Conserving Energy in Compressed Air Systems
Presented to the
MA Toxic Use Reduction Institute
Resource Conservation Training
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Presentation Outline
• How Much Does CAir Cost -Introduction
• Supply Side
  – Components – how they perform and work together
  – Where to look for savings
• Demand Side
  – System components
  – Appropriate and inappropriate uses
  – Control Issues
  – Where to look for savings

Welcome to the Wonderful World of Compressed Air
CAir analysis needs a different mind set.
Example: A leak is blowing out 100 CFM
Questions:
Will more air be wasted at 50 psi or 100 psi?
Will more energy be wasted at 50 psi or 100 psi?

10 Year Compressor Ownership Costs

Cost of Compressed Air
Example: 6” grinder: 50 CFM or 1.0 kW electric
18 kW / 100 CFM (typical eff. of comp.)
18 kW / 100 x 50 = 9 kW
9 / 1 = CAir is 9 times more expensive
With only 50% effective conversion rate
CAir is 18 times more expensive
(1 constant CFM > $237/year @ $0.15/kWh)
Supply Side Components

- Compressors
  - Controls
- Dryers
  - Controls
- Traps
- Receiver
- Filters

Types of Compressors

Operating Range of Compressor Types

| Component Type | Operating Range (psi) | Compression Ratio | Displacement (cubic feet per minute) | Efficiency (%)
|----------------|-----------------------|-------------------|-------------------------------------|----------------
| Double Acting 2 Stage Reciprocating | 50 - 1,200 | 2:1 | 100 | 90 |
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| Reciprocating | 50 - 1,200 | 2:1 | 100 | 90 |

Comparision of Compressor Technologies

<table>
<thead>
<tr>
<th>Component Design</th>
<th>High</th>
<th>Acme</th>
<th>Danner</th>
<th>Smith</th>
<th>Sunbeam</th>
<th>Westmoreland</th>
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<tbody>
<tr>
<td>Type</td>
<td>Single Acting</td>
<td>Double Acting</td>
<td>Single Acting</td>
<td>Double Acting</td>
<td>Single Acting</td>
<td>Double Acting</td>
</tr>
<tr>
<td>RPM (RPM)</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>Power (kW)</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Cooling (kW)</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Horsepower (HP)</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
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<tr>
<td>Horsepower (kW)</td>
<td>19</td>
<td>22</td>
<td>26</td>
<td>30</td>
<td>34</td>
<td>38</td>
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<tr>
<td>Torque (Nm)</td>
<td>350</td>
<td>420</td>
<td>490</td>
<td>560</td>
<td>630</td>
<td>700</td>
</tr>
<tr>
<td>Torque (lbf-ft)</td>
<td>250</td>
<td>300</td>
<td>350</td>
<td>400</td>
<td>450</td>
<td>500</td>
</tr>
<tr>
<td>Displacement (cubic feet per minute)</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td>350</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Noise Level (dB)</td>
<td>70</td>
<td>75</td>
<td>80</td>
<td>85</td>
<td>90</td>
<td>95</td>
</tr>
<tr>
<td>Size (cm)</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td>350</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>500</td>
<td>750</td>
<td>1000</td>
<td>1250</td>
<td>1500</td>
<td>1750</td>
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</table>
Small On/Off Reciprocating

Reciprocating Compressor Controls

- On / Off
- Step Unloading

Reciprocating Compressor Control Comparisons

Centrifugal Compressor

Centrifugal Compressor

Centrifugal Compressor Control

- Modulating
  - Inlet Guide Vanes
  - Butterfly Valve
- Dual / Auto Dual
Screw Compressor

Cut Away of a Screw

Screw Geometry Control

Screw Compressor Controls

- Modulating (Inlet Valve)
- Load / Unload
- Dual / Auto Dual
- Geometry (Turn/Spiral, Poppet valves)
- Variable Speed
- Effects of Receiver Size
Screw Compressor Control Comparisons

On-Line/Off-Line Cycle

Air Compressor On-Line / Off-Line Performance Based on Air Receiver Capacity

CAGI Compressor Data Sheet
Rotary Compressor: Variable Speed Drive

Air Compressor Curve Tool.XLS -- INPUTS
**Other Common Types of Compressors**

- Liquid Ring
- Sliding Vane
- Axial
- Lobe

**Liquid Ring Air Compressor**

**Sliding Vane Compressor**

**Axial Compressor**
Lobe Compressor

Compressor Conservation Measures

- Lower operating pressure
  - 1% savings for each 2 psi drop
- Coordinate control of multiple comps
  - Partly load only one compressor
- Add storage for on-line/off-line controlled compressors
- Get intake air from outside
- Turn off during unoccupied times

Refrigerated Dryer

Non-Cycling
- Dew points to 28°F

Cycling

Cold Regeneration Desiccant Dryer

Dew points to ~90°F
Purge ~20% of rated

Dry compressed air
Most compressed air
Desiccant Dryers

- Internal heat reactivated
  - Dew points to -40 F
  - Purge ~ 5% of rated
- External heat reactivated
  - Dew points to -40 F
  - Purge ~ 2% of rated

Heat Of Compression Dryer

Dryer Conservation Measure

For ~ 35°F dew points
- Replace non-cycling refrigerated dryer with cycling refrigerated dryer
- Clean air-cooled condenser

For < 20°F dew points
- Install heat of compression dryer
- Install dew point control on desiccant dryers

Receiver Location – Before Dryer

Advantages:
- Favorable dryer size.
- Non-turbulent flow
- Lower CAir entry temp.
- Lower condensate amount

Disadvantages:
- Condensate in receiver
- Overload of the Dryer

Receiver Location – After Dryer

Advantages:
- No condensate in receiver
- Consistent CAir quality

Disadvantages:
- Large size dryer
- Stress with Recip.
- High entry temp of CAir
- Large quantity of condensate
- Each compressor has its own dryer

CAGI Dryer Data Sheet

Ref: Refrigerated Dryers

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Traps and Drains

Timed Cycle Trap
- Very reliable operation
- Electricity connection required
- No alarm function
- Operates all the time no matter the CAir load
- Doesn’t differentiate between air and water

Air and Water Leakage.XLS

Orifice Flow Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (ft)</td>
<td>0</td>
</tr>
<tr>
<td>Pressure (psig)</td>
<td>100</td>
</tr>
<tr>
<td>Temp (deg F)</td>
<td>80</td>
</tr>
<tr>
<td>Orifice diameter</td>
<td>0.225</td>
</tr>
<tr>
<td>Orifice flow coeff.</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Absolute Atmospheric Pressure: 14.7 psia

Air Flow Rate: 15.7 SCFM
Water Flow Rate: 0.33 GPM

Electronic Level Sensing Trap
- Very reliable operation even with problematic condensates
- Large discharge
- No pressure loss
- Electricity connection required
- Alarm function
- External malfunction signal.

Mechanical Float Trap
- Very reliable operation even with problematic condensates
- Large discharge
- No pressure loss
- Electricity connection required
- Alarm function (at 3)

Trap Conservation Measure
- Avoid manual blow down
- Replace Timed Cycle Trap
- Periodically check traps for proper operation
- Periodically clean traps
**Filters**

**Particulate**
- Dust separator > 50 micron
- Pre-filter > 3 micron
- Micro filters > 0.01 micron

**Coalescing**
- Removes particles, moisture and oil to 0.1 microns

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**Filter Conservation Measures**

- Replace with low pressure drop filters
  - Will only save energy if compressor operating pressure reduced
    - (1% kW saved for each 2 psi drop)

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**Supply Side Conservation Measures**

<table>
<thead>
<tr>
<th>ECO</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low pressure drop inlet filter</td>
<td>2%</td>
</tr>
<tr>
<td>More efficient compressor</td>
<td>10-15%</td>
</tr>
<tr>
<td>Replace/Stop leaking isolation valve</td>
<td>10-20 cfm</td>
</tr>
<tr>
<td>Micro processor sequencer</td>
<td>shut off idling compressor, reduce deadband</td>
</tr>
<tr>
<td>Replace condensate traps</td>
<td>40-80 cfm</td>
</tr>
<tr>
<td>Replace filters</td>
<td>3-10 psi</td>
</tr>
<tr>
<td>Replace dryer</td>
<td>&gt;50% of dryer usage</td>
</tr>
</tbody>
</table>

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**Demand Side of Typical Industrial CAir User**

- Productive Demand: 50%
- Inappropriate Uses / Applications: 10%
- Artificial Demand: 10%
- Leakage Losses: 30%

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**Demand Side Components**

**Distribution System**
- Demand Expander / Intermediate Pressure Controller
- Piping
- Hoses
- FLR (filter, lubricator, regulator)
Demand Expander

- A very quick acting full bore pressure reducer

**Advantages**
- Reduces leakage
- Reduces artificial demand
- Adds capacitance to system

**Disadvantage**
- Requires compressor to operate at higher pressures

Demand Side Components

**End Uses**
- Productive uses
- Inappropriate uses
- Leakage
- Artificial demand

Demand Side Conservation Measures

- Replace nozzles with engineered nozzles
- Purchase more conservative equipment

Reduce Productive Usage

Eliminating or reducing the other components of the graph will increase Productive Demand

Demand Side Conservation Measures

Eliminate Inappropriate Uses

Inappropriate Uses of Compressed Air

- Open blowing
- Aspirating
- Padding
- Dense phase transport
- Personnel cooling
- Cabinet cooling
- Open hand held blowguns
- Sparging
- Atomizing
- Dilute phase transport
- Vacuum generation
- Diaphragm pumps
- Vacuum venturies
Demand Side Conservation Measures

- Artificial Demand
  
  Artificial demand is the excess volume of air that is required by unregulated end uses as a result of supplying higher pressure than necessary for applications.

Reduce Artificial Demand

- Demand Expander / Pressure Controller
- Remote Storage
- End Use Pressure Regulators
- Reduce System Pressure
- Loop Header
- Enlarge Piping
- Low Pressure Drop Filters and other components

Demand Side Conservation Measures

- Leakage Losses

Reduce Leakage

- Perform Detailed Survey
- Make Leak Repairs
- Institute On Going Leak Reduction Program

Testing For Leakage

- Ultrasonic leak detector
- Receiver bleed down test

\[
\text{Leakage, CFM} = \frac{\text{Volume} \times (P_1 - P_2)}{\text{Time} \times 14.7 \times 1.25}
\]

- \( P_1 \) = start pressure, psig
- \( P_2 \) = end pressure, psig
- Volume is in cubic feet
- Time is in minutes

If leakage is greater than 10% of compressor capacity, action should be taken.

Heat Recovery

- Compressed air 4%
- Electrical power 100%
- Hot oil 67%
- Latent heat 2%

* The additional 2% latent heat is the energy released when the moisture in the air condenses.

Recuperative heat 90%
Available Heat To Recover
Compressor Heat Calculator.XLS

<table>
<thead>
<tr>
<th>Absolute Atmospheric Pressure</th>
<th>PPA</th>
<th>14.7 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>single stage</td>
<td>tons</td>
<td>556,185 Btu/hr</td>
</tr>
<tr>
<td>two stage with intercooler</td>
<td>tons</td>
<td>579,985 Btu/hr</td>
</tr>
<tr>
<td>two stage without intercooler</td>
<td>tons</td>
<td>590,250 Btu/hr</td>
</tr>
</tbody>
</table>


Demand Side Conservation Measures

<table>
<thead>
<tr>
<th>ECO</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Expander / Pressure regulator</td>
<td>10 - 15 psi</td>
</tr>
<tr>
<td>Leaks, quick disconnects, open nozzles</td>
<td>10% or more</td>
</tr>
<tr>
<td>Point of use storage</td>
<td>5 - 10 psi</td>
</tr>
<tr>
<td>Complete loop</td>
<td>2.5 - 5 psi</td>
</tr>
<tr>
<td>New main</td>
<td>3 - 8 psi</td>
</tr>
<tr>
<td>New drops</td>
<td>2 - 6 psi</td>
</tr>
</tbody>
</table>


Rules Of Thumb

- Air compressors normally deliver 4 to 5 cfm per horsepower at 100 psi
- Every 2 psi pressure change in pressure equals 1% change in compressor power draw
- Power cost for each hp operating constantly for 1 year = $1,100 @ 15¢/kwh
- A 50 hp compressor rejects heat at about 126,000 btu/h and about 119,000 (> 90%) is recoverable
- Water vapor content of 100°F saturated compressed air = ~ 2 gallons per hour per 100 cfm
- Every 100 cfm of 100 psig air produces 20 gallons of condensate per day

Rules Of Thumb

- Total pressure drop across all components should not be greater than 15 psi
- Locate filters and dryers in the air line before any pressure reducing valve (highest pressure) and after air is cooled to 100°F or less (lowest temperature)
- Water cooled after coolers require ~ 3 gpm per 100 cfm @100 psig
- Most air motors require 30 cfm at 90 psig per horsepower rating
- At 100 psig every 20°F increase in saturated air temp DOUBLES the amount of moisture in the air