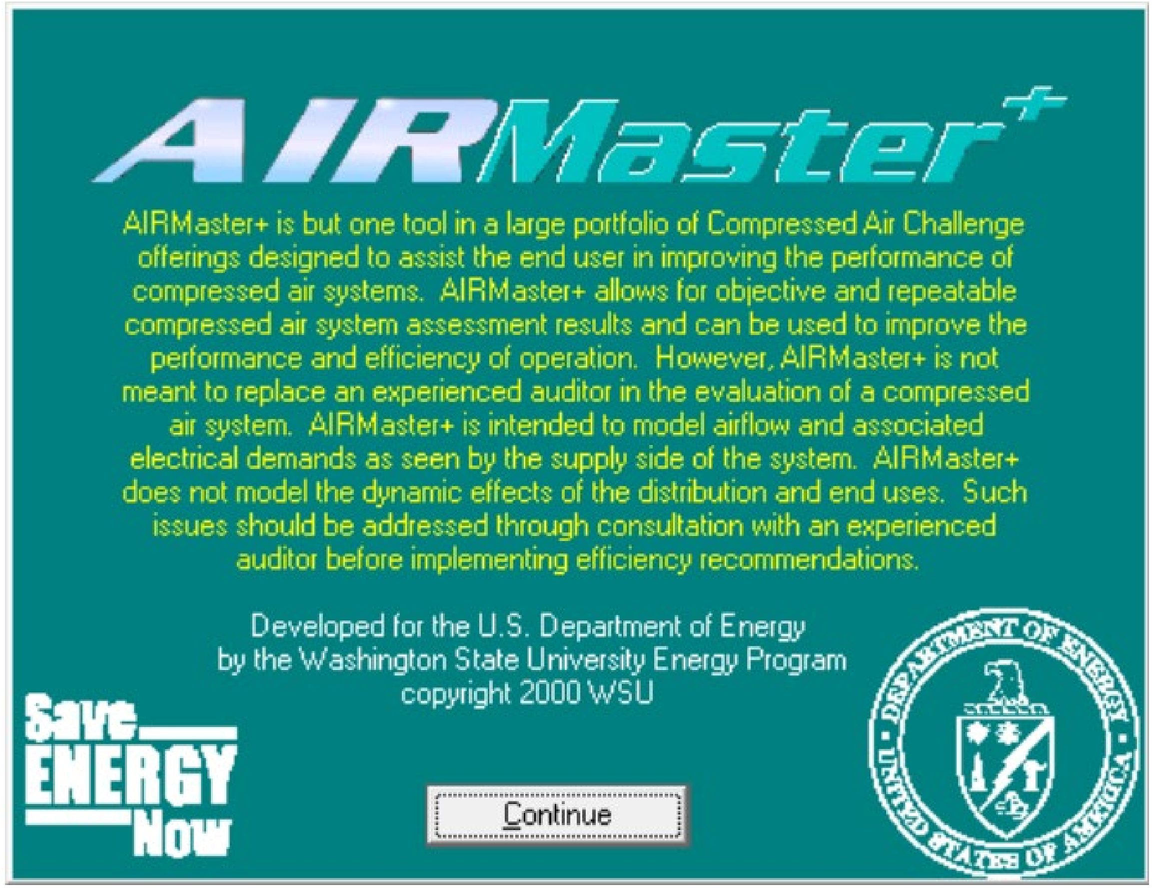


Interval data (4 seconds) for System (Not Assigned) and Periods (Baseline)
1/23/2022 7:41:01 PM to 1/23/2022 11:07:34 PM

Localized Pressure Drawdown During CIP



AIRMaster+ , LogTool and MEASUR



AIRMaster+ Features

- AIRMaster+ is a Windows-based software tool used to analyze industrial compressed air systems:
- Simulates existing and modified compressed air system operation
- Models part load system operation
- Assigns electrical utility energy schedules
- Enters 24-hour metered airflow or power data
- Is not a substitute for an experienced auditor!
- 30 years old and has been replaced by the MEASUR Tool

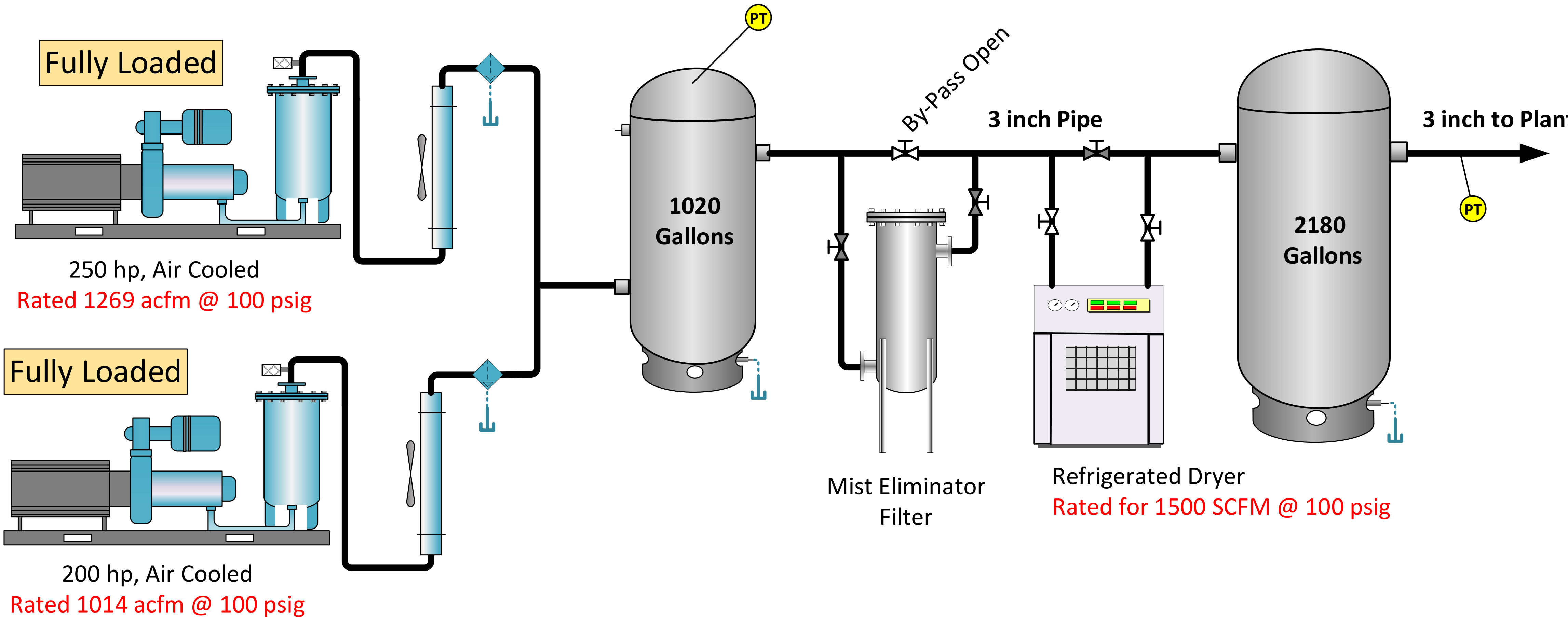
MEASUR Features

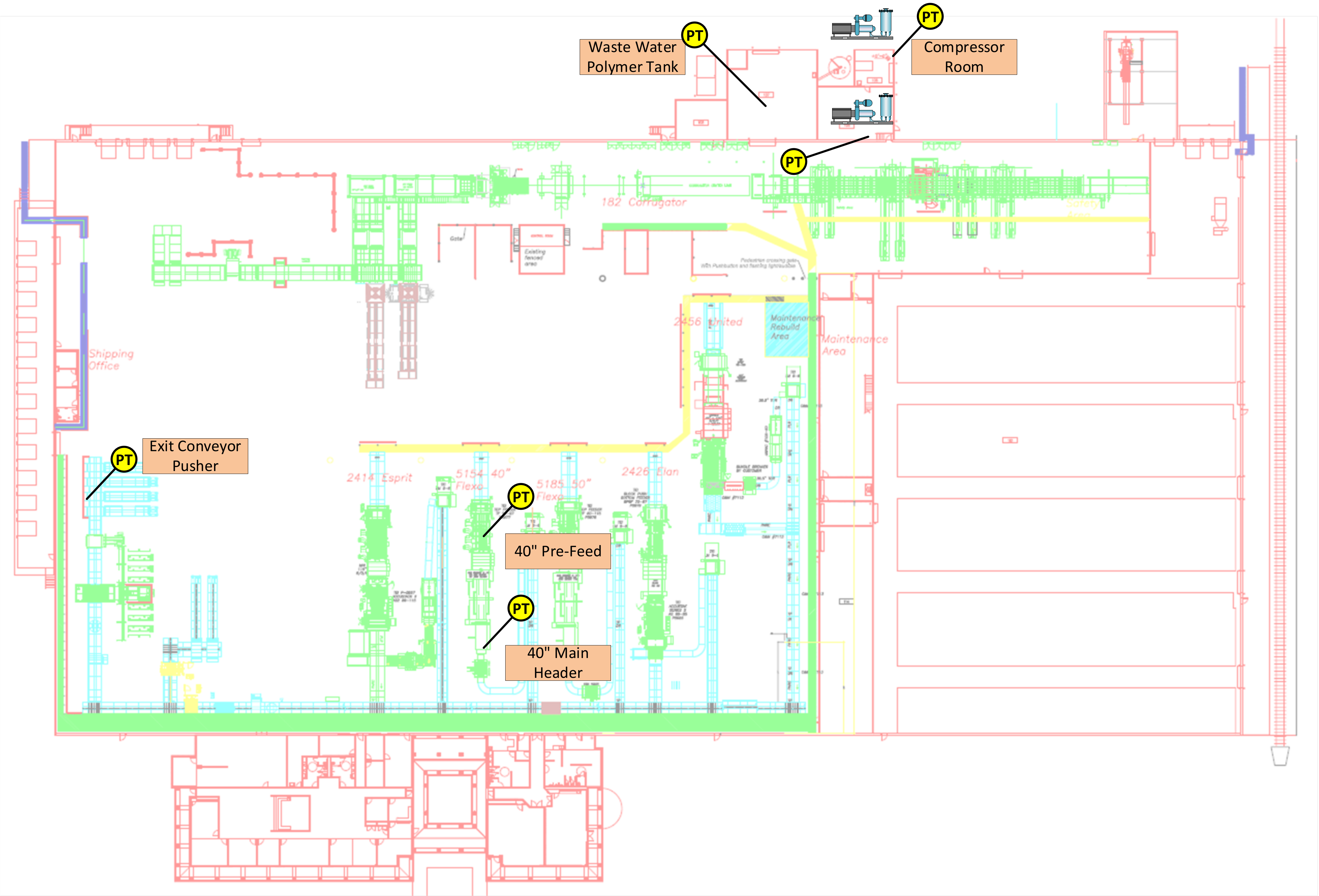
- MEASUR includes a series of tools that help users analyze energy use and savings opportunities in industrial compressed air systems.
- It can baseline existing and model future system operations improvements and evaluate energy and dollar savings from many energy efficiency measures (EEM's).
- MEASUR can be used in a variety of ways of analyze and optimize your facilities' energy performance.
- You can conduct assessments of systems, track equipment inventory, and do quick calculations with over 70 different calculators.

LogTool is Designed To:

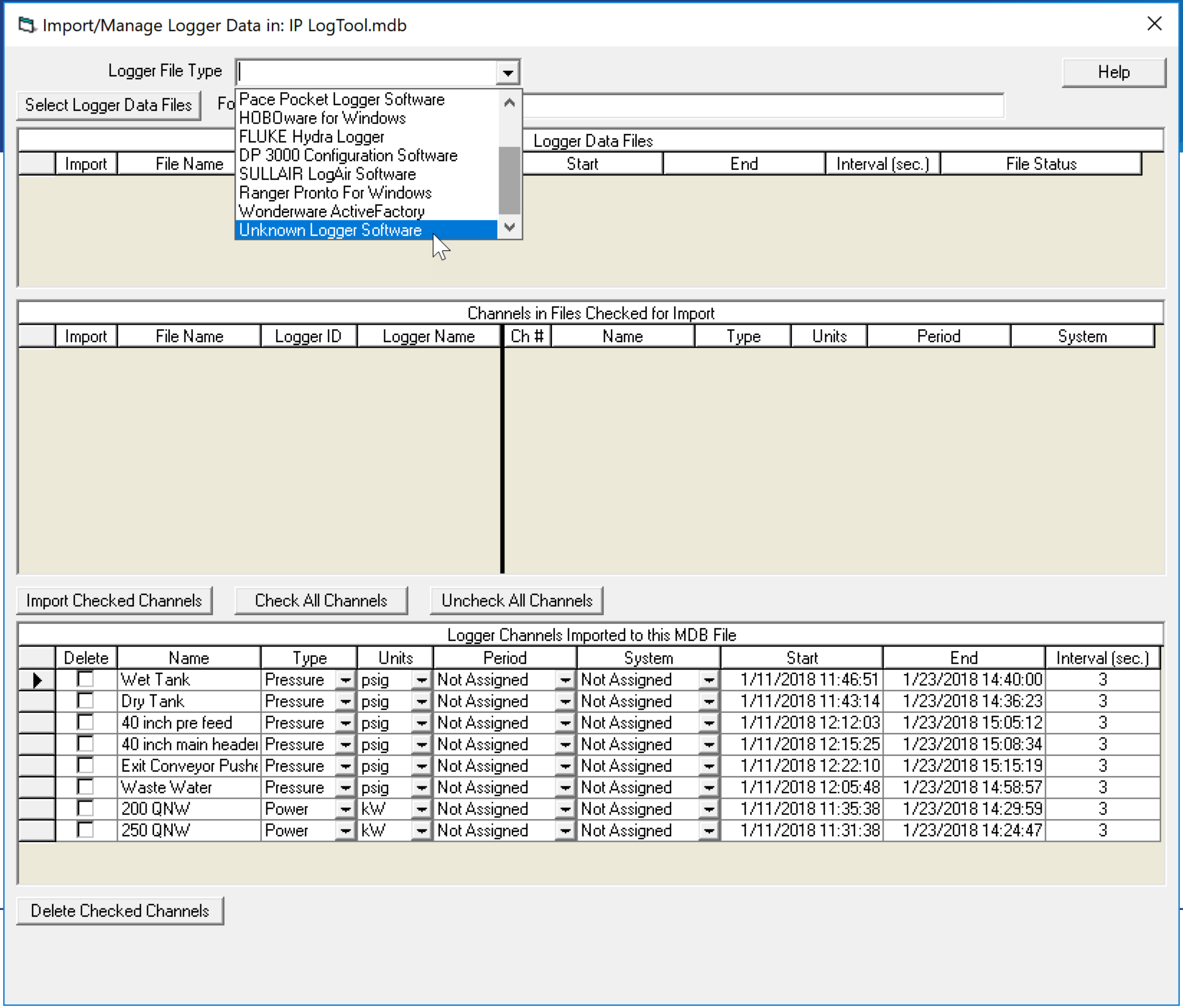
- Import data which is exported from different types of data loggers.
- Select logger data channels and modify their properties.
  - e.g., name, type, units, etc.
- View data values for one or more logger channels.
- Display trend plots on one or two Y axis.
- Display scatter plots.
- Display daytype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

Box Plant Example:



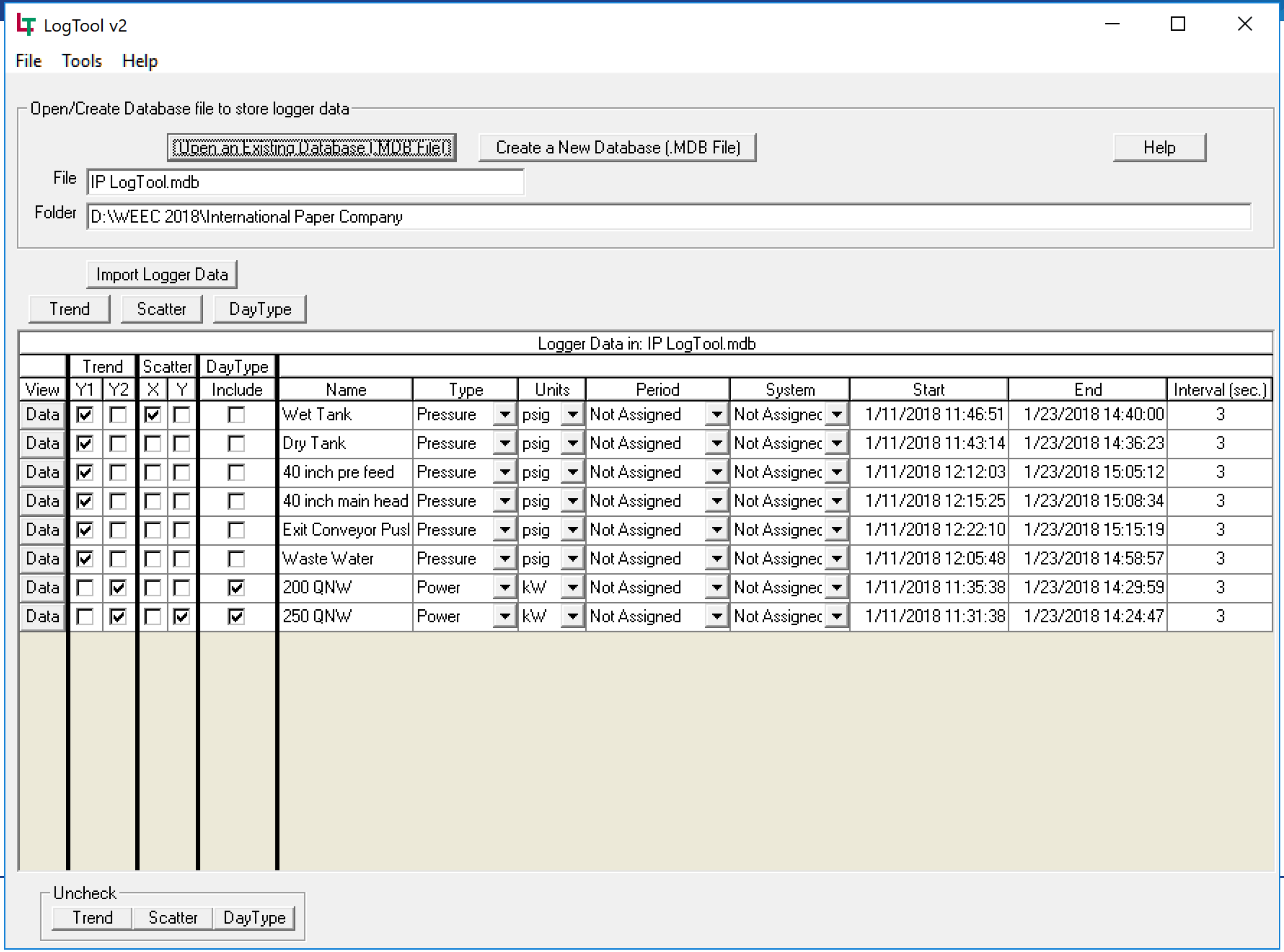


Waste Water Polymer Tank
PT
Compressor Room
PT
PT
182 Corrugator
Shipping Office
2456 United
Maintenance Rebuild Area
Maintenance Area
Exit Conveyor Pusher
PT
2414 Esprit
5154 40" Flexo
5185 50" Flexo
2426 Elan
PT
40" Pre-Feed
PT
40" Main Header



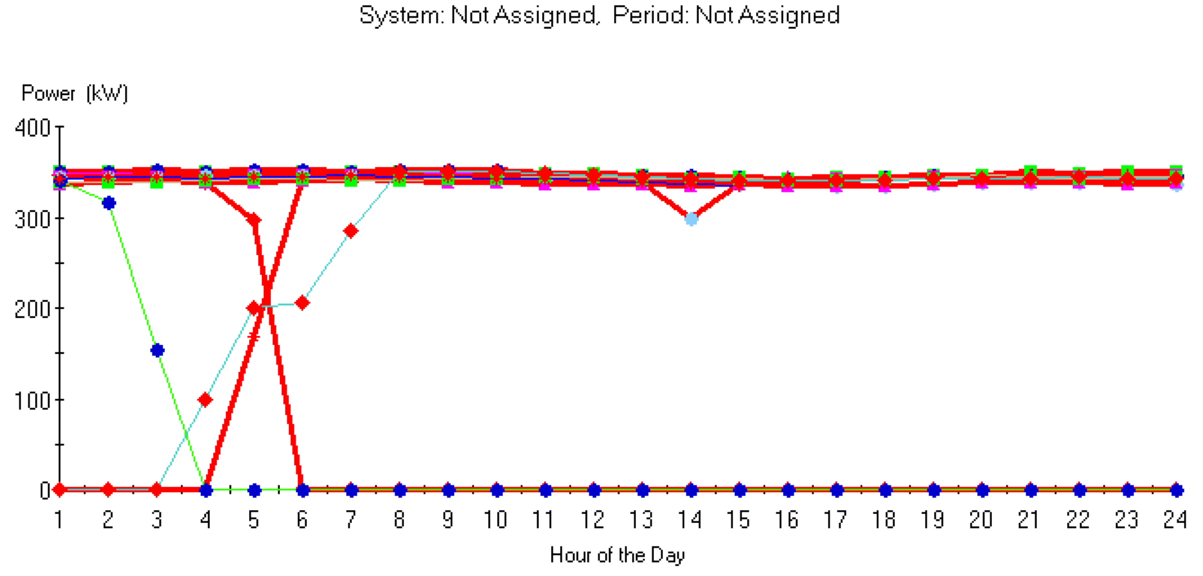
Delete	Name	Type	Units	Period	System	Start	End	Interval (sec.)
☐	Wet Tank	Pressure	psig	Not Assigned	Not Assigned	1/11/2018 11:46:51	1/23/2018 14:40:00	3
☐	Dry Tank	Pressure	psig	Not Assigned	Not Assigned	1/11/2018 11:43:14	1/23/2018 14:36:23	3
☐	40 inch pre feed	Pressure	psig	Not Assigned	Not Assigned	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

LogTool Main Menu



Enter LogTool Data Into AIRMaster

DayType Analysis



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...

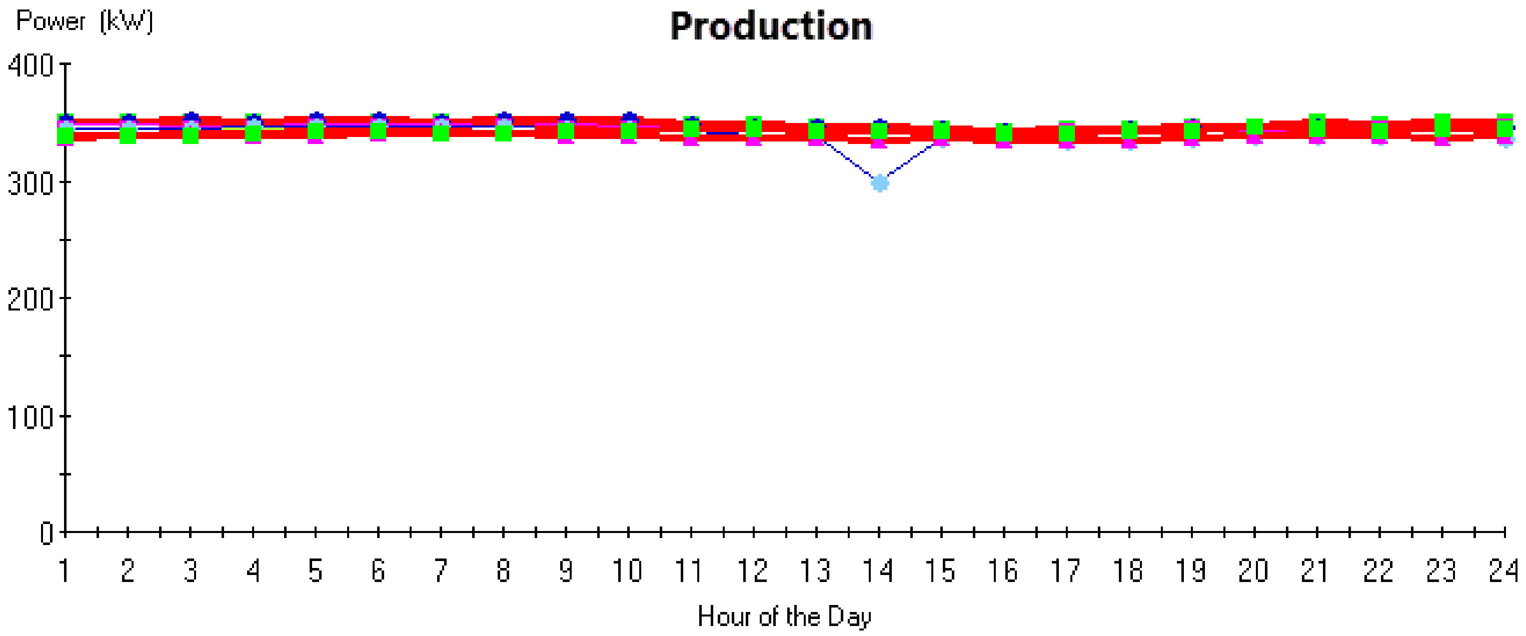
Caution: Day profiles can be similar even though different equipment, e.g., compressors, is operating. Use Trend Plots to examine the details of equipment operation before determining whether days should be assigned to the same daytype.

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

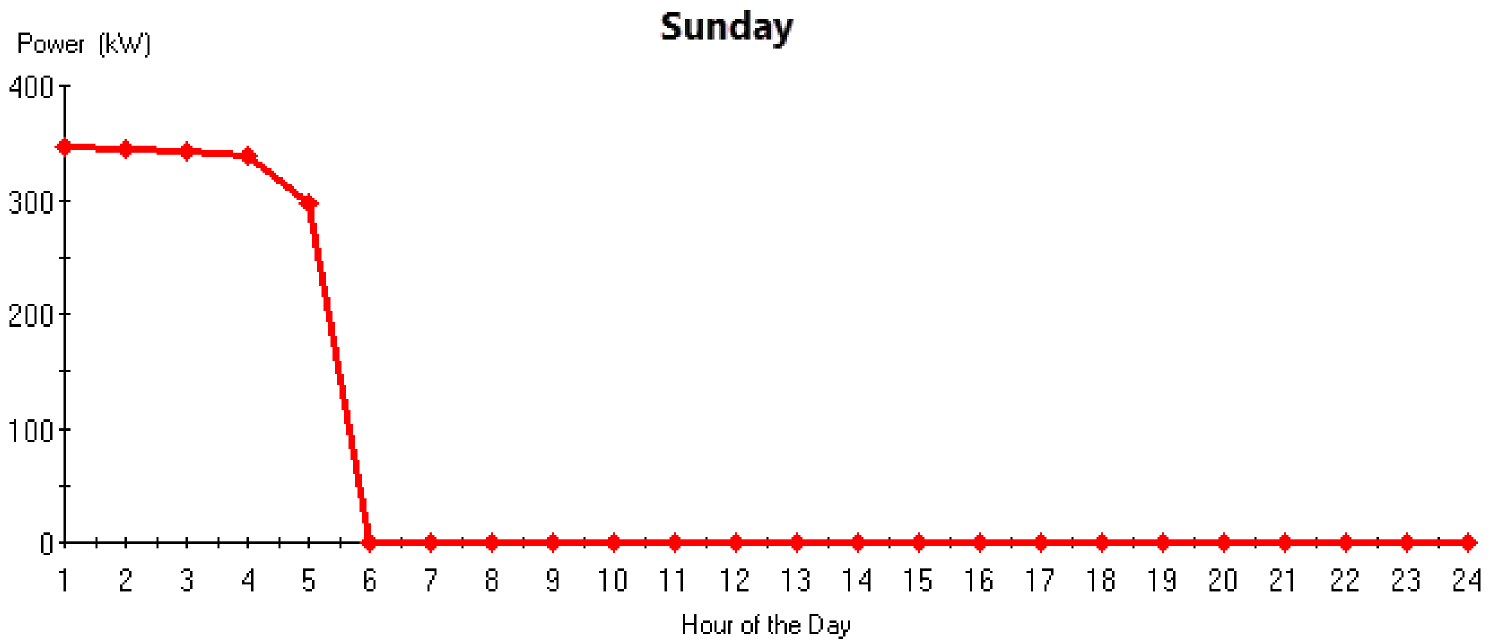
System DayType Profiles

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

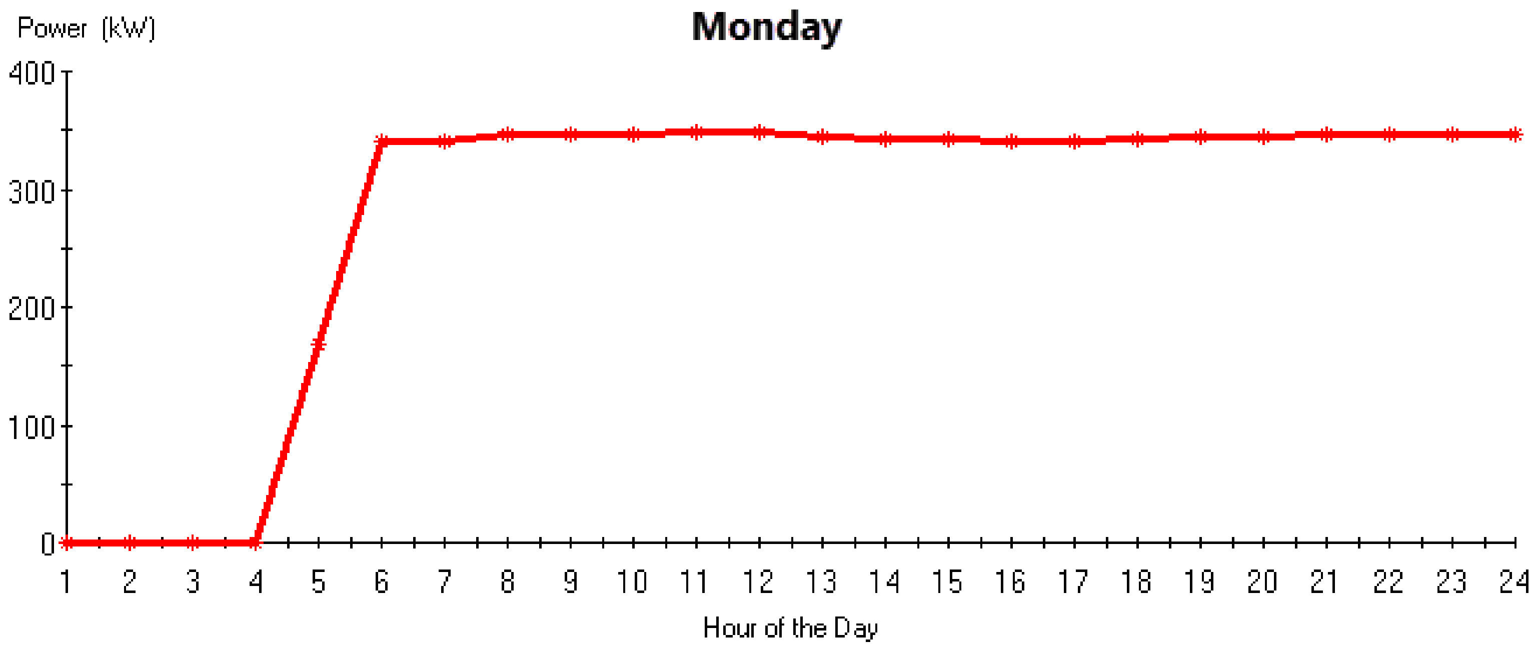
DayType Profiles



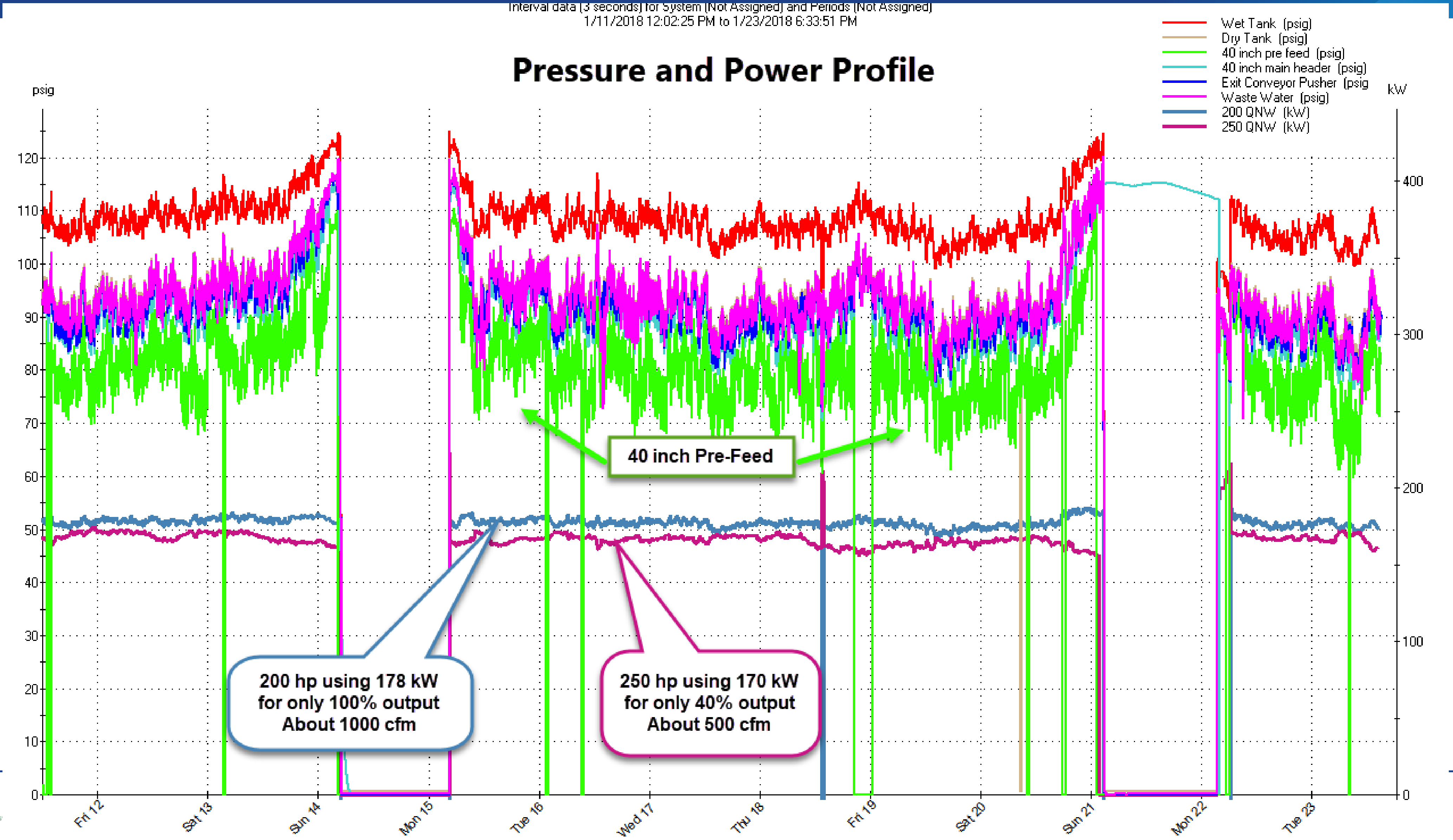
DayType Profiles

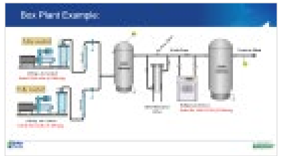


DayType Profiles



LogTool Trend Plot





Better Plants U.S. DEPARTMENT OF ENERGY

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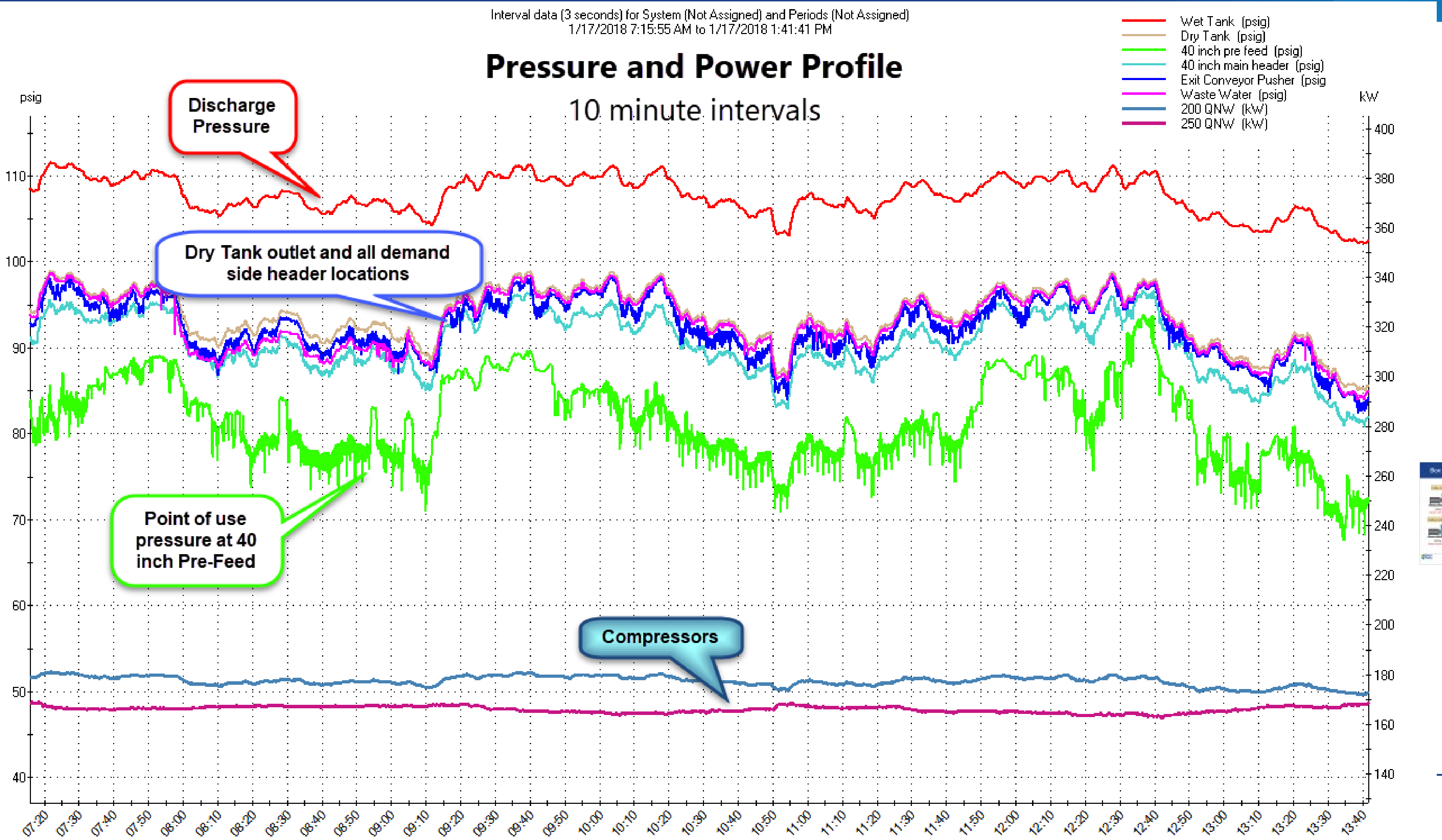
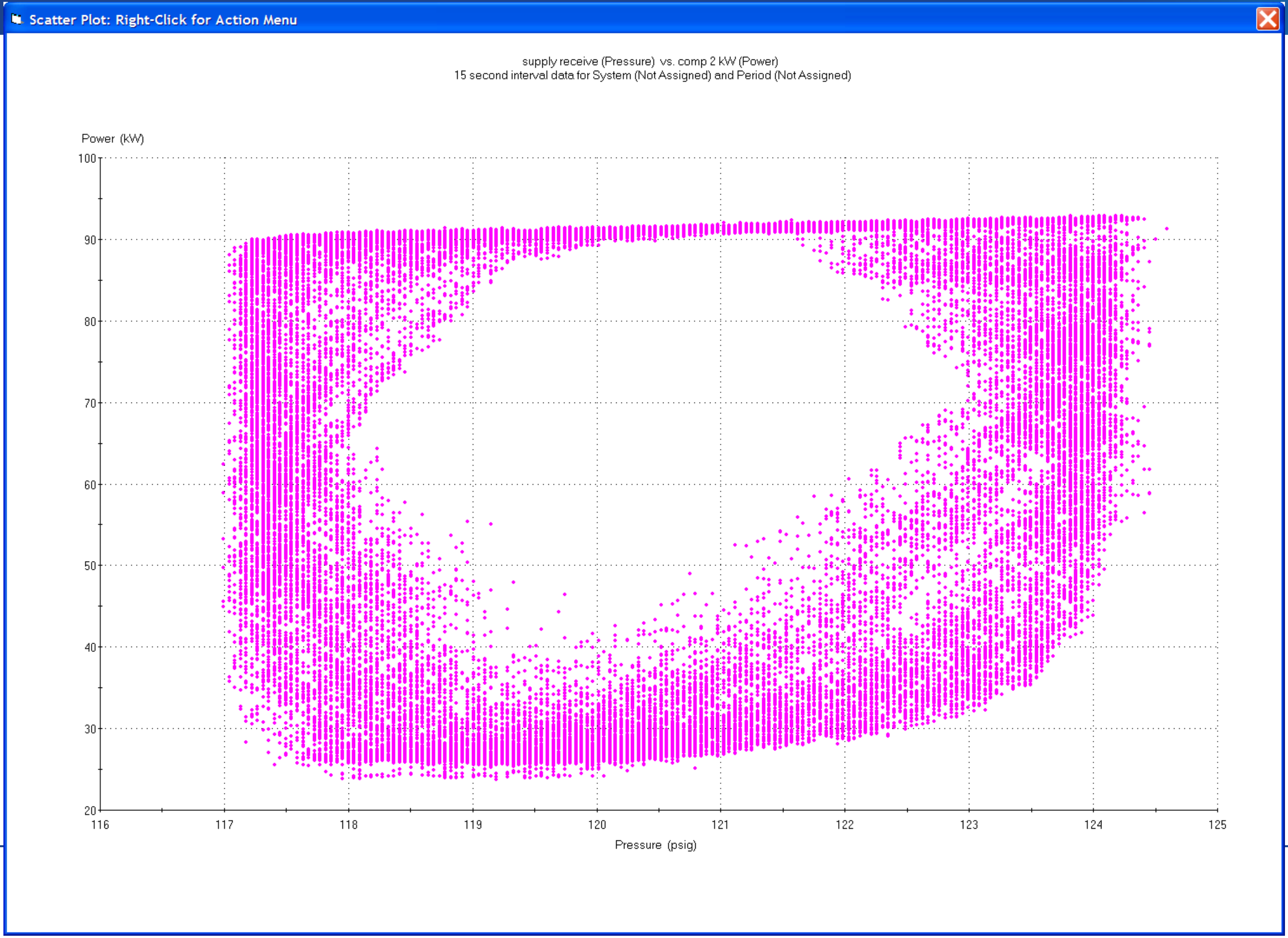
LogTool Trend Plot



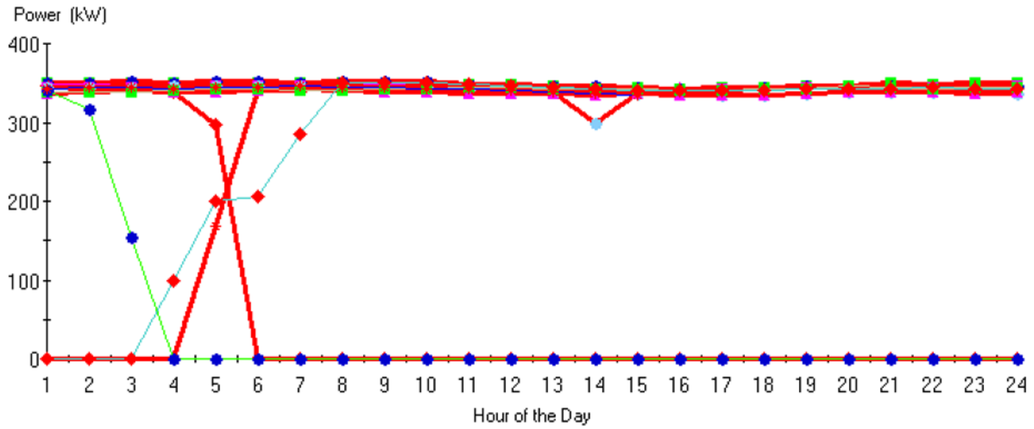
LogTool Scatter Plot



Create the baseline from the Data

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
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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

Enter LogTool Data Into AIRMaster

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

International Paper
Hon
Fujifilm
Fuji
Corning Inc
Corning Inc
SRP
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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
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Motors
Process Cooling
Process Heating
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Wastewater
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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.
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Motor Inventory
Pump Inventory
Data Exploration
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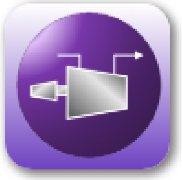
Energy Efficiency & Renewable Energy

MEASUR Tool Calculators

Compressed Air Calculators



Compressed Air Reduction

Quantify the energy savings associated with reducing compressed air usage.

Compressed Air Pressure Reduction

Quantify the energy savings associated with reducing compressed air system pressure.

Compressed Air - Leak Survey

Quantify the energy savings associated with reducing compressed air leaks.

Actual to Standard Airflow

Converts acfm (Actual cubic feet per minute) to scfm (Standard cubic feet per minute) and vice versa for the given conditions using either ASME standard conditions or CAGI/ISO standard conditions.

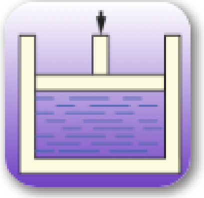
MEASUR Tool Calculators

Bleed Test

Estimate leak rate for the system. Also called a Dropdown test or a Pressure Decay test.

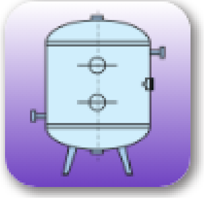
Leak Loss Estimator - Bag Method

Estimates the leakage losses in a compressed air system using the bag method



Pneumatic Air Requirement

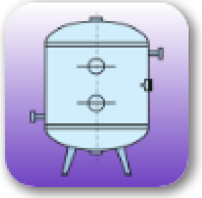
Estimate the quantity of air required by a specific single acting or a double acting piston cylinder compressor



Receiver Tank Sizing

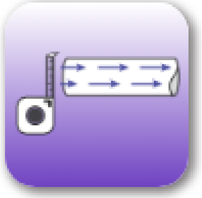
Calculate the required size of the receiver tank

MEASUR Tool Calculators



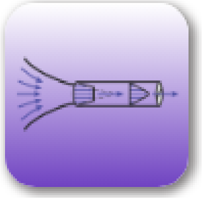
Usable Air Capacity

Estimate the quantity of compressed air that is available for use



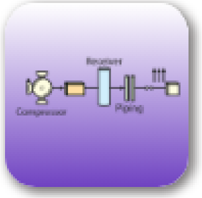
Pipe Sizing

Determine pipe diameter when the volumetric flow velocity, pressure, and design velocity are known



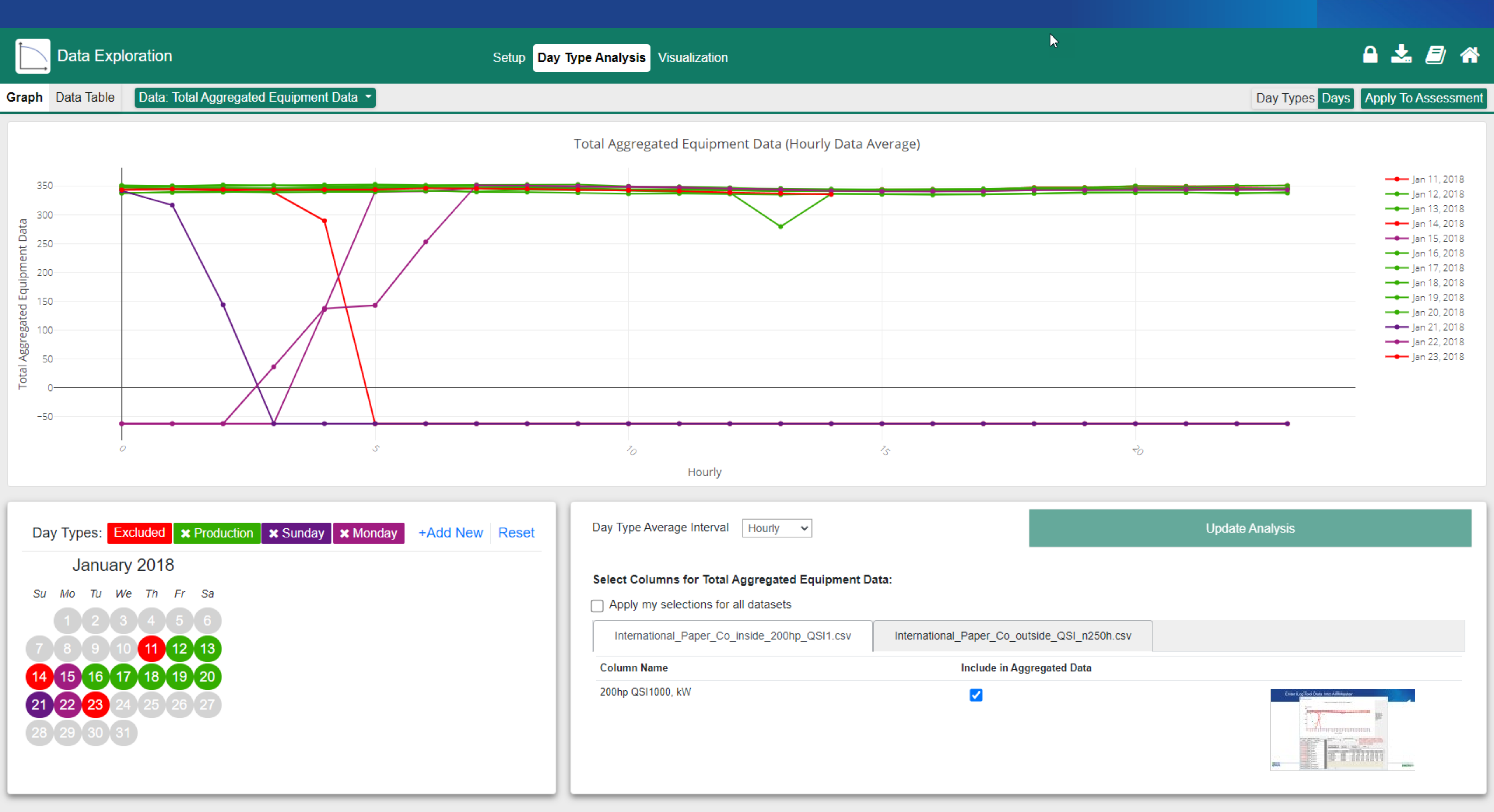
Velocity in the Piping

Estimate the velocity of compressed air throughout system piping



System Capacity

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


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

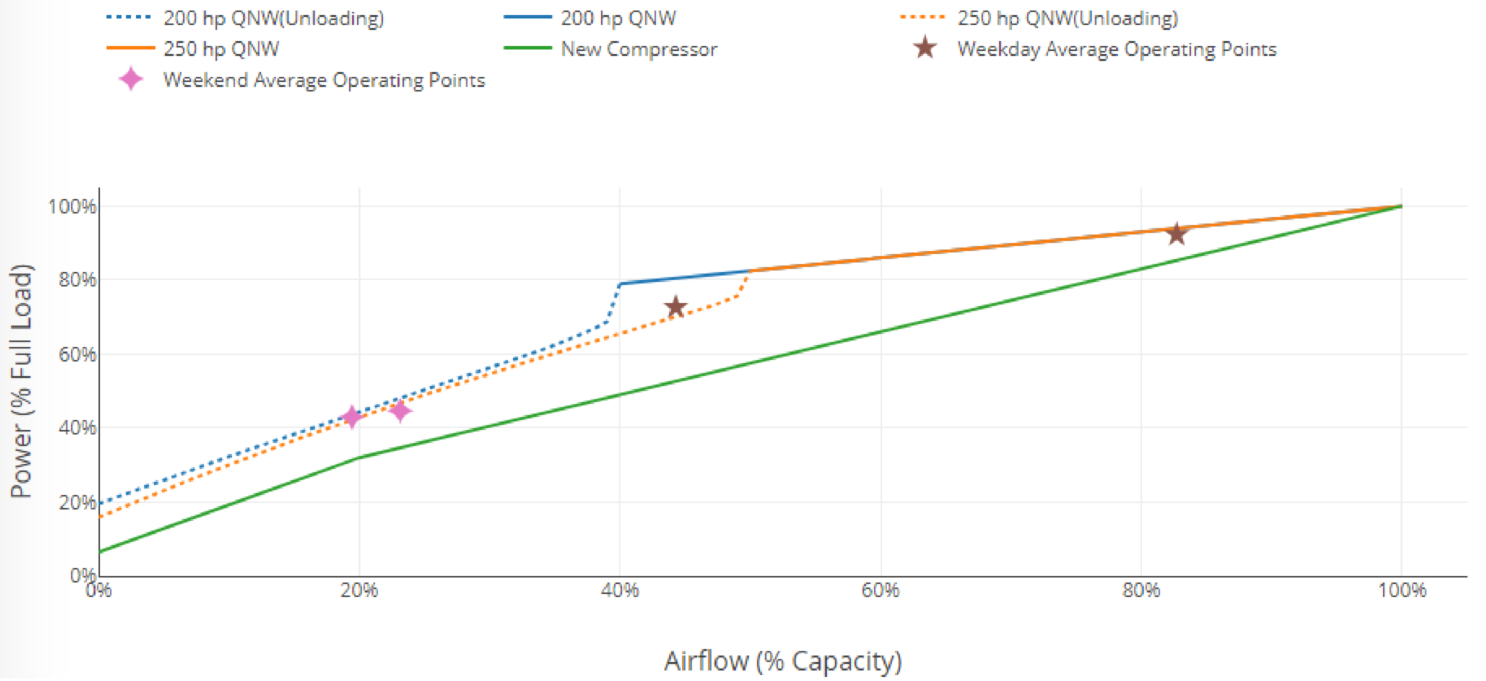
CURRENT INVENTORY | HELP

Name	Compressor Type	Control Type	Pressure Range
200 hp QNW	Single stage lubricant-injected rotary screw	Inlet modulation with unloading	115 - 127 psig
250 hp QNW	Single stage lubricant-injected rotary screw	Inlet modulation with unloading	100 - 110 psig
New Compressor	Single stage lubricant-injected rotary screw	VFD	115 - 119.8 psig

+Add New Compressor

Performance Profile

☑ Graph All Compressors ☑ Graph Average Operating Points



MEASUR Tool Energy Efficiency Measures

SELECT POTENTIAL ADJUSTMENT PROJECTS

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

Add New Scenario

Modification Name	VSD

Reduce Air Leaks | *Demand* — 1

Implementation Cost	5000 $
Leak Flow	600 acfm
Leak Reduction	50 %

Improve End Use Efficiency | *Demand* — Off

Reduce System Air Pressure | *Supply* — Off

Reduce Run Time | *Supply* — Off

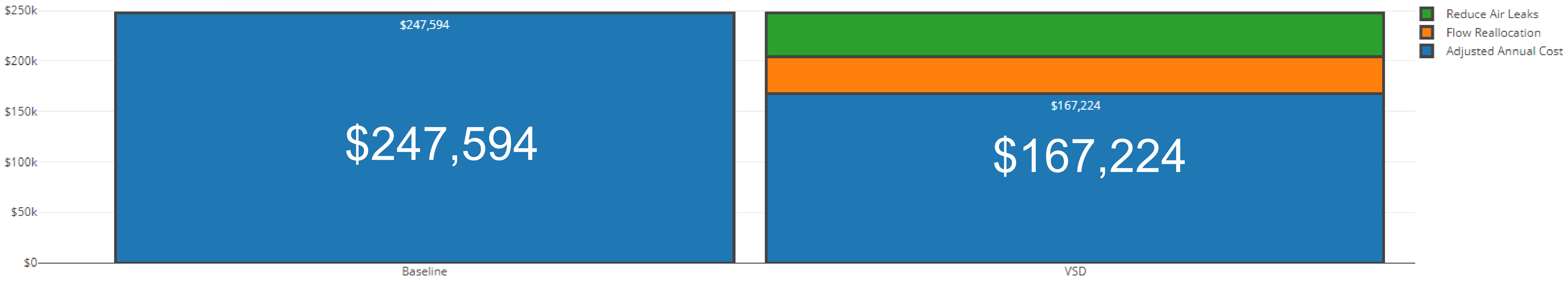
Add Primary Receiver Volume | *Supply* — Off

MODIFICATION RESULTS | PERFORMANCE PROFILE | HELP | NOTES

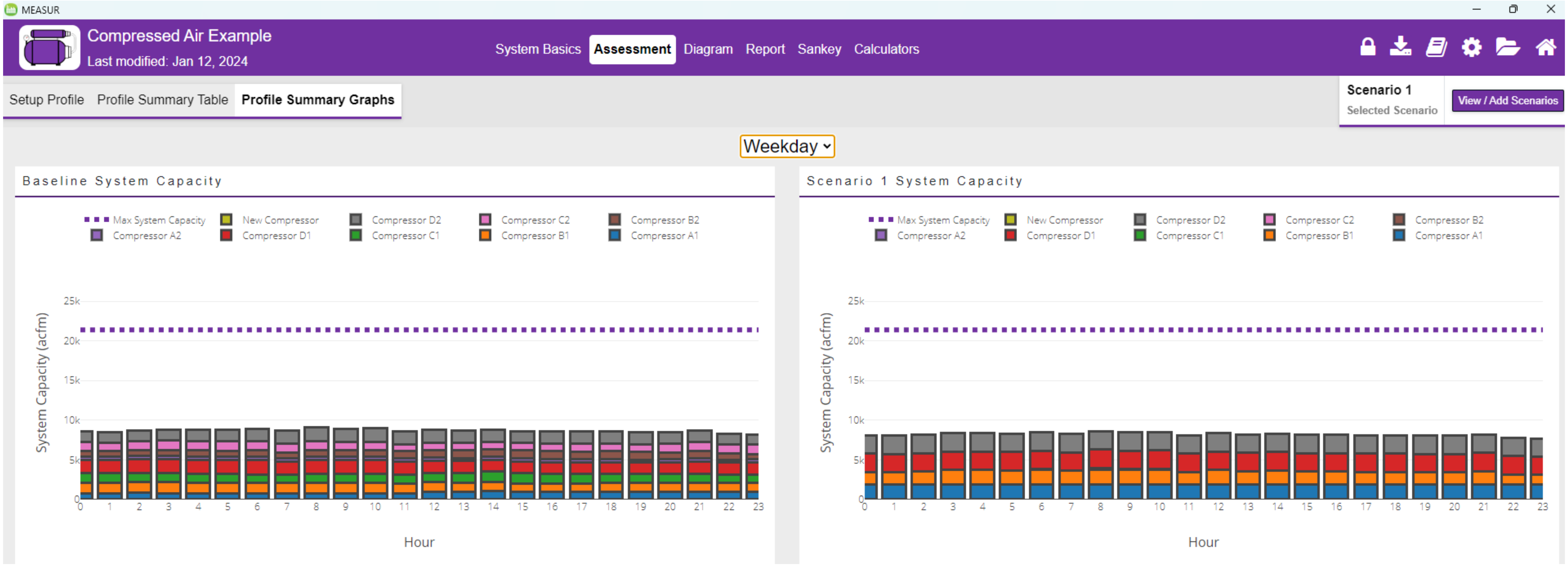
All Day Types

	Baseline	VSD
Percent Savings (%)	— —	32.5%
Flow Reallocation Energy Savings	— —	391,627 kWh
Reduce Air Leaks Energy Savings	— —	458,853 kWh
Peak Demand	**346.6 kW**	**251.24 kW**
Annual Energy	**2,620,045 kWh**	**1,769,565 kWh**
Annual Emission Output Rate	**1,051 (tonne CO_2)**	**710 (tonne CO_2)**
Peak Demand Savings	**— —**	**95.36 kW**
Annual Energy Savings	**— —**	**850,480 kWh**
Annual Emission Savings	**— —**	**341 (tonne CO_2)**
Flow Reallocation Savings	— —	$25,847.38
Reduce Air Leaks Savings	— —	$43,361.61
Peak Demand Cost	**$0.00**	**$0.00**
Annual Energy Cost	**$247,594.21**	**$167,223.85**
Annual Cost	**$247,594.21**	**$167,223.85**
Peak Demand Cost Savings	**— —**	**$0.00**
Annual Energy Cost Savings	**— —**	**$80,370.36**
Annual Cost Savings	**— —**	**$80,370.36**

MEASUR Tool


$250k
$200k
$150k
$100k
$50k
$0
$247,594
$247,594
Baseline
$167,224
$167,224
VSD
Reduce Air Leaks
Flow Reallocation
Adjusted Annual Cost

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
Scenario 1 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)
25k
20k
15k
10k
5k
0
Hour

Virtual Session 1 – The Basics

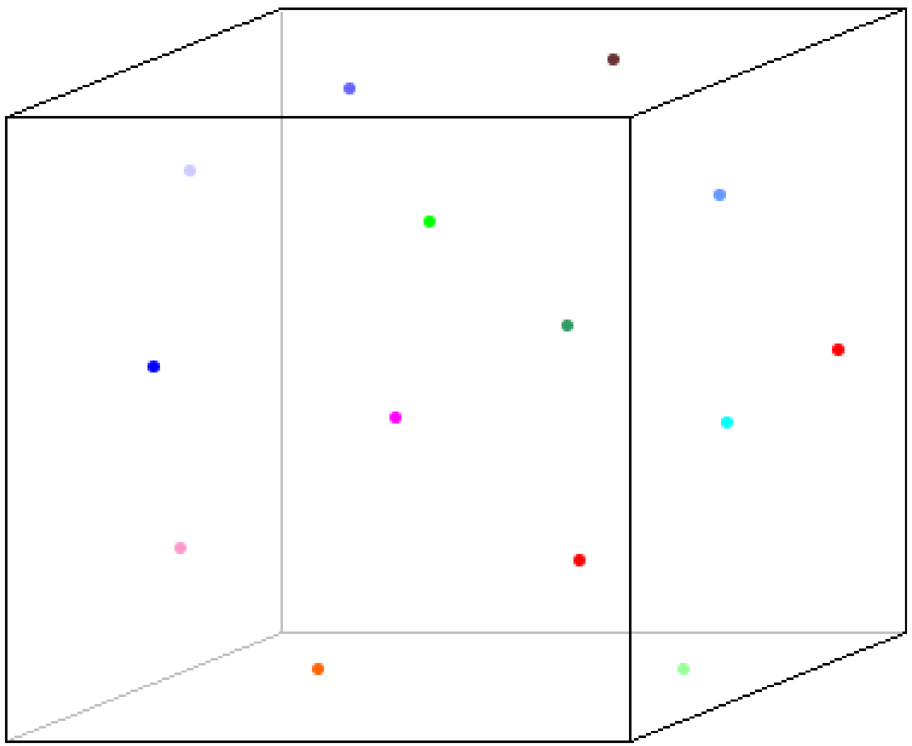
Let's leave the compressor room and have a look out in the demand……

You'll have to keep coming back each week for this session and more……

Week 1

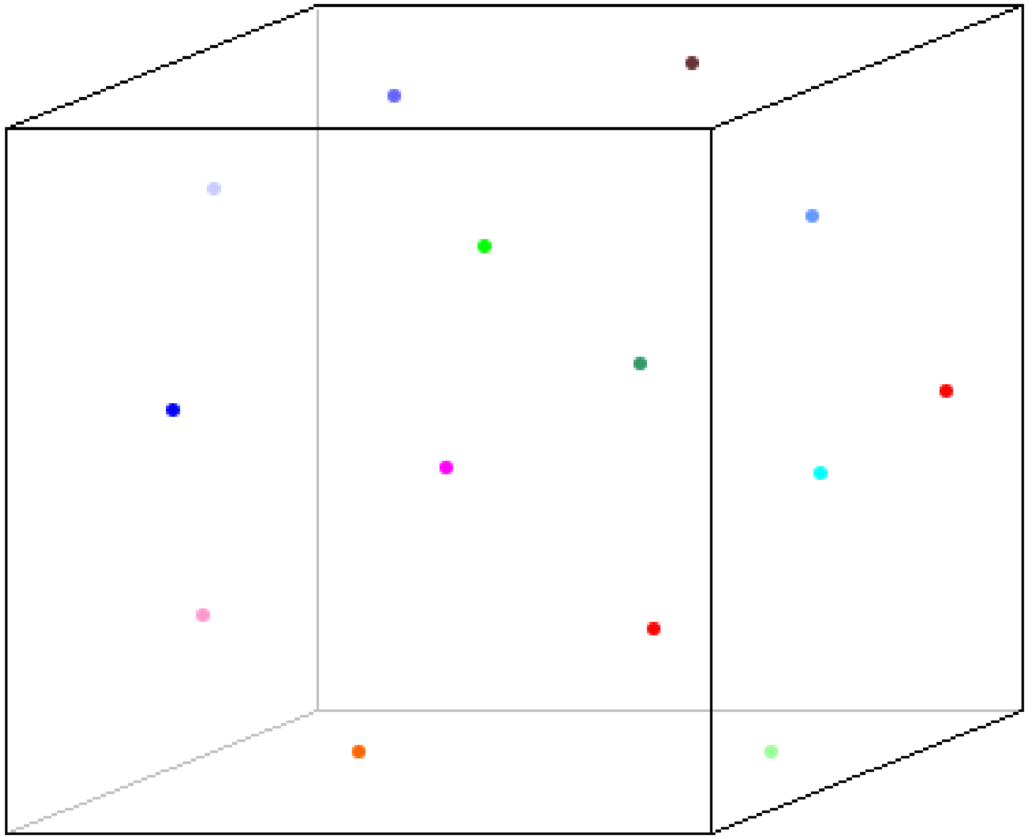
Compressed Air Fundamentals

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.

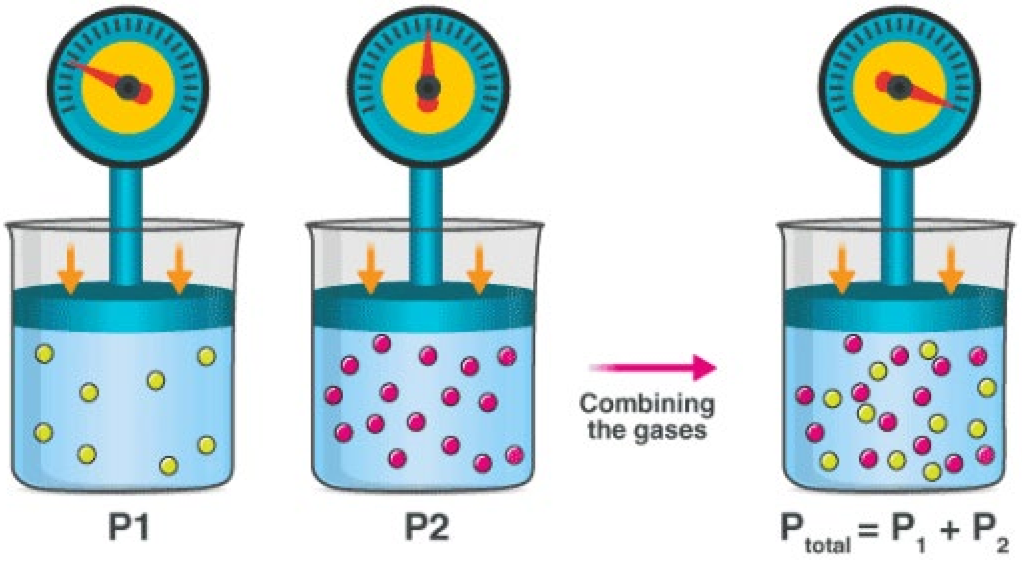
Gas Theory



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

Gas Theory (Daltons Law)



Dalton's Law of Partial Pressures

The "partial gas pressure law" primarily refers to Dalton's Law of Partial Pressures.

This states that in a mixture of non-reacting gases, the total pressure exerted by the mixture is equal to the sum of the partial pressures of each individual gas in the mixture;

Essentially, each gas contributes its own pressure as if it occupied the container alone.

Gas Theory

- Air pressure relationship is explained by three scientific laws:
  - Boyle's Law explains that if air volume halves during compression, the pressure is doubled.
  - Charles' Law states that the volume of air changes in direct proportion to the temperature.
  - The First Law of Thermodynamics tells us that an increase in pressure equals a rise in heat and that compressing air creates a proportional increase in heat.
  - Collectively, these three laws explain that pressure, volume, and temperature are proportional. If you change one variable, then one or two of the others will also change, according to this equation:

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$$

Compressed Air Fundamentals

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

Compressed Air Fundamentals

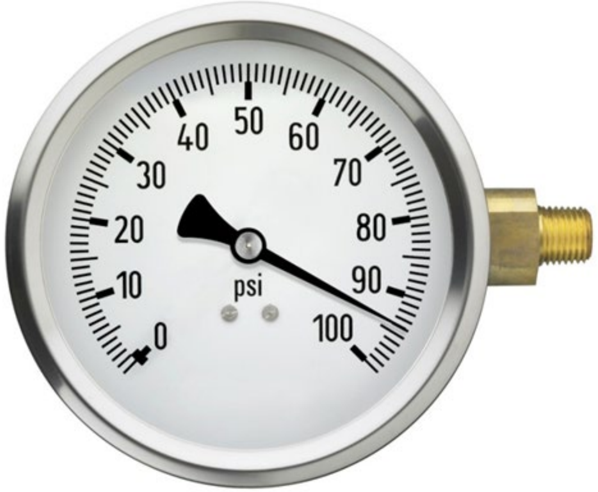
- In Death Valley, which is 500 feet below sea level, The air pressure is 14.94 psia

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

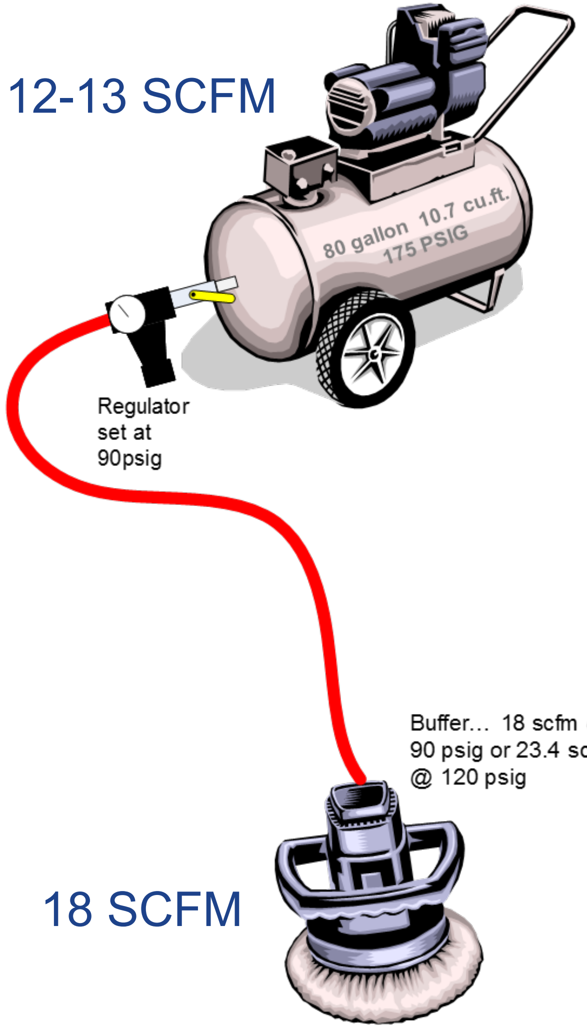


Compressed Air Fundamentals

- Compress: To press together or force into a smaller space; condense
- Air: A colorless, odorless, tasteless gaseous mixture, mainly nitrogen (78%) and oxygen (21%) and 1-2% water vapor and, carbon dioxide and other gases
- When controlled, compressed air can be used to perform work.

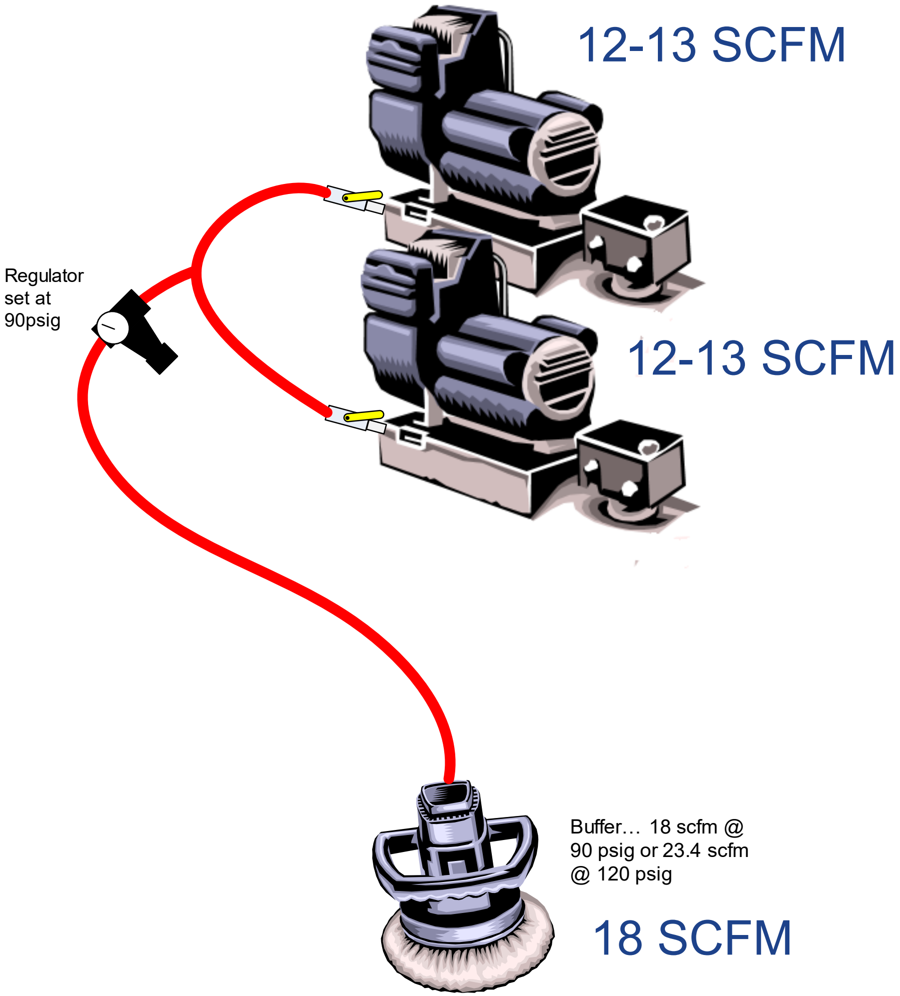
A Simple Example of Stored Energy

- A paint area in a body shop has a 5 HP compressor mounted on an 80-gallon air receiver.
- This receiver is pumped up to 175 psig.
- The air flow to the buffer which uses 18 SCFM at 90 PSIG, is regulated to 90 PSIG outflow from the regulator.
- The compressor delivers 12-13 SCFM at 90 psig but yet it runs the 18 SCFM sander OK.
- How can this work???
- The buffer uses more volume(scfm) than the compressor can deliver !!

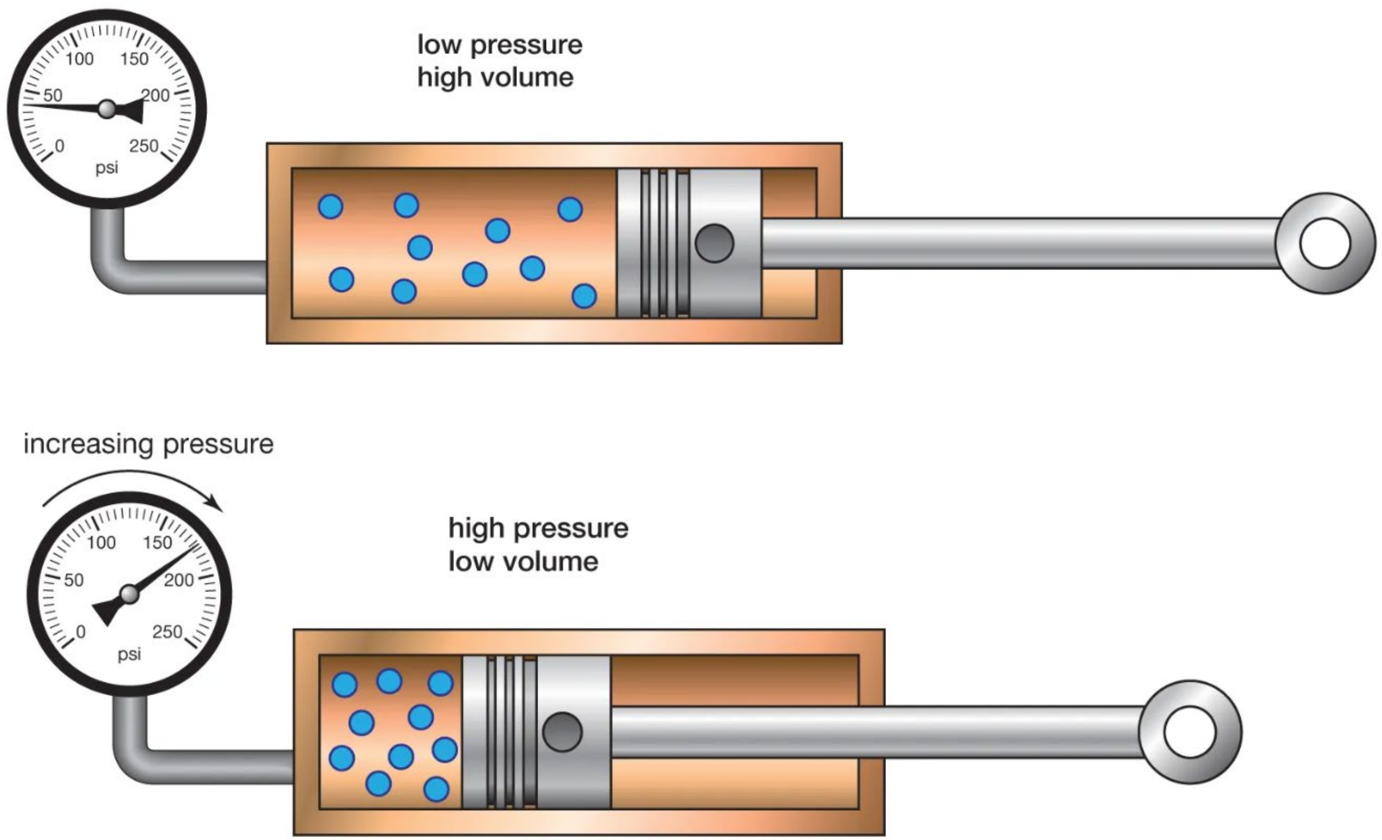


A Simple Example

- With no receiver, the painter must install a second 5 hp compressor and therefore use twice the energy as before

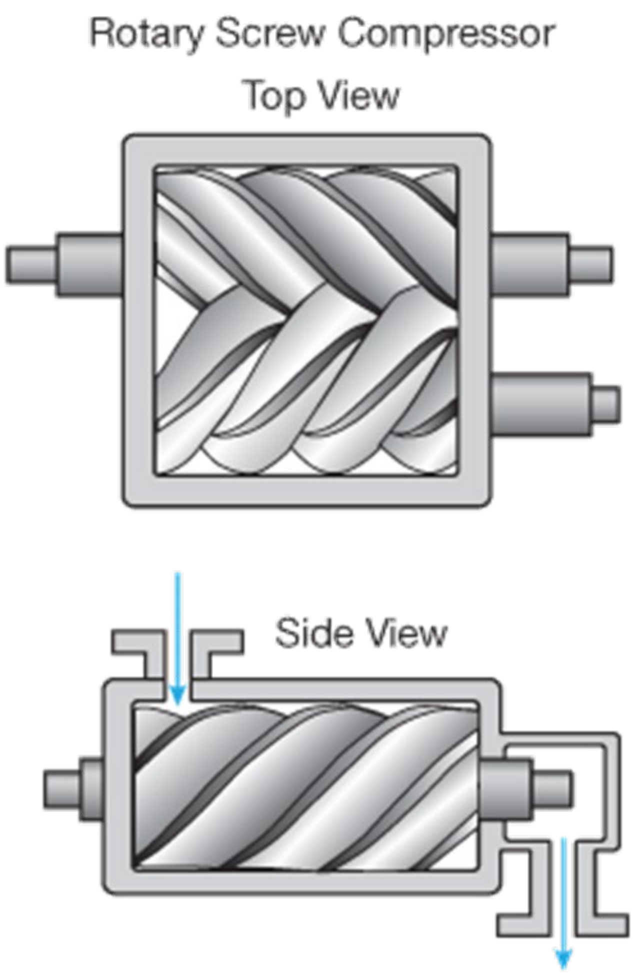


Compressed Air Fundamentals



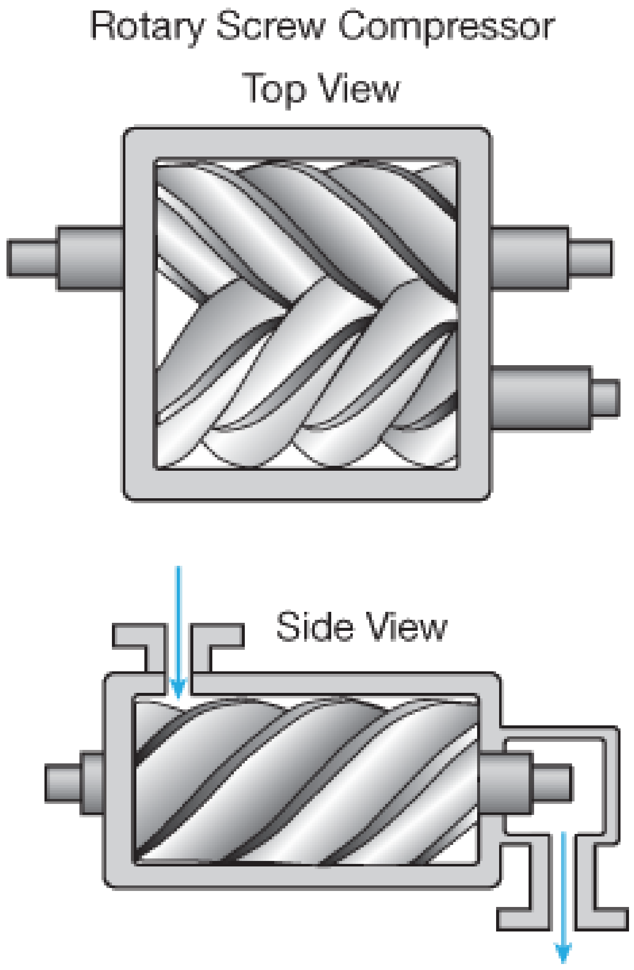
- Step 1: Air is trapped in a cylinder, tank, or similar container
- Step 2: The space in that tank becomes smaller, which forces the air molecules closer together
- The now-compressed air remains trapped in this smaller state, waiting to expand again until it's ready for use.

Compressed Air Fundamentals

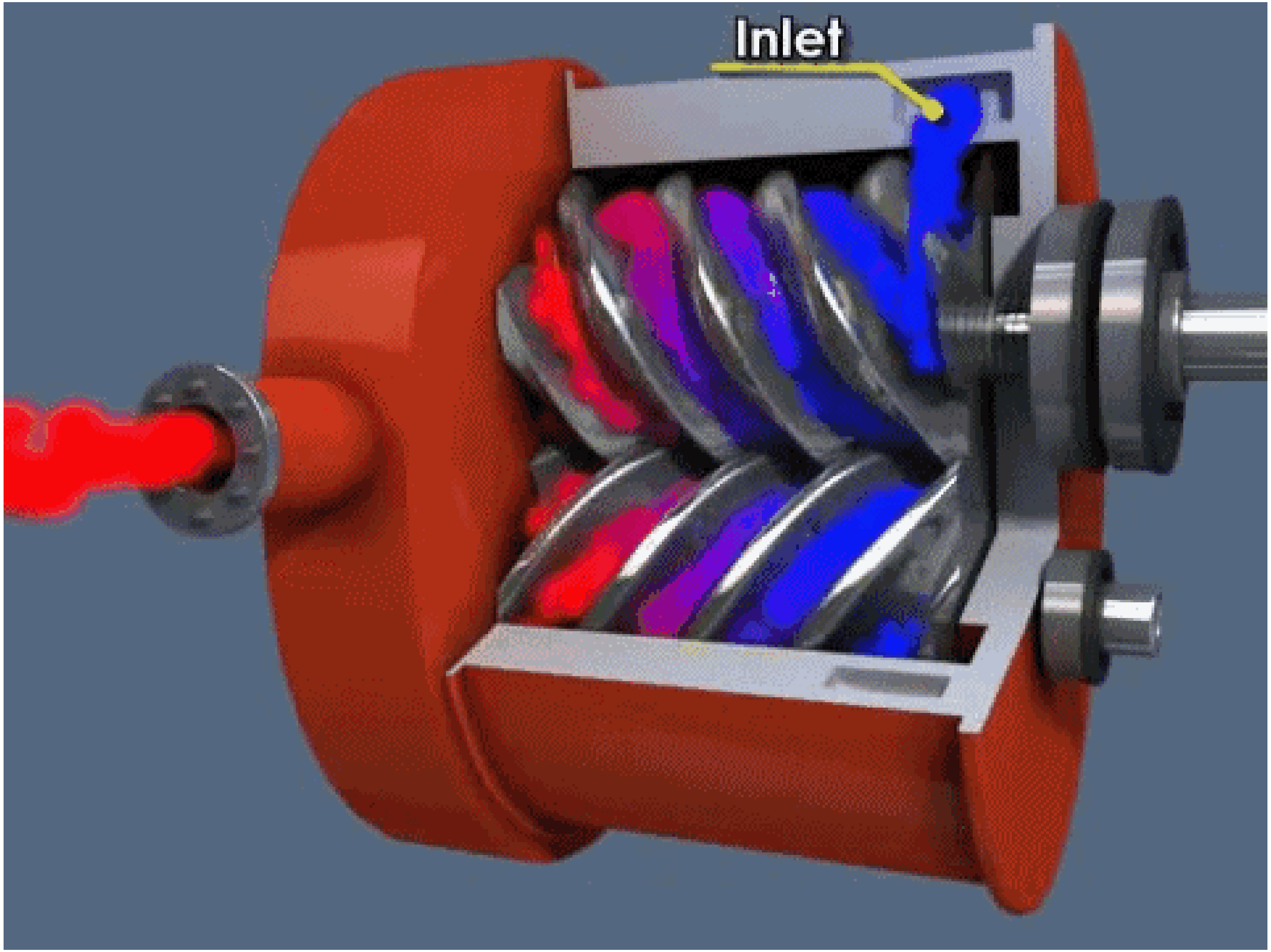


- But pistons aren't the only way to force air into a smaller space. There are numerous styles of air compressors on the market, each with its advantages and disadvantages.
- For example, rotary screw air compressors use dual spinning screws to push air down and compress it:

Compressed Air Fundamentals



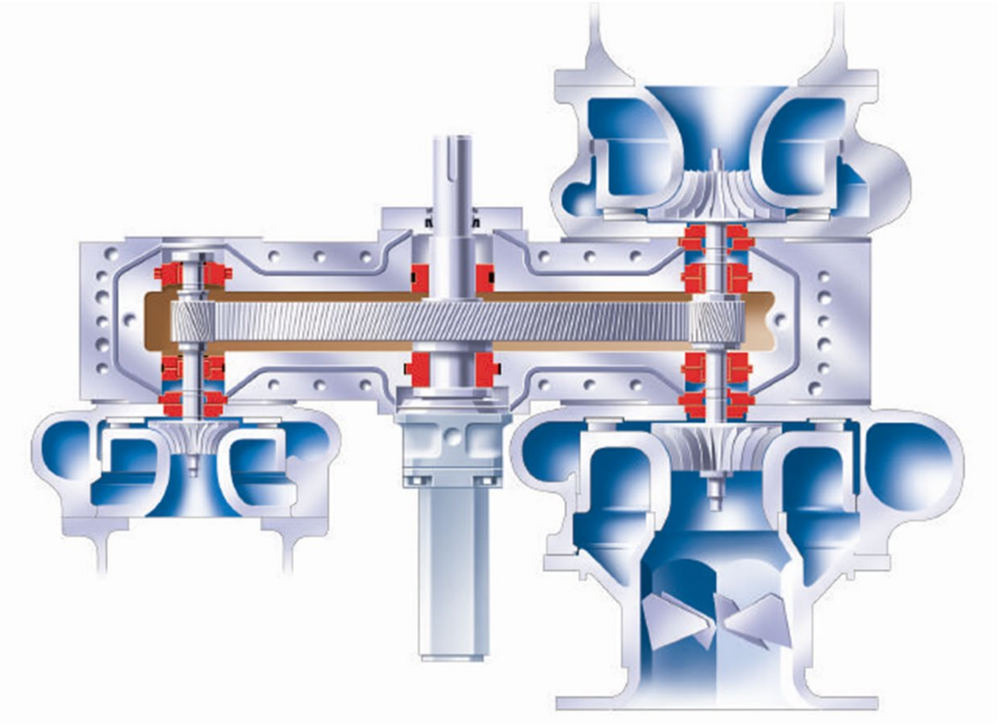
- Rotary screw air compressors are chosen over reciprocating because they are compact, powerful, and can run continuously.
- Regardless of the mechanism used, air is always compressed by taking atmospheric air and squishing it down, so the molecules are condensed and pressurized.


Inlet

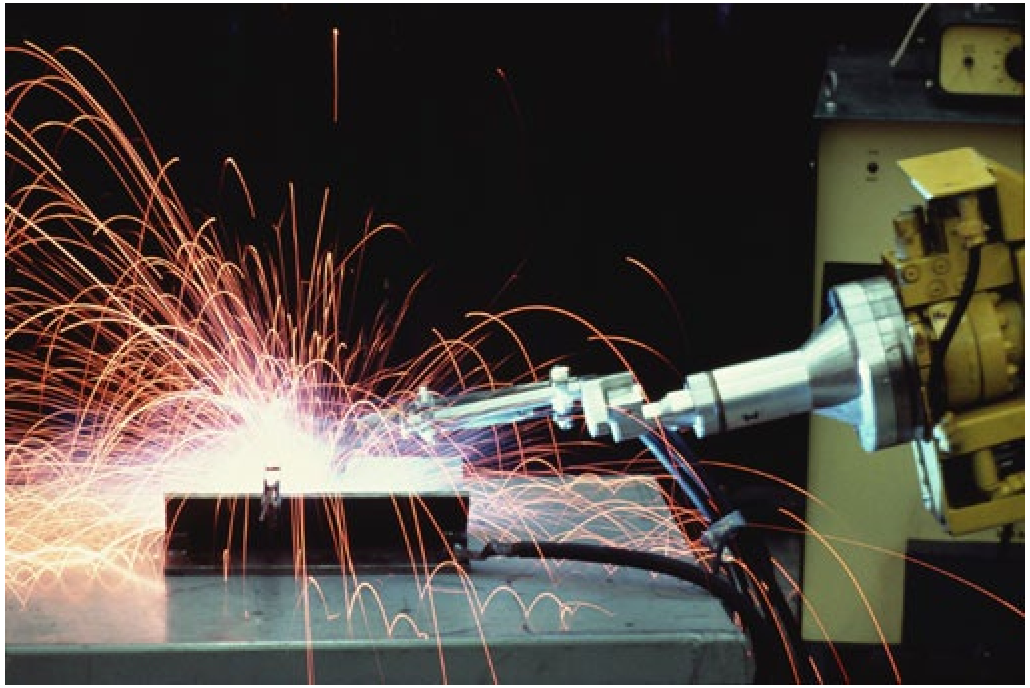
Compressed Air Fundamentals

- Dynamic compressors can be axial or centrifugal.

- Centrifugal compressors are widely used and function based on a straightforward principle that transforms air velocity into higher air pressure.
- In these compressors, the rotating impeller boosts the speed of the incoming air. This increase in velocity is achieved through centrifugal force.
- The pressure and output capacity of a centrifugal compressor are directly proportional to the shaft's rotational speed that holds the impeller.

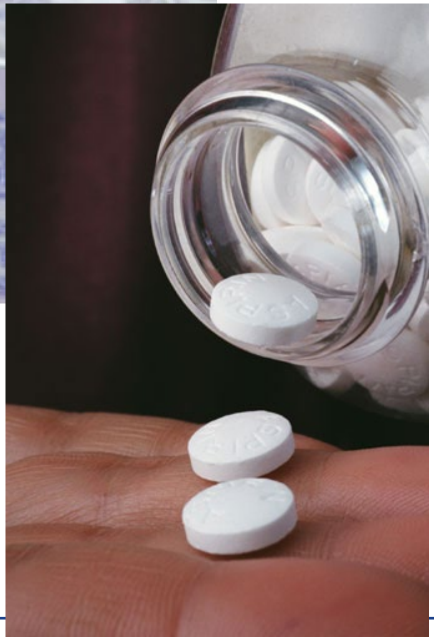


Compressed Air Fundamentals



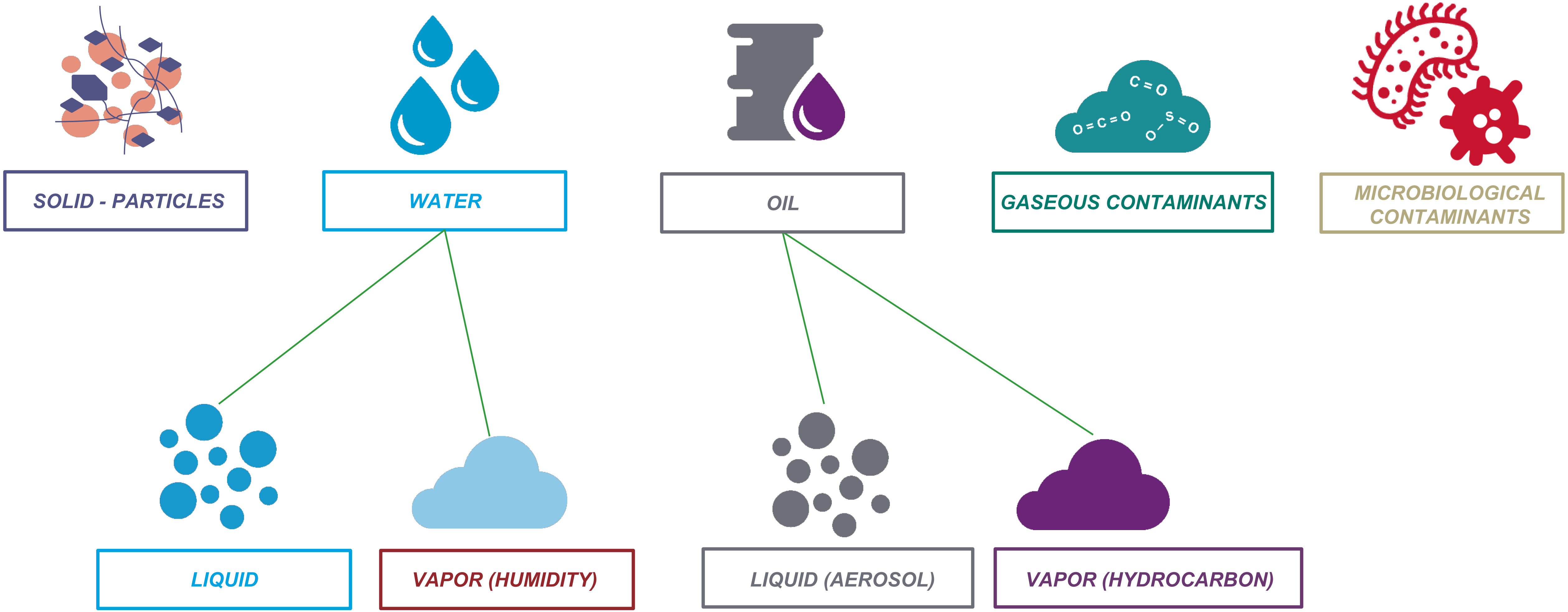
- Energy from compressed air is used to power pneumatic production equipment.
  - E.G.--air motors, actuators, instrumentation, tools, etc.
- To cool components or parts during fabrication
- To blow off waste material

Compressed Air Fundamentals

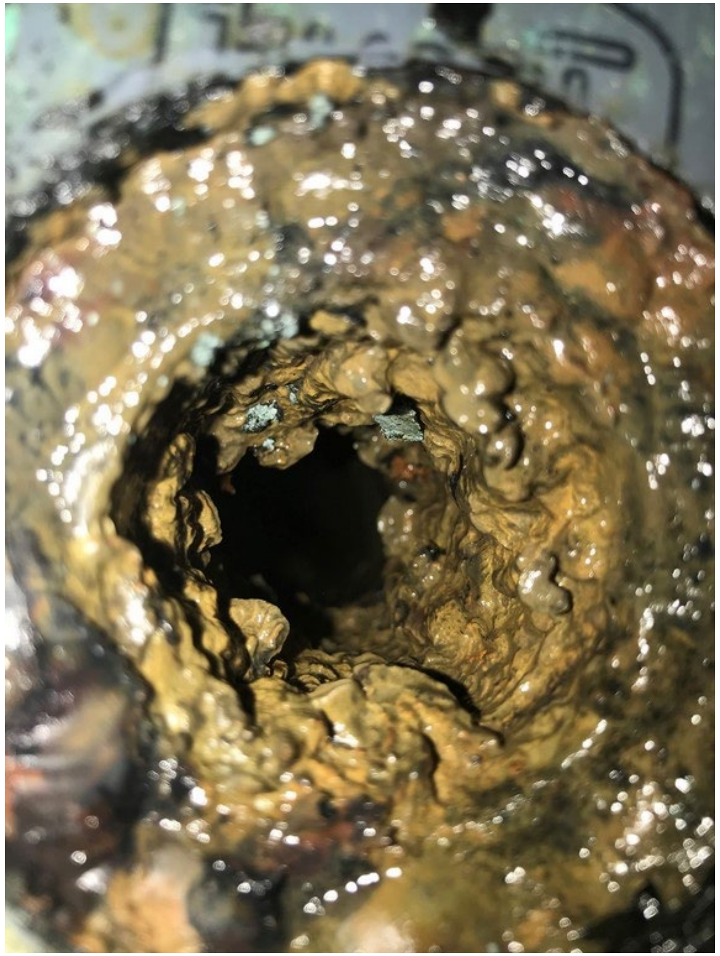


- Process Air
- Compressed air is an integral part of a process, and/or comes in contact with product.
  - Chemicals
  - Pharmaceuticals
  - Food & Beverage
  - Aeration and agitation
  - Semiconductor & Electronics
  - Medical Breathing Air
- CDA Quality--means Clean, Dry, Air

Which Contaminants do we find in compressed air?



Which Contaminants do we find in compressed air?



Compressed Air Quality

- As illustrated in the following table, a number of different air quality levels can be achieved.
- Care should be taken when using these terms and actual specifications for air quality should always be given.

Quality	Applications
Plant Air	Air tools, general plant air
Instrument Air	Laboratories, some paint spraying, powder coating, climate control
Process Air	Food and pharmaceutical process air, electronics
Breathing Air	Some hospital air systems, diving tank refill stations, respirators for cleaning and/or grit blasting

ISO 8573-1 Compressed Air Quality Classes

- ISO 8573 provides detailed standards on air-quality classes for various levels of particulate, moisture, and lubricant contaminants.

ISO 8573-1:2010 Compressed Air Quality Classes

Class	Max. Particle Size		Pressure dewpoint		Max Oil Content
	(µm)	(mg/m³)	(°C/°F)	(g/m³)	(mg/m³)
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.

Air Quality

- The air quality level required is a function of the dryness and contaminant level required by the end-uses, and is accomplished with separating, filtering and drying equipment.
- For certain applications, more than one class may be considered.
- Ambient conditions will influence the selection, especially dew point.
- Point of use equipment manufacturers should be consulted to determine their specific needs.

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%

Capacity Ratings and Corrections

- ASME Standard

Pressure	14.7 PSIA
Temperature	68° F
R/H	36%

- ISO, CAGI, Pneurop Standard

Pressure	14.5 PSIA
Temperature	68° F
R/H	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.

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

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

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

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

Ps = standard pressure, psia
Pa = Atmospheric pressure, psia
PPwv = Partial Pressure water vapor at ambient temperature
Rh = Relative Humidify
Ta = Ambient Temperature, °F
Ts = Standard Temperature,°F

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

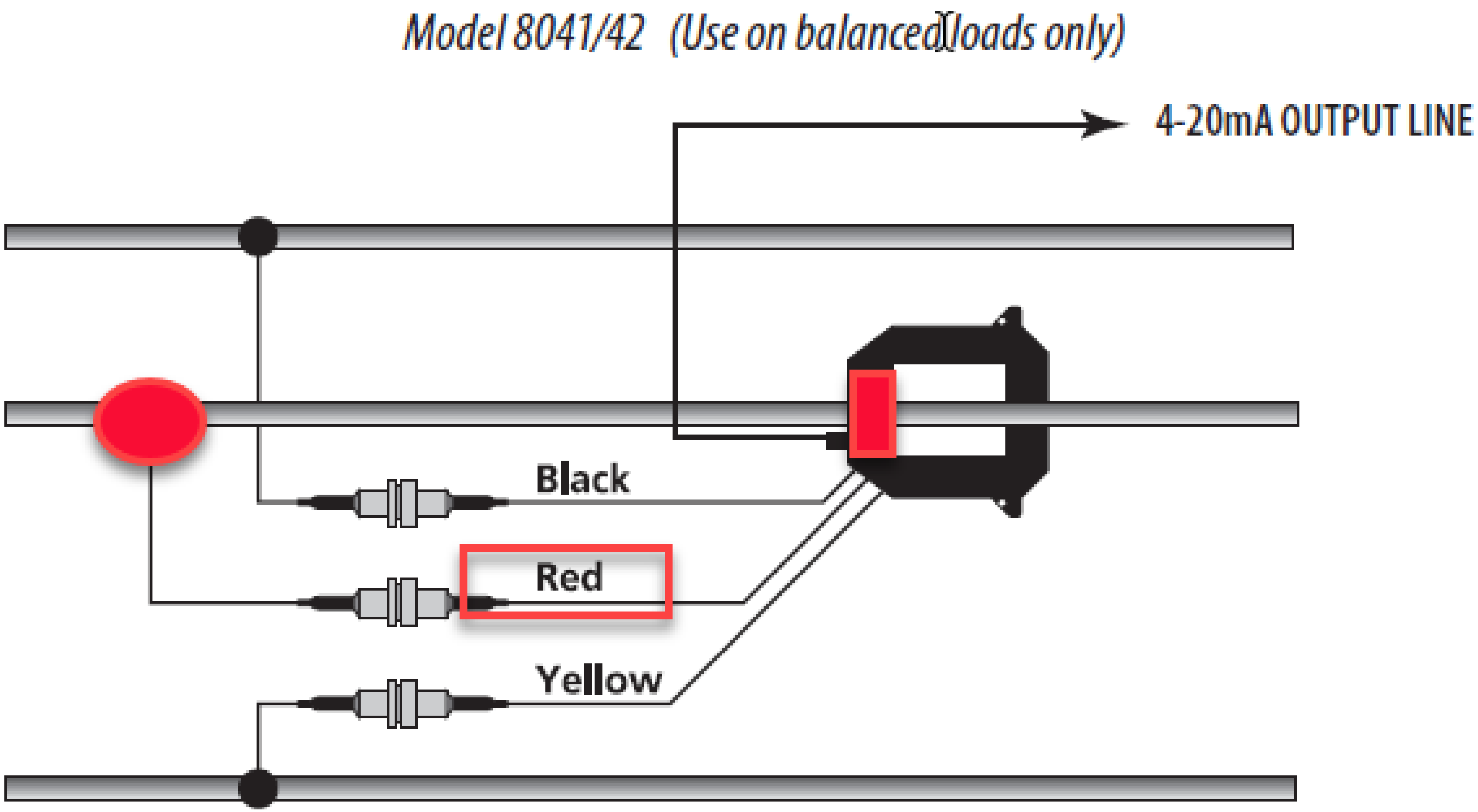
The Need to Make Measurements

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

Measurement Tools

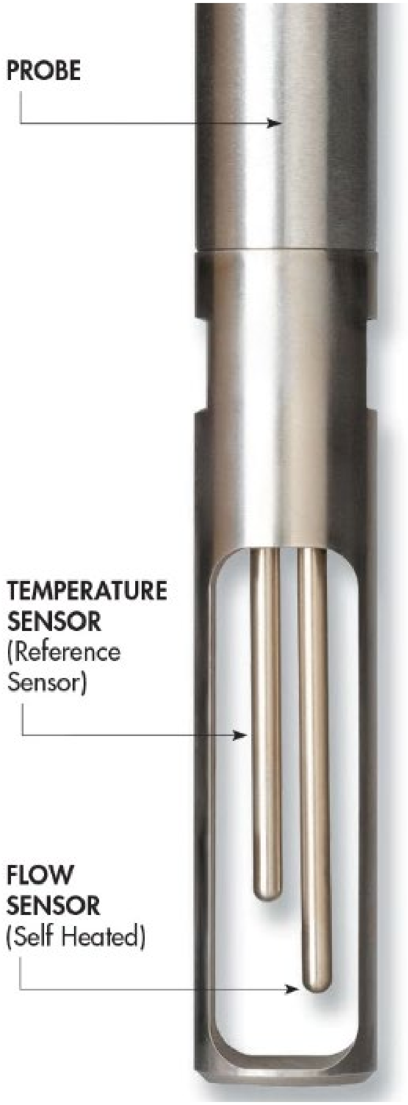
Measurement Tools

Measurement Tools

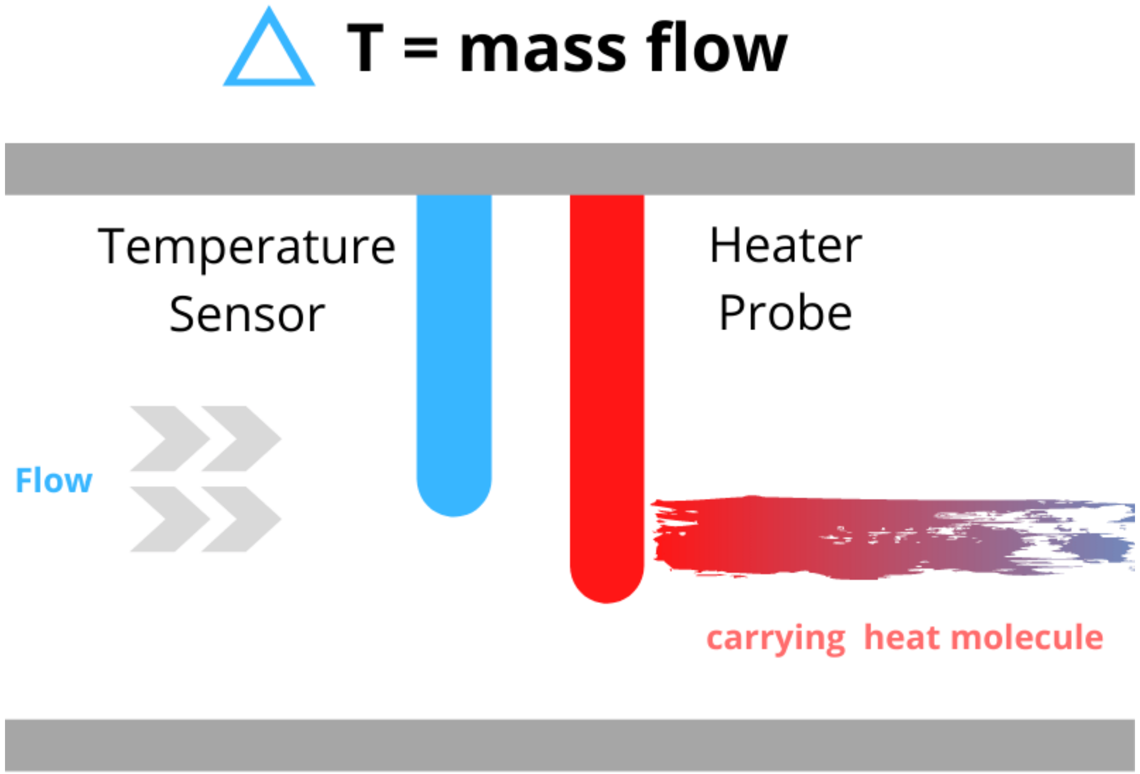


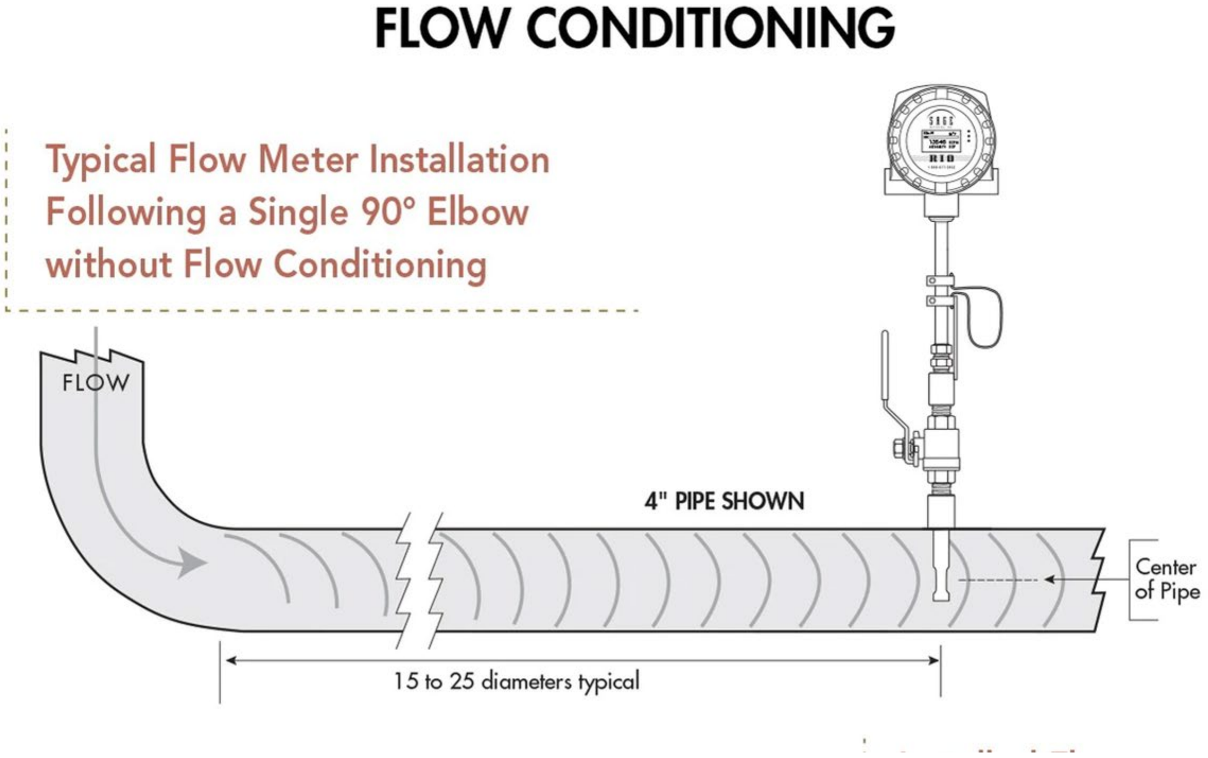
Thermal mass measurement versus other technologies

- Understanding the difference between a thermal mass flowmeter and other measurement technologies is the first step in deciding if the TMFM is the correct device for an application.
- The primary difference between a TMFM and other technologies is that it directly measures mass flow versus volumetric flow based on heat transfer.
- 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.

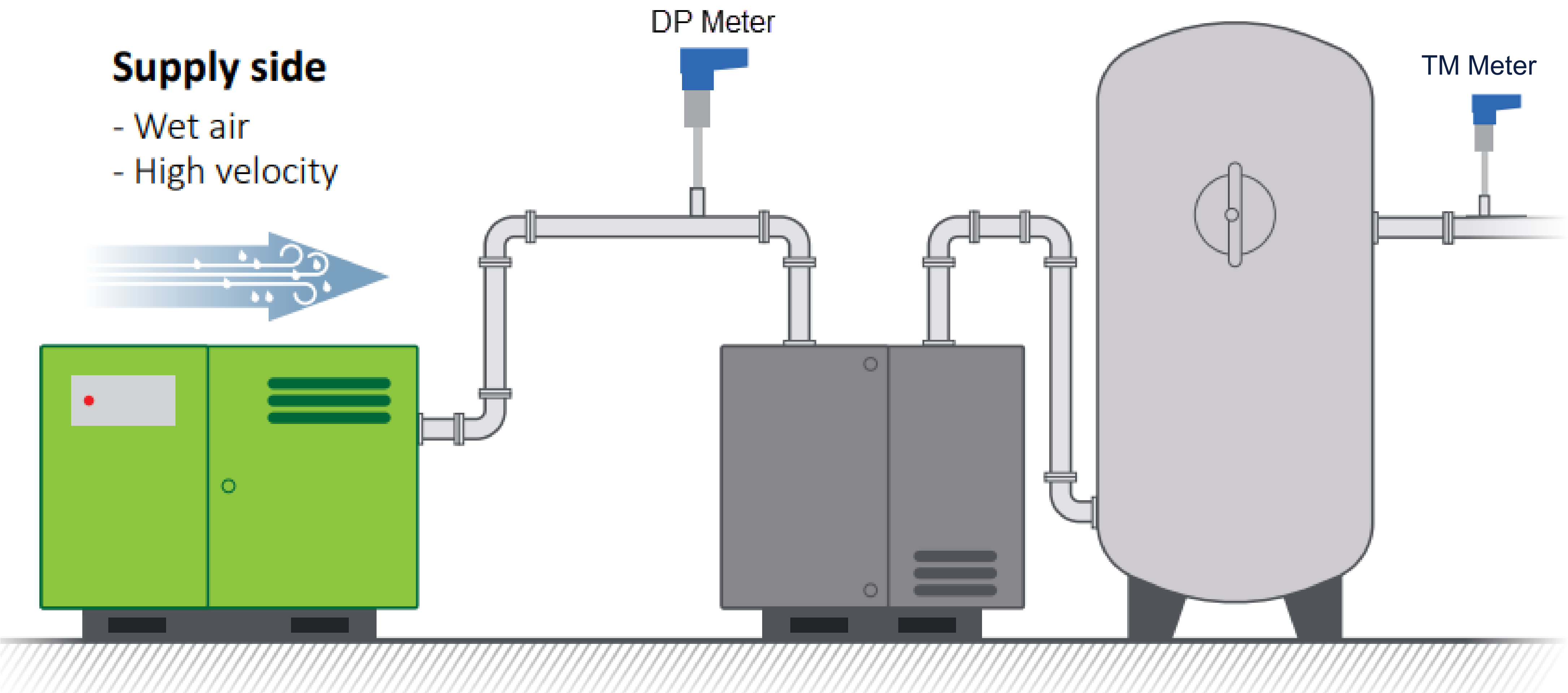


Measurement Tools





Flow Meters



How to Hot Tap


Apollo

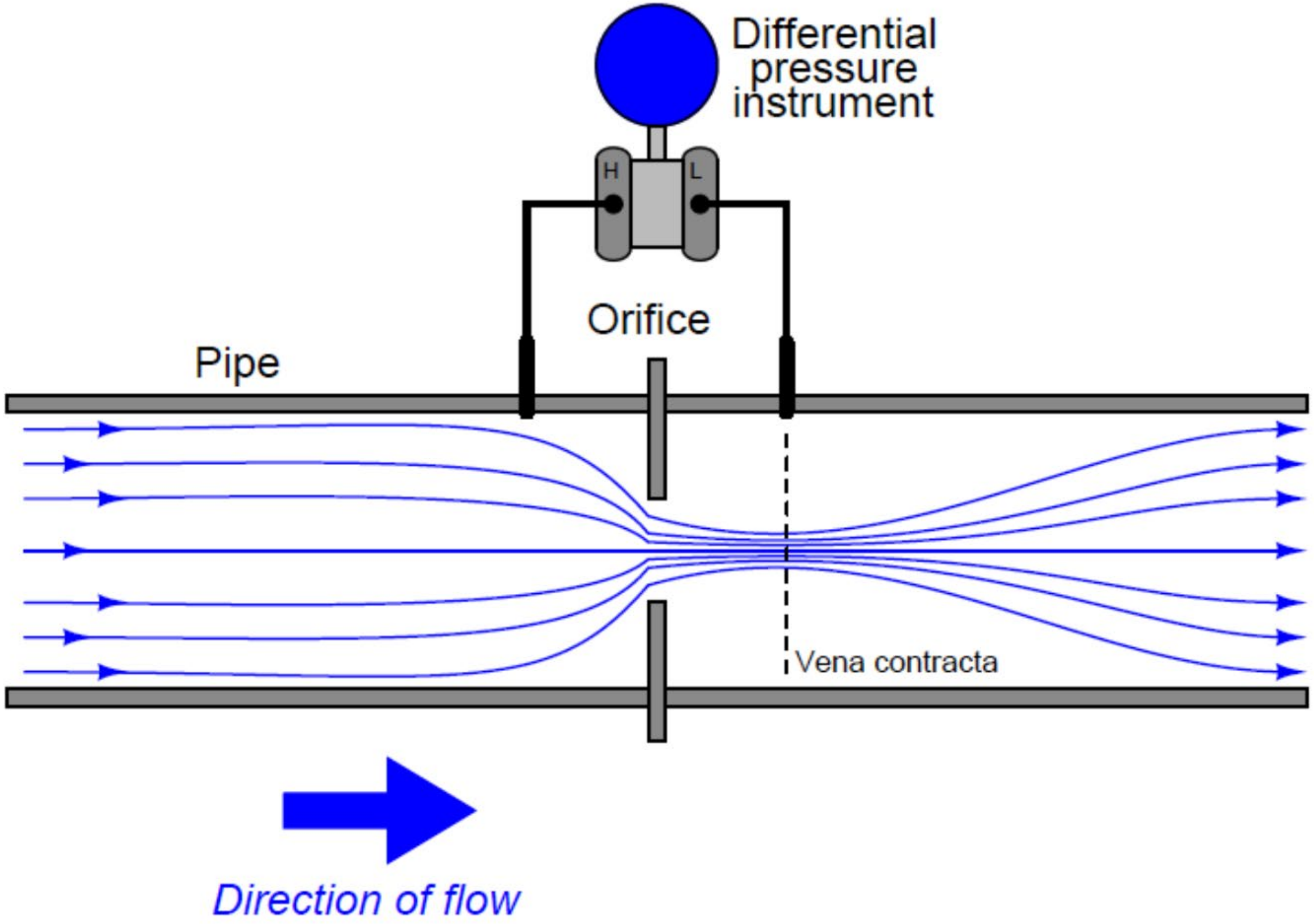

44

Orifice Plate Flow Meters

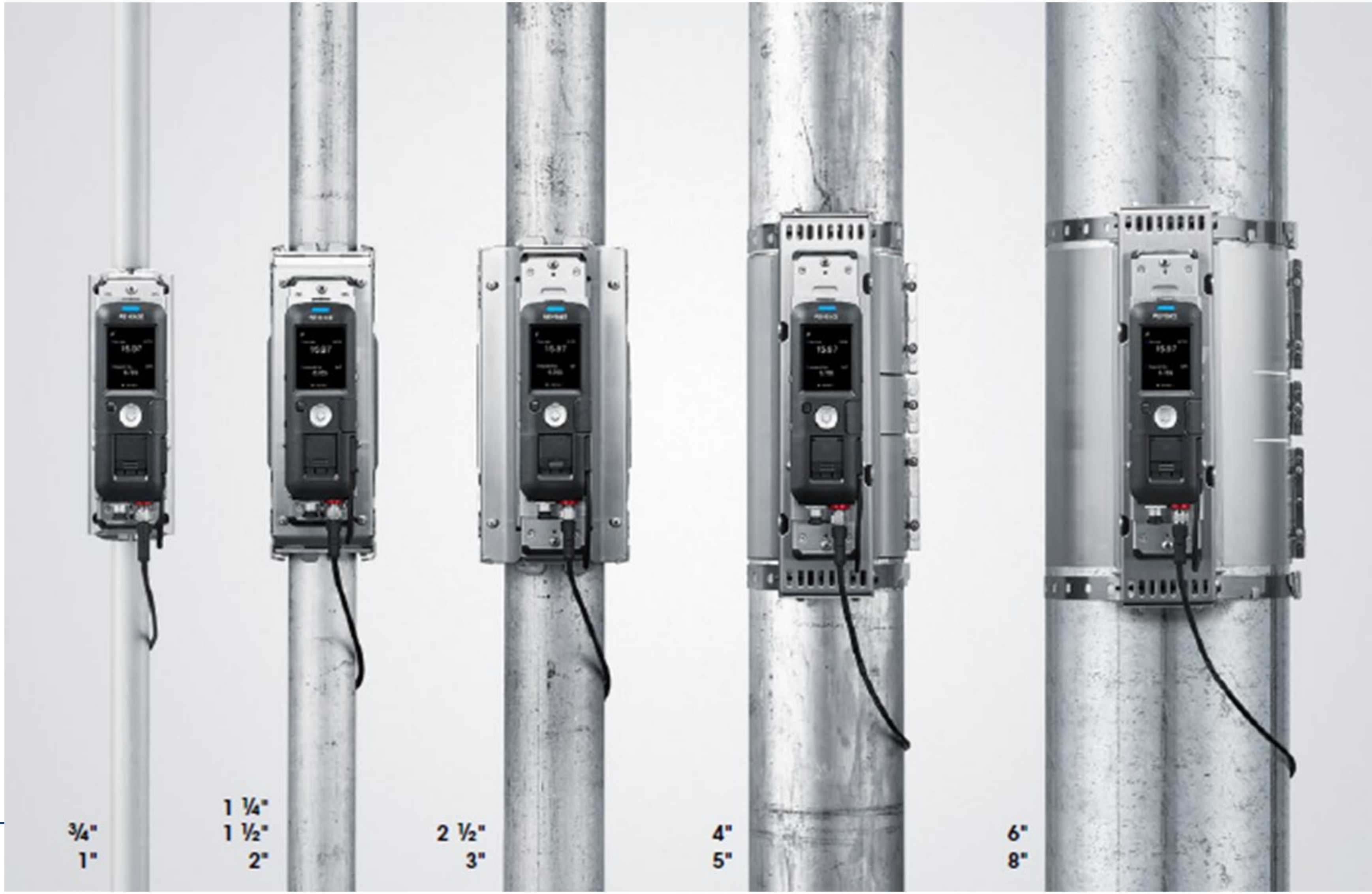
These meters are another carry over from fluid engineering.

They operate on the physics of a pressure drop being created as a medium flows through an orifice.

The problem with these meters is just that; they, themselves are a pressure drop.



Ultrasonic Flow Meters



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

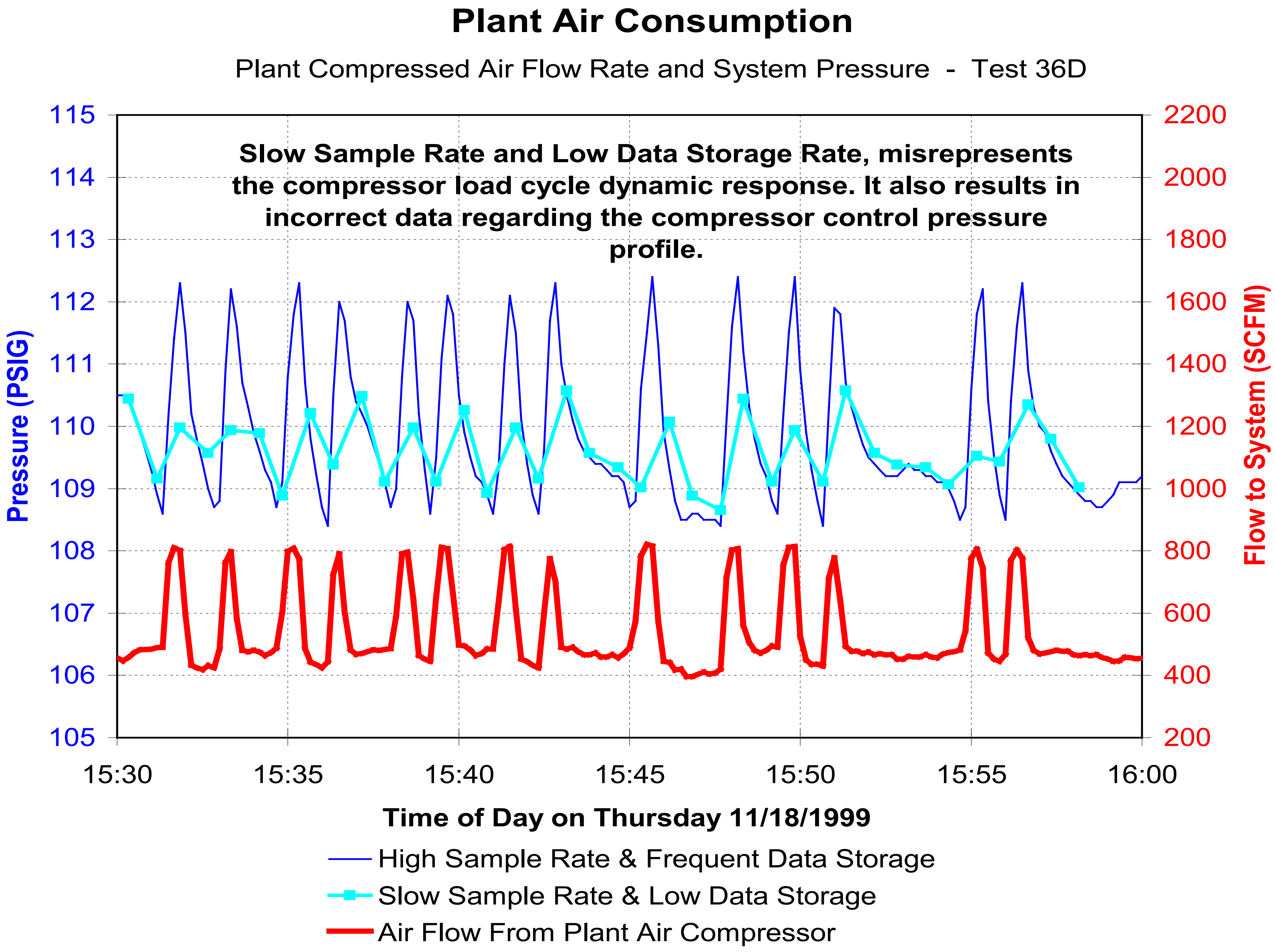
Measurements – A Snapshot Versus a Movie

- Taking data at a single point, or even during various shifts can provide some answers, but not the complete picture.
- The use of data logs 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

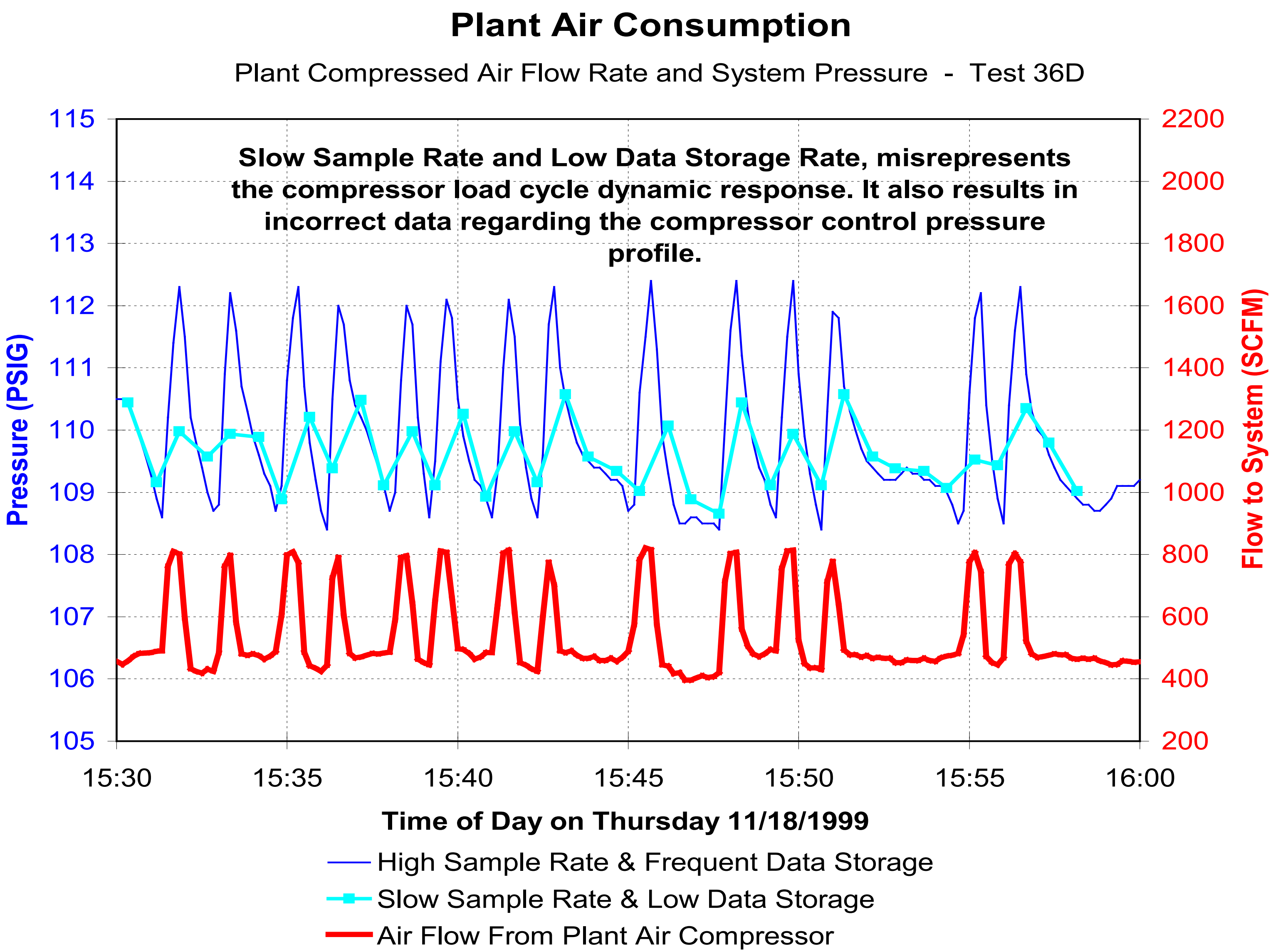


Better Plants U.S. DEPARTMENT OF ENERGY

Measurements – A Snapshot Versus a Movie

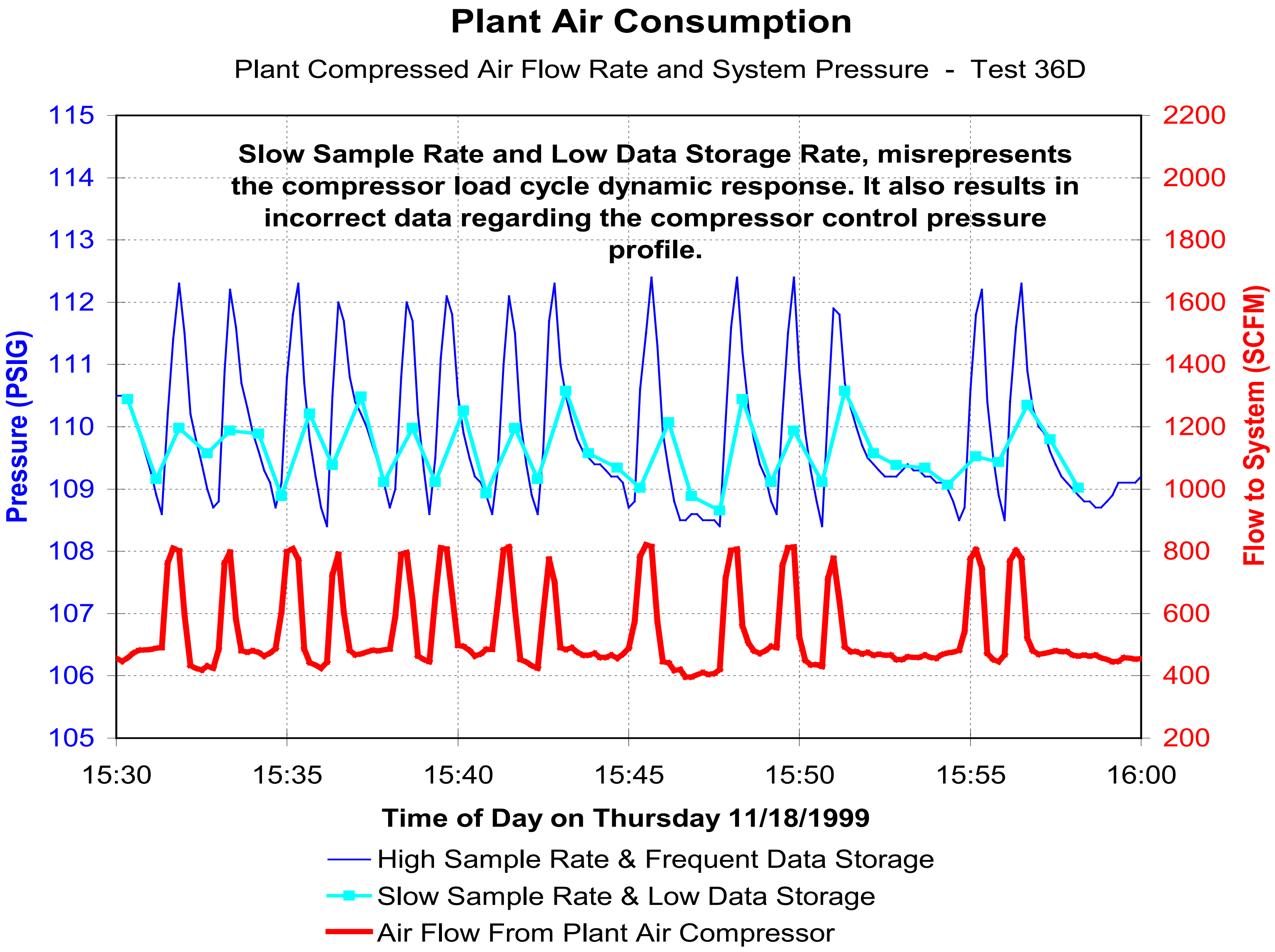
- Signal aliasing in the data tracing above could easily lead to misinterpretation of the recorded system dynamics.
- The 350 scfm swing in flow to the system is NOT a demand event.
- The true wave forms, collected at the high sample rate, clearly show a direct correlation of increasing flow with increasing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

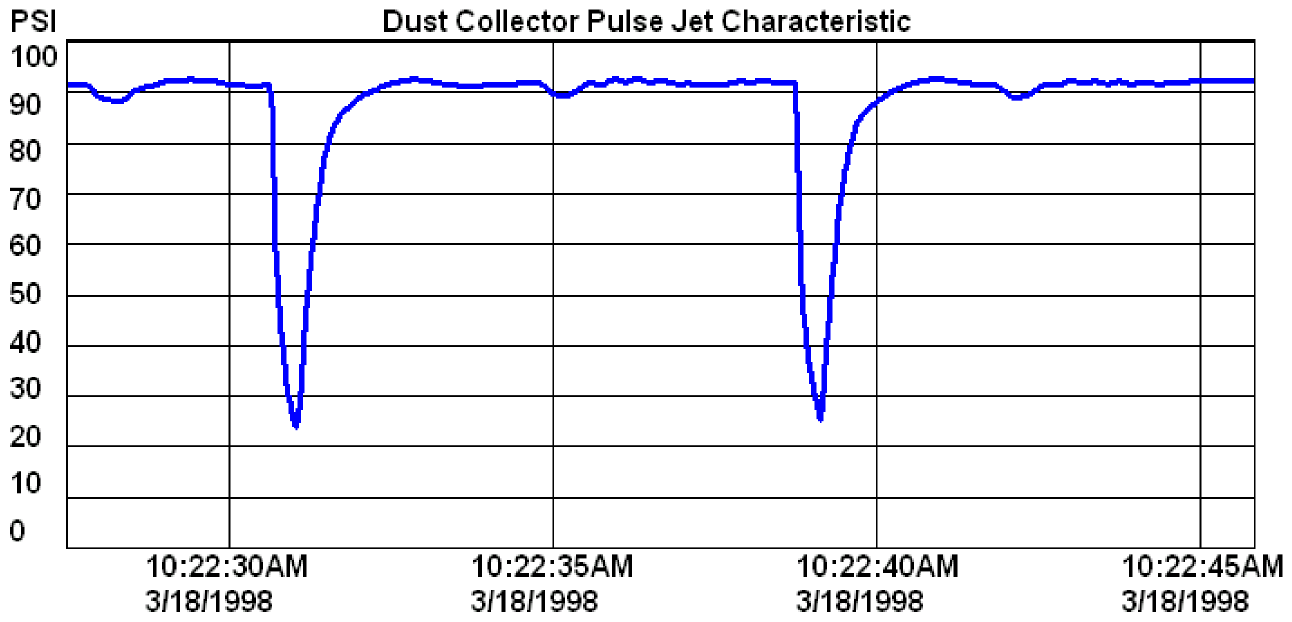


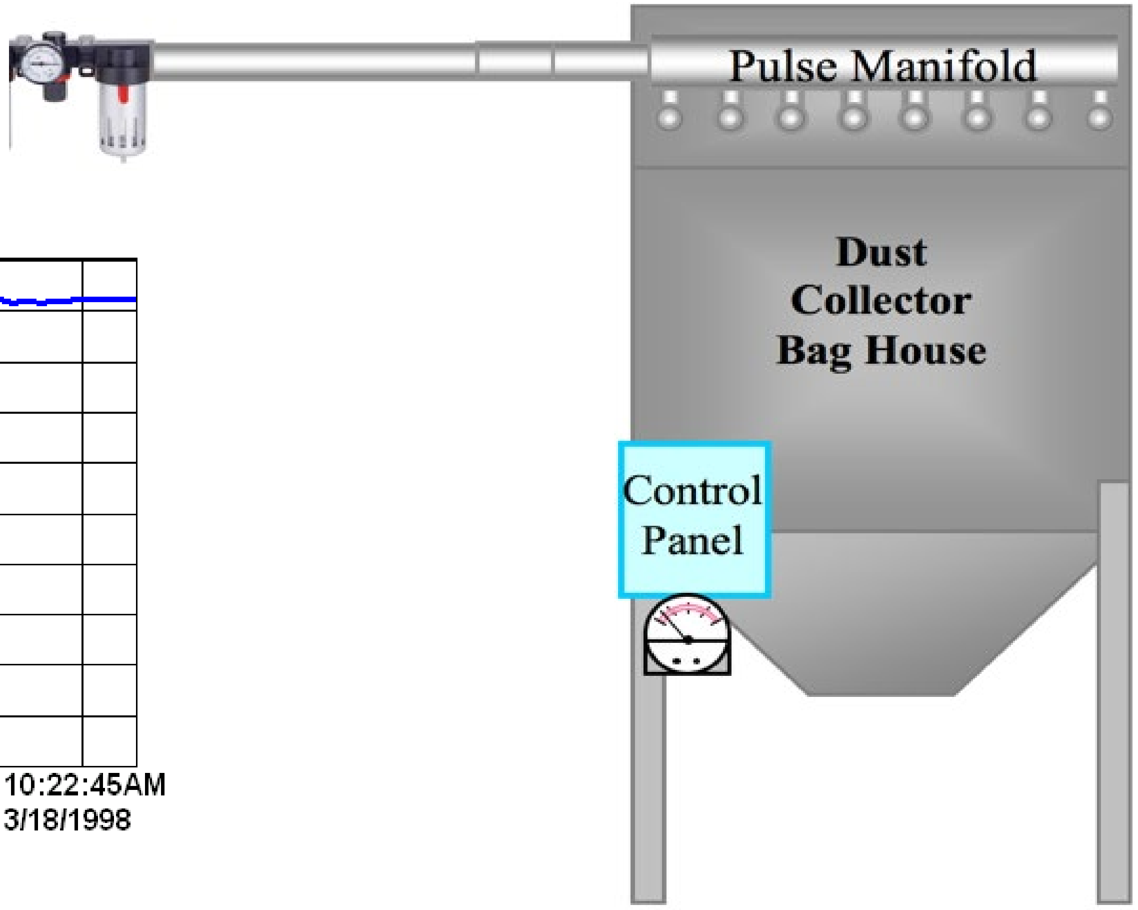
Measurements – A Snapshot Versus a Movie

- 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.**



High Speed Data Collection





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.

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

Next Week – Compressor Types and Ventilation

- Positive Displacement – Typically Rotary Screw
- Dynamic Compressors – Typically Centrifugal
- Compressor Room Ventilation
- Homework ….

Homework for Week 1 – Block Diagram

- Draw a block diagram of your compressed air system.
  - No P&ID drawings please.
- Include supply side and demand side if possible.
- Indicate compressor type and horsepower.
- Show dryer type and any filters.

Homework for Week 1 – Example Diagram