

MANUFACTURING INFORMATION / MODIFICATION REQUEST		(1) CHECK ONE INFORMATION MODIFICATION X	(2) MIMR No. 7077383	(3) DATE 01/08/2021	(4) Page 1 of 5
(5) ITEM NAME ZBOM PRODUCTION SOLENOID, MU2E EXPERIMENT				(7) S/N(s) N/A	
(6) DWG/SPEC. NO. 39532-D-3401				(6a) Revision Level A	
(8) QTY. ITEMS 1	(9) PROJECT NUMBER/NAME 39532	(9a) Work Location EMS Tupelo	(10) RELATED MIMRs: N/A	CSI/CAI: NO	
(11) IDENTIFY REQUIREMENTS GA QM-2 Revised parameters for PS1 splice weld Per Operation 700 in the PS1 Winding and Insulating Work Instruction, 39532P00051, weld Layer 2 conductor to Layer 1 per Conductor Splice Weld Procedure, 39532P00015 rev. A.		(12) DESCRIBE PROPOSED MODIFICATION(S) / STATE QUESTION(S) MIMR 12PD Proposed Modification See long text Based on Fermilab's Modification to the Joint Welding Procedure for the Mu2e Production Solenoid Cables, Mu2eMag-doc-131, in Subcontract Modification No. 09, modify General Atomics Conductor Splice Weld Procedure, 39532P00015 rev. A, paragraph 5.1, to include the following revised welding parameters for the PS1 Layer to Layer splices: In paragraph 5.1.2 - The current during the welding shall be limited to 120A at the welder's control panel. DC current with the negative tungsten polarity shall be used for all joint welds. In paragraphs 5.1.2 and 5.1.5 - The welding shall be performed manually by a qualified welder. The average welding speed shall be approximately 1.6 mm/s, with the rate to be adjusted to produce a weld bead width of 4 mm - 5 mm* at the surface. The weld bead shall be centered on the seam between the conductor bars +/- 1 mm to prevent off-center weld penetration. A separate person shall visually monitor the welding current and voltage (or power), the water flow rate and the water temperature. In addition to the data required in paragraph 5.1.4, measurements of the width and depth of the removal of aluminum material from the conductor (i.e., the "weld prep") at 20 cm intervals over the length of the weld area prior to performing the welds shall be recorded. Also, the name of the welder that performed the welding shall be documented. In paragraph 5.1.5 - The typical voltage observed on the welding machine's panel during the welding shall be on the order 18-20 V, which corresponds to a peak power of 3.0 kW. (*See block 17)			
(13) JUSTIFICATION MIMR 13JT Justification Technical Based on successful completion of bench test splice samples using the revised welding parameters, Fermi directs GA to proceed with PS1 layer to layer splices using these revised welding parameters.			(14) ATTACHMENTS (LIST) 39532P00015A redlined		
(15) MANUFACTURING APPROVALS					
Robert Mackintosh <hr/> (MANUFACTURING ENGINEER) 01/08/21 <hr/> (DATE)		KEVIN SPIELDENNER <hr/> (QUALITY CONTROL) 01/08/21 <hr/> (DATE)			
(16) PROPOSED CHANGE: <input checked="" type="checkbox"/> APPROVED <input type="checkbox"/> DISAPPROVED <input type="checkbox"/> NOT APPLICABLE		(17) MODIFICATION CLARIFICATION / ANSWER TO QUESTION See long text *Following discussions with Tom Page (Fermilab) on 01/08/21, a slightly narrower weld bead width is acceptable. E-mail attached			
(18) PROJECT APPROVALS:					
Mark J. Myers <hr/> (ENGINEERING) 01/08/21 <hr/> (DATE)		KEVIN SPIELDENNER <hr/> (QUALITY ASSURANCE) 01/08/21 <hr/> (DATE)		N/A <hr/> (CUSTOMER REPRESENTATIVE) N/A <hr/> (DATE)	

5.1.1 Tool Set-up (to be updated after fixture design is completed)

- Assemble Inner Curved Backing Plate onto pistons in the Inner Curved Reaction Base.
- Install Inner Curved Lower Chill Bar on top of the Backing Plate.
- Install Layer 1 Conductor onto Inner Curved Lower Chill Bar.
- Install Inner Curved Upper Chill Bar on top of Layer 1 Conductor.
- Connect high pressure GN2 Pressure Regulator to K-Bottle and pressurize Inner Clamping Pistons to 1400 psi.
- Assemble Outer Curved Backing Plate onto pistons in the Outer Curved Reaction Base.
- Install Outer Curved Lower Chill Bar on top of the Backing Plate.
- Install Layer 2 Conductor onto Outer Curved Lower Chill Bar.
- Install Outer Curved Upper Chill Bar on top of Layer 2 Conductor.
- Connect high pressure GN2 Pressure Regulator to K-Bottle and pressurize Outer Clamping Pistons to 1400 psi.
- Activate Linear Slide to close and clamp the conductor splice joint for welding.
- Tool is now ready for welding one side of conductor.
- Flip tool end for end and repeat the same assembly process to perform welding on the opposite side of conductor.

5.1.2 Weld Parameters

Parameter	Setting
Pressure Regulator Setting of gas nitrogen K-bottle	1800 psi for PS-PS
Current during the welding	175 A maximum 120 A maximum
Cooling water flow rate	3 gram per minute (3gm), minimum
Cooling water temperature	30°C (86°F) maximum
Welding speed	5mm/s (-12 inches/min) minimum approx 1.6 mm/sec
Splice length	1 m minimum

Weld bead width and location

4mm - 5mm and centered (+/- 1mm)*

5.1.3 Cooling Water Set-up

All the blocks of a given setup shall be connected in series by flexible water lines and plugged to an external water system to keep the temperature of Superconducting filaments in the conductor below 150°C during the welding.

- Identify an external water system capable of delivering the water flow of at least 3 gpm and maintaining the water temperature below 30° C throughout the welding operation.
- Connect the cooling upper and lower cooling copper tubes in series and plugged to the above external water system.
- Install two thermocouples on the inlet water line.
- Install two thermocouples on the outlet water lines.
- Turn on the water and check the water flow rate and temperatures.

5.1.4 Monitoring Set-up

The actual welding current and voltage, water flow rate and temperature shall be monitored and recorded. These parameters shall be included in the report and submitted to Fermi for each joint.

- Weld prep width and depth measurements at 20 cm intervals over weld area prior to weld.
- Place DC current clamp over the welding cable.

* See block 17 of MIMR 7077383

- Set up digital scope meter or Power Quality Clamp Meter to monitor/record the current. Set the sampling time at 1 Hz. Monitor and record the voltage drop simultaneously.
- Monitor the cooling water flow rate and temperature.
- Set up alarm to go off if the inlet water temperature goes above 30° C.

- Name of the welder performing the weld.

5.1.5 Welding Procedure (refer to WPS #148)

The welding current rheostat on the welding machine main control panel shall be adjusted so that at full current foot control the maximum available welding current will be as indicated in section 5.1.2 above for the splice being welded.

The arc voltage is controlled by the welder by virtue of the arc length while welding. The welder shall use the best welding practice to maintain arc voltage at 18-~~22~~²⁰ volts by holding a consistent arc length that results in an arc voltage within this range. Arc voltage will be monitored using a meter device as indicated in section 4 above.

approx. 1.6 mm/second

Weld travel speed shall be maintained as best as possible to a ~~minimum of 12 inches/minute~~ as stated above in section 5.1.2. It is understood that the welder has complete control of welding speed and to maintain this travel speed.

Start and stop areas are excluded from the current, arc voltage, and travel speed restrictions as it is recognized that these parameters are in a dynamic range and changing as these areas are transitioning.

Welding steps: (to be updated after fixture designed)

- Monitor and record all the parameters as required listed in section 6 during the welding.
- Weld one side of the fixture.
- Visually inspect the weld and make the correction if necessary.
- Turn off the water and remove the weld fixture after it is cooled down to room temperature.
- Rearrange the fixture for other side of welding
- Visually inspect the weld and make the correction if necessary.
- Turn off the water and remove the weld fixture after it is cooled down to room temperature.
- Remove any excess filler material to make the weld flush with the conductor surfaces. Protect winding and insulation from metal shaving, chips and FOD while removing any excess filler material.
- Clean the weld joints with high purity alcohol.
- Download the recorded data for report

6 REPORT/DOCUMENTATION

All welding steps and parameters for each joint shall be documented in a traveler. As a minimum, it shall include:

Welding machine make and model	
All settings recorded from the welder's front panel	
Current	
Time Stamp	
Photo of front panel	
Filler rod type, including the certificates	
Shielding gas type	
Sizes of the welding cup and the tungsten electrode	
Pressure regulator setting on K-bottle	
Cooling water	
Flow rate	
Inlet water temperature, thermometer 1	
Inlet water temperature, thermometer 2	
Outlet water temperature, thermometer 3	
Outlet water temperature, thermometer 4	
Signature of FNAL representative upon inspection of the welding setup	
Beginning time of each joint welding	
Ending time of each joint welding	
Recorded welding current and voltage vs. time plot (data @ 1Hz or less)	

From: [Miller, Jonathan](#)
To: [Thomas M. Page](#)
Cc: [Michael J Lamm](#); [James A Hocker](#); [Ronald E Ray](#); [Juliana Whitmore](#); [Karie E. Badgley](#); [Vadim Kashikhin](#); [Sandor Feher](#); [Clark, Paul](#); [Mackintosh, Robert F.](#); [Spieldenner, Kevin](#)
Subject: RE: weld bead size
Date: Monday, January 11, 2021 12:37:42 PM

Thanks Tom

From: Thomas M. Page <tpage@fnal.gov>
Sent: Monday, January 11, 2021 2:20 PM
To: Miller, Jonathan <Jonathan.Miller@ga.com>
Cc: Michael J Lamm <lamm@fnal.gov>; James A Hocker <hocker@fnal.gov>; Ronald E Ray <rray@fnal.gov>; Juliana Whitmore <jaws@fnal.gov>; Karie E. Badgley <kbadgley@fnal.gov>; Vadim Kashikhin <vadim@fnal.gov>; Sandor Feher <fehers@fnal.gov>; Clark, Paul <Paul.Clark@ga.com>; Mackintosh, Robert F. <Robert.Mackintosh@ga.com>; Thomas M. Page <tpage@fnal.gov>
Subject: -EXT-weld bead size

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Jonathan,

As discussed and accepted during the splice test welds, a weld bead size of 3.5 mm - 5 mm would be acceptable.

Thanks.

-Tom

Thomas Page
Mechanical Engineer

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