Manufacturing Systems Demonstration

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WD-FH-0004 Task 3.2

Manufacture and Preparation of Test Specimens for Johnson-Cook Material Characterization

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Manufacture and Preparation of Test Specimens for Johnson-Cook Material Characterization

As a revision to Contract #W56HZV-05-0721 (WD-FH-0004), this task was added to the current project for the purpose of performing material characterizations and developing Johnson-Cook (J-C) strength and damage constants of friction stir welded (FSW) ballistic joints. These material constants will be used by the government for ballistic blast and other types of modeling and simulation, and will be included in the Elastic Plastic Impact Code (EPIC) library. This report describes the welding and machining processes used to manufacture the material test specimens used for the J-C material characterization tests and provides the results of metallurgical analysis for the FSW joint of each selected armor material.
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1.0 INTRODUCTION

As a revision to Contract #W56HZV-05-0721 (WD-FH-0004), this task was added to the current project for the purpose of performing material characterizations and developing Johnson-Cook (J-C) strength and damage constants of friction stir welded (FSW) ballistic joints. These material constants will be used by the government for ballistic, blast and other types of modeling and simulation, and will be included in the Elastic Plastic Impact Code (EPIC) library. This report describes the welding and machining processes used to manufacture the material test specimens used for the J-C material characterization tests and provides the results of metallurgical analysis for the FSW joint of each selected armor material.

At the onset of this project, U.S. Army TARDEC personnel identified six armor materials (See Table 1-1) which were either currently in use or under consideration for future use for ballistic structures and had not undergone FSW joint material strength characterization. Due to budgetary limitations, only three of these materials were selected for J-C analysis: 6061, 5083, and 2139 aluminum alloys. TARDEC wanted high-hardness steel armor to be one of the chosen materials however preliminary FSW tool trials using a tungsten-rhenium tool to weld ½-inch thick plate of this material indicated that excessive tool wear would prohibit its inclusion in this study. Development of FSW weld joints of high-hardness steel armor are continuing at FH-CAT with the goal of including this material in a future J-C material characterization study.

<table>
<thead>
<tr>
<th>#</th>
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<th>Class</th>
<th>MIL-Standard</th>
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<tbody>
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<td>1.</td>
<td>6061-T6511 aluminum alloy, Class 1, MIL-DTL-32262</td>
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<td>2.</td>
<td>Steel - high-hardness, MIL-DTL-46100E</td>
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<td>3.</td>
<td>5083-H131 aluminum alloy, Class 1, MIL-DTL-46027K</td>
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<td>4.</td>
<td>2139-T8 aluminum alloy, Class 1, MIL-DTL-32341</td>
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<td></td>
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<td>5.</td>
<td>2195-T64 aluminum alloy, Class 2, MIL-DTL-32341</td>
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<td>6.</td>
<td>Steel – homogeneous, Class 1 or 2, MIL-DTL-12560J</td>
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2.0 WELD COUPON MANUFACTURING

2.1 Material
The 6061 aluminum armor used for this project was manufactured by Kaiser Aluminum (Fairfield, IL) and was delivered as 1-in. x 2-in. x 12-ft. bars (Lot #Z00222015). The full-length bars were then cut into 8-in. lengths\(^1\) using a band saw with cooling fluid.

The 2139 aluminum armor used for this project was manufactured by Alcan Rolled Products (Ravenswood, WV). Due to the limited availability of this experimental armor, it was delivered as three large plates: one 1-in. x 24-in. x 47.5-in. (Lot #820081) and two 1-in. x 48-in. x 48 in. (Lot # 820091). The plates were cut into 2-in. wide bars using a water-jet machine and these bars were then cut into 8-in. lengths using a band saw with cooling fluid. One side of each bar was milled to remove the surface finish left by the water-jet cutting process.

The 5083 aluminum armor used for this project was also manufactured by Alcan and originally delivered to Sunshine Metals (Glenpool, OK) as a 1 1/8-in. x 20-in. x 170-in. plate (Lot #125831). At Sunshine, the plate was then milled to 1.0-in. thick and then sawed into the 12-in. x 156-in. plate that was subsequently delivered to FH-CAT\(^2\). The plate was then cut into 2-in. x 8-in. segments using a band saw with cooling fluid. One side of each bar was milled to remove the saw marks.

2.2 Coupon Production
The weld coupons (Figure 2-1) were all manufactured on the same FH-CAT FSW machine, a Transformation Technologies, Inc. (Elkhart, IN) Model GG1 (Figure 2-2), in single batches for each material. For all three materials, an FSW tool made of H13 tool steel with a scrolled pin and shoulder (See Figure 2-3) was used however the different heat requirements of the materials required that different tool shoulder diameters be used; 50.8-mm for 6061 and 40-mm for 5083 and 2139. The 6061 coupons were

\(^1\)At the beginning of this expedited project an FSW coupon fixture and machine program that was currently in use at FH-CAT at that time was used for coupon manufacturing.

\(^2\) This 12-in. wide plate was originally ordered as material for ballistic target weldments.
completed on July 11, 2011, the 5083 coupons on August 2, 2011, and the 2139 coupons on November 9, 2011.

Figure 2-1: 6061 FSW Coupon

Figure 2-2: Friction Stir Weld Machine

Figure 2-3: FSW Tool (40-mm dia. shown)
Other than the material-specific welding parameters shown in Table 2-1, the manufacturing of each coupon followed the following process:

1. Clean two material bars with ethyl alcohol and a disposable towel.
2. Blow debris from the fixture using a compressed air nozzle.
3. Place the bars into the fixture (See Figure 2-4), with the square/milled sides at the joint, and tighten the fixture clamps with a hex head torque wrench (25 ft-lbs).
4. Inspect the material installation to confirm proper positioning and fit.
5. Using machine manual mode, lower the spindle so that the FSW tool tip is near the top of the material bars. The exact point of where the tip contacts the material is then found using the manual mode micro adjustment knob. Recalibrate the Z-axis positioning to account for fixture height variations caused by heat variations.
6. Initiate the CNC welding program via the machine’s operator interface panel.
7. Visually monitor the entire welding cycle.
8. Upon completion of the automated welding cycle, the welded coupon remains in the fixture for 1-2 minutes to allow cooling.
9. Visually inspect the quality of the weld.
10. After the in-fixture cooling period, release the clamps and transfer the coupon to the machine’s bed plate to allow it to cool to room temperature.
11. During this cooling step, mark the coupon with a sequential number using a paint pen.
12. Allow the empty fixture to cool before installing the next set of material bars.
   (The cooling period was 10 minutes minimum for the 6061 and 5083 materials. Due to high spindle torque during welding of 2139 coupons, the fixture and machine were cooled for a minimum of 30 minutes.)

On several occasions for all material batches, the time span between individual coupon welding was several hours to several days because of personnel and shop work schedules.
As preparation for X-ray inspection of the welds, each coupon was machined to remove the inherent FSW flaws. Both ends of the coupons were removed using a laboratory precision wet saw to remove the weld starts and exit holes and to set the final coupon lengths of 4.5-in. The top surface of each coupon was then milled to remove weld flash.

Each material batch of coupons was then X-ray inspected at Magna Chek Inc. (Madison Heights, MI). None of the coupons exhibited any internal flaws.
3.0 WELD JOINT METALLURGICAL ANALYSIS

3.1 Sample Preparation
After the material-specific FSW process parameters were optimized (See Appendix A for development process parameters.), a set of coupons was segmented using a laboratory wet saw to provide transverse weld joint samples for hardness evaluation, micrographs, scanning electron microscopy (SEM), electron backscatter diffraction (EBSD), and tensile strength analysis. As required, samples were mounted, polished, and/or chemical etched (Keller’s reagent). The transverse tensile test specimens (ASTM E8 – flat, sub-size) were machined and tested at FH-CAT (See Figure 3-1).

![Figure 3-1: FH-CAT Tensile Test Specimen Location](image)

3.2 Microstructural Analysis
Microstructural analysis was conducted using a Nikon Eclipse LV150 optical microscope and a Zeiss EVO MA10 SEM. Images were obtained from the optical microscope using a calibrated digital camera, and Scentis software. Optical microscope images were captured at 500x magnification and SEM images were captured at 500x and 1000x magnifications. Figures 3-2, 3-3 and 3-4 show the microscopic results for Al 6061, Al 5083, and Al 2139 respectively.
Figure 3-2: Microscopic Views of 6061 FSW Joint
Figure 3-3: Microscopic Views of 5083 FSW Joint.
Figure 3-4: Microscopic Views of 2139 FSW Joint.
3.3  Microhardness

Microhardness charts were created using a Leco LM100AT hardness tester. Figure 3-5 compares the microhardness charts for the 6061, 5083, and 2139 FSW weld joints.

![Microhardness charts for 6061, 5083, and 2139 FSW joints](image)

*Figure 3-5: FSW Joint Micro-Hardness (HV)*
3.4 **Electron Backscatter Diffraction**

Further definition of the metallurgic grain structure across the weld joint was conducted using EBSD. Prepared FSW joint samples were analyzed with a Hikari/EDAX backscatter detection system mounted to a Zeiss EVO MA10 SEM. Figures 3-6, 3-7, and 3-8 show the EBSD results.

*Figure 3-6: EBSD of 6061 FSW Joint*
Figure 3-7: EBSD of 5083 FSW Joint
Figure 3-8: EBSD of 2139 FSW Joint
3.5 Tensile Strength

Tensile tests were conducted using an Instron Model 5982 universal testing machine with a strain rate of 1 mm/min. The force was measured using a 100 kN load cell, and elongation was measured using a 1-in. length extensometer. Table 3-1 compares the strength test results for all three FSW materials with their respective base materials. Figures 3-9, 3-10, and 3-11 show the stress vs. strain relationships of the FSW joints.

Table 3-1: Tensile Test Results

<table>
<thead>
<tr>
<th></th>
<th>Yield Strength (MPa)</th>
<th>Ultimate Yield (MPa)</th>
<th>% Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>6061 FSW</td>
<td>194</td>
<td>270</td>
<td>7.06%</td>
</tr>
<tr>
<td>6061 Base</td>
<td>507</td>
<td>576</td>
<td>12%</td>
</tr>
<tr>
<td>% Change</td>
<td>-61.7%</td>
<td>-53.1%</td>
<td>-41.2%</td>
</tr>
<tr>
<td>5083 FSW</td>
<td>229</td>
<td>394</td>
<td>18.4%</td>
</tr>
<tr>
<td>5083 Base</td>
<td>333</td>
<td>442</td>
<td>19%</td>
</tr>
<tr>
<td>% Change</td>
<td>-31.2%</td>
<td>-10.9%</td>
<td>-3.2%</td>
</tr>
<tr>
<td>2139 FSW</td>
<td>235</td>
<td>405</td>
<td>14.9%</td>
</tr>
<tr>
<td>2139 Base</td>
<td>475</td>
<td>500</td>
<td>13.1%</td>
</tr>
<tr>
<td>% Change</td>
<td>-50.5%</td>
<td>-19.0%</td>
<td>13.7%</td>
</tr>
</tbody>
</table>
Figure 3-9: 6061 FSW Stress vs. Strain

Figure 3-10: 5083 FSW Stress vs. Strain

Figure 3-11: 2139 FSW Stress vs. Strain
3.5 J-C Test Specimen Location

SWRI selected the centerline positions of the final specimens using the coupon transverse micro-hardness chart (See Figure 3-12) and macro-etch sample for each material. While the weakest part of an FSW joint is typically the thermo-mechanically affected zone (TMAZ) where the softest material is found, commonality with a previous FSW joint characterization study\(^3\) was the driving factor for the positions selected for this project. For only the 2139 FSW zone material, the horizontal centerline of the specimen location was slightly lower (1.3-mm) than all other locations to avoid a small area of relatively harder material in the upper, advancing side of the FSW zone.

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\(^3\) TARDEC Report 18.12544/026, *Mechanical Characterization of Friction Stir Welded Aluminum 5059-H131 (Weld and Heat Affected Zone) for Determination of Johnson-Cook Constitutive Constants*, Sep 2010, Southwest Research Institute, San Antonio, TX
4.0 **FINAL SPECIMEN MACHINING**

After returning from X-ray inspection, three specimen bars were longitudinally extracted from each FSW coupon; FSW zone, HAZ advancing side, and HAZ retreating side (See Figure 4-1).

![Figure 4-1: Specimen Bar Coupon Locations](image)

To duplicate previous J-C strength and damage studies of armor material conducted at SWRI, several different specimen configurations were required from each of the coupon specimen positions (See Table 4-1). See Appendix B for the specimen design prints and Appendix C for FH-CAT machining process descriptions.

For all of the specimen bars of the 6061 and 5083 material sets, one end was machined using a Cincinnati 630XT CNC machining center to a diameter of 0.75-in. (0.80-in. for B and E Notch Tension specimen bars) to aid subsequent processes. One end of $\frac{3}{4}$-13 UNC-2A threads for the B and E Notch Tension specimen bars were also machined at this operation. Throughout the FH-CAT manufacturing process, material coupons, specimen bars, and specimens were segregated into separate bins, bags, and/or laser marked between process steps. Each specimen was individually bagged for shipping to SWRI.

6061 and 5083 base material .250 Tension specimens were initially produced as a machining process trial and then provided to SWRI for inspection and approval. With their approval, “production” manufacturing of the FSW test specimens began.
The Quasistatic Tension, SHPB Tension, SHPB Compression, and Taylor Anvil Impact Test specimens of the 6061 and 5083 materials were machined at FH-CAT. Due to machine resource limitations at FH-CAT, the machining of the 6061 and 5083 B-Notch Tension, E-Notch Tension, and Sub-size Torsion specimens and all of the 2139 specimens was done by the SWRI machine shop using FSW material blanks provided by FH-CAT.

The FH-CAT Quasistatic and SHPB Tension specimens were turned to final shape and threaded using a Mazak 100-III3 CNC machining center yielding one specimen per material blank. These specimens were then manually polished using a bench grinder with a 6-in. dia. sewn cotton buffing wheel. For the final operation, each tension
specimen was inserted into a ½-in. inside diameter plastic tube to protect the surface finish and then cut to final length using the Mazak 100. Figure 4-2 depicts the complete manufacturing process, material bars thru final machining, for the tension specimens.

The Taylor Anvil Impact Test (TAIT) specimen blanks were turned to 0.625-in. diameter using the Mazak 100 and subsequently turned to final diameter and rough length using a Hardinge Conquest T42 CNC lathe. This process yielded three specimens per material blank. The TAIT specimens were then milled to final length using a Cincinnati VMC500 CNC machining center.

The SHPB Compression specimens were turned to final diameter and rough length (four per blank) using the Hardinge CNC lathe and were then milled to final length using the Cincinnati VMC500.

![Figure 4-2: Specimen Manufacturing - Material Stock Thru Final Machining](image-url)
Appendix A

FSW Process Parameter Development
## DOE for FSP/FSW of 6061-T651 Al

**Operator:** 
Date: 04/13/11

Substrate Material: 6061-T651 Al, 1” thick plate, 8” × 2” in size

<table>
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<tr>
<th>Tool Material</th>
<th>Tool pin geometry</th>
<th>Shoulder diameter (mm)</th>
<th>Pin length (mm)</th>
<th>Pin diameter (mm)</th>
<th>Pitch width (mm)</th>
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<tbody>
<tr>
<td>H13 steel, Rc 54</td>
<td>Scrolled, conical</td>
<td>38</td>
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### Tool plunging

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<th>Rotation rate (rpm)</th>
<th>Force (KN)</th>
<th>Feed rate (mm/min)</th>
<th>W (mm)</th>
<th>Z (mm)</th>
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<tbody>
<tr>
<td></td>
<td>800</td>
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<td>20</td>
<td>- 24</td>
<td>- 25</td>
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### Travers speed

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<td>10 mm</td>
</tr>
<tr>
<td>80</td>
<td>25 mm</td>
</tr>
<tr>
<td>XX</td>
<td>150 mm</td>
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### Run Order (S.N.)

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<th>Rotation rate (rpm)</th>
<th>Traverse speed (mm/min)</th>
<th>Force (KN)</th>
<th>Actual Force (kN)</th>
<th>Tool tilt (degree)</th>
<th>Remarks on weld quality</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>1(9)</td>
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<td>100</td>
<td>35</td>
<td>34</td>
<td>2</td>
<td></td>
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<tr>
<td>2(10)</td>
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<td>35</td>
<td>36</td>
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<td></td>
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<tr>
<td>3(11)</td>
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<td>2</td>
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<td>4(7)</td>
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<td></td>
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<tr>
<td>5(8)</td>
<td>400</td>
<td>150</td>
<td>35</td>
<td>28</td>
<td>2</td>
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DOE for FSP/FSW of 6061-T651 Al

**Substrate Material:** 6061-T651 Al, 1” thick plate, 10” × 2” in size

**Operator:**
Date: 04/28/11

### Tool Material

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<th>Force (KN)</th>
<th>Actual Force (kN)</th>
<th>Tool tilt (degree)</th>
<th>Remarks on weld quality</th>
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<td>48</td>
<td>2</td>
<td>No defect</td>
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<tr>
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### DOE for FSW of Al 5083-H131

**Operator:**

Substrate Material: Al 5083-H131, 1” thick plate, 6” × 2” in size

**Date:** 06/08/11

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<th>Force (KN)</th>
<th>Feed rate (mm/min)</th>
<th>W (mm)</th>
<th>Z (mm)</th>
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<tbody>
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<td>600</td>
<td>60</td>
<td>20</td>
<td>- 24.0</td>
<td>- 24.17</td>
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<table>
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<th>Distance</th>
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<td>40</td>
<td>20 mm</td>
</tr>
<tr>
<td>XX</td>
<td>90 mm</td>
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<th>Force (KN)</th>
<th>Actual Force (kN)</th>
<th>Tool tilt (degree)</th>
<th>Remarks on weld quality</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Macroscopic</td>
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Substrate Material: Al 5083-H131, 1" thick plate, 6” × 2” in size

### Tool Material and Geometry

<table>
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<tr>
<th>Tool Material</th>
<th>Tool pin geometry</th>
<th>Shoulder diameter (mm)</th>
<th>Pin length (mm)</th>
<th>Pin diameter (mm)</th>
<th>Pitch width (mm)</th>
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<tbody>
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<td>H13 steel, Rc 54</td>
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### Tool Plunging Parameters

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<th>Rotation rate (rpm)</th>
<th>Force (KN)</th>
<th>Feed rate (mm/min)</th>
<th>W (mm)</th>
<th>Z (mm)</th>
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### Travers Speed

- **Travers speed (mm/min)**: 20
- **Distance**: 10 mm to 90 mm

### Run Order and Parameters

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<th>Run Order (S.N.)</th>
<th>Rotation rate (rpm)</th>
<th>Traverse speed (mm/min)</th>
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<td>30-31</td>
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## DOE for FSW of Al 5083-H131

**Operator:**

Substrate Material: Al 5083-H131, 1” thick plate, 6” × 2” in size

### Tool Material

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<th>Tool Material</th>
<th>Tool pin geometry</th>
<th>Shoulder diameter (mm)</th>
<th>Pin length (mm)</th>
<th>Pin diameter (mm)</th>
<th>Pitch width (mm)</th>
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### Travers speed (mm/min)

<table>
<thead>
<tr>
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<th>20 XX</th>
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<td>Distance</td>
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### Run Order (S.N.)

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<th>Force (KN)</th>
<th>Actual Force (kN)</th>
<th>Tool tilt (degree)</th>
<th>Remarks on weld quality</th>
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**Substrate Material:** Al 5083-H131, 1” thick plate, 6” × 2” in size

**Operator:**  
Date: 06/24/11

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### Tool Material and Geometry

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<th>Tool pin geometry</th>
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<th>Pitch width (mm)</th>
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<tbody>
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### Tool Plunging Parameters

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<th>Rotation rate (rpm)</th>
<th>Force (KN)</th>
<th>Feed rate (mm/min)</th>
<th>W (mm)</th>
<th>Z (mm)</th>
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<tr>
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### Traverse Speed and Distance

- **Distance:** 10 mm to 90 mm
- **Traverse speed:** 20 mm/min

---

### Run Order and Remarks on Weld Quality

<table>
<thead>
<tr>
<th>Run Order (S.N.)</th>
<th>Rotation rate (rpm)</th>
<th>Traverse speed (mm/min)</th>
<th>Force (KN)</th>
<th>Actual Force (kN)</th>
<th>Tool tilt (degree)</th>
<th>Remarks on weld quality</th>
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<tr>
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<td>34</td>
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<td>60</td>
<td>33</td>
<td>3</td>
<td>No defect</td>
</tr>
<tr>
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<td>30</td>
<td>3</td>
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Substrate Material: Al 2139-T8, 1" thick plate, 8 " × 2 " in size

**Operator:**

**Date:** 09/26/11

---

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<th>Tool Material</th>
<th>Tool pin geometry</th>
<th>Shoulder diameter (mm)</th>
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<th>Pin diameter (mm)</th>
<th>Pitch width (mm)</th>
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**Travers speed (mm/min)**

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**Run Order (S.N.)**

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Substrate Material: Al 2139-T8, 1” thick plate, 8” × 2” in size

Operator: Date: 09/26/11

DOE for FSW of Al 2139-T8  DOE 023

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<th>Tool Material</th>
<th>Tool pin geometry</th>
<th>Shoulder diameter (mm)</th>
<th>Pin length (mm)</th>
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<th>Force (KN)</th>
<th>Feed rate (mm/min)</th>
<th>W (mm)</th>
<th>Z (mm)</th>
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<tbody>
<tr>
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| Travers speed (mm/min) | 60 | XX | 10 mm | 50 mm |

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<th>Rotation rate (rpm)</th>
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<td>300</td>
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**DOE for FSW of Al 2139-T8**

**DOE 024**

**Operator:**

**Date: 09/28/11**

Substrate Material: Al 2139-T8, 1” thick plate, 8 ” × 2 ” in size

<table>
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<tr>
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<th>Shoulder diameter (mm)</th>
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<th>Pin diameter (mm)</th>
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<tbody>
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<th>Force (KN)</th>
<th>Feed rate (mm/min)</th>
<th>W (mm)</th>
<th>Z (mm)</th>
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<table>
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<th>Travers speed (mm/min)</th>
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Distance: 5 mm to 150 mm

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<td>40-45</td>
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</tr>
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Appendix B

J-C Test Specimen Prints
**NOTE: USE LOI STRESS MACHINING PROCEDURE**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PART</th>
<th>NONCONFORMITY OR DESCRIPTION</th>
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<td>F1151</td>
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<td>1.250</td>
</tr>
</tbody>
</table>

**T.A.I.T Specimen**

Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78510

10-11-2005

A. E. Nicholls

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NOTE: 1. SMALL CENTERS ARE PERMISSIBLE
2. USE LOW STRESS MACHINING PROCEDURE
Material:
As supplied.

Notes:
I.D. and O.D. finish B-18 RMS

Torsion Specimen Subsize

Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78210

07-21-2005
A. E. Nicholls

UNCLASSIFIED
Appendix C

FH-CAT Machining Processes
Focus: HOPE Process routing/Shop traveler

Customer: **Southwest Research Institute**

<table>
<thead>
<tr>
<th>Op No</th>
<th>Labor Code</th>
<th>Operation Description</th>
</tr>
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<tbody>
<tr>
<td>10</td>
<td>Height Gage &amp; Scribe</td>
<td>Find, and scribe weld centerline on ends of block.</td>
</tr>
<tr>
<td>20</td>
<td>Mill</td>
<td>Mill TOP to 0.875</td>
</tr>
<tr>
<td>30</td>
<td>Laser Marker</td>
<td>Mark TOP face of coupon per print (MMMM-X-TOP-NN, Where X=A,W, or R)</td>
</tr>
<tr>
<td>40</td>
<td>Mill</td>
<td>Mill BOTTOM to 0.750 thick</td>
</tr>
<tr>
<td>50</td>
<td>Mill</td>
<td>Mill coupon to 1.38 from weld centerline (retreating side)</td>
</tr>
<tr>
<td>60</td>
<td>Band Saw</td>
<td>Saw Block W .475 (minimum) from weld centerline (retreating side) SET ASIDE CUT OFF BLOCK &quot;R&quot;</td>
</tr>
<tr>
<td>70</td>
<td>Mill</td>
<td>Mill coupon to .375 from weld centerline (retreating side)</td>
</tr>
<tr>
<td>80</td>
<td>Mill</td>
<td>Flip around (TOP still facing up) and mill coupon to 1.75</td>
</tr>
<tr>
<td>90</td>
<td>Band Saw</td>
<td>Saw block at 'A' to .850 and remaining strip 'W' at .900 ref</td>
</tr>
<tr>
<td>100</td>
<td>Mill</td>
<td>Mill 'W' to .750 (from saw cut side)</td>
</tr>
<tr>
<td>110</td>
<td>Mill</td>
<td>Mill R to .750 (From saw cut side)</td>
</tr>
<tr>
<td>120</td>
<td>Mill</td>
<td>Mill A to .750 (from saw cut side)</td>
</tr>
<tr>
<td>130</td>
<td></td>
<td>Measurement of finished blocks, per inspection check sheet</td>
</tr>
</tbody>
</table>
UNCLASSIFIED

RETREATING SIDE (CLAMP MARKS)

SCRIBED WELD CENTELINE BOTH ENDS

DECIMALS

TOLERANCES

1 PLACE...... ±0.45
2 PLACE...... ±0.30
3 PLACE...... ±0.15
4 PLACE...... ±0.05

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

MATERIAL: 5083 ALUMINUM

DATE: 9/23/11

CI-ECKED BY: R
D: 9/23/11

RELEASED BY: UNITS

INCHES

PART NAME: TESTING STRIPS

PART NUMBER: P10

DRAWN BY: L.

SIGNED BY: L.

PRINTED ON SHEET: 1 OF 1
RETREATING SIDE (CLAMP MARKS)

WELD CENTERLINE

3.7 REF

.025

.88 .90 REF

4.50 REF

DECIMALS

1 PLACE........ 0.045
2 PLACE........ 0.030
3 PLACE........ 0.015
4 PLACE........ 0.005

TOLERANCES

± 1/16

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL: 5083 ALUMINUM

TOLERANCES

± 0.045
± 0.030
± 0.015
± 0.005

ANGULAR

± 0° 30'

FRACTIONS

± 1/16
MATERIAL: 5083 aluminum

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

TOLERANCES
DECIMALS
1 PLACE........ 1.045
2 PLACE........ 1.030
3 PLACE........ 1.015
4 PLACE........ 1.005

ANGULAR
±0°30'

FRACTIONS
±1/16

REF: 4.50

REF: .88

WELD CENTERLINE MMMM-W-TOP-NN

WELD CENTERLINE MMMM-R-TOP-NN

MATERIAL: 5083 aluminum

MITEM = 5083
TOLERANCES

DECIMALS
1 PLACE........ ±.045
2 PLACE........ ±.030
3 PLACE........ ±.015
4 PLACE........ ±.005

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 5083 ALUMINUM

ANGULAR
±0°30'

FRACTIONS
±1/16
CLAMP MARKS

WELD CENTERLINE

WELD CENTERLINE

M MMMM-R-TOP-NN

M MMMM-W-TOP-NN

M MMMM-A-TOP-NN

~4.50 REF~

~4.7 REF~

1.38

3.7 REF

3.23 REF

1.045 ±

1.030 ±

1.015 ±

1.005 ±

DECIMALS TOLERANCES

1 PLACE 2 PLACE 3 PLACE 4 PLACE

ANGULAR ±0°20' ±0°30' ±0°15' ±0°10'

FRACTIONS ±\frac{1}{16}

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL: 5083 ALUMINUM

UNCLASSIFIED
RESULT OF CUT OFF

MMMR - R - TOP - NN

WELD CENTERLINE

MMMR - W - TOP - NN

MMMR - A - TOP - NN

DECIMALS
1 PLACE............ ± .045
2 PLACE............ ± .020
3 PLACE............ ± .005
4 PLACE............ ± .005

ANGULAR
10° 30’

TOEARS

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

MATERIAL: 5083 ALUMINUM

TOLERANCES
WELD CENTERLINE MMMM-W-TOP-NN

TOLERANCES

DECIMALS
1 PLACE........ 0.045
2 PLACE........ 0.005
3 PLACE........ 0.000
4 PLACE........ 0.000

ANGLES
1 PLACE........ 107.30°

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 5083 ALUMINUM

MATERIAL: 5083 ALUMINUM

MMMM-A-TOP-NN
WELD CENTERLINE MMMM-W-TOP-NN

WELD CENTERLINE MMMM-A-TOP-NN

TOLERANCES

DECIMALS
1 PLACE: ±.040
2 PLACE: ±.020
3 PLACE: ±.010
4 PLACE: ±.005

ANGULAR
±0'30'

FRACTIONS
±1/16

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 5083 ALUMINUM

UNCLASSIFIED
RESULT OF CUT OFF

WELD CENTERLINE

M MMMM-W-TOP-NN

.900 REF

.475 +.015
.

.000

4.50 REF

M MMMM-A-TOP-NN

.850 +.015
.

.000

RESULT OF CUT OFF

DECIMALS

1 PLACE........ +.045
2 PLACE........ +.020
3 PLACE........ +.015
4 PLACE........ +.005

ANGULAR

FRACTIONS

±0°30'

±1/16

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL: 5083 ALUMINUM

CHANGE RESTRICTED USAGE:

ARMY - FSP

PART NAME: TESTING STRIPS

DRAWN BY: TESTING STRIPS, MVP

Dwg. No. N/A

REV. 5.7

REVISION OF

INCHES

N/A

C

NO. 907

5.7

1 1/4
**TOLERANCES**

**DECIMALS**
- 1 PLACE: ±.045
- 2 PLACE: ±.005
- 3 PLACE: ±.000

**FRACTIONS**
- ±1/16

**ANGULAR**
- ±10°30'

**UNLESS OTHERWISE SPECIFIED**
- BREAK ALL SHARP EDGES

**MATERIAL:** 5083 ALUMINUM

**REVISIONS**

- BREAK ALL SHARP EDGES
- MATERIAL: 5083 ALUMINUM

**DRAWN BY**

- [Name]

**CHECKED BY**

- [Name]

**APPROVED BY**

- [Name]

**REV**

- [Number]

**DRAWN**

- [Date]

**SCALE**

- [Inches]

**LEVEL 1**

- [Number]

**REV**

- [Number]

**SHEET**

- [Number]
TOLERANCES

DECIMALS
1 PLACE........ ±.040
2 PLACE........ ±.020
3 PLACE........ ±.010
4 PLACE........ ±.005

ANGULAR
±0.10°

FRACTIONS
±1/16

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

MATERIAL: 5083 ALUMINUM

DATE: 9/23/11
DRAWN BY: R D
CHECKED BY: R D
RELEASED BY: N/A

SCALE: SHEET OF 100

SIZE: LEVEL1
REV: N/A
UNITS: INCHES

PART NAME: TESTING STRIP
PART NO.: 7.3.1
DRAWN: 9/23/11
CHECKED: 7.3.1
RELEASED: N/A

CHANGE RESTRICTED USAGE:
ARMY - FSP

NOTE: DRAWN TO PER MILIS specification

DRAWN BY: R D
CHECKED BY: R D
RELEASED BY: N/A

SCALE: SHEET OF 100
SIZE: LEVEL1
REV: N/A
UNITS: INCHES

PART NAME: TESTING STRIP
PART NO.: 7.3.1
DRAWN: 9/23/11
CHECKED: 7.3.1
RELEASED: N/A
TOP VIEW OF 3 FINISHED BLOCKS

WELD CENTERLINE

MILLIMETERS

MATERIAL: 5083 ALUMINUM

TOLERANCES

DECIMALS

1 PLACE: ±.045
2 PLACE: ±.005
3 PLACE: ±.0025
4 PLACE: ±.0005

ANGULAR

±0°30'

±1°16'

FRACTIONS

± 1/16

± 1/32

± 1/64

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

UNCLASSIFIED
Focus: HOPE Process routing/Shop traveler

Customer: Southwest Research Institute
Street Address: 
City State Zip: 

Stock: 4 x 4.850 x .950 coupon (54)

Part Number: Strips
Description: Johnson-Cook test specimen blocks (2139)
Revision:

<table>
<thead>
<tr>
<th>Op No</th>
<th>Labor Code</th>
<th>Operation Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Mill</td>
<td>Mill TOP to 0.850</td>
</tr>
<tr>
<td>20</td>
<td>Height Gage &amp; Scribe</td>
<td>Find, and scribe weld centerlines on Top and Ends of block.</td>
</tr>
<tr>
<td>30</td>
<td>Laser Marker</td>
<td>Mark TOP face of coupon per print (MMMM-X-TOP-NN, Where X=A,W, or R)</td>
</tr>
<tr>
<td>40</td>
<td>Mill</td>
<td>Mill BOTTOM to 0.800 thick</td>
</tr>
<tr>
<td>50</td>
<td>Mill</td>
<td>Mill coupon to 1.2456 from weld centerline (retreating side)</td>
</tr>
<tr>
<td>60</td>
<td>Band Saw</td>
<td>Saw Block R(retreating side) to .675 SET ASIDE</td>
</tr>
<tr>
<td>70</td>
<td>Mill</td>
<td>Mill coupon to .400 from weld centerline (retreating side)</td>
</tr>
<tr>
<td>80</td>
<td>Mill</td>
<td>Flip around (TOP still facing up) and mill coupon to 1.6456</td>
</tr>
<tr>
<td>90</td>
<td>Band Saw</td>
<td>Saw block at 'A' to .675 and remaining strip 'W' at .9706 ref</td>
</tr>
<tr>
<td>100</td>
<td>Mill</td>
<td>Mill 'W' to .800 (from saw cut side)</td>
</tr>
<tr>
<td>110</td>
<td>Mill</td>
<td>Mill R to .625 (From saw cut side)</td>
</tr>
<tr>
<td>120</td>
<td>Mill</td>
<td>Mill A to .625 (from saw cut side)</td>
</tr>
<tr>
<td>130</td>
<td>Mill</td>
<td>Mill block 'R' BOTTOM .1375 REF to 0.6535</td>
</tr>
<tr>
<td>140</td>
<td>Mill</td>
<td>Mill block 'R' TOP .0285 REF to 0.625</td>
</tr>
<tr>
<td>150</td>
<td>Mill</td>
<td>Mill block 'A' BOTTOM .1375 REF to 0.6535</td>
</tr>
<tr>
<td>160</td>
<td>Mill</td>
<td>Mill block 'A' TOP .0285 REF to 0.625</td>
</tr>
<tr>
<td>170</td>
<td></td>
<td>Measurement of finished blocks, per inspection check sheet</td>
</tr>
</tbody>
</table>
RETREATING SIDE (CLAMP MARKS)

WELD CENTELINE

DECIMALS TOLERANCES ANGULAR
1 PLACE...... ±.030 ±0° 30'
2 PLACE...... ±.010
3 PLACE...... ±.005 FRACTIONS
4 PLACE...... ±.0005 1/64

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 2139 AL

PART NAME: TESTING STRIPS
DRAWN BY: DATE DWG NO.
B 11/22/11 10

CHECKED BY: SHEET OF
A 100

UNCLASSIFIED
**SCRIBE LINE** (WELD CENTERLINE)

**RETREATING SIDE** (CLAMP MARKS)

**SCRIBE LINES**

**TOLERANCES**

DECIMALS

1 PLACE........ ±0.030
2 PLACE........ ±0.010
3 PLACE........ ±0.005
4 PLACE........ ±0.0005

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL: 2036 AL

**SCALE**

I SIZE

LEVEL

REV

1 N/A

SHEET OF

**DRAWN BY**

DATE DWG NO.

C_TESTING_5TRJP5_
P2Q_DWG

**CHECKED BY**

PART NO.

R D z

**RELEASED BY**

**UNITS**

**INCHES**

**UNCLASSIFIED**
scribes
lines
(weld
centerline)

scribe
centerline)

retreating side
(clamp marks)

2139-R-TOP-NN

2.25

5.00 REF

2.0 REF

.13-.25

4.0 REF

.9331

.9331

2139-W-TOP-NN

2139-A-TOP-NN

.450

.500

.350

.350 REF

tolerances
decimals
angular
1 place  ± 0.030 ± 10°.30'
2 place  ± 0.010
3 place  ± 0.005
4 place  ± 0.0005

fractions
± 1/16

unless otherwise specified
break all sharp edges
material: 2139 al

1p30

dwg

check by

part no.

rd

11/29/11

released by

units

inches

scale

size

idwg

level

rev

1

n/a

sheet

unclassified

unclassified

unclassified

unclassified

unclassified

unclassified

unclassified
2139-R-TOP-NN

WELD CENTERLINE 2139-W-TOP-NN

2139-A-TOP-NN

CLAMP MARKS

TOLERANCES

DECIMALS
1 PLACE...... ±.030
2 PLACE....... ±.010
3 PLACE....... ±.005
4 PLACE....... ±.0005

FRACTIONS
±1/16

ANGULAR
±0°30'

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 2139 AL

MATERIAL: 2139 AL
RESULT OF CUTOFF

2139-R-TOP-NN

WELD CENTERLINE

2139-W-TOP-NN

2139-A-TOP-NN

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 2139 AL

TOLERANCES

DECIMALS
1 PLACE: .030
2 PLACE: .010
3 PLACE: .005
4 PLACE: .0005

ANGULAR
±0° 30'

FRACTIONS
±1/16

INCHES

SCALE

UNCLASSIFIED
WELD CENTERLINE 2139-W-TOP-NN

2139-A-TOP-NN

DECIMALS

1 PLACE:...... ±0.030
2 PLACE:...... ±0.010
3 PLACE:...... ±0.005
4 PLACE:...... ±0.0005

TOLERANCES

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL: 2139 AL

ANGULAR ±10° 30'

FRACTIONS ±1/16
WELD CENTERLINE

2139-W-TOP-NN

2139-A-TOP-NN

5.00 REF

1.6456

2.4

0.7544

TOLERANCES

DECIMALS
1 PLBCE........... .030
2 PLACE............... .010
3 PLACE............... .005
4 PLACE............... .0005

FRACTIONS
ANGULAR ±0°30'

± 1/16

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 2139 AL

MATERIAL: 2139 AL
WELD CENTERLINE

RESULT OF CUTOFF

2139-A-TOP-NN

5.00 REF

TOLERANCES

DEIMALS
1 PLACE......... : .030
2 PLACE........ : .010
3 PLACE......... : .005
4 PLACE......... : .0005

ANGULAR
± 0° 30'

FRACTIONS
± 1/16

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 2139 AL
2139-R-TOP-NN

5.00 REF

MATERIAL: 2139 AL

TOLERANCES

DECIMALS
1 PLACE: ........ +0.030
2 PLACE: ........ +0.010
3 PLACE: ........ +0.005
4 PLACE: ........ +0.0005

±

FRAC TIONS

±1/16

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

2139 AL

ANGULAR

±30°
SAW CUT

2139-A-TOP-NN

5.00 REF

MATERIAL: 2139 AL

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

TOLERANCES

DECIMALS

1 PLACE........ 0.030
2 PLACE........ 0.010
3 PLACE........ 0.005
4 PLACE........ 0.0005

ANGULAR

±0°30'

FRACTIONS

±1/16

UNCLASSIFIED
TOLERANCES

DECIMALS
1 PLACE:....... ±0.030
2 PLACE:....... ±0.010
3 PLACE:....... ±0.005
4 PLACE:....... ±0.0005

ANGULAR
±0°30'

FRACTIONS
±1/16

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

MATERIAL: 2139 AL

FINISHING STRIPS

CHANGE

ARMY - FSP

TESTING STRIPS

DRAWN

DATE DWG

NO.

CHECKED BY

PART NO.

RELEASED BY

UNITS

SCALE

DWG LEVEL

REV

SHEET

OF

1

N/A
2139-A-TOP-NN

TOLERANCES
DECIMALS
1 PLACE:....... ±.030
2 PLACE:....... ±.010
3 PLACE:....... ±.005
4 PLACE:....... ±.0005

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 2139 AL
TOP VIEW OF 3 FINISHED BLOCKS

2139-R-TOP-NN

WELD CENTERLINE

2139-W-TOP-NN

2139-A-TOP-NN

TOLERANCES

DECIMALS          ANGULAR
1 PLACE........ ±0.030       ±0.30°
2 PLACE........ ±0.010
3 PLACE........ ±0.005       ±1/64
4 PLACE........ ±0.0005

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: 2139 AL
Focus: HOPE Process routing/Shop traveler

Customer: **Southwest Research Institute**

Street Address:  
City State Zip:

Stock: **3/4” x 3/4” x 4 1/2” FSW weld coupon (4 RET)**

Part Number: **TAIT specimen**

Description: **Johnson-Cook test specimens**

<table>
<thead>
<tr>
<th>Op No</th>
<th>Labor Code</th>
<th>Operation Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>See 'Strips' Process Sheet for initial specimen extraction operations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Extreme care must be taken to keep Specimen Types R, W, and A, and Materials 6061 and 5083 properly segregated. THIS IS EXTREMELY IMPORTANT,</strong></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Confirm that all specimens are &quot;6061-A&quot;</td>
</tr>
<tr>
<td>20</td>
<td>MILL</td>
<td>Circular interpolate end to .70 dia x .88</td>
</tr>
<tr>
<td>30</td>
<td>CNC</td>
<td>Center Drill, Turn square end round to .252/.254 x 1.5, .625 x 1.3; cut-off at 1.375</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>Retrieve and label specimen</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>DO NOT mark the final part in any way (laser, paint, etc.)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Individually bag each part and mark each bag &quot;61A-N-#&quot; for Block Number and # for specimen</td>
</tr>
<tr>
<td>50</td>
<td>CNC</td>
<td>rechuck part against shoulder; turn to .252/.254 dia. x 1.5</td>
</tr>
<tr>
<td>60</td>
<td>CNC</td>
<td>Turn to .252/.254 dia. x 1.5; cut-off at 1.375</td>
</tr>
<tr>
<td>70</td>
<td></td>
<td>Retrieve and label specimens</td>
</tr>
<tr>
<td>80</td>
<td>MILL</td>
<td>Face mill each specimen to 1.3</td>
</tr>
<tr>
<td>90</td>
<td>MILL</td>
<td>Flip part and face mill 1.250</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td>Bag and Label</td>
</tr>
</tbody>
</table>
\[ \phi = 0.70 \quad (\text{REF} = 0.88) \]

\[ \phi = 0.625 \quad \text{MIN} \quad 0.75 \quad \text{REF} \]

\[ 1.7 \quad \text{REF} \quad 1.300 \quad 1.500 \]

\[ 1.375 \quad 0.253 \quad (\pm 0.00) \]

\[ \text{MAX} \quad 0.125 \quad \text{(RESULT OF CUTOFF)} \]

TOLERANCES

DECIMALS:
1 PLACE: \pm 0.030
2 PLACE: \pm 0.010
3 PLACE: \pm 0.005
4 PLACE: \pm 0.0005

ANGULAR:

FRACTIONS:
\pm 0.30'

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL:

MAX (RESULT OF CUTOFF)
UNCLASSIFIED

TOLERANCES

DECIMALS

1. PLACE........ ±.030
2. PLACE........ ±.010
3. PLACE........ ±.005
4. PLACE........ ±.0005

ANGULAR

FRACTIONS

±0'30''

±1/64

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

MATERIAL:

.253 ±.001

.200

1.500

1.5

1.3 REF

.625 REF

.75 REF

TP50 DWG
TOLERANCES

DECIMALS

1 PLACE:........±0.030
2 PLACE:........±0.010
3 PLACE:........±0.005
4 PLACE:........±0.0005

ANGULAR

FRACTIONS

±0° 30'

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL:

ø .253 +0.001

REF

3.0
UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED

1.5

REF

1.375

REF

.125

MAX.

(RESULT OF CUTOFF)

1.25

MAX.

TOLERANCES

DECIMALS

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

ANGULAR

±0°30'

FRACTIONS

±1/64

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL:

ARMY-PSF

SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:

A TOLERANCES

B DECIMALS ANGULAR

1 PLACE . . . . ±0.030
2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

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2 PLACE . . . . ±0.010
3 PLACE . . . . ±0.005
4 PLACE . . . . ±0.0005

C MATERIAL:

ARMY-PSF

D SCALE: INCHES

NOTES:
TOLERANCES

DECIMALS  ANGULAR
1 PLACE..... ±0.030  ±0° 30'
2 PLACE..... ±0.010
3 PLACE..... ±0.005  FRACTIONS  ±1/64
4 PLACE..... ±0.0005

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

MATERIAL:
COMPLETION OF PROCESS RESULTS IN 3 PIECES

\[ \phi \approx 253 \pm 0.001 \] (TYP)

\[ \text{REF} \]

\[ 1.250 \]

\[ 1.30 \]

\[ \text{TOLERANCES} \]

DECIMALS
1 PLACE: \[ .030 \]
2 PLACE: \[ .010 \]
3 PLACE: \[ .005 \]
4 PLACE: \[ .0005 \]

ANGULAR
1 PLACE: \[ \pm 0'.30' \]
2 PLACE: \[ \pm 0'.01' \]
3 PLACE: \[ \pm 0'.001' \]

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

MATERIAL: [INCHES] N/A
**Focus: HOPE Process routing/Shop traveler**

Customer: **Southwest Research Institute**

Street Address:
City State Zip:

**Stock:** 3/4 x 3/4 x 4 1/2 coupon (8)

**Part Number:** **A-250in_SmoothTensile**  
**Description:** **Johnson-Cook test specimen**  
**Revision:**

<table>
<thead>
<tr>
<th>Op No</th>
<th>Labor Code</th>
<th>Operation Description</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>10</td>
<td></td>
<td>Confirm that all material blocks are marked &quot;6061-W&quot;</td>
</tr>
<tr>
<td>20</td>
<td>Mill</td>
<td>Square mill end, round (circular interpolate) end to 0.70 dia x 0.88 and center drill</td>
</tr>
<tr>
<td>30</td>
<td>Laser</td>
<td>Mark end &quot;61W-#&quot; (where # = 1 thru 8)</td>
</tr>
<tr>
<td>40</td>
<td>Mazak</td>
<td>Center drill, rough contour turn, final contour turn, single point thread</td>
</tr>
<tr>
<td>50</td>
<td>Laser</td>
<td>Mark end &quot;61W-#&quot; (where # = 1 thru 8)</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>Individually bag each part</td>
</tr>
<tr>
<td>70</td>
<td></td>
<td>Label Bags</td>
</tr>
<tr>
<td>80</td>
<td></td>
<td>Polish Longitudinally</td>
</tr>
<tr>
<td>90</td>
<td>Mazak</td>
<td>Cover polished area with rubber hose. Cut-off to final length 3.000</td>
</tr>
</tbody>
</table>
MMMM - X - TOP - NN

4.50

REF

0.75

REF

TOLERANCES

DECIMALS

1 PLACE........ 0.030
2 PLACE........ 0.010
3 PLACE........ 0.003
4 PLACE........ 0.0005

UNLESS OTHERWISE SPECIFIED

MATERIAL:

FRACTIONS

±0.030
±0.010
±0.003
±1/64

ANGULAR

±0° 30'
UNCLASSIFIED

DECIMALS | TOLERANCES | ANGULAR
---|---|---
1 PLACE | ±.030 | ±0.30°
2 PLACE | ±.010 |
3 PLACE | ±.003 | FRACTIONS
4 PLACE | ±.0005 |

UNLESS OTHERWISE SPECIFIED

MATERIAL:

[Diagram of a cylindrical object with dimensions labeled: .70 diameter, .75 length, 4.50 length, and other dimensions marked for measurement and tolerance.]
DIMENSIONS

DECIMALS | TOLERANCES | ANGULAR
1 PLACE     ± .030 | ± 0.30°
2 PLACE     ± .010 | ± .010°
3 PLACE     ± .0005 | ± 1/64°

UNLESS OTHERWISE SPECIFIED

MATERIAL:

RcZc 10/4/11
1/2-13 UNC 2A

\[ \sqrt{8-16} \]

\[ R \, 0.250 \] (TYP)

\[ \phi \, 0.250 \]

0.67

1.250

0.875

3,000

TOLERANCES (INCH):

<table>
<thead>
<tr>
<th>DECIMALS</th>
<th>1 PLACE</th>
<th>2 PLACE</th>
<th>3 PLACE</th>
<th>4 PLACE</th>
<th>FRACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>\pm 0.30</td>
<td>\pm 0.10</td>
<td>\pm 0.03</td>
<td>\pm 0.005</td>
<td>\pm 1/64</td>
</tr>
</tbody>
</table>

UNLESS OTHERWISE SPECIFIED

MATERIAL: 1P40 DRAWN BY A250 INCH SMOOTH TENSILE DRAWN BY A250

CHECKED BY 1N_SMOOTHTENS

RELEASED BY N/A SHEET 1 OF 1

ANGULAR "10° 30'"

PART NAME A250IN_SMOOTH_TENSILE

DRAWN: 10/4/11

CHANGE: RESTRICTED USAGE: ARMY FSP
Focus: HOPE Process routing/Shop traveler

Customer: TACOM Warren

Stock: .650 x 2.525" FSW weld coupon (4)

Part Number: .375 Compression Specimen (SHPBC)
Description: Split Hopkinson Pressure Bar test specimen

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<tr>
<td>10</td>
<td>CNC</td>
<td>Confirm that all material blocks are marked &quot;6061-W&quot;</td>
</tr>
<tr>
<td>20</td>
<td>CNC</td>
<td>Turn to 0.375 dia x 1.5</td>
</tr>
<tr>
<td>30</td>
<td>CNC</td>
<td>Turn to .375 dia x 1.325; cut-off at 1.2</td>
</tr>
<tr>
<td>40</td>
<td>CNC</td>
<td>DO NOT mark the final part in any way (laser, paint, etc.)</td>
</tr>
<tr>
<td>50</td>
<td>CNC</td>
<td>Individually bag each part and mark each bag &quot;61W&quot;</td>
</tr>
<tr>
<td>60</td>
<td>CNC</td>
<td>Face mill end; clean surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face mill end to final length</td>
</tr>
</tbody>
</table>
Center for Turning

Material:

Decimals
1 PLACE: ±.030
2 PLACE: ±.010
3 PLACE: ±.005
4 PLACE: ±.0005

Angular Tolerances
±0°30'

Fractions
±1/16

Unless otherwise specified
Break all sharp edges

UNCLASSIFIED
TOLERANCES

DECIMALS

1. PLACE ........ ± .030
2. PLACE ........ ± .020
3. PLACE ........ ± .010
4. PLACE ........ ± .0005

ANGULAR

±0°30'

FRACTIONS

± 1/16

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL:
TOLERANCES

DECIMALS

1 PLACE ....... ± 0.030
2 PLACE ....... ± 0.010
3 PLACE ....... ± 0.005
4 PLACE ....... ± 0.0005

ANGULAR

± 0° 30'

FRACTIONS

± 1/16

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL:
TOLERANCES

DECIMALS
1 PLACE ........ ±.030
2 PLACE ........ ±.010
3 PLACE ........ ±.005
4 PLACE ........ ±.0005

ANGULAR
±0°30'

FRAGIONS
±1/16

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL: BREAf\ ALL SHARP EDGES
DRAWN
DATE
BY
11/3/11
Shpbc_lp40_dwg

SCALE
SIZE
LEVEl
REV

INCHES
N/A
1

RELEASED
UNITS

LPS NAME
MANUFACTURER

1P40

QWG

UNCLASSIFIED
CUTTING TOOL LOSS

\[ \phi \cdot \frac{375}{1050} \] (Typ)

\[ \frac{1.25}{1.10} \] (Typ)

DECIMALS

1. PLACE: \( \pm 0.030 \)
2. PLACE: \( \pm 0.010 \)
3. PLACE: \( \pm 0.005 \)
4. PLACE: \( \pm 0.0005 \)

TOLERANCES

ANGULAR

FRACTIONS

\( \pm 0\degree 30' \)

\( \pm \frac{1}{16} \)

UNLESS OTHERWISE SPECIFIED

BREAK ALL SHARP EDGES

MATERIAL:

FRACTIONS

\( \pm \frac{1}{64} \)

\( \pm \frac{1}{128} \)

\( \pm \frac{1}{256} \)

\( \pm \frac{1}{512} \)
TOLERANCES

DECIMALS

1 PLACE ........ 0.030
2 PLACE ........ 0.010
3 PLACE ........ 0.005
4 PLACE ........ 0.0005

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES

MATERIAL:

ANGLES

±0° 30'

FRAC TIONS

±1/16

0.375 REF

0.850 (TYP)

0.125 (TYP)
**TOLERANCES**

**DECIMALS**  **ANGULAR**

1 PLACE........ ±.030  ±0'30"
2 PLACE........ ±.010
3 PLACE........ ±.005  FRACTIONS
4 PLACE........ ±.0005  ±1/64"

**UNLESS OTHERWISE SPECIFIED**

**BREAK ALL SHARP EDGES**

**MATERIAL:**

- IP70
- DWG
0.050 (TYP)

0.750 (TYP)

TOLERANCES

DECIMALS  ANGULAR
1 PLACE..... ±0.030  ±0° 30'
2 PLACE..... ±0.010  ±0° 15'
3 PLACE..... ±0.005  ±1/64
4 PLACE..... ±0.0005

UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES
MATERIAL:

1 F80

DWG
Focus: HOPE Process routing/Shop traveler

Customer: Southwest Research Institute

Stock: 3/4 x 3/4 x 4 1/2 coupon (8)

Part Number: SHPB Tensile (5083/6061)

Description: Johnson-Cook test specimen

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<td>Mill</td>
<td>Square mill end, round (circular interpolate) end to 0.70 dia x 0.88 and center drill</td>
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<td>30</td>
<td>Laser</td>
<td>Mark end &quot;61W-#&quot; (where # = 1 thru 8)</td>
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<tr>
<td>40</td>
<td>Mill</td>
<td>Mill end square, center drill, rough contour turn, final contour turn, single point thread, and finally turn thread OD to .490 dia</td>
</tr>
<tr>
<td>50</td>
<td>laser marker</td>
<td>Mark 2 Places (ends) &quot;61W-#&quot; (where # = 1 thru 8)</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>Individually bag each part</td>
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<td></td>
<td>Label Bags</td>
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<tr>
<td>80</td>
<td></td>
<td>Polish Longitudinally</td>
</tr>
<tr>
<td>90</td>
<td></td>
<td>Cut-off to final length 2.235</td>
</tr>
</tbody>
</table>
UNCLASSIFIED

TOLERANCES

DECIMALS: ANGULAR
1 PLACE: 0.030 ±0° 30'
2 PLACE: 0.010
3 PLACE: 0.003 FRACTIONS
4 PLACE: 0.0005 ±1/64
UNLESS OTHERWISE SPECIFIED

MATERIAL: MMMM - X - TOP - NN

10/6/11

DRAWN BY

CHECKED BY

RELEASED BY

SCALE

UNCLASSIFIED
#2 C'DRILL
\( \phi = 0.105 \pm 0.005 \)
120 MAX. DEPTH

\( \phi = 0.70 \)

DECIMALS TOLERANCES ANGULAR
1 PLACE \( \pm 0.030 \) :030
2 PLACE \( \pm 0.010 \) :010
3 PLACE \( \pm 0.003 \) :003
4 PLACE \( \pm 0.0005 \) :1/64

UNLESS OTHERWISE SPECIFIED

MATERIAL: RcZc

DRAWN BY: 10/6/11 5HPB_TEN51LE_IP20_DWG
CHECKED BY:

RELEASED BY:

DRAWN BY: 10/6/11

SCALE

SIZE

DWG
LEVEL
REV
SHEET
1 OF 1
N/A
UNCLASSIFIED

4.50

WGS TOLERANCES

1 PLACE: ± .030
2 PLACE: ± .010
3 PLACE: ± .003
4 PLACE: ± .0005

ANGULAR

1° 30‘

DECIMALS

FRACTIONS

1/64

UNLESS OTHERWISE SPECIFIED

MATERIAL:

5HPB/TECN LE

DRAWN BY

5HPB_TEN51LE_IPGO_DWG

CHECKED BY

PART

10/6/11

RELEASED BY

SCALE

DEL. LEVEL

REV

1

N/A

1

10/6/11

3

2

4

UNCLASSIFIED