Energy Impacts of Compressed Air

Rusty Friend
AMEC Foster Wheeler
August 14, 2017
Energy Impacts of Compressed Air

- Energy use and opportunity
- Typical Industrial Uses
- Types of Compressors and Dryers
- Types of end users
- Alternatives to inappropriate usage
- Leaks
- Strategies for large compressed air systems
Compressed Air Energy Use and Opportunity

- 7 out of 10 industries use compressed air.
- Compressed air accounts for 10% of electricity use in the US.
- Electricity makes up around $\frac{3}{4}$ of the costs for a compressed air systems total cost of ownership.
- Inherently inefficient, only about $\frac{1}{8}$ of energy consumed provides useful air power.
Compressed air systems

- A compressed air system uses electrical energy and stores it as potential in the form of air pressure to be used when needed.
- Typical air system includes one or more compressors, dry, storage tank, and lines.
Types of Compressors

• There are two commonly used types of Industrial Compressors
  – Rotary
  – Reciprocating

• Choosing type is based on pressure, flow, air quality, environment and more

• Rules of Thumb
  – 2 PSIG change ≈ 1% change HP
  – 10° F drop in inlet air ≈ 2% change HP
  – 4-5 CFM per HP at 100 PSIG
Types of Compressors

- Rotary compressors use rotating parts to continuously compress air.
- Multiple types including screw, vane, scroll
Types of Compressors

- Reciprocating compressors use pistons to compress a certain volume of air with each stroke.
- Range from 1-50 HP
- Typically used when high-pressure and low flow is needed
Types of Dryers

• Dryers help prevent damage to the system by removing the moisture in the air that is condensed during compression

• There are two main types of dryers
  – Refrigerant
  – Desiccant

• The three factors in choosing the right dryer are required dew point, operating pressure and inlet temperature of the compressed air
Type of Dryers

- Refrigerant dryer uses a refrigeration cycle to condense water and drain from lines
- Good for general industrial use
- Reduces dew point to 35-40°F, uses less energy but doesn’t dry as well as desiccant
- Costs is ~10 kWh/day/100cfm
- ~6% of system energy
Type of Dryers

- Desiccant dryers use silica gel, activated alumina or other media to absorb moisture
- Reduces dew point to -40°F, higher quality air but at a price
- Desiccant can be either consumable or regenerated through purge air or recycled heat from compression.
- Costs is ~65 kwh/day/100cfm
Type of End User

• What do we use the air for?
• Uses include
  – Pneumatic hand tools
  – HVAC controls
  – Pneumatic process controls
  – Cleaning - bag house pulsing
  – Plastic molding ejection
  – Product conveying
  – Painting and coating
In my experience inefficient use of compressed air is usually due to one of the following:

- Ignorance of cost
- Convenience
- Because its fun!
### Inefficient uses of compressed air

<table>
<thead>
<tr>
<th>Possible Inappropriate Uses</th>
<th>Suggested Alternatives/Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean-up, Drying, Process cooling</td>
<td>Low pressure blowers, electric fans, brooms, nozzles</td>
</tr>
<tr>
<td>Sparging</td>
<td>Low pressure blowers and mixers</td>
</tr>
<tr>
<td>Aspirating, Atomizing</td>
<td>Low pressure blowers</td>
</tr>
<tr>
<td>Padding</td>
<td>Low to medium pressure blowers</td>
</tr>
<tr>
<td>Vacuum generator</td>
<td>Dedicated vacuum pump or central vacuum system</td>
</tr>
<tr>
<td>Personnel cooling</td>
<td>Electric fans</td>
</tr>
<tr>
<td>Compressed air-operated cabinet coolers</td>
<td>Air-to-air heat exchanger or air conditioner</td>
</tr>
<tr>
<td>Air motor-driven mixer</td>
<td>Electric motor driven mixer</td>
</tr>
<tr>
<td>Air-operated diaphragm pumps</td>
<td>Proper regulator and speed control; electric pump</td>
</tr>
<tr>
<td>Idle equipment*</td>
<td>Put an air-stop valve at the compressed air inlet</td>
</tr>
<tr>
<td>Abandoned equipment**</td>
<td>Disconnect air supply to equipment</td>
</tr>
</tbody>
</table>

*Equipment that is temporarily not in use during the production cycle.
**Equipment that is no longer in use either due to a process change or malfunction.

www.nrel.gov
Alternatives to inappropriate usage

• Blowers instead of compressed air for cleaning (~75% savings)
• Brooms or vacuums (shop vacs) instead of compressed air
• Cooling fans or HVAC instead of cabinet coolers
• Pneumatic motors or actuators should be replaced with electric if possible
Leaks

- Leaks can be 10%-50% of load on system
- Leaks often occur at joints and the connections to machinery
- Cost of leak is related to size

<table>
<thead>
<tr>
<th>Diameter of Hole</th>
<th>CFM lost at 100 psig</th>
<th>Est. kWh lost annually (.18kW/CFM)</th>
<th>Annual cost (.10 $/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/16”</td>
<td>6.49</td>
<td>9345.6</td>
<td>$935</td>
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<tr>
<td>1/4”</td>
<td>104</td>
<td>149760</td>
<td>$14,976</td>
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<tr>
<td>1/2”</td>
<td>415</td>
<td>597600</td>
<td>$59,760</td>
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<tr>
<td>1”</td>
<td>1,661</td>
<td>2391840</td>
<td>$239,184</td>
</tr>
</tbody>
</table>
Estimating Leak Costs

How to estimate total leak loss (and cost):

1. Time your air compressor operation (loaded, unloaded and off) for 10 minutes when there is compressed air demand

2. Loaded time/10 minutes = leak demand as percentage of compressor capacity

3. Multiply the nameplate power (HP) by the number of minutes at full load and 35% of nameplate power (HP) by the number of minutes unloaded, add together and divide by 10. This is the continuous HP that it takes to maintain your leaks

4. Convert HP to kW and multiply by the annual hours of operation, multiply by your electric rate and you have the annual cost of maintaining your leaks
Leak Identification

• How to identify leaks
  – Listen and feel – only works for large leaks
  – Ultrasonic acoustic – Uses a microphone to pick up high frequency noises from the leaks
  – Soapy water – Brush on areas that are probably leaking, see if it bubbles
Correcting Leaks

1. Most leaks are at pipe unions. Pay close attention to hose reels, FRLs (filter, regulator, lubricators)
2. Inspect quick connect fittings for wear
3. Look for cracked drain valves. These are not an acceptable alternative to proper drying
Strategies for large compressed air systems

Pressure Control

• Minimize header pressure – A system should be able to operate at a compressor pressure no more than 10 psi above the compressor set point

• Stage compressors
  – Program lead/lag controls to small psi range
  – Locate compressors together
  – Have sufficient storage

• Install local capacity tanks

• Isolate low-flow high-pressure demand

• Turn system off when not needed
Strategies for large compressed air systems

Manage Compressor Heat

• Use compressor waste heat for building heat – deflect heat outside in the summer and inside in the winter

• Make sure that compressor rooms are well ventilated

• Follow compressor maintenance/oil change schedules

• Don’t allow hot outlet air from one compressor become the inlet air to its neighbor

• Consider water-cooled for large systems
Strategies for large compressed air systems

Use compressor controls to help match the supply of the air with the demand, minimizing waste

• These controls differ based on whether it’s a single or multi-compressor system as well as demand type

• Use a flow controller - A flow controller is a device that receives and stores air at a higher pressure and supplies a lower pressure constant flow. This lets a compressor run at a more efficient full-load and stabilizes fluctuations

• Properly sized storage tanks also allow better response to peak demands by reducing pressure drops
Take something back home to your facility

1. Perform the leak cost estimator test
2. Perform your own compressed air leak audit:
   a) Take a stroll around your facility when it is quiet and listen for and locate leaks- tag them.
   b) Use your hands to feel for leaks around FLRs, hose reels, and quick-connect fittings (better yet use your soap spray bottle) and tag them
   c) Schedule a maintenance assistant and go around and repair leaks together
3. Slowly drop the header pressure 1 psi per day until someone complains
4. Redo the leak cost estimator test and compare to the first one.
5. Calculate how much money you saved and what a hero you are

Good Luck – Questions?
Air Quality

- Air Quality is a measure of three contaminants: water vapor, solid particles, and oil content
- Four general categories are used to group quality needs: Power, Instrument, Process, Breathing
- ISO 8573.1 is a common reference for quality classifications
  - Each contaminant has a quality class and the typical class assigned for different applications
Air Quality

- Solid particles are removed using filters
  - Filters remove dust, rust and other solids down to one micron. Will remove some lubricant and desiccant fines too
- Filter placement and strategies to correct
  - Start large and progress smaller
Air Quality

- Oil is introduced from compressor lubrication
- Oil vapor droplets are small enough to pass through mechanical filters; if a lower oil ppm is needed coalescing oil filters and oil vapor adsorber can be used
- Filter placement and strategies to correct
  - Fill
Controls

• Single Compressor controls include:
  – Start/Stop – Simply turns motor on/off to meet pressure requirements. Not good for frequent cycling
  – Load/Unload – Instead of turning the motor off it unloads the compressor and runs at 15-35% of full load horsepower
  – Modulating Controls – Throttles inlet to match flow requirements (typically used on rotary screw)
  – Part-load Controls - Compressors designed to run at different loads (i.e. 0%, 50%, 100%) to match demand.
  – Variable Frequency Drives (VFDs) - Becoming a viable option. Controls motor speed to maintain pressure
Controls

• Multi-Compressor Controls
  – Sequencer – These turn on/off compressors to match the current demands and maintain required pressure
  – Multi-Master – Creates a network between compressors controlling the individual compressors as well as the whole system

[Diagram showing CFM-AAD/AIR CONSUMPTION vs TIME with load profiles and VSD speed control]

The VSD is able to slow down and speed up to match all the compressors output capacity to the existing demand capacities without control gaps.