Veneer Sandthroughs
Phase III: Feasibility and Warpage Studies

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Nathan Christensen, Mft.E
Background Info.

Veneer roughly 0.02 inches thick
The Problem

• Sandthroughs
  – Veneer damage from *Heesemann* sanding process
Finishing Line

- Heesemann wide-belt sander with 5 heads

1. Boards loaded on conveyor
2. Boards are sanded
3. Boards are stained & Sealed
4. Unloaded & placed on rack

What side was just finished?
- Front
- Back

To Assembly
Phase I: Data Collection

Sand-throughs (Count)

0  200  400  600

1

Two-Side-B   Two-Side-F   One-Side
Phase II: Root Cause Analysis

- **Man**
  - Not measuring board thickness
  - Special treatment of ‘hot racks’
  - Communication between operators
  - Pressure
  - Calibration

- **Material**
  - Measuring board thickness
  - Running 3 of 5 heads
  - Pressure
  - Calibration
  - Swelling
  - Warp
  - Uneven belt wear

- **Environment**
  - Swelling
  - Warp
  - Uneven belt wear
  - Running 3 of 5 heads
  - Calibration
  - Loading patterns

- **Measurements**
  - Sand-Throughs
<table>
<thead>
<tr>
<th>Pattern</th>
<th>Defect</th>
<th>Observed</th>
<th>% Defective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stacked</td>
<td>3</td>
<td>239</td>
<td>1.3%</td>
</tr>
<tr>
<td>Fenced</td>
<td>2</td>
<td>94</td>
<td>2.1%</td>
</tr>
<tr>
<td>Single Piece</td>
<td>46</td>
<td>1092</td>
<td>4.2%</td>
</tr>
<tr>
<td>Parallel</td>
<td>51</td>
<td>394</td>
<td>12.9%</td>
</tr>
<tr>
<td>Mixed</td>
<td>20</td>
<td>150</td>
<td>13.3%</td>
</tr>
</tbody>
</table>
Phase II

Initial Warp Study

- Avg. Warp (in.):
  - All 70 boards: 0.045
  - Avg. Unstained: 0.032
  - Avg. Stained: 0.050
  - Top 10% > 0.102
Phase III

1. Simulation study of single piece loading
   - Eliminate patterns
   - More balanced finishing line

2. Warp Study
   - Determine where warp occurs
   - Quantify degree of warp

3. Sanding belt life extension experimentation
   - Current State: Belt’s used for one 8 hour shift
   - Potential State: Belt’s used for two 8 hour shifts
Simulation: Single Piece

• Current State: All patterns
• Future 1: Just single piece
• Future 2: Eliminate ‘Parallel’ & ‘Mixed’

• Current state validation

<table>
<thead>
<tr>
<th>Components Produced</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>1713</td>
</tr>
<tr>
<td>Simulation</td>
<td>1723</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time In Operation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>2.65</td>
</tr>
<tr>
<td>Simulation</td>
<td>2.25</td>
</tr>
</tbody>
</table>
Simulation: Current

Variable Summary (Avg. Reps)

<table>
<thead>
<tr>
<th>Replication</th>
<th>Name</th>
<th>Total Changes</th>
<th>Average Time Per Change (Min)</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
<th>Current Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>thruput</td>
<td>1,723.80</td>
<td>0.28</td>
<td>0.00</td>
<td>1,723.80</td>
<td>1,723.80</td>
</tr>
<tr>
<td>Avg</td>
<td>WIP</td>
<td>76.87</td>
<td>6.23</td>
<td>0.00</td>
<td>76.87</td>
<td>76.87</td>
</tr>
</tbody>
</table>

Multiple Capacity Location States - Current State (Avg. Reps)

- Component rack: 100% Empty
- Unload table: 100% Full
- Sanding machine exit: 50% Empty, 50% Part Occupied
- Coatings table: 50% Empty, 50% Part Occupied
- Coatings conveyor: 20% Empty, 80% Part Occupied
Simulation: Future 1
Simulation: Future 2

### Variable Summary (Avg. Reps)

<table>
<thead>
<tr>
<th>Replication</th>
<th>Name</th>
<th>Total Changes</th>
<th>Average Time Per Change (Min)</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
<th>Current Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>thrupt</td>
<td>1,377.56</td>
<td>0.35</td>
<td>0.00</td>
<td>1,377.56</td>
<td>1,377.56</td>
</tr>
<tr>
<td>Avg</td>
<td>WIP</td>
<td>74.00</td>
<td>6.47</td>
<td>0.00</td>
<td>74.00</td>
<td>74.00</td>
</tr>
</tbody>
</table>

![Multiple Capacity Location States - Current State (Avg. Reps)](chart)

- **Component rack**: Mostly full, with a small percentage of empty space.
- **Unload table**: Mostly full, with a small percentage of empty space.
- **Sanding machine exit**: Mostly full, with a small percentage of empty space.
- **Coatings table**: A mix of empty and full states.
- **Coatings conveyor**: A mix of empty and full states.
Simulation: Recommendations

• Perform real life trial runs
  – Future 2

• Evaluate trade offs
  – Throughput ↓  Rework ↓  Quality ↑

<table>
<thead>
<tr>
<th>State</th>
<th>Throughput</th>
<th>Estimate Defect %</th>
<th>Estimate Defect #</th>
<th>Rework (Hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>1723</td>
<td>6.20%</td>
<td>107</td>
<td>8.0</td>
</tr>
<tr>
<td>Future 1</td>
<td>1088</td>
<td>4.20%</td>
<td>46</td>
<td>3.4</td>
</tr>
<tr>
<td>Future 2</td>
<td>1338</td>
<td>3.58%</td>
<td>48</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Warp Study

- Phase II identified warpage as significant
- Warp caused by uneven **heat and moisture**
Warp Study

Hot Press

• Two warp orientations before
  – Smile 😊 or Frown ☹️
• Stacks of boards have ‘turning point’ 😃
• Boards generally enter face down
• Exposed to bottom platen longer
  – Warped toward smile

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>Difference</th>
<th>% of pop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.021</td>
<td>0.027</td>
<td>0.006</td>
<td>100%</td>
</tr>
<tr>
<td>Frown avg.</td>
<td>0.033</td>
<td>0.029</td>
<td>-0.004</td>
<td>63%</td>
</tr>
<tr>
<td>Smile avg.</td>
<td>0.027</td>
<td>0.033</td>
<td>0.005</td>
<td>37%</td>
</tr>
</tbody>
</table>
• Largest warpage contributor
• Finish line warps toward frown
• 2/3 of boards come to line frowning in 1st pass
  – Face down, Face concave
• Face sanded at highest warpage

<table>
<thead>
<tr>
<th></th>
<th>Before 1st</th>
<th>Mid 1st</th>
<th>Before 2nd</th>
<th>Mid 2nd</th>
<th>End</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>0.002</td>
<td>0.008</td>
<td>0.026</td>
<td>0.019</td>
<td>0.011</td>
<td>0.013</td>
</tr>
<tr>
<td>Frown</td>
<td>0.021</td>
<td>0.025</td>
<td>0.043</td>
<td>0.034</td>
<td>0.023</td>
<td>0.029</td>
</tr>
<tr>
<td>Smile</td>
<td>-0.019</td>
<td>-0.009</td>
<td>0.008</td>
<td>0.001</td>
<td>-0.003</td>
<td>-0.004</td>
</tr>
<tr>
<td>Absolute</td>
<td>0.020</td>
<td>0.019</td>
<td>0.028</td>
<td>0.022</td>
<td>0.017</td>
<td>0.021</td>
</tr>
</tbody>
</table>
Warp Study

Recommendations

• Warp should be minimized before 2\textsuperscript{nd} pass

• Flip boards to frown before hot press
  – No need to measure: ‘turning point’
  – Overall reduction in warp
  – Ergonomic considerations for operator

• Face veneer on top side in hot press
  – Second pass during minimal warp
Belt Life Extension

- Goal: Reduce belt usage by 50%
- Test parts run normally except ends unsanded
- Samples taken at 0, 4, 8, 12, & 16 hour mark
- Four species of wood at each hour mark
- Microscope measurements determined removal rate
- Test parts ‘eye’ tested for quality
Belt Life Extension

Quality Rating Scale
1 = Great, I love it
2 = I like it
3 = Acceptable
4 = I don't like it
5 = Bad, unacceptable

Eye Test Ratings

<table>
<thead>
<tr>
<th>Hour</th>
<th>Rating</th>
<th>Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.6</td>
<td>0.0084</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0.0034</td>
</tr>
<tr>
<td>8</td>
<td>3.5</td>
<td>0.0036</td>
</tr>
<tr>
<td>12</td>
<td>3.45</td>
<td>0.0035</td>
</tr>
<tr>
<td>16</td>
<td>4.35</td>
<td>0.0040</td>
</tr>
</tbody>
</table>
Belt Life Extension

• Belt grits recently changed

• Potential savings: $10,000

• Test will be re-done with new grits
  – Identical test performed
  – Similar test, replacing only first cross belt
Recommendations

Summary

• Perform real life test of future states
  – Compare with simulation
  – Evaluate trade offs

• Apply veneer in hot press to top of frowning boards

• Re-evaluate belt life extension with new grits
  – Treat test parts normally
  – Change first cross belt only
Questions?

The GMIC Team would like to thank:

- Dennis Carlson
- Mark Drelles
- Mark Atchison
- Bob Greenhoe

For making this project possible
Excess Material Optimization

Air National Guard

Presentation by:
Shaun Shields
Collaboration

Green Manufacturing
Industrial Consortium

Retired Engineer
Technical Assistance
Program (RETAP)

United States Air National
Guard 110th Airlift Wing

Michigan Department of
Environmental Quality
**Objective**: Improve and Establish Recycling Programs

- Operate Efficiently
- Cost Effective
- Waste Stream Analysis
- Commodity Market Feasibility Study
- Cost Benefit Analysis

**Implementation**

- Metals Sorting Program
- Excess Material Optimization
- Additional Programs
Material Optimization

110th Airlift Wing Transition

• Change of Mission Objectives

• Base Operation Changed
  – No Longer Operate and Maintain Airplanes and other Aircraft
  – Change of Supply Ordering and use
  – Surplus Materials
Excess Materials

**Surplus Materials and Waste**

- Aircraft Maintenance
- Cleaners and Solvents
- Vehicle Maintenance
- Specialty Fluids
- Used Materials
Disposal Costs

• $5,000 Initial estimate cost for material disposal
  • Covers all parts of handling and disposal
    • Based on:
      • Material Type
      • Container Type
      • Weight

• Scope and quantity of materials increased
  • Estimated cost in excess of $20,000
  • Majority of materials would be incinerated
Overall Process

1. Identify and Catalogue Materials
2. Classify Materials
3. Identify Outlets for Material Re-use or Disposition
4. Assist in Pursuing and Contacting Outlets
5. Aid in Material Tracking and Evaluation
## Item Cataloging

<table>
<thead>
<tr>
<th>Item Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Name</td>
</tr>
<tr>
<td>• Trade/Associated Names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quantification</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Individual Containers</td>
</tr>
<tr>
<td>• Total Weight and Volume</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shelf Life Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Open: Y/N</td>
</tr>
<tr>
<td>• Expired/Extendable: Y/N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Intended Uses</td>
</tr>
<tr>
<td>• Lubricant, Cleaner, Adhesive, etc.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Safety Data Sheets</td>
</tr>
<tr>
<td>• Manufacturer Information</td>
</tr>
</tbody>
</table>
Material Statistics

There are over 150 different items in this project

- 4768 Gallons
- 18 Tons
  - 9 Tons Fire Fighting Foam
  - 2.6 Tons Unexpired Items
  - 3.2 Tons Extendable Items
Material Statistics

(Cont.)

- Fire Fighting Foam: 50%
- De-Icer: 10%
- Used Oil: 11%
- Lubricants: 6%
- Specialty Fluids: 8%
- Cleaners: 3%
- Solvents: 2%
- Waste: 9%
- Other Materials: 1%
Re-Use/Disposal Options

Material Catalogue

- Sealed, Non-expired or Extendable
  - Free Issue to Another Base
  - Donation to Non-Profit
  - Fuel Blending
  - Incineration
  - Landfill

- Expired/Opened
Select Items/Materials

- Sealed Containers
- Sufficient Quantity
- Appropriate Shelf Life
  - Unexpired Items
  - Extendable Items

Benefits

- Purchase Cost Savings
- Items Utilized for Intended Purposes
- Increased Cooperation Between Bases

Costs

- Handling
- Transportation
Community Donation
Fire Fighting Foam

- Can be applied in many fire fighting situations
  - Well suited for industrial applications
- There is considerable amount of usable fire fighting foam
  - Donation of foam to local fire departments
    - Lowers fire station’s expenditures
    - Involvement in community
- Past shelf life fire fighting foam
  - Not fit for direct applications
  - Can be used for firefighting training and practice
    - Saves the usable foam for real use
    - Allow for additional training exercises
Secondary Uses for Materials

• Unopened and extendable materials
  • 3.2 Tons

• Many materials unsuitable for direct automotive or aircraft applications

• Educational opportunities
  • Classroom and laboratory applications
  • Lubricants, cleaners, and specialty chemicals
Fuel Blending

Solvents and Oils

- Combusted at high temperatures
- Alternative fuel for cement kilns and other high temperature processes
- Over 70 gallons/ 600 pounds of solvents
  - Alternative to Incineration
  - Handled and Disposed of safely
Cost Savings

110th Airlift Wing Cost Aversion

- Incineration

Recipients

- Product Cost

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity (Gal)</th>
<th>Approximate Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ansul Fire Fighting Foam</td>
<td>2200</td>
<td>$ 44,650.00</td>
</tr>
<tr>
<td>Aircraft Hydraulic Fluid</td>
<td>220</td>
<td>$ 4,000.00</td>
</tr>
<tr>
<td>Aircraft Lubricating Oil</td>
<td>220</td>
<td>$ 4,000.00</td>
</tr>
<tr>
<td>Inspection Penetrant</td>
<td>55</td>
<td>$ 1,500.00</td>
</tr>
</tbody>
</table>
Additional Benefits

• Environmental Benefits
  – Re-use of Materials
  – Incineration Reduction
    • CO$_2$ Formation
    • Energy Costs
• Community Involvement
  – Cost Alleviation
  – Cooperation with Local Organizations
Questions?

I would like to thank Richard Edwards, LtCol James Shay, TSgt Patrick O’Keelean, SMSgt Rolando Garza, John Ihling and all others involved at the 110th Airlift Wing, MDEQ, and GMIC for their hard work and help.
Compressed Air Leak Study – Review 2

Colin Knue, Project Coordinator
Suresh Kumar Baskaran, Graduate Research Assistant
Objective

• The following are the two main activities of this project:
  – Identifying and fixing the leaks
  – Compressed air leak maintenance program
Background study

• Compressed Air
• Compressed Air Leak Detection
• Methods of Finding Air Leak
  • Soap method
  • Ultrasonic device
Ultra-Probe 3000
# Recording the Leak Survey Data

## Leak TAG - Tracking Sheet

<table>
<thead>
<tr>
<th>Review No.</th>
<th>Time</th>
<th>Leak Improvements</th>
<th>Review Meeting</th>
<th>Review date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- No of Issues highlighted: 0
- No of Issues closed: 0
- No of Issues Red: 0
- Ongoing improvements: 0

<table>
<thead>
<tr>
<th>Tag No</th>
<th>Date</th>
<th>Area</th>
<th>Location</th>
<th>Leak type/problem</th>
<th>Pressure at leak</th>
<th>dB reading</th>
<th>Size of Leak (cfm)</th>
<th>Compressor working Hours</th>
<th>Compressor working Hours</th>
<th>Leak Severity</th>
<th>Identified leaks</th>
<th>Cost Avoidance</th>
<th>Energy Avoidance (kWh)</th>
<th>Target date</th>
<th>Responsibility</th>
<th>Closure date</th>
<th>Status</th>
</tr>
</thead>
</table>

[Continue the table with additional columns and data entries as shown in the image.]
<table>
<thead>
<tr>
<th>Level</th>
<th>Leak size in CFM</th>
<th>Leak severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>1</td>
<td>0.01</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>10</td>
</tr>
</tbody>
</table>
Decibel to Cubic Feet per Minute

<table>
<thead>
<tr>
<th>Building</th>
<th>Pressure at line</th>
<th>dB reading</th>
<th>Leak rate (CFM)</th>
<th>Cost</th>
<th>Energy (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building 1</td>
<td>125</td>
<td>30</td>
<td>1.9</td>
<td>$380.43</td>
<td>3170</td>
</tr>
<tr>
<td>Building 2</td>
<td>100</td>
<td>30</td>
<td>1.6</td>
<td>$101.36</td>
<td>845</td>
</tr>
<tr>
<td>Building 4</td>
<td>125</td>
<td>30</td>
<td>1.9</td>
<td>$112.90</td>
<td>941</td>
</tr>
<tr>
<td>Building 5</td>
<td>125</td>
<td>30</td>
<td>1.9</td>
<td>$112.90</td>
<td>941</td>
</tr>
<tr>
<td>Building 6</td>
<td>100</td>
<td>30</td>
<td>1.6</td>
<td>$101.36</td>
<td>845</td>
</tr>
</tbody>
</table>
## Anticipated savings

<table>
<thead>
<tr>
<th>Month</th>
<th>Building</th>
<th>Annual Compressor operating time (hrs.)</th>
<th>Total Number of Leaks Identified</th>
<th>Total Identified size of Leak (cfm)</th>
<th>Annual Cost Avoidance</th>
<th>Annual Energy Avoidance (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2013</td>
<td>Building 1</td>
<td>8424</td>
<td>23</td>
<td>84.1</td>
<td>$16,776.75</td>
<td>139,806.26</td>
</tr>
<tr>
<td></td>
<td>Building 2</td>
<td>2610</td>
<td>70</td>
<td>194.7</td>
<td>$12,040.20</td>
<td>100,335.03</td>
</tr>
<tr>
<td></td>
<td>Building 2 (upper level)</td>
<td>2610</td>
<td>35</td>
<td>64.3</td>
<td>$3,976.16</td>
<td>33,134.66</td>
</tr>
<tr>
<td></td>
<td>Building 4</td>
<td>2500</td>
<td>8</td>
<td>32.3</td>
<td>$1,910.70</td>
<td>15,922.54</td>
</tr>
<tr>
<td></td>
<td>Building 5</td>
<td>2500</td>
<td>6</td>
<td>20.0</td>
<td>$1,182.61</td>
<td>9,855.06</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18644</strong></td>
<td><strong>142</strong></td>
<td><strong>395.4</strong></td>
<td><strong>$35,886.43</strong></td>
<td><strong>299,053.55</strong></td>
<td></td>
</tr>
</tbody>
</table>
Leak Repair
Leak Tag

Air-Leak TAG

<table>
<thead>
<tr>
<th>DATE</th>
<th>TAG NO</th>
<th>NAME OF THE PERSON</th>
<th>LOCATION / Department</th>
<th>Type of Leak</th>
<th>Severity</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/10</td>
<td>100</td>
<td>Suresh</td>
<td>4132</td>
<td>Valve Joint Leak (hole)</td>
<td>High</td>
<td>L+1</td>
</tr>
</tbody>
</table>

ACTION DATE:

SIGNATURE:
Valve – hose connection
Pneumatic hose connection
FRL – hose connection
Air gun – hose connection
Plant 2 - upper level leak

Leak points are marked in red colour.
Numbers marked in red are Leak / Tag Number.
March 2014
### Anticipated savings

<table>
<thead>
<tr>
<th>Month</th>
<th>Building</th>
<th>Annual Compressor operating time (hrs.)</th>
<th>Total Number of Leaks Identified</th>
<th>Total Identified size of Leak (cfm)</th>
<th>Annual Cost Avoidance</th>
<th>Annual Energy Avoidance (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 2014</td>
<td>Building 1 &amp; 5</td>
<td>8424</td>
<td>5</td>
<td>22.1</td>
<td>$1,368.56</td>
<td>11,404.64</td>
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<tr>
<td></td>
<td>Building 2</td>
<td>2610</td>
<td>17</td>
<td>82.2</td>
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<td>42,344.86</td>
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<tr>
<td></td>
<td>Building 2 (upper level)</td>
<td>2610</td>
<td>11</td>
<td>29.7</td>
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<tr>
<td></td>
<td>Building 4</td>
<td>2500</td>
<td>3</td>
<td>8.9</td>
<td>$549.83</td>
<td>4,581.88</td>
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<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>18644</strong></td>
<td><strong>36</strong></td>
<td><strong>142.9</strong></td>
<td><strong>$8,835.77</strong></td>
<td><strong>73,633.03</strong></td>
</tr>
</tbody>
</table>
Identified size of Leak (cfm)

Building 1 & 5
- 18% (Jul-13)
- 82% (Mar-14)

Building 2
- 30% (Jul-13)
- 70% (Mar-14)

Building 4
- 22% (Jul-13)
- 78% (Mar-14)
Type of Leak

- 68% Air gun and tube connecting area leak
- 21% Hose - FRL connection leak
- 8% Hose - hose connection coupling leak
- 3% hose - Pnuematic line connection joint
Coiled hose blow gun
## Implementation savings

<table>
<thead>
<tr>
<th>Month</th>
<th>Building</th>
<th>Annual Compressor operating time (hrs.)</th>
<th>Total Number of Leaks Identified</th>
<th>Identified size of Leak (cfm)</th>
<th>Annual Cost Avoidance</th>
<th>Annual Energy Avoidance (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul-13</td>
<td>1,2,4&amp;5</td>
<td>18644</td>
<td>142</td>
<td>395.4</td>
<td>$35,886</td>
<td>299,054</td>
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<tr>
<td>Mar-14</td>
<td>16144</td>
<td>36</td>
<td>142.9</td>
<td>$8,836</td>
<td></td>
<td>73,633</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>size of Leak (cfm)</th>
<th>Annual Cost</th>
<th>Annual Energy (kWh)</th>
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</thead>
<tbody>
<tr>
<td>252.5</td>
<td>$27,050.66</td>
<td>225,420.52</td>
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</table>
## New Leaks saving

<table>
<thead>
<tr>
<th>Month</th>
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<th>Annual Compressor operating time (hrs.)</th>
<th>Total Number of Leaks Identified</th>
<th>Identified size of Leak (cfm)</th>
<th>Annual Cost Avoidance</th>
<th>Annual Energy Avoidance (kWh)</th>
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</thead>
<tbody>
<tr>
<td>Mar-14</td>
<td>Building 6</td>
<td>2610</td>
<td>13</td>
<td>73.7</td>
<td>$4,558.28</td>
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<tr>
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<td>8424</td>
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<td>17.2</td>
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<tr>
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<td>11</td>
<td>21.1</td>
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<tr>
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<td>58,796.56</td>
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<tr>
<td>Month</td>
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<td>Annual Compressor operating time (hrs.)</td>
<td>Total Number of Leaks Identified</td>
<td>Identified size of Leak (cfm)</td>
<td>Annual Cost Avoidance</td>
<td>Annual Energy Avoidance (kWh)</td>
</tr>
<tr>
<td>-------</td>
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<td>------------------------------</td>
<td>-----------------------</td>
<td>-----------------------------</td>
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<tr>
<td>Mar-14</td>
<td>Building 1&amp;5</td>
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<td>5</td>
<td>22</td>
<td>$1,369</td>
<td>11,405</td>
</tr>
<tr>
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<td>Building 2</td>
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<td>17</td>
<td>82</td>
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<td>42,345</td>
</tr>
<tr>
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<td>$550</td>
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<tr>
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<td>74</td>
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<td>37,986</td>
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<td></td>
<td>Building 1 (UL)</td>
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<td>17</td>
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<td>8,881</td>
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<tr>
<td></td>
<td>Building 4 (UL)</td>
<td>2500</td>
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<td>2</td>
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<td>1,071</td>
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<tr>
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<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>32288</strong></td>
<td><strong>68</strong></td>
<td><strong>257</strong></td>
<td><strong>$15,891</strong></td>
<td><strong>$132,430</strong></td>
</tr>
</tbody>
</table>
Sustain the gain

- Periodical Checks
- Proper Documentation
- Point-of-use pressure regulation
- Use of isolation valves and lock out valves
# Sustain the gain

## Leak TAG - Tracking Sheet

<table>
<thead>
<tr>
<th>Review No.</th>
<th>Time</th>
<th>Leak Improvements Review Meeting</th>
<th>Review date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **No of Issues highlighted**: 142
- **No of Issues closed**: 43
- **No of Issues Red**: 99
- **Ongoing improvements**: 0

## Table

<table>
<thead>
<tr>
<th>Tag No</th>
<th>Date</th>
<th>Area</th>
<th>Location</th>
<th>Leak type/problem</th>
<th>Pressure at leak</th>
<th>dB reading</th>
<th>Size of Leak (cfm)</th>
<th>Compressor working Hours</th>
<th>Compressor working Hours</th>
<th>Leak Severity</th>
<th>Identified leaks</th>
<th>Cost Avoidance (kWh)</th>
<th>Energy Avoidance (kWh)</th>
<th>Target date</th>
<th>Responsibility</th>
<th>Closure date</th>
<th>Status</th>
</tr>
</thead>
</table>

---

**Western Michigan University**

[College of Engineering and Applied Sciences]

[Manufacturing Research Center]
Reference

- Industrial Assessment Center at Indiana University Purdue University at Indianapolis (IUPUI) - Energy assessment for Polywood.


- Stuhlman, Roy: Compressed Air: Your Most Expensive Utility Chemical Engineering; Jun 2008; 115, 6; ABI/INFORM Complete pg. 39.

- U.S. Department of Energy http://www1.eere.energy.gov/industry/saveenergynow/
Thank you for listening!

Questions?
Ergonomics Study Follow-Up
LED Lighting Assembly (Optic Installation)

Marylin N. Glass-Hedges, IE, EM (Speaker)
Lorena S. Peña Jiménez, IE
Objectives

- Identify risks for long-term ergonomic injuries in the current process.
- Investigate potential costs of such risks and benefits of improving ergonomic conditions of the job.
LED Lighting Assembly

OPTIC INSTALLATION

Tri-boards assembly → Clean bed → Dry/brush bed → Place tri-board on bed → Press tri-board onto bed → Dome-to-post assembly

Input materials:
- Dome casting
- Tri-boards
- IPA wipes
- Wire brush
- Press hand-tool
- Digital dynamometer
- Timer

Repeat as many times as needed until all tri-boards are placed on their corresponding beds.
LED Lighting Assembly

31 pounds (force)
20 seconds
16 or 32 times per dome
LED Lighting Assembly
Working across midline of the body

Force exertion greater than 10 Kg and constantly repeated

Back flexion abduction to the left

Neck minor flexion

Shoulder abduction

Shoulder adduction

Elbow flexion

Wrist extension and mid-pronation

Wrist extension and hook grip

Trunk bent and twisted away from the neutral position

Right Side

Elbow flexion

Working across midline of the body

Wrist extension, supination, and hook grip

Left Side

Back flexion abduction to the left

Neck minor flexion

Shoulder abduction

Shoulder adduction

Elbow flexion

Wrist extension and mid-pronation

Wrist extension and hook grip

Trunk bent and twisted away from the neutral position

Trunk is side-bending
Musculoskeletal Disorders (MSDs)

- According to the task characteristics, the operator is at risk of developing:
  - **Epicondylitis**: inflammation of the tendons that join the forearm because of over use.
  - **Carpal Tunnel Syndrome**: compression at the wrist of the median nerve (arm) causing numbness and tingling.
  - **Tenosynovitis**: commonly caused by wrist deviation from the neutral posture, it is the inflammation of the tissue covering the tendons.
  - **Tendinitis**: inflammation of the tendons, usually in the shoulders, elbows, wrists, knees, and hips.

#### Annual Cost per MSD in 2012

<table>
<thead>
<tr>
<th>Musculoskeletal Disorder</th>
<th>Annual cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epicondylitis</td>
<td>$ 9,723.00</td>
</tr>
<tr>
<td>Carpal tunnel syndrome</td>
<td>$18,216.00</td>
</tr>
<tr>
<td>Hand/wrist tendinitis</td>
<td>$10,714.00</td>
</tr>
<tr>
<td>Elbow/forearm strain</td>
<td>$ 6,516.00</td>
</tr>
<tr>
<td>Neck strain</td>
<td>$11,520.00</td>
</tr>
<tr>
<td>Shoulder strain</td>
<td>$11,565.00</td>
</tr>
<tr>
<td>Hand/wrist strain</td>
<td>$ 8,562.00</td>
</tr>
<tr>
<td>All other MSDs</td>
<td>$ 9,208.00</td>
</tr>
</tbody>
</table>

Recommendations

1. Workstation redesign for the operator to alternate between seating and standing postures
   - Adding an adjustable work surface and keep the adjustable chair.
   - Train the personnel in how to fit the station to them.

2. Add a fixture to hold the dome

3. Use power grip hand tools for horizontal work

4. Automate most demanding task
Mechanic Arm

(Revised) Economic analysis considering 2 operators at a rate of US$ 23/hour:

- **Purchase cost:** $24,500.00 x 2 = $49,000.00
- **Effectiveness of the solution:** A mechanic arm will eliminate the need for gripping with high force as well as the awkward posture of the wrist, if designed appropriately.
- **Productivity improvements:** Standardizes (ideally reduces) the assembly time.
- **Estimated annual benefits:** $79,025.00
- **Estimated net benefits after one year:** $30,025.00
- **Payback:** 0.62 years (7.44 months)
LED Lighting Assembly

Improved

Western Michigan University
College of Engineering and Applied Sciences
Manufacturing Research Center
Methodology

1. Workers Interviews
2. Exposure Measures
   - Workstation Design Evaluation
   - Direct Observation
     • Hazard Evaluation
     • Posture Analysis
   - Static Work Evaluation
3. Outcome Measures
   - RULA
   - REBA
   - Body Discomfort Analysis
Workstation Design

TO AVOID INJURY...

Always adjust the table to your elbow height, from the top of the dome, before starting your task.

Thank you for your cooperation!
Result: Immediate actions should be taken to reduce health and safety risks:
- Change operators’ body posture
- Reduce force exertion
- Reduce exposure time
Posture Analysis

- Force exertion greater than 10 Kg and constantly repeated
- Back flexion abduction to the left
- Neck minor flexion
- Shoulder adduction
- Elbow flexion
- Wrist extension and mid-pronation
- Trunk bent and twisted away from the neutral position
- Shoulder abduction
- Elbow flexion
- Wrist extension, supination, and hook grip
Posture Analysis (Cont.)
**Endurance should be 2.54 mins.**
Time the operator can resist the effort demanded by the task

**Recovery time should be 8 secs.**
Minimum time the operators’ muscles need to rest after each force exertion based on the task demands and operators’ characteristics.

**%MVC utilization should be max. 15%**
Percentage of the Maximum Voluntary Contraction (Force) the operator can exert.

**Task demands 5.33 to 10.66 min per LED lighting product**

**Operators had the choice of assembling the tri-boards consecutively.**

**Operator %MVC was from 28% to 34% during the assembly**
Static Work

- [32, 64] seconds of “pressing” time required per dome
  - 2 seconds/press
- 10 pounds or less force required
- Endurance/Resting Time Calculations NOT Necessary
  - %MVC < than 15% of total force exerted
  - Range ~[7%, 11%]
- 30 seconds of resting time built in the process
- Sequential versus Repetitive Operations
  - Single Piece Processing
  - Batch Processing
BEFORE

Task score = 7
7 = investigate and change immediately

AFTER

Task score = 2
1 or 2 = Acceptable
BEFORE

Task score = 11
Very High Risk Level
Action Necessary
Now

AFTER

Task score = 1
Negligible Risk Level
Action None Necessary

REBA
Rapid Entire Body Assessment
Body Discomfort Analysis

Area experiencing discomfort after assembly

BEFORE

Rating | Description
--- | ---
0 | No discomfort
1 | Fairly comfortable
2 | Moderate discomfort
3 |
4 |
5 |
6 |
7 | Very uncomfortable
8 |
9 |
10 | Extreme discomfort

AFTER
• **Expected sales growth**
  
• **Normalized production**
  – Improve process flow
  – Line balancing (time studies)
  – Implement standard work (SW)
  – Quality assurance (scrap rate?)
  – Ergonomics (sustain)

• **Continuous Improvement**
Thank you for listening!

Questions, comments?
Warehouse Optimization
Improving the Inventory Management System

Marylin N. Glass-Hedges, IE, EM
Suresh Kumar Baskaran, ME, LM
Lorena S. Peña-Jiménez, IE (Speaker)
Current State

• Inventory: Quick-Ship Products (MTS, 3-day lead time)
  – Other products: MTO, 10-day lead time
• Rapid growth – Sales increase more than expected per year
• Evident concern: warehouse capacity
• Storage/retrieval system: combination of Dedicated and Random IMSs
  – Does not consider picking frequencies and adjacency to staging/shipping area

**PROBLEM** ➔ If the warehouse cannot process orders efficiently, PW’s overall supply chain suffers!
Objectives

• **Assess for current efficiency**
  - Costs, material handling, space, personnel, processing times, inventory, and forecasting.

• **Forecasting**: same expected growth across all products *versus* expected growth per product

• **Determine if other IMSs are more efficient**
  - Class-Based, Cube-Per-Order-Index, Combination, other.

• **Compare proposed systems with current and assess for improvement (using simulation/statistics tools)**
  - ProModel, Minitab16, VIP Plant Opt, MS Excel
  - Costs implications
Data Collection

- Literature Review
- Warehouse’s Full Drawing
  - Process Flow Chart
  - Value Stream Map
  - Process Routings/Paths
    - Material Handling
    - FIFO, LIFO, other?
      - SKUs
      - Batches
  - Material Handling
  - FIFO, LIFO, other?
  - SKUs
  - Batches
- Arrival Frequencies
- Products’ Dimensions (Packaged)
- Picking Frequencies
- Racks’ Dimensions, Capacity, Utilization
- Outsourced Goods?
  - Time Studies
  - Personnel
  - Costs
To be answered...

• Does PW need to double up in size to handle all warehousing operations?

• Do space requirements decrease if a different management system is implemented?

• Is there an optimal system that supports PW’s future growth?

Recommendations based on improving picking operations, increasing value added services and increasing overall productivity and safety
Next steps?
Moving forward
Questions, comments, ideas...???
THANK YOU!