INL/MIS-20-60318-Revision-0

MEDE 5-Zone Furnace System Checkout at NHL and EDL (Qualification)

February 2021

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Changing the World's Energy Future

Idaho National Laboratory

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http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Document ID: MFC-ITP-0202
Revision ID: 1
Effective Date: 02/04/21

Installation and Test Procedure

MEDE 5-Zone Furnace System Checkout at NHL and EDL (Qualification)

Project No. 33293

EJ -2972

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1. INTRODUCTION

1.1 Purpose

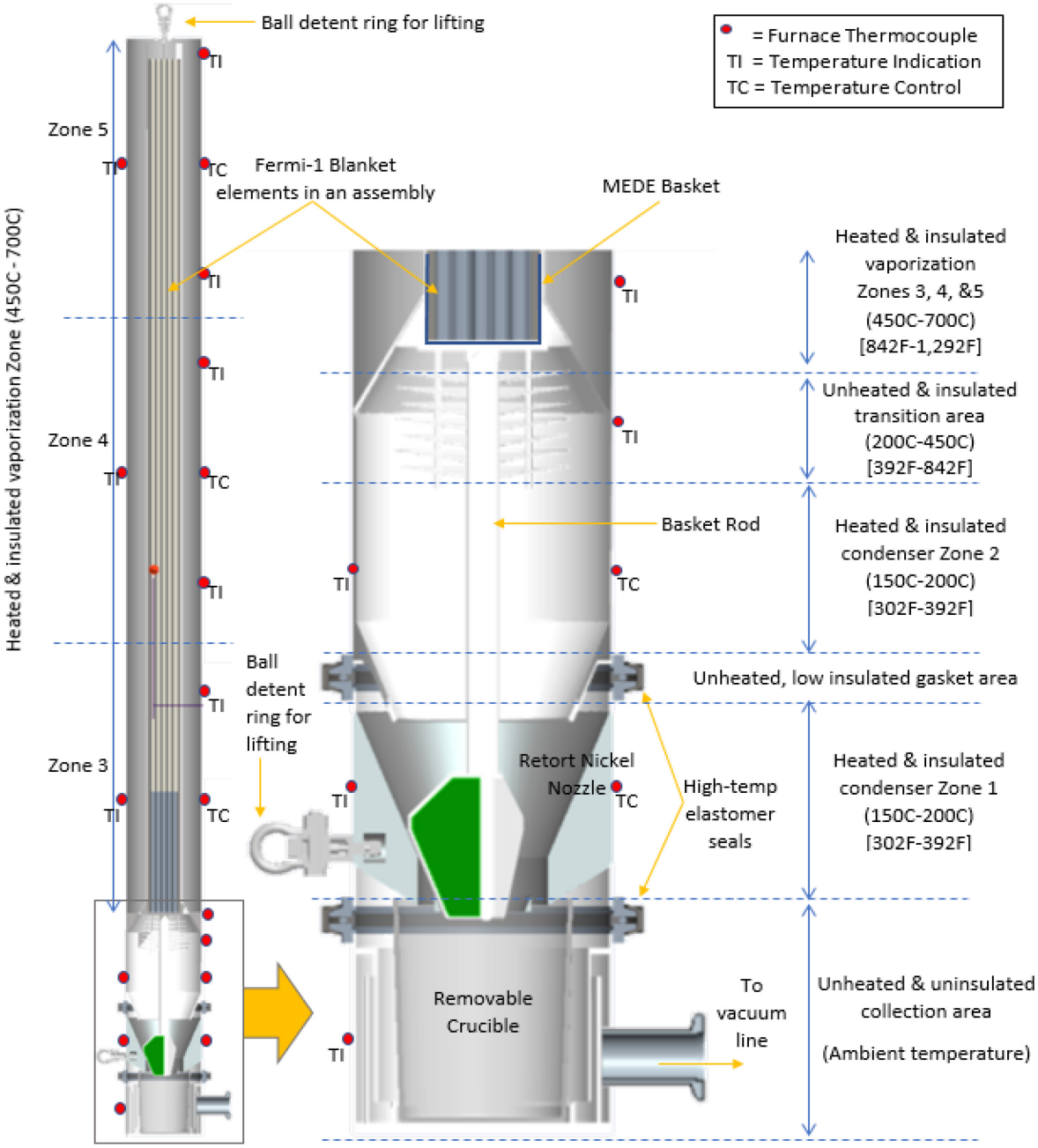
This document contains instructions for the assembly and checkout of the Melt Evaporate Drain (MEDE) project 5-Zone Furnace system that is required for demonstration of sodium removal from a Fermi-1 reactor blanket element. Equipment to be tested includes the Mellen 5-Zone furnace assemblies, a blanket element retort with internal thermocouples, vacuum pump system, and computer control equipment, software, and a non-sparking radial saw. Instructions are intended to verify mechanical and electrical components fit properly and operate as intended and that the selected saw cuts evenly without giving off sparks. This includes testing all electrical components from the in-glovebox furnace to the out-of-glovebox control cabinets. After all of the components are assembled and prove to be operational, the system will be used to bake out the furnace and the blanket element retort. Following bake out, all of the MEDE components will be used to gather data for a step-by-step recipe of zone furnace temperatures verses soak time.

This plan will cover all PLC component electrical and software qualifications at the North Holms Lab (NHL) in Idaho Falls prior to shipment of that PLC to the Engineering Development & Welding Laboratory (EDL) at MFC. This plan will also cover all of the mechanical and electrical equipment checkout, bake out operations, and furnace recipe data collection at EDL.

1.2 SYSTEM DESCRIPTION

The MEDE 5-Zone furnace system is designed to provide the necessary heat to distill sodium from a non-irradiated Fermi-1 reactor blanket elements. If proven successful, this furnace, or a furnace of similar design, may be used in a hot cell environment to remove sodium from more than 12 tons of irradiated blanket elements.

The system is composed of a high temperature 5-zone furnace and an interior retort connected to a vacuum assembly. The 5–zone furnace is a split tube vertical furnace. The following figure shows the retort that nests within this furnace and the Fermi-1 reactor blanket elements that are nested within the retort. As shown on this figure, the lower furnace condenser zones 1 and 2 have a maximum operating temperature of 200°C. The upper zones 3, 4, and 5 have a maximum operating temperature of 650°C. There are multiple thermocouple ports for monitoring the temperature vertically. The base of this retort is connected to a vacuum assembly which uses an Agilent (Varian) IDP-15 scroll style vacuum pump with a nominal pressure rating of 100 mTorr. The rest of the vacuum assembly consists of isolation valves, various filters, a pressure relief valve, a pressure sensor, hoses, fittings etc.



2. SCOPE

This document will only provide instructions necessary to complete the assembly, checkout, operability testing, bake out, and temperature profiling activities at NHL and EDL.

2.1 Overview

At the conclusion of this test, the 5-Zone Furnace assemblies will be transferred to the pyro-chemistry glovebox at the FASB facility at MFC for operations in the pyrochemistry glovebox for the MEDE project.

Powered operation of the components will be performed at two locations. The NHL facility in Idaho Falls and the EDL facility at MFC.

At NHL, a controls engineer will ensure that the control cabinet is wired properly and the PLC inputs and outputs are scaled correctly without initially powering up the main heater loads. The controls engineer, using the appropriate software, will supply input signals to verify proper logic control and system functionality as well as the correct Human Machine Interface (HMI) data display. The controls engineer will document results of this testing using the "Control Cabinet PLC/IO Test" table in Appendix A.

At EDL, the baseplate and furnace are assembled outside the bay door in preparation for furnace bake out (performing bake-out inside the bay door is also an option). Furnace thermocouples, control signals and power connections are then terminated at the control cabinet. At that point, the MEDE retort is assembled by cutting the ends off of a mockup Fermi-1 blanket fuel bundle and using that truncated mockup bundle during assembly of the MEDE retort (PLC and vacuum equipment testing without the truncated assembly in the retort is also an option). The assembled retort is lifted by a mobile coffing hoist and placed in the baseplate's "support cup." Control and power cables are routed from the vacuum components (pump, valves, pressure gauge, etc.), back to the control cabinet. The PLC and equipment are then tested to ensure proper control using data in Appendix B. The retort is then removed from the furnace and the furnace is baked out to remove the furnace insulation binders. Following bake out, the retort is reinstalled in the furnace, evacuated, and heated to remove any residual retort oils. If bake out is performed outside, the retort, baseplate, and furnace are moved to the interior of EDL for final testing. This final testing involves adjusting the furnace temperatures to achieve the desired retort interior temperatures and recording the duration (several iterations may be required for this step). This data will provide critical information used in the establishment of a MEDE recipe for Fermi-1 bundle sodium removal.

During the assembly and checkout, it is likely that changes will be required for some of the equipment and software. Not all components may fit together as designed or may not operate as intended. Therefore, it may be necessary to make changes to the mechanical components, electrical components, control cabinets, or the OCS/PLC software during the assembly and checkout process. A set of drawings will be at the applicable testing facility during implementation of this plan. These drawings shall be red-lined to indicate changes to the hardware or electrical components as changes occur. In the event that a step in the test plan

cannot be performed as indicated, or if a hardware or software change nullifies a previously performed step or requires additional steps, the instructions in this procedure may be modified by making red-line changes to the steps and the steps may be repeated as necessary. Any changes or additions to steps should be evaluated by the lead technician or facility supervisor and lead engineer as appropriate to ensure that hazards stay within the controls of this document and new hazards are not introduced.

Work control at NHL and EDL is governed by the Laboratory Instructions (LI) for that facility. The following is a list of specific LI's that govern work at NHL and EDL that may be associated with this system test:

- LI-RDSS0002, Use of Stand Alone Equipment Within R&D Manufacturing Services
- LI-RDSS0003, Welding, Metal Casting and Other Hot Work
- LI-RDSS0004, General Work Activities within the R&D Manufacturing Services Facilities
- LI-RDSS0009, Assembly and Testing of Pressurized Systems
- LI-RDSS0023, Electronics Testing, Troubleshooting, and Measurements
- LI-RDSS0026, Compressed Gas Cylinder Handling and Usage
- LI-623, Energized Electrical Work
- LI-654, Pyroprocessing General Laboratory Activities
- LI-784, NS&T Pyroprocessing Experiments
- LI-928, GENERAL Fabrication & Assembly ACTIVITIES WITHIN Pyrochemistry & Molten Salt Systems laboratories.

2.2 Quality Information

Quality Level Determination Number, QLD #: MFC-001519

Quality Level: Engineering Calculations and Analysis – 3
Engineering Inputs – 3
Engineering Verification – 3
R&D Manufacturing Services Work Management Implementation – 3
Work Management – 3
Software – 3

3. PRECAUTIONS AND LIMITATIONS

3.1 Precautions

3.1.1 Control Cabinet and Heaters

The control cabinets are powered by a 208 volt, 3 phase power source by way of a welding receptacle. LI-623 procedures for working with these voltages shall be followed.

The furnace is designed to operate at 650°C upper zones and 200°C lower zones. Upper and lower zones will be operated at those temperatures during this phase of the testing per manufacturer's recommendation. The manufacturer recommends taking the furnace to a prescribed temperature in an air atmosphere (furnace bake-out) prior to being used in the argon atmosphere (FASB PC Glovebox). The external surface temperature of the furnace can reach 150°C (during prior EDL testing of a similar two zone furnace, most external temperatures were below 150°C except for those measured at the seam (split furnace) which were greater). Provide the necessary exclusion barrier and precautions to avoid burn hazards when operating the furnace.

To mitigate issues with fumes during furnace bake-out, the furnace may be place outside the EDL roll-up door during the bake-out process then subsequently brought inside for further testing. If bake out is performed outside, weather will need to be monitored carefully, to ensure that low humidity and low wind conditions are present during the entire time the furnace is outside the building.

3.2 Risks and Controls

Activity	Hazard Text	Control Text
1. Electrical Work within the work area (performed by I&C technician, electrician, or other trained, qualified, and authorized workers).	1. Electrical shock and arc flash.	1. 1) Live parts shall always be de-energized prior to electrical work being done on equipment operating at 50V or higher unless it can be demonstrated that de-energizing introduces additional or increased hazards or is not feasible due to equipment design or operations limitations. Perform LO/TO per LWP-9400 (NHL) or SP-94.0.0 (EDL) as required. 2) Only trained, qualified, and authorized workers can work in electrical panels and on electrical equipment, when exposing energized components. ANY access within the panel must be approved by the facility manager. Personnel receiving Higher-Than-Normal-Risk Electrical Safety (000INL59) training are allowed to enter the exclusion area, and go up to the restricted approach boundary, without escort when authorized. In order to be authorized to be within the exclusion area, the employee must have the skills and knowledge related to the operation of the particular equipment as well as the required safety training to recognize the hazards involved with the task.

Activity	Hazard Text	Control Text
		3) At NHL the electrical supply to the main control cabinet (MF-CP-001) is fed from a 208 Volt 3-phase 60 amp welding receptacle (fused at 40 amps). At EDL the 208 Volt 3-phase 100 amp electrical supply to the main control cabinet (MF-CP-001) is fed from a portable power station that is transformed from a 480 VAC, 60 amp, 3-phase welding receptacle. The portable power station has a 45 kVA transformer with 6.9% impedance. The maximum fault current would be limited to approximately 1,800 amps. TEV-4031 documents a code compliant SCCR for the industrial control panel. 4) Currently, NFPA 70E, 2018 has no arc flash analysis exemptions for 208 Vac systems. However, based on past editions of 70E and practical experience at the INL, an arc flash incident of 1.2 cal/cm2 or greater is unlikely as long as the 480 - 208/120 Vac transformer is 75 kVA or less. 5) Wear the following PPE for voltage readings, current readings, troubleshooting, and any activity within the restricted space: - Class 00 gloves or greater with leather glove protectors. 6) Use at least a Cat. III meter for electrical measurements on this system.

Activity	Hazard Text	Control Text
		7) Use voltage rated insulated tools when required. 8) There are no exposed energized components for the electrical loads and associated cabling fed from the main control cabinet. All connectors maintain the electrical arrangement of the plug being closest to the load and the receptacle being closest to the source; this allows disconnection without exposing energized components. 9) Electrical work shall be performed in accordance with LI-623, Energized Electrical Work. 10) Establish physical barriers or control access to the exclusion area (3 ft 6 in.) or the flash protection boundary (FPB), whichever is greater. Exposed equipment must NOT be left unattended or without proper barriers and posting. 11) Conduct a pre-job briefing and ensure proper barriers are in place prior to any work.
2. Performing furnace heat-up tests.	2a. Burns due to exposure to hot surfaces.	2a. 1) Erect signs and/or barriers to prevent personnel from entering the immediate area adjacent to the furnace during heat-up tests to prevent exposure to hot surfaces. Signs should read: “DANGER – Severe Contact Burn – Avoid Contact” 2) Allow adequate time for post cool-down of the equipment.

Activity	Hazard Text	Control Text
		3) Maintain a safe distance away from the equipment until adequate time has passed to allow sufficient cooling. 4) Use tongs or wear thermal protective gloves when it is necessary to handle hot components. 5) Hot items should cool to less than 125°F prior to touching without thermal protection gloves.
	2b. Fire.	2b. 1) There should be a portable fire extinguisher in the immediate work area. 2) There should be a "hot work" permit in place during heater operations. 3) A fire watch may be required per facility management direction. 4) Maintain a combustible material buffer zone around and above the furnace. Check for combustible material prior to energizing the furnace.
	2c. Odors/off gas generated when heated.	2c. Provide temporary ventilation as required.
3. General handling of equipment	3. Laceration from sharp edges.	3. Wear ANSI Level IV cut resistant gloves for cut protection during handling.
4. Movement of retort with coffing hoist	4a. Striking against hazard caused by a moving or projected work piece/unsupported or unsecured work piece.	4a. Adequately secure materials (with clamps, jigs, or vise), where possible, to prevent unwanted movement during processing.

Activity	Hazard Text	Control Text
	4b. Struck-by moving loads.	4b. 1) Maintain safe body position by avoiding placement of body parts between moving and stationary objects. 2) Communicate the desired path of travel for the movement of equipment/materials to ensure other personnel remain aware during the movement.
	4c. Pinch points and foot crushing hazards.	4c. 1) Wear leather gloves and keep hands from being caught between stationary and moving objects. 2) Identify pinch points and maintain safe body and hand position. 3) Make sure travel path is clear of obstruction. 4) Wear protective safety shoes during retort handling/movement
5. Operating, maintaining, and passing under roll-up doors.	5a. Crushing/unexpected release of stored energy/ uncontrolled descent of door/pinching hazards.	5. 1) Do not stand or walk under rollup door while door is in motion. 2) Use personnel doors whenever possible. 3) Operator shall ensure personnel maintain safe distance from door while in motion. 4) Maintain constant awareness when working around a roll-up door in the up position. 5) Keep doorway clear and in full view while operating door(s).

Activity	Hazard Text	Control Text
		6) Only trained personnel are allowed to conduct maintenance and repairs on overhead doors. 7) Observe overhead door postings.
6. Operating stationary machining tools including lathes, mills, grinders, belt sanders, and drill presses.	6a. Rotating equipment, entanglement hazard, "struck by" hazard, and lacerations.	6a. 1) Ensure all machine guards designed to protect moving parts are in place and properly adjusted while machine is in use. 2) Do not wear gloves around rotating machinery. 3) Do not lean or rest hands on a moving table, chuck, part or tool. 4) Do not attempt to mount, measure, or adjust work until cutter is completely stopped. 5) Remove or secure loose clothing, security badge, gloves, neckties, rings, bracelets, or other items that can become entangled in moving parts. 6) Confine long hair.
	6b. Pinch points, entanglement hazards, lacerations, and flying chips/shards.	6b. 1) Ensure equipment guards are in place as designed and installed. 2) Use guarding/ shielding at the point of operation to the maximum extent possible with regard for the overall safety provided.

Activity	Hazard Text	Control Text
		3) In those occasional instances where positioning the guard or shield interferes with required movement of the tooling or work piece, or when use of a shield or guard interferes with proper operation of the equipment, contact a safety professional for additional guidance.
	6c. Lacerations or burns from hot, flying chips or foreign objects in the eye.	6c. 1) Wear ANSI Z87.1 rated safety glasses with side shields. 2) Use a chip shield or wear a face shield when making heavy cuts that throw chips. 3) Do not use hands to remove chips.
	6d. Lacerations from chip removal.	6d. 1) If feasible, stop the machine before removing accumulated chips. 2) Never remove chips by hand; use a brush, rake, pliers or vacuum. 3) If it is necessary to clear fine chips from the machine while in operation, use compressed air or liquid spray only. 4) Do not use anything that can be drawn into the cutter (e.g., brush or rag). 5) If using compressed air, point the nozzle in a direction away from yourself and others in the immediate area.

3.3 Permits

No special Permits have been identified.

3.4 Hoisting and Rigging

Lifts are not required at the NHL facility since the retort will be lifted and placed into the 5-zone furnace base plate at EDL.

The EDL coffing hoist (supported on a portable I-beam A-frame) will be used to lift a loaded retort by its end detent ring (see figure in section 1.2) and lower the retort into a weighted baseplate receiver weldment support ("support cup"). The weighted baseplate support is designed to hold the retort vertically without additional support. After placement in the baseplate cup, the retort coffing hoist support and associated retort detent ring(s) are removed. The open furnace is then slid along its base rails until the retort is nested inside the furnace[1]. The furnace is then closed, heated, cooled, opened, pulled back, and the retort is again fastened to the coffing hoist with a detent ring, lifted, and, laid on the ground (or other horizontal surface).

Per the approved lift plan, no lifts have been identified as "critical lifts" at the EDL facility.

All lifting hardware shall be load tested prior to use. All of the 5-Zone furnace items (including the retort) are below 1000 lbs. If feasible, equipment weights will be recorded and documented in this test plan or on the drawings.

4. PREREQUISITES

4.1 Personnel Protective Equipment

During set up and running of tests, safety glasses with side shields shall be worn as required by the facility.

4.2 Conditions

A pre-job briefing shall be conducted prior to the start of work.

All barriers shall be in place prior to start of work.

Inform building occupants of possible odors or off-gases caused when the furnace is heated for the first time.

[1] Once the retort is secured in a closed furnace, the loaded furnace could be secured to the hoist A-frame or left as-is.

4.3 Training/Qualifications

Activity	Training Required
General Shop Work	00INL288, "Personal Protective equipment" OR 00INL722, "Laboratory Protective Equipment" 00INL815, "Hazard Communication" 00INL838, "Industrial Ergonomics" QNRDSS00, "Safe Work Practices" QL00HEAR, "Hearing conservation (only for employees enrolled in the HC program)" 0INL1140, "INL Ladder and Roof Safety" QN000PSA, "BEA Pressure Systems Assembler" 00INL670, "R&D Laboratory Awareness"
Working in an R&D Laboratory	0INL1491, "Laboratory Ergonomics Training"
Working with elevated temperatures	00INL722, "Laboratory Protective Equipment"
Working with electronics	QNRDREWT, "INL Research and Electronics Worker"
Operating circuit breakers or switches greater than 240 volts	ESHTN000, "HTNR Electrical Safety" OR ESEEA000, "Electrical Energy Awareness" OR QNRDREWT, "INL Research and Electronics Worker"
Servicing/maintenance on electrical systems 300 volts or less	QNRDREWT, "INL Research and Electronics Worker" OR ESEEA000, "Electrical Energy Awareness"
Servicing/maintenance on electrical systems greater than 300 volts	ESEEA000, "Electrical Energy Awareness"

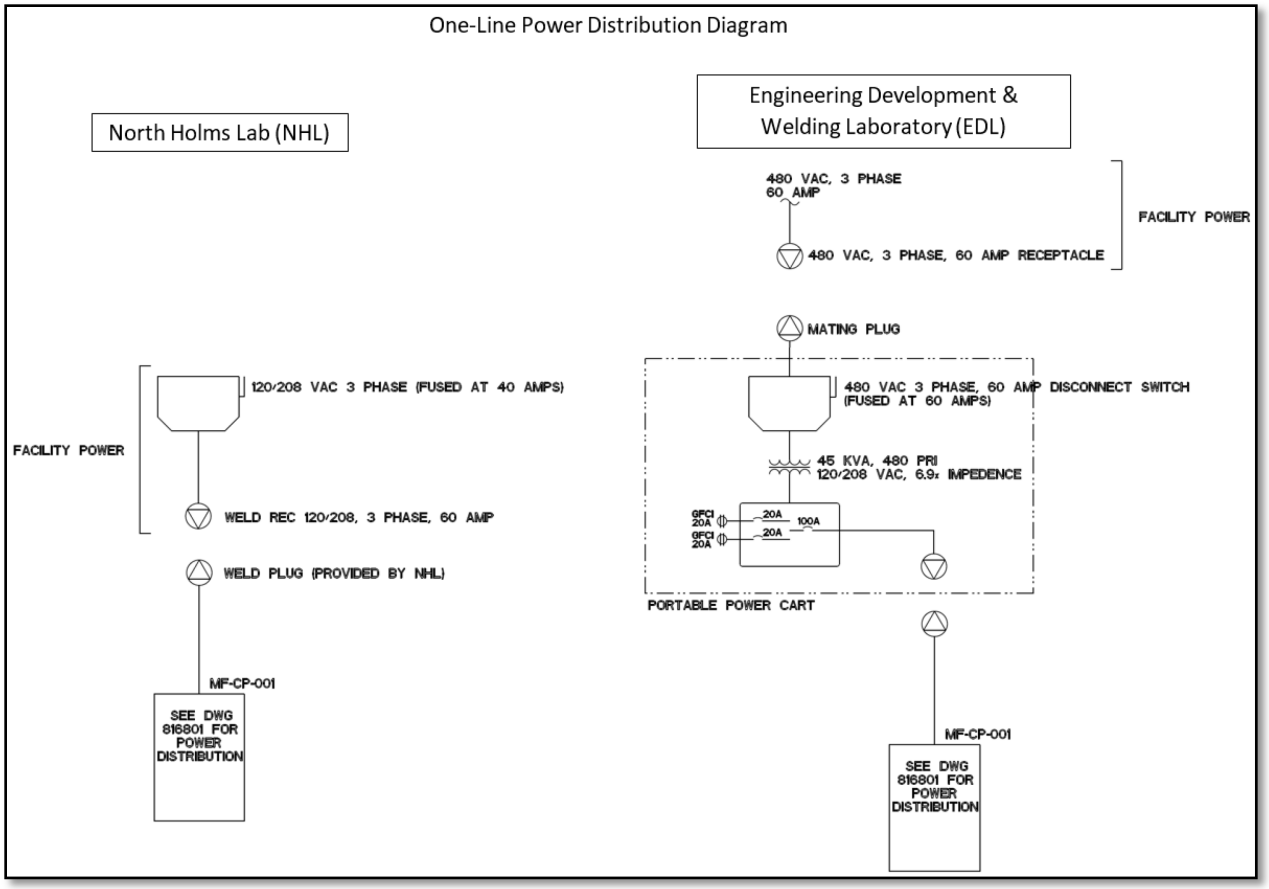
Activity	Training Required
Prepare, install, perform zero-energy verifications, or work under the protection of, or remove simple LO/TO and/or assigned as work group representative to accept or release a complex LO/TO and/or is assigned to work under the protection of a complex LO/TO	QNLTWORK, "INL Lock/Tag Auth Emp Limited"
To operate or use a machine or equipment on which servicing or maintenance is being performed under LO/TO	QNLT00AE, "INL Lock/Tag Affected Employee"

4.4 Utilities and Materials

4.4.1 Electrical Utilities

At NHL, a fused disconnected switch/ welding receptacle (fused at 40 amps) supplies the 120/208VAC needed to verify the proper function of the low power equipment inside the control cabinet.

At EDL, the required 120/208 VAC , 3 phase, 100 amp, supply voltage will come through a portable power station that is transformed from a 480 VAC, 60 amp, 3-phase welding receptacle. Full power will be needed to perform the furnace "bake out," as well as a full system function verification.



4.4.2 Materials

No special materials are required other than those necessary to complete assembly of the equipment.

5. NHL INSTRUCTIONS

Changes or additions will be reviewed by the lead engineer and lead technician, PIC (Person in Charge), or facility supervisor to ensure that no new hazards are introduced. A set of drawings will be made available during testing and red-line markups shall be made on the drawings as changes occur. Notify the engineer prior to making any changes to the hardware and note the changes on the drawings and in this procedure. These instructions shall be performed by NHL personnel.

Throughout the completion of this procedure, photograph the equipment and noteworthy activities to augment the documentation of the equipment and/or qualification process. At a minimum, photograph the equipment at the conclusion of the procedure to fully document the equipment in its final configuration. Insert the photographs into Appendix C.

5.1 PLC Assembly

5.1.1 Ensure that the control cabinet, MF-CP-001 has been assembled per INL Dwgs. 816801, 816802, 816803, 816804, 816805, 816806, 816807, 816808, and 816809. Perform a PLC I/O test to verify that the cabinet MF-CP-001 is wired properly per instructions in Appendix A. Acceptance criteria includes verification of proper logic control and system functionality as well as the correct Human Machine Interface (HMI) data display. Note any issues.

5.2 Equipment Testing

The purpose of this test is to verify that the cabinet MF-CP-001 is wired properly and the PLC inputs and outputs are scaled correctly. Refer to Dwgs. 816801, 816802, 816803, 816804, 816805, 816806, 816807, 816808, 816809 and the table in the appendix A. In appendix A, a signal was injected into the control cabinet and read from the PLC or generated from the PLC and read elsewhere. This test is to be performed by the controls engineer and the NHL personnel.

5.2.1 Using the PLC/OCS software, perform the control cabinet PLC/IO tests identified in Appendix A. The software engineer may make any necessary changes to the software in order to optimize the process and operations. Changes to the software will be documented by the software engineer and changes to the testing steps will be noted in the instructions in Appendix A. Resulting changes to the hardware will be noted on the drawings using red-line markups. Note any issues.

5.2.2 Confirm that the tests were executed according to the instructions in Appendix A and that the results are satisfactory.

Software Engineer: _____ Date: _____

Test Technician: _____ Date: _____

Lead Engineer: _____ Date: _____

5.2.3 Package the components sufficiently to protect them from dirt or grease during transfer to EDL at MFC.

6. EDL INSTRUCTIONS

All steps in this procedure may be repeated or modified as necessary and additional steps may be added with the concurrence of the lead engineer. Changes or additions will be reviewed by the lead engineer and lead technician, PIC (Person in Charge), or facility supervisor to ensure that no new hazards are introduced. A set of drawings and vendor reference documents will be made available during testing. Red-line markups shall be made on the drawings as changes occur. As items are assembled, look for interferences, alignment issues, or other assembly issues. Notify the engineer prior to making any changes to the hardware and note the changes on the drawings and in this procedure. A set of vendor instructions for resistance checking the heater elements and performing furnace bake out will also be made available during testing. The instructions within the test plan shall be performed by NHL, EDL, or operations personnel under direction of the lead engineer. If necessary, steps in this procedure may be skipped or performed out of sequence with approval from the lead engineer.

6.1 Retort Baseplate and Furnace Assembly for Bake-Out

6.1.1 Assemble the retort baseplate (see INL Dwg. 824747) on support blocks outside the EDL bay door. IF the decision is made to assemble the furnace inside the EDL bay door, THEN skip section 6.6 . This will allow movement with a hand cart (or other) after bake out operations. Note any issues.

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6.1.2 Assemble the 5-Zone furnaces, per Dwg. SWA19383-001, on top of the retort baseplate. Ensure that the hole in the bottom of the furnace is centered over the retort baseplate receiver weldment support when the open clam shell furnace is pushed forward on the furnace rails. Note any issues.

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6.1.3 Prior to connecting the furnace to the power leads, measure the resistance across each heater element and compare to the vendor supplied "furnace element resistance testing" document from the MELLEN Company. If discrepancies are present, note below and contact the lead engineer prior to continuing to the next step.

6.1.4 Connect the three power leads between furnace and PLC cabinet (per PLC cabinet per INL Dwg. 816801) using the supplied jumpers in place of the glovebox pass-through fittings. Note any issues.

6.1.5 Connect the two thermocouple leads between furnace and PLC cabinet (per INL Dwg. 816801) using the supplied jumpers in place of the glovebox pass-through fittings. Note any issues.

6.1.6 Repeat any of the previous steps in in this section as necessary to ensure that all of the components fit correctly. Note any problems with cables or connectors and make any necessary changes as directed by the engineer.

6.1.7 Confirm that all 5-Zone Furnace and associated equipment are assembled properly and all interferences and issues have been resolved. Complete mechanical assembly of the 5-Zone furnace is not required for electrical checkout/testing.

Test Technician: _____ Date: _____

Lead Engineer: _____ Date: _____

6.1.8 Take photographs of the various 5-Zone furnace and equipment (control cabinets, junction boxes, cabling layout, furnaces, etc.) and note the photo numbers in Appendix C.

6.2 Mockup Fuel Assembly Cutting

6.2.1 Ensure that the mockup fuel assembly was fabricated with end caps per INL Dwg. 855009. Note any issues.

_____

_____

_____

6.2.2 Use the selected radial saw, cut along the pre-marked line on both ends of the fuel assembly. After the cuts, the tubes should be un-crimped enough to allow the interior metal rods to slide out. If crimping occurs, used hand tools to re-open the tubes. Record the cuts on video and photograph cuts. Note the results (straightness of cut, crimping, sparks, etc.), any issues, and corrective measure. Insert the photographs into Appendix C.

_____

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_____

6.3 Retort Assembly and Installation

6.3.1 Place wire labels on the two thermocouple wires attached to the nickel nozzle (INL Dwg. 824760). Labels should read #12 (top) and #13 (bottom). Labels should be located to enable wire identification with all components assembled except the Receiver Thermo Test Fixture Assembly (INL Dwg. 824760 item 4 and INL Dwg. 824756). Note any issues.

6.3.2 Assemble the mockup retort, pre-cut mockup fuel assembly (from section 6.2 if applicable), and multipoint thermocouple per INL Dwg. 824760. Leave off Receiver Thermo Test Fixture Assembly (INL Dwg. 824756). Note any issues.

6.3.3 Ensure that all thermocouple wires, protruding from the base of the assembled retort, are labeled 1 through 13. Note any issues.

6.3.4 Attach all 13 TC wires (11 from the multipoint thermocouple and two from the nickel nozzle) to thermocouple feedthrough wires (INL Dwg. 824756 item 8) attached to the Receiver Thermo Test Fixture Assembly. Label each external thermocouple feedthrough wire with associated wire number. Note any issues.

6.3.5 Attach Receiver Thermo Test Fixture Assembly to nickel nozzle per INL Dwg. 824760. Note any issues.

6.3.6 Test fit all of the lifting, handling, and miscellaneous tools with the retort. Identify the need for any additional tooling or lifting fixtures that may be required. Note any issues.

6.3.7 Use the EDL coffing hoist (or approved alternative) to lift the assembled retort by its end detent ring (see figure in section 1.2), move the retort to the assembled baseplate, and lower the retort into the weighted baseplate receiver weldment support ("support cup") per the supplied and approved lift plan. Note any issues.

6.3.8 After the retort is placed in the baseplate cup, remove the coffing hoist support(s) and the associated retort end detent ring. If attached, also remove the side detent ring on the nickel nozzle. Slide the open furnace along its base rails until the baseplate supported retort is nested inside the furnace. Close and latch the furnace. Note any issues.

6.3.9 Once the retort is secured in a closed furnace, per engineering direction, either secure the loaded furnace to the hoist A-frame or leave as-is. Note the final configuration.

6.3.10 Assemble and test fit all the vacuum lines, filters, the pressure sensor, valves, clamps, and vacuum pump to the retort Receiver Thermo Test Fixture Assembly per P&ID Dwg. 821678 and INL Dwg. 855500. Note any issues.

6.3.11 Connect control and power cables from the vacuum release solenoid valve MF-SOV-001, the pressure transmitter MF-PT-001, and the vacuum pump MF-PMP-001 to the PLC cabinet (per INL Dwg. 816801). Note any problems and make any necessary changes to the cabling as directed by the engineer.

6.3.12 Repeat any of the previous steps as necessary to ensure that all of the components fit correctly. Note any problems with cables or connectors and make any necessary changes as directed by the engineer.

6.3.13 Confirm that all retort and associated equipment (retort, vacuum fittings, data logger, etc.) are assembled properly and all interferences and issues have been resolved.

Test Technician: _____ Date: _____

Lead Engineer: _____ Date: _____

6.3.14 Take photographs of the various retort components and equipment and note the photo numbers in Appendix C.

6.4 PLC and Equipment Testing

The purpose of these tests is to ensure that the software controlling the various components is correct, the system wiring/cabling is correct, and the components work properly. Refer to Dwgs. 816801, 816802, 816803, 816804, 816805, 816806, 816807, 816808, 816809, 824747, 824756, 824760, 855009, SWA19383-001 and the tables in appendix B. This test is to be performed by the controls engineer and the EDL personnel. The controls engineer will exercise each piece of equipment via the PLC/OCS. All indications will be read/verified from the OCS, however, it may be necessary for EDL personnel to connect test equipment at various points to verify signals.

When command from the OCS, the PLC initiates the command (sends control signal), the component executes the command, the field device responds properly, and any feedback is correctly received and processed by the PLC and displayed on the OCS. If the system does not respond as expected/desired troubleshoot, repair, and repeat the step.

Troubleshooting includes analyzing or changing the OCS/PLC code by the controls engineer and any activity by EDL personnel allowed by their work control policies and procedures. Steps in Appendix B, Table 1 are performed at the EDL facility and may be performed in any order and as many times as necessary to ensure the systems work as desired. Steps in Appendix B, Table 1 may be combined in any order to perform a higher level activity such as enable the component, establish a setpoint, and then disable the component to ensure the component is truly disabled.

Appendix B, Table 2 is very similar to appendix A. In appendix A, a signal was injected into the control cabinet and read from the PLC or generated from the PLC and read elsewhere. Appendix B, Table 2 deals with signals sent to and received from field devices. As such they may not necessarily be measured with test equipment.

6.4.1 Using the PLC/OCS software, perform the equipment functional and operational tests identified in Appendix B, Tables 1 and 2. The software engineer may make any necessary changes to the software in order to optimize the process and operations. Changes to the software will be documented by the software engineer and changes to the testing steps will be noted in the instructions in Appendix B. Resulting changes to the hardware will be noted on the drawings using red-line markups. Note any issues.

_____

_____

_____

6.4.2 Using the PLC/OCS software, perform *Off-Normal* equipment tests identified in Appendix B, Tables 1 (add other off-Normal conditions as necessary). The software engineer may make any necessary changes to the software in order to optimize the process and operations. Changes to the software will be documented by the software engineer and changes to the testing steps will be noted in the instructions in Appendix B. Resulting changes to the hardware will be noted on the drawings using red-line markups. Note any issues.

_____

_____

_____

6.4.3 Confirm that the tests were executed according to the instructions in B and that the results are satisfactory.

Software Engineer: _____ Date: _____

Test Technician: _____ Date: _____

Lead Engineer: _____ Date: _____

6.5 Furnace Bake-Out

The bake out process removes binders from the furnace insulation and oils from the exterior and interior of the retort. Non-toxic chemical fumes will be released from the furnace, retort exterior, and vacuum exhaust (retort interior) during this step.

6.5.1 Disable the PLC furnace cooling fan control. Note any issues.

6.5.2 If the retort is located inside the furnace, detach vacuum fittings from the retort Receiver Thermo Test Fixture Assembly, disconnect the TC wires leading to the data logger, open the furnace then slide the furnace away from the retort along its base rails. Attach the detent ring to the top of the retort then use the coffing hoist (or approved equivalent) to lift the retort out of the baseplate and transport it to the applicable laydown area in EDL per the approved lift plan. Note any issues.

6.5.3 Perform furnace bake-out per the vendor supplied “Multi Zone Furnace Low Temperature Bakeout Procedure” from the MELLEN Company. Note any issues.

6.5.4 If not already performed in the previous step, power down the furnace. Note any issues.

6.5.5 Reinstall the retort (including the pre-cut mockup assembly) into the furnace following steps 6.3.6 through 6.3.13. Note any issues.

6.5.6 Start the vacuum pump (do not apply heat to the furnace) and run the pump until the retort interior pressure falls below 200 mtorr. Note any issues.

6.5.7 Enable the PLC furnace cooling fan control and ensure that the furnace fan control is set to initiate when furnace zones 1 and 2 reach 250C.

6.5.8 Set the furnace control to heat zones 1 and 2 beyond 250C.

6.5.9 Confirm that the furnace fan control performs the following functions:

- Shuts down the zone 1 and 2 heater elements when the zone 1 or 2 thermocouples read 250C
- Turns on the furnace cooling fan after zone 1 or 2 heater elements are powered down
- Turns off the furnace cooling fan when zone 1 or 2 thermocouples read 150C
- Turns on the zone 1 and 2 heater elements after the cooling fan is powered down. Note any issues.

6.5.10 Disable the PLC furnace cooling fan control. Note any issues.

6.5.11 Heat the retort to 650C in zones 3, 4, and 5. While simultaneously heating zones 1 and 2 to 250C. Hold this temperature until the vacuum level stabilizes. This may be time consuming. Note any issues.

6.5.12 Disable the furnace heater. Note any issues.

6.6 Move Retort, Baseplate, and Furnace Assembly into EDL (Only applicable if bake out occurs outside)

6.6.1 Detach vacuum fittings from the retort Receiver Thermo Test Fixture Assembly, open the furnace then slide the furnace away from the retort along its base rails. Attach the detent ring to the top of the retort then use the coffing hoist (or approved equivalent) to lift the retort out of the baseplate and transport it into the EDL facility per the approved lift plan. Note any issues.

6.6.2 Remove thermocouple and power cables from furnace. Then disconnect control and power cables from the vacuum release solenoid valve MF-SOV-001, the pressure transmitter MF-PT-001, and the vacuum pump MF-PMP-001. Note any issues.

6.6.3 Move the base plate and furnace, as one unit, into the EDL facility using a hand cart (or approved equivalent) and place on support blocks. Note any issues.

6.6.4 Use the EDL coffing hoist (or approved equivalent) to lower the retort into the weighted baseplate receiver weldment support “support cup” per the supplied and approved lift plan. Note any issues.

6.6.5 After the retort is placed in the baseplate cup, remove the coffing hoist support(s) and the associated retort end detent ring. Slide the open furnace along its base rails until the baseplate supported retort is nested inside the furnace. Close and latch the furnace. Note any issues.

6.6.6 Once the retort is secured in a closed furnace, per engineering direction, either secure the loaded furnace to the hoist A-frame or leave as-is. Note the final configuration.

6.6.7 Assemble and test fit all the vacuum lines, filters, the pressure sensor, valves, clamps, and vacuum pump to the retort Receiver Thermo Test Fixture Assembly per P&ID Dwg. 821678 and INL Dwg. 855500. Note any issues.

6.6.8 Connect all 13 internal thermocouple wires (11 from multipoint TC and 2 from nickel nozzle TCs) from the retort Receiver Thermo Test Fixture Assembly and 2 external thermocouple wires (on retort elastomer seals) to the separate data logger. Note any problems and make any necessary changes to the cabling as directed by the engineer.

6.6.9 Connect control and power cables from the vacuum release solenoid valve MF-SOV-001, the pressure transmitter MF-PT-001, and the vacuum pump MF-PMP-001 to the PLC cabinet (per INL Dwg. 816801). Note any problems and make any necessary changes to the cabling as directed by the engineer.

6.6.10 Repeat any of the previous steps as necessary to ensure that all of the components fit correctly. Note any problems with cables or connectors and make any necessary changes as directed by the engineer.

6.6.11 Confirm that all retort and associated equipment (retort, vacuum fittings, data logger, etc.) are assembled properly and all interferences and issues have been resolved.

Test Technician: _____ Date: _____

Lead Engineer: _____ Date: _____

6.6.12 Take photographs of the various retort components and equipment and note the photo numbers in Appendix C.

6.7 Collect MEDE Furnace Recipe Data

This section collects data to support the creation of a step-by-step recipe of zone furnace temperatures verses soak time. This test is to be performed by the principle investigator, controls engineer, and the EDL personnel. For each step, the controls engineer will adjust individual zone furnace temperatures with the PLC/OCS to an initial set point. The controls engineer will then adjust furnace temperature to achieve the desired internal zone temperatures read from a separate data logger. The start time, end time, final furnace zone temperature, and final internal zone temperature will then be recorded. All indications will be read/verified from the OCS, however, it may be necessary for EDL personnel to connect test equipment at various points to verify signals. The initial conditions for this section area as follows:

- The furnace and retort are already baked out
- The mockup assembly is in retort and retort is inside furnace.

6.7.1 Disable the PLC furnace cooling fan control. Note any issues.

6.7.2 Start vacuum pump and verify pressure below 200 mtorr. If the retort pressure reads above 220 mtorr during any part of the testing in Steps 6.7.1 through 6.7.4, then pause the experiment and contact the lead engineer for further instructions. Note any issues.

6.7.3 Heat zones 1, 2, 3, and 5 to the initial furnace set point temperature of 200C at 5C/min, which should raise the internal temperature in these zones to approximately 200C. Adjust the furnace zone temperatures as needed to achieve the desired internal temperature. Hold all zones at the final furnace temperatures until internal thermocouple readings have stabilized. This allows the open ends of the blanket elements (zones 3 and 5) to heat first before heating the center of the element (zone 4). Document the start time, end time, final furnace zone temperature, and final internal zone temperature below. Note any issues.

Start Time	
End Time	

	Final Furnace Temp	Final Internal Temp
Zone 1		
Zone 2		
Zone 3		
Zone 4		
Zone 5		

6.7.4 Heat zone 4 to the initial furnace set point temperature of 200C at 5C/min, which should raise the internal temperature in this zone to approximately 200C. Adjust the furnace zone 4 furnace temperature as needed to achieve the desired internal temperature. Hold all zones at the final furnace temperatures until internal thermocouple readings have stabilized. Document the start time, end time, final furnace zone temperature, and final internal zone temperature below. Note any issues.

Start Time	
End Time	

	Final Furnace Temp	Final Internal Temp
Zone 1		
Zone 2		
Zone 3		
Zone 4		
Zone 5		

6.7.5 Heat zone 3, 4, and 5 to the initial furnace set point temperature of 650C at 10C/min, which should raise the internal temperature of zones 3, 4, and 5 to approximately 650C while maintaining the internal temperature of zones 1 and 2 at approximately 200C. Adjust the furnace zone temperatures as needed to achieve the desired internal temperatures. Hold all zones at the final furnace temperatures until internal thermocouple readings have stabilized. Document the start time, end time, final furnace zone temperature, and final internal zone temperature below. Note any issues.

Start Time	
End Time	

	Final Furnace Temp	Final Internal Temp
Zone 1		
Zone 2		
Zone 3		
Zone 4		
Zone 5		

6.7.6 At end of run, de-energize all heater zones; allow system to cool down overnight. Note any issues.

6.7.7 De-energize vacuum pump and open furnace the next morning to accelerate cool down, only after all zone temperatures have dropped below 200C. Note any issues.

6.7.8 Confirm that the tests were executed according to the instructions and that the results are satisfactory.

Software Engineer: _____ Date: _____

Test Technician: _____ Date: _____

Lead Engineer: _____ Date: _____

6.8 MEDE System Disassembly and Packaging

6.8.1 Disassemble the retort, furnace, and vacuum system. Note any visible damage or distortion below.

6.8.2 Package the components sufficiently to protect them from dirt or grease during transfer to FASB at MFC. NOTE: The furnace insulation will be brittle due to the bake-out process. Handle and package with extreme care.

7. RECORDS

This document, the red-lined drawing changes, and any additional testing information shall be documented in EDMS, updated drawings (855500, 855009, 824760, 824756, 824747, 821678, 816809, 816808, 816807, 816806, 816805, 816804, 816803, 816802, 816801, SWA19383-001), or included in the Engineering Job file, EJ-2972.

8. REFERENCES

EJ-2972 Rev 1_Element 1_Furnace, Retort, Tools, & Mockup

EJ-2972 Rev 1_Element 2_PLC

9. APPENDIXES

Appendix A – Control Cabinet PLC/IO Tests

Appendix B – Equipment Functional and Operational Tests

Appendix C – Equipment Photographs

Appendix A

Control Cabinet PLC/IO Tests

The purpose of this test is to ensure the control cabinet is wired properly and the PLC inputs and outputs are scaled correctly. Refer to Dwg. 816801 (the electrical drawing) and the table below. This test is to be performed by the controls engineer and NHL personal. The controls engineer, using the appropriate software, will supply input signals to verify proper logic control and system functionality as well as the correct Human Machine Interface (HMI) data display. The controls engineer will document results of this testing using the following table. Signals labeled "Input" will be generated by an appropriate device and injected at the location labeled "Taps." Signals labeled "Outputs will be generated by the PLC and read at the location labeled "Taps." The column labeled "Test Signal" represents the value of the of the signal type used in the test. In some cases signals are generated/received between components and the PLC, therefore no taps are required.

Input Type	Channel	Tag	Signal Type	Test Signal	Taps	Observation
Digital Out	Local:3:O.CH0DATA	TSH-001 zone 4 Hi Temp Reset	24V	N/A	TB1-42,43	
Digital Out	Local:3:O.CH1DATA	TSH-002 zone 4 Hi Temp Reset	24V	N/A	TB1-47,48	
Digital Out	Local:3:O.CH2DATA	JS-001 Zone 4 Enable	24V	N/A	TB1-51,52	
Digital Out	Local:3:O.CH3DATA	TSH-003 Hi Temp Reset	24V	N/A	TB1-54,55	
Digital Out	Local:4:O.CH0DATA	JS-002 Zone 2 Enable	24V	N/A	TB1-75,76	
Digital Out	Local:4:O.CH1DATA	TSH-007 zone 2 Hi Temp Reset	24V	N/A	TB1-78,79	
Digital Out	Local:4:O.CH2DATA	TSH-008 zone 2 Hi Temp Reset	24V	N/A	TB1-83,84	
Digital Out	Local:4:O.CH3DATA	JS-005 Zone 1 Enable	24V	N/A	TB1-87,88	
Digital Out	Local:4:O.CH4DATA	TSH-009 zone 1 Hi Temp Reset	24V	N/A	TB1-90,91	
Digital Out	Local:4:O.CH5DATA	TSH-010 zone 1 Hi Temp Reset	24V	N/A	TB1-95,96	

Input Type	Channel	Tag	Signal Type	Test Signal	Taps	Observation
Digital Out	Local:5:O.CH1DATA	FAN-001 Heater Fan Control	24V	N/A		
Dig In	Local:6:I.CH0DATA	TSH-001 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH1DATA	TSH-002 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH2DATA	TSH-003 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH3DATA	TSH-004 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH4DATA	TSH-005 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH5DATA	TSH-006 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH6DATA	TSH-007 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH7DATA	TSH-008 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH81DATA	TSH-008 Hi Temp SW Status	24V	N/A	N/A	
Dig In	Local:6:I.CH9DATA	TSH-009 Hi Temp SW Status	24V	N/A	N/A	
INPUT (TC)	Local:7:I.CH0DATA	TE_009	Type K	100C,500C,1000C	P1A S,T	
INPUT (TC)	Local:7:I.CH1DATA	TE_010	Type K	100C,500C,1000C	P1A U,Z	
INPUT (TC)	Local:7:I.CH2DATA	TE_011	Type K	100C,500C,1000C	P1A W,X	
INPUT (TC)	Local:7:I.CH3DATA	TE_012	Type K	100C,500C,1000C	P1A Y,Z	
INPUT (TC)	Local:7:I.CH4DATA	TE_013	Type K	100C,500C,1000C	P1A a,b	
INPUT (TC)	Local:7:I.CH5DATA	TE_014	Type K	100C,500C,1000C	P1A c,d	

Input Type	Channel	Tag	Signal Type	Test Signal	Taps	Observation
INPUT (TC)	Local:8:I.CH0DATA	TE_015	Type K	100C,500C,1000C	P1A e,f	
INPUT (TC)	Local:8:I.CH1DATA	TE_016	Type K	100C,500C,1000C	P1A g,h	
INPUT (TC)	Local:8:I.CH2DATA	TE_017	Type K	100C,500C,1000C	P1A j,k	
INPUT (TC)	Local:8:I.CH3DATA	TE_018	Type K	100C,500C,1000C	P1A l,m	
INPUT (TC)	Local:8:I.CH4DATA	TE_019	Type K	100C,500C,1000C	P1A n,p	
INPUT (TC)	Local:8:I.CH5DATA	TE_020	Type K	100C,500C,1000C	P1A r,s	
INPUT (TC)	Local:9:I.CH0DATA	TE_021	Type K	100C,500C,1000C	P1A t,u	
INPUT (TC)	Local:9:I.CH1DATA	TE_022	Type K	100C,500C,1000C	P1A v,w	
INPUT (TC)	Local:9:I.CH2DATA	TE_023	Type K	100C,500C,1000C	P1A x,y	
INPUT (TC)	Local:10:I.CH0DATA	TE_026	Type K	100C,500C,1000C	P1B W,X	
INPUT (TC)	Local:10:I.CH1DATA	TE_027	Type K	100C,500C,1000C	P1B Y,Z	
INPUT (TC)	Local:10:I.CH2DATA	TE_028	Type K	100C,500C,1000C	P1B a,b	
INPUT (TC)	Local:10:I.CH3DATA	TE_029	Type K	100C,500C,1000C	P1B c,d	

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Appendix B

Equipment Functional and Operational Tests

Table 1. Components and functions to be tested. Perform each test by following the directions in the column labeled "Action" and document appropriately in the column labeled "Observations." Additional spaces are provided and may be filled in as needed and additional pages may be added as necessary.

Component	Function	Action	Observations
SOV-001	Open SOV-001	Open 3-way iso valve	Test that valve opens
SOV-001	Close SOV-001	Close 3-way iso valve	Test that valve closes
PMP-001	Start PMP_001	Start vacuum pump	Test that vacuum starts
PMP-001	Stop PMP_001	Stop vacuum pump	Test that vacuum stops
PT-001	Monitor system pressure	Read system pressure during vacuum start and stop	Test that vacuum increased (pressure decreases) during pump start and returns to zero after the vacuum pump is turned off
TSH-002	Reset TSH-002	Send signal to reset TSH-002(Zone 4 over temp)	Test that TSH-002 receives reset signal
TSH-004	Reset TSH-004	Send signal to reset TSH-004 (Zone 3 over temp)	Test that TSH-004 receives reset signal
TSH-006	Reset TSH-006	Send signal to reset TSH-006 (Zone 2 over temp)	Test that TSH-006 receives reset signal
TSH-008	Reset TSH-008	Send signal to reset TSH-008 (Zone 1 over temp)	Test that TSH-008 receives reset signal
TSH-010	Reset TSH-010	Send signal to reset TSH-010 (Zone 5 over temp)	Test that TSH-010 receives reset signal
JS-001	JS-001 enable	Enable/Disable Zone 4 HTRS	Test HTRS
JS-002	JS-002 enable	Enable/Disable Zone 3 HTRS	Test HTRS
JS-003	JS-003 enable	Enable/Disable Zone 5 HTRS	Test HTRS
JS-004	JS-004 enable	Enable/Disable Zone 2 HTRS	Test HTRS
JS-005	JS-005 enable	Enable/Disable Zone 1 HTRS	Test HTRS
TE-020	Control Zone 1 Temp	Set/Maintain Zone 1 Temp	Test Zone 1 temp control

Component	Function	Action	Observations
TE-018	Control Zone 2 Temp	Set/Maintain Zone 2 Temp	Test Zone 2 temp control
TE-013	Control Zone 3 Temp	Set/Maintain Zone 3 Temp	Test Zone 3 temp control
TE-010	Control Zone 4 Temp	Set/Maintain Zone 4 Temp	Test Zone 4 temp control
TE-027	Control Zone 5 Temp	Set/Maintain Zone 5 Temp	Test Zone 5 temp control
FAN-001	Heater Control Fan	Turn the fan on	Test fan turns on
FAN-001	Heater Control Fan	Turn the fan off	Test fan turns off

Off-Normal Conditions

Component	Function	Action	Observations
PMP-001	Vacuum Pump Fails	Simulate Pump off during a recipe (not expected)	Test that pump fails
JC-001	Zone 4 Heater Fails	Simulate Zone 4 off during recipe	Test Zone 4 heater fail
JC-002	Zone 3 Heater Fails	Simulate Zone 3 off during recipe	Test Zone 3 heater fail
JC-003	Zone 5 Heater Fails	Simulate Zone 5 off during recipe	Test Zone5 heater fail
JC-004	Zone 2 Heater Fails	Simulate Zone 2 off during recipe	Test Zone 2 heater fail
JC-005	Zone 1 Heater Fails	Simulate Zone 1 off during recipe	Test Zone 1 heater fail
PMP-001	Vacuum Pump Isolation Valve fails.	Simulate Vacuum Pump isolation valve failure when pump turned off.	Test vacuum pump isolation valve fail

Table 2: Generate expected signals by performing steps in Table 1. Record observations and expected signals in the appropriate columns below. Additional spaces are provided and may be filled in as needed and additional pages may be added as necessary.

Cabinet No.						
Input Type	Channel	Tag	Signal Type	PLC scaling	Expected Signal	Observation
INPUT	Local:1:I.CH0DATA	IT_001 Zone 5 amp	4-20mA			
INPUT	Local:1:I.CH1DATA	IT_002 Zone 4 amp	4-20mA			
INPUT	Local:1:I.CH2DATA	IT_003 Zone 3 amp	4-20mA			
INPUT	Local:1:I.CH3DATA	IT_004 Zone 2 amp	4-20mA			
INPUT	Local:1:I.CH4DATA	IT_005 Zone 1 amp	4-20mA			
INPUT	Local:1:I.CH5DATA	PT_001	0-7V			
INPUT	Local:1:I.CH6DATA	IT_006 PMP-001	4-20mA			
INPUT	Local:1:I.CH7DATA	IT_007 FAN-001	4-20mA			
Output	Local:2:O.CH0DATA	JC-001 Zone 5 temp control	4-20mA			
Output	Local:2:O.CH1DATA	JC-002 Zone 4 temp control	4-20mA			
Output	Local:2:O.CH2DATA	JC-002 Zone 3 temp control	4-20mA			
Output	Local:2:O.CH3DATA	JC-002 Zone 2 temp control	4-20mA			
Output	Local:2:O.CH4DATA	JC-002 Zone 1 temp control	4-20mA			
Digital Out	Local:3:O.CH0DATA	TSH-001 zone 4 Hi Temp Reset	Digital			
Digital Out	Local:3:O.CH1DATA	TSH-002 zone 4 Hi Temp Reset	Digital			
Digital Out	Local:3:O.CH2DATA	JS-001 Zone 4 Enable	Digital			
Digital Out	Local:3:O.CH3DATA	TSH-003 Hi Temp Reset	Digital			

Cabinet No.						
Input Type	Channel	Tag	Signal Type	PLC scaling	Expected Signal	Observation
Digital Out	Local:4:O.CH0DATA	JS-002 Zone 2 Enable	Digital			
Digital Out	Local:4:O.CH1DATA	TSH-007 zone 2 Hi Temp Reset	Digital			
Digital Out	Local:4:O.CH2DATA	TSH-008 zone 2 Hi Temp Reset	Digital			
Digital Out	Local:4:O.CH3DATA	JS-005 Zone 1 Enable	Digital			
Digital Out	Local:4:O.CH4DATA	TSH-009 zone 1 Hi Temp Reset	Digital			
Digital Out	Local:4:O.CH5DATA	TSH-010 zone 1 Hi Temp Reset	Digital			
Digital Out	Local:5:O.CH1DATA	FAN-001 Heater Fan Control	24V			
Dig In	Local:6:I.CH0DATA	TSH-001 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH1DATA	TSH-002 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH2DATA	TSH-003 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH3DATA	TSH-004 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH4DATA	TSH-005 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH5DATA	TSH-006 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH6DATA	TSH-007 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH7DATA	TSH-008 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH81DATA	TSH-008 Hi Temp SW Status	Digital			
Dig In	Local:6:I.CH9DATA	TSH-009 Hi Temp SW Status	Digital			

Cabinet No.						
Input Type	Channel	Tag	Signal Type	PLC scaling	Expected Signal	Observation
INPUT (TC)	Local:7:I.CH0DATA	TE_009	Type K			
INPUT (TC)	Local:7:I.CH1DATA	TE_010	Type K			
INPUT (TC)	Local:7:I.CH2DATA	TE_011	Type K			
INPUT (TC)	Local:7:I.CH3DATA	TE_012	Type K			
INPUT (TC)	Local:7:I.CH4DATA	TE_013	Type K			
INPUT (TC)	Local:7:I.CH5DATA	TE_014	Type K			
INPUT (TC)	Local:8:I.CH0DATA	TE_015	Type K			
INPUT (TC)	Local:8:I.CH1DATA	TE_016	Type K			
INPUT (TC)	Local:8:I.CH2DATA	TE_017	Type K			
INPUT (TC)	Local:8:I.CH3DATA	TE_018	Type K			
INPUT (TC)	Local:8:I.CH4DATA	TE_019	Type K			
INPUT (TC)	Local:8:I.CH5DATA	TE_020	Type K			
INPUT (TC)	Local:9:I.CH0DATA	TE_021	Type K			
INPUT (TC)	Local:9:I.CH1DATA	TE_022	Type K			
INPUT (TC)	Local:9:I.CH2DATA	TE_023	Type K			
INPUT (TC)	Local:10:I.CH0DATA	TE_026	Type K			
INPUT (TC)	Local:10:I.CH1DATA	TE_027	Type K			
INPUT (TC)	Local:10:I.CH2DATA	TE_028	Type K			
INPUT (TC)	Local:10:I.CH3DATA	TE_029	Type K			

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Appendix C

Equipment Photographs