Air Compressors
Two Types

- Positive Displacement
  - Reciprocating
  - Rotary Screw

- Dynamic
  - Centrifugal
  - Axial flow
QUINCY PLT - TWO-CYLINDER, TWO-STAGE CUTAWAY

Valve design provides the highest volumetric efficiency in the marketplace, using stainless-steel valves for maximum strength.

One-piece aluminum head for strength and optimum heat dissipation.

ASME-code interstage pressure relief valves.

Graphite cylinder and head gaskets for positive sealing integrity.

Coalescing aluminum mesh crankcase breather reduces oil vapor.

Cast-iron cylinders maintain rigid tolerances for high efficiency.

Two-piece connecting rods make service easier.

High-performance three-piece rings allow less than 5 ppm oil carryover.

Electronically balanced fan-type cast-iron flywheel delivers a powerful flow of air across the intercooler, cylinder and heads for effective unit cooling and smooth operation.

High-efficiency fin and tube intercooler reduces interstage air temperature for maximum performance and increased valve life.

Pressure lubrication 10 and 15 hp models (5 and 7.5 hp crankshaft bearings only).

Computer Aided Designed, balanced counter-weighted crankshaft assures smooth, trouble-free operation.

Cast-iron construction for dependability and smooth operation.

Extra capacity oil reservoir assures low oil temperature.

Low-oil level float cavity.

Gerotor positive displacement pump (counter clockwise rotation only).

Industrial-class bearings ensure long operating life.

Oil level sight gauge.
**Individual valve pockets** allow easy access for routine maintenance.

**High-pressure pistons** are cast-iron for strength and long life.

**Cast-iron cylinders** maintain rigid tolerances for high efficiency.

**Intake unloaders** allow for loadless starting, system flexibility, energy savings, and less wear on the motor.

**Cast-iron valve seats** are lapped for a total seal, eliminating the need for a discharge line check valve.

**Steel valve discs** use a unique low lift design and cast-iron bumpers for increased efficiency and less downtime.

**Intercooler** has large circular fins for maximum heat dissipation and longer life.

**Rifle-drilled, counter-weighted, one-piece crankshaft** reduces vibration, extends life of bearings and wrist pins.

**Cast-iron crankcase and flywheel** for strength and durability.

**Tapered roller bearings** are oversized and easily adjusted for trouble-free operation.

**Aluminum connecting rods** with oil passage for full-flow lubrication to piston pins to extend compressor life.

**Hydraulic unloader and Safe-Q-Lube** protects compressor if oil pressure drops below normal (when loadless starting or dual control is specified).

**Pressure lubrication with positive displacement oil pump** to assure constant lubrication of all critical wear areas.

**Spin-on oil filter** for convenient, clean lubrication.
Rotary Screw Compressors
Rotary Screw Compressors

• “Direct Injection”, “Oil-injected”, “Direct-cooled”, “Flooded”
  - Various names are suggestive of the direct contact of lubricating/cooling oil onto the rotating screw parts
  - Requires a separator just after compression to remove oil from the compressed air

• “Oil-free”, “Oil-less”, “Dry” compressors also available (food industry, hospitals, etc.)
Animations

- http://www.youtube.com/watch?v=g8VpnTRWESQ
- http://www.youtube.com/watch?v=WFZ1bhFEh2U
- http://www.youtube.com/watch?v=zQd-BTxNQHU
Due to overlapping and continuous compression cycles, the rotary screw design generates virtually no vibration. Disturbing noise is minimized, providing a wider choice for the unit's location on the vehicle.

<table>
<thead>
<tr>
<th>Description</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ends of the rotors uncover the inlet: air enters the compression chamber.</td>
<td><img src="image1.png" alt="Diagram" /></td>
</tr>
<tr>
<td>The air is entrapped in the 'compartment' formed by a male lobe and a female flute.</td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>As the rotors turn, the compartment becomes progressively smaller, thereby compressing the entrapped air.</td>
<td><img src="image3.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Compressed air leaves through the outlet port</td>
<td><img src="image4.png" alt="Diagram" /></td>
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</table>
Centrifugal Compressors
Centrifugal Compressors

• https://www.youtube.com/watch?v=rtlF1LdZTak
Improving Compressed Air System Performance

a sourcebook for industry

http://www1.eere.energy.gov/industry/bestpractices/pdfs/compressed_air_sourcebook.pdf
Figure 1.1 Components of a Typical Industrial Compressed Air System.
Compressor Controls

- On/Off (Start/Stop)
- Modulated
- Load/Unload
- Variable Displacement
- Variable Speed Drive (VSD)
Figure 2.4 Pressure Profile Over a Defined Time Period.
Interval data (4 seconds) for System (Not Assigned) and Periods (Not Assigned)
12/15/2008 11:54:06 PM to 12/17/2008 12:32:05 AM
Interval data (4 seconds) for System (Not Assigned) and Periods (Not Assigned)
12/16/2008 10:24:15 AM to 12/16/2008 10:33:08 AM

Amps

Curr_250_hp_rent (Amps)
Curr_250_hp (Amps)
Curr_100_hp (Amps)
Compressors - Saving Energy

• Reduce run time – turn off when not needed
• Lower system pressure to lowest possible level
• Repair leaks
• Recover waste heat
• Additional system volume (load/unload only)
• Reduce use of pneumatic tools
Lower Pressure

• Rule of thumb:
  For systems in the 100 psig range, every 2 psi decrease in discharge pressure results in approximately 1 percent power decrease at full output flow
Lower Pressure – Unregulated Usage

• Rule of thumb:
  For systems with 30 to 50 percent unregulated usage, a 2 psi decrease in header pressure will decrease energy consumption by about 0.6 to 1.0 percent because of unregulated air

• Total is 1.6% to 2% power decrease for every 2 psi drop
Lower Pressure

• Calculations
  – Estimate annual energy usage
    (assume compressor runs fully loaded unless you know otherwise)
    \[ \text{KWh} = \frac{\text{HP}}{\eta_m} \times 0.746 \times \text{LF} \times \text{H} \]
  – Compute reductions: every 2psi reduction is a 1.6% to 2.0% reduction in power, so each 2psi reduction gives 0.984 to 0.98 of the previous value
    \[ \text{kWh}_{\text{new}} = \text{kWh}_{\text{old}} \times (1 - \text{PCT})^{\frac{\Delta P}{2}} \]
    \[ \approx \text{kWh}_{\text{old}} \times (1 - \text{PCT} \times \Delta P/2) \]
Example – Reduce Pressure

• A 150hp compressor runs 90% loaded 12 hours per day 5 days per week at a delivery pressure of 110psi. Estimate the energy and cost savings if the pressure is reduced to 90psi. Assume $0.05/kWh for electricity and the motor is 95% efficient

• Solution:
Assume a 1.8% reduction for every 2psi to account for unregulated usage. First estimate the annual energy usage:
Example/Solution – Reduce Pressure

\[ \text{kWh} = \frac{\text{HP}}{\eta_m} \times 0.746 \times \text{LF} \times H \]

\[ = \frac{150 \text{ hp}}{0.95} \times 0.746 \text{ kW/hp} \times 0.9 \times 3120 \text{ hrs} \]

\[ = 330,753 \text{ kWh/yr} \]

Compute reductions

\[ \text{kWh}_{\text{new}} = 330,753 \text{ kWh} \times (1 - 0.018)^{20/2} \]

\[ = 275,816 \text{ kWh} \]

Energy Savings are 54,937 kWh/yr

Net reduction is 16.6%

At $0.05/kWh, this amounts to $2,747/yr
Reduce Air Leaks

• A typical plant that has not been well maintained will likely have a leak rate equal to 20 percent of total compressed air production capacity.

• Proactive leak detection and repair can reduce leaks to less than 10 percent of compressor output.

Costs calculated using electricity rate of $0.05 per kilowatt-hour, assuming constant operation and an efficient compressor.
Reduce Air Leaks

• Calculations
  – Savings realized depend on the type of compressor controls
  – Input power decreases linearly with decrease in airflow

<table>
<thead>
<tr>
<th>Control</th>
<th>Start/Stop</th>
<th>Mod</th>
<th>Unload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope ($\Delta kW%/\Delta cfm%$)</td>
<td>100/100</td>
<td>35/100</td>
<td>80/100</td>
</tr>
</tbody>
</table>

– So for a 10% reduction in flow by repairing leaks

<table>
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<tr>
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<th>Mod</th>
<th>Unload</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta kW%$</td>
<td>10%</td>
<td>3.5%</td>
<td>8%</td>
</tr>
</tbody>
</table>
Example - Reduce Leaks

• The compressor from the previous example uses modulating controls. The system reduces flow by 10% through a leaks program. Estimate energy and monetary savings at $0.05 per kWh.

• Solution:
  For a 10% reduction in flow, a 3.0% reduction in power results:
Example - Reduce Leaks

Savings = 275,816 kWh/yr x 0.035
= 9,654 kWh/yr

At $0.05/kWh, this comes to:
Cost Savings = 9,654 kWh/yr x $0.05/kWh
= $ 83
Recover Waste Heat

• As much as 80 to 93 percent of the electrical energy used by an industrial air compressor is converted into heat.

• In many cases, a properly designed heat recovery unit can recover anywhere from 50 to 90 percent of this available thermal energy and put it to useful work heating air or water.

• Net potential is 40% to 84% recovery
Example - Recover Waste Heat

• The compressor from the previous example is air cooled. Estimate the amount of natural gas heating that could be displaced during twelve weeks of winter operation, and the cost savings at 85% combustion efficiency and $4.00 /MMBtu fuel cost.

• Solution: Assume 50% of the input power can be recovered:
Example - Recover Waste Heat

\[ \text{Savings} = \text{HP} \times \text{LF} \times 2545 \text{Btu/hp-hr} \times 50\% \times H \]
\[ = 150 \text{hp} \times 0.90 \times 2545 \text{Btu/hp-hr} \times 0.50 \]
\[ \times (12 \text{wks} \times 5 \text{days/wk} \times 12 \text{hrs/day}) \times \frac{1 \text{ MMBtu}}{1 \text{E6Btu}} \]
\[ = 123.7 \text{ MMBtu} \]

\[ \text{Cost Savings} = \frac{\text{Savings}}{\text{EFF}} \times \text{FuelCost} \]
\[ = \frac{123.7}{0.85} \times \$4.00 \]
\[ = \$582 \]
**Examples - Summary**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Energy</th>
<th>Cost/Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline operation</td>
<td>330,753 kWh/yr</td>
<td>$16,538 /yr</td>
</tr>
<tr>
<td>Reduce Pressure</td>
<td>54,937 kWh/yr</td>
<td>$ 2,747 /yr</td>
</tr>
<tr>
<td>Repair Leaks</td>
<td>9,654 kWh/yr</td>
<td>$ 483 /yr</td>
</tr>
<tr>
<td>Recover Waste Heat*</td>
<td>36,254 kWh/yr</td>
<td>$ 582 /yr</td>
</tr>
<tr>
<td>(123.7 MMBtu/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL SAVINGS - Energy</td>
<td>100,845 kWh/yr</td>
<td></td>
</tr>
<tr>
<td>TOTAL SAVINGS - Cost</td>
<td></td>
<td>$ 3,812</td>
</tr>
</tbody>
</table>

*Assumes plant can use all available heat over a 12-week period*
Additional Volume

Figure 2.6  Lubricant-Injected Rotary Compressor with Inlet Valve Modulation.
Figure 2.5  Effect of Receiver Capacity on Lubricant-Injected, Rotary Compressor with Load/Unload Capacity Control.