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 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.
- These trainings are held either in person or via web.
- Through Better Plants:
  - Industrial organizations commit to efficiency goals
  - Receive technical assistance and national recognition for their achievements

About Your Instructor

- 45 years 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 MEASUR Tool
- 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

COMPRESSED AIR SYSTEM SPECIALIST
CAGI
Compressed Air & Gas Institute
CERTIFIED

TRAINING • EDUCATION • EFFICIENCY
COMPRESSED AIR
CHALLENGE
INSTRUCTOR

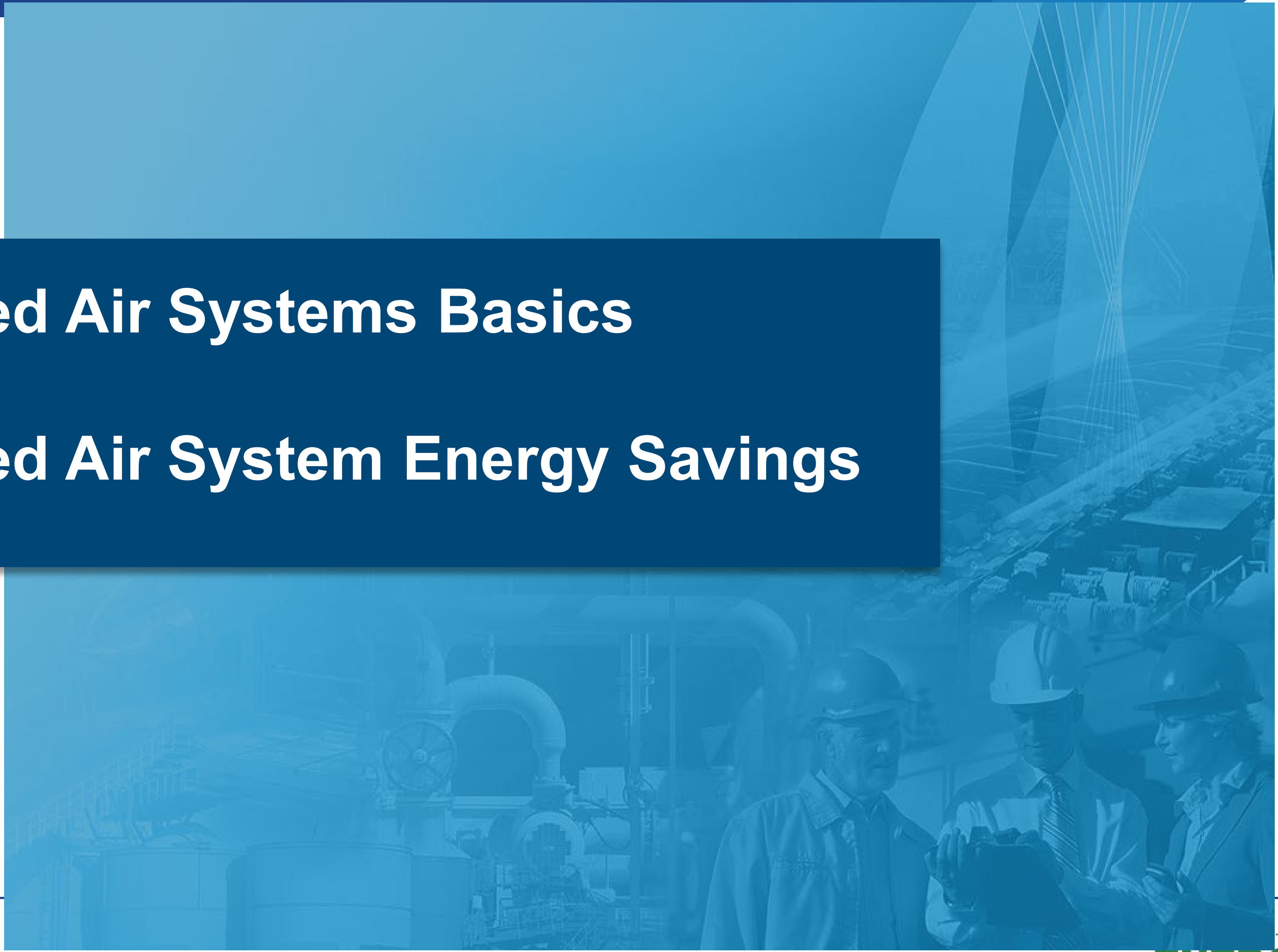
Assessment Process

- **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

Week 1



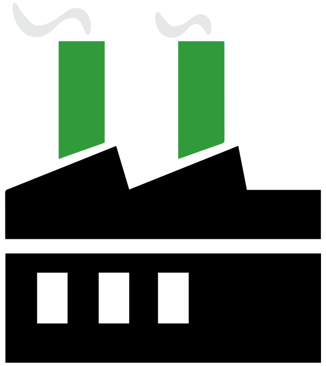
Compressed Air Systems Basics

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.

Energy → Electricity



Compressed → Air

Product →

Powerhouse / Compressor Station

↓

Producers of Compressed Air

↓

Produce Air More Efficiently

Manufacturing Plant

↓

Consumers of Compressed Air

↓

Use Less Compressed Air

→ **Total Energy Savings** ←

Energy Audit Walkthrough

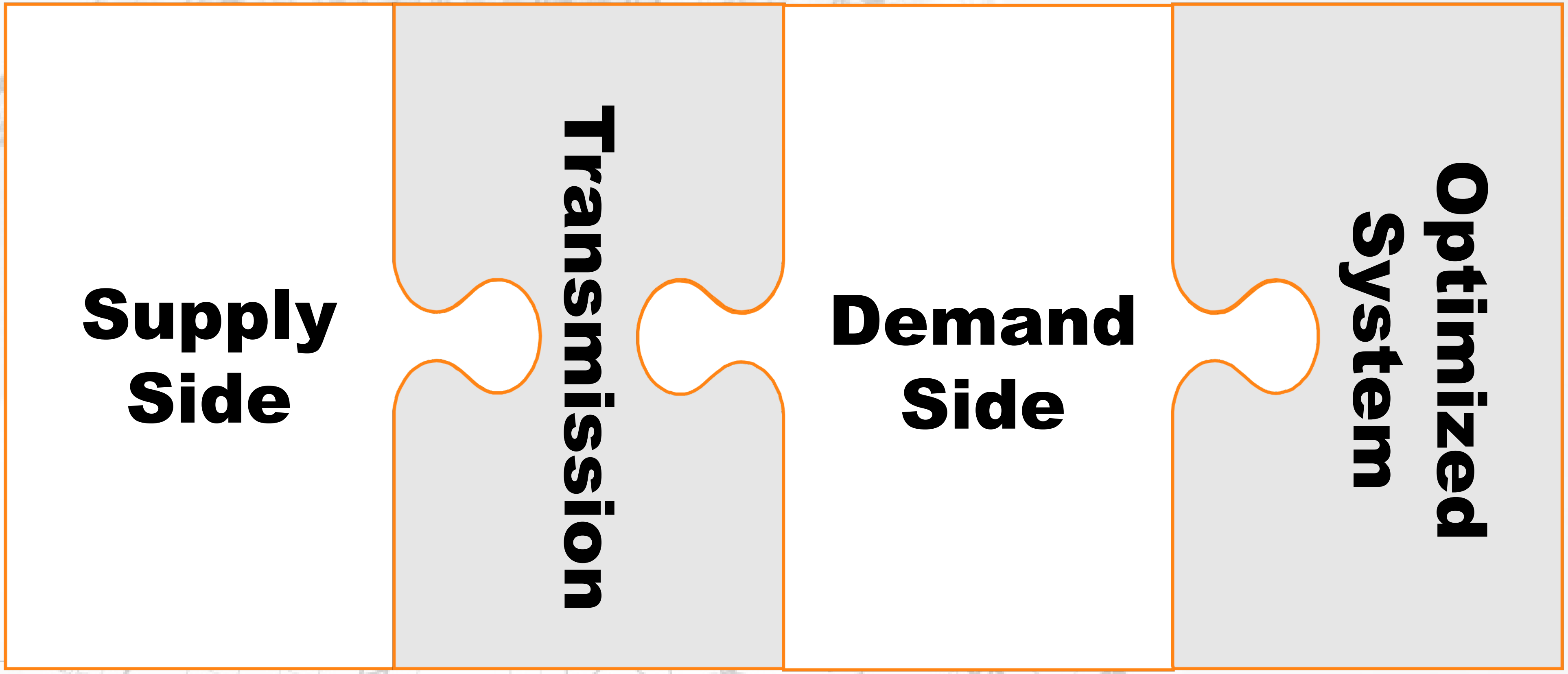
What am I looking for?

Goals

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 use 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

There are generally many different options for accomplishing a given task with compressed air, and it is important to apply the equipment properly.

Often if a system is performing poorly, it is not because the equipment is faulty, but because it has been applied improperly or poorly maintained.

Almost every compressed air system has room for performance improvement, from a modern system in a 2-year-old plant to one that has been modified and updated over the last 40 years.

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.

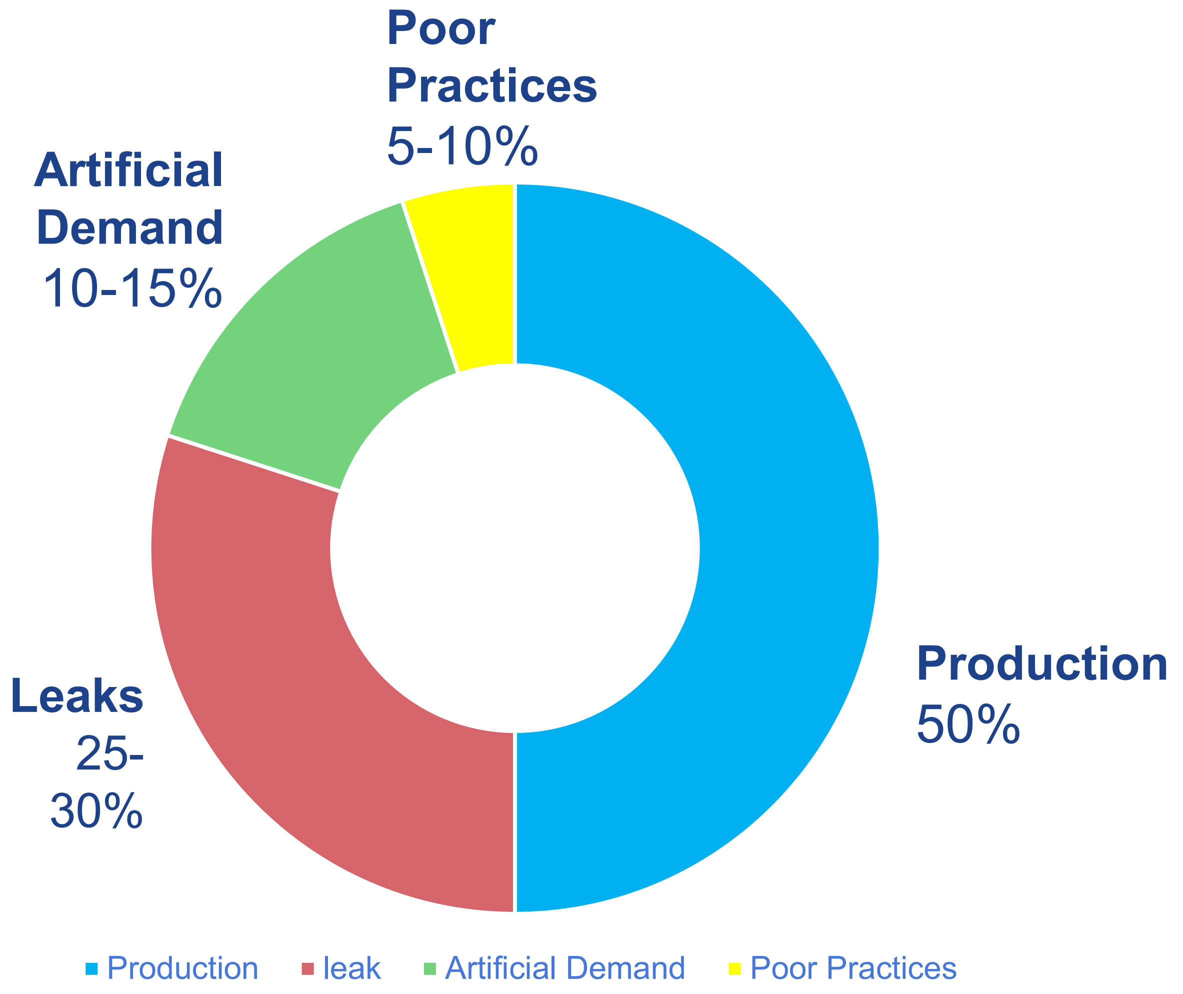
Compressed Air Versus Other Energy Sources

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

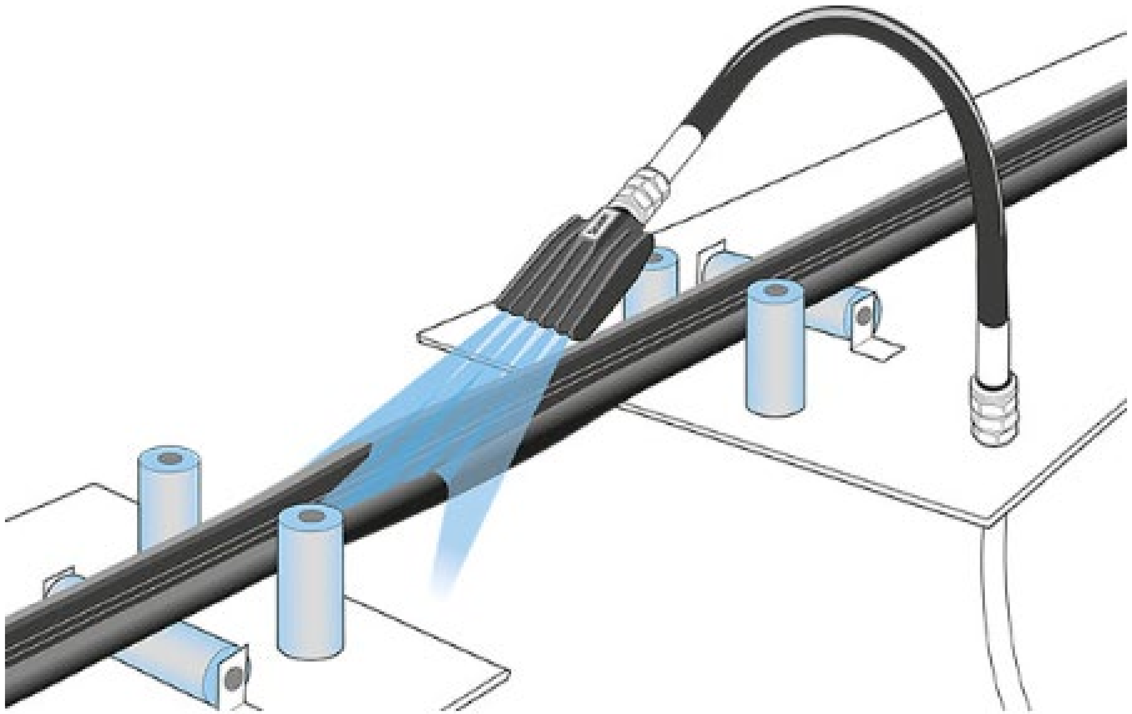
- You may be surprised, in most industrial plants, only 50% of the compressed air generated supplies productive air use.
- The other 50% is consumed by various losses.
- The losses are

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

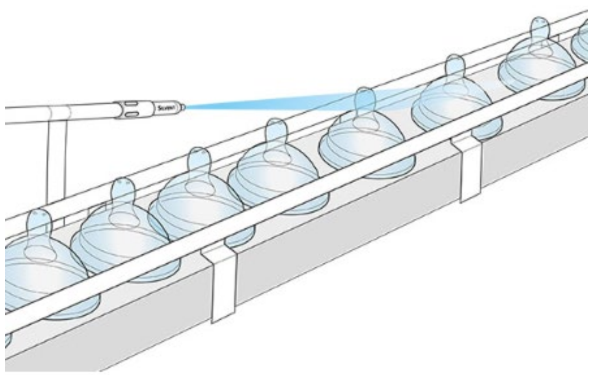
Where does the air go?



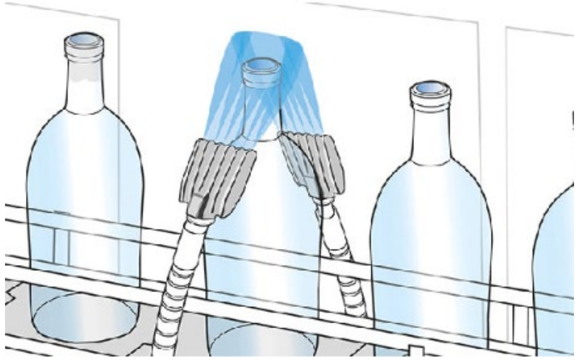
Where does the air go? Is it Controlled?



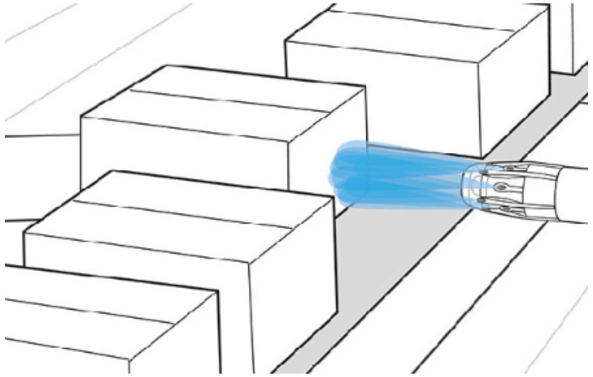
Cleaning



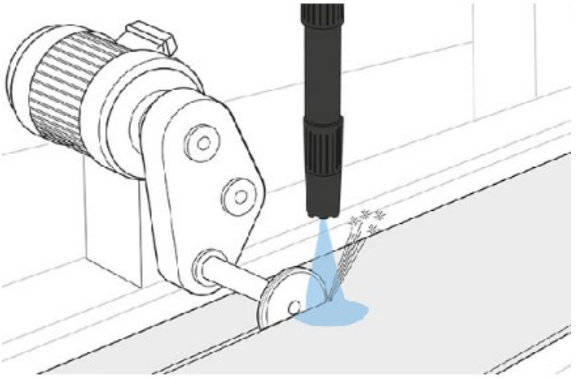
Transporting



Drying

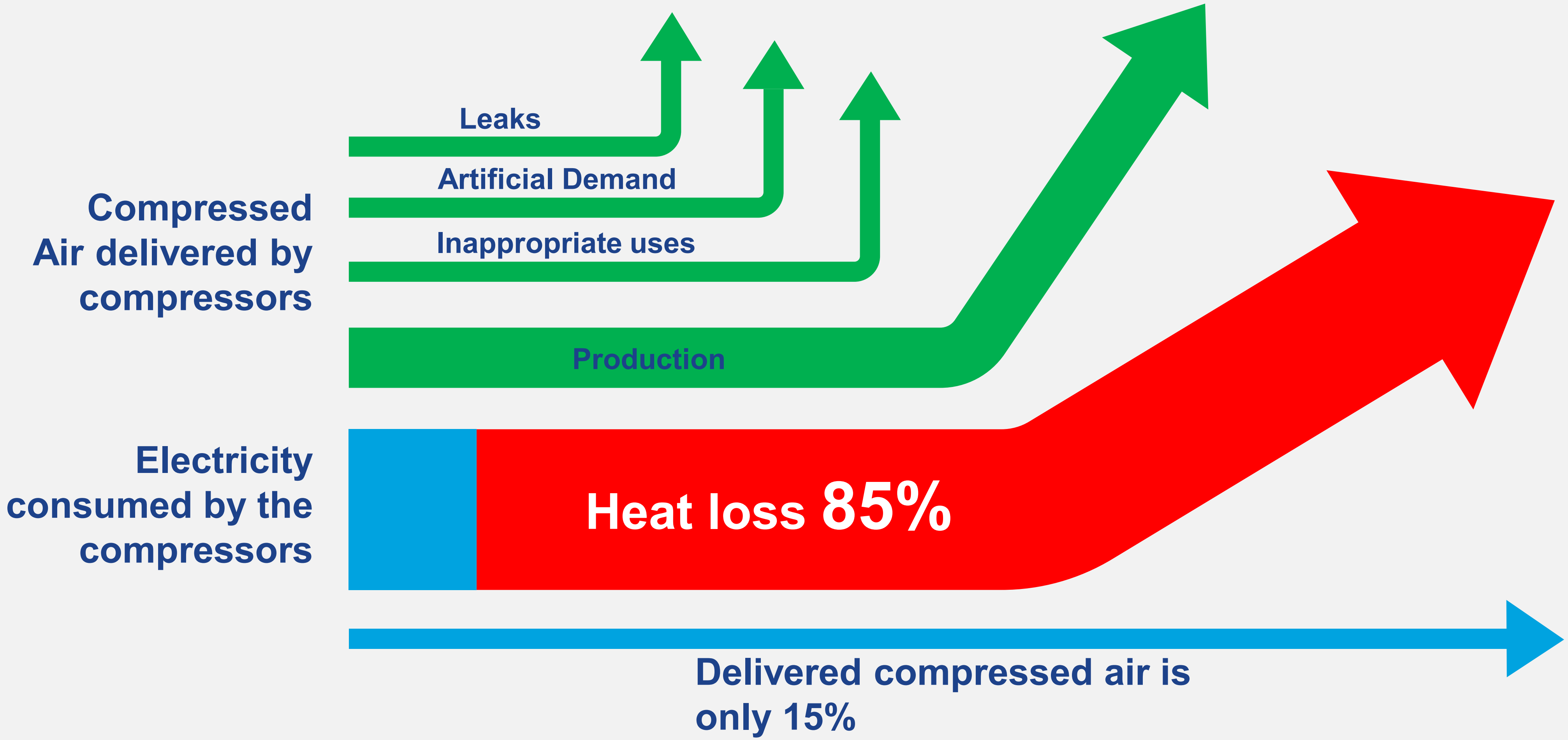


Sorting

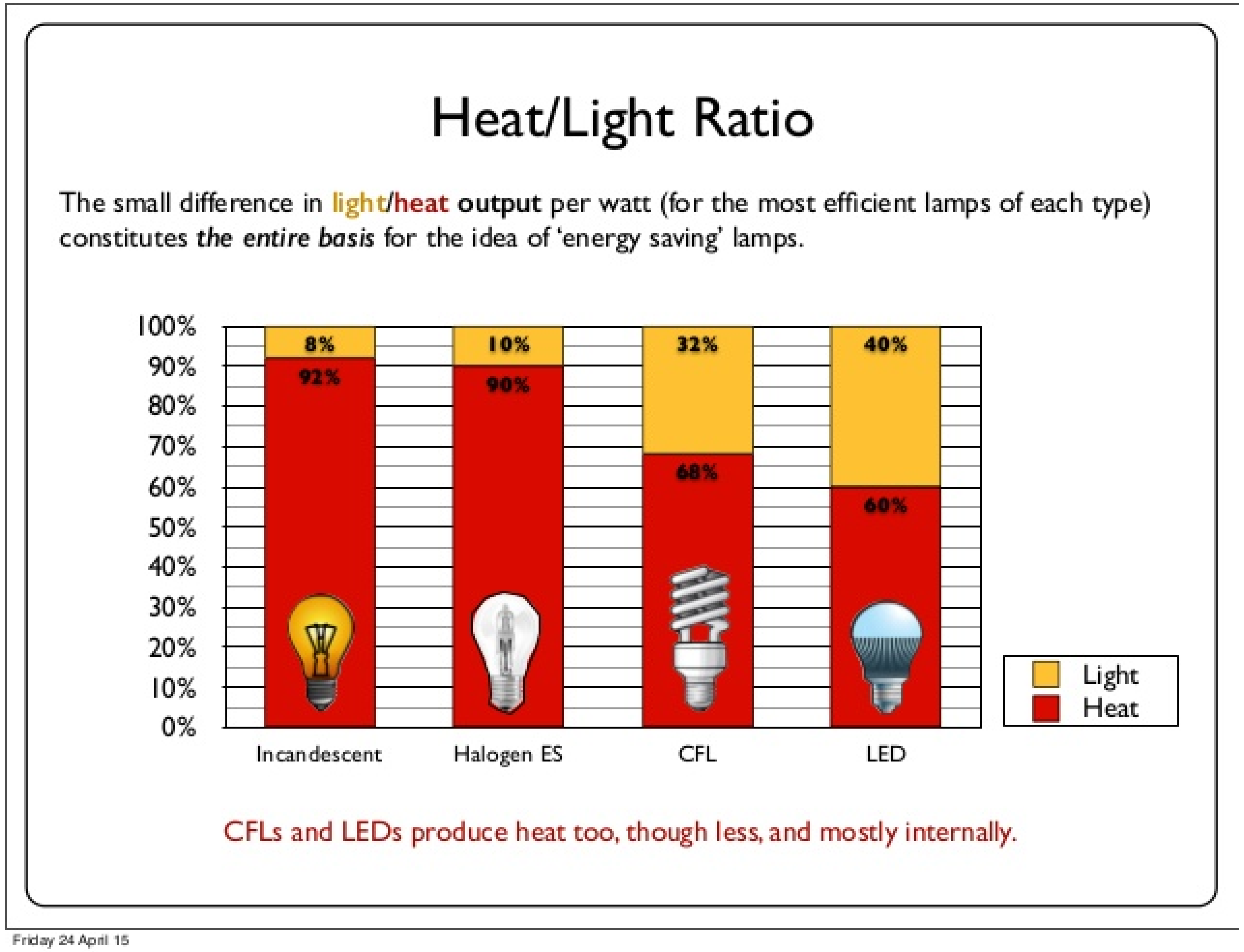


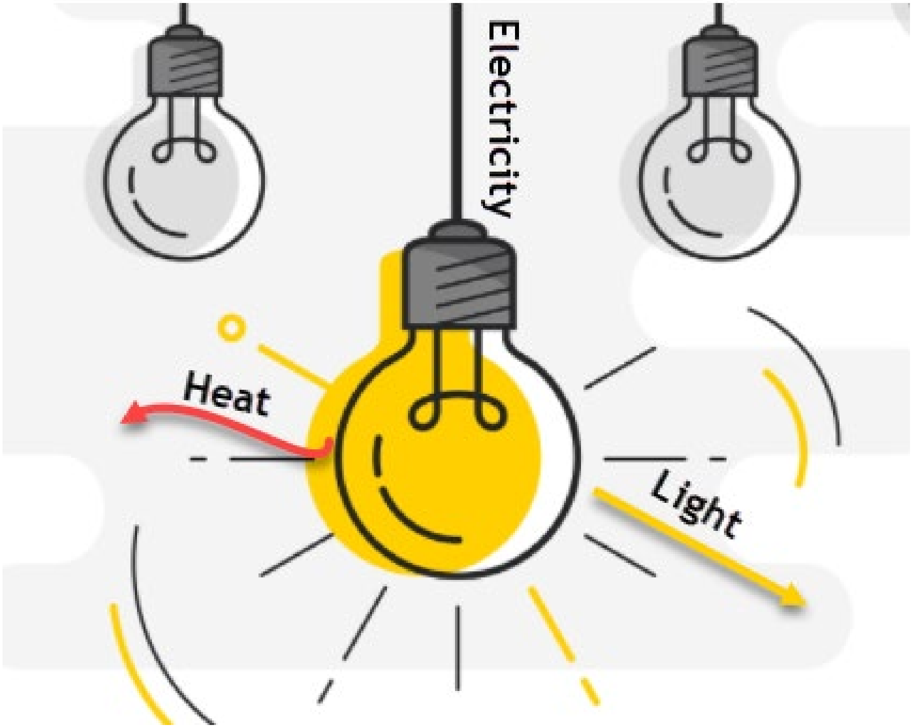
Cooling

Not very efficient!



Not very efficient!

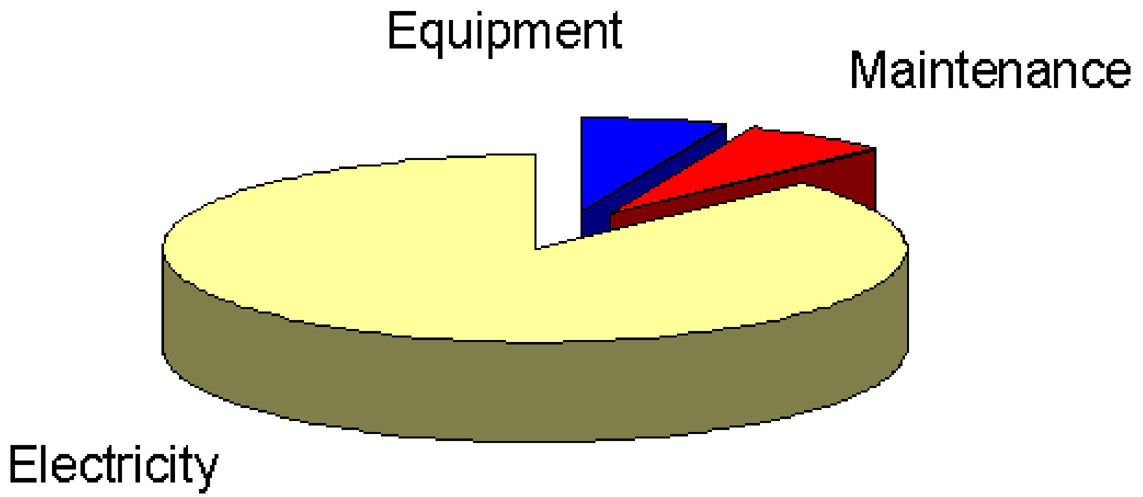




Compressed Air Systems
Total Cost of Ownership

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

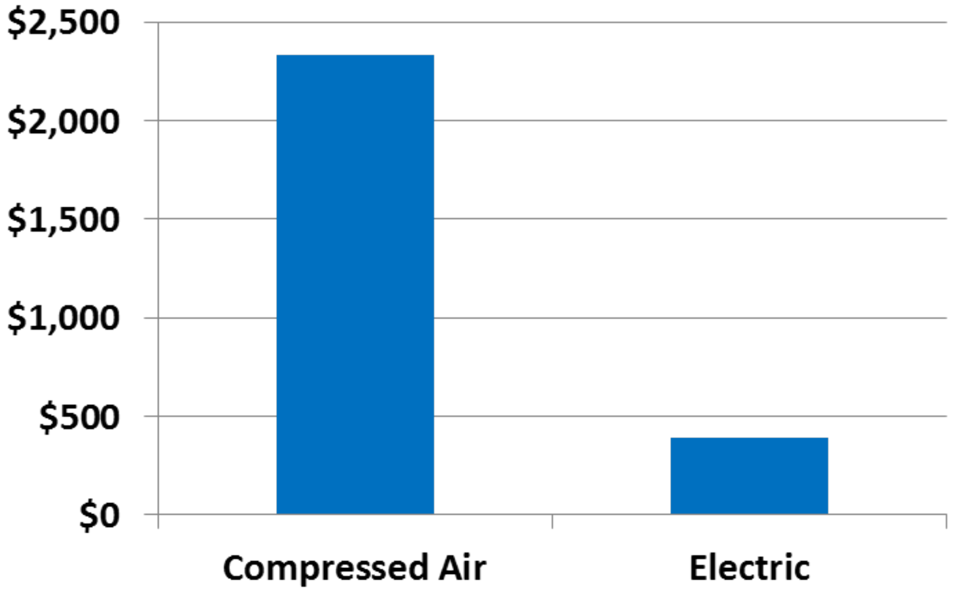
Electrical cost usually exceeds 75% of the total operating expense.



Source: Compressed Air Challenge®

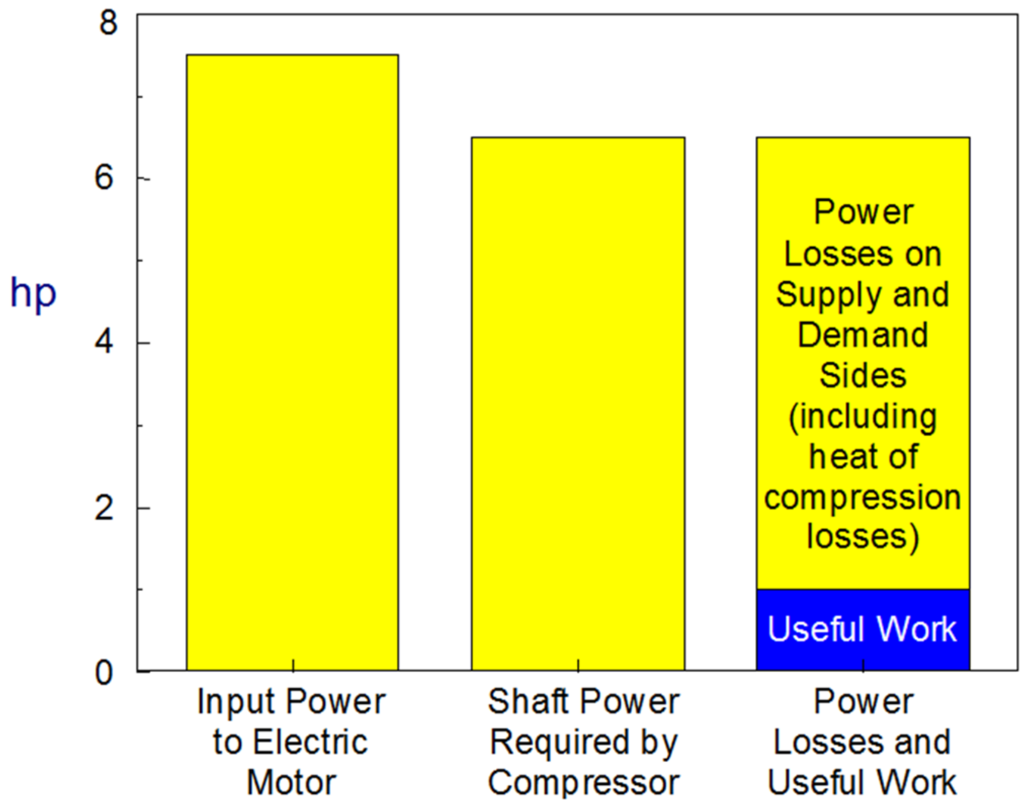
Compressed Air Versus Other Energy Sources

- The overall efficiency of a typical compressed air system can be as low as 10-15 percent
- Annual energy costs for a 1 hp air motor versus a 1 hp electric motor, 5 day per week, 2 shift operation, $0.10/kWh
  - ……$ 2,330 (compressed air)
  - ……$ 390 (electric)



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

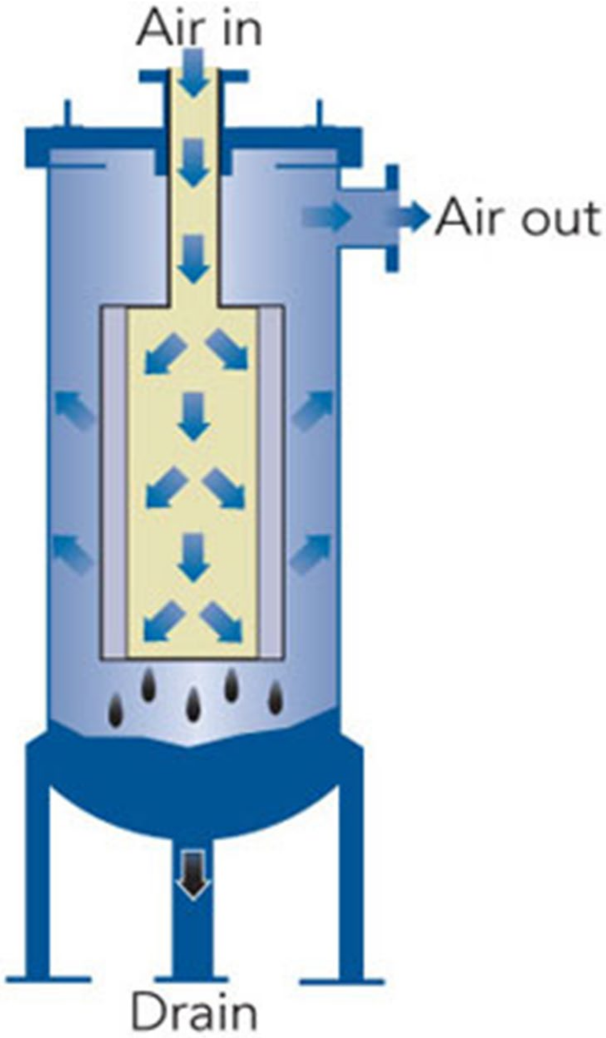
Problems?
Why did this happen?

Warnings

No Wet Tank

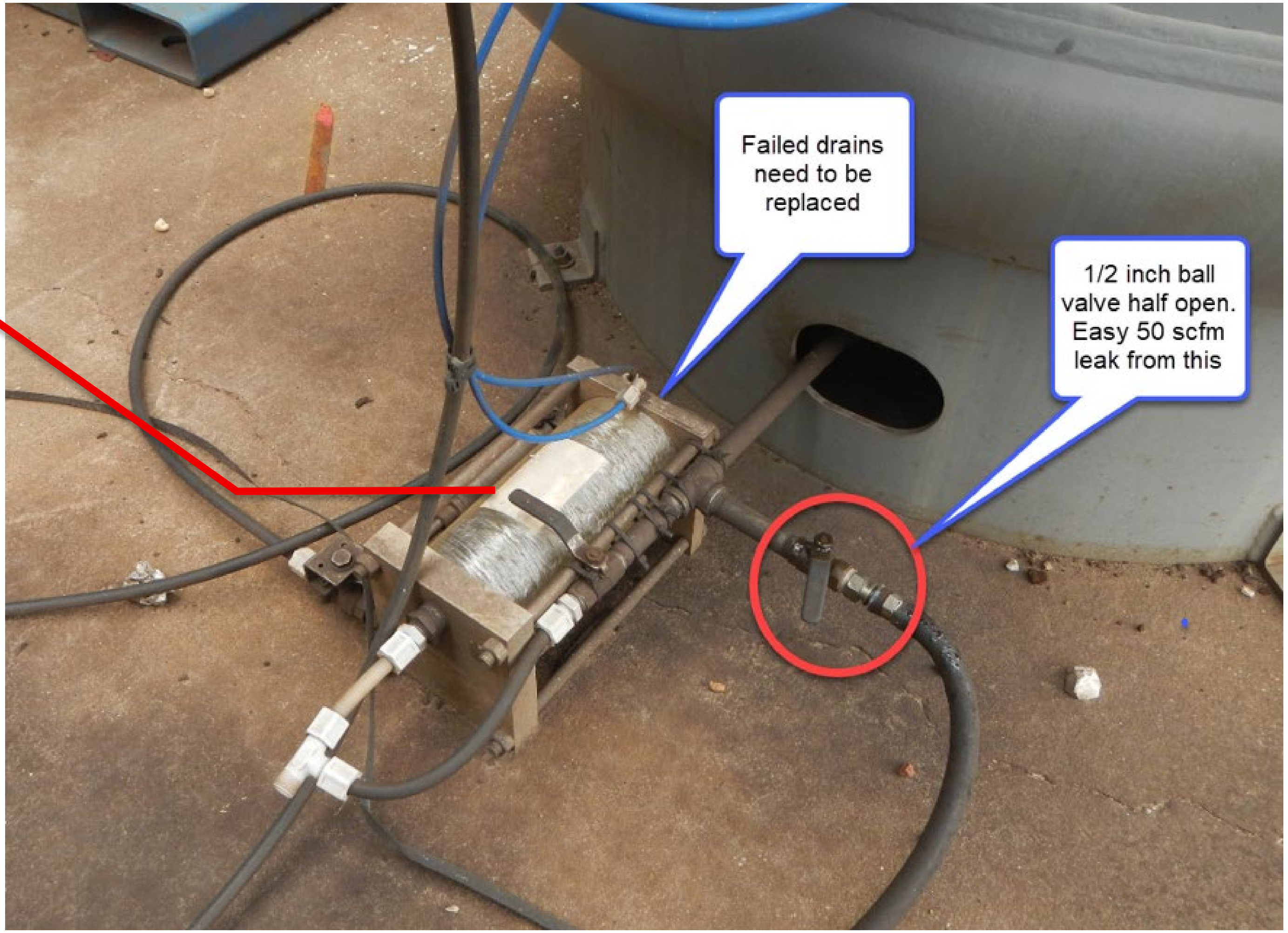
Failed Drain

Pressure Drop Losses



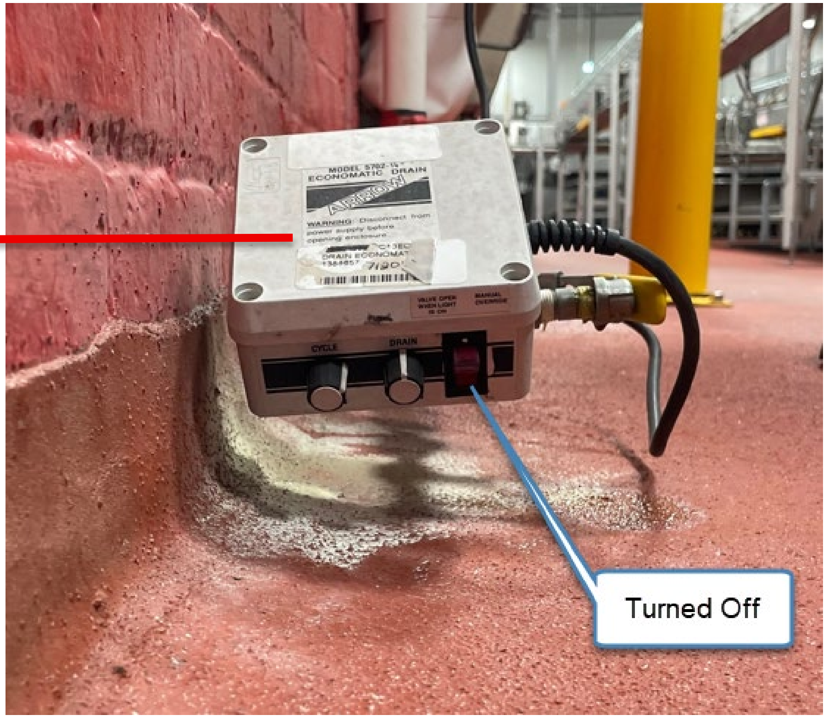
Condensate Removal

No Such Thing as a Maintenance Free Drain



Condensate Removal

Failed Drains



Condensate Removal

Failed Drain

Proper Ducting

Poor Ducting Design

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Proper Ducting

Poor Intake Design

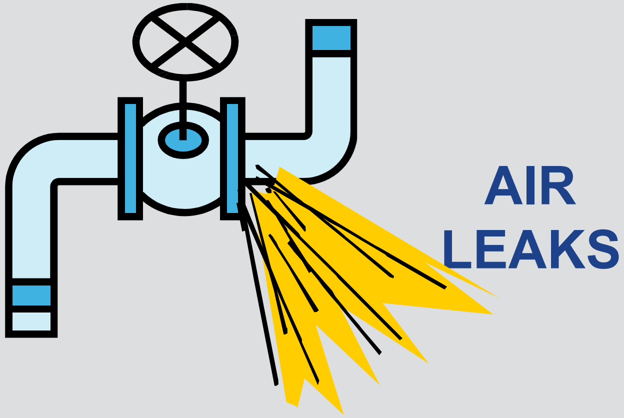
Reduce Pressure at Source

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

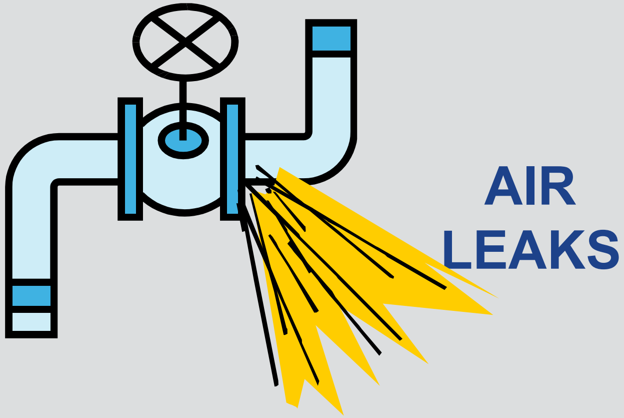
At 120PSIG



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..

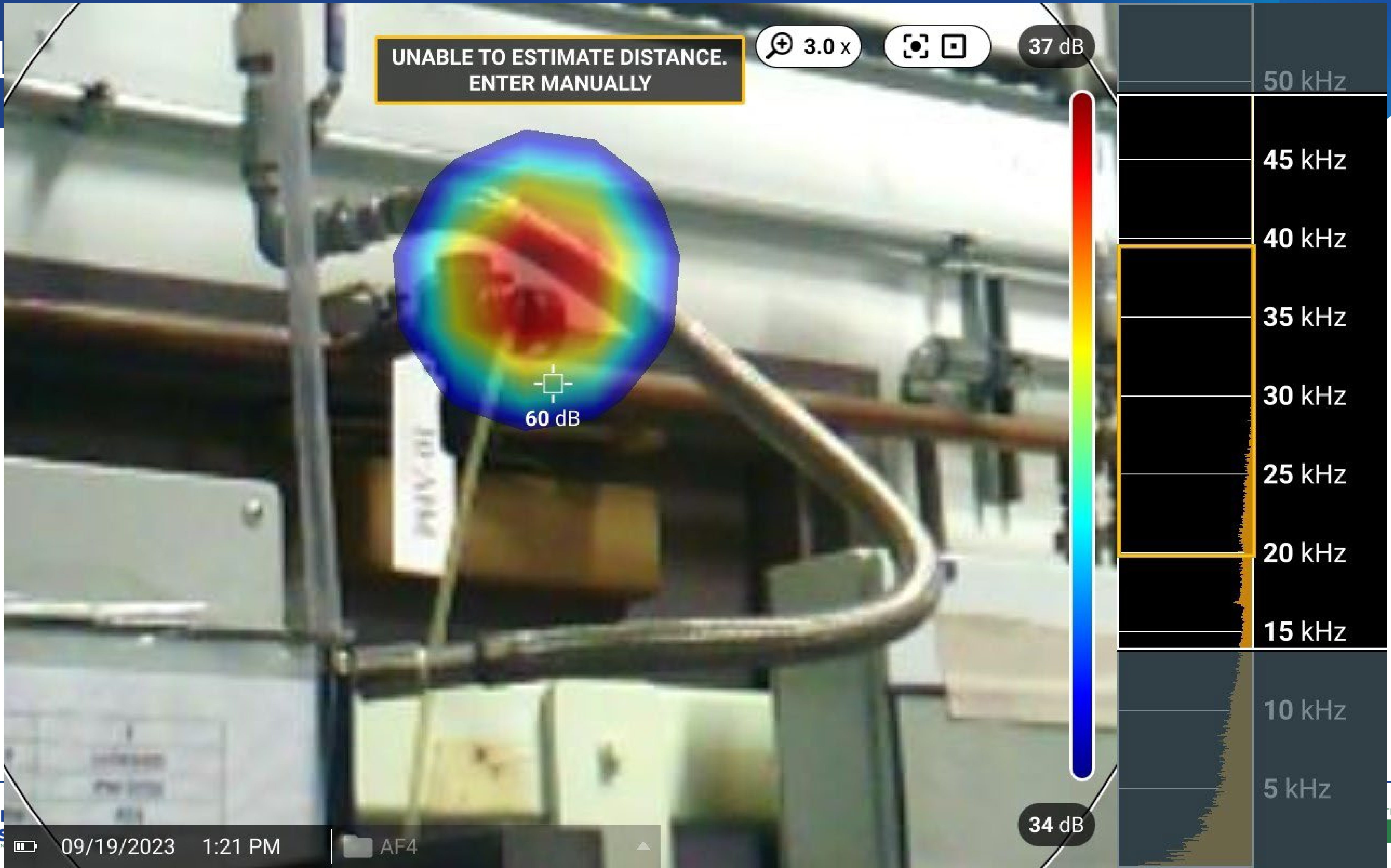
How Acoustic Camera Leak Detection Works

- 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

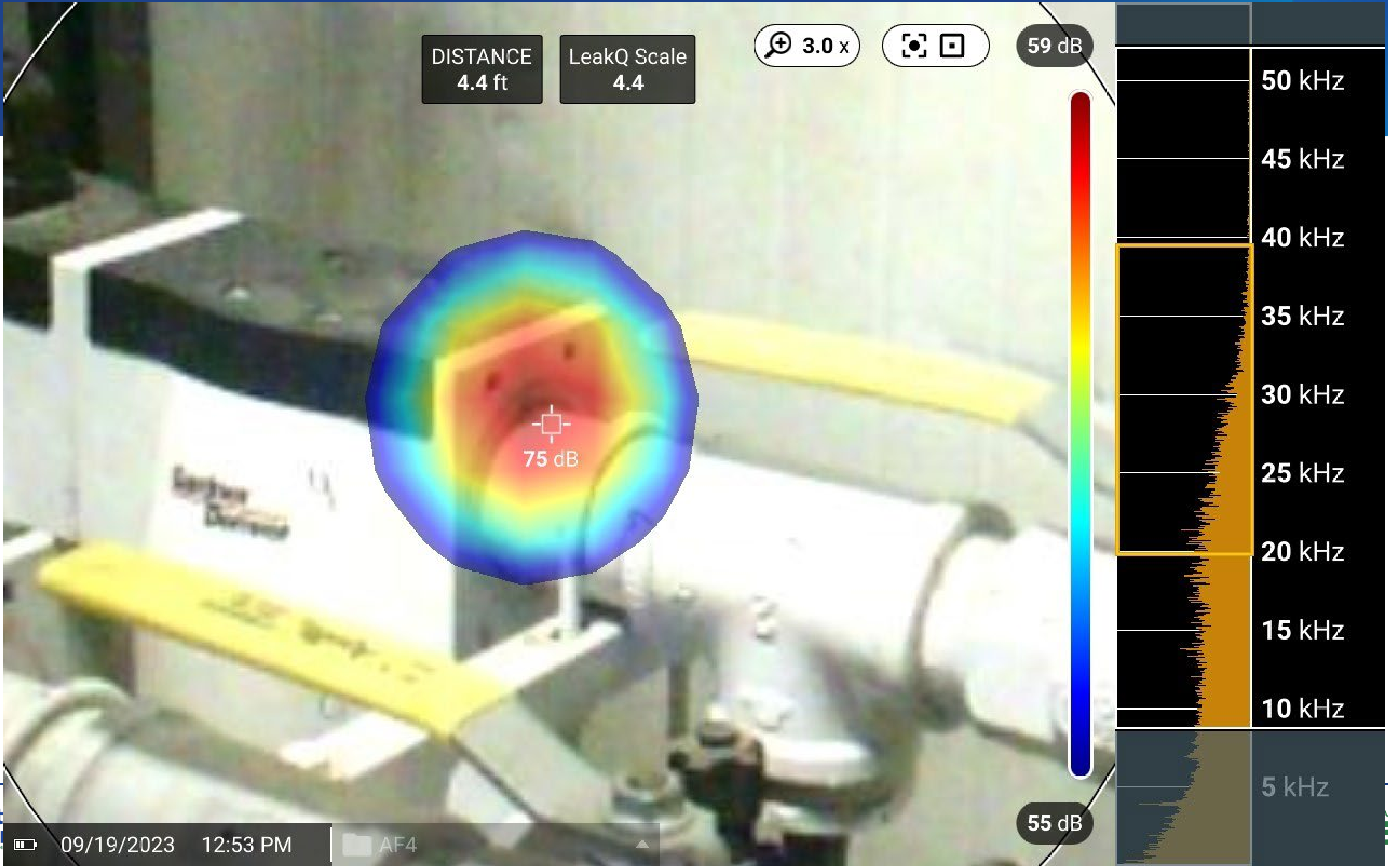
Imager Vs. Conventional Ultrasonic Leak Detector

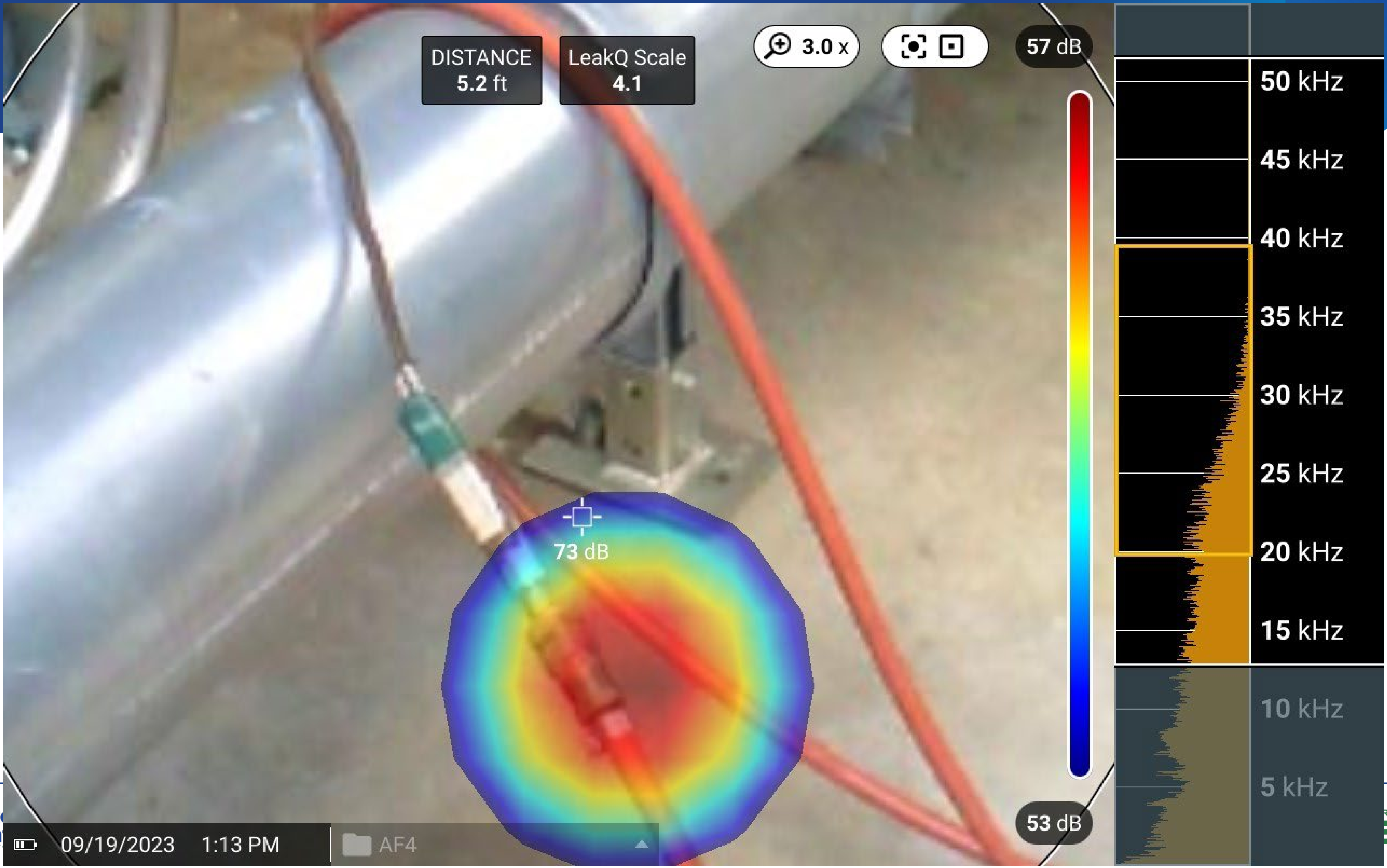
- With acoustic imager type, multiple microphones enable the inspection of an expansive area from a distance.
- A conventional Ultrasonic Leak Detector inspects plants point by point looking for leaks in each hose, coupling, trap, drain, valve and gasket.
  - What if I don’t have an ultrasonic leak detector?

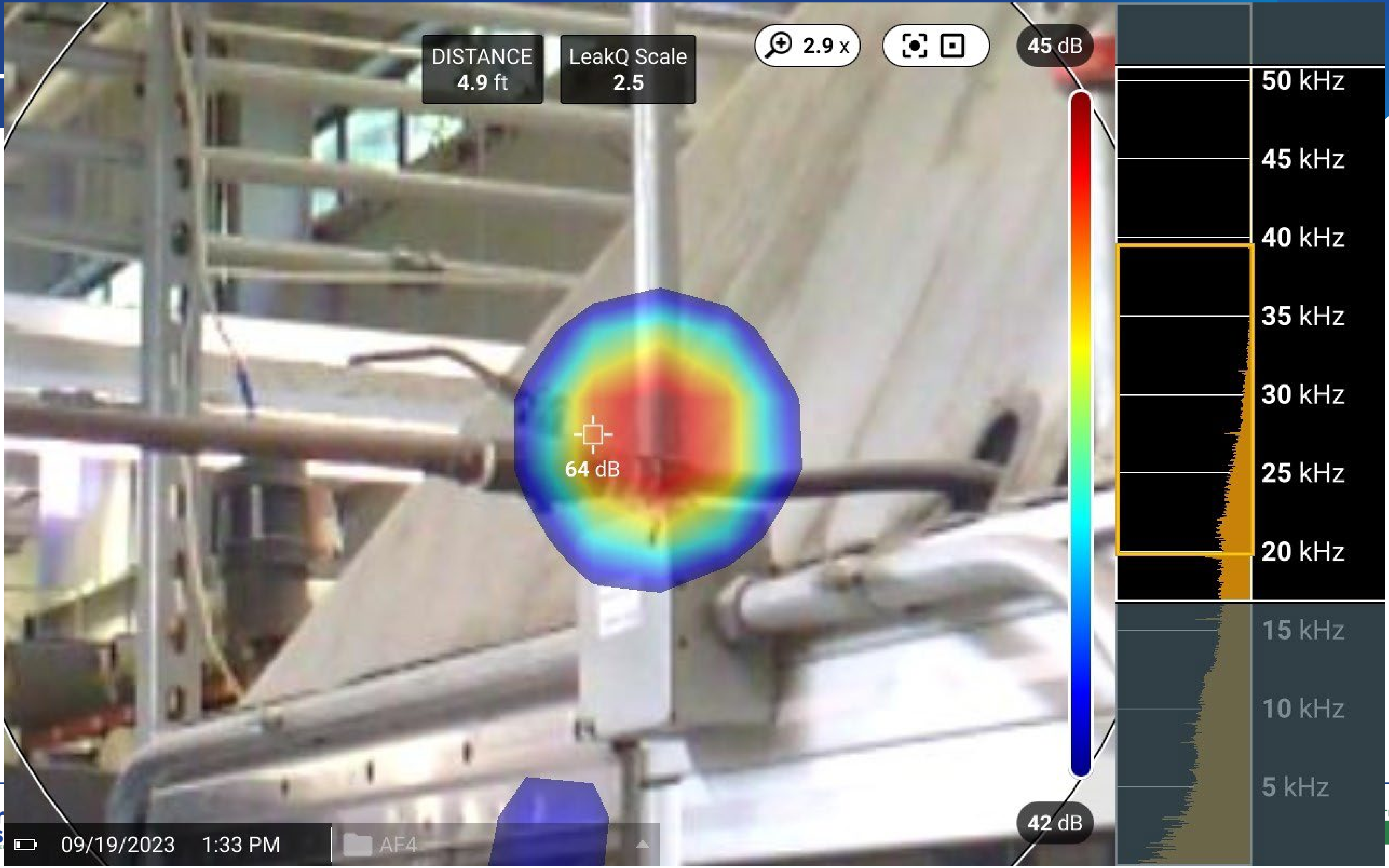

34 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
M_22
0:10
0:00:00



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

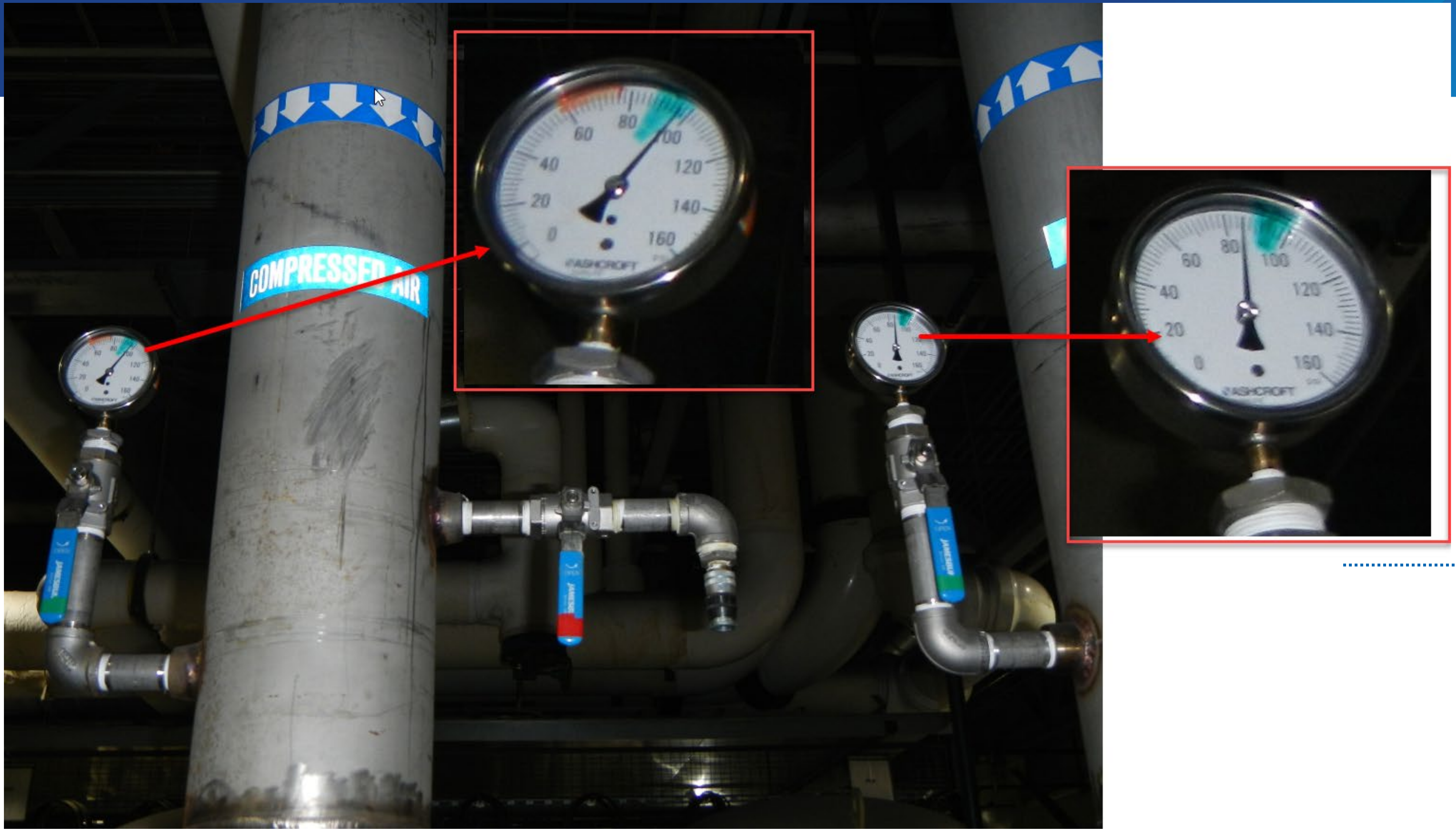

DISTANCE
4.4 ft
LeakQ Scale
4.4
3.0 x
59 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
75 dB
55 dB
09/19/2023
12:53 PM
AF4


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

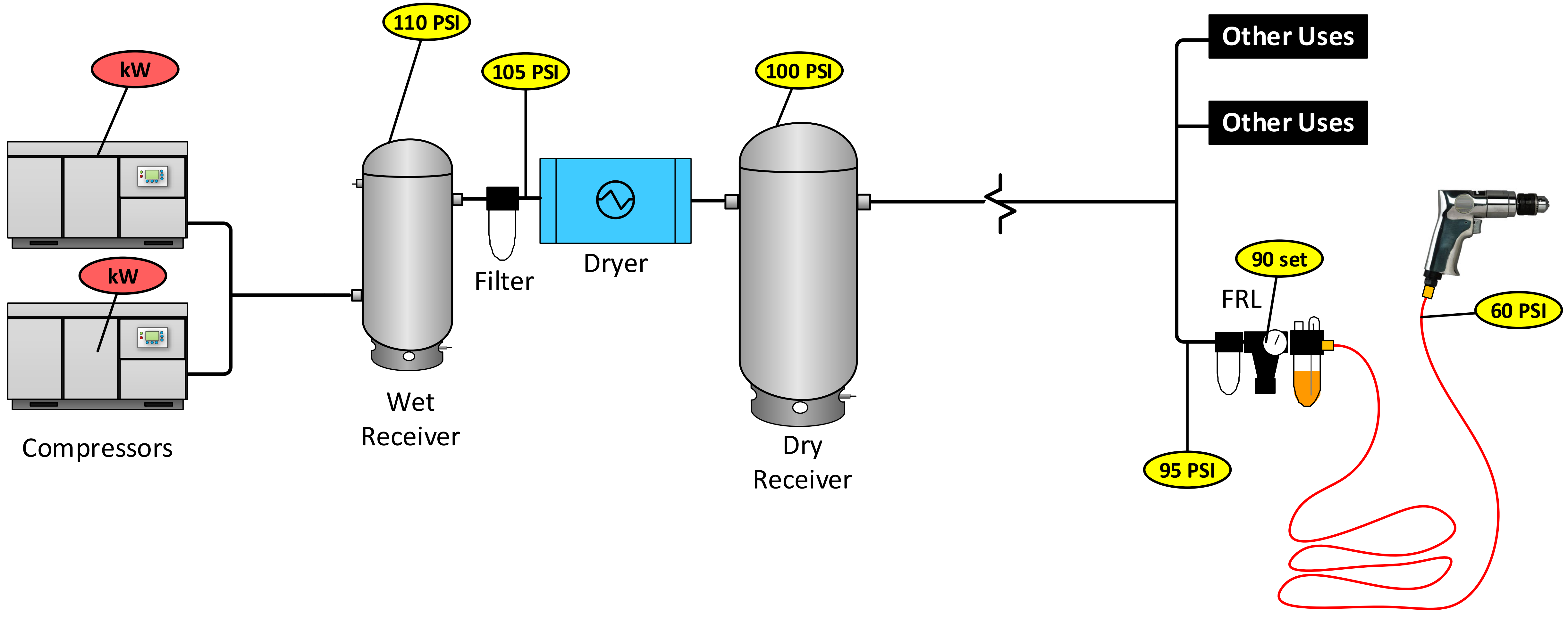

51 dB
50 kHz
45 kHz
40 kHz
35 kHz
30 kHz
25 kHz
20 kHz
15 kHz
10 kHz
5 kHz
0:00:01
0:00:09

Reduce Pressure at Source (Cont'd)

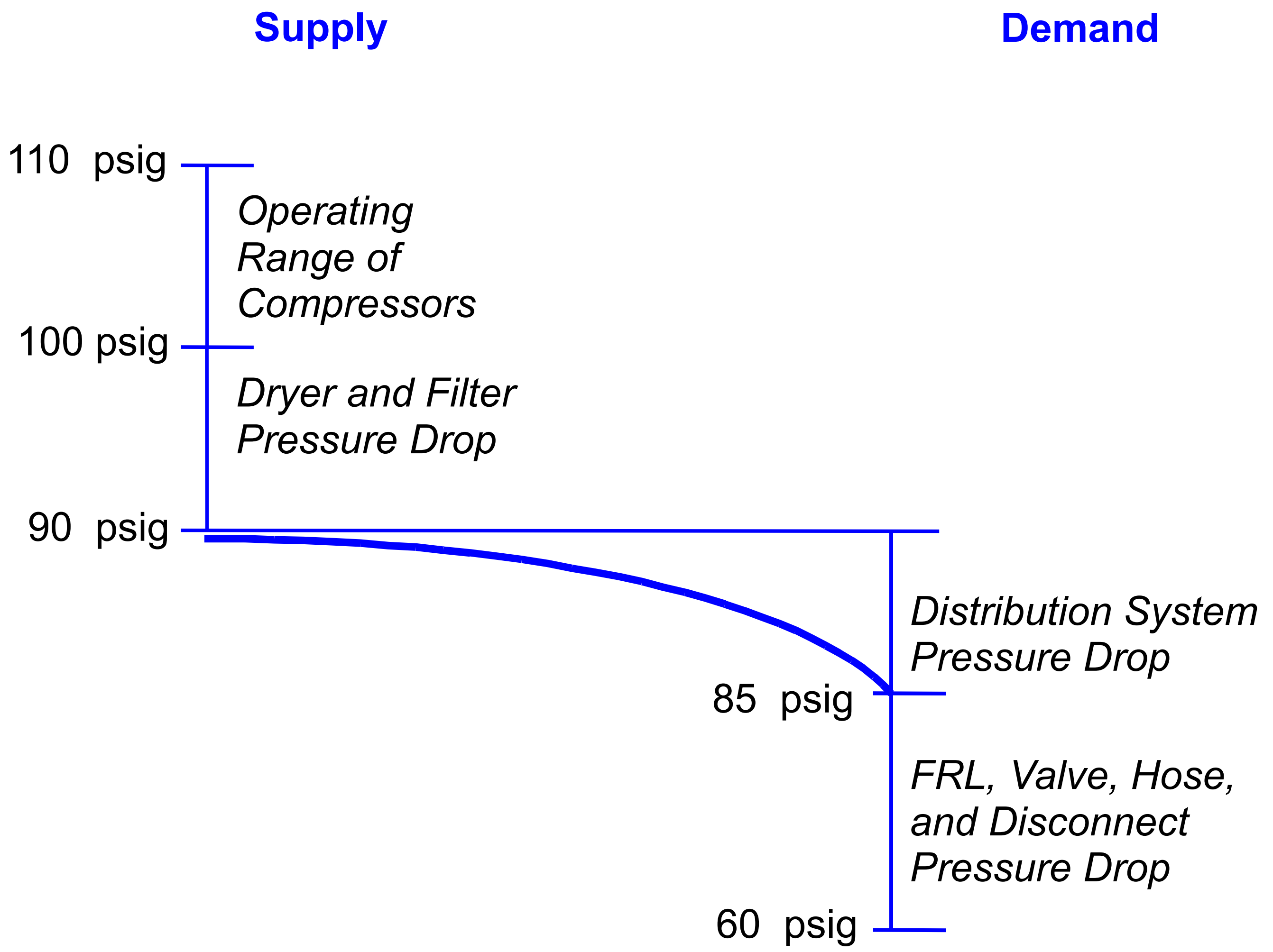

COMPRESSED AIR
0
20
40
60
80
100
120
140
160
ASHCROFT

Reduce Pressure at Source (Cont'd)

What Measurements Should I Record?

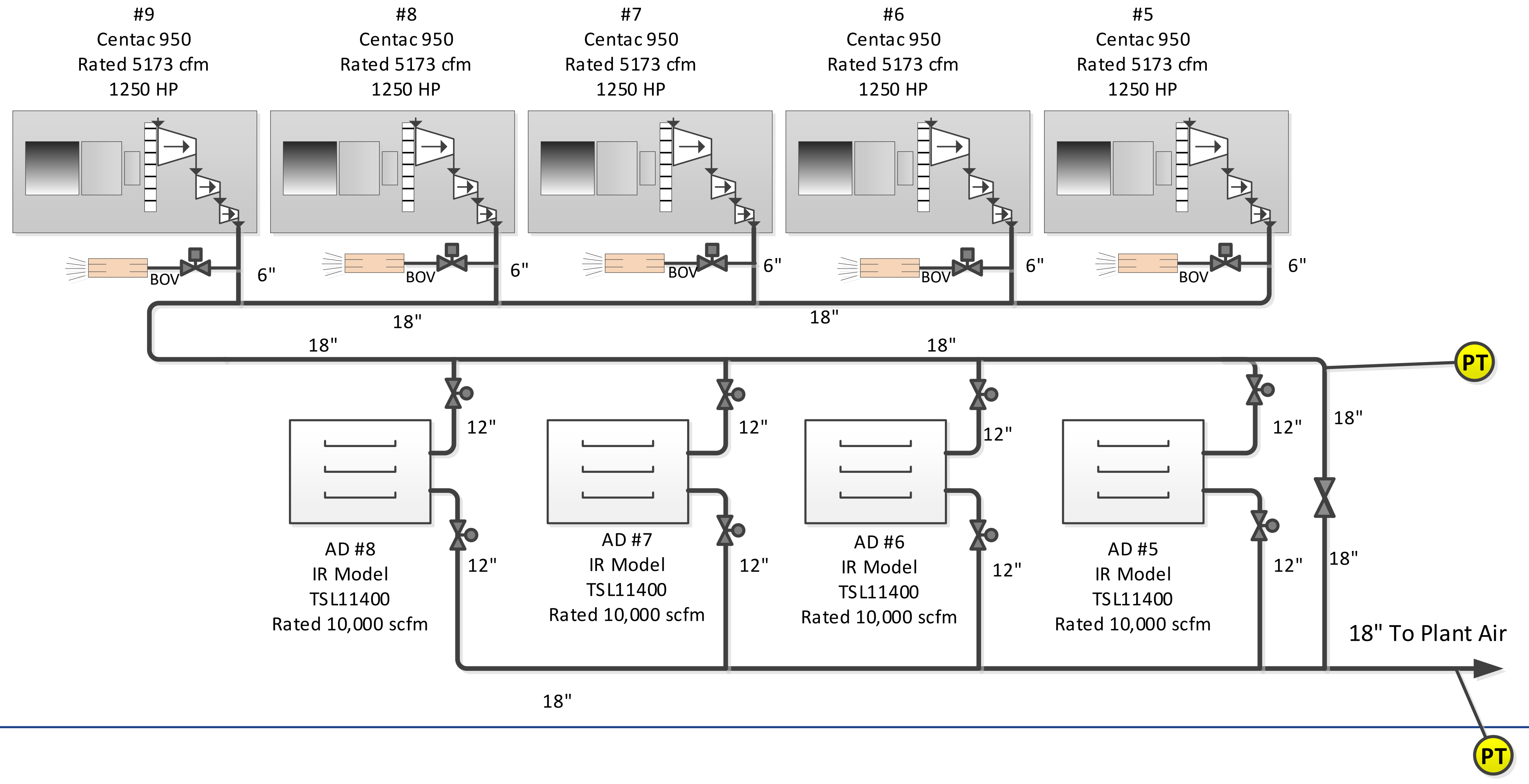


System Pressure Profile

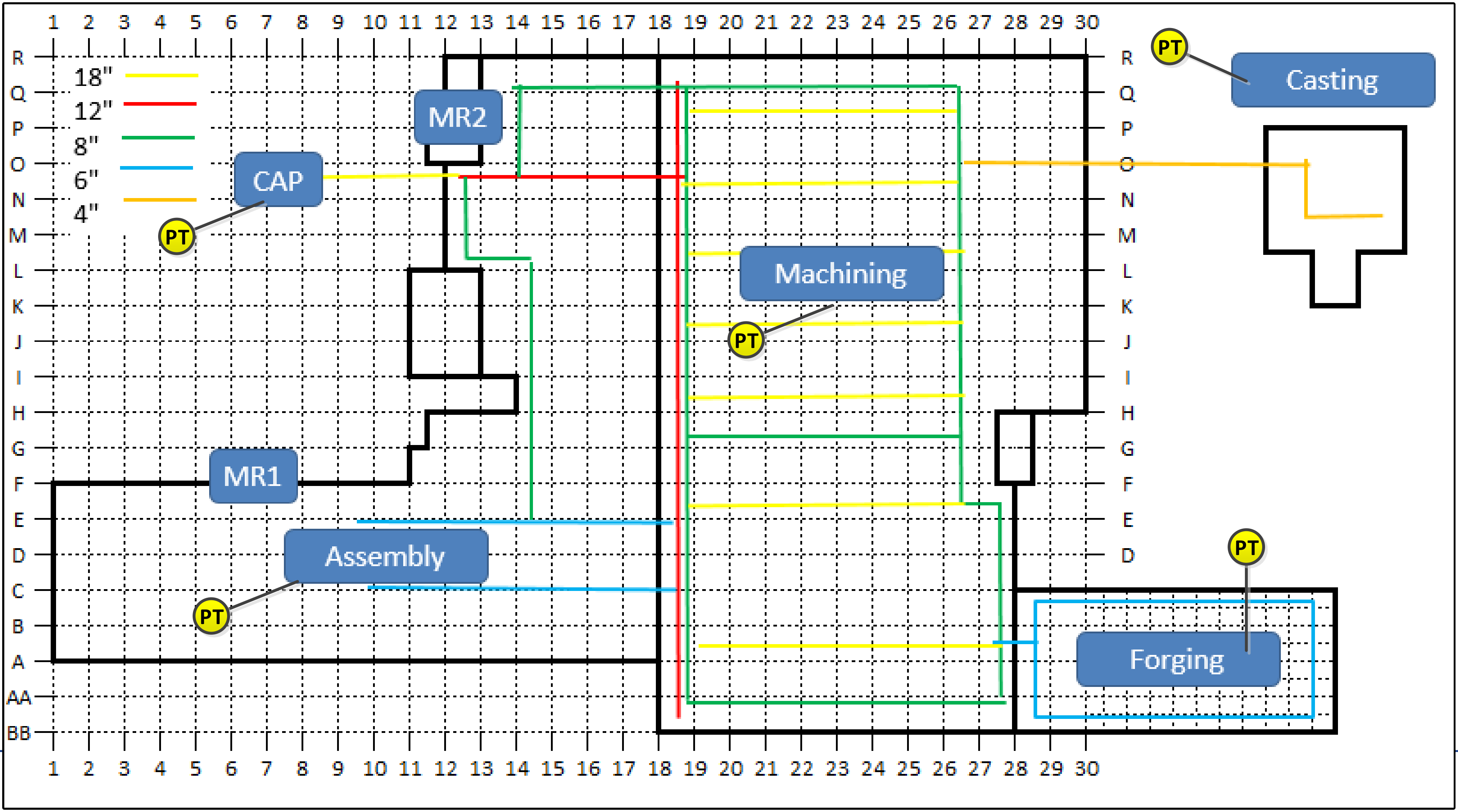


What Measurements Should I Record?

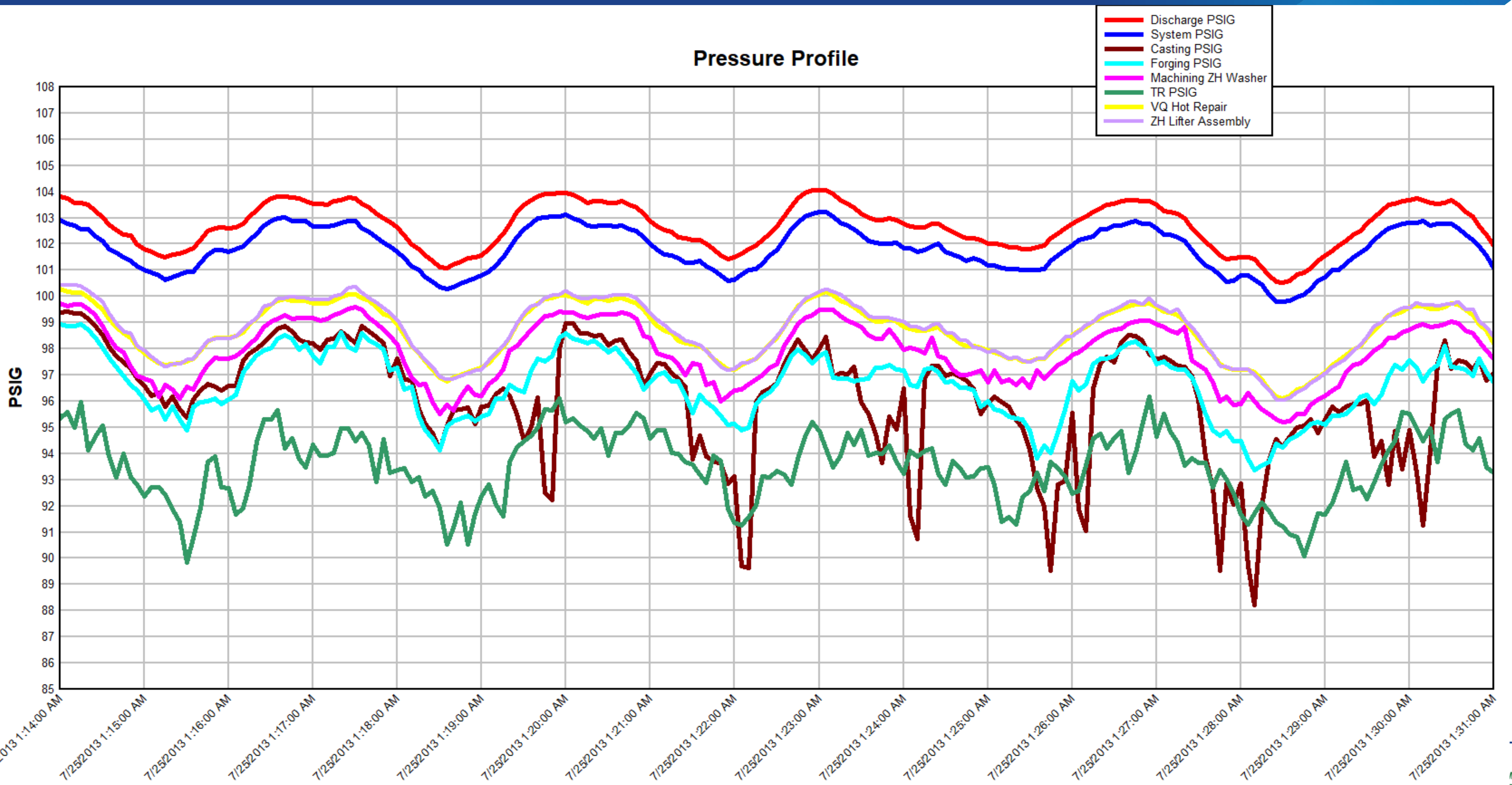
Compressed Air Plant



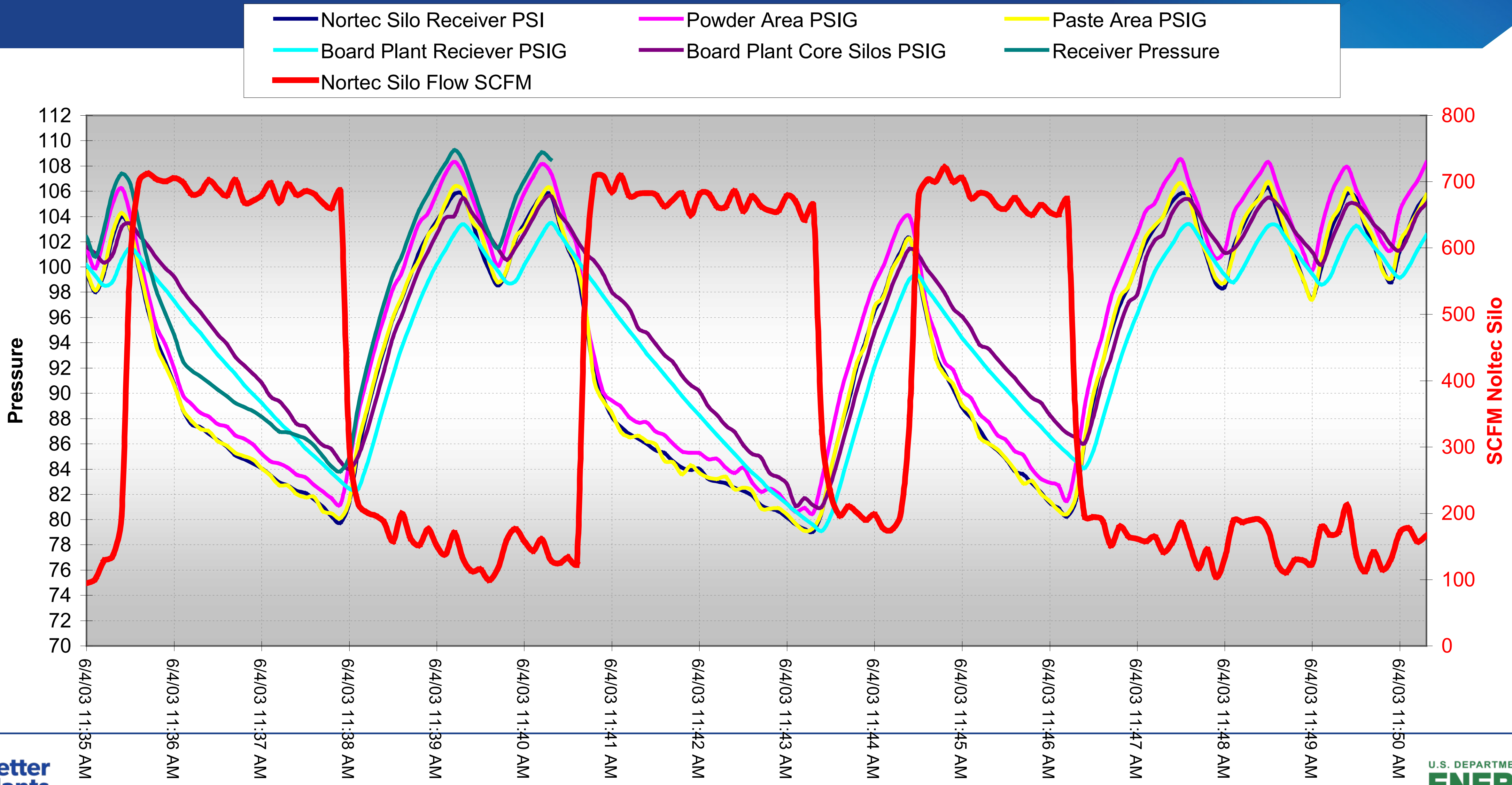
What Measurements Should I Record?



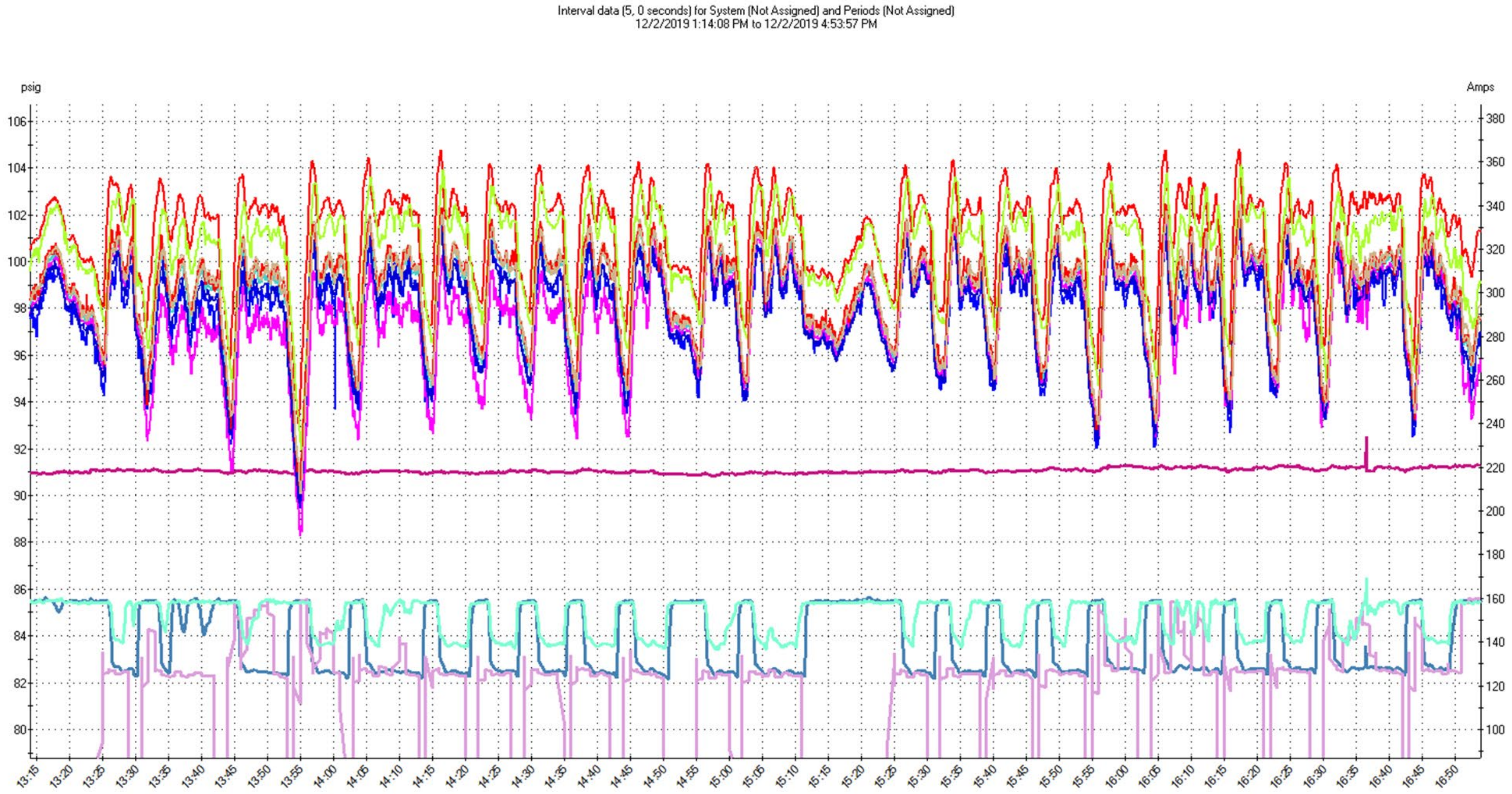
Data Collection Can Be Interpreted



Data Collection Can Be Interpreted

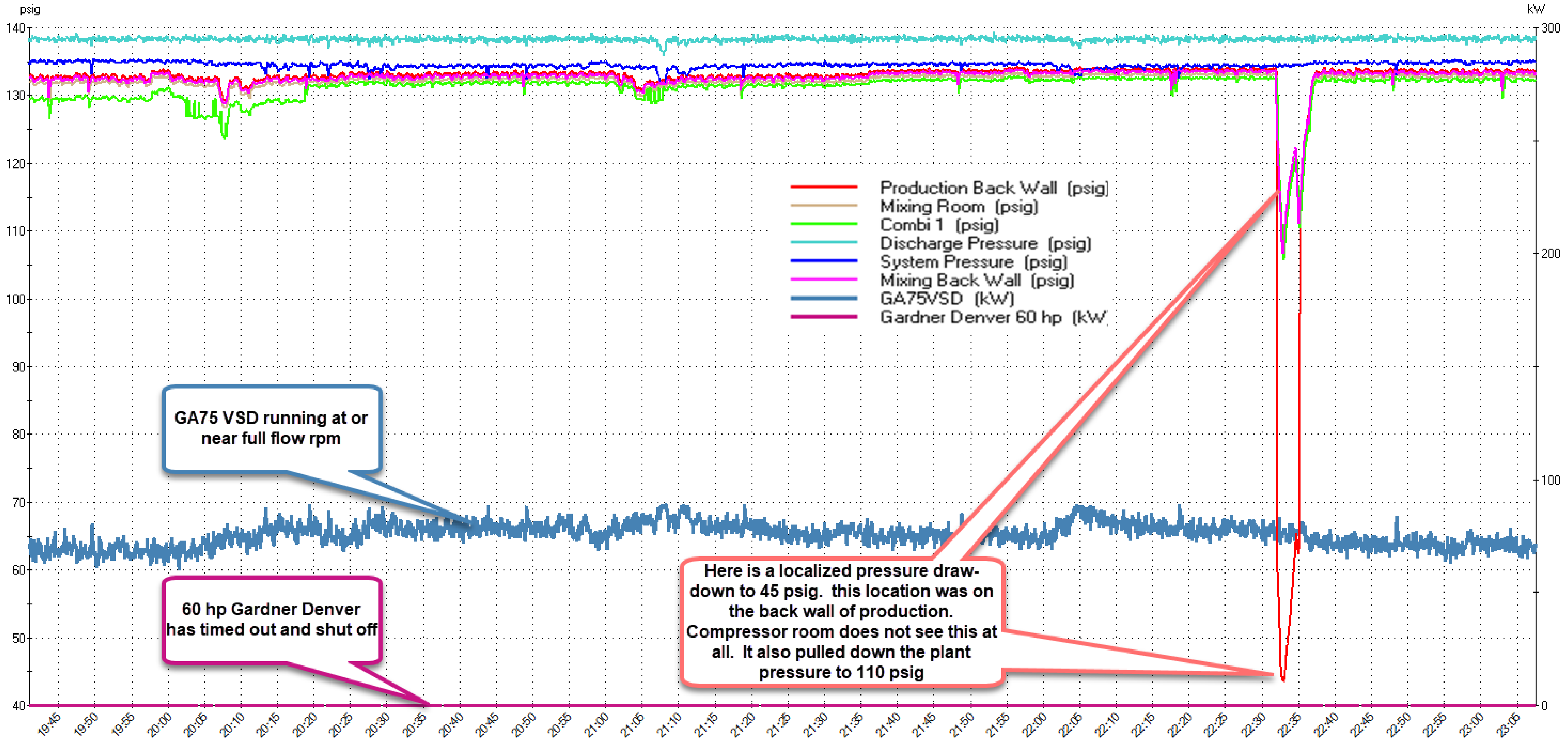


Comparing Pressure and Power



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

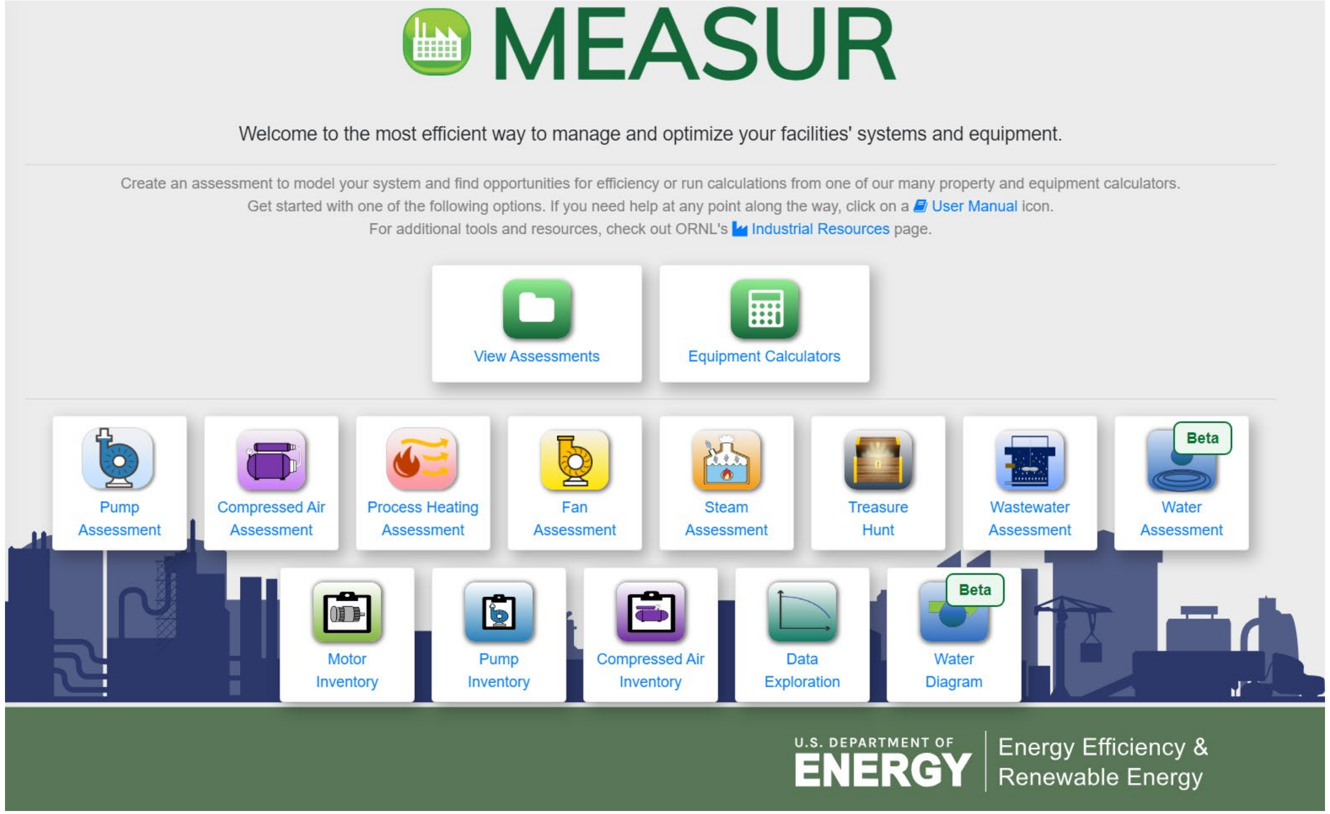
Localized Pressure Drawdown During CIP



What Software Can I use to Analyze?

MEASURE and LogTool……

AIRMaster+ and LogTool



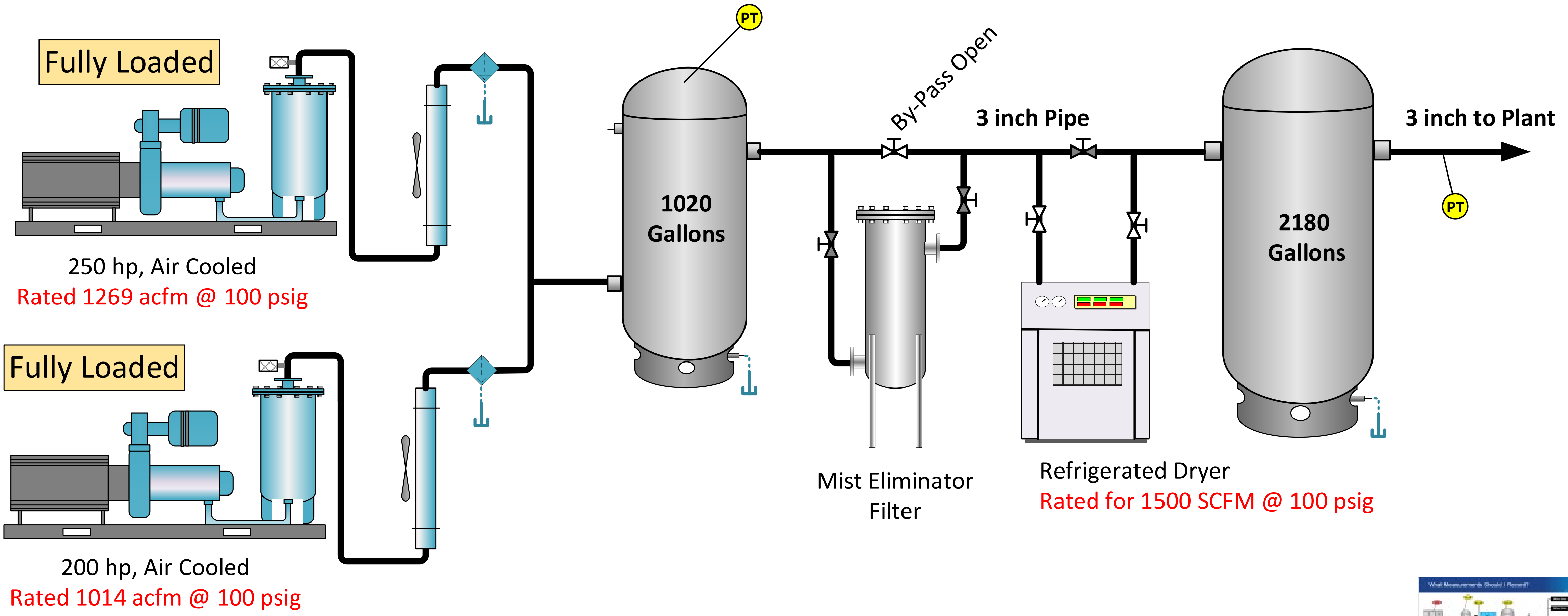
MEASUR Features

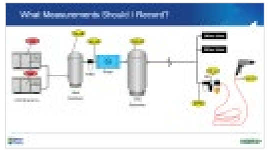
- Inputs
  - To use the Compressed Air module, users need actual compressed air system data, though use of the generic database minimizes the data required:
  - Compressed air system information (storage capacity, sequencer controls, elevation or atmospheric pressure)
  - Compressor inventory data (nameplate data, controls, design details, performance data)
  - Compressor profile data for each day type (hourly or daily averages of airflow, power, load factor, or voltage, current and power factor)
- Outputs
  - Based on inputs, the Compressed Air module will provide the following:
  - Individual compressor power vs. air flow performance profiles
  - Compressor system profiles
  - Estimated energy use in “what-if” scenarios
  - Equipment annual energy use and costs
  - Peak demand estimation and cost
  - Potential annual energy savings

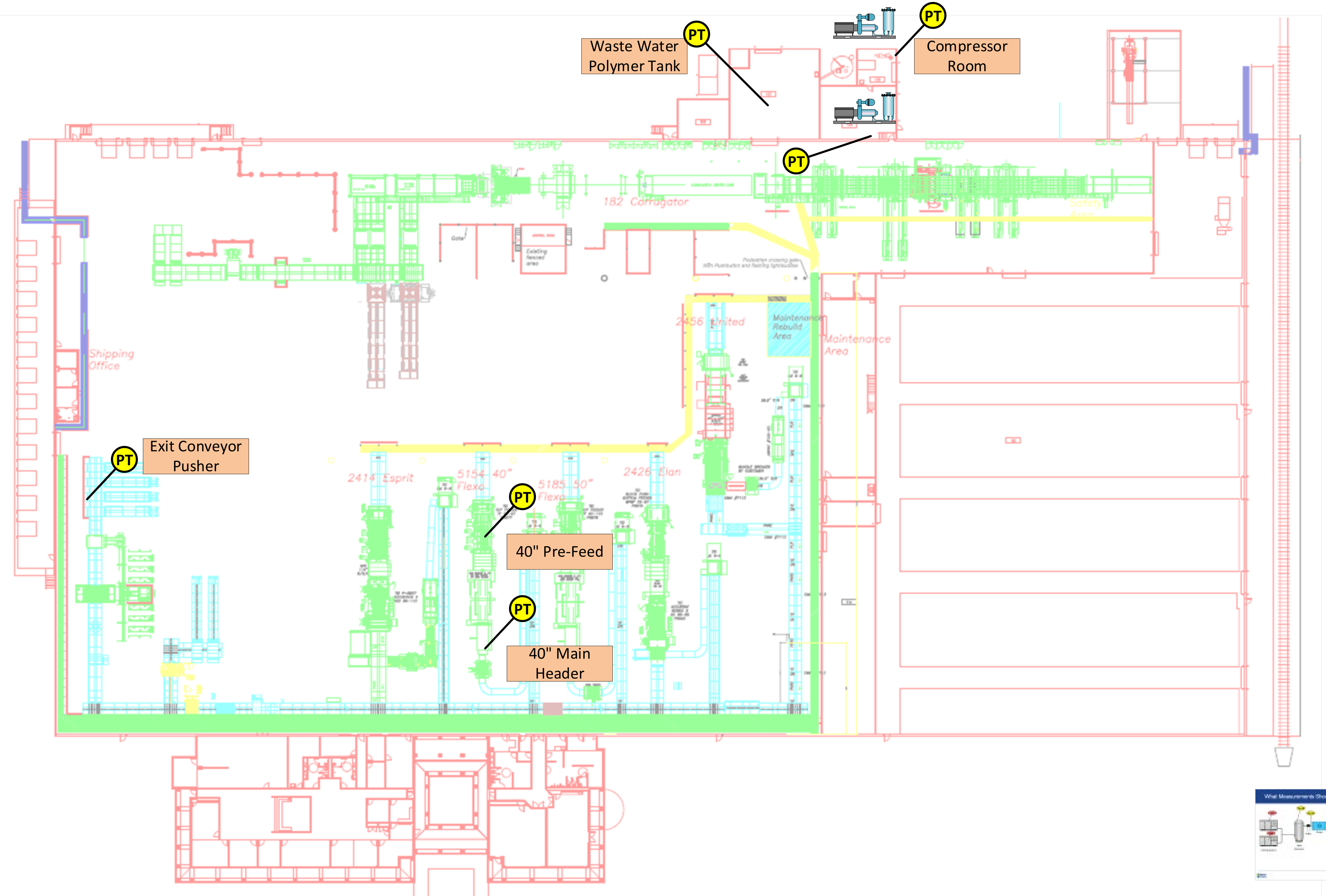
LogTool is Designed To:

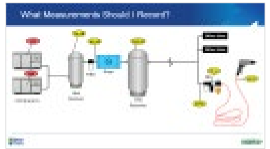
- Import data which is exported from different types of data loggers.
- Select logger data channels and modify their properties.
  - e.g., name, type, units, etc.
- View data values for one or more logger channels.
- Display trend plots on one or two Y axis.
- Display scatter plots.
- Display daytype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

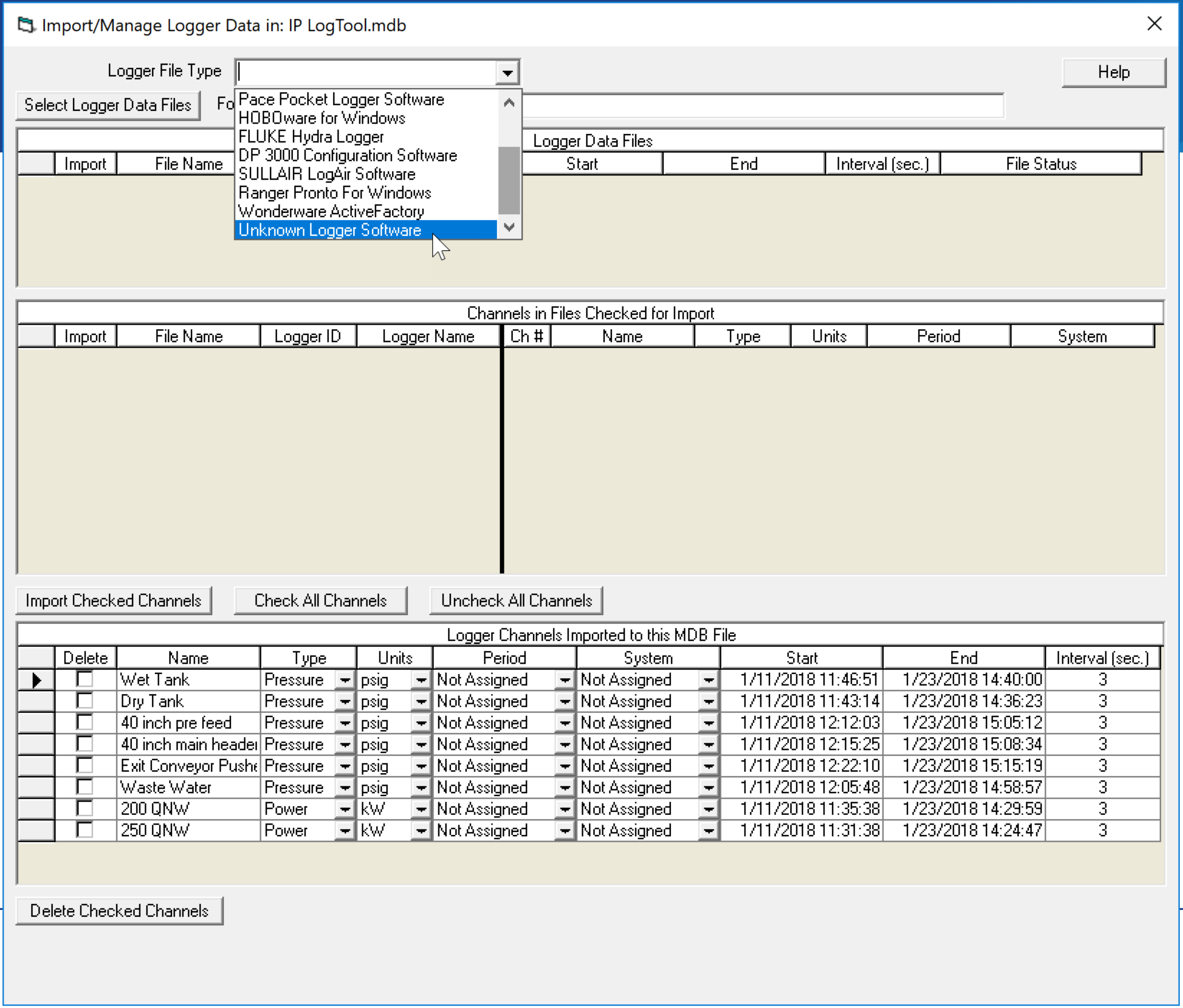
Box Plant Example:



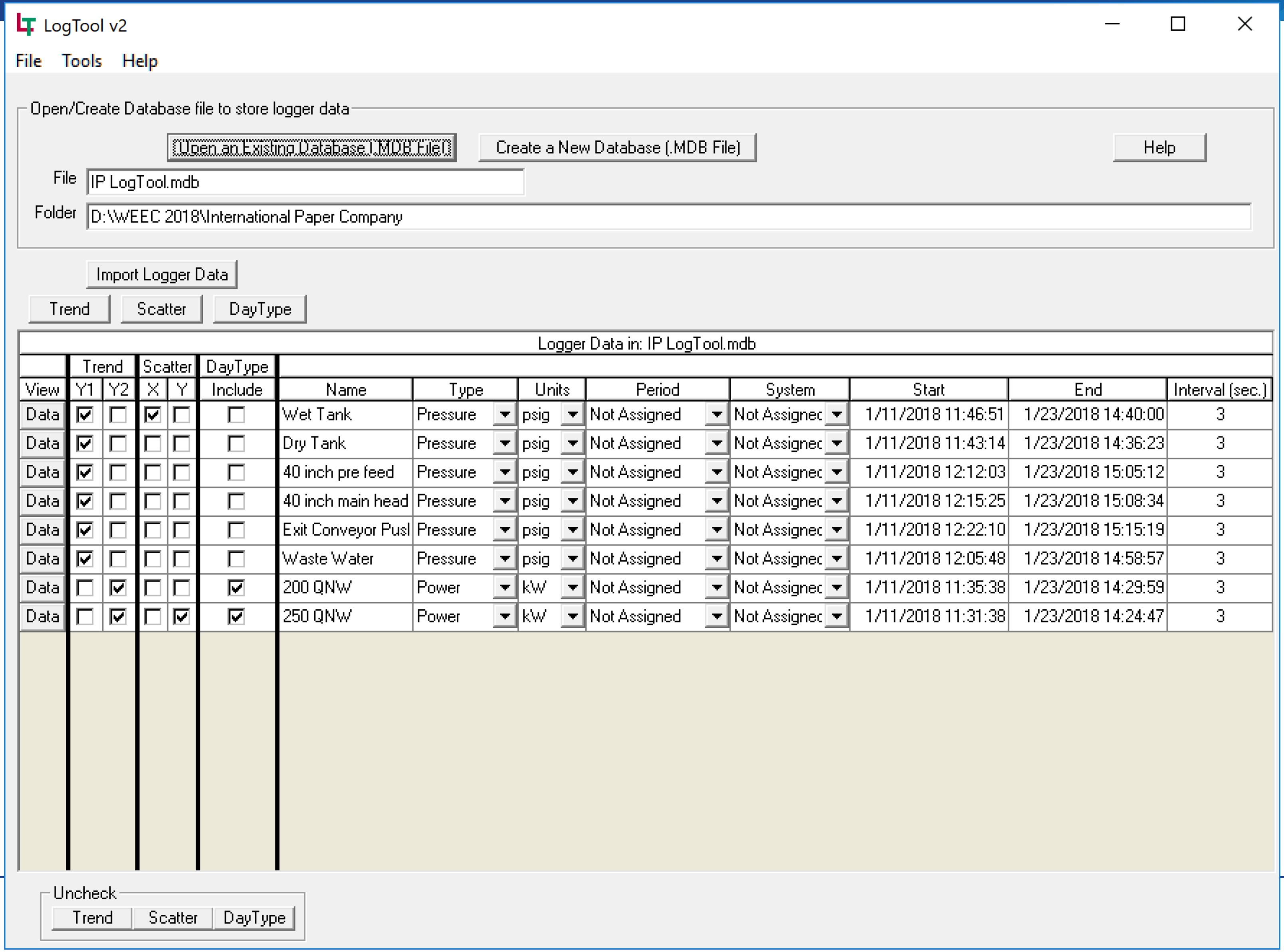



Waste Water Polymer Tank
PT
Compressor Room
PT
PT
182 Corrugator
Shipping Office
2456 United
Maintenance Rebuild Area
Maintenance Area
Exit Conveyor Pusher
PT
2414 Esprit
5154 40" Flexo
5185 50" Flexo
2426 Elan
PT
40" Pre-Feed
PT
40" Main Header



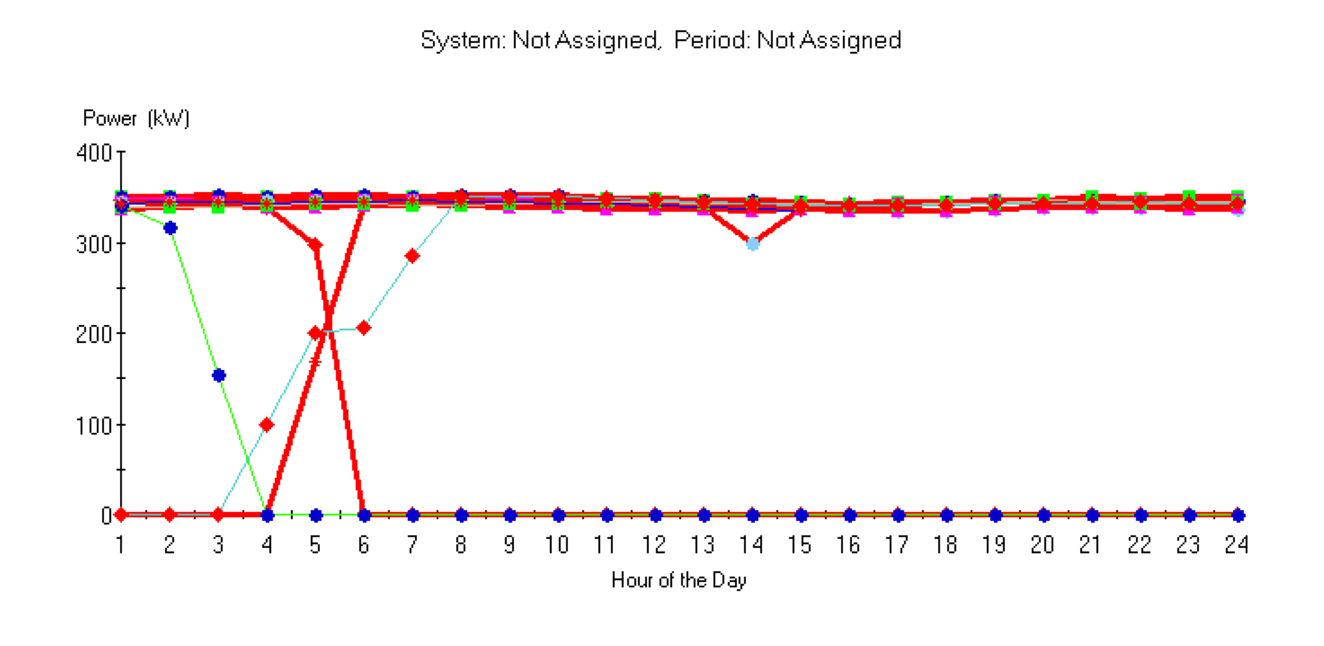

Import/Manage Logger Data in: IP LogTool.mdb
Logger File Type
Help
Select Logger Data Files
Pace Pocket Logger Software
HOBOware for Windows
FLUKE Hydra Logger
DP 3000 Configuration Software
SULLAIR LogAir Software
Ranger Pronto For Windows
Wonderware ActiveFactory
Unknown Logger Software
Logger Data Files
Import
File Name
Start
End
Interval (sec.)
File Status
Channels in Files Checked for Import
Import
File Name
Logger ID
Logger Name
Ch #
Name
Type
Units
Period
System
Import Checked Channels
Check All Channels
Uncheck All Channels
Logger Channels Imported to this MDB File
Delete
Name
Type
Units
Period
System
Start
End
Interval (sec.)
Wet Tank Pressure psig Not Assigned Not Assigned 1/11/2018 11:46:51 1/23/2018 14:40:00 3
Dry Tank Pressure psig Not Assigned Not Assigned 1/11/2018 11:43:14 1/23/2018 14:36:23 3
40 inch pre feed Pressure psig Not Assigned Not Assigned 1/11/2018 12:12:03 1/23/2018 15:05:12 3
40 inch main header Pressure psig Not Assigned Not Assigned 1/11/2018 12:15:25 1/23/2018 15:08:34 3
Exit Conveyor Pushe Pressure psig Not Assigned Not Assigned 1/11/2018 12:22:10 1/23/2018 15:15:19 3
Waste Water Pressure psig Not Assigned Not Assigned 1/11/2018 12:05:48 1/23/2018 14:58:57 3
200 QNW Power kW Not Assigned Not Assigned 1/11/2018 11:35:38 1/23/2018 14:29:59 3
250 QNW Power kW Not Assigned Not Assigned 1/11/2018 11:31:38 1/23/2018 14:24:47 3
Delete Checked Channels

LogTool Main Menu



LogTool Can Create DayTypes

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...

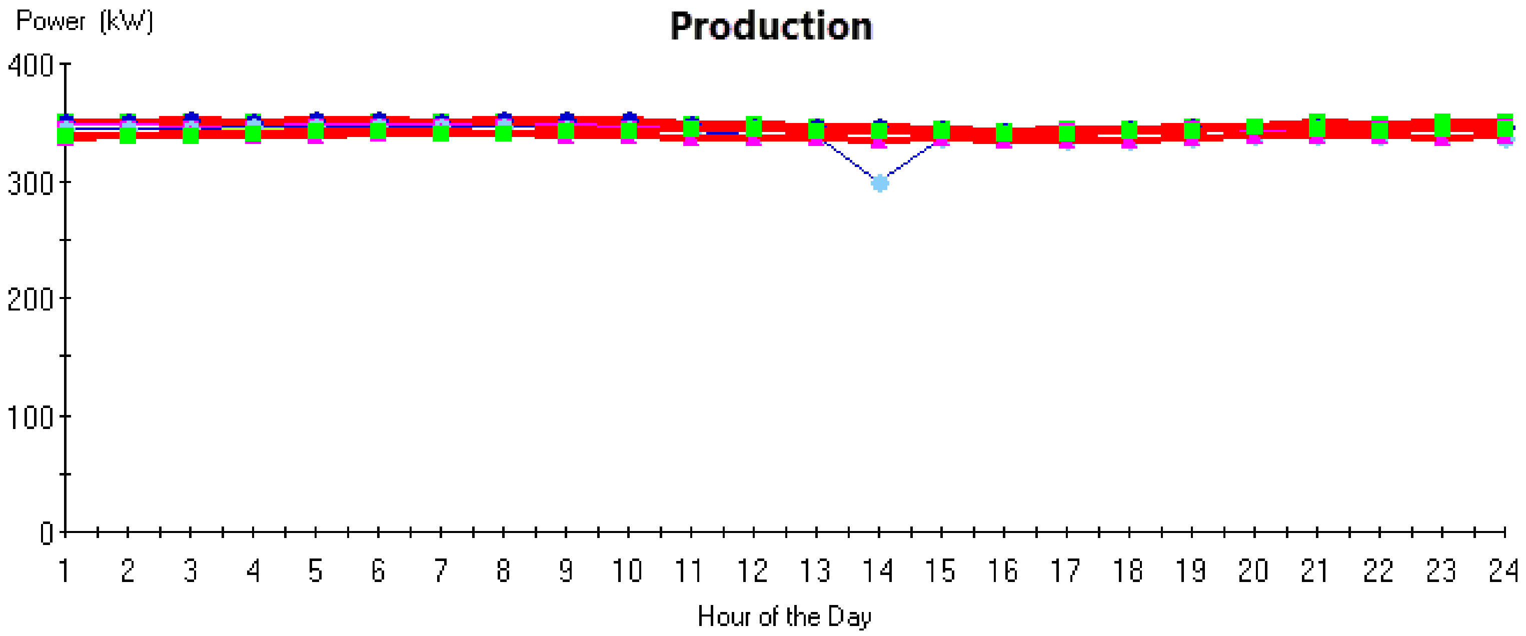
Caution: Day profiles can be similar even though different equipment, e.g., compressors, is operating. Use Trend Plots to examine the details of equipment operation before determining whether days should be assigned to the same daytype.

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

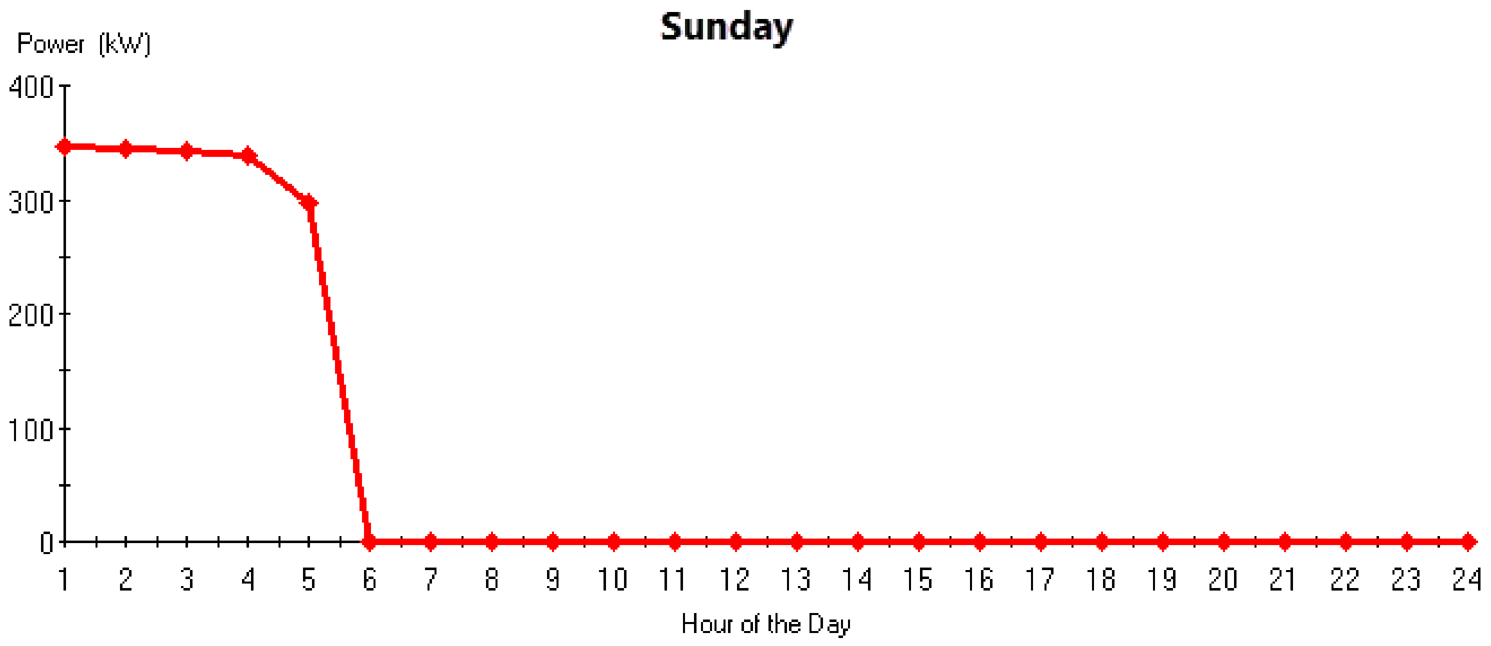
System DayType Profiles

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

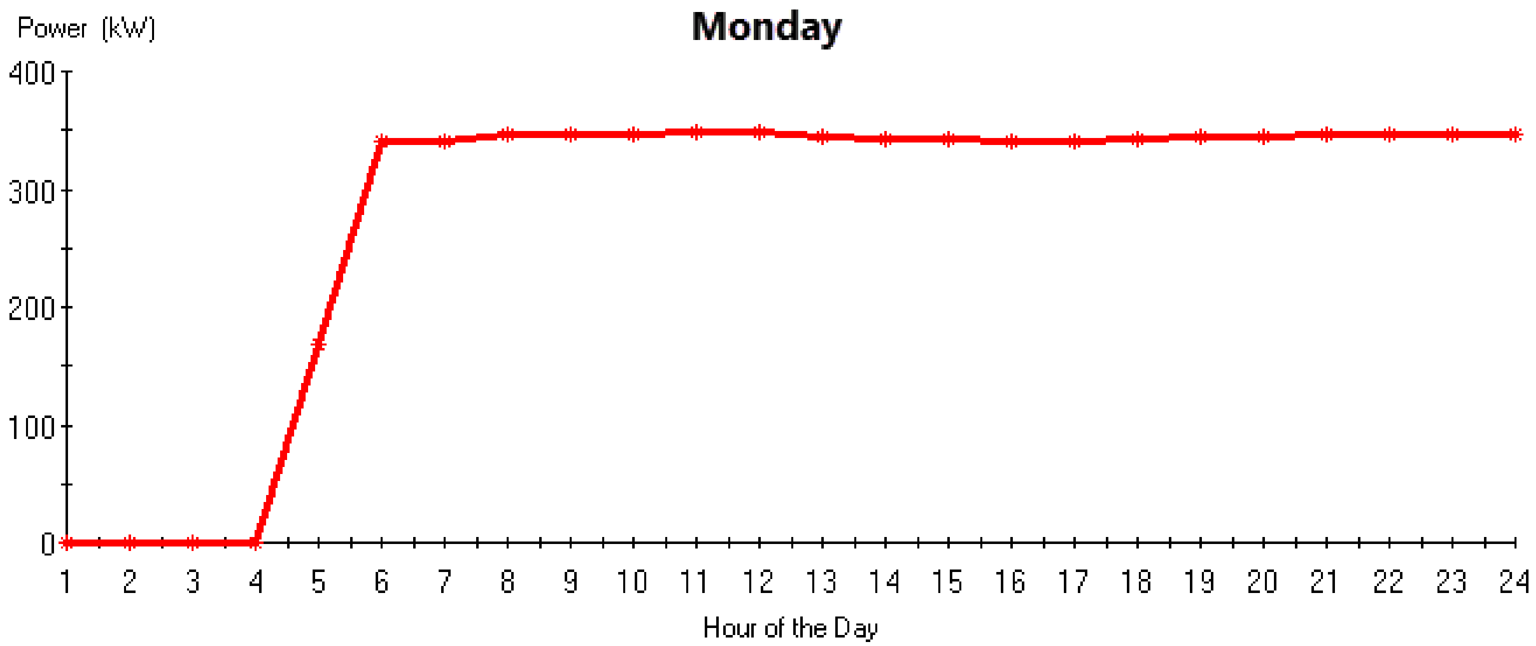
DayType Profiles



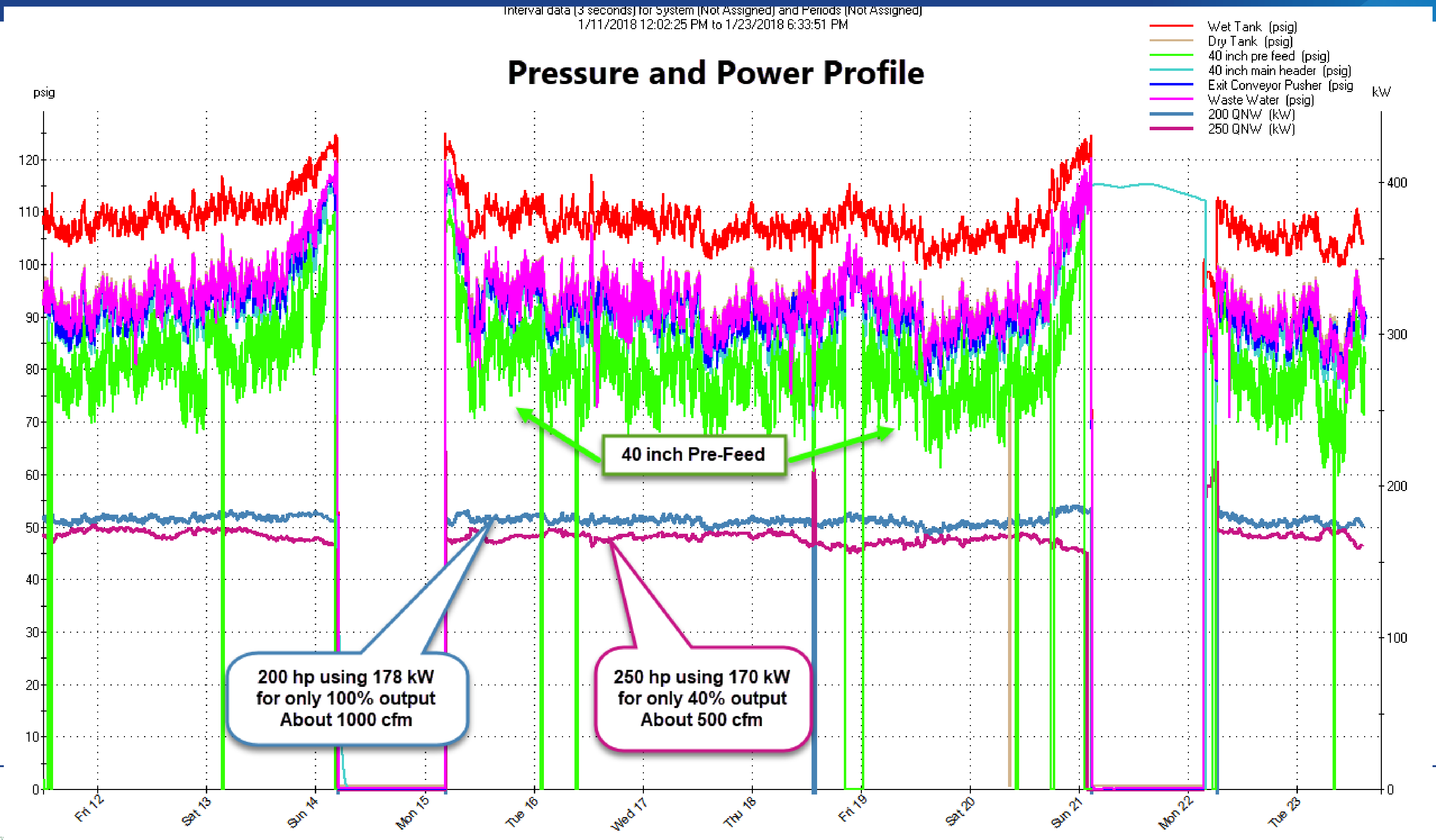
DayType Profiles



DayType Profiles



LogTool Trend Plot



Better Plants U.S. DEPARTMENT OF ENERGY

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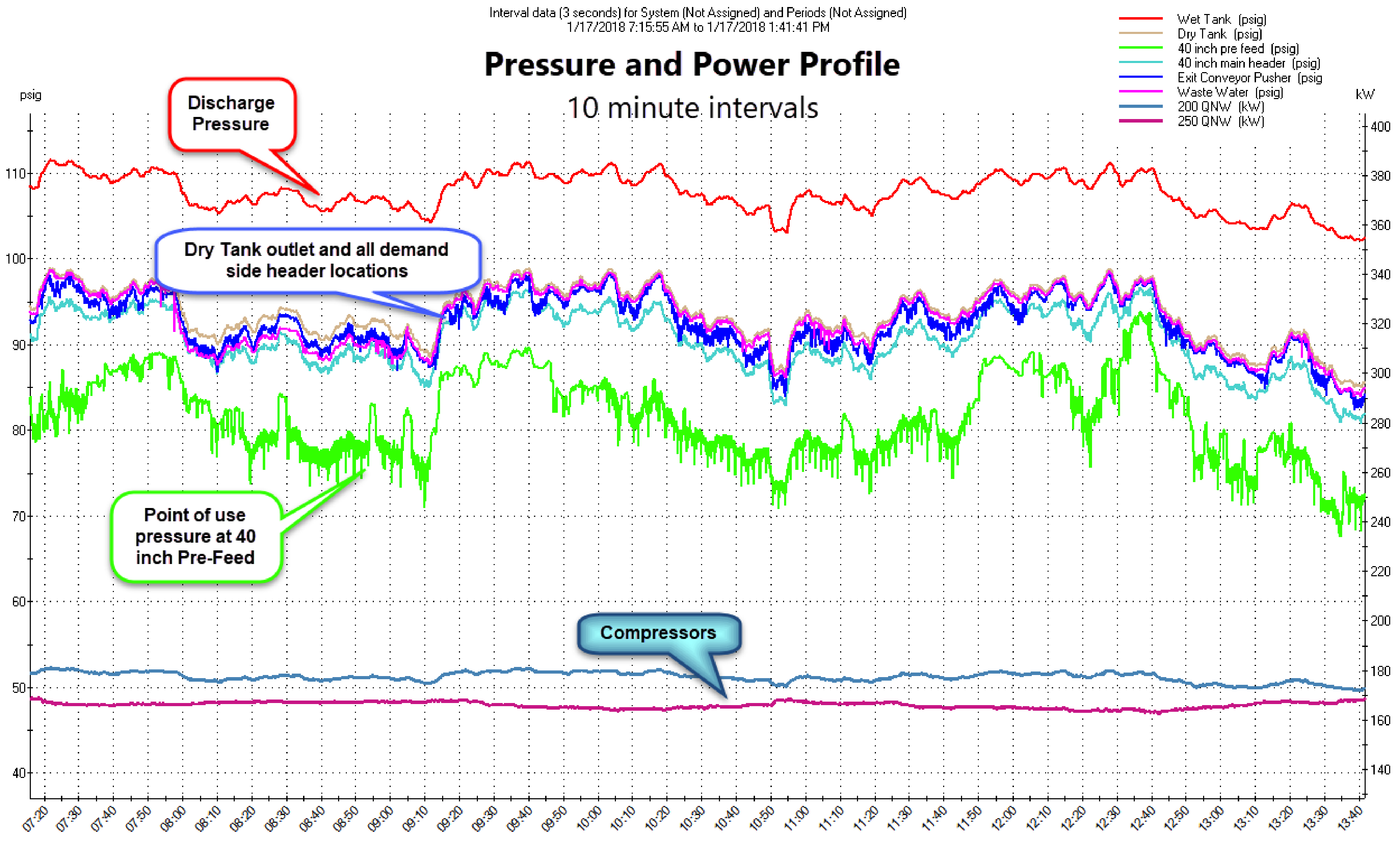
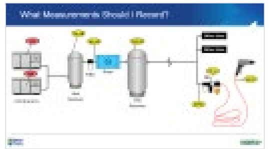
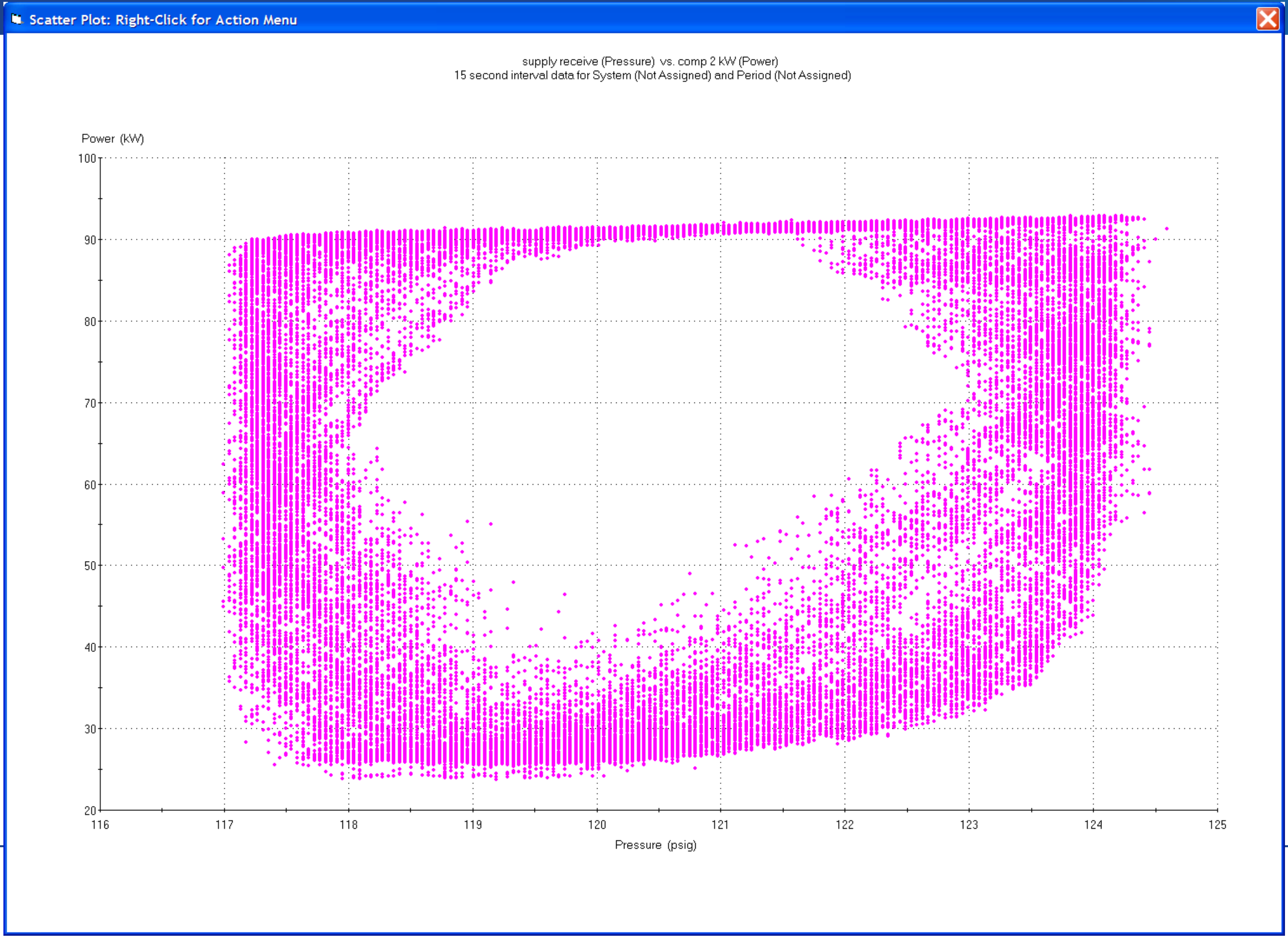
LogTool Trend Plot





LogTool Scatter Plot



International Paper
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Fujifilm
Fuji
Corning Inc
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SRP
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Waste Water Example
Treasure Hunt Example
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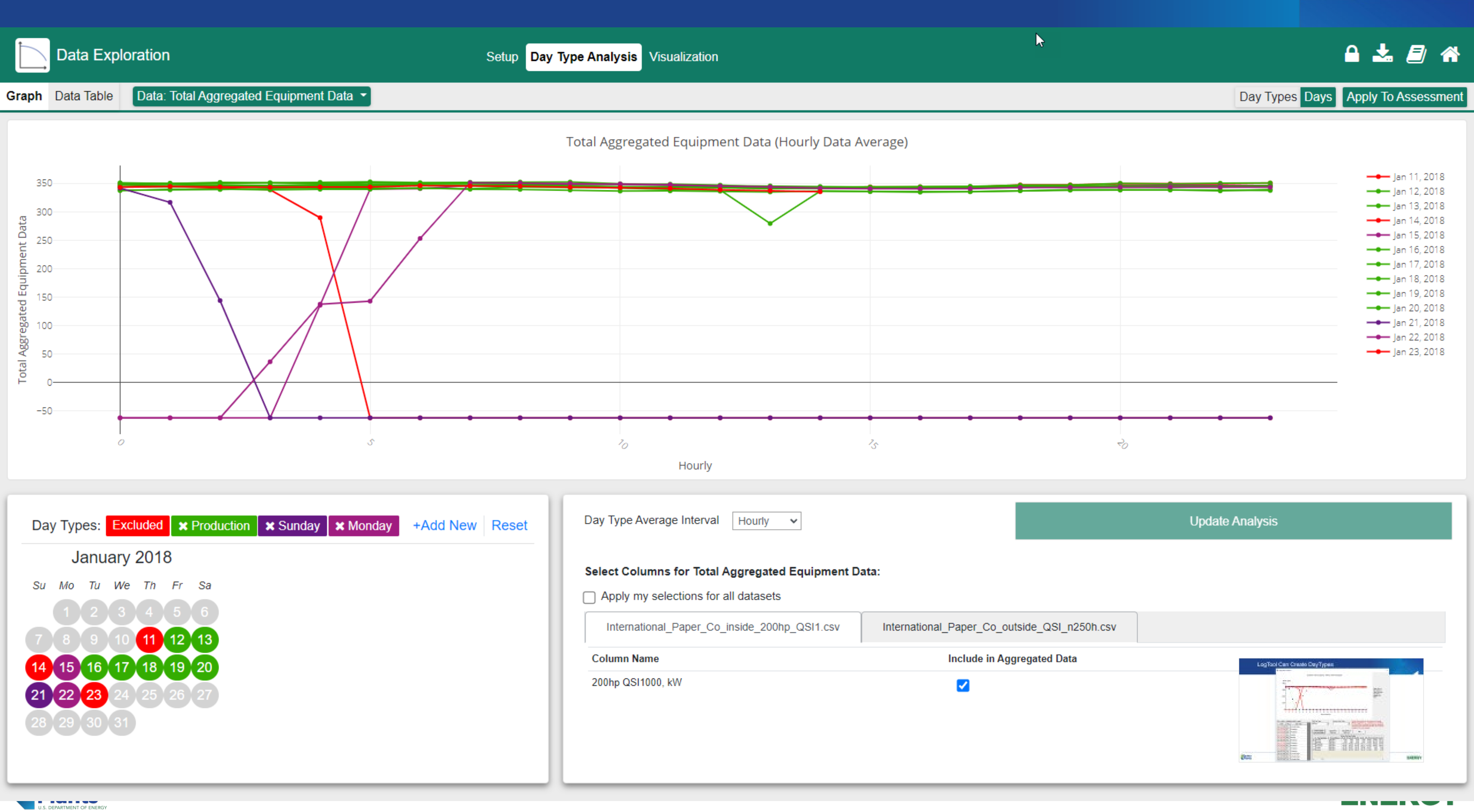
Welcome to the most efficient way to manage and optimize your facilities' systems and equipment.
Create an assessment to model your system and find opportunities for efficiency or run calculations from one of our many property and equipment calculators.
Get started with one of the following options.
If you need help at any point along the way, click on a User Manual icon.
View Assessments
Equipment Calculators
Pump Assessment
Compressed Air Assessment
Process Heating Assessment
Fan Assessment
Steam Assessment
Treasure Hunt
Wastewater Assessment
Motor Inventory
Pump Inventory
Data Exploration
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy


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
350
300
250
200
150
100
50
0
−50
0
5
10
15
20
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
1 2 3 4 5 6
7 8 9 10 11 12 13
14 15 16 17 18 19 20
21 22 23 24 25 26 27
28 29 30 31
Day Type Average Interval
Hourly
Update Analysis
Select Columns for Total Aggregated Equipment Data:
Apply my selections for all datasets
International_Paper_Co_inside_200hp_QSI1.csv
International_Paper_Co_outside_QSI_n250h.csv
Column Name
Include in Aggregated Data
200hp QSI1000, kW
LogTool Can Create DayTypes
U.S. DEPARTMENT OF ENERGY

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

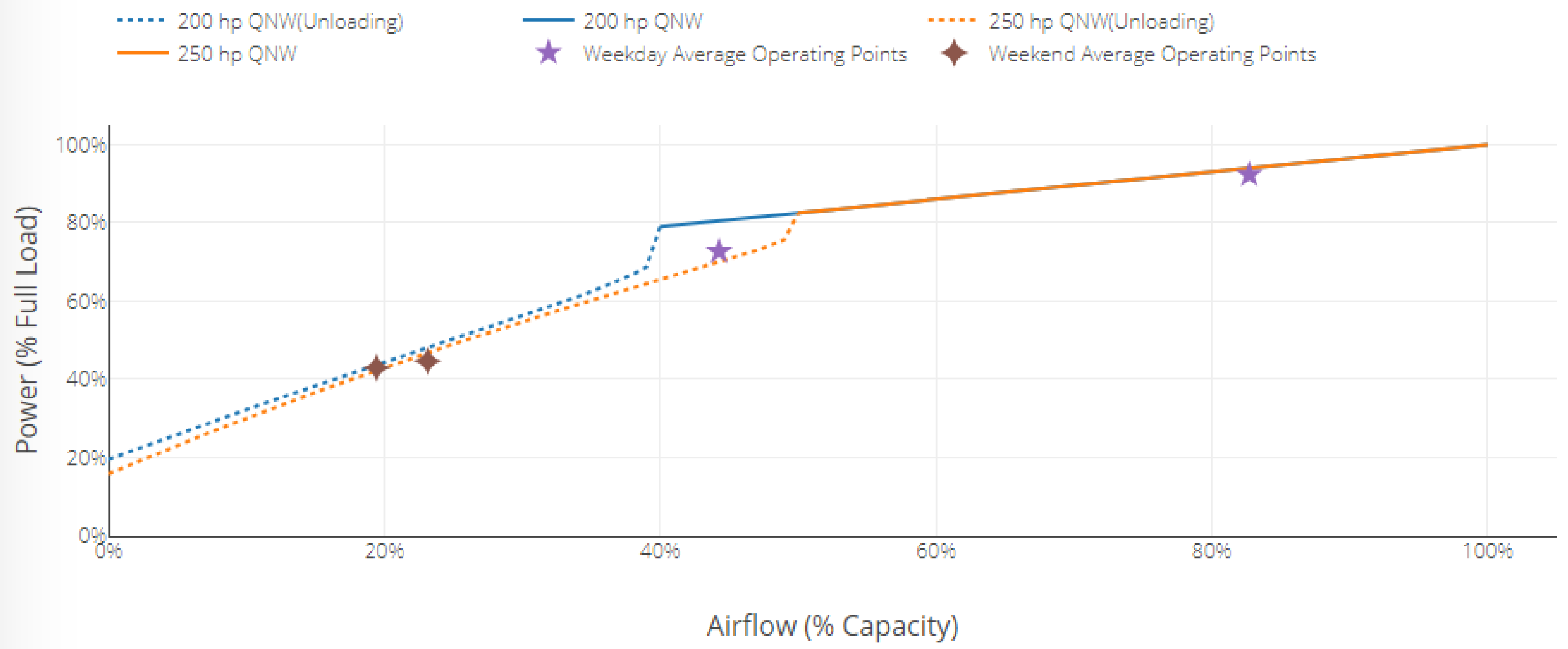
MEASUR Tool Energy Efficiency Measures

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

Performance Profile

- [x] Graph All Compressors
- [x] Graph Average Operating Points



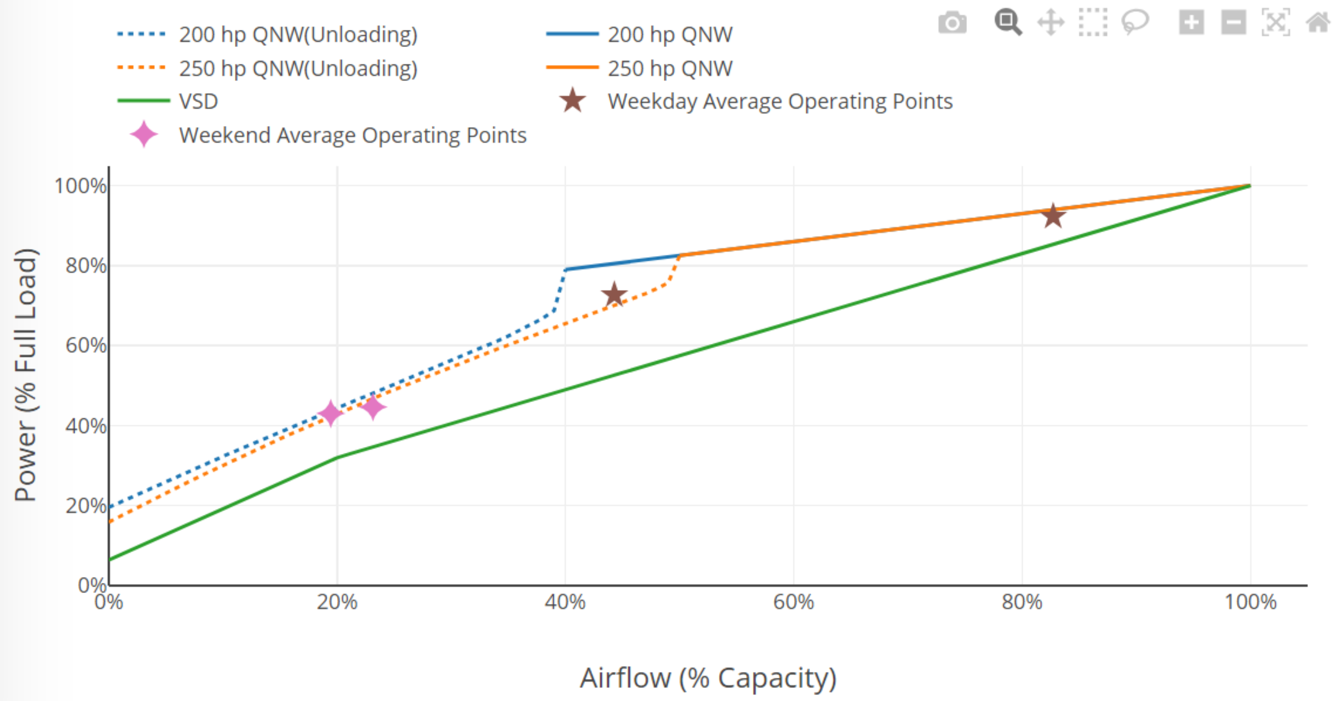
MEASUR Tool Energy Efficiency Measures

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
VSD	Single stage lubricant-injected rotary screw	VFD	100 - 104.8 psig

Performance Profile

☑ Graph All Compressors ☑ Graph Average Operating Points



MEASUR Tool Energy Efficiency Measures

International Paper
Last modified: Jan 6, 2026

Baseline Assessment Diagram Report Sankey Calculators

1 Assessment Basics | 2 System Information | 3 Inventory | 4 Day Types | **5 System Profile** | 6 End Uses

Setup Profile | Profile Summary | Graphs | Annual Summary | Compressor Summary

Select Day Type	Weekday	Data Interval	1 hr
Profile Data Type	Power, kW	Pressure Control Range	100 - 127 psig

Compressor Ordering (Base/Trim)

Trim compressor selection required for all day types using Base/Trim system controls.

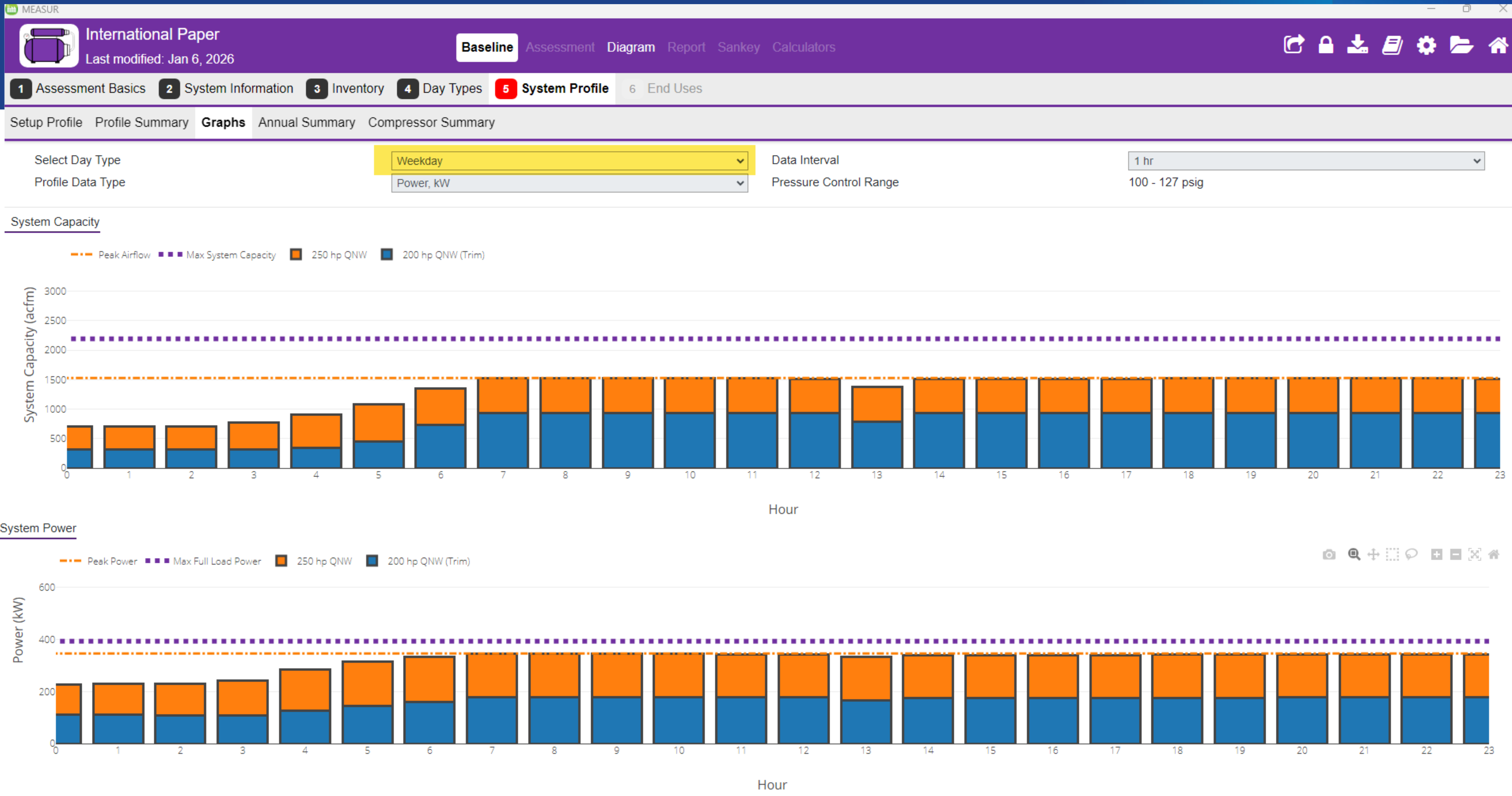
☐ Fill right on change | Turn All Off | Turn All On

	FLP	Trim	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
200 hp QNW	115	◉	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim	Trim
250 hp QNW	100	○	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base

Profile Data

☐ Fill right on change | Set Data From Data Explorer | Visit Data Explorer | Select "Profile Data Type" for all Day Type's before setting Data Explorer Options

		0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
200 hp QNW	Power	109.8	109.90(	109.4	108.4	125.2	143.2	161.4	179.1	178.50(	178.4	177.1	177.2	177.3	165.2	174.7	175.3	175.4	174.9	176	175.8	177	177.6	177.3	178.1
250 hp QNW	Power	118.5	119	119.40(	134.4	160.8	173.2	170.8	167.5	167.7	167.1	167.2	166.6	165	167.1	165.6	164.7	164.4	165.4	166.2	166.8	166.6	166.1	166	165.8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International Paper
Last modified: Jan 6, 2026
Baseline
Assessment
Diagram
Report
Sankey
Calculators
1 Assessment Basics
2 System Information
3 Inventory
4 Day Types
5 System Profile
6 End Uses
Setup Profile
Profile Summary
Graphs
Annual Summary
Compressor Summary
Select Day Type
Weekday
Profile Data Type
Power, kW
Data Interval
1 hr
Pressure Control Range
100 - 127 psig
System Capacity
Peak Airflow
Max System Capacity
250 hp QNW
200 hp QNW (Trim)
System Capacity (acfm)
Hour
System Power
Peak Power
Max Full Load Power
250 hp QNW
200 hp QNW (Trim)
Power (kW)
Hour

International Paper
Last modified: Jan 6, 2026

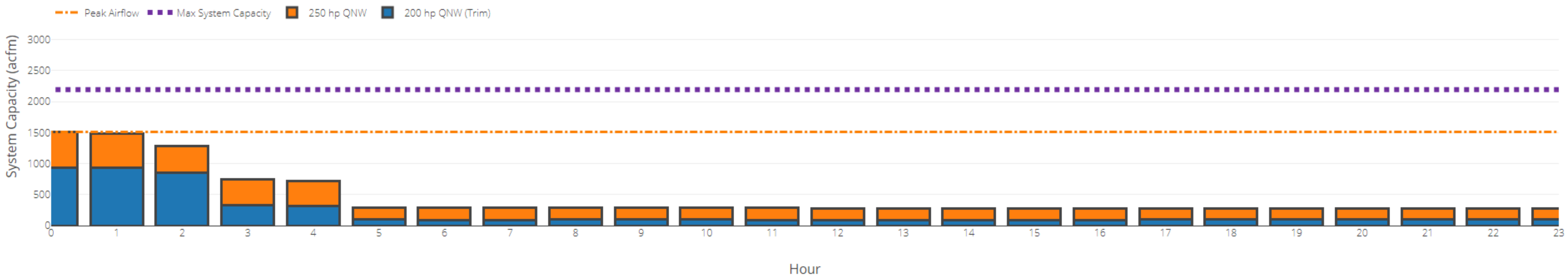
Baseline Assessment Diagram Report Sankey Calculators

1 Assessment Basics | 2 System Information | 3 Inventory | 4 Day Types | **5 System Profile** | 6 End Uses

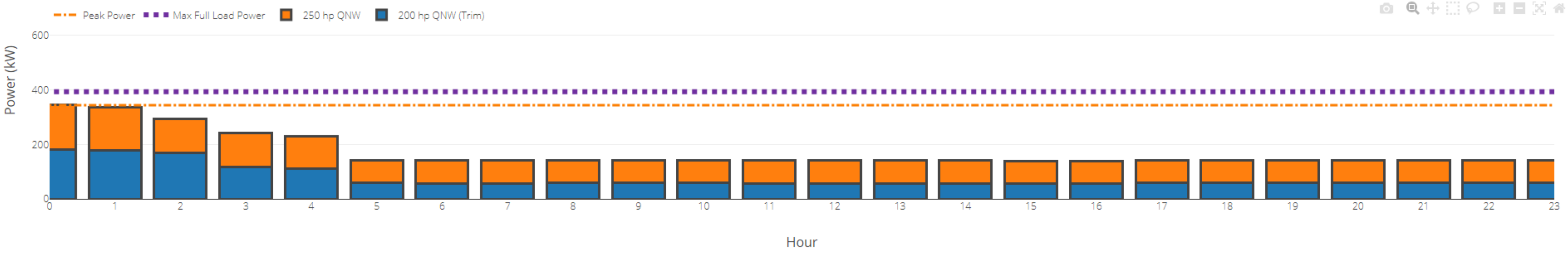
Setup Profile | Profile Summary | **Graphs** | Annual Summary | Compressor Summary

Select Day Type	Weekend	Data Interval	1 hr
Profile Data Type	Power, kW	Pressure Control Range	100 - 127 psig

System Capacity



System Power



International Paper
Last modified: Jan 20, 2026

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

Explore Opportunities | Profile Summary Table | Profile Summary Graphs

Scenario 1
Selected Scenario
View / Add Scenarios

SELECT POTENTIAL ENERGY EFFICIENCY MEASURES

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

Add New Scenario

Modification Name	Scenario 1
Flow Reallocation Implementation Cost	0

Reduce Air Leaks | *Demand* — 1

Implementation Cost	0 $
Leak Flow	200 acfm
Leak Reduction	100 %

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	Scenario 1
Percent Savings (%)	— —	27.9%
Flow Reallocation Energy Savings	— —	391,627 kWh
Reduce Air Leaks Energy Savings	— —	338,820 kWh
Peak Demand	**346.6 kW**	**269.18 kW**
Annual Energy	**2,620,045 kWh**	**1,889,597 kWh**
Annual Emission Output Rate	**1,051 (tonne CO_2)**	**758 (tonne CO_2)**
Peak Demand Savings	— —	**77.42 kW**
Annual Energy Savings	— —	**730,447 kWh**
Annual Emission Savings	— —	**293 (tonne CO_2)**
Flow Reallocation Savings	— —	$37,008.74
Reduce Air Leaks Savings	— —	$32,018.52
Peak Demand Cost	**$0.00**	**$0.00**
Annual Energy Cost	**$247,594.21**	**$178,566.95**
Annual Cost	**$247,594.21**	**$178,566.95**
Peak Demand Cost Savings	— —	**$0.00**
Annual Energy Cost Savings	— —	**$69,027.26**
Annual Cost Savings	— —	**$69,027.26**

MEASUR Tool

MEASUR

Compressed Air Example
Last modified: Jul 29, 2022

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

Scenario 1
Selected Scenario
View / Add Scenarios

Setup Profile | Profile Summary Table | Profile Summary Graphs

SELECT POTENTIAL ADJUSTMENT PROJECTS

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

Add New Scenario

Modification Name: Scenario 1

Reduce Air Leaks | *Demand* — 1

Implementation Cost	1000 $
Leak Flow	2000 acfm
Leak Reduction	10 %

Improve End Use Efficiency | *Demand* — 2

New Nozzels

Implementation Cost	500 $
Substitute Auxiliary Equipment?	No
Airflow Reduction Type	(●) Fixed ( ) Variable
Airflow Reduction	200 acfm

Day Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Weekday	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Weekend	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

+Add Efficiency Improvement

Reduce System Air Pressure | *Supply* — 3

Implementation Cost	400 $
Average System Pressure Reduction	2 psig

Adjust Cascading Set Points | *Supply* — Off

Reduce Run Time | *Supply* — Off

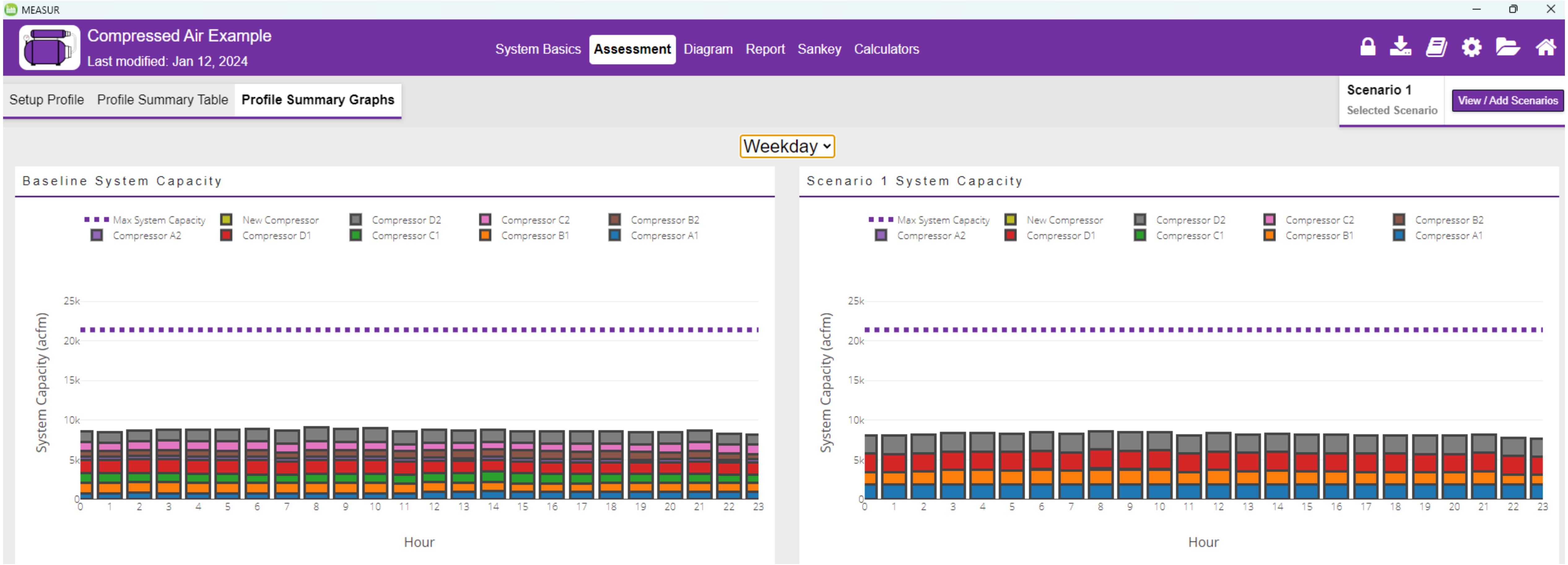
Add Primary Receiver Volume | *Supply* — Off

MODIFICATION RESULTS | PERFORMANCE PROFILE | HELP | NOTES

All Day Types

	Baseline	Scenario 1
Percent Savings (%)	— —	54.7%
Flow Reallocation Energy Savings	— —	6,181,004 kWh
Improve End Use Efficiency Energy Savings	— —	542,044 kWh
Reduce Air Leaks Energy Savings	— —	476,610 kWh
Reduce System Air Pressure Energy Savings	— —	300,157 kWh
Peak Demand	**2,655.2 kW**	**1,968.64 kW**
Annual Energy	**20,569,267 kWh**	**13,069,452 kWh**
Annual Emission Output Rate	**8,860,829 kg CO_2**	**5,630,059 kg CO_2**
Peak Demand Savings	— —	**686.56 kW**
Annual Energy Savings	— —	**7,499,815 kWh**
Annual Emission Savings	— —	**3,230,770 kg CO_2**
Flow Reallocation Savings	— —	$407,946.29
Improve End Use Efficiency Savings	— —	$35,774.92
Reduce Air Leaks Savings	— —	$31,456.24
Reduce System Air Pressure Savings	— —	$19,810.36
Peak Demand Cost	**$159,312.00**	**$118,118.26**
Annual Energy Cost	**$1,357,571.65**	**$862,583.83**
Annual Cost	**$1,516,883.65**	**$980,702.09**
Peak Demand Cost Savings	— —	**$41,193.74**
Annual Energy Cost Savings	— —	**$494,987.82**
Annual Cost Savings	— —	**$536,181.56**

MEASUR Tool


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

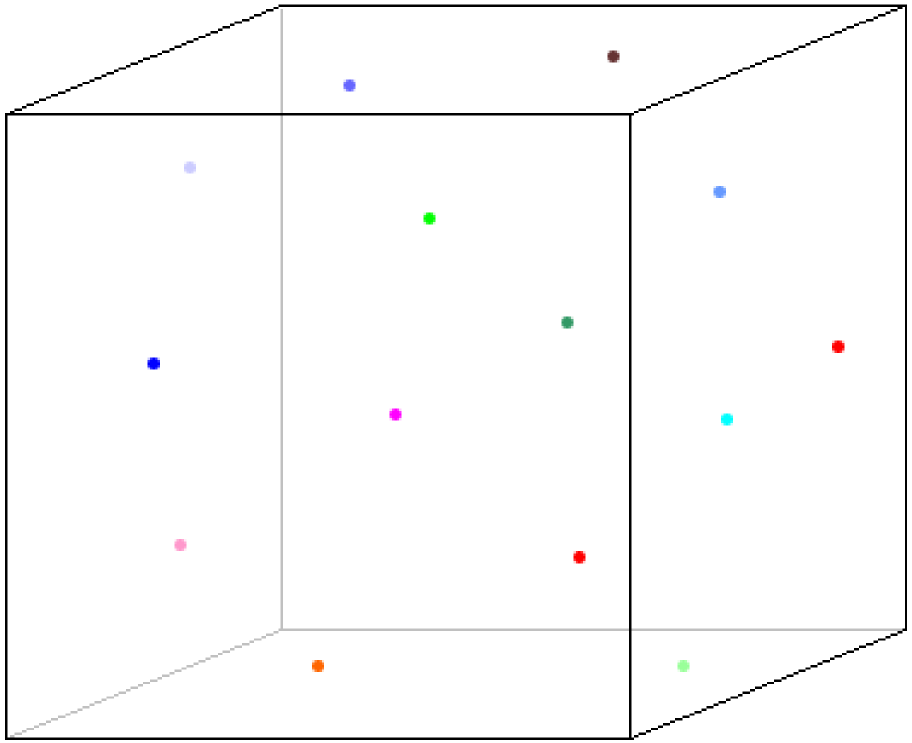
Virtual Session 1 – The Basics

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…… 😊

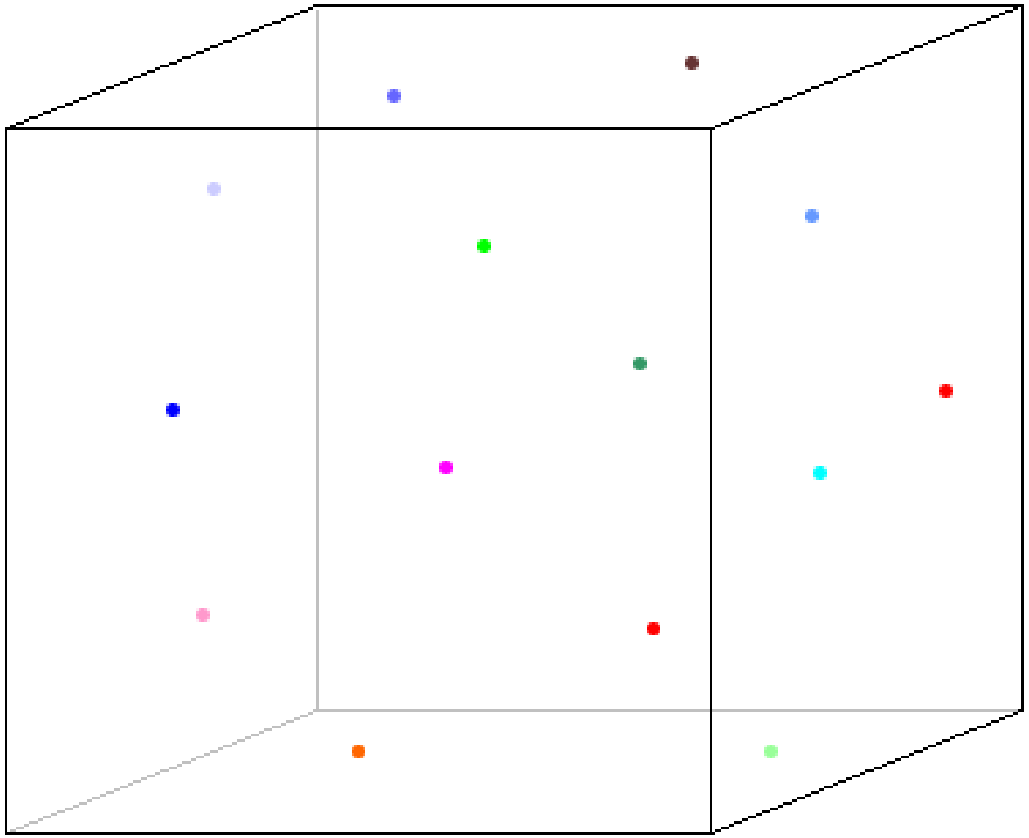
Compressed Air Fundamentals

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

- Air pressure 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 Energy is conserved (cannot be created or destroyed, only changed) Therefore 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:

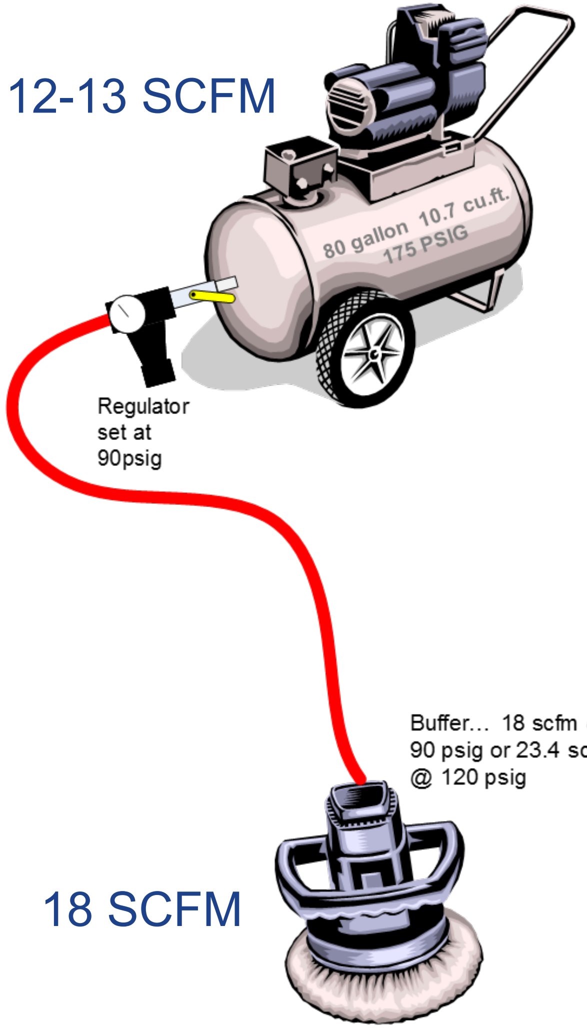
$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$$

Pneumatic capacitance and Boyle's Law --- covered in week 7

- Boyle's Law explains the fundamental pressure-volume relationship of gases, while pneumatic capacitance describes the storage capacity within a pneumatic system.
  - Boyle's Law is a fundamental gas law that describes the inverse relationship between the pressure and volume of a gas when the temperature and amount of gas remain constant. $P_1V_1=P_2V_2$
- Pneumatic capacitance, on the other hand, refers to the ability of a pneumatic system to store compressed air.
  - It is analogous to electrical capacitance, where a capacitor stores electrical energy. In a pneumatic system, the receiver tank acts as the capacitor, storing compressed air under pressure.

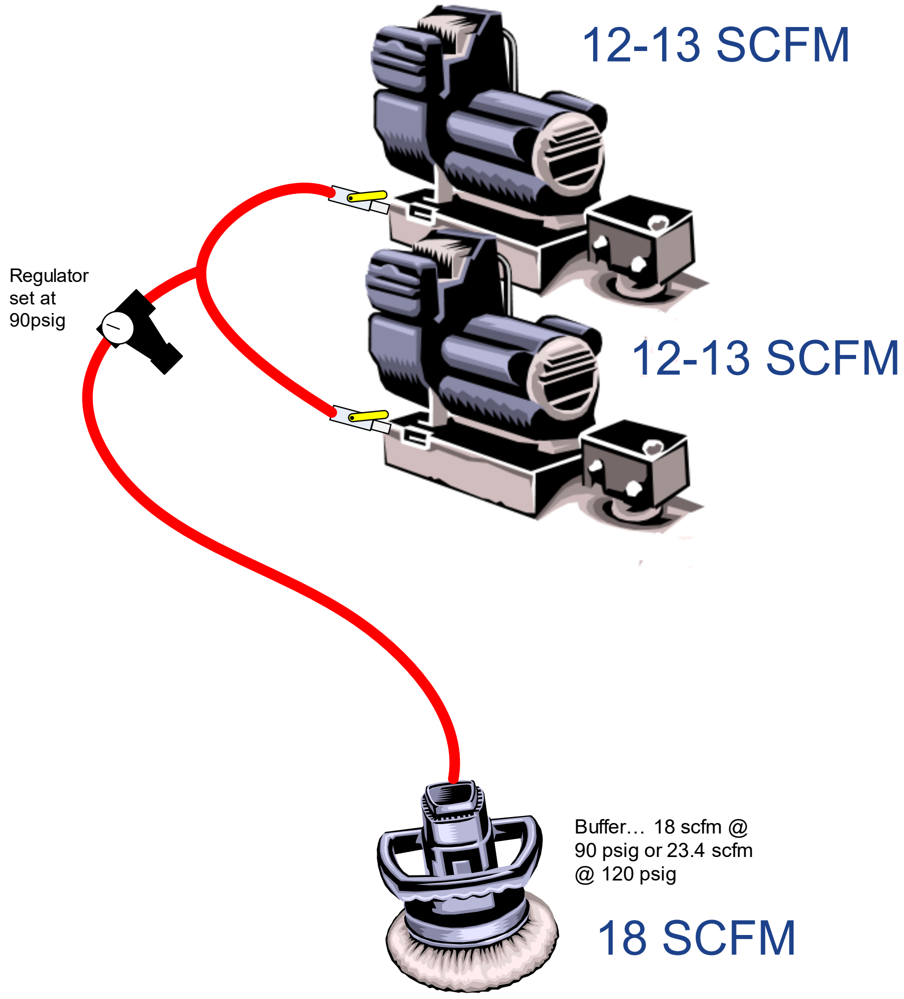
A Simple Example

- 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

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

Compressed Air Fundamentals

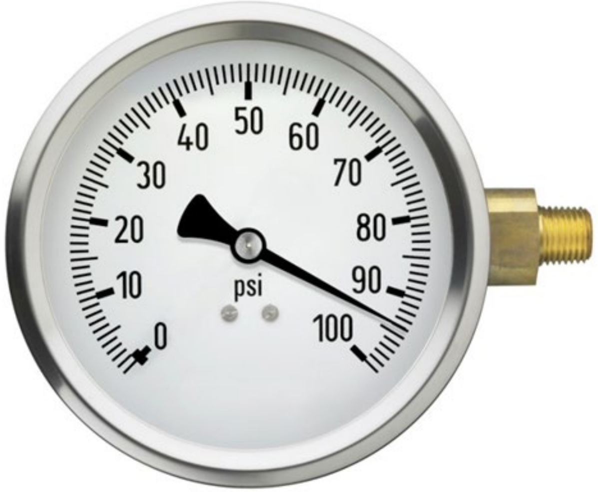
- In Death Valley, which is 500 feet below sea level, The air pressure is 14.94 psia

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

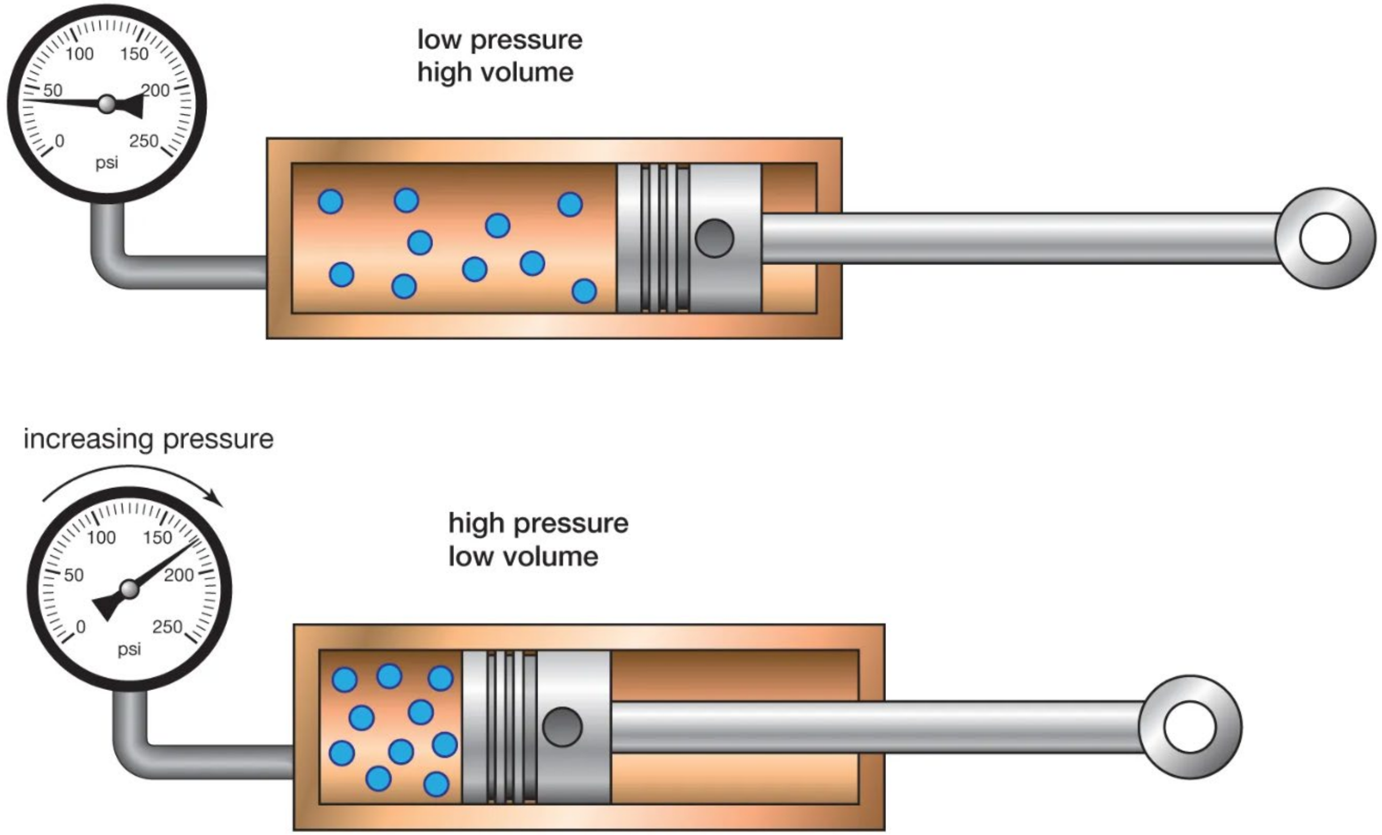
- psig is pounds per square inch gauge - the pressure on the gauge or digital readout of the compressor's controller.
- At zero gauge, the pressure is at atmospheric pressure. If the gauge reads 100 psig, then that means the pressure is 100 pounds above ambient atmospheric pressure.
- psia is pounds 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.

Compressed Air Fundamentals



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- 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.

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.

Definitions and Formulas

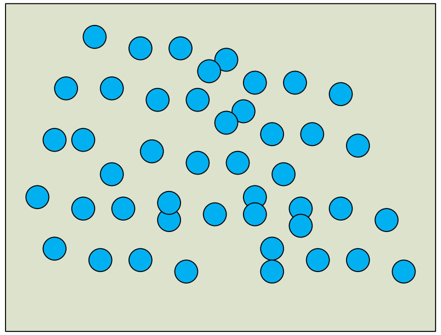
- Flow rate in pneumatic systems is rated in cubic feet per minute (cfm)
- We know that a cubic foot of air can be under various pressures.
- A cubic foot of air can be at 90 psi, 100 psi, or 60 psi. But the cubic foot of air referred to in the term cfm generally indicates a cubic foot of air at the vicinity of the compressor intake.
- Free air is a term which refers to the condition of the air supply available to a compressor.
- This is the air of the ambient or the surrounding air at the compressor's inlet.
- After this air is compressed, it will have a smaller volume depending on how much it has been compressed.

Definitions and Formulas

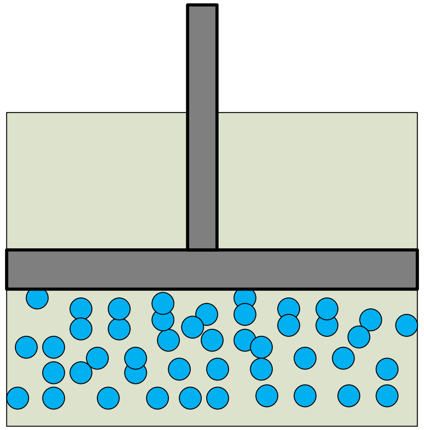
- As this reduced volume passes through system piping, it is still referred to as a cubic foot of air since that is what it is under normal conditions.
- Since atmospheric conditions vary from day to day and from place to place, free air varies widely in it's properties and therefore this is not a good term to use when comparing flow rates between various systems or for flow ratings of compressors.
- For this reason, cubic feet of free air is usually converted mathematically to cubic feet of standard air.
- A standard cubic foot of air is defined as air at a barometric pressure of 29.92 inches of mercury (this would be sea level 14.7 psia) with a temperature of 68°F/20°C and a relative humidity of 36%
- ISO Standard is 14.5 psia,68°F /20°C, 0% RH

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

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

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%

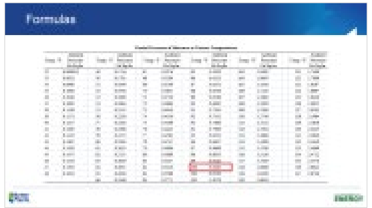
  - Ambient pressure at 5000 ft. = 12.2 psia
  - Partial pressure of moisture at 100°F from vapor pressure chart = 0.95 psia
  - Partial pressure at 50% RH = 0.95 x 0.50

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

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

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

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

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.

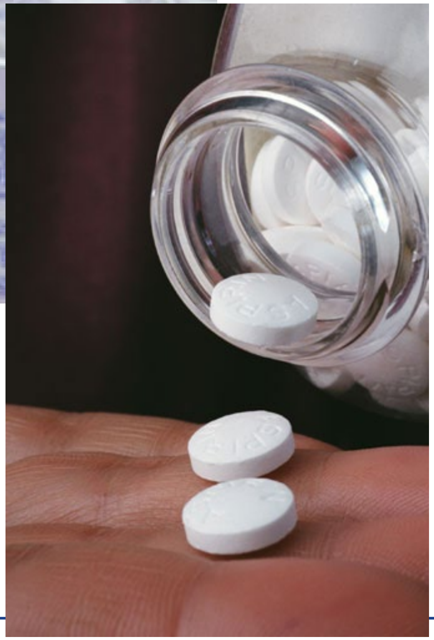
Compressed Air Fundamentals

- 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

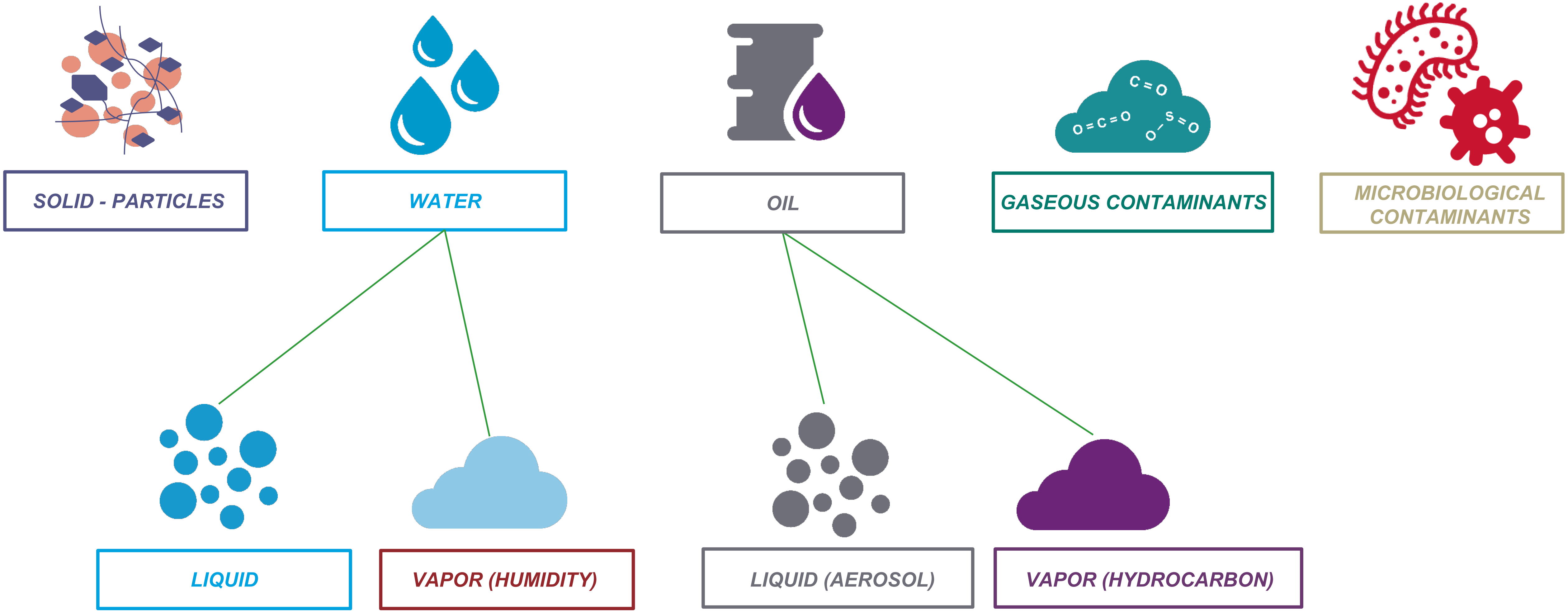
- Rotary screw air compressors are chosen over reciprocating because they are compact, powerful, and can run continuously.
- Regardless of the mechanism used, air is always compressed by taking atmospheric air and squishing it down, so the molecules are condensed and pressurized.

Compressed Air Fundamentals

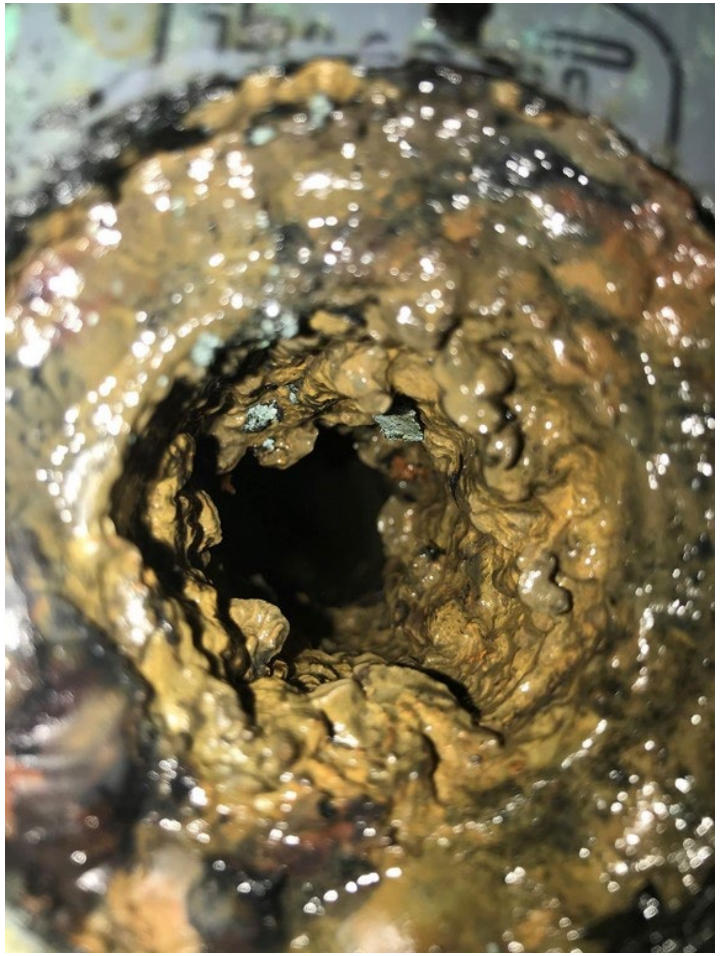


- Process Air
- Compressed air is an integral part of a process, and/or comes in contact with product.
  - Chemicals
  - Pharmaceuticals
  - Food & Beverage
  - Aeration and agitation
  - Semiconductor & Electronics
  - Medical Breathing Air
- CDA Quality--means Clean, Dry, Air

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

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

Air Quality --- covered in week 4

- 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.

Taking Measurements

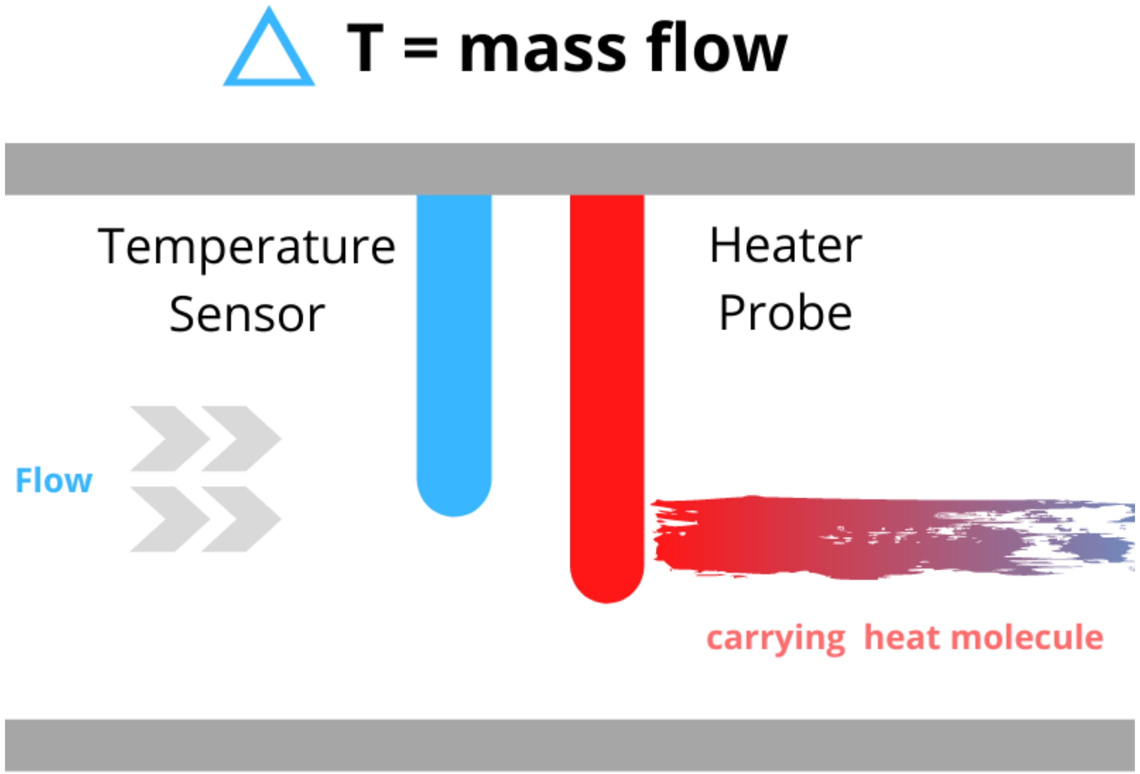
The Need to Make Measurements

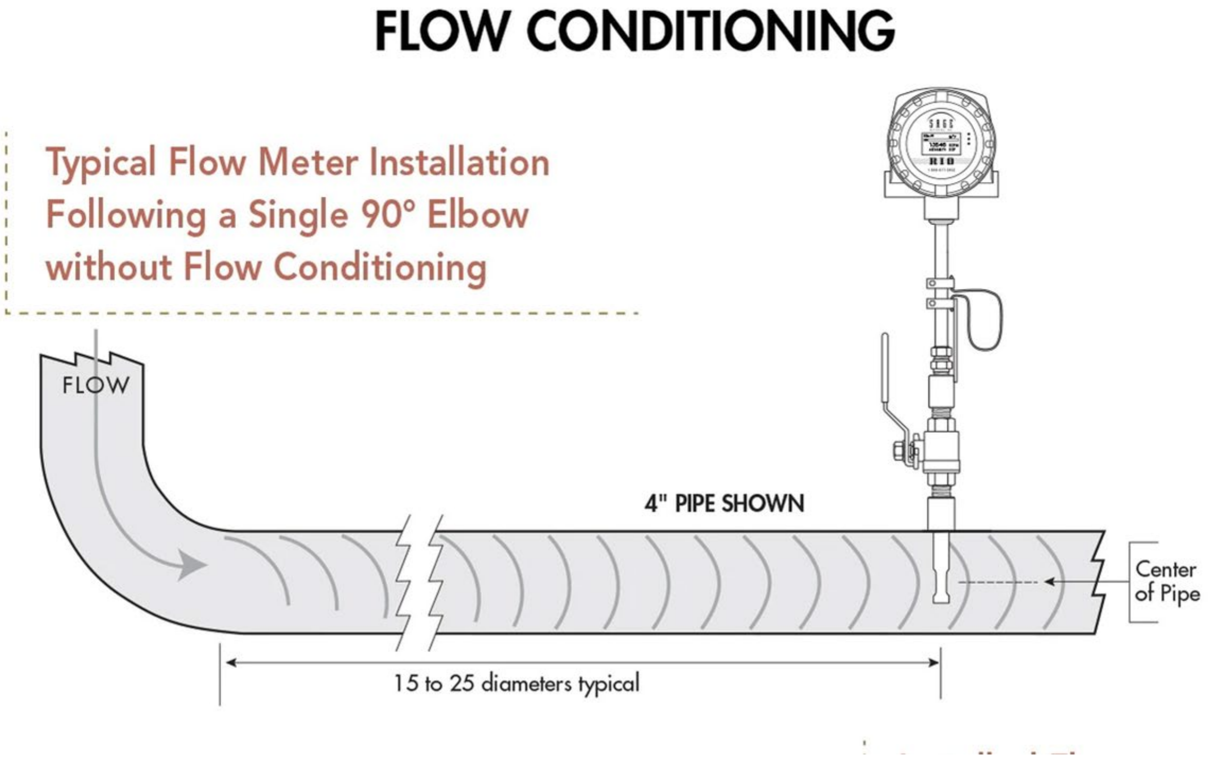
- Flow (cfm)
- Pressure (psi)
- Power (kW)
- Energy (kWh)
- Dollars ($)

Measurement Tools

Measurement Tools

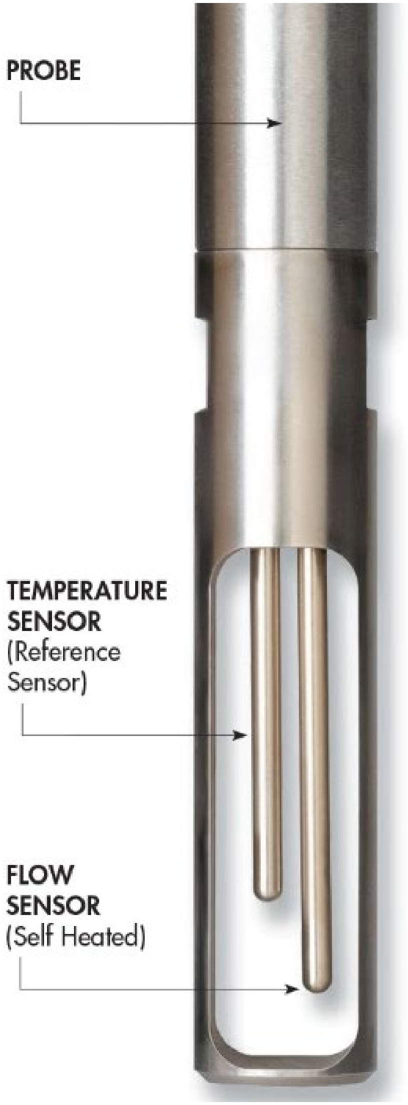
Measurement Tools





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.



How to Hot Tap


Apollo

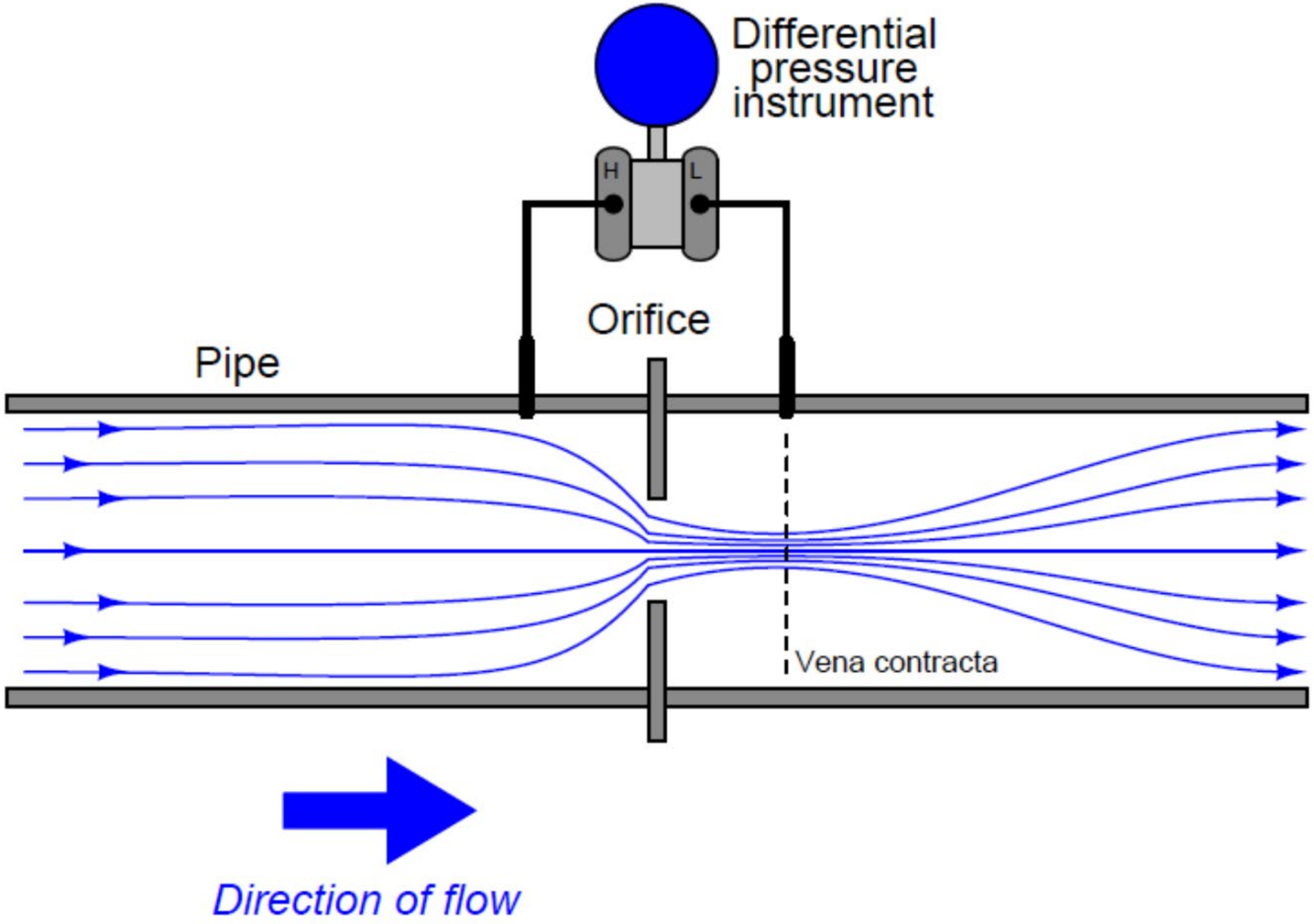

44

Orifice Plate Flow Meters

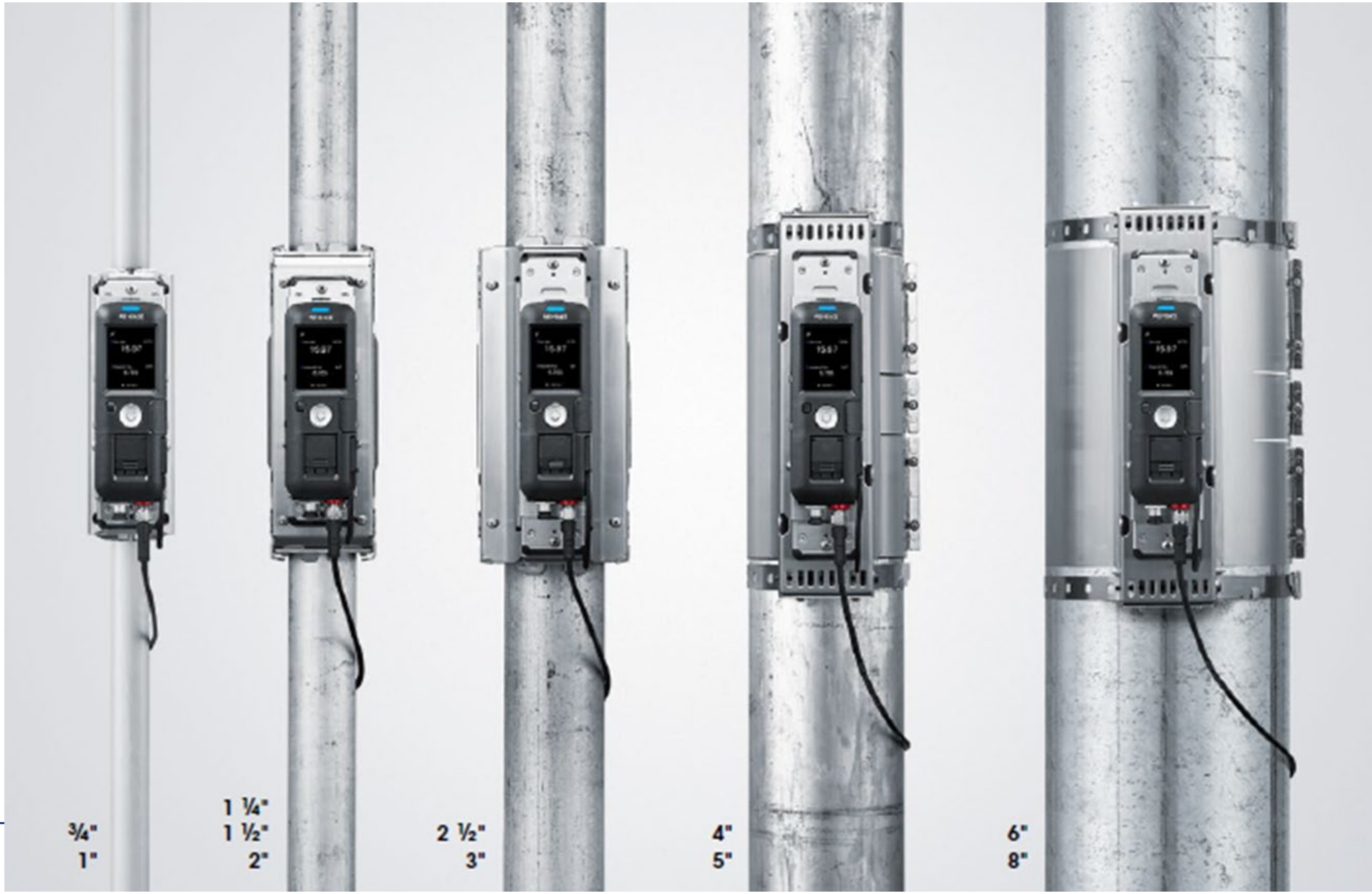
These meters are another carry over from fluid engineering.

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

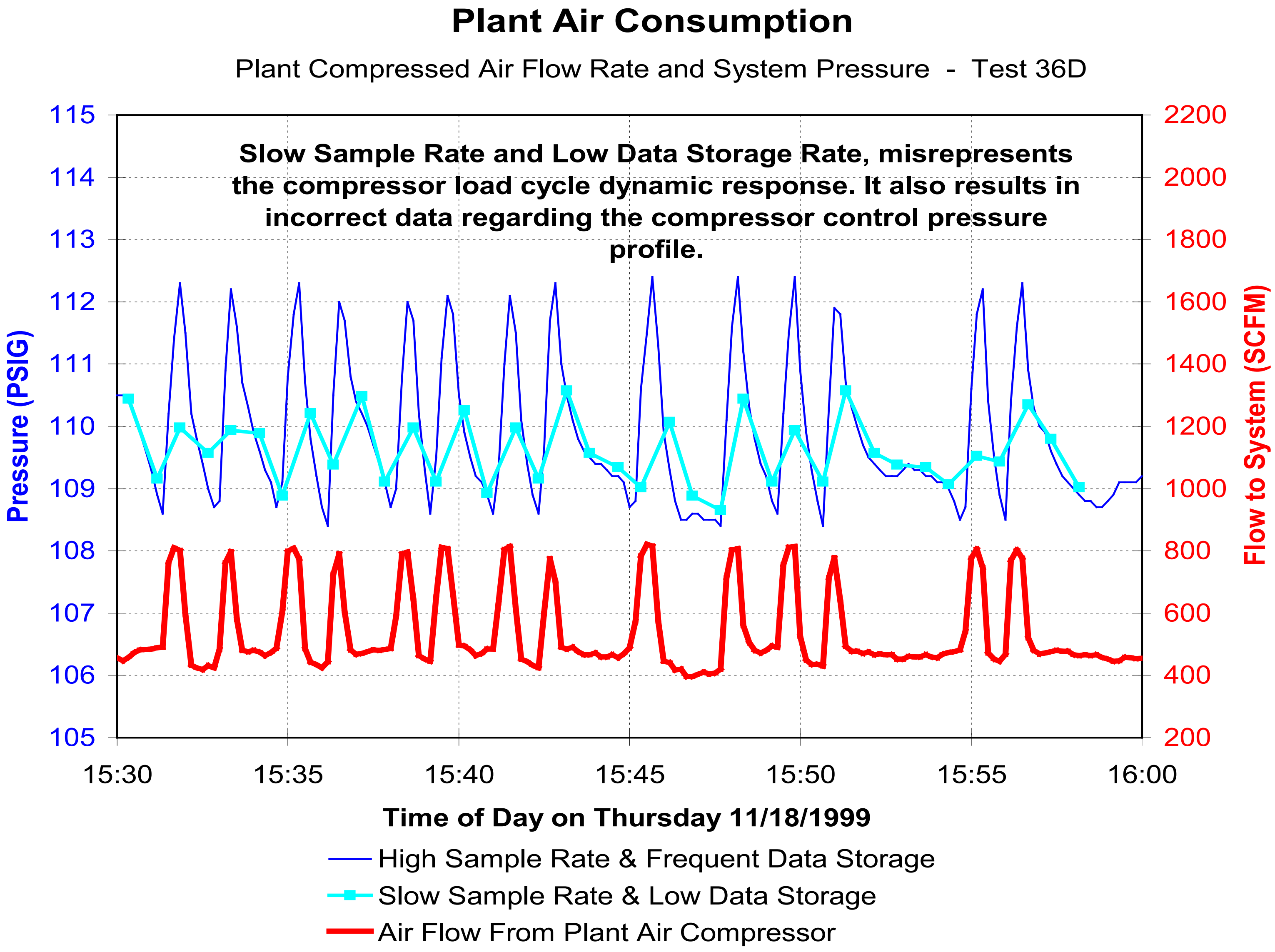
Measurements – A Snapshot Versus a Movie

- 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

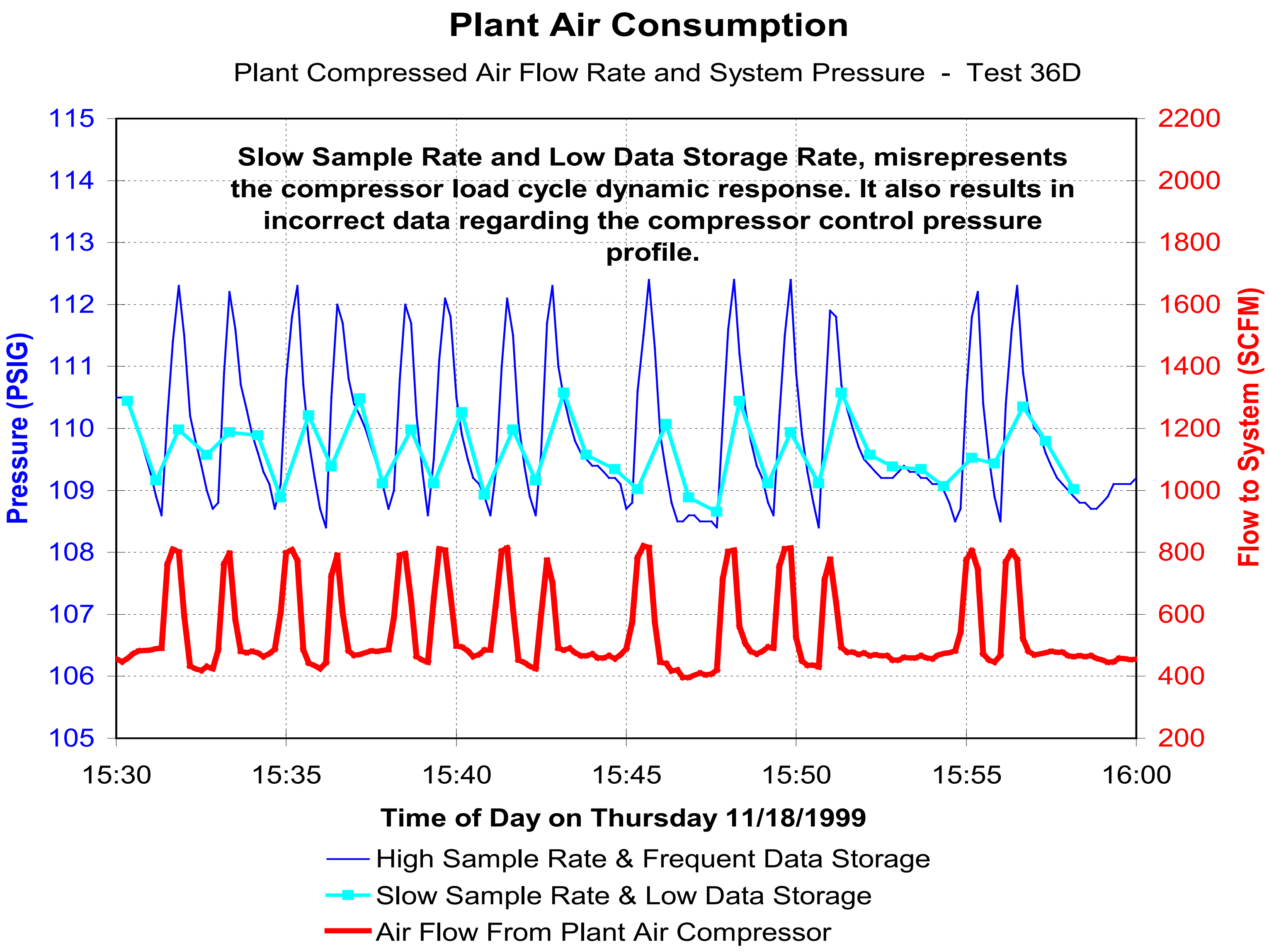


Better Plants U.S. DEPARTMENT OF ENERGY

Measurements – A Snapshot Versus a Movie

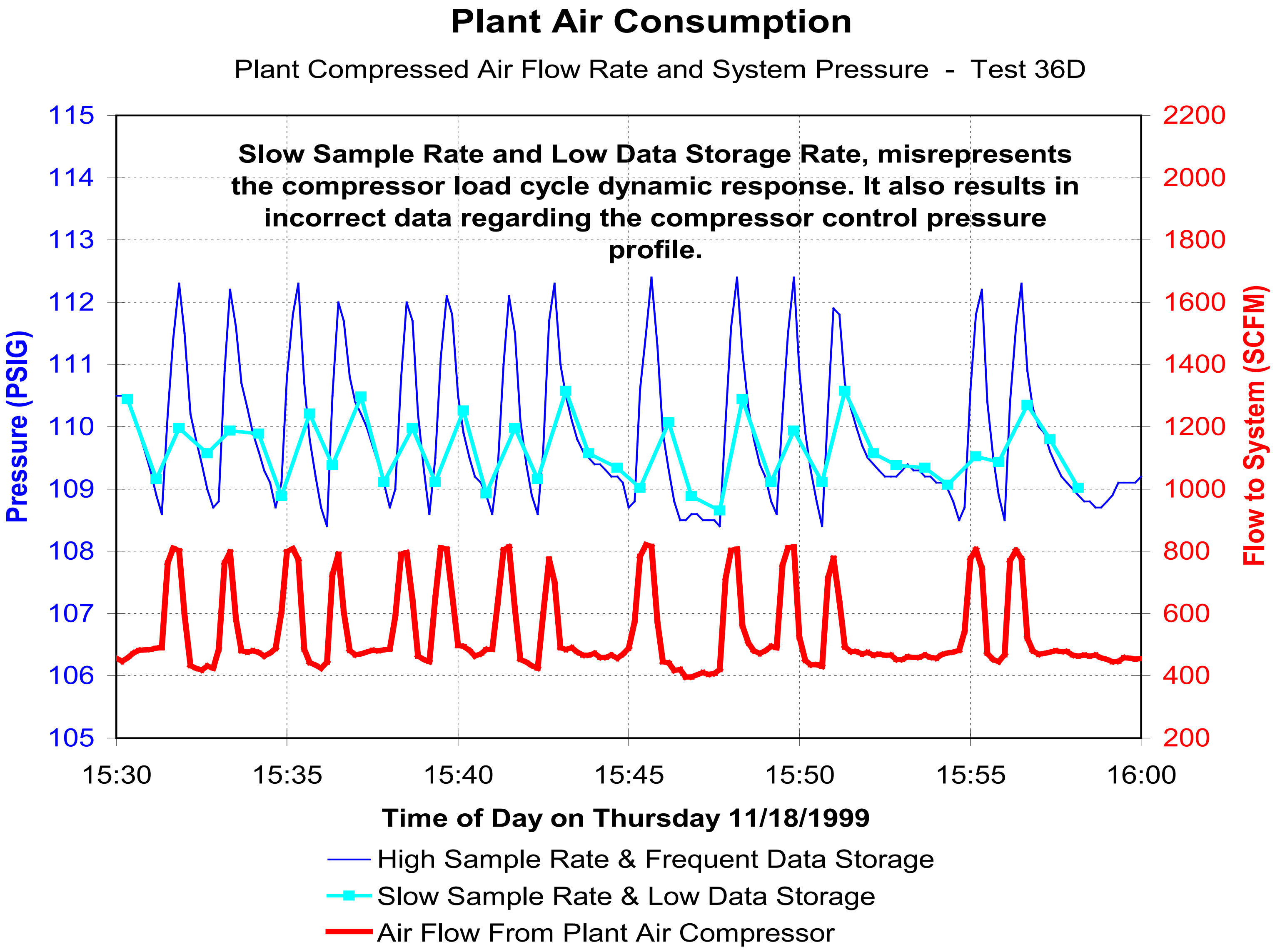
- Signal aliasing in the data tracing above could easily lead to misinterpretation of the recorded system dynamics.
- The 350 scfm swing in flow to the system is NOT a demand event.
- The true wave forms, collected at the high sample rate, clearly show a direct correlation of increasing flow with increasing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

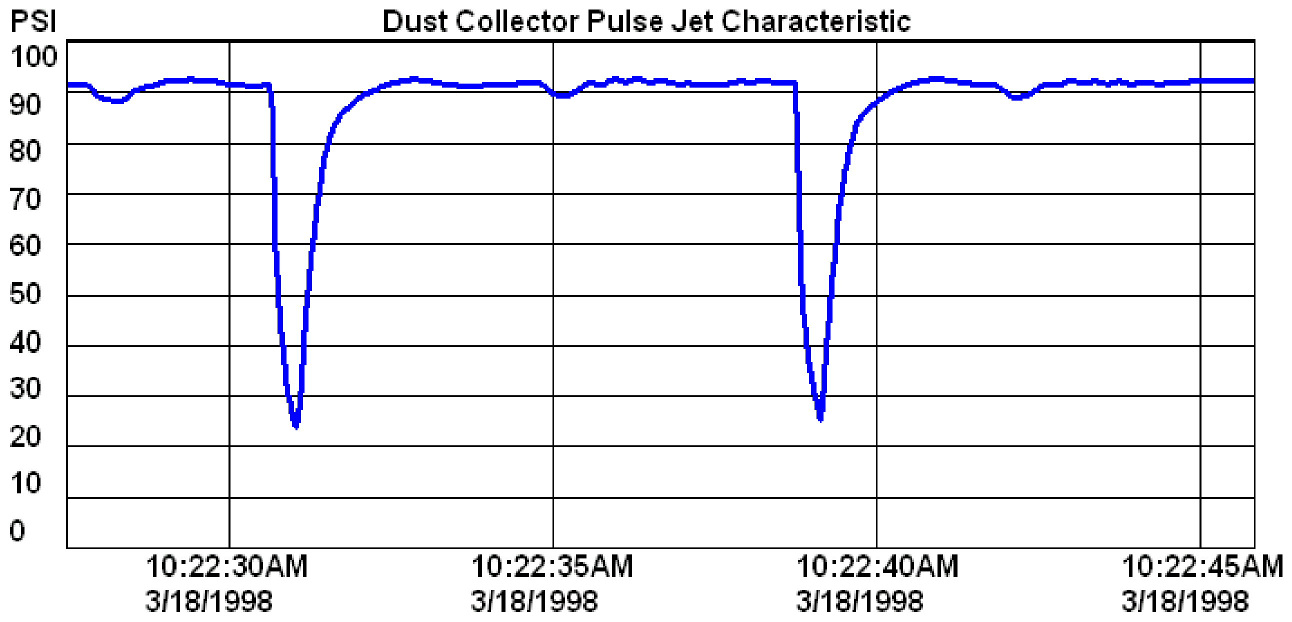


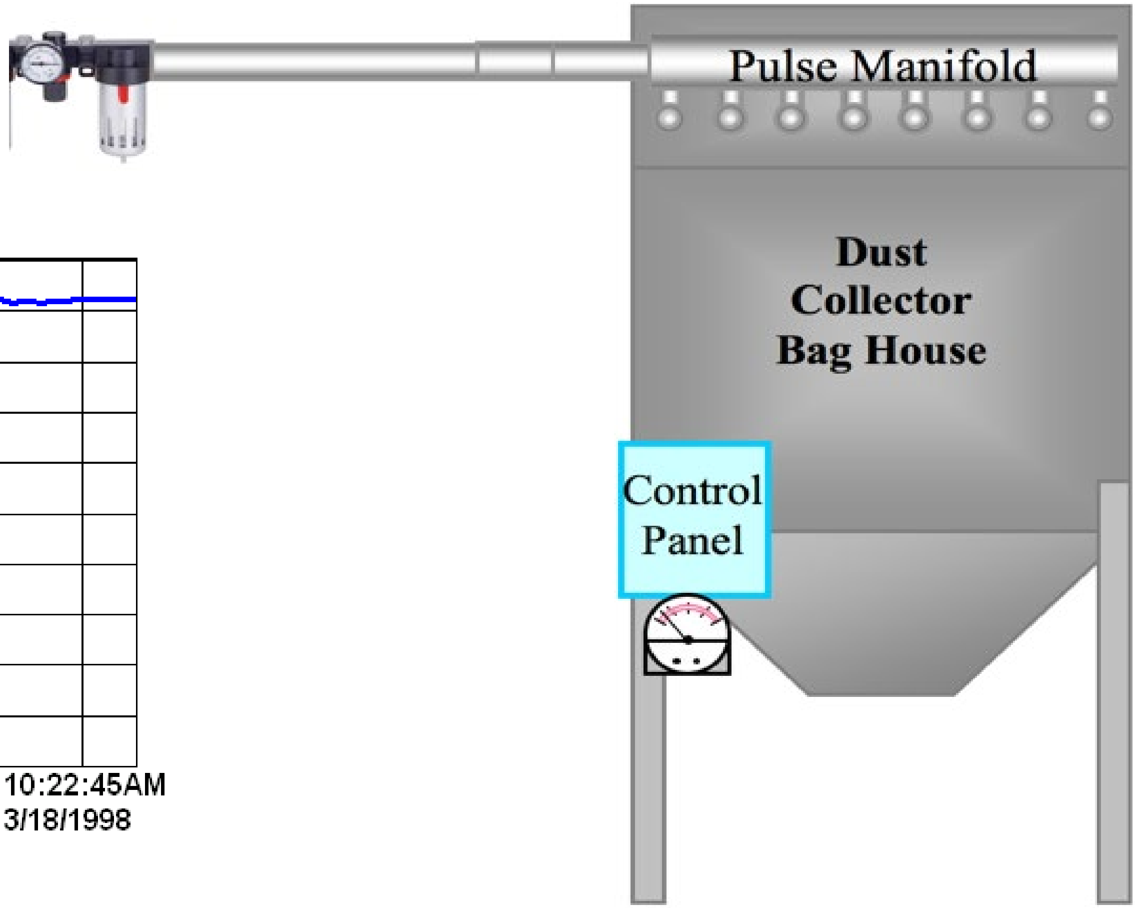
Measurements – A Snapshot Versus a Movie

- 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

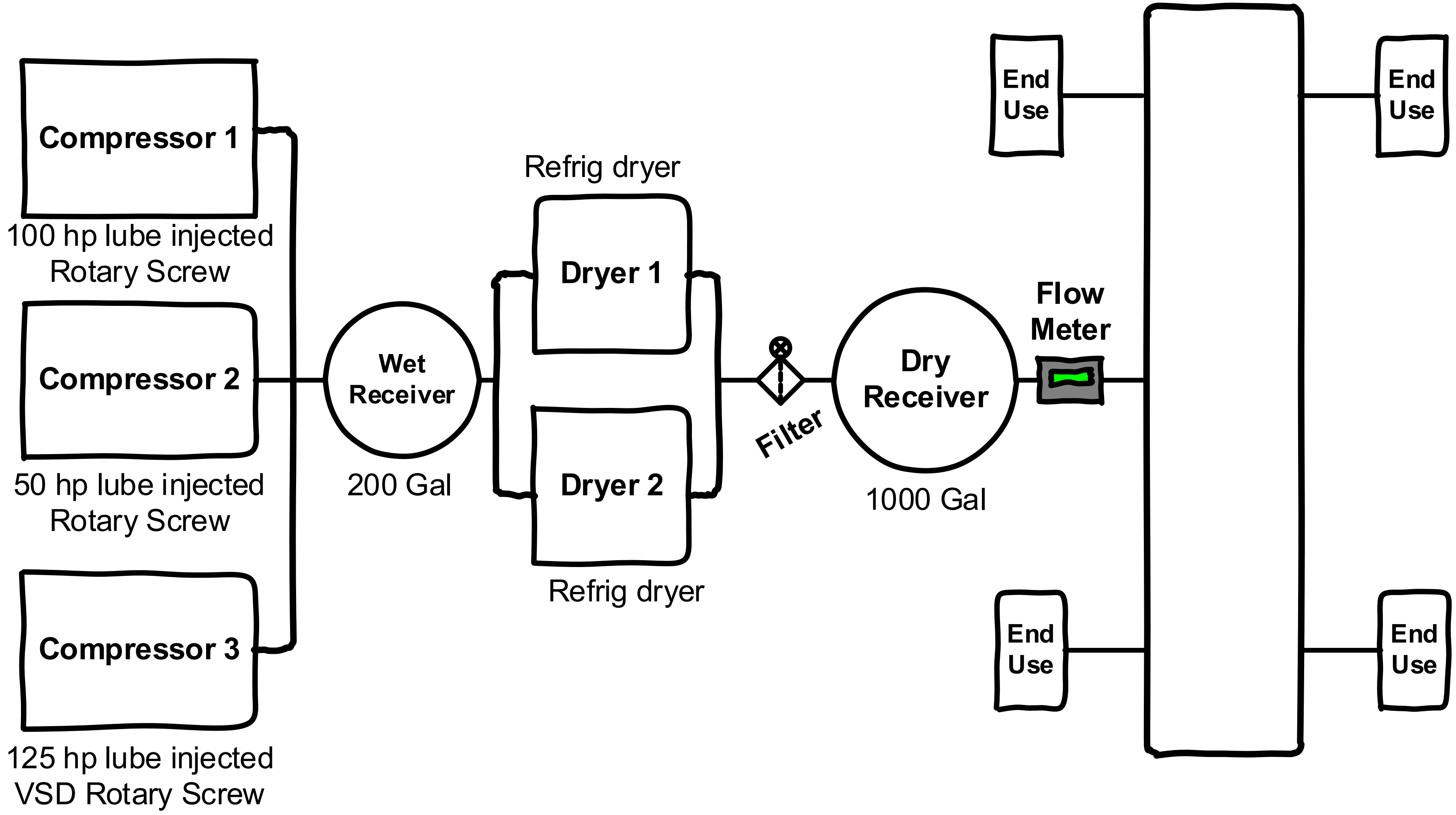
Next Week

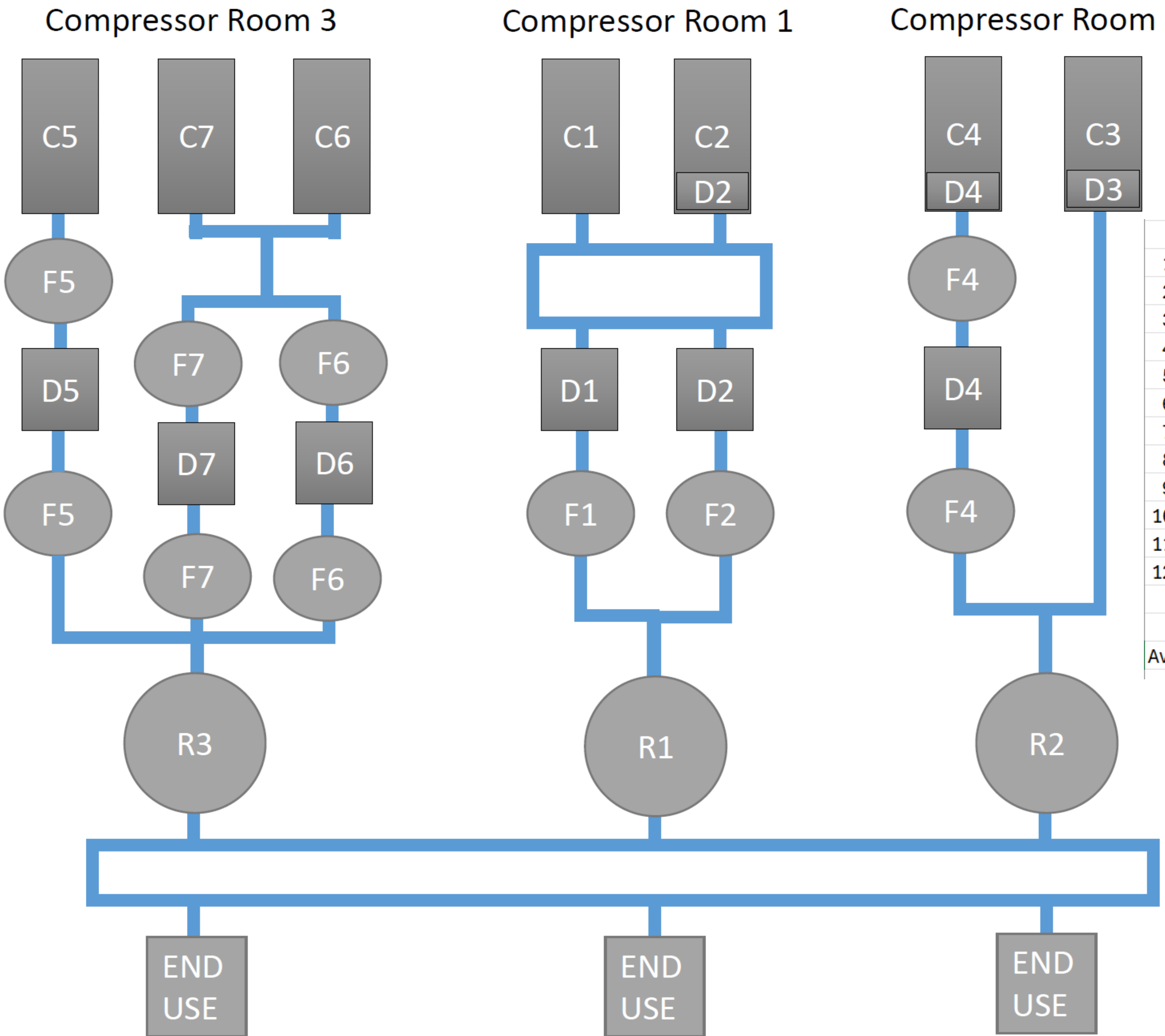
- Positive Displacement – Typically Rotary Screw
- Dynamic Compressors – Typically Centrifugal
- Compressor Room Ventilation
- Homework

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





	Month	Total Bill ($)	Usage (kWh)	
1	Dec-25	$143,828.29	1,834,834	
2	Nov-25	$143,566.25	1,899,463	
3	Oct-25	$171,794.60	2,464,135	
4	Sep-25	$190,591.03	2,361,101	
5	Aug-25	$187,825.55	2,268,289	
6	Jul-25	$180,527.15	2,030,978	
7	Jun-25	$182,300.87	2,199,237	
8	May-25	$160,046.20	2,087,167	
9	Apr-25	$165,761.96	2,107,926	
10	Mar-25	$164,678.19	2,058,323	
11	Feb-25	$161,127.56	1,913,389	
12	Jan-25	$166,484.01	2,105,421	
		a	b	
	Totals:	$2,018,531.66	25,330,263	
Average Electricity Cost [divide (a) by (b)] =				$0.0797 Dollars per kWh

Compressor #1:

Nameplate Information

- **Compressor#:** C1 (from block diagram)
- **Manufacturer:** Atlas Copco
- **Model:** Atlas Copco GA75+
- **Type:** Oil-Injected Rotary Screw Air Compressor
- **Motor Nameplate Horsepower:** 100 hp (75kW)
- **Rated CFM:** 481.4 cfm

Compressor #2

Nameplate Information

- **Compressor#:** C2 (from block diagram)
- **Manufacturer:** Atlas Copco
- **Model:** Atlas Copco GA90FF
- **Type:** Oil-Injected Rotary Screw Air Compressor
- **Motor Nameplate Horsepower:** 125 hp (90kW)
- **Rated CFM:** 565.2 cfm

Compressor #3

Nameplate Information

- **Compressor#:** C3 (from block diagram)
- **Manufacturer:** Atlas Copco
- **Model:** Atlas Copco GA90FF
- **Type:** Oil-Injected Rotary Screw Air Compressor
- **Motor Nameplate Horsepower:** 125 hp (90kW)
- **Rated CFM:** 565.2 cfm

Compressor #4

Nameplate Information

- **Compressor#:** C4 (from block diagram)
- **Manufacturer:** Atlas Copco
- **Model:** Atlas Copco GA90FF
- **Type:** Oil-Injected Rotary Screw Air Compressor
- **Motor Nameplate Horsepower:** 120.69 hp (90kW)
- **Rated CFM:** 588.3 cfm

Compressor #5

Nameplate Information

- **Compressor#:** C5 (from block diagram)
- **Manufacturer:** Gardner Denver
- **Model:** VS80-110A
- **Type:** Oil-Injected Rotary Screw Air Compressor
- **Motor Nameplate Horsepower:** 148 hp (110kW)
- **Rated CFM:** 556 cfm

Compressor #6

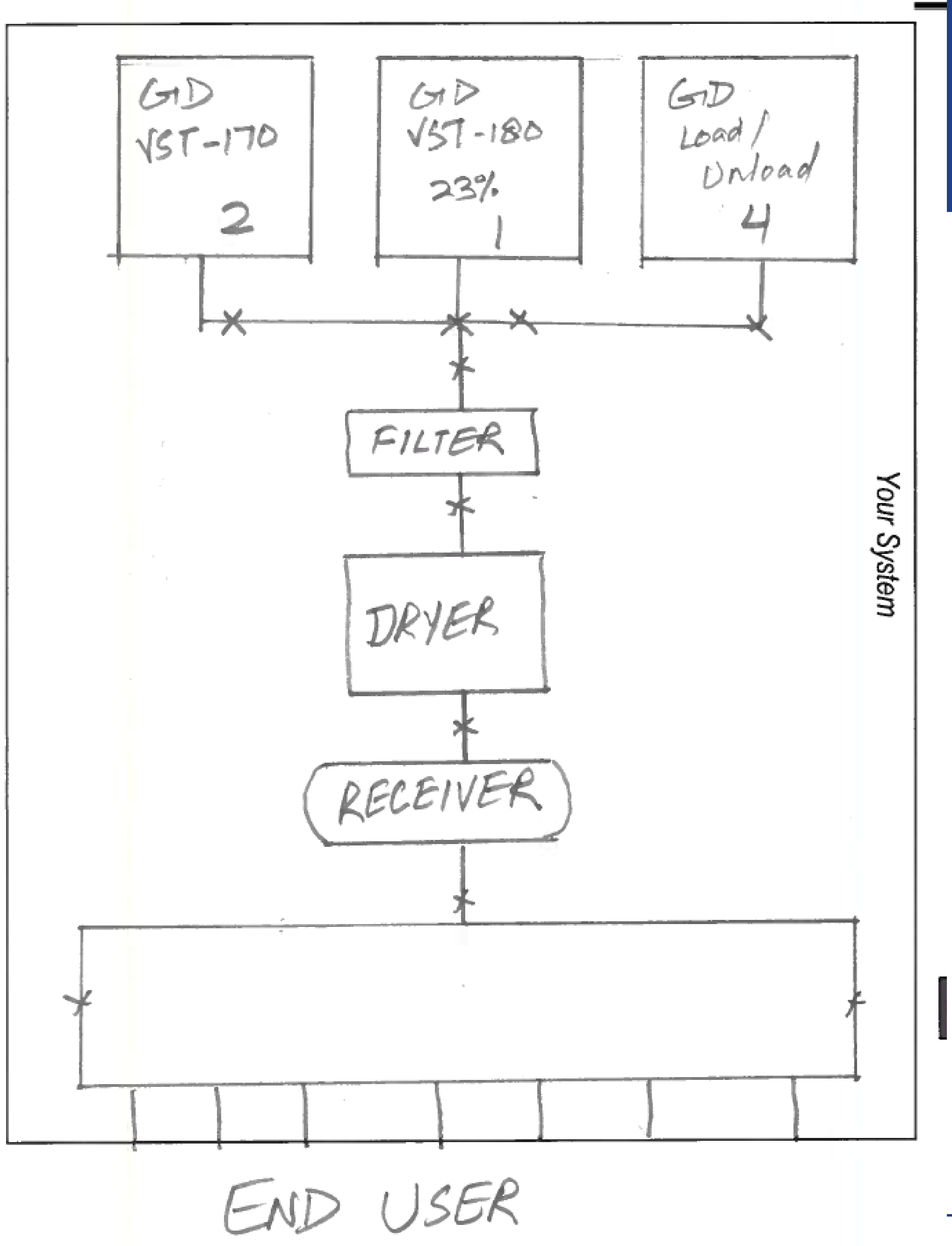
Nameplate Information

- **Compressor#:** C6 (from block diagram)
- **Manufacturer:** Gardner Denver
- **Model:** EBP99K
- **Type:** Oil-Injected Rotary Screw Air Compressor
- **Motor Nameplate Horsepower:** 100 hp
- **Rated CFM:** 450 - 495 cfm

Compressor #7

Nameplate Information

- **Compressor#:** C7 (from block diagram)
- **Manufacturer:** Gardner Denver
- **Model:** EBP99K
- **Type:** Oil-Injected Rotary Screw Air Compressor
- **Motor Nameplate Horsepower:** 100 hp
- **Rated CFM:** 450 - 495 cfm



GD VST-170 2
GD VST-180 23% 1
GD Load / Unload 4
FILTER
DRYER
RECEIVER
Your System
END USER