AVS Meeting
January 25, 2012

Vacuum Chambers:
The Atmosphere of Excellence
Some Facts about GNB
Some Facts

• Founded in 1968 by Gary N. Burnett
• Located in Elk Grove, CA (South of Sacramento)
• 60 Employees (7 Design Engineers)
• 62,500 Sq Ft. Facility
• Focused on Vacuum Chambers and Valves
• ISO 2000 – 9001 Certified
Focus: Large Manufacturing
Vacuum Valves
4” to over 100”
Vacuum Chambers

9 ft Diameter x 16 ft Long
Vacuum Chambers Are Exciting
How Could a Metal Box be Exciting?

- New tools make it fun to design chambers
- Welding is faster and tighter than ever
- Unique advantages of combining or separating parts
- UHV is bigger and cheaper
- Fit and finish for any budget
Finite Element Analysis

• FEA tools make analyzing complex shapes possible
  – Lighter weight chambers
  – Increased rigidity
  – Reduced costs
  – Heat transfer, deflection and stress are primary calculations
Stress Analysis Example
Complex Shapes can be Difficult to Analyze

Given:
- 304 sst
- 99.63” OD x 206.25” L
- Wall thickness 3/8”
- Operating temp 200F
Minimizing Deflection is the Key to Great Vacuum Chambers

Figure 8: Displacement, All loads, Unclipped, Isometric View
Secondly, We Analyze Stress at Elevated Temperatures

Figure 4: Stress, All loads, Unclipped, Bottom View
Factor of Safety was 1.17

Figure 7: Factor of Safety, All loads, Unclipped, Front View
Risks and Benefits of FEA Tools

Benefits
- Ability to analyze complex shapes
- Fast process
- Temperature is included

Risks
- Incorrect restraints and assumptions
- Over confidence in numbers by inexperienced users
- Fabrications are not as exact as models
Waterjet

• 5-axis Waterjet can be used to prepare edges for welding
• No heat involved, there will be no thermal stress in the material and the cut will be oxide free
CAM Systems

• In conjunction with waterjet cutting have revolutionized chamber manufacturing
  – No machining on most parts
  – 5-axis cutting

• Reduced paper
5-axis Waterjet Cutting Makes Port Fitting Simple
Welding Layouts are Done by CNC Programming
Measurement Goes to the Work Piece

Inspection Arms

Laser Scanners
With Inspection at the Part During Welding no Post Weld Machining is Required
Welding Processes for Vacuum Chambers

• TIG (Tungsten Inert Gas)
  – Standard process for critical vacuum welds

• MIG (Metal Inert Gas)
  – Standard process for structural welds

• Dual Shield MIG
Welding Processes for Vacuum Chambers

- Electron Beam Welding
  - Deep penetration
  - Small heat impact zone

- Friction Stir Welding
  - For Aluminum
Stress Relieving

- The benefits of stress relieving after/during welding are:
  - Less stress in material
  - Less deformations of chamber during and following machining operations
  - Better quality of welding seam if vibratory stress relieving is done during welding
Vibratory Stress Relieving

– Alternative to thermal stress relieving for very large structures
– Vibrations 60% to 100% of resonance frequency are implemented into work piece
Integration of Components Into a Vacuum Chamber
Benefits of Integration

- The traditional layout of a system has components flanged onto a chamber.
- The benefit is higher flexibility.
- Integrating valves, baffles and other components into a chamber can save costs and most of the time will reduce the size of the system.
Chamber with Gate Valves
Chamber with Curved Gate

- GNB Engineered Chamber measuring 1.5m in diameter.
- Includes a 170° custom valve that seals with differential pressure in either direction.
Load Lock Module

- Door, LL chamber and transfer valves can be combined into one compact package.
UHV is Bigger & Less Expensive
Typical UHV Seals

- Wire seal flanges
- Conflat flanges
- Garlock Helicoflex
- Ferrofluidic seal
Two Challenges

- Larger flanges
- Reduced costs
4 Meter Long All-metal Seal
Correct Material Selection

Approximate outgassing rates to use for choosing vacuum materials or calculating gas loads
(All rates are for 1 hour of pumping)

<table>
<thead>
<tr>
<th>Vacuum Material</th>
<th>Outgassing Rate (torr liter/sec/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless Steel</td>
<td>$6 \times 10^{-9}$</td>
</tr>
<tr>
<td>Aluminum</td>
<td>$7 \times 10^{-9}$</td>
</tr>
<tr>
<td>Mild Steel</td>
<td>$5 \times 10^{-6}$</td>
</tr>
<tr>
<td>Brass</td>
<td>$4 \times 10^{-6}$</td>
</tr>
<tr>
<td>High Density Ceramic</td>
<td>$3 \times 10^{-9}$</td>
</tr>
<tr>
<td>Pyrex</td>
<td>$8 \times 10^{-9}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vacuum Material</th>
<th>Outgassing Rate (torr liter/sec/linear cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viton (Unbaked)</td>
<td>$8 \times 10^{-7}$</td>
</tr>
<tr>
<td>Viton (Baked)</td>
<td>$4 \times 10^{-8}$</td>
</tr>
</tbody>
</table>
If some elements are not permitted in a chamber, keep them away!

- **Mild Steel**
  - No mild steel fixtures, carbide cutting tools

- **Tungsten**
  - No TIG welding
Cleaning Processes

- Depends on desired vacuum level and process
  - High pressure wash
  - Wash with DI water
  - Alcohol wipe down
  - Ultrasonic chemical clean
  - Passivation and electro-polishing
  - Bake out
Passivation

• According to ASTM A380, passivation is "the removal of exogenous iron or iron compounds from the surface of stainless steel"

• Will avoid corrosion especially in 300 series stainless

• Typically done with acids followed by a water (or DI water) rinse
Electro-polishing

- Deburrs
- Smooths
- Brightens
- Passivates
- Redefines oxide layer
- Removes surface contaminants
5 Main Reasons for Selecting a Surface Finish

• Aesthetics
• Gas load
• Fit up
• Elimination of trapped volumes
• Ease of cleaning

The cost can be large and many companies over specify!
Waterjet Cutting has Dramatically Changed Chamber Manufacturing

Waterjet edges are specified by “Q” codes. The better the finish, the slower the cut.
15 Common Surface Finishes

- Number 0 finish is hot rolled annealed (also known as mill-scale)
- Number 1 finish is hot rolled
- Number 2D finish is cold rolled
- Number 2B finish, cold rolled bright finish
- Number 2BA is bright annealed finish, nearly a mirror
- Number 3 grained, sanded in a uniform direction with 80-100 grit
- Number 4 grained, sanded in a uniform direction with 150 grit
- Number 6 finish is plate sanded with a rotating abrasive cloth; “Satin Blend” is an example
- Number 7 finish is buffed, highly reflective, some fine scratches
- Number 8 finish is a true blemish-free mirror finish
- Bead blasted
- Blanchard ground
- Machined all over
- Electro-polished
- A lapped finish
Surface Roughness for Typical Chamber Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Roughness Height Ra (µ inch)</th>
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<tbody>
<tr>
<td>Flame Cutting</td>
<td>2000 XXXX</td>
</tr>
<tr>
<td>Waterjet</td>
<td>1000 XXXX</td>
</tr>
<tr>
<td>Sawing</td>
<td>500 XXXXX</td>
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<tr>
<td>EDM</td>
<td>250 XXXX XXXX XXXX XXXX XXXX</td>
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<td>Milling</td>
<td>125 XXXX XXXX XXXX XXXX XXXX</td>
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<tr>
<td>Turning</td>
<td>63 XXXX XXXX XXXX XXXX XXXX</td>
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<tr>
<td>Laser</td>
<td>32 XXXX XXXX XXXX XXXX XXXX</td>
</tr>
<tr>
<td>Grinding</td>
<td>16 XXXX XXXX XXXX XXXX XXXX</td>
</tr>
<tr>
<td>#4 Grained</td>
<td>8 XXXX XXXX XXXX XXXX XXXX</td>
</tr>
<tr>
<td>Electro-Polish</td>
<td>4 XXXX XXXX XXXX XXXX XXXX</td>
</tr>
<tr>
<td>Lapping</td>
<td></td>
</tr>
</tbody>
</table>
To Eliminate the Conversion Confusion

<table>
<thead>
<tr>
<th>Ra (µ inch)</th>
<th>RMS (µ inch)</th>
<th>Ra (µ meter)</th>
<th>RMS (µ meter)</th>
<th>Grit Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4.5</td>
<td>0.10</td>
<td>0.11</td>
<td>Mirror</td>
</tr>
<tr>
<td>8</td>
<td>9.0</td>
<td>0.20</td>
<td>0.23</td>
<td>400</td>
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<tr>
<td>16</td>
<td>18</td>
<td>0.41</td>
<td>0.46</td>
<td>240</td>
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<tr>
<td>32</td>
<td>36</td>
<td>0.81</td>
<td>0.91</td>
<td>180</td>
</tr>
<tr>
<td>63</td>
<td>71</td>
<td>1.60</td>
<td>1.80</td>
<td>120</td>
</tr>
<tr>
<td>125</td>
<td>141</td>
<td>3.18</td>
<td>3.57</td>
<td>36</td>
</tr>
<tr>
<td>250</td>
<td>281</td>
<td>6.35</td>
<td>7.14</td>
<td>NA</td>
</tr>
<tr>
<td>500</td>
<td>560</td>
<td>12.7</td>
<td>14.3</td>
<td>NA</td>
</tr>
<tr>
<td>1000</td>
<td>1125</td>
<td>25.4</td>
<td>28.6</td>
<td>NA</td>
</tr>
<tr>
<td>2000</td>
<td>2250</td>
<td>50.8</td>
<td>57.2</td>
<td>NA</td>
</tr>
</tbody>
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Misconceptions

• Shiny surfaces are always better
  – Electro-polishing and graining, particularly, introduces contaminants into the metal.

• Electro-polishing is required for UHV
  – The greatest reduction in gas load occurs between a mill-scale and brushed mill-scale finish. It is difficult to find a difference in gas load between a #4 grained finish and an electro-polished finish.
Thank You!

Questions?

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