Independent Design Analysis and Verification of "Heater Canister" as Part of the Salt Defense Disposal Investigation

Comprehensive Final Report

Subcontract Number 253219
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Stoller
A Subsidiary of Huntington Ingalls Industries

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Executive Summary

The Salt Defense Disposal Investigation (SDDI) is a test program that is the basis for placing heat-generating radioactive waste in a salt formation. The overall test program includes designing, fabricating, and testing a prototype canister heater, then in the future deploying ten canister heaters in the Waste Isolation Pilot Plant (WIPP) underground, with five of the heaters simulating the majority of the defense high level waste (DHLW) inventory and five simulating higher level thermal waste. Stoller was contracted to fabricate the designed canister, support Los Alamos National Laboratory Carlsbad Operation (LANL-CO) and generate a report with lessons learned, as-built drawings, and recommendations. During the prototype canister heater construction, Stoller was responsible for coordination with LANL and Stoller sub-tier subcontractors to support procurement, fabrication, assembly, and testing activities. The prototype canister heater is used to test design features, fabrication methods, and operational parameters.

There were two phases in the development of the prototype heater canister. Phase I was to complete the design review, including selection of vendors for fabrication and component delivery. It also included ensuring that the heater canister's electrical requirements were acceptable within the WIPP underground safety and operational parameters. Phase II included fabrication and assembly of the prototype canister heater with the comprehensive final report to follow.

Design reviews of the prototype canister heater were conducted by an integrated team of LANL-CO, the consulting firm RESPEC, and Stoller personnel with the design reviews coordinated by LANL-CO. In the early phases of the design, weekly and bi-weekly meetings were scheduled by LANL-CO to discuss equipment options, thermodynamic modeling, system constructability, control philosophies, and specific control variables. Through using an informal interactive review approach during meetings, the RESPEC designers were able to present design options to ensure that LANL-CO specifications were met and that the prototype heater canister could be fabricated and tested during fiscal year 2014.

The fabrication of the prototype heater canister followed the RESPEC design and specifications, but, as in any prototype design-build, several design changes were required for fabrication. Each one was discussed among LANL-CO, RESPEC, and Stoller to determine the best solutions and all design changes were documented in as-built drawings. The basic fabrication of the prototype consisted of cutting and welding the canister and the fabrication of the heater element assembly that was inserted into the canister. The canister was initially cut multiple times to determine the best method of cutting and re-welding the ends. The heater element assembly was composed of a 16 inch diameter, schedule 40 steel pipe, with spacers welded at three equal distances along the circumference of the pipe, then placed at equal distances along the length of the steel pipe (see Attachment E). Six 600 Watt strip heaters, procured from WATLOW, were adhered to the 16 inch steel pipe. The heaters were adhered using a specifically recommended adhesive. The assembly of the prototype heater canister involved several organizations and required complex coordination. The assembly process required the following steps:

- inserting the fabricated heater element assembly into the canister
- pouring in Cerabeads
- wiring the heaters inside the internal junction box
- installing the O-ring and securing the end cap

- wiring all the pass-through connectors
- re-attaching the pintle end by welding
- finishing compaction and filling the canister with Cerabeads.

The prototype heater canister operated as anticipated and within design parameters. At the initial set points of 750 and 1,500 watts, the prototype heater canister increased in temperature. Both automatic shutdowns successfully shut down power to the heaters after exceeding the high wattage and high temperature set points. Following the initial testing, the prototype heater canister was allowed to operate overnight with a set point of 750 watts. The next day, the overnight operability was verified by reviewing temperature data and the system was powered down. The data logger was left operational to collect temperature data related to system cool down over the weekend. Temperature readings (all degrees Celsius) obtained from the data logger indicated:

- Primary Heater #1 = 93.2
- Primary Heater #2 = 98.0
- Primary Heater #3 = 101.2
- Secondary Heather #1 = 82.8
- Secondary Heather #2 = 85.7
- Secondary Heather #3 = 82.4

The prototype heater canister was successfully tested, fabricated, assembled, and delivered to LANL-CO. The following recommendations and the associated path forward are presented for consideration during future heater canister fabrication and testing:

- Incorporate three thermocouples per heater assembly in future canister build. This will require a larger thermocouple pass-through connector with a capability for at least 18 thermocouples (36 wires).

- Finalize electrical design for multiple canister system (wiring for multiple relays to control primary and secondary heaters).

- Perform long duration testing with the prototype heater canister. The first stage of testing would require limited development of additional test plans and should not incorporate run of mine salt or other overburden around the canister. This test would operate the prototype heater canister for weeks or months to allow the canister to reach steady state operations. Temperature data could be compared to develop thermal modeling for similar conditions, and longer term operability of canister components would be validated to ensure failure of components is not a problem.

1. Introduction

Under Subcontract Number 253219, The S.M. Stoller Corporation (Stoller) was contracted to fabricate and test a prototype canister, support Los Alamos National Laboratory Carlsbad Operation (LANL-CO), and generate a report with lessons learned, as-built drawings, and recommendations. The following sections detail the activities associated with performance of this work.

1.1 Project Background and Scope Overview

The Salt Defense Disposal Investigation (SDDI) is a test program that is the basis for placing heat-generating radioactive waste in a salt formation. The overall test program includes designing, fabricating, and testing a prototype canister heater, then in the future deploying ten canister heaters in the Waste Isolation Pilot Plant (WIPP) underground, with five of the heaters simulating the majority of the defense high level waste (DHLW) inventory and five simulating higher level thermal waste. Stoller was contracted to fabricate the designed canister, support LANL-CO, and generate a report with lessons learned, as-built drawings, and recommendations. During the SDDI canister heater prototype construction, Stoller was responsible for coordination with LANL and Stoller sub-tier subcontractors to support procurement, fabrication, assembly, and testing activities. The prototype canister heater will be used to test design features, fabrication methods, and operational parameters.

Figure 1: Heater canister in original condition

1.2 Approach – Project Phases and Objectives

Development of the prototype heater canister involved two phases. Phase I was to complete the design review, including selection of vendors for fabrication and component delivery. It also included ensuring that the heater canister's electrical requirements were acceptable within the WIPP underground safety and operational parameters. Phase II included fabrication and assembly of the prototype canister heater with the comprehensive final report to follow.

Phase I: Design Support
Stoller interfaced with LANL-CO and RESPEC on the conceptual design of the SDDI test heaters and controls, coordinated issues associated with the design, and managed resolution during the design. Stoller also provided feasibility and constructability expertise to the design process; subcontracted with a local machine and welding company for custom fabrication capabilities; and worked with LANL-CO personnel regarding the electrical demands of the heaters and controllers.

Phase II: Canister Fabrication
This phase included procurement of heaters and heater control systems that are capable of accommodating wet and inhospitable environments, fabrication of canister and ancillary heater

supports, and assembly of heater test equipment. LANL-CO was responsible for programming the supervisory control and data acquisition (SCADA) system. Stoller and LANL-CO jointly developed the test plan and operating procedures, including test duration, temperature requirements, power criteria, instrumentation requirements, testing of redundant heater through simulation of heater failure, definition of hold points, and criteria to define successful test completion.

Stoller compiled report data and produced the final report detailing the fabrication and procurement lessons learned, the design as-builts, and the heater start-up data along with recommendations, paths forward, and conclusions.

2. Design Support

Design reviews of the SDDI heater canister prototype were conducted by an integrated team of LANL-CO, Stoller, and RESPEC personnel with the design reviews coordinated by LANL-CO. In the early phases of the design, weekly and bi-weekly meetings were scheduled by LANL-CO to discuss equipment options, thermodynamic modeling, system constructability, control philosophies, and specific control variables. Through using an informal interactive review approach during meetings, the RESPEC designers were able to present design options to ensure that LANL-CO specifications were met and that the canister prototype could be fabricated and tested during fiscal year 2014.

2.1 Design Review

After the informal reviews, the RESPEC design was submitted to LANL-CO for formal review and comment. Stoller and the fabrication contractor participated in the design reviews to ensure the constructability issues were addressed prior to fabrication and assembly of canister components. After resolution of comments, the RESPEC final design was submitted to LANL-CO on June 6th, 2014. To ensure fabrication and assembly could be completed prior to the end of fiscal year 2014, Stoller prioritized procurement of RESPEC-identified SDDI components with an emphasis on identifying long lead items. The incorporation of Stoller and the fabrication contractor in the early design review process resulted in familiarity with the assembly, fabrication, and component procurement requirements that would normally have taken additional time after delivery of the final design. This turned out to be critical in completing the SDDI canister testing prior to the end of fiscal year 2014 as Stoller had less than four months to procure, fabricate, assemble, and successfully test the SDDI heater canister system, with system testing initiated the week of August 18th and finalized the week of August 22nd.

From the beginning of the design phase, Stoller worked with RESPEC in design coordination and reviews regarding feasibility and constructability. Additionally, Stoller provided input on thermodynamics and component/material accessibility and feasibly. This included several coordination meetings, research and coordination with subcontractors and potential vendors, and several design reviews. Two studies were conducted concurrent with the design review, the Canister Cut Analysis and the Canister Welding Study. Data derived from these activities supported the design review and fabrication. The design support studies were completed within the existing schedule and budget for fabrication, assembly, and testing of the prototype heater canister.

2.2 Canister Welding Study


Figure 2: Initial canister cut

In the preliminary design stages of the Heater Canister Prototype, Stoller coordinated closely with LANL-CO and RESPEC to ensure that accurate internal and external measurements were taken. Stoller coordinated with the fabrication contractor to take the measurements. Along with recording accurate dimensions, removing one of the ends gave an inside view of the canister so that RESPEC could begin to consider specifications for adhering and installing heaters. It also allowed reconsideration of the cutting method due to possible damage that could be done to internal components. At the time of this welding study, the design considered adhering flexible heater strips directly to the inside circumference of the heater canister. The application of the heater strips was subsequently redesigned to adhere to an inner sleeve that would fit within the canister, making the concern about the heat from welding a non-issue.
(Appendix A – Canister Cut Analysis)

2.3 Design Review

During the design phase of the project it was initially proposed to adhere the strip heaters to the inside of the canister metal. There was concern that during the welding to reattach the canister top, the heat buildup could damage the specified rubber strip heaters and wiring. To eliminate this concern, thermocouples were installed to record temperature extremes and then reattach the canister end, working the same way the welding would be done during the canister fabrication and assembly. This would provide evidence of the effects of canister welding on the heaters and wiring, which were rated to withstand 500 degrees Fahrenheit. Stoller coordinated with the fabrication contractor to arrange the experiment. The canister weld study validated that welding could be performed without damaging silicone heaters secured to the interior of the canister shell (Appendix B, Canister Welding Study).

Lessons Learned:

- Integrated project team meeting and reviews involving LANL-CO, RESPEC, and Stoller were critical to quickly performing formal design reviews, component procurements, fabrication, assembly, and testing of the SDDI prototype canister heater.

3. Canister Fabrication

Procurement was a critical element in the success of the canister fabrication. Stoller used the design and specifications provided by RESPEC, which included recommended vendors and a components list. Stoller maintained the original list and added additional information by recording the actual quantities for each vendor as items were received. (This updated list is Attachment F.) Stoller's prototype heater canister fabrication bid was prepared without final designs for heater fabrication and did not include costs associated with testing to support the final designs. As discussed using integrated design reviews, Stoller realigned labor costs to allow for fabrication and canister component costs. Therefore, to provide LANL-CO with the data necessary for future fabrication, Stoller's generic costs associated with the fabrication and canister components are provided (does not include Stoller labor associated with these activities):

• Fabrication costs	$14,500.00
• Canister components	$23,260.00
• Total cost for components and fabrication	$37,760.00

3.1 Procurement

Figure 3: WATLOW strip heater

Efficiencies were accomplished through using local businesses when possible and implementing improvements by the Stoller, RESPEC, and the LANL-CO staff. Critical path components with long lead times were identified early and procured to meet the schedule. One specific change was the addition of a junction box used to safely house the wiring inside the canister.

Lesson Learned

- Organize procurements so that critical path items are ordered first with frequent calls to supplier to ensure timely delivery.
- Review engineer/design components with vendors to ensure compatibility
- Continue to check in with vendors to ensure items are being produced/manufactured within the requested time frame.
- Ensure purchase orders are issued with the appropriate terms and conditions, clearly defined schedule requirements, specific shipping details, and requirements for vendor acknowledgment.

3.2 Fabrication

Figure 4: Adhering strip heaters to 16" pipe

The fabrication of the prototype heater canister followed the RESPEC design and specifications, but, as in any prototype design-build, several design changes were required for fabrication. Each one was discussed among LANL-CO, RESPEC, and Stoller to determine the best solutions, and all design changes were documented in as-built drawings. The basic fabrication of the prototype consisted of cutting and welding the canister and the fabrication of the heater element assembly that was inserted into the canister. The canister was initially cut multiple times to determine the best method of cutting and re-welding the ends. The heater element assembly was composed of a 16 inch diameter, schedule 40 steel pipe, with spacers welded at three equal distances along the circumference of the pipe, then placed at equal distances along the length of the steel pipe (Attachment E). Six 600 watt strip heaters, procured from WATLOW, were adhered to the 16 inch steel pipe. The heaters were adhered using a specifically recommended room temperature vulcanizing (RTV) Red adhesive, which was also procured from WATLOW.

Various materials, such as silica sand, used grit blasting media, and Cerabeads, were considered to fill the canister void spaces during assembly. Ultimately Cerabeads (an aluminum and silica oxide artificial sand) were selected for their thermodynamic properties and the flowability of the beads. One-inch diameter holes were drilled in the 16 inch pipe to allow the Cerabeads to flow into outer voids. Angle iron supports were welded to the inside of the 16 inch pipe to mount a junction box that would eventually house the terminal blocks for the heaters. The final fabricated component was the end cap designed by RESPEC, in which the high-temperature pass through connectors would be installed.

Lessons Learned:

- After cutting the canister, the method used (plasma torch) left the edge of the canister sharp and jagged, causing concern about the integrity of the wiring insulation where it came in contact with the sharp edge during canister assembly. To remedy this potential issue, sleeving was installed over the wires to protect them from sharp edges. Alternate cutting methods should be investigated before future canister fabrication and assembly.
- Increase the frequency of the holes drilled in the heater element assembly to allow better settlement and flow of Cerabeads.
- To help alignment when inserting the heater element assembly into the canister, increase the number of spacers along the length of the heater element.
- To allow the heater element assembly to be set on the floor without damaging the heater or wires, increase the number of spacers around circumference. This will also help with alignment when inserting the pipe into the canister.
- Decrease tolerances on the spacers to allow easier installation of the heater element assembly into the canister.

3.3 Assembly

Figure 5: Filling with Cerabeads

Prior to final assembly of the prototype heater canister, component testing was conducted at the fabrication contractor facility before attaching the top and before filling the canister with Cerabeads. The heater element assembly, inserted inside the canister, was wired directly to the power supply and data logger. It was then powered up, following the Power-Up Procedure and the manufacturers operating instructions. (Appendix D) Readings taken from thermocouples confirmed that the heaters were working. Once it was documented that the heaters were functioning properly, the element wiring was disconnected and the canister was prepared for final assembly.

The assembly of the prototype heater canister involved several organizations and required complex coordination. The assembly process required:

- inserting the fabricated heater element assembly into the canister
- pouring in Cerabeads
- wiring the heaters inside the internal junction box

- installing the O-ring and securing the end cap
- wiring the pass through connectors
- re-attaching the pintle end by welding
- finishing compaction and filling of the canister with Cerabeads.


Figure 6: Reattaching pintle end

After the initial assembly was finished, the canister was completed at the fabrication contractor facility by wiring the canister to the power supply and data logger.

Lessons Learned

As with any one of a kind initial assembly, lessons were learned in both activities that went well and opportunities for improvement. Overall, no major issues or setbacks were associated with assembly of the prototype heater canister system that could not be resolved by LANL-CO and Stoller personnel. The following lessons learned were identified throughout canister assembly:

- The final design required revision to correctly wire the heater relay to toggle between primary and secondary heaters. As-built design drawings show revisions that were required for the heater relay wiring.

- The thermocouple connector (part number MTC-24-FC) does not have sufficient thread length to be secured to the end cap with the provided nut (the end cap thickness does not allow engagement of the bulkhead threads). The as-built drawing will indicate the need to provide a counter sink to accommodate connecting the thermocouple connector.

- Consider removing the five-pin connector and replacing it with three single pin connectors, for easier handling and assembly and disassembly.

- Procure spare crimp connectors for crimping power supply, voltage sense, and thermocouple wiring to pass through connecters. Adequate spares were procured for the thermocouple connectors, but additional spares for the Kemlon connectors would have been beneficial.

- Replace the O-ring with flange gasket material rated for the operating temperature of the prototype heater canister.

- The junction box for the supply power wiring inside the canister had limited space to accommodate four terminal blocks. A common terminal block for the

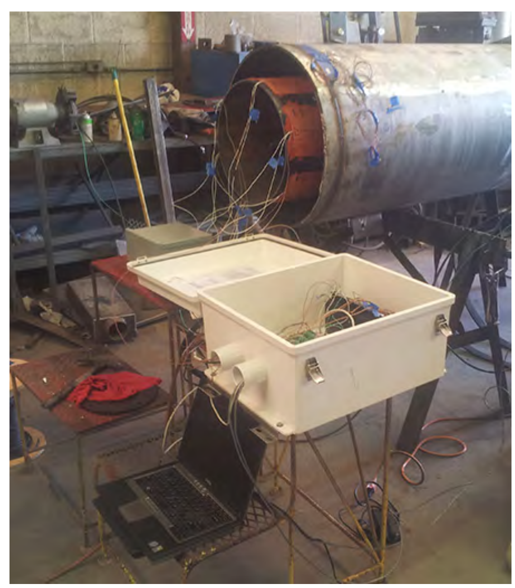
Figure 7: Preliminary start-up component testing

negative wiring was installed in the junction box due to the limited space requirements. This revision is reflected on the as-built drawings and should be incorporated into future canister fabrication and assembly.

- High-temperature sleeving was installed over the heater wire during assembly to minimize abrasion of the wire on the cut end of the canister. The sleeving was effective in protecting the heater wire insulation from abrasion during assembly.

- Install additional holes in the heater element assembly to promote flow of the Cerabeads from the annular section of the sleeve during filling.

- The Cerabeads performed well during canister filling. Dust generation was not excessive and easily directed away from worker using ventilation fans. The Cerabeads flowed easily from the annular section of the heater sleeve during filling.

- Consider slight mechanical vibration to promote settling of the Cerabeads. Tapping with a small sledge hammer was effective, but slight mechanical vibration could promote settling throughout the process of filling the canister.

Figure 8: Cerabeads #850 sieve size (.010 mm)

- The thermocouples installed on the interior shell of the canister consisted of small gauge thermocouple wires. The wire was easily damaged/kinked and was too small for the crimp connections on the thermocouple pass through. Future designs should include additional heater thermocouples. Three thermocouples per heater assembly would allow monitoring heater temperature at both end points and the center of the canister.

- Recording the primary and secondary heater resistances during assembly was invaluable. Repeatedly measuring heater resistance throughout the assembly process ensured that neither the heaters nor the heater wiring was damaged during the assembly process. Incorporate repeated measurements of the heater resistance into future canister fabrication.

- Consider installation of a cover to protect the pass-through connection during transport and eventual back filling with run of mine salt for future designs. Damage of the pass through connecters would result in major rework for removal of the canister lid and installation of new connectors.

- Consider robust hermetically sealed pass through connecters for future design of the power supply pass through connectors. The 5-pin pass-through connector was particularly difficult to install without damaging pins due to the tight tolerances associated with the boot connector.

4. Prototype Heater Canister Testing

The prototype heater canister testing was a collaboration between Stoller and LANL-CO personnel. Stoller was responsible for fabrication and assembly of the prototype heater canister system and LANL-CO was responsible for programming the control system and Human Machine Interface (HMI).

4.1 Testing Results

After completion of final assembly and component testing, the prototype canister heater was tested to verify operation was within design parameters. The initial power-up involved operations at both 750 watts and 1,500 watts to validate operation over a range of test conditions. Automatic shutdowns associated with high wattage and high temperature set points were also validated during testing.

Fabrication and assembly of the canister was completed by Stoller, the fabrication contractor, and the electrical contractor. LANL-CO personnel provided final assembly and programming of the Programmable Logic Controller (PLC) and HMI interfaces to control the prototype canister system. Based on modeling performed by LANL-CO, approximately one month of continuous operations in a salt drift will be required for an SDDI canister to approach steady state operations. Initial testing with the prototype heater canister was not scoped or designed for this duration of testing, but some testing was required to validate that the SDDI canister system is acceptable for longer duration tests. The initial prototype canister testing was performed at the fabrication contractor facility with the canister exposed to ambient conditions. No run of mine salt or fill material was used to cover the canister for this testing.

Initial testing involved supplying the prototype heater canister with a set point of 750 watts and observing the internally measured power and temperature instruments to verify that the canister was heating up. The canister set point was then increased to 1,500 watts to verify operation at the higher wattage design criteria. After validating operation at both 750 and 1,500 watts, the high wattage and high temperature automatic shutdowns were tested by manipulating the PLC set points.

In all instances, the prototype canister system operated as anticipated and within design parameters. At the initial set points of 750 and 1,550 watts, the prototype heater canister system increased in temperature. Both automatic shutdowns successfully shut down power to the heaters after exceeding the high wattage and high temperature set points. Stoller and LANL-CO personnel were able to successfully restart the canister heater (this requires manual re-entry of process set points) after automatic shutdown of the system.

Following the initial testing, the prototype heater canister system was allowed to operate overnight with a set point of 750 watts. The next day, the overnight operability was verified by reviewing temperature data and the system was powered down. The data logger was left operational to collect temperature data related to system cool down over the weekend.

Figure 9: Acquiring test data

4.2 Test Data

Assembly of the SDDI prototype heater canister was completed on August 21, 2014. The power-up procedures detailed in Appendix D were used to initiate operations and verify system operability. Stoller and LANL-CO personnel operated the system on Thursday and Friday (8/21 and 8/22) to verify operating conditions and system shutdowns. Prior to performing extended testing, the control system and power supply operations were verified. (See Appendix D for the "power-up" procedure.) Turning "ON" and the ability to toggle between primary and secondary heaters was verified as operational. Notes on additional system operability testing are detailed below.

August 21, 2014

1) 09:52 System Power to the primary heaters (PH) is "ON" with a wattage set point of 750. Ambient Temperature =~27.5 Celsius. TDK Lambda Output = 157.7 volts and 4.77 amps

2) 10:30 The primary heater temperatures as indicated by heater thermocouples are 36 – 41 Celsius

3) 11:05 The primary heater wattage is increased from 750 to 1500. System is allowed to operate at 1500 watts to test the high wattage range.

4) 14:30 TDK Lambda power readings 221 V and 6.68 A with a wattage set point of 1500.Temperature readings are PH1 = 80, PH2 = 88, PH3 = 93, SH1 = 60, SH2 = 63, SH3 = 61 (all Celsius).

5) 15:20 High temperature shut down testing initiated. The high temperature set point was reduced to 94° C. The heaters continued operating until the 94° C high temp was exceeded. The system successfully shutdown. Reestablished the high temperature set point at 180° C. Entered a Theoretical System Power set point of 1475 watts. TDK Lambda outputs = 221 V and 6.68 A.

6) 15:25 High wattage shutdown testing initiated. High wattage shutdown set point = 1500 watts. Increase the Theoretical System Power to 1550 watts to force shutdown. The PLC immediately shut down the heaters upon increase of power to the heaters. Restarted operation with a Theoretical System Power of 750 watts. TDK Lambda Output = 157.7 V and 4.77 A.

7) At approximately 16:00 the control program was uploaded to the PLC. Thermocouple PH3 began working again.

8) At approximately 16:30 personnel departed and allowed the heater system to operate with a 750 watt set point overnight.

August 22, 2014

1) At approximately 09:00 Stoller and LANL-CO personnel continued monitoring SDDI heater testing. All operations were normal and all heater thermocouples were providing readings.

2) 10:00 TDK Lambda Output = 157.7 V and 4.77 A. Temperature readings are PH1 = 93.2, PH2 = 98, PH3 = 101.2, SH1 = 82.8, SH2 = 85.7, SH3 = 82.4 (all degrees Celsius)

3) 10:07 Test Complete. Power off by entering a Theoretical System Power of 0 watts. TDK Lambda output = 0.7 V and 0.03 A. Turned off TDK Lambda using the local switch. Unplugged the TDK Lambda power from the wall receptacle. PLC and data logger power remains "ON" to collect thermocouple cool down data.

5. Recommendations and Path Forward

The prototype heater canister was successfully tested, fabricated, assembled, and delivered to LANL-CO. The following recommendations and the associated path forward are presented for consideration during future heater canister fabrication and testing:

- Perform long-duration testing with the prototype heater canister. This first stage of testing would require limited development of additional test plans and should not incorporate run of mine salt or other overburden around the canister. This test would operate the prototype heater canister for weeks or months to allow the canister to reach steady state operations. Temperature data could be compared to develop thermal modeling for similar conditions, and longer term operability of canister components would be validated to ensure failure of components are not a problem.

- Develop plans for SDDI heater system testing in simulated above ground WIPP drifts. The test plans would incorporate desired operating conditions, additional instruments that require testing, amount and configuration of run of mine salt overburden, and duration of the individual tests.

- Replace potentially problematic electrical connections on the end cap. If more robust hermetic connections for the single and 5 pin Kemlon connectors are desired, they should be replaced and tested prior to long term testing with run of mine salt. In addition, any other end cap modification such as the addition of a junction box should be incorporated prior to testing with run of mine salt.

- Above ground exposed testing will allow WIPP subject matter experts to provide requirements for heater canisters that will be tested in WIPP drifts.

Lessons Learned for Future Fabrications

- Incorporate three thermocouples per heater assembly in future canister. This will require a larger thermocouple pass through connector with a capability for at least 18 thermocouples (36 wires).

- Consider placing several thermocouples on the canister exterior, instead of the interior, to help prevent damage during assembly; however, implications with placement of run of mine salt would need to be considered.

- Measure resistance on each heater and combine heaters with similar resistances into primary and secondary heater circuits. Anomalies should be incorporated into secondary heater circuits.

- Identify an alternative method to provide a cleaner cut when cutting pintle end of canister. Procurement of large diameter rotary cutters should be considered for future cuts.

- Finalize electrical design for multiple canister system (wiring for multiple relays and power supplies to control primary and secondary heaters).

- Install a junction box on the top of pintle end to protect pass through connectors and wiring connections.

- Consider using slight mechanical vibration to help Cerabeads compact or settle better during the filling process.

Appendixes A-D
Attachments E and F

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The following appendixes present detailed information, documentary photographs, test results, and operating instructions related to specific activities during the design and fabrication of the prototype heater canister as part of the Salt Defense Disposal Investigation. Appendixes A-D are presented within the numbered 8.5 x 11 inch pages. Attachment E consists of a set of as-built drawings that are 11 x 17 inches; Attachment F is a spreadsheet of the materials list.

Appendix A, Canister Cut Analysis

Appendix A
Canister Cut Analysis

OVERVIEW OF STOLLER SCOPE

BACKGROUND

Located near Carlsbad, the Waste Isolation Pilot Plant (WIPP) is a deep geological repository for safe, permanent disposal of transuranic (TRU) waste materials generated by atomic energy defense activities. The Salt Defense Disposal Investigation (SDDI) is research to test thermally driven processes involved with radioactive decay and disposal in salt. The SDDI project will be conducted in the WIPP underground and will test an in-drift heater emplacement concept with thermal loads aligned with Department of energy (DOE) defense high level waste canisters.

SCOPE

Stoller is supporting Los Alamos National Laboratory Carlsbad Operations (LANL-CO) in the management, integration, fabrication, and testing of the SDDI heater testing project. Ultimately, the SDDI will provide data regarding the thermal processes of radioactive decay and disposal in salt. Stoller is responsible for managing design, fabrication, and assembly changes throughout the heater testing project.

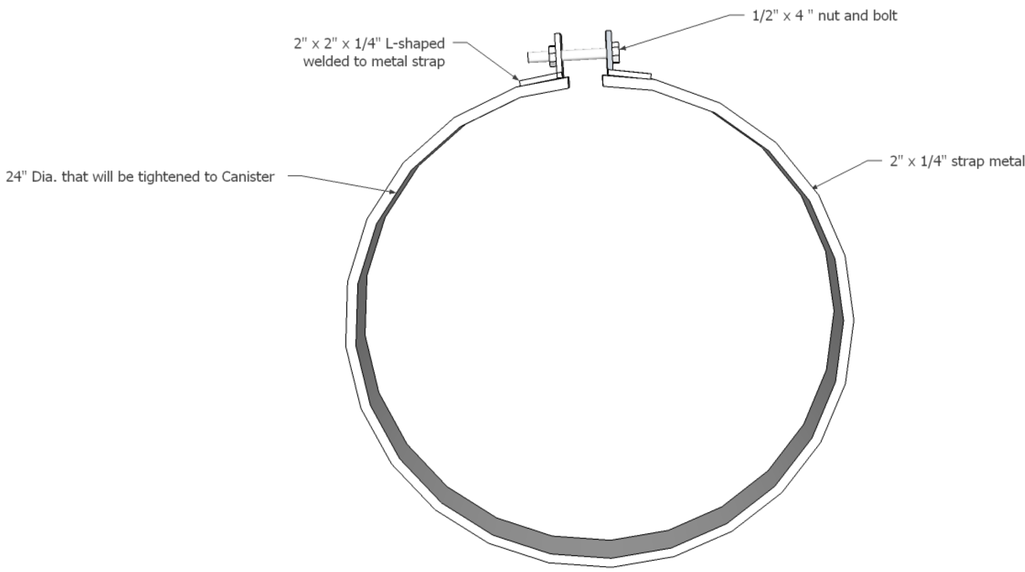
PURPOSE OF CANISTER ANALYSIS

The purpose of the Canister Analysis was to provide specific details related to canister dimensions to all entities involved with the SDDI heater test. Cutting the canister allowed accurate dimensions to be obtained, as well as verification of canister dimensions referenced on historical canister fabrication drawings. It also provides an inside view of the canister, which will assist the design engineering firm contracted to prepare the design and specifications for the SDDI heater system.

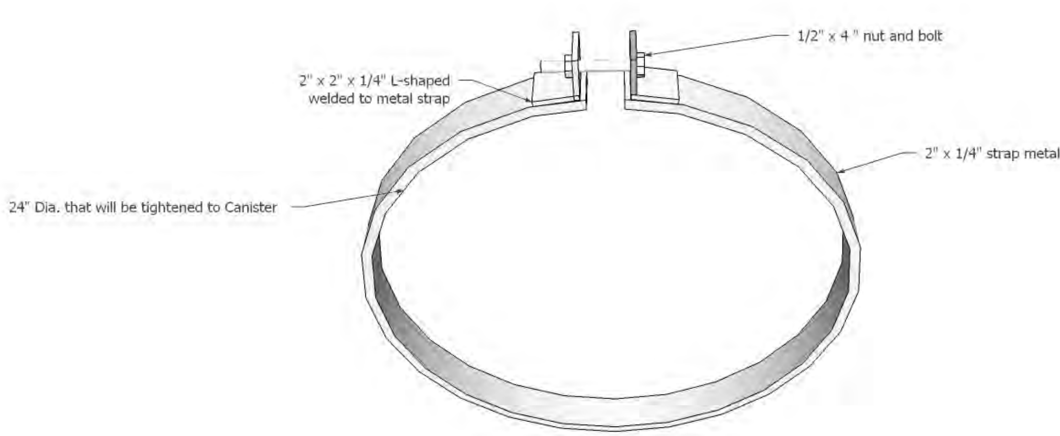
CUTTING THE CANISTER

Stoller contracted a local machine shop (Hall Machine & Welding Co.) to perform the procedure to analyze the canister in which the heating units are to be installed. After coordination and planning meetings with the contracted shop, the best course of action was to prepare a “jig,” (*see schematic*) as a guide, and cut the front of the LANL-CO provided canister. The canister was cut with a plasma cutting torch on January 16, 2014.

Schematic of Jig:



Front View of "Jig"



Top View of "Jig

Results:

Dimensions:

Diameter:

The diameter was obtained using a decimal tape measure, measuring several locations around circumference, as well as a pipe diameter tape measure.

Inside Canister Diameter - **23.138 in**

Outside Canister Diameter - **23.955 in**

Front Flange Diameter - **9.000 in**

Flanged Fill Nozzle Diameter - Inside Diameter**- 4.500 in** Outside Diameter **- 4.875 in**

Thickness:

The thickness dimension was obtained using digital calipers as well as micrometers. Several measurements were taken and a 0.003 inch variance was observed.

Minimum Canister Wall Thickness - **0.402 in**

Maximum Canister Wall Thickness - **0.405 in**

Front Flange Thickness - **2.000 in**

Length:

The length of canister was obtained using rigid straight edges and a decimal tape measure. Measurements were taken at several locations to compile accurate length data.

Center Material - **95.875 in**

Back Edge to Cut - **98.125 in**

Canister Length - **110.750 in**

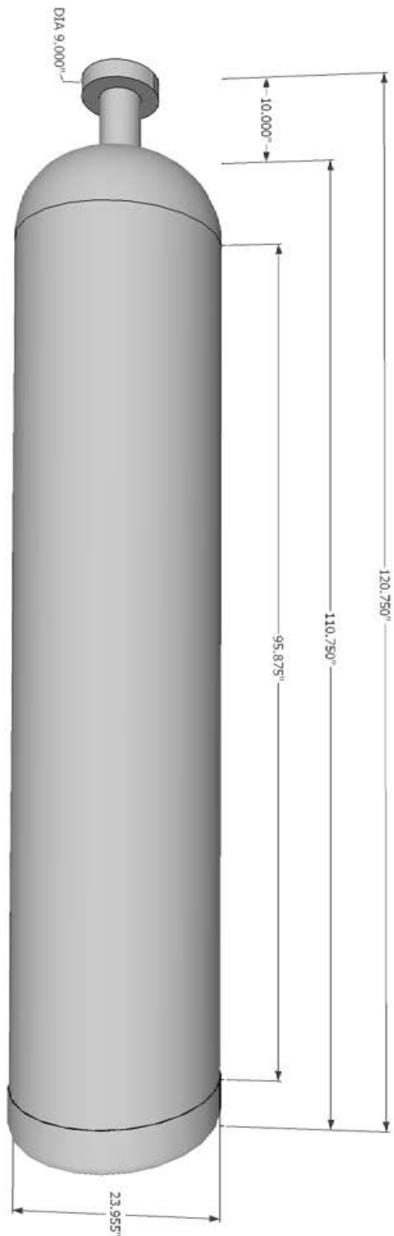
Overall Length - **120.750 in**

See schematic with dimensions

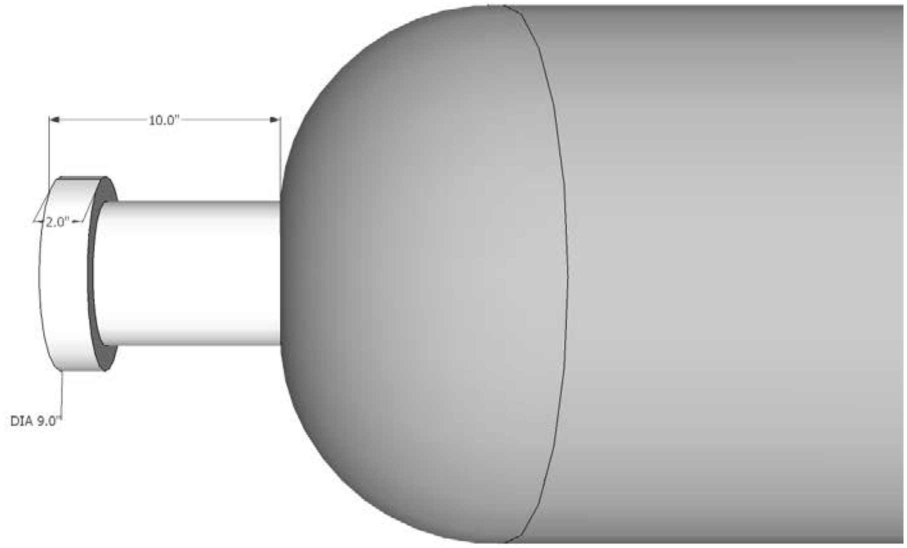
Observations:

- Both end caps appear to be thicker than center material. Caps are beveled at weld joints to match center material thickness. Measured to be approximately **0.625 in** thick.
- End cap has a concaved bottom, with a depth measuring **1.750 in.** from bottom edge of canister.
- The inside of the canisters are dirty. Light scale or surface corrosion is visible on the internal canister walls. No gross accumulation of debris or canister material degradation was observed during cutting or subsequent observations.
- The canister(s) should be cleaned before installing heaters and heating agent material.
- Overall the cutting went very smooth. It took 22 minutes from the time the cut began to the time the cap was removed. The only recommendation for future cutting is the incorporation of a roller system under the canister to enable the machinist to position himself and allow simpler maneuvering of the canister while cutting and welding.

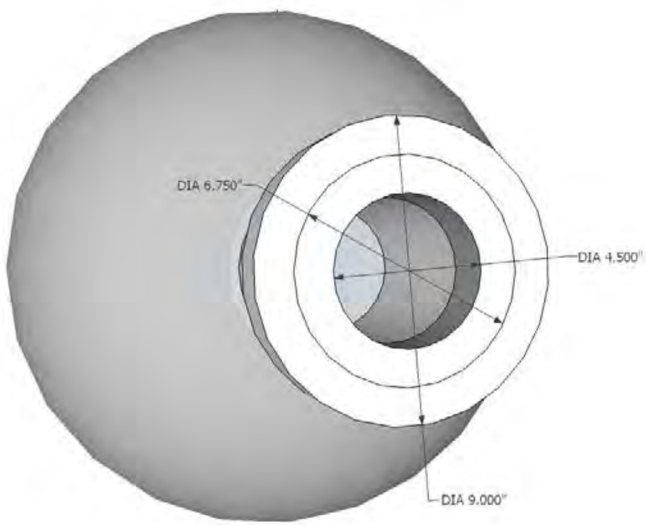
Canister Schematics with Dimensions



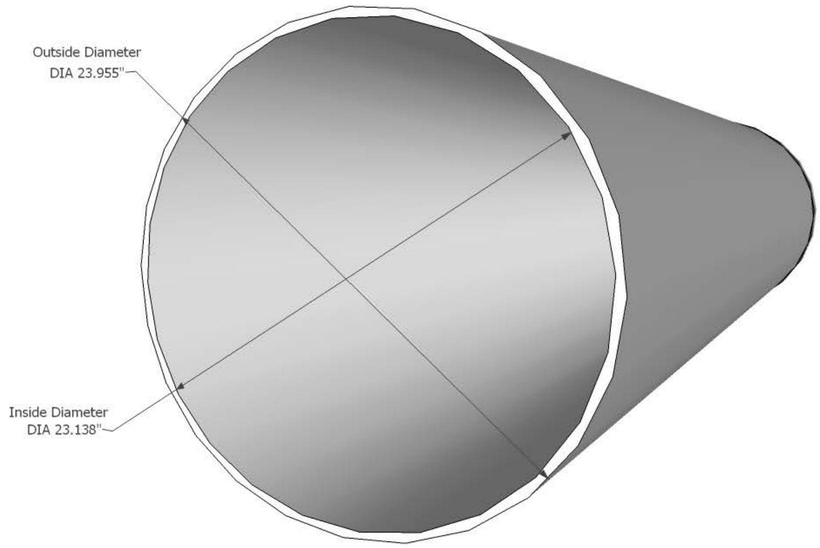
Overall Side View of Canister



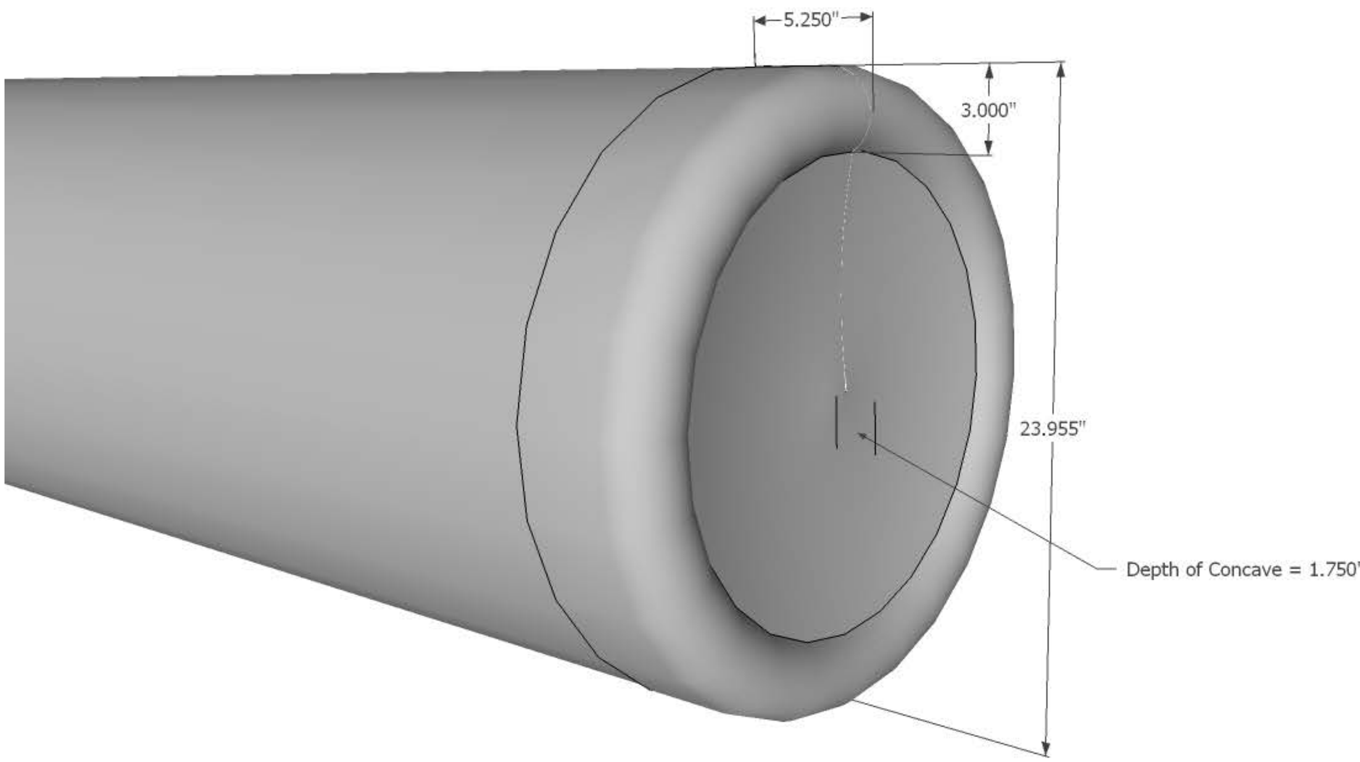
Canister: Side View of Front



Canister: Front View of Cap



Front View with Cap Removed



Back View

Photographs

Canister Side View Before Cutting

Canister Back View Before Cutting

Beginning Cut

Side View of Cutting in Progress

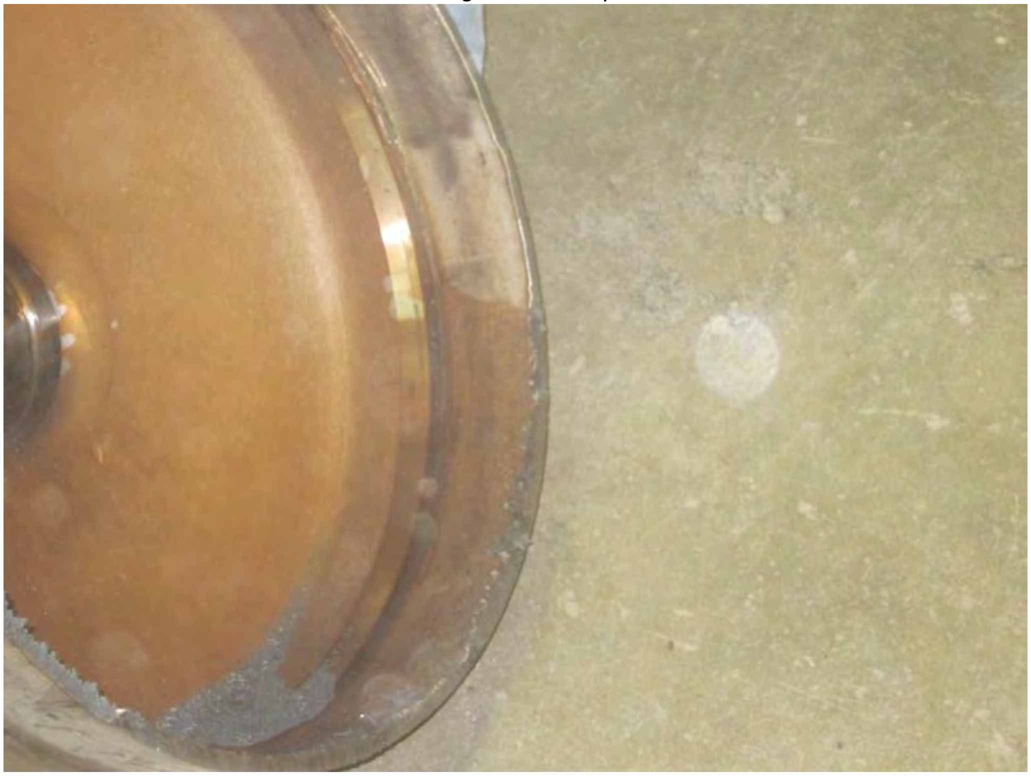
Close Up of Cut in Progress

Machinist Positioning

Canister after Cutting Complete

Inside View of Canister

Machinist Beveling Canister Cap with Grinder



Difference in Material Thickness and Bevel

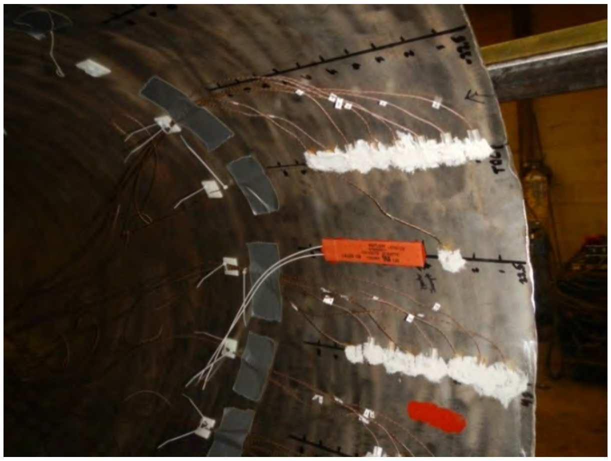
Appendix B

Canister Welding Study

Appendix B, Canister Welding Study
April 10-14, 2014

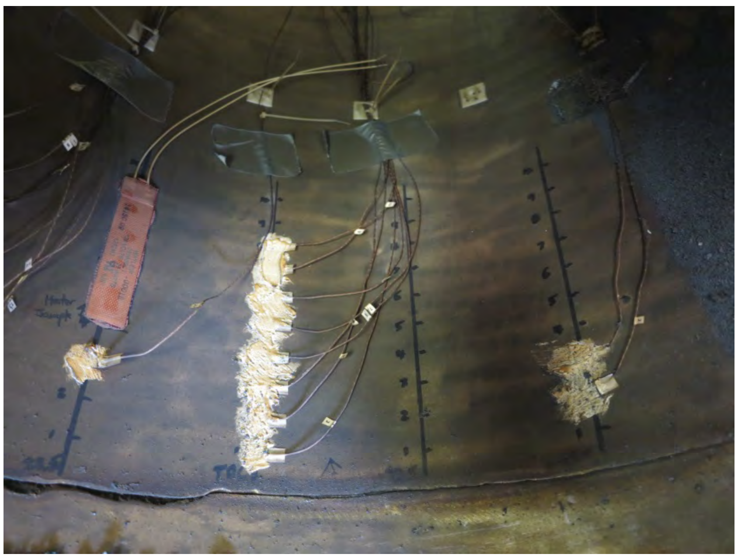
The purpose of the Canister Welding Study was to confirm that the temperatures experienced on the inside circumference of the canister heater 4-7 inches from the weld face/edge will not exceed the design specifications of the planned strip heaters (assumed to be approximately 500◦ F). At the time of this welding study, the design considered adhering flexible heater strips directly to the inside circumference of the heater canister. Application of the heater strips was subsequently redesigned to adhere to an inner sleeve that would fit within the canister, making the concern about the heat from welding a non-issue.

On Thursday 4/10/2014, the bottom end of the prototype canister was removed, the canister cleaned, and 37 thermocouples were installed in a pattern shown in the following photos. Additionally, a portion of the strip heater material and buttons of room temperature vulcanizing (RTV) Red adhesive were also installed. The wiring was run through the end of the canister and connected to a Data Logger reading at 1-second intervals.



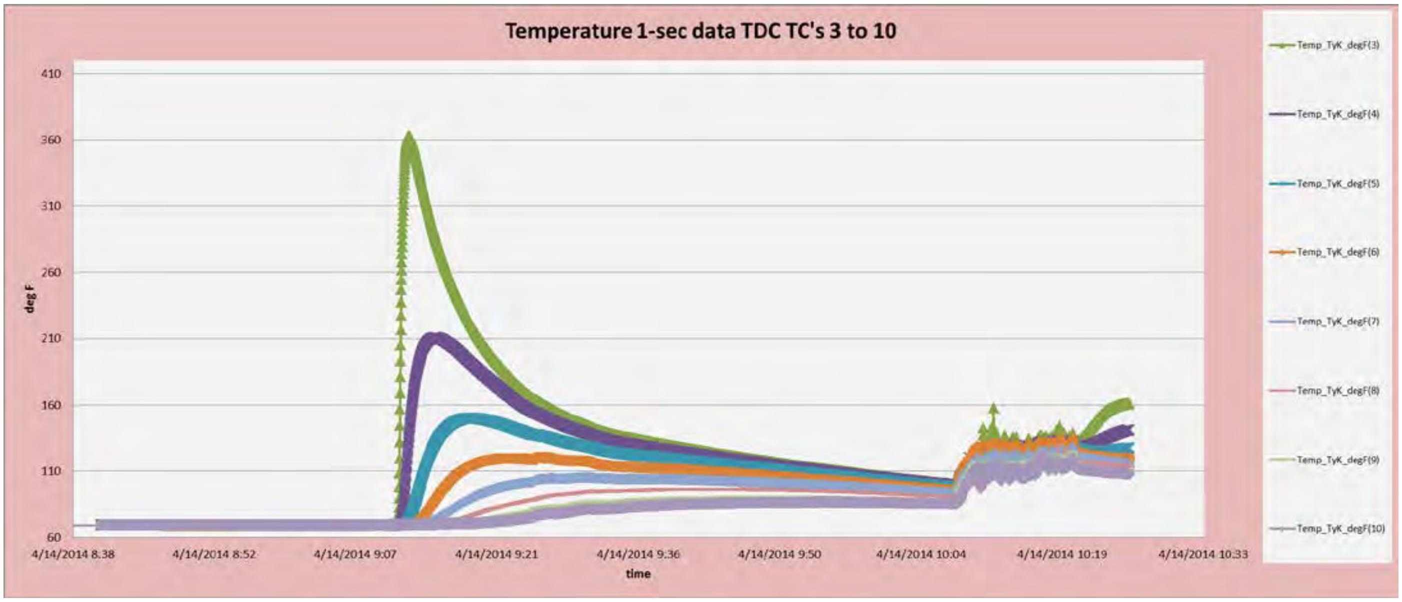
The thermocouple cement and RTV was allowed to dry over the weekend. The end of the canister was "tacked" on in three places to hold it for the weld test. Welding was conducted in a "typical" fashion for approximately half the weld length and in a "worst case" condition (i.e. slower/hotter weld) for the remaining half.

Once data was collected for the welding portion of the study, the end of the canister was cut off. Data collection continued during the torching. Observations were made of the heater material and RTV.

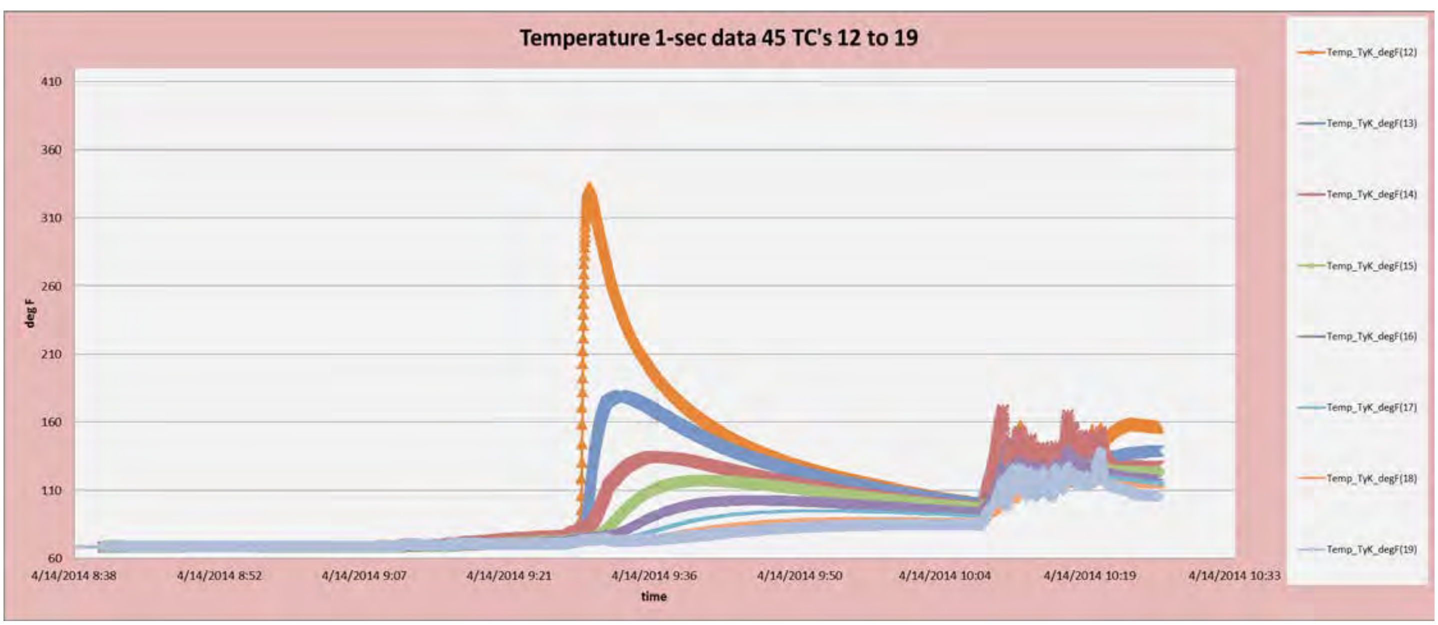


Data was collected on 1-second intervals. The closest thermocouples (TCs) approximately 1 inch from the weld face/edge experienced temperatures nearing 400 degree F. The TCs at the locations where the edge of the heater material would typically be installed (4-7inches from the weld) saw temperatures less than 150 degree F. The spike around 10:00 am was from the removal (via torching) of the canister end.

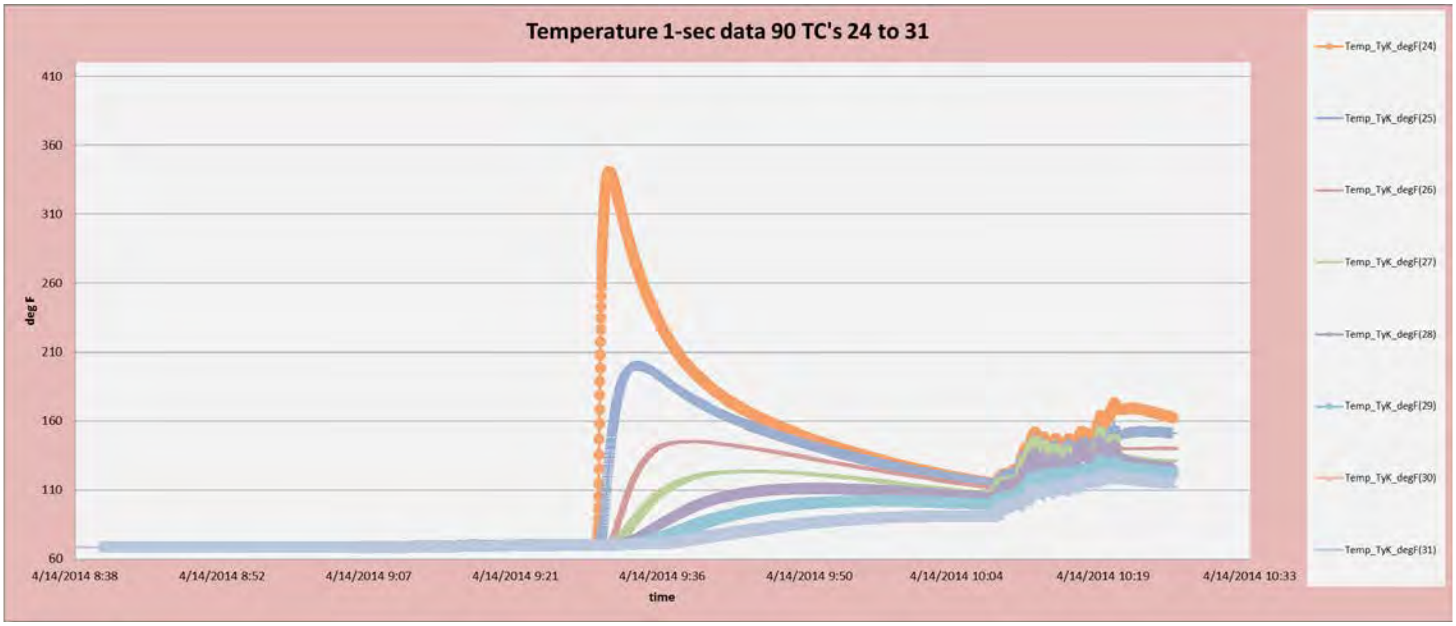
This graph is from the first full TC array, TCs # 3 through #10. Welding began at the -45 degree mark and progressed to 135 deg.



This graph is from the second full TC array, TCs # 12 through #19. Welding began at the -45 degree mark and progressed to 135 deg.



This graph is from the third full TC array, TCs # 24 through #31. Welding began at the -45 degree mark and progressed to 135 deg.



Appendix C

SDDI Canister Assembly

Appendix C, SDDI Canister Assembly

Assembly of the SDDI prototype heater canister was performed at the fabrication contractor shop. Assembly involved inserting the heater sleeve into the cut prototype heater canister, as described in Section 3.2. The canister was then transported to the fabrication contractor yard for final assembly, since the yard provided additional ceiling height and bridge crane capacities. The assembly instructions were developed to provide the baseline guidance for assembly of the prototype heater canister and the actual steps for assembly of the SDDI canister.

1.0 Canister Assembly

1.1 Securing canister and prepare for loading with Cerabeads

1.1.1 Transport the canister assembly to the fabrication contractor yard.

1.1.2 Deliver Cerabeads to fabrication contractor yard just prior to beginning filling canister.

1.1.3 Install the retaining ring to concrete floor using expandable concrete anchors.

1.1.4 Install the canister vertically inside the retaining ring using the bridge crane.

1.1.5 Secure the canister vertically to eliminate potential tipping of the canister

1.1.6 Position the scissor lift/man lift near the canister assembly.

1.1.7 Position the heater canister and thermocouple wiring to minimize disturbance during canister filling with Cerabeads.

1.1.8 Position ventilation fans upwind of workers on the scissor/man lift.

1.1.9 Turn on the ventilation fans.

1.2 Preliminary electrical and TC labeling.

1.2.1 Label supply power wire as follows:

1) Primary Heaters supply power hot (P1+, P2+, and P3+)
2) Primary Heaters supply power negative (P1-, P2-, and P3-)
3) Secondary heaters supply power hot (S1+, S2+, and S3+)
4) Secondary heaters supply power neutral (S1-, S2-, and S3-)

1.2.2 Label the TC wires as follows

Note: For TC and Extension wire, the yellow wire is positive and the red wire is negative. Polarity must be maintained during 24 pin assembly.

1) P1 = Primary heater #1 TC
2) P2 = Primary heater #2
3) P3 = Primary heater #3
4) S1 = Secondary heater #1
5) S2 = Secondary heater #2
6) S3 = Secondary heater 3 TC
7) 7 = Canister TC#7 - Canister pintle end
8) 8 = Canister TC#8

9) 9 = Canister TC#9
10) 10 = Canister TC#10
11) 11 = Canister TC#11
12) 12 = Canister TC#12

1.2.3 Electrician to install heat/protective sleeves to protect wires.

1.3 Adding Cerabeads to the Canister.

1.3.1 Load 5 gallon buckets ~1/2 full from the super sacks at the fabrication contractor yard

1.3.2 Transport 5 gallon buckets of Cerabeads to the scissor/man lift and place on the platform

1.3.3 Elevate the scissor lift platform

1.3.4 Manually dump Cerabeads into the canister.

1.3.5 Lower the scissor/man lift,

1.3.6 Repeat steps 1.3.1 through 1.3.5 until the Cerabeads approach the level of the junction box. It should take approximately 50 buckets to fill the canister to desired level.

1.4 Connecting the heater electrical leads inside the junction box.

1.4.1 The Stoller contracted electrician shall use the scissor/man lift to perform electrical connections.

1.4.2 Raise the scissor lift to provide access to the SDDI canister internals.

1.4.3 Mount terminal blocks in the SDDI canister junction box.

1.4.4 Install terminal block jumpers.

1.4.5 Trim heater elements lead wires for connection to the junction box terminal blocks.

1.4.6 Perform resistance measurements on each of the six heater elements and record in the table below.

Date	Heater ID	Resistance (ohms)
8/19/14	PH1	110.2
8/19/14	PH2	94
8/19/14	PH3	94.5
8/19/14	SH1	94
8/19/14	SH2	94.1
8/19/14	SH3	94.5

1.4.7 Connect heater wires to the terminal block as shown on the design drawings.

1.4.8 Connect the supply power electrical leads to the terminal blocks as shown on the design drawings.

1.4.9 Label the supply power electrical leads as follows.

P+ -- Primary heater supply power positive

S+ -- Secondary heater supply power negative

N – Common supply power negative

1.4.10 Connect voltage sense signal wires to the terminal blocks as indicated on the design drawings.

1.4.11 Perform resistance measurements on each of the six heater elements and record in the table below.

Date	Heater ID	Resistance (ohms)
8/19/14	Primary Heater Circuit	32.6
8/19/14	Secondary Heater Circuit	31.1

1.4.12 Seal the junction box with RTV.

1.4.13 Lower the scissor/man lift.

1.5 Continue filling the canister with Cerabeads.

1.5.1 Load 5 gallon buckets ~1/2 full from the super sacks at the fabrication contractor yard

1.5.2 Transport 5 gallon buckets of Cerabeads to the scissor/man lift and place on the platform.

1.5.3 Elevate the scissor lift platform

1.5.4 Manually dump Cerabeads into the canister.

1.5.5 Lower the scissor/man lift.

1.5.6 Repeat steps 1.5.1 through 1.5.5 until the Cerabeads approach the top cut of the canister.

Note: Approximately 65 half full 5-gallon buckets were required to fill the canister prior to welding of the pintle end to the canister.

1.6 Welding the pintle end to the canister.

1.6.1 Welder and helper shall elevate the scissor/man lift to a comfortable working height.

1.6.2 Ensure all wiring is in place and will not be damaged when aligning pintle end.

1.6.3 Position the pintle end above the canister.

1.6.4 Route electrical and thermocouple wires through the flange on the pintle of the canister.

1.6.5 Align pintle end to weld to the canister.

1.6.6 Tack weld the pintle end to the canister to provide support for continued welding.

1.6.7 Weld the pintle end solid to the canister.

1.6.8 Lower the scissor/man lift.

1.7 Continue adding Cerabeads to the canister. (2 – 5 additional bucket loads)

1.7.1 Load 5 gallon buckets ~1/2 full from the super sacks at the fabrication contractor yard

1.7.2 Transport 5 gallon buckets of Cerabeads to the scissor/man lift and place on the platform.

1.7.3 Elevate the scissor lift platform

1.7.4 Manually dump Cerabeads into the canister.

1.7.5 Repeat steps 1.6.1 through 1.6.4 until the Cerabeads approach the top of the SDDI canister.

1.8 Installation of the thermocouple and electrical connection to the end cap.
Note: Be sure to leave enough wire length to assemble Kemlon and Omega fittings and wiring to the end cap.

1.8.1 Elevate the scissor/man lift to perform electrical connections.

1.8.2 Install the O-ring on the end cap of the canister.

1.8.3 Cut the thermocouple wires to length to accommodate the Omega 24 pin pass-through fitting and re-label wire as identified in step 1.2.2.

1.8.4 Crimp connectors to the wires using an Omega Crimping tool.

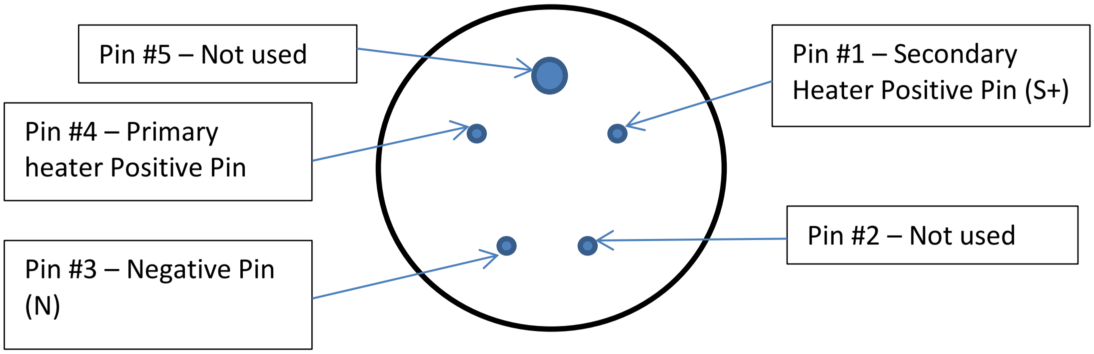
1.8.5 Install the TC wires into the Omega pass-through per the following pinout.

Pin Number	TC Extension Wire Number	Wire ID	Description
1	1	P1	Primary heater TC #1 positive –yellow
2		P1	Primary Heater TC #1 negative – red
3	2	P2	Primary heater TC #2 positive–yellow
4		P2	Primary Heater TC #2 negative– red
5	3	P3	Primary heater TC #3 positive–yellow
6		P3	Primary Heater TC #3 negative– red

7	4	S1	Secondary heater TC #1 positive–yellow
8		S1	Secondary Heater TC #1 negative–red
9	5	S2	Secondary heater TC #2 positive–yellow
10		S2	Secondary Heater TC #2 negative–red
11	6	S3	Secondary heater TC #3 positive–yellow
12		S3	Secondary Heater TC #3 negative–red
13	7	7	Canister TC#7 positive–yellow
14		7	Canister TC#7 negative– red
15	8	8	Canister TC#8 positive–yellow
16		8	Canister TC#8 negative– red
17	9	9	Canister TC#9 positive–yellow
18		9	Canister TC#9 negative– red
19	10	10	Canister TC#10 positive–yellow
20		10	Canister TC#10 negative– red
21	11	11	Canister TC#11 positive–yellow
22		11	Canister TC11 negative– red
23	12	12	Canister TC#12 positive–yellow
24		12	Canister TC#12 negative– red

1.8.6 Install the in-canister end of the Omega pass-through to the end cap.
1.8.7 Install the Kemlon 5 pin connector into the canister lid
1.8.8 Crimp connectors to the voltage sense wire on the internals of the canister.
1.8.9 Install heat shrink tubing on the voltage sense wires.
1.8.10 Attach the voltage sense connectors to the Kemlon 5 pin connector.
1.8.11 Slide the heat shrink tubing over the connectors and shrink the tubing using a heat gun.
1.8.12 Record the pin numbers for the voltage sense connections on the diagram below.

Note: The pins below are the view from the top of the end cap with the pins exposed.



1.8.13 Cut the supply power wire to length to accommodate assembly into the Kemlon pass-through fittings and re-label the wire as identified in step 1.2.1.
1.8.14 Crimp connectors to the primary and secondary heater supply power wiring.
1.8.15 Install the in-canister end of the Kemlon pass-through connectors to the end cap.
1.8.16 Label the top of the end cap for the Primary and secondary supply wiring locations with the following identifiers.
1) P+ -- Primary Heater supply power hot
2) S+ -- Secondary heater supply power hot
3) N – Combined heater supply power negative
1.8.17 Carefully place all the loose wire in the end pintle of the canister and place the end cap on the pintle end of the canister.
1.8.18 Connect the end cap to the pintle end using the flange bolts.
1.8.19 Slowly add additional Cerabeads, using a funnel, through the 3/8" NPT pipe thread hole to fill the canister.
Note: Approximately 6 half full 5-gallon buckets were required to fill the canister pintle end. The Cerabeads were settled by tapping the outside of the canister with a small sledge hammer after 4.5 buckets were added to the canister. Continued tapping and filling resulted in the addition of approximately 1.5 half full 5-gallon buckets to the canister.
1.8.20 Place steel wool in the 3/8" hole to ensure Cerabeads remain in the canister
1.8.21 Install 3/8" NPT SST pipe plug.
1.8.22 Weight the assembled canister using a load cell and record weight below.
4,072 pounds.

1.9 Transport canister to the fabrication contractor shop.
1.9.1 Place dunnage on the transport vehicle.
1.9.2 Rig to the canister to lift on to transport vehicle.

1.9.3 Lift canister and place on the transport vehicle.
1.9.4 Secure canister to the transport vehicle

1.9.5 Transport to the fabrication contractor shop.
1.9.6 Unload Canister at the fabrication contractor shop.

2.0 Final Wiring at the fabrication contractor shop

2.1 Cut thermocouple extension wire, power wiring, and voltage sense wiring to 30 foot lengths for electrical assembly.
2.2 Thermocouple extension wire shall be labeled per the table in section 1.8.5.
2.3 Kemlon 5-pin wiring shall be labeled in accordance with the diagram in Section 1.8.12
2.4 Kemlon single pin wiring shall be labeled in accordance the table in Section 1.4.9.
2.5 Install thermocouple, power and voltage sense wiring in accordance with final design drawings and instruction provided in the TDK Lambda and Campbell Scientific operations manuals.
2.6 Wire the TDK Lambda to the appropriate plug to supply 240 volt single phase AC power.
2.7 Perform system testing in accordance with Section 3.4.

3.0 Deliver to LANL facility

3.1.1 Coordinate the transport with fabrication contractor and LANL personnel.
3.1.2 Disconnect the thermocouple and Kemlon pass-through connectors from the end cap.
3.1.3 Disconnect wiring from the TDK Lambda power supply.
3.1.4 Coil wiring and stage for transport with Campbell Scientific and TDK Lambda enclosures.
3.1.5 Place dunnage on the transport vehicle.
3.1.6 Rig to the canister to lift on to transport vehicle.
3.1.7 Lift canister and place on the transport vehicle.
3.1.8 Secure canister to the transport vehicle
3.1.9 Transport to the specified LANL facility
3.1.10 LANL personnel will off-load the canister at LANL facilities.
3.1.11 Wire the appropriate 240 VAC plug to the TDK Lambda supply power based on LANL facility plug requirements.

Appendix D

Power-Up Procedures

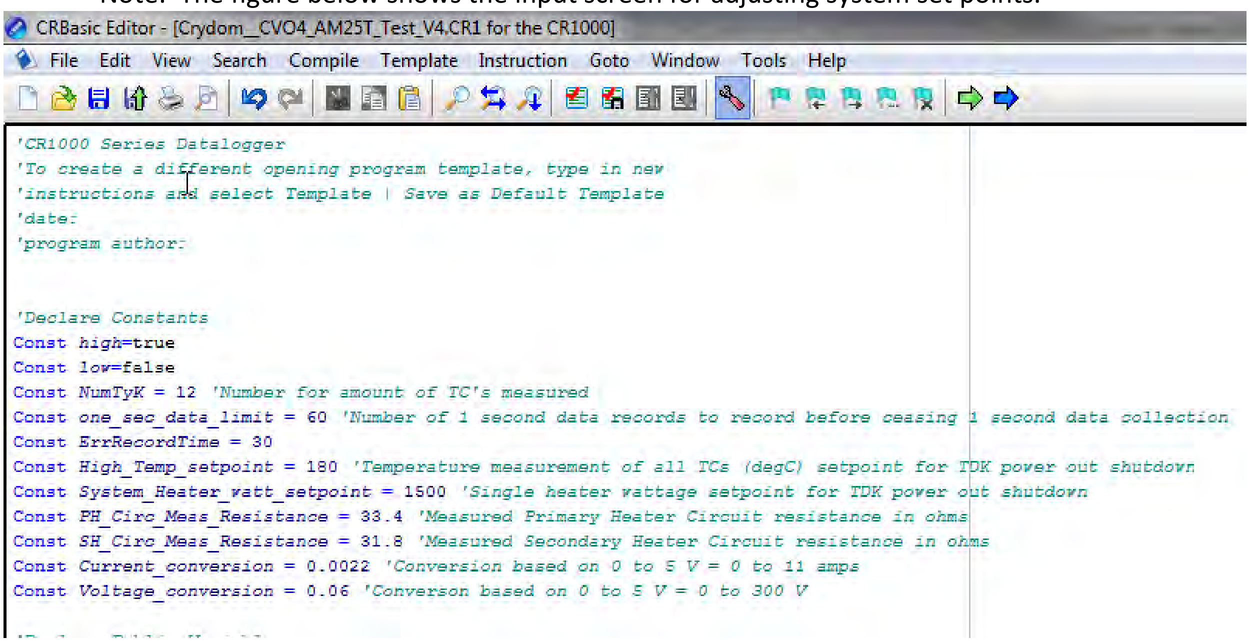
Appendix D, Power-Up Procedures

Operation of the prototype heater canister system is accomplished by both manual interfaces with the process equipment and set point entries by an operator on the human-machine interface (HMI). Both functions are fairly simple and are defined below.

4.1.1 Verify system set points by performing the following

1) On the HMI, open the CRBasic Editor to access the control program.
2) Verify that the primary resistance heater set point is 33.4 ohms
3) Verify that the secondary resistance heater set point is 31.8 ohms.
4) Verify that the high temperature set point is 180 Celsius
5) Verify that the wattage set point 1500 W.
6) IF changes are made then click on **Compile**, and then **Compile, Save, and Send** to send new configuration to the datalogger.

Note: The figure below shows the input screen for adjusting system set points.



4.1.2 From the HMI screen, verify that the control thermocouples are operational.

1) Thermocouples #1 – 6 are required for operation of the system. These thermocouples are integral to the primary and secondary heater and are integrated into the high temperature shutdown.
2) Thermocouples #7-12 are optional for operation. These thermocouples measure the internal temperature of the canister wall, but are not used for control of system operations.

4.1.3 Plug the TDK Lambda power supply into a 240 VAC single phase wall receptacle.

4.1.4 Turn the TDK Lambda "ON" using the local switch on the power supply.

4.1.5 Press the "OUT" button on the TDK Lambda faceplate.

4.1.6 Verify that the primary heaters are selected for testing by performing the following.

1) Open the connect screen on the HMI

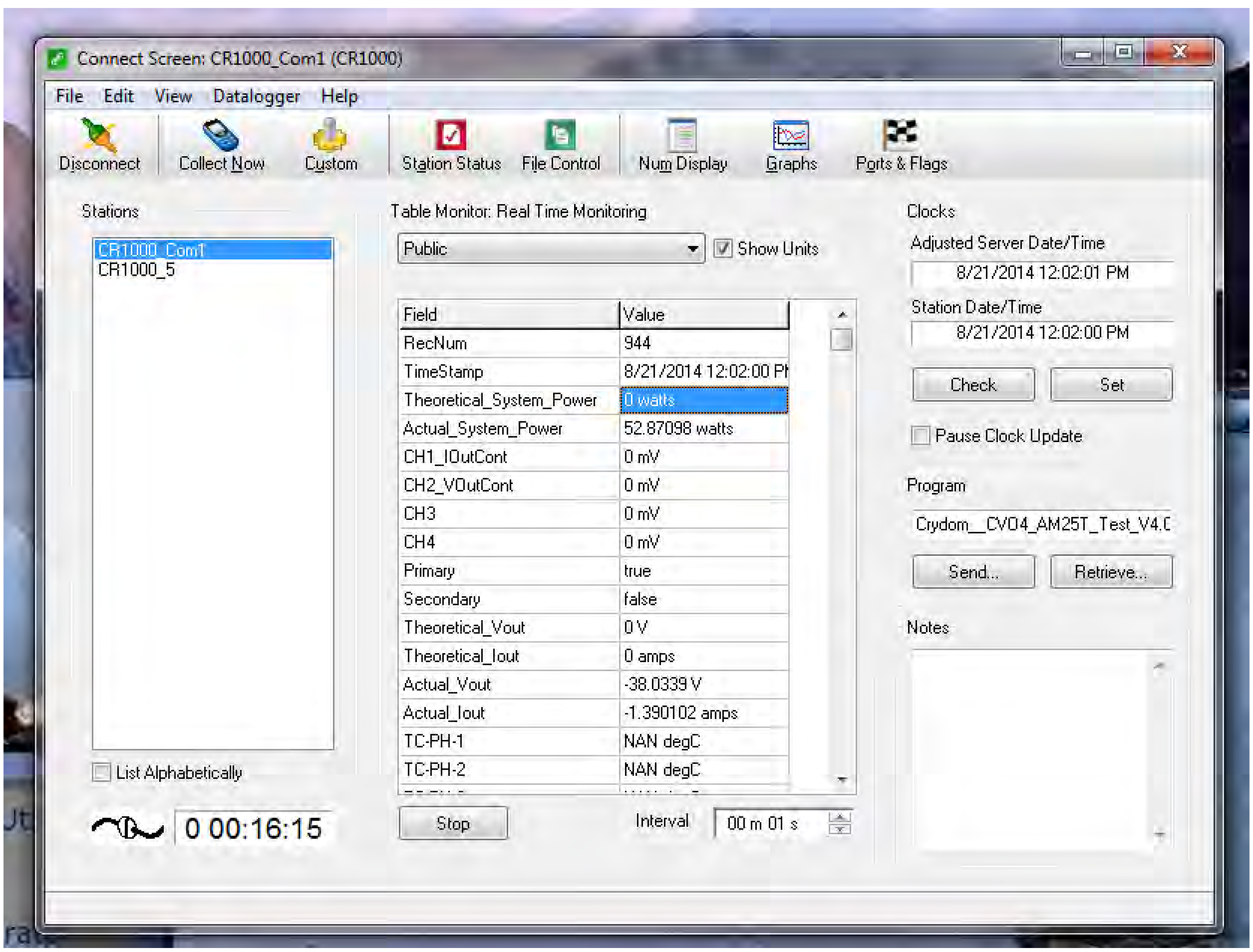
2) Verify that “Primary” is set to “True”
3) Verify that Secondary is set to “False”
4) If Primary and Secondary heater selection needs change, see Section 4.1.9

4.1.7 Set the power for the test by performing the following.

Note: The Theoretical System Power is use to set the wattage for the test. By entering the Theoretical System Wattage, the PLC will control the output voltage and current to maintain the entered wattage set point. Upon startup, after a power outage, or after the program is the sent to the datalogger; the Theoretical System Power will default value of 0 watts.

1) Open the connect screen on the HMI
2) Use the mouse to right click on the “Theoretical System Power” value
3) Click on the **View/Modify Value** after it appears
4) Enter the desired voltage for the test conditions (voltage will typically be 750 or 1500 watts)
5) Click on **“Apply”**

Note: The figure below shows the connect screen used to enter the Theoretical System Power.



4.1.8 Monitor to TDK Lambda outputs and heater temperature.

4.1.9 Perform the following to toggle from primary to secondary heaters.

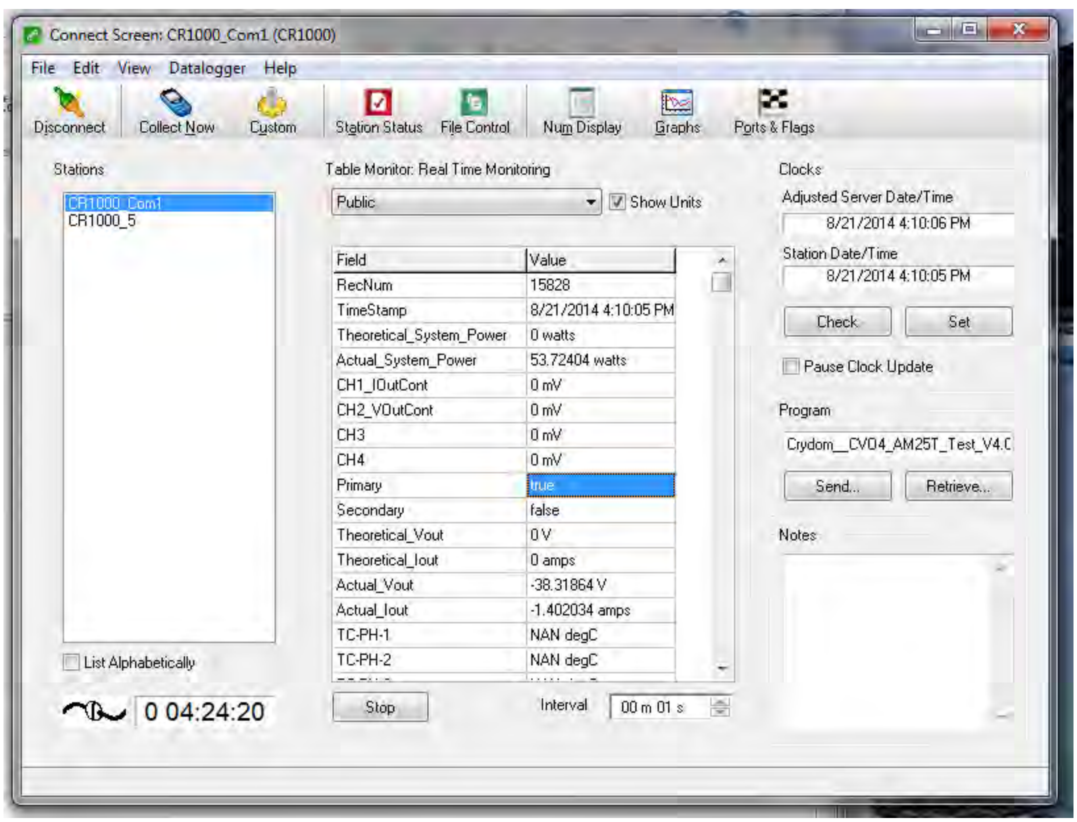
Note: The Primary Heater is the Default heaters. The primary and secondary heaters are controlled by changing values on the "Connect Screen" with "True" = on and False = off. The primary and secondary heaters cannot be true (on) at the same time, but they can be set to false (off) at the same time.

1) Use the mouse to right click on the "Primary" value
2) Click on the **View/Modify Value** after it appears
3) Enter "False"
4) Click on **"Apply"**
5) Use the mouse to right click on the "Secondary" value
6) Click on the **View/Modify Value** after it appears
7) Enter "True"
8) Click on **"Apply"**

4.10 Perform the following to toggle from secondary to primary heaters.

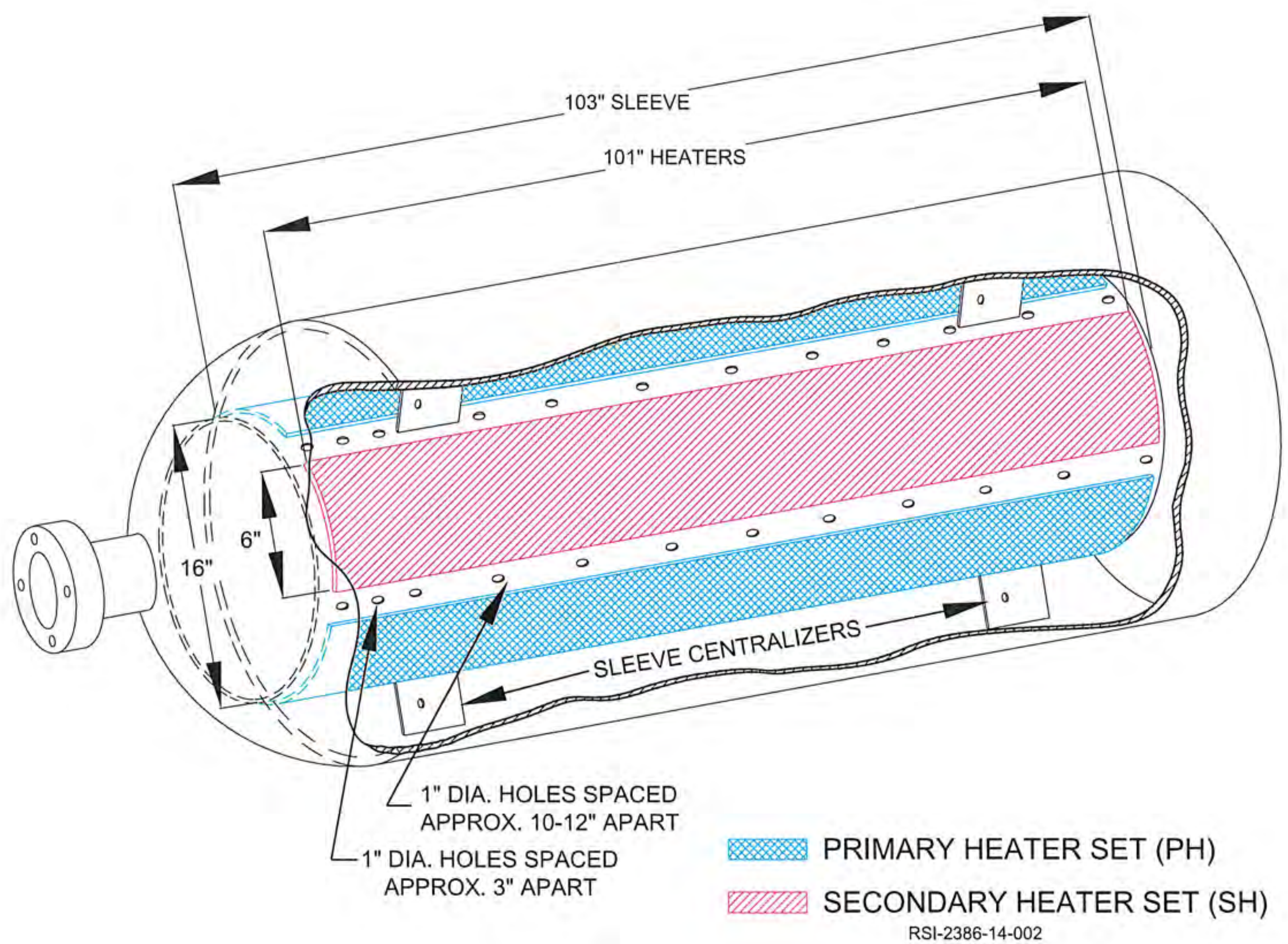
1) Use the mouse to right click on the "Secondary" value
2) Click on the **View/Modify Value** after it appears
3) Enter "False"
4) Click on **"Apply"**
5) Use the mouse to right click on the "Primary" value
6) Click on the **View/Modify Value** after it appears
7) Enter "True"
8) Click on **"Apply"**

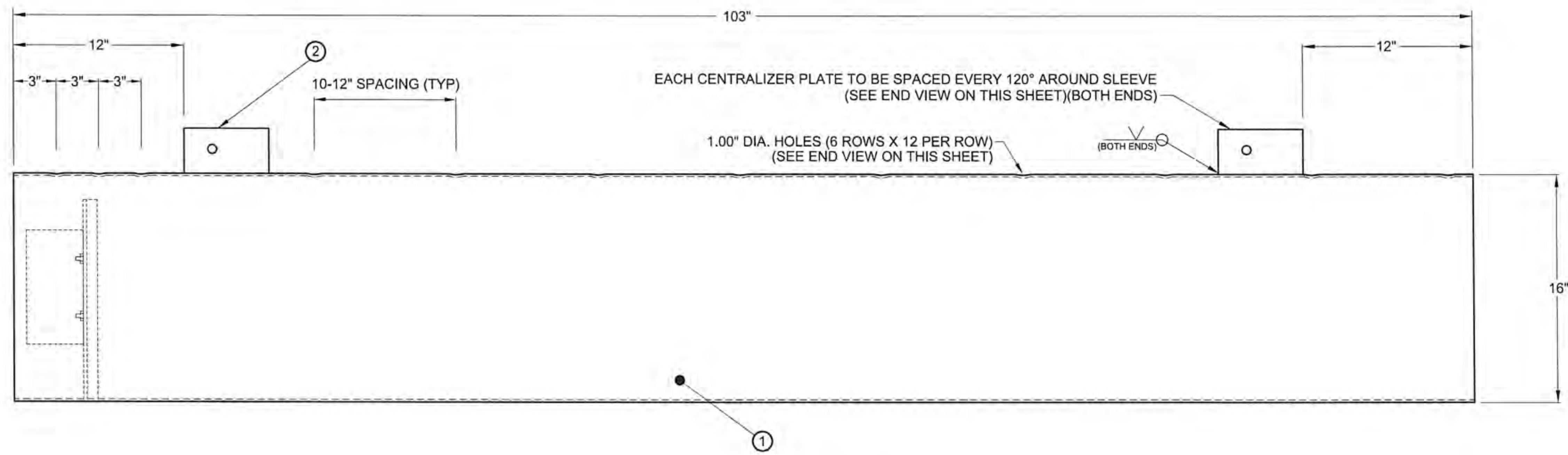
Note: The figure below shows the connect screen used to toggle between primary and secondary heaters.

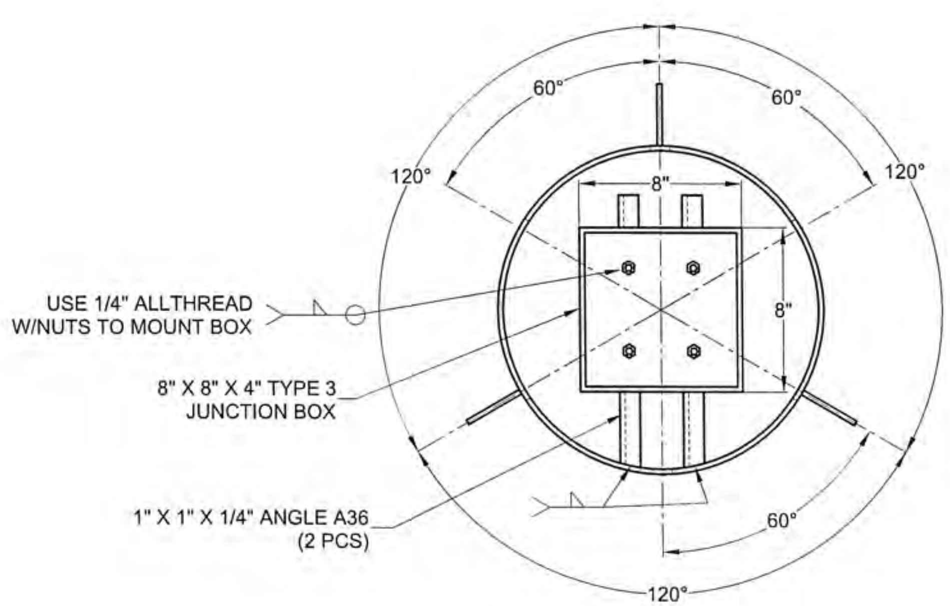


Attachment E, As-Built Drawings
See attached as-built drawings.

Attachment F, SDDI Prototype Heater Canister Materials List
See attached spreadsheet


103" SLEEVE
101" HEATERS
6"
16"
SLEEVE CENTRALIZERS
1" DIA. HOLES SPACED
APPROX. 10-12" APART
1" DIA. HOLES SPACED
APPROX. 3" APART
PRIMARY HEATER SET (PH)
SECONDARY HEATER SET (SH)
RSI-2386-14-002





END VIEW

ITEM	QUAN.	DRAWING NUMBER	DESCRIPTION
2	6	B-2386-14-008	HEATER SLEEVE CENTRALIZER PLATE
1	1	——	HEATER SLEEVE

TOLERANCES UNLESS NOTED OTHERWISE
FRACTIONS ±
TWO PLACES ±
THREE PLACES ±
FOUR PLACES ±
MATERIAL

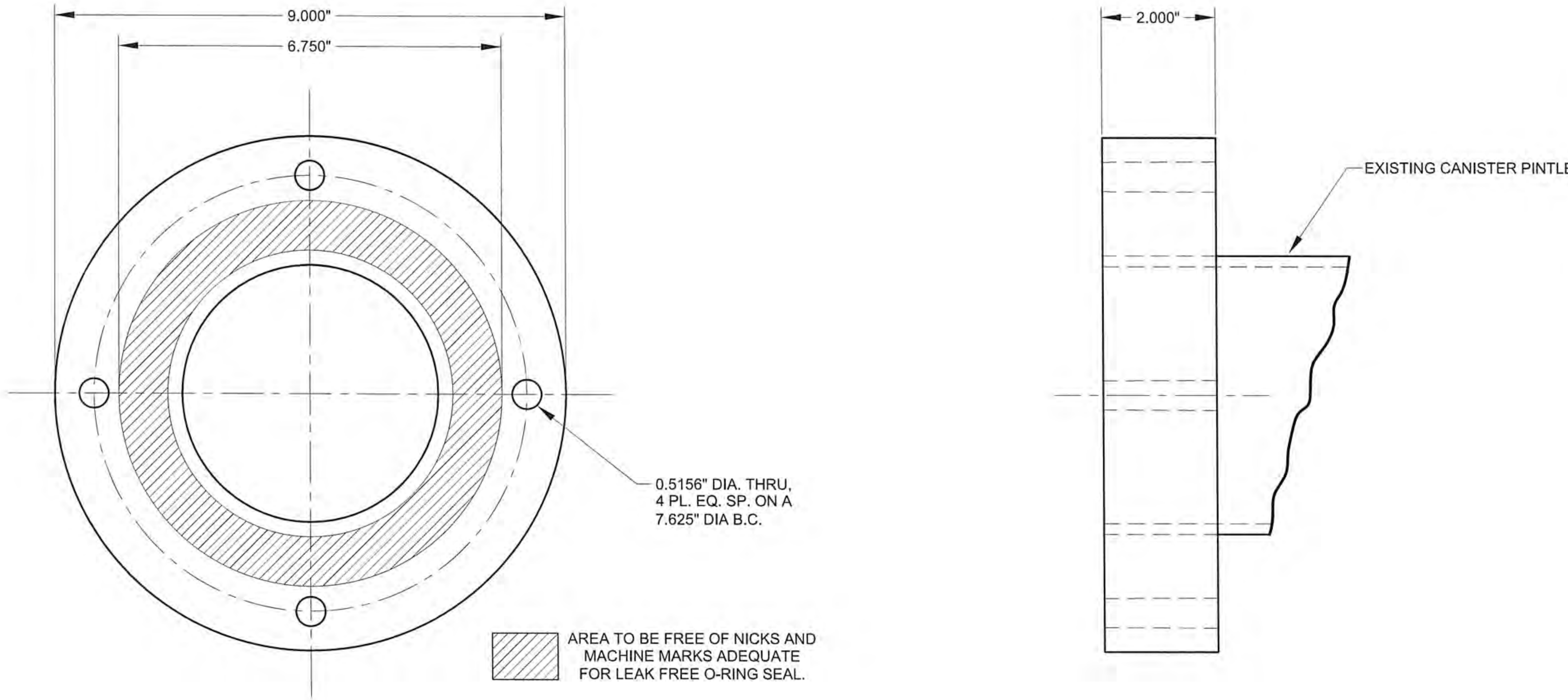
ANGLES ±
BREAK ALL EDGES R
SURFACES FINISHED EXCEPT AS NOTED

DRAFTSMAN	DATE
CHK'D	DATE
DIV. APVD.	DATE
Q.A. APVD.	DATE

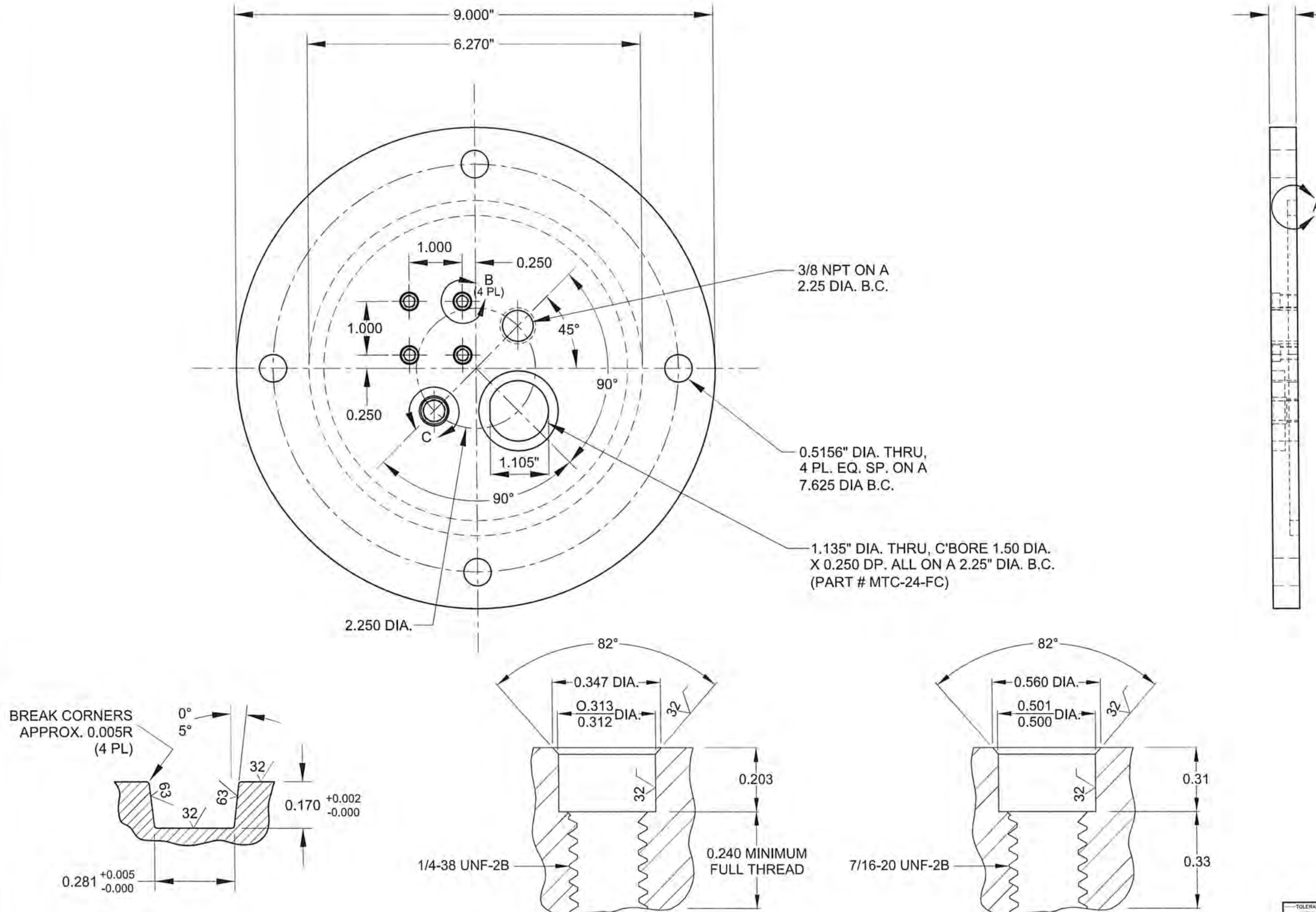
RESPEC CONSULTING & SERVICES

TITLE: HEATER SLEEVE ASSEMBLY

REV.	SCALE	SIZE	JOB NO.	ASSY. NO.	DWG. NO.
		B	2386	14	010



TOLERANCES UNLESS NOTED OTHERWISE		ITEM	QUAN.	DRAWING NUMBER		DESCRIPTION
FRACTIONS	±			ANGLES ± 2	BREAK ALL EDGES 0.010 R	RESPEC CONSULTING & SERVICES
TWO PLACES	± 0.02			SURFACES FINISHED EXCEPT AS NOTED	64 ✓	
THREE PLACES	± 0.010			DRAFTSMAN	DATE	
FOUR PLACES	±					
MATERIAL				CHK'D	DATE	TITLE: CANISTER PINTLE
				DIV. APVD.	DATE	
				Q.A. APVD.	DATE	REV. / SCALE: FULL / SIZE: C / JOB NO.: 2386 / ASSY. NO.: 14 / DRWG. NO.: 004

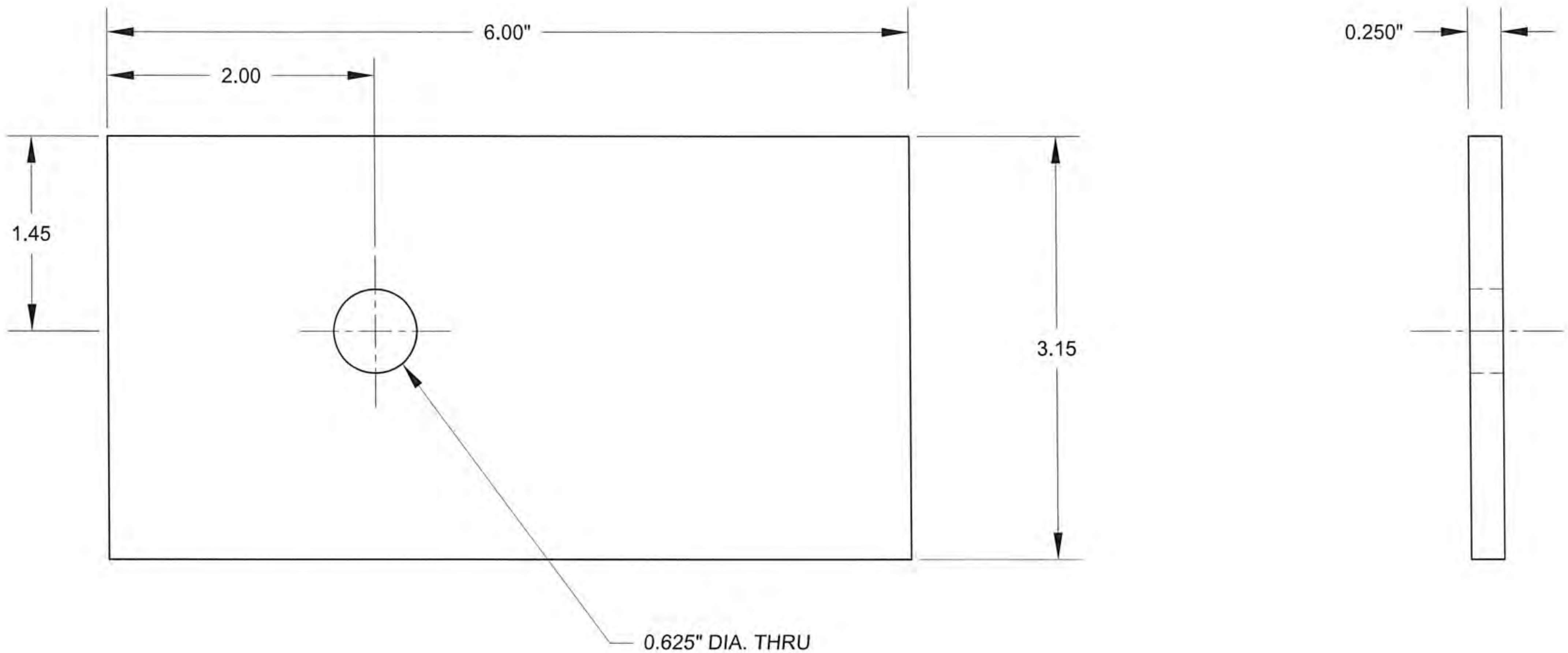


DETAIL A
SCALE :NONE
ONE REQUIRED
PARKER #360 0-RING

DETAIL B
SCALE :NONE
4 PLACES
(PART # 16-B-18865)

DETAIL C
SCALE :NONE
ONE REQUIRED
(PART # 16-B-8420)

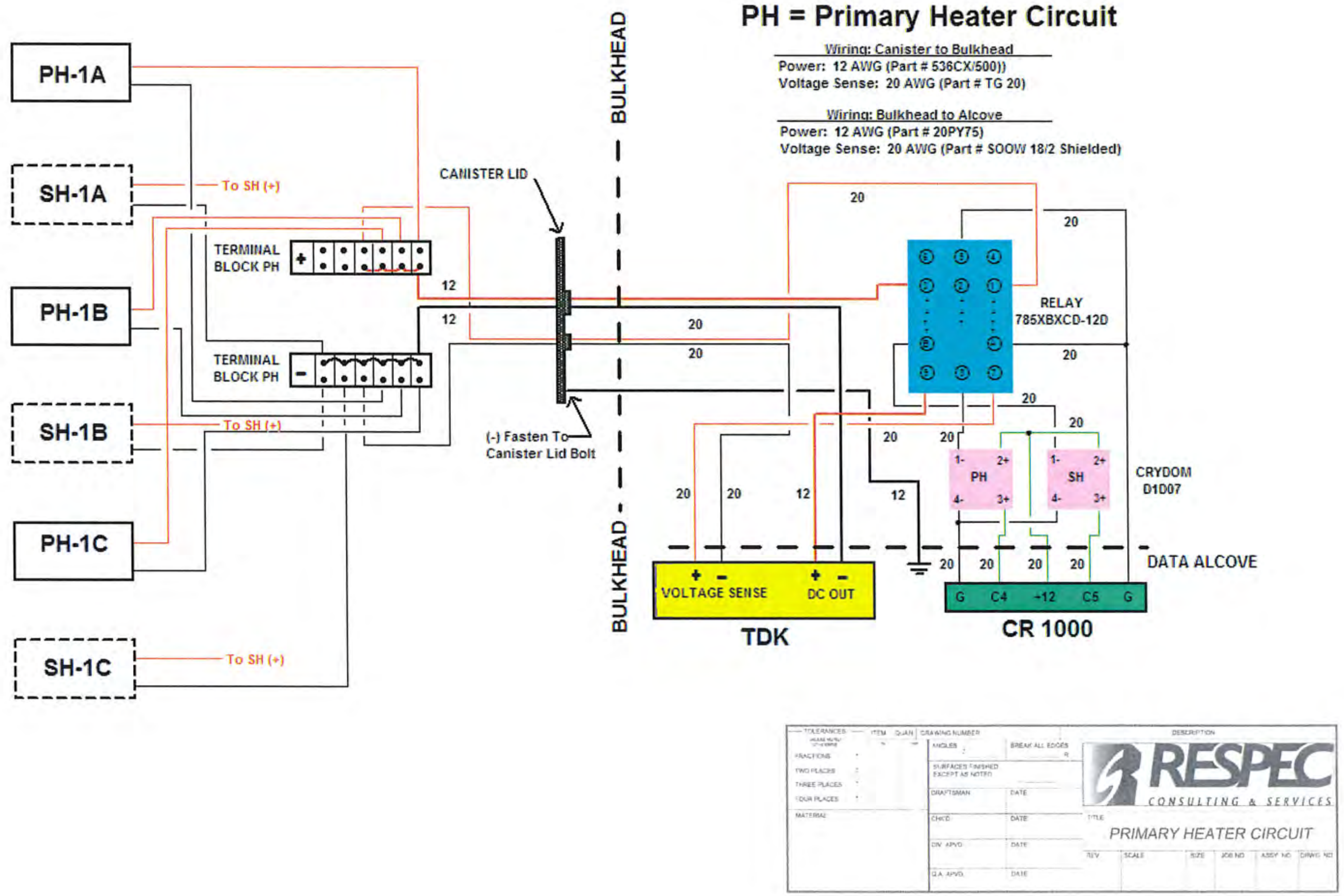
TOLERANCES UNLESS NOTED OTHERWISE	ITEM	QUAN.	DRAWING NUMBER		DESCRIPTION
FRACTIONS ±			ANGLES ± 2	BREAK ALL EDGES 0.010 R	RESPEC CONSULTING & SERVICES
TWO PLACES ±	0.02		SURFACES FINISHED EXCEPT AS NOTED 64		
THREE PLACES ±	0.010				
FOUR PLACES ±			DRAFTSMAN	DATE	
MATERIAL			CHK'D	DATE	TITLE: CANISTER ENDCAP
304L STANLESS STEEL OR EQUIVALENT			DIV. APVD.	DATE	REV. / SCALE: FULL / SIZE: C / JOB NO.: 2386 / ASSY. NO.: 14 / DRWG. NO.: 003
			Q.A. APVD.	DATE	

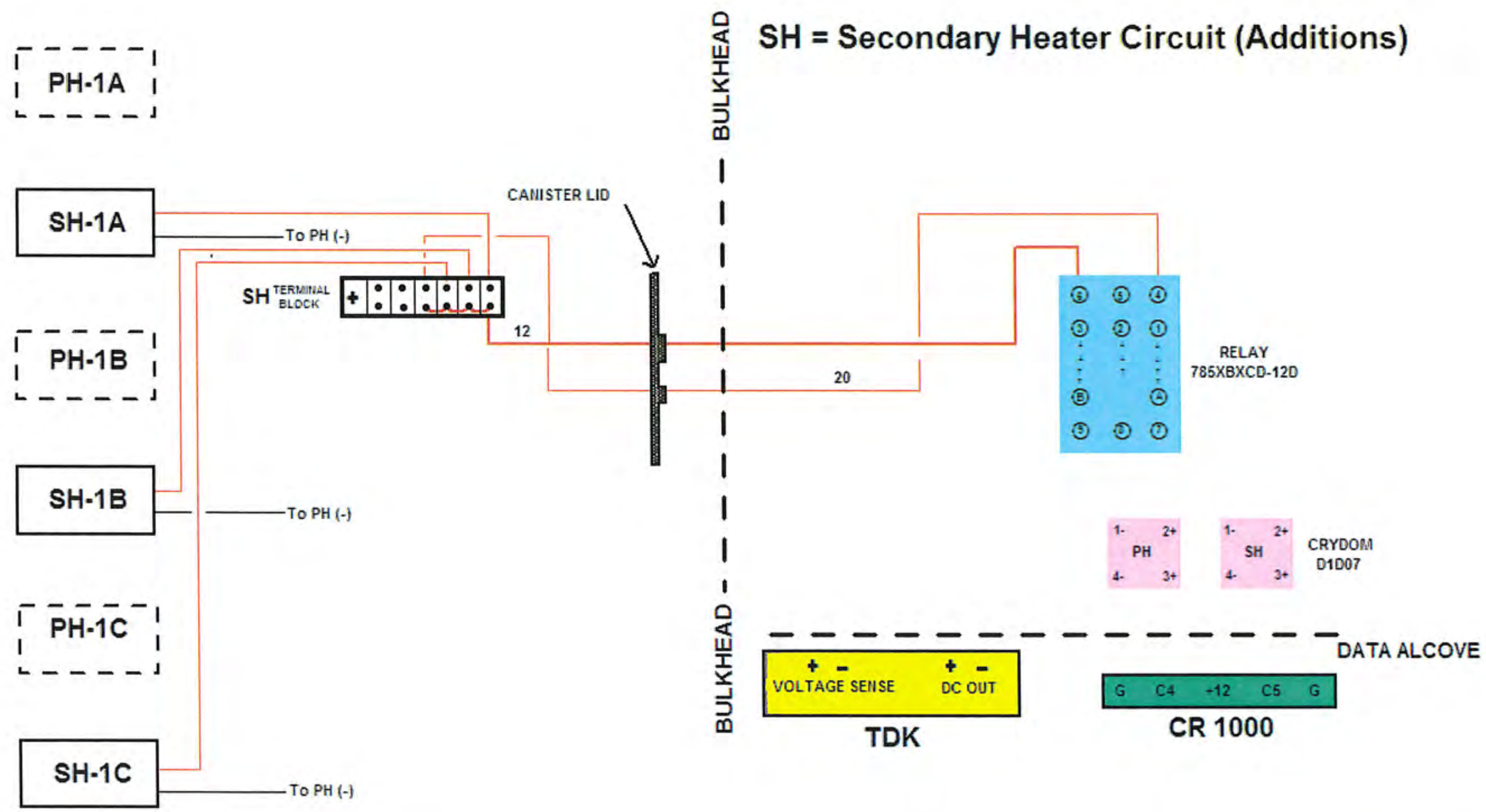


NOTE: ALL DIMENSIONS ARE IN INCHES

TOLERANCES UNLESS NOTED OTHERWISE	ITEM	QUAN.	DRAWING NUMBER	DESCRIPTION
FRACTIONS ± / TWO PLACES ± / THREE PLACES ± / FOUR PLACES ±	IN	mm	ANGLES ± 2 / BREAK ALL EDGES 0.015 R / SURFACES FINISHED EXCEPT AS NOTED	RESPEC CONSULTING & SERVICES
MATERIAL: 1018 MILD STEEL OR EQUIVALENT			DRAFTSMAN / DATE; CHK'D / DATE; DIV. APVD. / DATE; Q.A. APVD. / DATE	TITLE: HEATER SLEEVE CENTRALIZER PLATE

REV.	SCALE	SIZE	JOB NO.	ASSY. NO.	DRWG. NO.
	FULL	B	2386	14	008


PH = Primary Heater Circuit
Wiring: Canister to Bulkhead
Power: 12 AWG (Part # 536CX/500))
Voltage Sense: 20 AWG (Part # TG 20)
Wiring: Bulkhead to Alcove
Power: 12 AWG (Part # 20PY75)
Voltage Sense: 20 AWG (Part # SOOW 18/2 Shielded)
PH-1A
SH-1A
PH-1B
SH-1B
PH-1C
SH-1C
To SH (+)
TERMINAL BLOCK PH
CANISTER LID
BULKHEAD
(-) Fasten To Canister Lid Bolt
RELAY 785XBXCD-12D
CRYDOM D1D07
PH
SH
DATA ALCOVE
VOLTAGE SENSE
DC OUT
TDK
CR 1000
G C4 +12 C5 G
RESPEC CONSULTING & SERVICES
PRIMARY HEATER CIRCUIT



TOLERANCES	ITEM	QUAN	DRAWING NUMBER		DESCRIPTION
FRACTIONS ±			ANGLES ±	BREAK ALL EDGES R	RESPEC CONSULTING & SERVICES
TWO PLACES ±			SURFACES FINISHED EXCEPT AS NOTED		
THREE PLACES ±			DRAFTSMAN	DATE	
FOUR PLACES ±					
MATERIAL			CHKD	DATE	TITLE SECONDARY HEATER CIRCUIT
			D/V APVD	DATE	REV / SCALE / SIZE / JOB NO / ASSY NO / DRWG NO
			Q.A. APVD	DATE	

Attachment F

SDDI Prototype Heater Canister Materials List	Test (High or low temp)	Supplier	Part Number	Quantity (Shop)
Heater Strips				
Option 1: Flexible Heater, Watlow, 6" x 101", Type K, 240V, 600W, shop price, specify center for TC	High Temp / Low Temp	Watlow	<TBD>	6
RTV Adhesive, 12 Oz Tube 1000 in^2, hi-temp	High Temp / Low Temp	Watlow	SA12	8
Thermocouple Parts, Feedthroughs, Extensions, and Tools				
Feedthrough: MTC 24-pin thermocouple connector, male, 20-24AWG	High Temp / Low Temp	Omega	MTC-24-MC	1
Feedthrough: MTC 24-pin thermocouple connector, female, 20-24AWG	High Temp / Low Temp	Omega	MTC-24-FC	1
Feedthrough: Male Pins-Chromega (+) spec. for Type K	High Temp / Low Temp	Omega	HPC-CH-P	1
Feedthrough: Male Pins-Alomega (-) spec for Type K	High Temp / Low Temp	Omega	HPC-AL-P	1
Feedthrough: Female Sockets-Chromega (+) spec for Type K	High Temp / Low Temp	Omega	HPC-CH-S	1
Feedthrough: Female Sockets-Alomega (-) spec for Type K	High Temp / Low Temp	Omega	HPC-AL-S	1
Feedthrough: Sealing Plugs for unused TC terminals	High Temp / Low Temp	Omega	MTC-HP	12
Extension wire, Type K, Duplex Insulated, 20 AWG (7x28), PFA insulation, twisted, shielded, 260C	High Temp / Low Temp	Omega	TT-K-20S-TWSH-1000	2
Tools for TC connectors				
Insertion tool		Omega	MTC-IT	1
Removal tool		Omega	MTC-RT	1
Heavy duty crimping tool		Omega	MTC-CT	1
Power Supply Parts, Feedthroughs, Extensions				
Feedthrough Power Connector; 200 C, 18 AMP, 500VDC, .062 pin	High Temp / Low Temp	KEMLON	16-B-18865-00	4
Feedthrough Power Connector Boot	High Temp / Low Temp	KEMLON	16-B-09845-13	4
Feedthrough Power Connector Crimp Pins	High Temp / Low Temp	KEMLON	16-B-08237-04	4
Option 1: Wiring, Power Supply Bulkhead to Canister, Single Conductor, Type TGGT, 12 AWG, 250 C, 600V, Teflo	High Temp / Low Temp	Carlsbad Electric Supply	-	500
Option 1: Wiring, Power Supply Alcove to Bulkhead, MSHA, 12/2, 25A, 600V, 100'	High Temp / Low Temp	Carlsbad Electric Supply	-	100
Terminal Block, Steatite, 500V, 44A, 240C, 12-post, 6-circuit, M5 (#10)	High Temp / Low Temp	Tempco	EHD-108-105	4
Wire terminal, non-insulated, nickel plated steel	High Temp / Low Temp	Tempco	TER-110-111	24
Remote Voltage Sense Parts				
Feedthrough 5-pin Connector; 2.2 AMP, 500VDC, 200C, .040 pin (.060 pin for pin #5-not used)	High Temp / Low Temp	KEMLON	16-B-8420	1
Feedthrough 5-pin Connector Boot, 20 AWG	High Temp / Low Temp	KEMLON	16-B-08421-06	1
Feedthrough Crimp Pins, 20 AWG	High Temp / Low Temp	KEMLON	16-A-09172-01	4
Option 1: Wiring, Power Supply Alcove to Bulkhead, MSHA, 18/2, shielded, 100'	High Temp / Low Temp	Carlsbad Electric Supply	-	500
Wiring, bulkhead to canister, Type TGGT, 20AWG, 250 C, 600V, Teflon, UL5256/UL5214, 500 ft	High Temp / Low Temp	Carlsbad Electric Supply	-	500
Wire terminal, non-insulated, nickel plated steel	High Temp / Low Temp	Tempco	TER-110-110	4

Attachment F

SDDI Prototype Heater Canister Materials List	Test (High or low temp)	Supplier	Part Number	Quantity (Shop)
Alcove: Rack, TDK Power Supply				
Power Supply, High Temp Test, 230VAC input, Output 300V, 3300 W	High Temp	TDK-Lambda	GEN 300-11-1P230	0
IS510 isolated analog programming, 0-5V, 0-10V	High Temp	TDK-Lambda	IS510	0
Male plug, 240VAC, 3-wire, 20A	Low Temp	Murrill Electric	Stoller Spec	1
19" Standard Half Rack, 24U high (48" overall height), 30" deep	High Temp / Low Temp	Carlsbad Electric Supply	-	1
Bulkhead				
Latching relay, DPDT, Primary-Secondary switching circuit, 16A, 300V, 4-wire, 2-coil, UL508	High Temp / Low Temp	Carlsbad Electric Supply	785XBXCD-12D	1
Mating Socket for Relay, 11 Terminal, Blade, DIN Rail or Panel Mount, 15A, 300V	High Temp / Low Temp	Carlsbad Electric Supply	70-463-1	1
Aluminum DIN Rail	High Temp / Low Temp	Carlsbad Electric Supply	16-700DIN	1
DIN Rail End Clip	High Temp / Low Temp	Carlsbad Electric Supply	16-DCLIP-1	2
Stainless Steel Spring Clip (Retainer)	High Temp / Low Temp	Carlsbad Electric Supply	16-1351	1
Junction Box (approx. 8"x8"x3")	High Temp / Low Temp	Carlsbad Electric Supply		
Endcap				
O-Ring, Hi-Temp Perfluoroelastomer FFKM, Highly Resistant to Sodium Chloride and HCl	High Temp / Low Temp	SW Seal & Supply	2-360FF200	1
Male Plug, NPT 3/8", (Argon purge), 316	High Temp / Low Temp	Grainger	1RTH2	2
All Thread, Pintel Lid, 1/2-13 x 12", 316	High Temp / Low Temp	Hall	4RDZ3	4
Nuts, for Pintel bolts, 1/2-13, 316	High Temp / Low Temp	Hall	1WB88	8
Washer, for Pintel bolts, 1/2, 316	High Temp / Low Temp	Hall	22UE44	-
Miscellaneous				
Potting material, Omega Bond 600 rated to 1426 C	High Temp / Low Temp	Omega	OB-600	2
Ceramic Beads (Sand), Cerabeads, 106 lb/ft^3, -0.03% thermal expansion, 0.69 W/mK, per ton	High Temp / Low Temp	Porter Warner	Cerabeads #850	2
Heat Shrink				
High Heat Tube		Provided by Electrician		