Electron Beam Welding
Titanium Stress Risers 42 Feet Long
Hi-Tech Welding and Forming

John Monsees
Hi-Tech Overview

1. Established 1984 (Privately Held)
2. Annual Sales $5.5 Million yr 2006 (+ 50% Annual Growth)
3. 77,000+ sq ft Facility
4. EB Welding / 2nd Generation Super-Plastic Forming
5. AS9100, NADCAP, D1-9000 Compliant
6. A Complete Build To Print, Full Service Fabricator
Customers, Projects & Programs

- **Northrop Grumman**
  - Weld repair and process development for B2
  - Global Hawk Exhaust Duct
- **Pratt & Whitney**
  - UCAS Exhaust Ducting
- **B.F. Goodrich**
  - Venture Starr
- **Solar Turbines**
  - Turbine Rotors
- **NSWC**
  - Titanium Prototypes & Ducting
- **Ametek Rotron**
  - Submarine Heat exchangers
- **Boeing**
  - EB Welded Castings
  - X-50 Components
- **Bath Iron Works (BIW)**
  - Titanium Closures
- **Teledyne Wah-Chang**
  - EB Welded Armor Plate
  - Weld Development of Ti4Al2.5V
- **General Electric Engine Group**
  - SPF Welded Mixers

- **US Air Force / Orbit**
  - Ground Radar Rigging
  - Manipulators
- **U.S. Army**
  - Field repair of Lightweight Titanium Howitzer
  - Development of Lightweight Stryker Doors
- **TIMET**
  - Titanium Stress Risers
  - Other Titanium Components
- **Lockheed**
  - F22 Gun Trough
- **Rolls-Royce**
  - JSF Nozzle Ducting
- **TREK Bicycles**
  - Development of production process
  - TREK High Production cell
- **ATF Titanium ducting**
  - Advance ducting development and manufacture
  - Tooling development, process development
- **Other Ducting Programs**
Key Manufacturing Processes

**Heat Treat**
- 5 Vacuum Furnaces up to 96” x 120” 2,400°F

**Machining**
- 5 Axis Milling 60” cube, 120” Longest length Precision Jig Boring HV Turning

**Laser Cutting**
- 6 Axis Laser Cutting 177” x 98” x 36” 2500 watt Gantry

**NDT Insp.**
- X-Ray 16’ x 18’ x 14’ Ultra-Precision CMM 64” x 48” x 32” FPI Mag Particle Ultrasonic

Hi-Tech Welding and Forming, ITA Titanium 2006, October 1-3, 2006
Process Overview

- Principles of Operation
### Process Overview

#### EB Weld Vs. MIG Weld

<table>
<thead>
<tr>
<th></th>
<th>E.B.</th>
<th>M.I.G.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage, Volts</td>
<td>$30 \times 10^3$</td>
<td>28.7</td>
</tr>
<tr>
<td>Current, Amps</td>
<td>$225 \times 10^{-3}$</td>
<td>360</td>
</tr>
<tr>
<td>Welding Speed, IPM</td>
<td>37</td>
<td>6.5</td>
</tr>
<tr>
<td>Power, Kilowatts</td>
<td>6.75</td>
<td>10.3</td>
</tr>
<tr>
<td>Energy, Kilojoules/In.</td>
<td>9.1</td>
<td>95.5</td>
</tr>
</tbody>
</table>
**Process Overview**

- **EB Weld Vs. TIG Weld**

<table>
<thead>
<tr>
<th>Process</th>
<th>E.B.</th>
<th>T.I.G.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Voltage, Volts</strong> 30 x 10³</td>
<td><strong>1st Pass</strong> 11.7, <strong>2nd Pass</strong> 13</td>
</tr>
<tr>
<td></td>
<td><strong>Current, Amps</strong> 200 x 10⁻³</td>
<td><strong>270</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Welding Speed, IPM</strong> 95</td>
<td><strong>270</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Power, Kilowatts</strong> 6</td>
<td><strong>6.5</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Energy, Kilojoules/In.</strong> 3.8</td>
<td><strong>3.2</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>29.6</strong></td>
</tr>
</tbody>
</table>

[Image of welding process]
Process Overview

• Advantages and Limitations
  – High electrical efficiency
  – Very high depth to width ratio
  – Minimum heat input, = low distortion
  – High-purity environment
  – Ability to project weld long distances
Advantages and Limitations

- Rapid welding speeds
- Ability to weld thick to thin, no filler
- Hermetic seal welds possible
- Magnetic oscillations can improve quality
- Relatively long depth of focus
### Characteristics of Weld

- **Excellent process for reactive or refractory metals**
  - Tungsten, Molybdenum, Titanium, Zirconium, etc.

<table>
<thead>
<tr>
<th>Purity Grade</th>
<th>Contamination Level, ppm</th>
<th>Where we weld!</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.95%</td>
<td>500</td>
<td>Argon</td>
</tr>
<tr>
<td>99.995%</td>
<td>50</td>
<td>Air</td>
</tr>
<tr>
<td>99.999%</td>
<td>10 x 10^{-3}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 x 10^{-3}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>38 x 10^{-3}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0 x 10^{-3}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0 x 10^{-4}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0 x 10^{-5}</td>
<td></td>
</tr>
</tbody>
</table>
Characteristics of Weld

• Low-energy Process
  – Low thermal distortion
  – Very rapid cooling rates
  – Significantly reduced heat affected zone

• High Degree of Reliability
  – Metallurgy very consistent
EB Welding Equipment

EB 1: 54 x 50 x 54
EB 2: 54 x 50 x 54
EB 3: 50 x 30 x 42
EB 4: 68 x 68 x 78
EB Welding Equipment

EB 5
EB 6
EB 7
EB 8

648 x 30 x 42
60 x 36 x 40
68 X 68 X 78
132 X 62 X 92

Installing Now
EB/TIG Welding Experience

1. Highly Experienced Staff / 30+yrs
2. Welding Very Complex Structures
3. Broad Experience in Materials Especially Titanium
4. Industry Recognized Capability
5. NADCAP Certified
6. Ongoing Training Program
Large EB/HT Machine
(Only ½ of length is visible, the other half is on the other side of weld head.)
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(Only ½ of length is visible, the other half is on the other side of weld head.)
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(Only ½ of length is visible, the other half is on the other side of weld head.)
Large Capacity / Unique Design

- Unique machine design enables unique part designs

- 42” dia. x over 648” long
- 4 ton capacity on carriage
- 42kw (2”-3” thick depending on metal)
- Very flexible arrangement
  - Chamber can be arranged for different shapes
  - Weld both diametrically and longitudinally
- Capable of adding filler metals
- Stress Relieving to 1,400°F in same chamber
Top Tension Production Riser Connectors

Premium riser connectors.

Used in TLP and SPAR Installations

- Low SCF for high fatigue duty
- Lightweight to minimise riser loadings
- High sealing integrity for dual and single barrier connections.
Titanium Riser Medusa Platform

• ’01 McDermott awarded contract to Murphy Oil
• ‘01 Timet / Hi-Tech Welding began development
  – Special EB joint design
  – Machine design & mfg. for unique capability
    • To include Heat Treat capability
  – Material characterization to meet customer needs
    • Ti 6Al-4VELI (Special Heat Treat)
• ’02 Hi-Tech Welding completed machine
  – Numerous samples were produced
  – Testing & certification of machine was completed
Titanium Riser Medusa Platform

'03 Timet / Hi-Tech Welding completed...
- CTOD & other required testing
- Product was shipped to Hi-Tech for welding
- Finished welded product was shipped to customer
  - Chemical cleaning
  - EB Welding
  - UT, RT (3 different sources)
  - Heat Treat

- **Actual welds took less than 15 minutes!**
  - *Average thickness 1.8*
  - *Zero Defect level possible*
  - *No filler metal*
EB Welded Titanium Stress Riser
EB Welded Titanium Stress Riser
EB Welded Titanium Stress Riser

Titanium Riser 42 feet long ~ 8,500 lbs of titanium Electron Beam welded in two places, with average thickness 1.800”, ASME Sect. IX
Unique Benefits of EB/HT

1. Ultra-clean Weld
2. Superior Dimensional Tolerances
3. Typically half the Material Req.
4. Virtually no size limitations
5. Very Short Cycle Times
6. Many Different Metal Combinations
Summary

Electron Beam Welding is:

• Established and well understood process
• Extremely versatile and yet precise
• Very unique weld geometry
  – Enabling unique part geometry
• High metallurgical quality
• Very cost competitive to other joining processes
  – Often less expensive, especially with production tooling
• Precisely controlled and highly reliable
Summary
What we will see in the future:

• Increased use in Oil & Gas industry
• Additional long tube type applications
  – Stress Risers (TLP)
  – Work Over Strings
  – Drill Pipe
  – Lay lines
• Shafts for propulsion
• Rail Gun
• Other unusual length driven applications requiring welds to improve productivity.
Thank You For Your Interest

For more information contact us at:

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