Compressed Air Systems Evaluation and Improvement

THESIS PRESENTATION
LUKE SWOBODA
Compressed Air Systems Evaluation and Improvement

- **Company Name:** Parker Hannifin
- **Industrial Supervisor:** Anil Verma
- **Senior Design Partner:** Sam Goldschmeding
- **Academic Supervisors:**
  - Dr. Tycho Fredericks
  - Dr. Steven Butt
Content

• Background Information
• First Steps
• External Quotes
• Data Analysis
• Recommendations
• Questions
The Situation

- Compressed air electrical energy consumption is high—27.8% of total plant consumption
- Compressor room is cluttered and laid out inefficiently

![Pie chart showing annual plant electric consumption and annual compressed air system electrical consumption.]

- Annual Plant Electric Consumption: $548,822
- Annual Compressed air System Electrical Consumption: $152,649
Aged Compressors

- Main System is 20 years old
  - 300 HP Sullair
- Back-up system is 50 years old
  - All switches are manual
  - Piston compressor
- Parker’s goal: full system replacement
Parker’s Request

• Layout of main compressor room
  – Labeling of existing machines
  – Specifications of existing machines

• System analysis

• At least three quotes for air compressor replacement
  – Air compressor dealers

• Our recommendation for replacement
Our First Steps
What’s That?

• Machines are not labeled
  – Makes maintenance difficult
  – Very unorganized
<table>
<thead>
<tr>
<th>Diagram #</th>
<th>Description</th>
<th>Length (&quot;)</th>
<th>Width (&quot;)</th>
<th>Area (ft^2)</th>
<th>Machine Number</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ingersoll Rand Compressor</td>
<td>119</td>
<td>73</td>
<td>60.32638889</td>
<td>300 XLE</td>
<td>Ingersoll Rand</td>
</tr>
<tr>
<td>2</td>
<td>Lockers beneath Air Exchange</td>
<td>156</td>
<td>102</td>
<td>110.5</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>DI Water (Four of These)</td>
<td>42</td>
<td>31</td>
<td>9.041666667</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>DI Water Control Pump</td>
<td>60</td>
<td>36</td>
<td>15</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>Electrical Panel</td>
<td>42</td>
<td>31</td>
<td>9.041666667</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Diagram:**
- **29** Air Filter
- **32** Drain Valve
Layout of the Compressor Room
Clean Compressor Room

<table>
<thead>
<tr>
<th>Total Used</th>
<th>Total Freed</th>
<th>% Cleared</th>
</tr>
</thead>
<tbody>
<tr>
<td>511.71</td>
<td>360.48</td>
<td>70.45%</td>
</tr>
</tbody>
</table>
External Quotes

- Parker requires three quotes for appropriation of funds
- Three quotes were received
  - Air Technologies
  - TMI
  - Ingersoll Rand
- Used to quantify our electrical demand with the current system
- Compilation of quotes

*SCFM: Standard Cubic Feet per Minute
TMI Recommendation

• 300 HP Steady State Sullair
• Estimated electrical savings per year: – $9,053
• Payback Period: 9.83 years
Air Technologies Recommendation

• Atlas Copco 200 HP VSD
• Estimated electrical savings per year:
  – $61,416
• Payback Period: 1.33 years
Ingersoll Rand Recommendation

• Ingersoll Rand 300 HP VSD

• Estimated electrical savings per year
  – $18,471

• Payback Period: 4.74 years
Energy Savings Per Year ($)

Energy Savings ($)

- **TMI**
  - Energy Savings: $10,000

- **Air Tech**
  - Energy Savings: $70,000

- **Ingersoll Rand**
  - Energy Savings: $20,000

SEEMS FISHY...
Graph of VSD versus Steady State
Leak Estimates

• Initial air loss: 40% of compressed air produced
  – Approximately 427 SCFM

• Compressed air costs about $0.22-$0.40 per 1,000 cubic feet

• Current air loss estimate: 20%
  – 256 SCFM

• Current estimated capital loss of $29,259
Scout Data Analysis

• Scout Sensors are tapped directly into pipe
• Gives real time feedback
• Shows direct air flow data

• Data was pulled over 10 minute intervals
• 4500 data points
• Two distinctly different analysis periods
  • Feb 16\textsuperscript{th}-Feb 24\textsuperscript{th}, March 26\textsuperscript{th}-April 10\textsuperscript{th}
  • Feb 25\textsuperscript{th}-March 19\textsuperscript{th}
**Analysis**

- **Bimodal**

- **Broken into high and low demand events**

- **High demand events**
  - Range from 650-1100 SCFM
  - 30% of data in high demand

- **Low demand events**
  - Range from around 450-650 SCFM
  - 70% of data in low demand

- **Need a unique system to accommodate the variation**
Short Term Recommendation

- Flow/Pressure Control System
  - Controls pressure by changing air flow volume
  - Holds pressure in system constant
  - Adjusts for pressure drops quickly and effectively

- Benefits from implementation
  - Leaks cost less
  - Compressor loads less frequently
    - Leads to energy savings

- Estimated annual savings: $11,882.23
Long Term Recommendation

• Purchase a 250 HP VSD compressor
  – Ingersoll Rand (IR)
  – Variable Speed Drive (VSD) is more energy efficient

• This compressor would easily account for low demand events

• Two 35 HP compressors would account for the high demand events
  – Already bought and paid for
  – Already tied into the main system

• Room for growth
Long Term Recommendation

• Fully automated compressed air system
  – Removes all manual operation
  – Reduced hassle for turning on the high demand and back-up systems

• Fix and maintain the majority of air leaks

• Create a training program for erroneous air usage
Long Term Recommendation Cost Accounting

**Compressor Cost:** $93,000  
**Estimated Annual Savings:** $33,014  
**Consumers Energy Rebate:** $27,500
## Long Term Recommendation Cost Accounting

<table>
<thead>
<tr>
<th>COSTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTOMATED SYSTEM</td>
<td>$22,000.00</td>
</tr>
<tr>
<td>LABOR TO FIX LEAKS</td>
<td>$7,200.00</td>
</tr>
<tr>
<td>COMPRESSOR</td>
<td>$93,000.00</td>
</tr>
<tr>
<td>FLOW CONTROLLER</td>
<td>$3,600.00</td>
</tr>
<tr>
<td>CONSUMERS REBATE (One Time)</td>
<td>$ (27,500.00)</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>SAVINGS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOW CONTROLLER</td>
<td>$ (11,882.23)</td>
</tr>
<tr>
<td>LEAK FIXES</td>
<td>$ (29,259.53)</td>
</tr>
<tr>
<td>COMPRESSOR ENERGY USAGE</td>
<td>$ (33,014.20)</td>
</tr>
</tbody>
</table>

| TOTAL EST COST                             | $98,300.00 |
| TOTAL EST ANNUAL SAVINGS                   | $ (74,155.95) |
| PAYBACK PERIOD (YEARS)                     | 1.33 |

*Note: All values in USD.*
Facilities Layout Analysis and Implementation

• Parker would like the new compressor installed before the old back-up system is removed

• Remove the equipment on the left highlighted in red
  – Allows for the movement of air tank #26 into the corner
  – New compressor can be installed in the free space
Removal of the Ingersoll Rand
Closing Remarks

• 250hp VSD Ingersoll Rand
  – Specifications are a good fit
  – Layout

• What we learned
  – Leaks are important
  – Know where your data comes from
Questions?
Leakage Rates at Various PSI

<table>
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<tr>
<th>Pressure</th>
<th>Orifice Diameter (inches)</th>
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<tbody>
<tr>
<td>psig</td>
<td>1/64</td>
</tr>
<tr>
<td>70</td>
<td>0.3</td>
</tr>
<tr>
<td>80</td>
<td>0.33</td>
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<tr>
<td>90</td>
<td>0.37</td>
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<tr>
<td>100</td>
<td>0.41</td>
</tr>
<tr>
<td>125</td>
<td>0.49</td>
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</table>
Energy Savings Estimates

\[ \text{ENERGY ESTIMATES} = \frac{(BHP) \times \left(\frac{kW}{hp}\right) \times (\% \text{ FULL LOAD BHP}) \times (\% \text{ TIME}) \times (HOURS) \times (RATE)}{\text{MOTOR EFFICIENCY}} \]
• Why our recommendation is better
Scout Sensor Data

Means

<table>
<thead>
<tr>
<th>Factor</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>95% CI</th>
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<tbody>
<tr>
<td>7-15</td>
<td>749</td>
<td>549.08</td>
<td>42.57</td>
<td>(546.22, 551.94)</td>
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<tr>
<td>15-23</td>
<td>749</td>
<td>538.59</td>
<td>42.65</td>
<td>(535.73, 541.45)</td>
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<tr>
<td>23-7</td>
<td>749</td>
<td>539.31</td>
<td>33.86</td>
<td>(536.45, 542.17)</td>
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Pooled StDev = 39.9051

Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F-Value</th>
<th>P-Value</th>
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<tbody>
<tr>
<td>Factor</td>
<td>2</td>
<td>51375</td>
<td>25687</td>
<td>16.13</td>
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<td>Error</td>
<td>2244</td>
<td>3573387</td>
<td>1592</td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>2246</td>
<td>3624762</td>
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Additional Analysis

Tukey Pairwise Comparisons

<table>
<thead>
<tr>
<th>Factor</th>
<th>N</th>
<th>Mean</th>
<th>Grouping</th>
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<tbody>
<tr>
<td>7-15</td>
<td>749</td>
<td>549.08</td>
<td>A</td>
</tr>
<tr>
<td>23-7</td>
<td>749</td>
<td>539.31</td>
<td>B</td>
</tr>
<tr>
<td>15-23</td>
<td>749</td>
<td>538.59</td>
<td>B</td>
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</tbody>
</table>

Means that do not share a letter are significantly different.
Pressure Analysis
## Project Planner

Select a period to highlight at right. A legend describing the charting follows.

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>PLAN START</th>
<th>PLAN DURATION</th>
<th>ACTUAL START</th>
<th>ACTUAL DURATION</th>
<th>PERCENT COMPLETE</th>
<th>PERIODS</th>
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</thead>
<tbody>
<tr>
<td>Host Air Vendors</td>
<td>1</td>
<td>10</td>
<td>1</td>
<td>10</td>
<td>100%</td>
<td>1</td>
</tr>
<tr>
<td>Start Air Analysis</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>100%</td>
<td>11</td>
</tr>
<tr>
<td>Create AutoCAD Layout</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>100%</td>
<td>12</td>
</tr>
<tr>
<td>Label Machines</td>
<td>12</td>
<td>2</td>
<td>12</td>
<td>2</td>
<td>100%</td>
<td>13</td>
</tr>
<tr>
<td>Presentation 1</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>100%</td>
<td>14</td>
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<tr>
<td>Presentation 2</td>
<td>11</td>
<td>1</td>
<td>11</td>
<td>1</td>
<td>100%</td>
<td>15</td>
</tr>
<tr>
<td>Dress Rehearsal</td>
<td>14</td>
<td>1</td>
<td>14</td>
<td>1</td>
<td>100%</td>
<td>16</td>
</tr>
<tr>
<td>Poster</td>
<td>10</td>
<td>3</td>
<td>10</td>
<td>3</td>
<td>100%</td>
<td>17</td>
</tr>
<tr>
<td>Paper</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>100%</td>
<td>18</td>
</tr>
</tbody>
</table>
Ideal Solution

• Eliminate compressed air entirely
  – Turn tables
  – Conveyor belts
  – Pushing parts with air

• Change to DC motors instead due to the cost of compressed air
• Savings through reduced electrical usage