Better Plants Online Learning Series

We’ll be starting in just a few minutes….

Visit our new Online Learning Series webpage on the Solution Center where you can see the schedule of upcoming webinars, RSVP, and access previously recorded webinars on other energy management topics.
Online Learning Series – Webinar #5
Compressed Air Systems

Eli Levine
Office of Energy Efficiency and Renewable Energy
### Better Plants Online Learning Series

#### NEW! Better Plants Online Learning Series

**Starting Thursday, April 16, 2020 | 1:00pm US-ET**

[CLICK HERE TO LEARN MORE](#)

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<th>Speaker</th>
<th>Date</th>
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<th>Link</th>
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<tr>
<td>1. Better Plants Town Hall</td>
<td>Eli Levine (DOE), feat. Al Hildreth (General Motors)</td>
<td>04/16/20</td>
<td>RECORDED</td>
<td>Watch Recording</td>
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<td>2. Basics of Energy</td>
<td>Thomas Wenning (ORNL)</td>
<td>04/23/20</td>
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<td>3. Lighting, HVAC, and Building Envelope</td>
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<td>04/29/20</td>
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<td>4. Resources You Should Know; USDA Rural Development Programs and the Department of Commerce Manufacturing Extension Partnership</td>
<td>Venus Welch-White (USDA) and David Stieren (NIST-MEP)</td>
<td>05/07/20</td>
<td>1:00 pm US-EST</td>
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<td>5. Compressed Air Systems</td>
<td>Thomas Wenning (ORNL)</td>
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<td>1:00 pm US-EST</td>
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<td>6. Water Efficiency</td>
<td>Sachin Nimbalkar (ORNL)</td>
<td>05/21/20</td>
<td>1:00 pm US-EST</td>
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Tom Wenning
Oak Ridge National Lab
Compressed Air Systems

Thomas Wenning, PE
Overview - Compressed Air Systems

- **Why care about compressed air systems?**
  - Wide application
  - Very inefficient

- **Compressed air systems**
  - Compressors
  - Compressor controls
  - Dryers

- **Energy savings opportunities**
  - How to use less (demand side)
  - How to generate compressed air more efficiently (supply side)
  - Others

- **Tools**
  - Software tools
  - Survey instruments

Source: Compressed Air Best Practices
Why Care about Compressed Air Systems?

- **Wide applications (e.g.)**
  - Conveyers
  - Pneumatic tools
  - Machine actuators
  - Paint sprayers
  - Robotic arms

- **Comparing to electrical**
  - **Smother power**
  - Variable speed and torque control
  - No potential hazards of electric shock
Why Care about Compressed Air Systems?

- Consumes **5-20% of a plant electricity**
- Very inefficient

Typical Compressed Air System Energy Lost

Typical Lifetime Compressed Air Costs

*Source: Compressed Air Tip Sheets*
Split into Two: Supply and Demand

**Supply Side** – supplies compressed air

**Demand Side** – uses compressed air

Source: Improve Compressed Air System Performance
Compressed Air Systems

Source: Compressed Air Challenge Best Practices Manual
Types of Compressors

Compressor

Positive Displacement

Reciprocating
- Single Acting
- Double Acting
- Helical Screw
  - Oil Flooded
  - Oil Free

Rotary

Centrifugal
- Axial
  - Scroll
  - Sliding Vane
  - Liquid Ring

Dynamic
Major Compressed Air Types

- **Reciprocating**
- **Rotary Screw**
- **Centrifugal**

- **For large capacity**
- **For medium capacity**
Compressor Controls

- **On/Off controls**
  - Turns on at low end of pressure range and turns off at the high end
  - Available on reciprocating or rotary compressors
  - Efficient if load is intermittent

- **Load and unload**
  - Unloads the compressor when discharge pressure is adequate.
  - Inefficient since ~50% power is drawn when compressor is unloaded

- **Inlet modulation**
  - Modulation of inlet valve in response to system pressure variation

- **Variable speed controls**
  - Can regulate capacity from **15% to 100%**
  - Provide a **soft start** and very **stable pressure band**
  - Operate in start/stop mode when it is below 15%
Start/Stop

- **On or off** in response to the discharge **pressure setpoint**
- Applicable to **reciprocating** or **rotary**
- Systems < 30 HP
- Can entail **higher maintenance cost**

Source: Quincy
Load/Unload

- When the discharge pressure meet setpoint, **motor still runs** continuously, but compressor unloads.
- Screw compressors **can use sliding valves**.
Inlet Modulation

- Inlet modulation valves for **screw compressors**
- Inlet guide vanes for **centrifugal compressors**
- Limited to the range from **100% to ~ 40% capacity**

Source: Compressed Air Challenge
Source: Best Practices Magazine
Variable Frequency Drives

- Adjust motor speed to match compressed air demand
- The most efficient way
- Best used as the trim compressor

Source: Compressed Air Challenge
Multiple Compressor Controls – Cascade Scheme

Compressor #1

Compressor #2

Compressor #3

Compressor #4

Pressure (psig)

80
85
90
95
100
105
110

Production minimum requirement

Source: Compressed Air Challenge
Network Controls – Single Setpoint

- Single set point used to make operational decisions
- All compressors are fully loaded except for the trim unit

![Pressure Graph](chart.png)

Source: Compressed Air Challenge
Compressor Sequencing

To provide efficient VSD regulation over the complete range of the air profile, the range of the VSD from min to max should be sized equal or greater than the load/no load machine.
When air enters with a dewpoint of 50 F, and is raised to 100 psig, the dewpoint rises to ~115 F

- Condensation occurs when temperature falls below the dewpoint
- Condensation in line causes corrosion and contamination

- Side Note - Heat generated during compression needs to be removed
  - Insulated compression of ambient air to 100 psig raises the temperature to ~500 F

Need Compressed Air Dryers?

http://airroengg.com
Refrigerant-Type Dryers

- Most common
  - Low capital and operating costs
- Cools air to 35-40ºF, removes moisture and reheats the air
  - Reheat should use hot incoming air
- Almost always air cooled (no cooling tower)
  - Condensing temperature can be very high

Source: GSA
Desiccant-Type Dryers

- **Desiccant medium** to absorb or adsorb moisture

- Most common design: **twin tower** regenerative
  - One is used while the other is regenerated
  - Uses large amount of compressed air to regenerate
  - **Lower dew points** (often to -40 F), but **More costly** than refrigeration type
  - Heated regens are more efficient
  - Less purge air (5% vs 15% for unheated)

Source: Vortex
System Approach to Improve Energy Efficiency

Two basic ways to save energy

- **Use less** compressed air
- **Produce** air more efficiently
Reduce Leakage Losses

- **Leaks** often account for **more than 20%** of the total amount of compressed air consumption
  - **Ultrasonic leak detectors** are extremely useful
  - **An ongoing program** involving all departments is essential
  - A program in a U.S. auto plant resulted in sustained savings of over **$2,000/day**
Leaks are a function of the supply pressure in an uncontrolled system
Higher pressure = greater flow
Lower pressure = less leak flow

### Discharge of air through an orifice (SCFM)

<table>
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<th>Supply Pressure (psi)</th>
<th>1/64”</th>
<th>1/32”</th>
<th>1/16”</th>
<th>1/8”</th>
<th>¼”</th>
<th>3/8”</th>
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<tr>
<td>70</td>
<td>.300</td>
<td>1.20</td>
<td>4.79</td>
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<tr>
<td>80</td>
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<tr>
<td>90</td>
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<td>94.8</td>
<td>213</td>
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<tr>
<td>100</td>
<td>.406</td>
<td>1.62</td>
<td>6.49</td>
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<td>125</td>
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<td>1.98</td>
<td>7.90</td>
<td>31.6</td>
<td>126</td>
<td>284</td>
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Identifying Leaks – Three Good Ways

- **Routinely** have **maintenance walk** the system looking for hissing noises
  - Ultrasonic probes can help
- Start an **employee tagging program** for air leaks
  - Reward workers where possible
- Perform **bleed down test** on the compressed air system when plant is not operating
  - Determine total leak rates with an estimate of system volume
Remove Inappropriate Air Demands

- **Inappropriate Uses**
  - Cabinet cooling
  - Liquid agitation or stirring
  - Vacuum generation
  - Unregulated Open Blowing
  - Air Motors
  - Atomizing

- Many applications can be served more **efficiently** by:
  - Low pressure air from a **fan** or **blower**
  - A vacuum pump
  - Electric motors
Lower Pressure Setpoints

- Lower pressure reduce leakage and usage rates
  - Every additional 2 psi costs 1.5% to 2% in energy

- Things to check
  - Check **pressure drops** through dryers, filters and piping systems
  - Applications that need higher pressure

- Measures to lower compressed air pressure
  - Modify **high pressure applications** to operate at lower pressure
  - Use an **amplifier or booster** to serve the single high-pressure point of need
Lower Compressor Inlet Air Temperature

- **Relocate compressor intake to cooler place**
  - If plant is conditioned, intake air from inside in the summer and outside in the winter
  - If plant is not conditioned, intake air from outside both in the summer and in the winter
  - Exceptions are some rotary screw compressors that can be damaged by the exposure to moisture and extreme cold

Because cooler air is more dense, compressors do less work compressing the air
No-loss Draining

- **Time-interval based drain**
  - *Wastes* compressed air
  - Only option for some old tanks and filters

- **No-loss drains**
  - *Liquid-level* based
  - Eliminates compressed air loss
  - Automatic
  - Can report with alarms
  - Feedback on dryer performance
Compressors can be ducted for waste heat recovery.
Recover Waste Heat – Water Cooled

- Up to 180F hot water
- Better year-round usage
AIRMaster+ Tool

AIRMaster+ a Windows based software tool used to model and analyze industrial compressed air systems:

- Measure / Calculate Annual Baseline Energy & Cost
- Input 24-hour metered airflow or power data
- Assign electrical utility energy schedules
- Simulate compressed air system operation
- Model system operation at various loads
- Estimate Savings of Energy Efficiency Measures
- Is not a substitute for an experienced auditor!

https://www.energy.gov/eere/amo/articles/airmaster
LogTool v2

- Import data from different types of data loggers
- Display trend plots with one or two Y axes
- Assist in the analysis of compressed system performance measurements
- Display DayType plots
- A companion tool for AIRMaster+, also available from the Compressed Air Challenge

https://www.energy.gov/eere/amo/articles/airmaster
Integrated Energy Software - MEASUR

- All system level software tools will be available through one platform
- Includes system modelers and individual calculators for field validation
- Includes built-in guides and tutorials

https://www.energy.gov/eere/amo/measur
Top 5 Energy Conservation Measures

1. **Eliminate inappropriate uses** of compressed air
2. **Minimize** compressed air **leaks**
3. **Lower pressure** of system (& requirements of end uses)
4. **Lower** inlet air **temperature**
5. **Provide appropriate quality** of compressed air for manufacturing processes (**do not over-dry** the air)
Rules of Thumb

- Lowering compressor pressure setpoints by 2 psig results in ~1.5% energy savings
- Lowering compressor inlet air temperature by 10°F will result in ~2% energy savings
- 80%-93% of the electricity going into compressors is lost as heat
- The energy consumption by a 1 hp air motor requires 7-8 hp at the air compressor
- A 1 hp air motor needs about 30 scfm at 90 psig
1. Improving Compressed Air System Performance: A Sourcebook for Industry
2. Better Plants Energy Treasure Hunts Info Cards
3. Better Plants Energy Treasure Hunt Cheat Sheets
4. Compressed Air System Tip Sheets
5. Compressed Air Best Practices
6. Better Plants In-Plant Training Calendar
7. Compressed Air Challenge Training Calendar
8. MEASUR Tool
9. AIRMaster+ and LogTool
Homework #3

1. Identify the **compressed air pressure setpoint**

2. Identify **5 leaks**

3. Identify **1 compressed air application that can be served lower pressure fan or blower**
Questions/Comments?
Q & A
Better Buildings

Better Buildings is an initiative of the U.S. Department of Energy (DOE) designed to improve the lives of the American people by driving leadership in energy innovation. Through Better Buildings, DOE partners with leaders in the public and private sectors to make the nation’s homes, commercial buildings and industrial plants more energy efficient by accelerating investment and sharing of successful best practices.
Better Plants Online Learning Series

**BETTER PLANTS TOWN HALL**
Thr, Apr 16, 2020 | 1:00 - 2:00 PM ET

**BASICS OF ENERGY**
Thr, Apr 23, 2020 | 1:00 - 3:00 PM ET

**LIGHTING, HVAC, AND BUILDING ENVELOPE**
Wed, Apr 29, 2020 | 1:00 - 3:00 PM ET

**RESOURCES YOU SHOULD KNOW:**
USDA Rural Development Programs & the Dept. of Commerce Manufacturing Extension Partnership
Thr, May 7, 2020 | 1:00 - 2:00 PM ET

**COMPRESSED AIR SYSTEMS**
Thr, May 14, 2020 | 1:00 - 3:00 PM ET

**WATER EFFICIENCY**
Thr, May 21, 2020 | 1:00 - 2:00 PM ET

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Additional Questions?

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http://betterbuildingssolutioncenter.energy.gov/better-plants

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