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

Visit our Online Learning Series page on the Solution Center to see our full series lineup, RSVP, and access previously recorded webinars.
Eli Levine
U.S. Department of Energy
<table>
<thead>
<tr>
<th>Webinar Topic</th>
<th>Speaker</th>
<th>Date</th>
<th>Time</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Energy Treasure Hunts with EPA</td>
<td>Alex Floyd (Tyson)</td>
<td>08/20/20</td>
<td>1:00 – 2:00pm EST</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Walt Brockway (ORNL)</td>
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<tr>
<td></td>
<td>Walt Tunnessen (EPA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Pumps and Fans</td>
<td>Thomas Wenning (ORNL)</td>
<td>08/27/20</td>
<td>1:00 – 2:30pm EST</td>
<td>Register</td>
</tr>
<tr>
<td>9. Process Heating and Waste Heat</td>
<td>Sachin Nimbalkar (ORNL)</td>
<td>09/03/20</td>
<td>1:00 – 2:30pm EST</td>
<td>Register</td>
</tr>
<tr>
<td>Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Field Validation</td>
<td>TBD</td>
<td>09/10/20</td>
<td>1:00 – 2:30pm EST</td>
<td>Register</td>
</tr>
<tr>
<td>11. Energy Management During a</td>
<td>TBD</td>
<td>09/17/20</td>
<td>1:00 – 2:30pm EST</td>
<td>Register</td>
</tr>
<tr>
<td>Pandemic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. MEASUR Tool Suite</td>
<td>Kristina Armstrong (ORNL)</td>
<td>09/24/20</td>
<td>1:00 – 2:00pm EST</td>
<td>Register</td>
</tr>
<tr>
<td>13. Process Cooling</td>
<td>Wei Guo (ORNL)</td>
<td>10/01/20</td>
<td>1:00 – 2:30pm EST</td>
<td>Register</td>
</tr>
</tbody>
</table>
Please go to www.slido.com using your mobile device, or by opening a new window

Enter Event Code

#DOE
Agenda for Today

1. Pumps and Fans– Overview
2. Q&A using Slido
Tom Wenning
Oak Ridge National Lab
Better Plants
U.S. DEPARTMENT OF ENERGY

Pumps and Fans

Thomas Wenning, PE
Potential Energy Saving Opportunities

Typical Energy Consumption Rates

- Process Heating/Steam Systems: 60 – 80%
- Electric Motor Systems: 8-15%
- Pumping Systems: 7-15%
- Compressed Air Systems: 2-7%
- Other*: < 2%

* Other ancillary energy usages such as lighting represent less than 2% of energy consumption

Potential Energy Saving Opportunities

- 10% to 30%
- 5% to 10%
- 10% to 20%
- 10% to 20%
- 5% to 10%
Fluid Flow System Fundamentals

Typical Motor System Losses

- Controller losses: <1 to ~5% for ASD
- Coupling device losses: <1 to >10% for large speed reduction
- Electrical distribution system losses: <1 to 5%
- Motor losses: 3.5 to >10%
- Driven load losses: 30 to 50% for pumps and fans
- Load modulation devices: 0 to >50%

Example:

- \[ W_{elec} = \frac{W_{fluid}}{\text{Eff}_{pump} \times \text{Eff}_{drive} \times \text{Eff}_{motor}} \]
- \[ W_{elec} = 1 \text{ kWh} / [.70 \times .92 \times .90 ] = 1.7 \text{ kWh} \]
Fluid Flow System Fundamentals

\[ W_{elec} = V \Delta P_{total} / [Eff_{pump} \times Eff_{drive} \times Eff_{motor}] \]

- Reduce volume flow rate
- Reduce required pump head
  \[ \Delta P_{static} \]
  \[ \Delta P_{velocity} \]
  \[ \Delta P_{elevation} \]
  \[ \Delta P_{headloss} \]
- Increase pump, drive, motor efficiency
Fluid Flow System Fundamentals

For Pump Systems

\[ W_{\text{brake}} (\text{hp}) = \frac{\text{Flow Rate (GPM)} \times \text{Head (ft w.c)} \times \text{S.G.}}{3960 \times \text{Eff}_{\text{pump}}} \]

For Fan Systems

\[ W_{\text{brake}} (\text{hp}) = \frac{\text{Flow Rate (CFM)} \times \text{Head (in w.c)}}{6356 \times \text{Eff}_{\text{fan}}} \]
\[ W_{\text{fluid}} = V \Delta P \]

\[ \Delta P_{\text{total}} = V (k V^2) = k V^3 \]

\[ W_{\text{friction}} = V \Delta P_{\text{friction}} = k / D^5 \]
Example scenarios indicating potential opportunity

- Throttle valve-controlled systems
- Bypass (recirculation) line normally open
- All parallel pumps run all the time
- Constant pump operation in a batch environment or frequent cycle batch operation in a continuous process
- Cavitation noise (at pump or elsewhere in the system)
- High maintenance cost
- Systems that have undergone change in function
## Top 10 Frequently Identified Pump Opportunities
### Save Energy Now Assessments - 2006 to 2011

<table>
<thead>
<tr>
<th>Top Ten Frequently Identified Pump Opportunities (ESAs - 2006 to 2011)</th>
<th>No. of Times Identified</th>
<th>Average Energy MMBtu Savings Identified (Source)</th>
<th>Average Source Energy Savings % Identified (%)</th>
<th>Average Energy Cost Savings Identified ($)</th>
<th>Average Energy Cost Savings % Identified (%)</th>
<th>Average of Payback Period Actual (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive valve friction loss all of the time</td>
<td>83</td>
<td>11,629</td>
<td>0.2</td>
<td>$55,878</td>
<td>0.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Less than optimal equipment for the application</td>
<td>58</td>
<td>7,611</td>
<td>0.2</td>
<td>$42,107</td>
<td>0.2</td>
<td>3.3</td>
</tr>
<tr>
<td>More flow than required to meet system requirements</td>
<td>50</td>
<td>6,161</td>
<td>0.3</td>
<td>$35,012</td>
<td>0.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Excessive valve friction loss part of the time</td>
<td>31</td>
<td>10,114</td>
<td>0.3</td>
<td>$56,864</td>
<td>0.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Excessive recirculation</td>
<td>27</td>
<td>7,211</td>
<td>0.3</td>
<td>$41,971</td>
<td>0.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Degraded equipment performance</td>
<td>15</td>
<td>6,242</td>
<td>0.6</td>
<td>$44,321</td>
<td>0.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Unneeded flow path</td>
<td>9</td>
<td>3,088</td>
<td>0.1</td>
<td>$20,373</td>
<td>0.1</td>
<td>2.0</td>
</tr>
<tr>
<td>Change time of use</td>
<td>7</td>
<td>7,314</td>
<td>0.2</td>
<td>$52,650</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Excessive friction loss due to system design</td>
<td>4</td>
<td>8,589</td>
<td>0.3</td>
<td>$51,794</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>System specs exceed system requirements</td>
<td>4</td>
<td>7,843</td>
<td>0.2</td>
<td>$51,723</td>
<td>0.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

*Based on Save Energy Now assessments conducted between 2006 to 2011. Numbers are as of October 1, 2011.*
30% to 50% Potential Savings

Conventional Pumping System (Efficiency ~ 31%)
- Input Power 100
- Standard motor efficiency = 90%
- Coupling efficiency = 98%
- Throttle efficiency = 66%
- Pipe efficiency = 69%
- Pump efficiency = 77%
- Output power = 31

Efficiency Optimized Pumping System (Efficiency ~ 72%)
- Input Power 100
- Variable speed drive efficiency = 96%
- High-efficiency motor (eff. ~ 95%)
- Coupling efficiency = 99%
- Improved piping (eff. ~ 90%)
- High efficiency pump (eff. ~ 88%)
- Output power = 71.5

Based on UNIDO, 2011.
Reduce Unnecessary Demand

- Potential Energy Savings – 1 to 3.5%
- Cost of conserved energy - 84 US $/MWh-saved
Increase Reservoir Level to Reduce Elevation Head

- 13 ft
- 15.5 ft
- $z = 2.5$ ft

Diagram showing a reservoir with water at 13 ft and elevation head at 15.5 ft.
Minimize Pipe Friction

Use Bigger Pipes/Ducts
- Use large diameter pipes:
  - $\Delta P$ head loss $\sim k / D^5$
  - Doubling pipe diameter reduces friction by 97%

Use Smooth Pipes/Ducts
- Use smooth plastic pipes:
  - $f_{\text{steel}} = 0.021$  $f_{\text{plastic}} = 0.018$
  - Pumping savings from plastic pipe
    $(0.021 - 0.018) / 0.018 = 17\%$
Fan Systems
Fan Systems Fundamentals

Comprehensive Approach: Fan Systems

- Motor Efficiency
- Fan Efficiency
- Electrical Input Power
- Mechanical Input Power
- Pressure
  - Variable
  - Fixed
- Flow
  - Non-productive Use
  - Productive Use

Focused on the Overall System
Fan Systems Fundamentals

Fan Power = \( \frac{\text{Flow} \times \text{Pressure}}{\text{Fan Efficiency}} \)

To Reduce Power
\( \rightarrow \) Reduce Flow and/or
\( \rightarrow \) Reduce Pressure and/or
\( \rightarrow \) Increase Efficiency

Fan Energy = Power \times Time

To Reduce Energy
\( \rightarrow \) Reduce Power and/or
\( \rightarrow \) Reduce Time
## Top 10 Frequently Identified Fan Opportunities

### Save Energy Now Assessments - 2006 to 2011

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</tr>
</thead>
<tbody>
<tr>
<td>Use Variable Speed Drive</td>
<td>80</td>
<td>12,892</td>
<td>0.2</td>
<td>$72,004</td>
<td>0.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Install new appropriately sized fan</td>
<td>34</td>
<td>20,891</td>
<td>0.7</td>
<td>$131,866</td>
<td>0.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Shut off unneeded fans</td>
<td>18</td>
<td>18,975</td>
<td>1.2</td>
<td>$125,246</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Change belt drive ratio</td>
<td>18</td>
<td>2,851</td>
<td>0.3</td>
<td>$15,658</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Install new appropriately sized impeller</td>
<td>16</td>
<td>24,430</td>
<td>0.5</td>
<td>$117,680</td>
<td>0.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Improve arrangement of air intake</td>
<td>5</td>
<td>8,237</td>
<td>0.1</td>
<td>$48,240</td>
<td>0.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Reconfigure pollution control equipment</td>
<td>5</td>
<td>17,393</td>
<td>1.1</td>
<td>$112,005</td>
<td>1.1</td>
<td>8.6</td>
</tr>
<tr>
<td>Recover heat from exhaust air</td>
<td>4</td>
<td>95,384</td>
<td>2.6</td>
<td>$588,210</td>
<td>3.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Rearrange ductwork at fan inlet or discharge</td>
<td>3</td>
<td>82,387</td>
<td>0.7</td>
<td>$300,633</td>
<td>0.6</td>
<td>1.3</td>
</tr>
<tr>
<td>De-tip fan blades</td>
<td>2</td>
<td>2,093</td>
<td>0.1</td>
<td>$10,300</td>
<td>0.1</td>
<td>3.9</td>
</tr>
</tbody>
</table>

*Based on Save Energy Now assessments conducted between 2006 to 2011. Numbers are as of October 1, 2011.*
Use Gradual Elbows

Credit: Vern Martin

Field Conditions

- Lack of planning?
- Capital costs?
- Existing obstructions?
- Lack of awareness?
Reduce Pressure Loss across Flow Components

Credit: Vern Martin
The Worst Case

Credit: Vern Martin
Retrofitting with High Efficiency Impellers

Model testing required to confirm performance prediction.

Credit: Vern Martin
Leakage and Buildup
Inefficient Flow Control

By-pass loop (No savings)  By-pass damper (No savings)  Outlet valve/damper (Small savings)  Inlet vanes (Moderate savings)

Credit: Dr. J. Kelly Kissock
Efficient Flow Control

- Trim impellor for constant-volume pumps
- Slow fan for constant-volume fans
- VFD for variable-volume pumps or fans

Credit: Dr. J. Kelly Kissock
Correct Fan Inlet/Exit Conditions

No

Yes

Credit: Dr. J. Kelly Kissock
Use Variable Speed Drive

- Matching speed to load
- Since fan power reduces as the cube of the speed ratio, there could be tremendous energy savings.
- VFDs provide much more precise control than dampers.
- Variable speed changes performance characteristics - Application sensitive
- Do complete analysis of ALL associated elements before applying
Useful Diagnostic Tools
Pressure Measurement
Very Low Pressures & Furnace Draft

Permit accurate resolution of pressures below 1 in w.c., such as:

- Furnace pressure or draft
- Very low line pressures or differentials
- Duct & pipe velocities & flows when used in conjunction with a pitot-static tube.

Advantages:
- Highly accurate, simple to use

Disadvantages:
- Requires careful leveling & zeroing, which must be rechecked periodically
- Fluid easily blown out by overpressure

Useful Tools - Draft Gauges & Inclined Manometers
Gas Flow (Velocity) Measurement

Useful Tools – Pitot Tube

Gas velocity \( \left( \frac{ft}{min} \right) = 1096.7 \times \sqrt{\frac{P_v (in. w. c. )}{D \left( \frac{lbs}{ft^3} \right)}} \)

Used with Differential Manometer to Measure the Velocity of Air or Flue Gases in Ducts, Piping, or Flues.

Pressure differentials are read at several predetermined points in duct. Values are averaged.

Differentials are converted to velocities with a chart or using the equation below.
Useful Tools – Fluid Manometers

Pressures up to ~60 in w.c. (15 kPa)

Fluid Manometers -- U-Tube (shown) or Straight Tube for Measuring:

- Air & Gas Pressures
- Air & Gas Differential Pressures (Orifice Meters)

Advantages:
- Easy to set up & use -- virtually “idiot-proof”
- No calibration problems or drift

Disadvantages:
- Awkward to use in cramped locations
- Pressure tubing subject to melt-through on hot surfaces
Alternative to liquid-filled manometer

Available in ranges as low as 0 – 1 in w.c. (0.25 kPa) and up to 145 psi (10 bar).

Advantages:

• More compact, easier to transport & handle than liquid manometer
• No filling or spilling of fluid
• No guessing at pressure readings

Disadvantages:

• Like all electronic instruments, subject to drift - requires periodic recalibration
• Not as wide a selection of pressure ranges/resolutions as liquid manometers

It’s wise to have a liquid manometer on hand to use as a calibration standard for the electronic gauge.
Field Validation and Diagnostic Equipment

Helping Better Plants Partners measure operational data to evaluate equipment performance and quantify energy performance improvement

- **Free of charge**, including shipping
- Use equipment for one day, or up to **four weeks**
- Some **technical assistance** with selection and usage
- First come, first serve application
- 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 10 Energy Conservation Measures for Pumps

1. Shut down pumps when not needed by manufacturing processes
2. Operate the minimum number of pumps that systems require
3. Use VFD instead of throttle valve for flow control
4. Trim or change pump impellers on oversized pumps
5. Reduce pipe and valve pressure losses
6. Re-tune pumping system when manufacturing process requirements change
7. Restore internal housing clearance
8. Replace worn throat bushings, wear rings, impellers, and pump bowls
9. Install new properly sized/selected pumps
10. Replace standard efficiency motors with NEMA premium motors
Top 5 Energy Conservation Measures for Fans

1. Shut down fans when not needed by manufacturing processes

2. Use VFD instead of modulating dampers for air flow control

3. Use VFD instead of inlet guide vanes for air flow control

4. Replace standard V-belts with cogged V-belts

5. Operate close to Best Efficiency Point
Rules of Thumb and Unit Conversions

- Annual motor operation cost: $300/hp*
- Decreasing pump flow rate by 50% can reduce pump power by 88%
- Fan power: 1000-1500 CFM/hp
- Fan annual energy cost: $350/1000 CFM**
- Air handling unit fan air flow sizing: 400 CFM/ton
- 1 in w.c. = 0.036 psi; 1 CFM = 28.3 l/min; 1 HP = 745.7 W
- 1 ft w.c. = 0.43 psi; 1 GPM = 0.00144 MGD

*Based on 5 cents/kWh, 93% efficiency, 3 shifts, 7 days a week operation, two weeks off/downtime.
** Based on 5 cents/kWh, 8760 hours per year.
Resources, Tools, and Training Opportunities

1. Improving Pump System Performance: A Sourcebook for Industry
2. Improving Fan System Performance: A Sourcebook for Industry
3. Better Plants Energy Treasure Hunts Info Cards and Cheat Sheets (Phase 2, Part 2)
4. Pump System Tip Sheets and Case Studies
5. Better Plants In-Plant Training Calendar
6. MEASUR Tool
7. Pumping System Assessment Tool
8. Fan System Assessment Tool
Submit Questions
www.slido.com event code #DOE
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ENERGY TREASURE HUNTS WITH EPA
Thr, Aug 20, 2020 | 1:00 - 2:00 PM ET

PUMPS AND FANS
Thr, Aug 27, 2020 | 1:00 - 2:30 PM ET

PROCESS HEATING & WASTE HEAT RECOVERY
Thr, Sep 3, 2020 | 1:00 - 2:00 PM ET

FIELD VALIDATION
Thr, Sep 10, 2020 | 1:00 - 2:00 PM ET

ENERGY MANAGEMENT DURING A PANDEMIC
Thr, Sep 17, 2020 | 1:00 - 2:00 PM ET

MEASUR TOOL SUITE
Thr, Sep 24, 2020 | 1:00 - 2:00 PM ET

PROCESS COOLING
Thr, Oct 1, 2020 | 1:00 - 2:00 PM ET

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