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 <p><b>THERMOCOUPLE MANUAL</b></p>		<p>TC 101          Issued: 1/11/23          Revision: 12          Page: 1 of 10</p>
<p><b>THERMOCOUPLE PROCEDURE THERMOCOUPLE AND FEEDTHROUGH FABRICATION</b></p>		

1. INTRODUCTION:

- Ø 1.1 SCOPE: This procedure prescribes the requirements for Quik-Tip pressure connector, twisted and welded, twisted and electric resistance methods, provided there is no addition of filler metals for fabricating thermocouples.
- 1.2 APPLICABILITY: This procedure is required for fabrication thermocouples used to measure and control process temperatures.
- 1.3 CALIBRATION INTERVAL: N/A
- 1.4 PRE-CALIBRATION REQUIREMENTS: N/A
- 1.5 AUTHORIZED ADJUSTMENTS AND SEQUENCE: N/A
- 1.6 SAFETY PRECAUTIONS:
  - 1.6.1 Safety glasses are required to be worn.
  - 1.6.2 To return blood flow to muscles and tendons that become fatigued, perform the following wrist stretches a minimum of once per day or when needed: wrist flexion, wrist extension, median nerve glide and the ulnar nerve glide. Further details and illustrations can be found in the Micro-Break Stretch Program located on the ergonomics home page of the Howmet EHS Management System intranet site.
- 1.7 STABILIZATION TIME: N/A

2. EQUIPMENT AND FACILITIES REQUIRED:

2.1 MAJOR EQUIPMENT:

Instrument Name	Model #	Range	Resolution	Accuracy
Leeds & Northrup Quik-Tip Compression Tool			N/A	N/A
Micro Products Co., Precision Welding Machine	EIS		N/A	N/A
Diamond Saw	Felker TM-75		N/A	N/A
4 & 6 ft Ruler	Starrett		+/-1/16"	+/- 1/8"
12 ft tape measure	Stanley		+/-1/32"	+/- 1/8"
Fluke indicator	52		N/A	N/A
Fluke multimeter	77		N/A	N/A
Altek	422		0.1F	(K)= 0.5F

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				(R) = 1.1F
HP multimeter	3478A		0.0001 mV	5.7uV @ 6mV DC
Miller syncrowave tig welder	250		N/A	N/A
Eubanks wire cutter	4600		N/A	N/A
Kwik Mark engraver used for serialization	KM-64		N/A	N/A
Zirconia Ultra Hi-Temp Ceramic adhesive	904		N/A	N/A

2.2 FACILITIES: Reference the Thermocouple Manual for drawings and unique build instructions. Unless otherwise specified, the overall length dimension of completed thermocouples and feedthroughs shall be accurate to within +/- 5% utilizing individual materials of similar accuracy. (Example: If the alumina insulation is cut short but within the tolerance, the wire and the protection tube shall coincide.)

2.3 MISCELLANEOUS:

- 2.3.1 Small hand tools (wire cutters, pliers, screwdriver, adjustable wrench, etc.)
- 2.3.2 Leeds & Northrup Quik-Tip thermocouple connectors or equivalent
- 2.3.3 Insulating material (ceramic insulators, Varglas or similar material, thermocouple plugs capable of withstanding the highest temperature for which the thermocouple will be used)
- 2.3.4 Spools of thermocouple wire (Type B, K, R, S, etc.) Spools of wire must be clearly identified as to type of wire, size, and calibration.
- 2.3.5 TC 101.01 (Supplement 1) is utilized for all GGE inventoried alumina and precious metal wire. Product removed from the shelf/bin used for thermocouple manufacturing is documented on the log sheets. GGE inventoried items will be automatically removed from Oracle when a manifest number is entered into the TBS. Log sheets can be used for inventory tracking at end of month accounting.
- 2.3.6 Build instructions in the Thermocouple Manual are utilized for precious metal Type B, R, and S thermocouples manufactured in the lab. The Serial # Prefix (generated in TBS) and lot quantity are integrated together as a serial number which is then engraved on each sensor using the Kwik Mark, or a printed tag, prior to shipment (reference TC 103). As processing is completed, each operation on the build instruction shall have the "Y" circled by the technician to indicate the step has been completed. Operations without the "Y" circled have not been performed. The build instruction shall remain with the product until each operation has been signed off as being complete.

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- 2.3.6.1 From the Thermocouple manual, print the T/C Part No#, and /or Build Instructions requiring a Build Deviation. Line out original, note change on TC Part No# and/or Build Instruction, and complete a TC105.05 (Build Deviation form). Retain the Build Deviation form with the modified document.
  - 2.3.6.2 HIP thermocouples are exempt from build instructions in the Thermocouple Manual and do not require serialization. HIP maintains and provides an activity instruction (315.04.001) for all the various thermocouple fabrications required. The part # and thermocouple calibration lot # shall be written on the alumina near the bare leads. The sheath will also be marked with tape showing the same information in the same location.
  - 2.3.6.3 Thermocouple feedthroughs have unique instructions built into the print and do not require any additional build instruction sheets or serial numbers. The instructions on the print include wire types, sizes, lengths, plugs, testing etc. required to complete the assembly.
  - 2.3.6.4 After the thermocouple wire type, diameter and accuracy has been properly selected the cutting and welding can be completed. When more than one thermocouple is built, the remaining build instruction steps may be performed in any order to increase the efficiency of the build process. The testing and inspection operations (if required) shall be completed prior to the finished build(s) moving to the stock shelf or packaged for shipment. Each operation shall be initialed and dated upon completion. In the comment box, note whether the build is "Stock" or what customer the TC's are being built for.
3. INITIAL CONDITIONS: When received, all 904 Zirconia Ultra Hi-Temp Ceramic adhesive will have the "Received Date", "Lot Number", "Expiration Date" and "First Use Date" written on the side of the container, and "First Use" date will also be documented on the cert. Before using the 904 Zirconia Ultra Hi-Temp Ceramic adhesive, verify the expiration date has not been exceeded.
  4. PROCEDURE:
    - 4.1 GENERAL PRESSURE CONNECTOR METHOD:
      - 4.1.1 Cut one thermocouple wire pair to correct length.
      - 4.1.2 Insert the ends of the wire pair into a Quik-Tip connector from the same side or from opposite sides depending on the type of connection required.

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- 4.1.3 Position the Quik-Tip connector (with inserted thermocouple wire pair) into the appropriate slot of the Quik-Tip tool and compress the connector. Release the compression tool (handle will not release until full compression stroke is achieved) and remove the thermocouple. Reject any thermocouple with more than 0.010" flash. (Flash is that portion of the Quik-Tip connector that may extrude out of the jaw of the tool.)
- 4.1.4 Insulate the thermocouple leads over their entire length with ceramic insulators, Varglas, or similar material capable of withstanding the highest temperature for which the thermocouple will be used. Leave enough bare wire at the cold end to make an appropriate connection (thermocouple plug, terminal board, etc.).
  - 4.1.4.1 Do not allow any of the wire insulation (PFTE tubing, fiberglass sleeving, FBGS polyvinyl etc.) to be under the screw in the connector.
- 4.1.5 Refer to 4.6 for "Testing of Thermocouples."
- 4.2 PRESSURE CONNECTOR METHOD - MECHANICAL TESTING TYPE K THERMOCOUPLES:  
(See TC K001 in the TC Manual)
  - 4.2.1 Calibration test samples assembled at HRC
    - 4.2.1.1 Cut a 19" length of 20 gauge special limits Chromel wire from the spool.
    - 4.2.1.2 Cut a 19" length of 20 gauge special limits Alumel wire from the spool.
    - 4.2.1.3 Insert the end of the 19" length special limits Chromel wire into a Quik-Tip connector approximately 1 1/2".
    - 4.2.1.4 Insert the end of the 19" length special limits Alumel wire into the same Quik-Tip connector from the opposite side approximately 1 1/2".
    - 4.2.1.5 Position the Quik-Tip connector (with inserted thermocouple wires) into the appropriate slot of the Quik-Tip tool and compress the connector. Release the compression tool (handle will not release until full compression stroke is achieved) and remove the thermocouple. Reject any thermocouple with more than 0.010" flash. (Flash is that portion of the Quik-Tip connector that may extrude out of the jaw of the tool.)
    - 4.2.1.6 Using small needle-nose pliers, hold the Quick-Tip connector and bend the 17 1/2" length of the wires so they are parallel.
    - 4.2.1.7 Using small needle-nose pliers, hold the Quick-Tip connector and bend the 1 1/2" length of the wires so they are approximately 1/2" apart.

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- 4.2.1.8 Insulate the 17 1/2" length of thermocouple wires with mullite ceramic insulators starting with one (1) 1" insulator followed by five (5) 3" insulators.
- 4.2.1.9 Using a magnet, find the magnetic wire and insert the magnetic wire into the negative or large connector on the Type K (yellow) plug and tighten the screw. Insert the non-magnetic wire into the positive or small connector on the plug and tighten the screw.\* Wires must extend past the screws.
- 4.2.1.10 Plug the male connector of the thermocouple into the female connector of the Fluke 52 meter or Altek and ensure a positive (+) reading by holding the Quik-Tip connector in hand.
- 4.2.2 Assembled by outside supplier: (TCK 001 kit creation & receiving inspection)
  - 4.2.2.1 Cut 19" lengths of 20 gauge special limits Chromel wire from the spool with the Eubanks wire cutting machine. Refer to TC 105 or 105A for details.
  - 4.2.2.2 Cut 19" lengths of 20 gauge special limits Alumel wire from the spool with the Eubanks wire cutting machine. Refer to TC 105 or 105A for details.
  - 4.2.2.3 Ensure wire is clearly labeled prior to creating a kit. Refer to TC 105 or 105A for details.
  - 4.2.2.4 Assemble calibration test samples. Refer to 4.2.1. Calibrate the test samples and place a copy of the calibration report with cut wires in the kit.
  - 4.2.2.5 Place an equal amount of nickel quick tips in the kit based on the amount of wire cut. Quick tips arrive from the vendor typically in bottles with labeled quantities.
  - 4.2.2.6 Place a bag with an equal amount of thermocouple plugs in the kit based on the amount of wire cut.
  - 4.2.2.7 Weigh a corresponding amount of 1" ceramic beads in the kit based on the amount of wire cut.
    - 4.2.2.7.1 Use the scale to bag the quantity required for the kit. **Remember to tare out the bag first.**

Quantity 1" beads	Weight (grams)
100	50
200	100
300	150
400	200
500	250
600	300

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- 4.2.2.8 Weigh a corresponding amount of 3" ceramic beads in the kit based on the amount of wire cut. Five (5) three inch beads are required for every 1" bead.
- 4.2.2.9 Use the scale to bag the quantity required for the kit. **Remember to tare out the bag first.**

Quantity 3" beads	Weight (grams)
500	733
1000	1467
1500	2200
2000	2933
2500	3667
3000	4400

- 4.2.2.10 Ensure the calibration report remains with the kit to be shipped out for assembly.
- 4.2.2.11 Receiving inspection: A minimum sampling of 10% of the batch shall be tested prior to production use. Complete Supplement TC 101.02.

- 4.2.2.11.1 If all samples tested are acceptable, the batch can be stickered green for use.
- 4.2.2.11.2 If some, but not all of the sample thermocouples fail the inspection, test the entire lot. In addition, contact the supplier to determine the course of action to eliminate the problem.
- 4.2.2.11.3 If all the sample thermocouples fail the inspection there are two options.

- Option 1: Return entire lot to supplier.
- Option 2: Test the entire lot, repair and re-test.

In either case, contact the supplier to determine the course of action to eliminate the problem.

- 4.2.2.12 Ensure the calibration report returns with the finished kit as well as un-used material. Un-used material will be placed back on the shelf for future shipments.

4.3 TWISTED AND TIG WELDED METHOD:

- 4.3.1 To simplify the thermocouple assembly, the negative leg may be marked with a red marker prior to cutting the thermocouple wire pair to the correct length.
- 4.3.2 Twist approximately 1/4" of one end of the pair of wires into a tight twist. Fusion weld the twisted end in an inert gas atmosphere.

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- 4.3.2.1 A quality weld varies by thermocouple type. Base metal type "K" and "J" may be discolored but still smooth. Precious metal type "B," "R" and "S" will have a shiny, smooth, round weld bead.
- 4.3.3 Apply insulation as described in step 4.1.4.
- 4.3.4 Repeat step 4.3.1 through 4.3.3 to complete batch quantity.
- 4.3.5 Locate the negative wire marked with the red marker or use fingers to feel for the softest (negative) wire and insert that into the negative or large connector on a plug (see 4.6 Table 1) and tighten screw with wire extending past the screw.
  - 4.3.5.1 Do not allow any of the wire insulation (PFTE tubing, fiberglass sleeving, FBGS polyvinyl etc.) to be under the screw in the connector.
- 4.3.6 Insert other wire into the positive or small connectors on the plug and tighten screw with wire extending past the screw.
  - 4.3.6.1 Do not allow any of the wire insulation (PFTE tubing, fiberglass sleeving, FBGS polyvinyl etc.) to be under the screw in the connector.
- 4.3.7 Refer to 4.6 for "Testing of Thermocouples."
- 4.4 TWISTED METHOD:
  - 4.4.1 To simplify the thermocouple assembly, the negative leg may be marked with a red marker prior to cutting the thermocouple wire pair to the correct length.
  - 4.4.2 Twist approximately 1/4" of one end of the pair of wires into a tight twist.
  - 4.4.3 Apply insulation as described in step 4.1.4.
  - 4.4.4 Repeat step 4.4.1 through 4.4.3 to complete batch quantity.
  - 4.4.5 Locate the negative wire marked with the red marker or use fingers to feel for the softest (negative) wire and insert that into the negative or large connector on a plug (see 4.6 Table 1) and tighten screw with wire extending past the screw.
    - 4.4.5.1 Do not allow any of the wire insulation (PFTE tubing, fiberglass sleeving, FBGS polyvinyl etc.) to be under the screw in the connector.
  - 4.4.6 Insert other wire into the positive or small connectors on the plug and tighten screw with wire extending past the screw.
    - 4.4.6.1 Do not allow any of the wire insulation (PFTE tubing, fiberglass sleeving, FBGS polyvinyl etc.) to be under the screw in the connector.
  - 4.4.7 Refer to 4.6 for "Testing of Thermocouples."

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### 4.5 ELECTRIC RESISTANCE BUTT WELD METHOD:

- 4.5.1 To simplify the thermocouple assembly, the negative leg may be marked with a red marker prior to cutting the thermocouple wire pair to the correct length.
- 4.5.2 Place the wires opposite each other in the grooves provided on the Precision Welding Machine with end surfaces making contact, clamp and weld. Release clamp and remove from machine.
  - 4.5.2.1 A quality weld varies by thermocouple type. Only clean shear cut dissimilar wire shall be welded together. Base metal type "K" and "J" will be discolored and may have some flash. While holding each dissimilar base metal wire with pliers near the weld, a good solid weld will not break apart when cold working. Precious metal type "B," "R" and "S" will have a shiny, smooth, round weld bead. Cold working is not recommended on precious metal.
- 4.5.3 Apply insulation as described in step 4.1.4.
- 4.5.4 Repeat steps 4.5.1 through 4.5.3 to complete batch quantity.
- 4.5.5 Locate the negative wire marked with the red marker or use fingers to feel for the softest (negative) wire and insert that into the negative or large connector on a plug (see 4.6 Table 1) and tighten screw with wire extending past the screw.
  - 4.5.5.1 Do not allow any of the wire insulation (PFTE tubing, fiberglass sleeving, FBGS polyvinyl etc.) to be under the screw in the connector.
- 4.5.6 Insert other wire into the positive or small connectors on the plug and tighten screw with wire extending past the screw.
  - 4.5.6.1 Do not allow any of the wire insulation (PFTE tubing, fiberglass sleeving, FBGS polyvinyl etc.) to be under the screw in the connector.
- 4.5.7 Refer to 4.6 for "Testing of Thermocouples."

### 4.6 Testing of Thermocouples

- 4.6.1 Plug the test battery into the female connector on the HP 3478A and make sure mV is stable and positive (+) to ensure leads are good. (If not repair leads and go to 4.6.1.)
- 4.6.2 Plug the thermocouple into the HP 3478A/ALTEK 422 or FLUKE 52 and warm the thermocouple and look for a positive (+) reading. (If negative (-) reading is displayed note as rework, flip wires and go back to step 4.6.1).
- 4.6.3 Take the reading up to mV (temp) listed on Table 1 per Type.



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- 4.6.4 Then plug the test battery into the female connector on the HP 3478A to see if mV are stable and positive (+) to ensure leads are still good. (If different, check leads, repair, and refer back to steps 4.6.1).
- 4.6.5 Test the Fluke 77 Digital Multimeter leads for continuity. Place the DMM into resistance (ohm) function. While touching the probe tips together, red to black, the DMM should read 0.5 ohms or less for good quality test leads. (If ohm reading is not stable or too high, repair/replace test leads and repeat 4.6.5)
- 4.6.6 If thermocouple uses a metallic protection tube use Fluke 77 to check sensor for grounded wires to tube.

Table 1

<b>INSTRUMENT USED</b>	<b>HP3478</b>		<b>ALTEK422/FLUKE 52</b>	
<b>TYPE OF T/C</b>	B	R/S	K	J
<b>mV readings = 200° F</b>	0.03 mV	0.6mV	80 °F	80 °F
<b>LOW TEMP PLUG COLOR</b>	WHITE	GREEN	YELLOW	BLACK
<b>HI TEMP PLUG COLOR</b>	RED	RED	RED	RED
<b>CODE</b>	B, CU, C	R, S	K	J

- 4.7 Application of 904 adhesive
  - 4.7.1 Casting Susceptor Thermocouples
    - 4.7.1.1 Verify adhesive has not exceeded the expiration date.
    - 4.7.1.2 Stir adhesive thoroughly.
    - 4.7.1.3 Pull fiberglass sleeving back a minimum of 5/8", exposing the thermocouple wires.
    - 4.7.1.4 Generously apply adhesive to the bare wires and the ends of the fiberglass sleeving, allow the excess to drip back into the container. Push fiberglass sleeving up tight to the insulator.
    - 4.7.1.5 Generously apply adhesive to the insulator starting approx. 1/2" from end with the sleeving, and extending along and around the insulator for approx. 2"
    - 4.7.1.6 Insert insulator into the alumina protection tube. Rotate the protection tube while sliding it up the insulator until it bottoms out, and allow the excess adhesive to drip back into the container.
    - 4.7.1.7 Place assembled thermocouple(s) on wire rack. Insert rack into drying oven, and allow to oven dry for a minimum of 2 hours at a set point of 160 deg. F.
    - 4.7.1.8 Note time thermocouple(s) are put into oven and enter the time on the thermocouple build supplement.

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- 4.7.1.9 After drying is complete, inspect glue for cracks, reapply adhesive to cracks and return to 4.7.1.7 as required.
- 4.7.2 Industrial Thermowell thermocouples
  - 4.7.2.1 Verify adhesive has not exceeded the expiration date.
  - 4.7.2.2 Stir adhesive thoroughly.
  - 4.7.2.3 Mark insulator for stopper location per thermocouple build instructions.
  - 4.7.2.4 Apply adhesive around entire insulator(s) as indicated in 4.7.2.3 and rotate stopper while inserting it over the insulator. Ensure concave section of stopper is filled to the top with adhesive.
  - 4.7.2.5 Place insulator on wire oven rack. Insert rack into drying oven and allow to oven dry for a minimum of two (2) hours at a set point of 160 deg. F.
  - 4.7.2.6 Note the time insulator are put into the oven and enter the time on the thermocouple build supplement.
  - 4.7.2.7 After drying is complete, inspect for cracks, reapply adhesive to cracks and return to 4.7.2.5 as required.
- 4.8 Reference CES 100, sections 6.7, 6.8 and 6.9 regarding, calibration records, out of tolerance reports and labeling, as required.

5. REFERENCES:

- 5.1 ASTM STP 470B Manual on the Use of Thermocouples in Temperature Measurement.
- 5.2 QP 13.03

∅ - Denotes change from previous issue