Margherita 2 Tube Manifold Assembly

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Abstract

The Margherita 2 serves as an improvement over the original Large-Area Picosecond Photo-detector (LAPPD) tile production facility, the Margherita. The Margherita 2 improvements include a removable bell jar for side-access to the internal fixturing, improved heating system, as well as a more compact cesium transport system. The outer manifold, constructed out of CF tubing[1] and VCR[2] is responsible for cesium introduction, transport, and pressure control during cesium deposition on the photo-detector tile. This vacuum-sealed process of *cesiation* is precisely controlled via temperature manipulations and closely monitored with real-time pressure, RGA, and temperature measurements. This paper documents the assembly process of installing and sealing the large and small tube manifold components on a steel cart, and constructing mechanical supports to keep the tubes suspended and thermally insulated from the cart.

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[1]Kurt J. Lesker Co. 2 3/4" and 4" O.D. ConFlat (CF) Tubing: http://www.lesker.com
[2]Swagelok VCR Fittings, https://www.swagelok.com

1 Manifold Overview

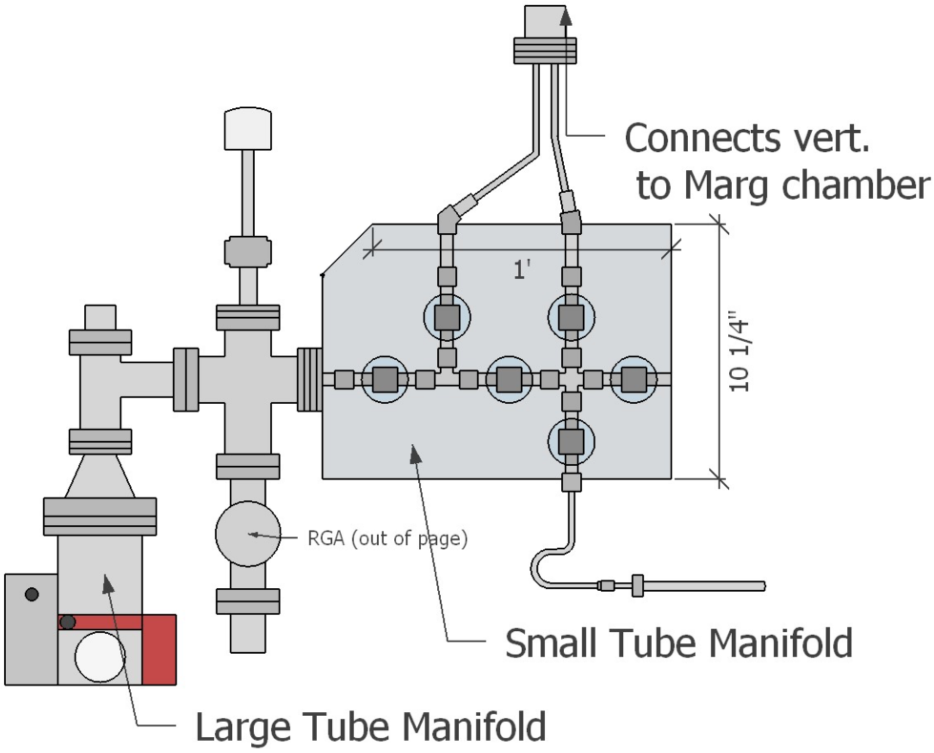

Figure 1: Schematic overview of the outer manifold (diagram courtesy of Hannah Tomlinson) responsible for controlled cesium vapor introduction and transport.

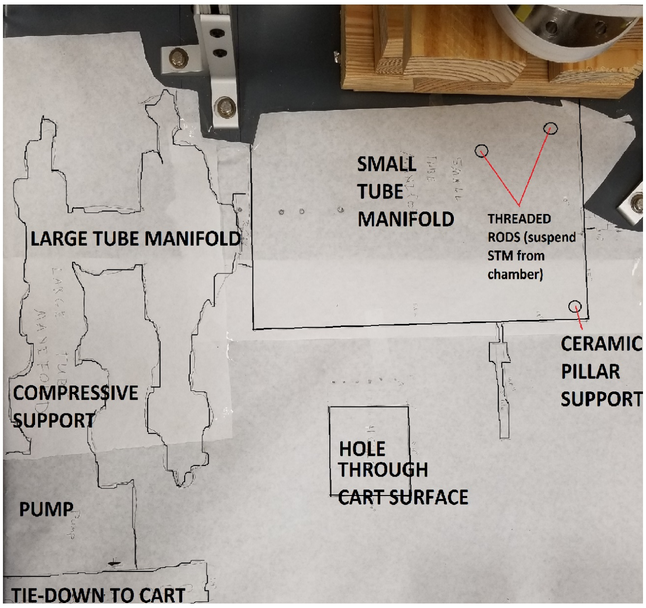

Figure 2: To-scale drawing of outer manifold on the top surface of the cart. Operation requires that the large tube manifold be suspended rigidly above the cart yet use supports located away from areas that need thermal insulation. Fig. 2 labels the two components of the large tubing cantilever support.

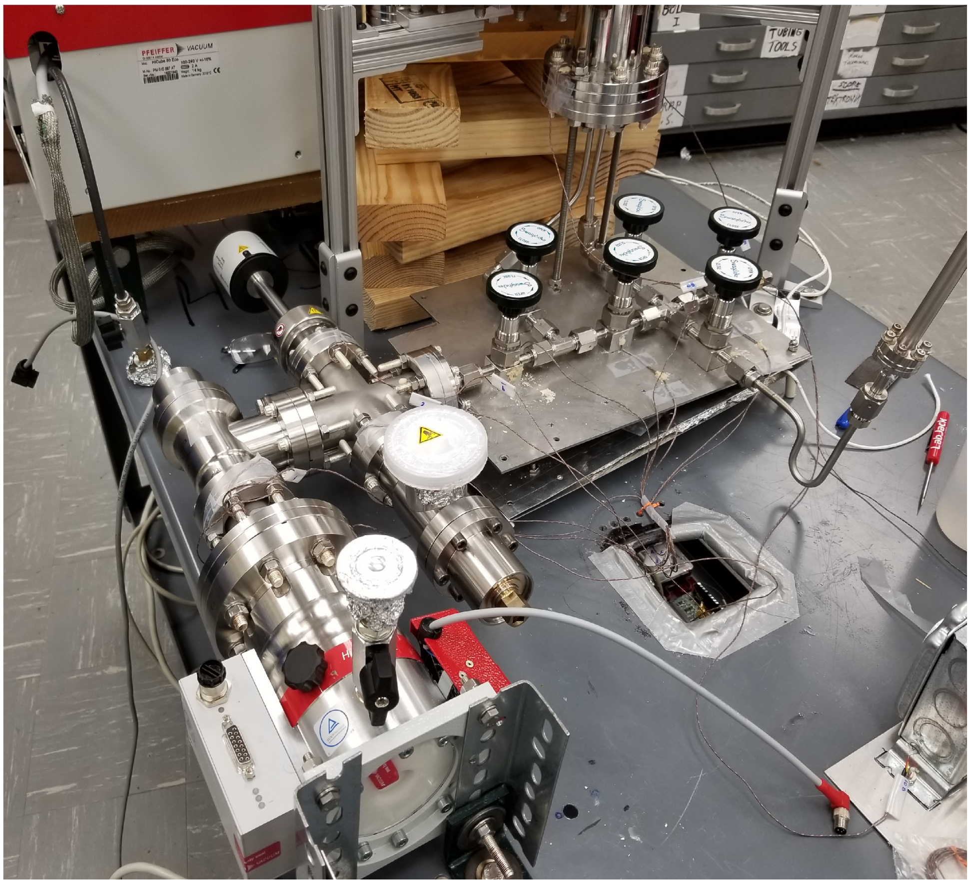

Figure 3: Outer manifold on June 27, 2017. Assembly is facilitated if the final attachment made is the heating plate, seen here ready for installation just below the Small Tube Manifold.

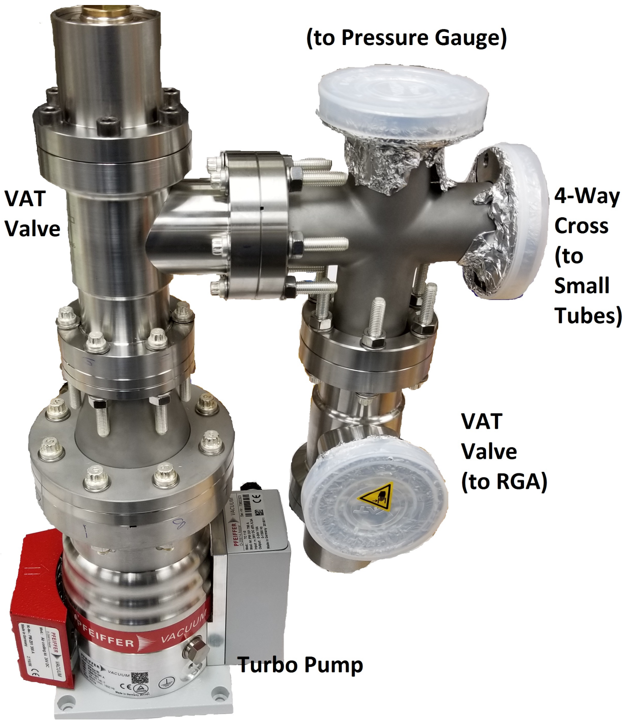

Figure 4: Photograph of the Large Tube Manifold

Figure 5: Residual gas analyzer, RGA 200, from Stanford Research Systems, which analyzes the composition of the vacuum, helping to trace contaminant outgassing as well as cesium pressure. The first RGA scan conducted on the Margherita 2 was qualitative, meant to provide an initial overall characterization of the system.

2 Large Tube Manifold Assembly

The Large Tube Manifold is a network of CF tubing [3] system for cesium pressure control. Its purpose is to connect a vacuum pump, pressure gauge, and Residual Gas Analyzer (RGA), and includes the following components:

1. RGA 200 [4] to monitor the composition of the gases in the Margherita 2 chamber (Fig. 5.).
2. Full nipple to accommodate the length of the ionizer on the RGA [5]
3. Two VAT valves[6]

[3]Kurt J. Lesker Co. 2 3/4" and 4" O.D. ConFlat (CF) Tubing: http://www.lesker.com

[4]Residual Gas Analyzer RGA 200 from Stanford Research Systems

[5]Full Nipple 2.75" OD Del Seal Flange, 1-1/2" OD from MDC Vacuums: https://mdcvacuum.com/DisplayPart.aspx?d=MDC&wr=&p=402002

[6]VAT Co. Series 541 DN 16-63MM and I.D. 5/8" -2 1/2" http://www.vatvalve.com

4. Vacuum turbo pump [7]
5. Conical reducer nipple[8] to adapt to turbo pump
6. Pfeiffer Pressure Gauge (Fig 6)[9]
7. Silver-plated bolts and gaskets (preferred over copper gaskets and stainless steel bolts; Teflon tape necessary for SS bolts)

Figure 6: Pfeiffer Compact FullRange Gauge PKR 251 (Pfeiffer Part No. PTR2600) fitted to the large tube manifold to measure the pressure inside the Margherita 2 in real time.

2.1 Vacuum Sealing ConFlat Tubes

In order to seal the tubes on all the pieces, every nut was tightened only 1/8th of a turn at first. After that cycle, a cross pattern of going across to the opposite nut from the one started was implemented, rotating clockwise to seal the flanges evenly. At all stages of assembly, vacuum cleaning and disposal of debris, as well as gloves and surgical masks, helped to achieve vacuum-tight CF tube sealings.

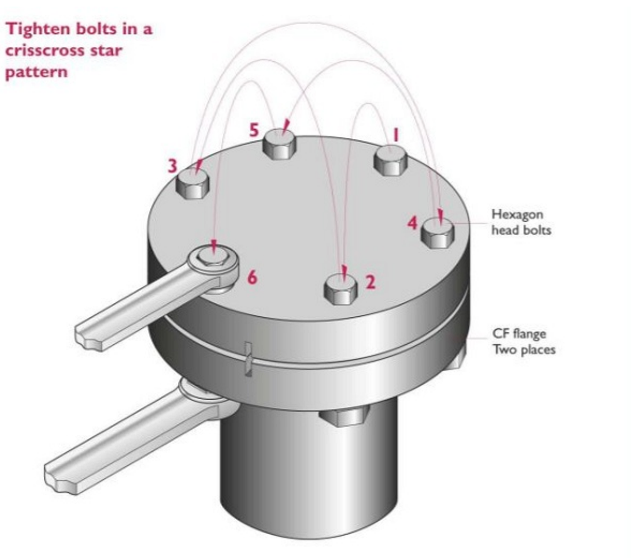

Figure 7: Best practice of even tightening of bolts when sealing CF tubing. Wear clean gloves and surgical masks, and clean sealing surfaces with ethyl alcohol, acetone, and/or isopropanol. Work in dust-free environment.

[7] HiPace 80 Turbo, Pfeiffer: https://www.pfeiffer-vacuum.com
[8] Kurt J. Lesker Co. Part No. CRN450X275, http://www.lesker.com
[9] Pfeiffer Compact FullRange Gauge PKR 251 (Pfeiffer Part No. PTR2600)

2.2 Constructing Mechanical Supports

Margherita 2 operation requires that the large tube manifold be suspended rigidly above the cart yet use supports located away from areas that need thermal insulation. Fig. 2 labels the two components of the large tubing cantilever support. Below the 4" CF flange of the conical reducer [10] connected to the turbo pump, successively thinner aluminum shims formed a precise compressive support. Steel angle brackets and scaffolds bolted the turbo pump mounting firmly to the cart (Fig. 3) to provide a downward force. The specific order of installation can facilitate installation (see Section 4: Order of Installation).

3 Small Tube Manifold Integration

The purpose of the small tube manifold is for introducing cesium into the Margherita. The cesium is heated to a gaseous state, in order to flow through a stainless steal J-Tube connected to the small tube, which leads to the Margherita. The curved part of the tube is kept at a cooler temperature in order to hold cesium at a liquid state. By controlling the temperature, the cesium can be better directed towards the tile.

3.1 Suspending the Small Tube Manifold from the Margherita 2 Chamber

The Small Tube Manifold is mounted on a 14" by 10" aluminum plate, on the bottom of which is attached a heating element sandwiched between two aluminum plates (Fig. 3 [11] For proper heating, supports for the tubing manifolds were limited to a few select locations to minimize heat loss to the metal cart and to leave space available for fiberglass insulation. In particular, Fig. 2 notes the Small Tube Manifold supports with red indicator lines. Two threaded rods replace two of the bolts that feed through the chamber-to-small tube 4" CF flange connection. These rods extend down through drilled holes in the Small Tube Manifold plate but not through the heating element plate, and securely bolt the Small Tube Manifold in its suspended position. A ceramic pillar between the cart and the Small Tube Manifold provides additional support. The goal of these supports is to fix the Small Tubes in place, completely independently of the large tube manifold to which it connects. The large tube manifold supports itself independently such that no mechanical stress is exchanged between the two manifolds.

4 Order of Installation

To facilitate installation, a particular order of assembly has been optimized in hindsight:

1. Make necessary holes in cart surface.
2. Mount Margherita 2 chamber on cart.
3. Construct wooden cribbing for Margherita 2 chamber as a safety precaution.
4. Assemble Large Tube Manifold 4, heating element, and Small Tube Manifold as independent parts.
5. Suspend Small Tube Manifold from chamber (Section 3), and seal (Fig. 7).
6. Position and level Large Tube Manifold in its position on cart. Shim conical reducer 4" CF flange with aluminum compressive support.

[10] Kurt J. Lesker Co. Part No. CRN450X275, http://www.lesker.com

[11] For detailed documentation on the construction of the heating element, refer to H. Tomlinson and B. Guthrie in LAPPD Document Library.

7. Mount turbo pump with angle brackets. Tighten bolts most of the way, leaving leeway for minor adjustments.

8. Seal CF flange (Fig. 7) between the Small and Large Tube Manifolds. Tighten angle bracket mountings.

9. Leak detection.

10. Install heating element and thermocouples.

11. Thermally insulate with fiberglass insulation.[12]

5 Leak Detection

The Pfeiffer leak detector was connected(Fig. 9 [13] directly onto the Pfeiffer Pump8[14] to the large tube manifold. The Pfieffer vacuum HiCube 80 Eco10[15] was used as an additional vacuum for the manifold to improve sensitivity in the case of small leaks.

With the Swagelock valves leading to the chamber closed, as well as the VAT Valve to the RGA closed, the ASM 340 was allowed to calibrate and start; then, the turbo pump was driven to full speed. Next, the outer manifold joints were probed with a small, helium-spraying needle. When the ASM 340 mass spectrometer registered an increased flow rate of helium, the location of the suspected leak was noted, the vacuum pump was shutoff, and the tubes vented in a safe manner, avoiding unnecessary stress on the bearings–never decelerating more than 10 Hz/s. The suspected leaks were fixed and the process repeated.

Figure 8: HiPace 80 Turbo Pump, which is integrated into the Margherita 2 vacuum pump station in series with the HiCube 80 Eco (Fig. 10).

6 Contaminant Identification via Residual Gas Analyzer (RGA)

Though the pressure gauge offers a quick metric of the extent of the vacuum, vacuum contaminant diagnosis cannot be performed via pressure measurement alone. Lower pressure does not necessarily imply a cleaner vacuum system. Furthermore, RGA mass spectrum measurements are far more precise than pressure gauges, and can be performed with built-in equipment almost as conveniently as pressure gauge measurements.

[12]10 and 11, as well as further DAQ and assembly, will be discussed in a separate report.

[13]ASM 340 Leak Detector with Rotary Vane Pump, https://www.pfeiffer-vacuum.com/en/products/leak-detectors/multipurpose/asm-340/

[14]Starter-Kit HiPace 80 ISO-K,https://www.pfeiffer-vacuum.com/en/products/turbopumps/hybrid-bearing/hipace-80/?detailPdoId=32054

[15]Hicube 80 Eco, https://www.pfeiffer-vacuum.com/en/products/pumping-stations/turbo-pumping-stations/hicube-eco/?detailPdoId=20020

Figure 9: Helium leak detector (ASM340), which was used to pump out the Margherita 2 Outer Manifold in conjunction with the Turbo Pump. While helium was sprayed into the CF and Swagelok leak-checking ports, the leak detector readings, in mbar*L/s He, was monitored for increase. A peak in He flow rate indicates that a leak has been momentarily sprayed; a plateau indicates that a leak has been sprayed for an extended period of time.

Figure 10: HiCube 80 Eco (Pfeiffer Turbo Pumping Station)

The RGA requires a null modem cable and a baud rate of 28,800 baud/s. PySerial on a script run off a Raspberry Pi 2[16] Pressure gauge should read below 10^{-6} Torr before an RGA scan is started. Once the filament of the ionizer is ignited, the pressure will spike; singlescan.py will read the pressure gauge and watch for the pressure to stabilize before proceeding with the scan.

Fig. 11 shows the first RGA analog mass spectrum scan of the manifold vacuum on July 13, 2017. As of July 19, sensitivity tuning of the RGA 200 is on the to-do list, although testing and adjusting the heating system for the outer manifold has priority at this time so that preparations for bake-out can be made. Thus, this initial scan is largely a qualitative measurement. More quantitative scans are planned for August 1 once the Margherita 2 has cooled from its initial bakeout.

[16]Setting a custom baud rate with a Raspberry Pi 3 requires a workaround. Thus, a Raspberry Pi 2 was a superior choice in the case of running the RGA.

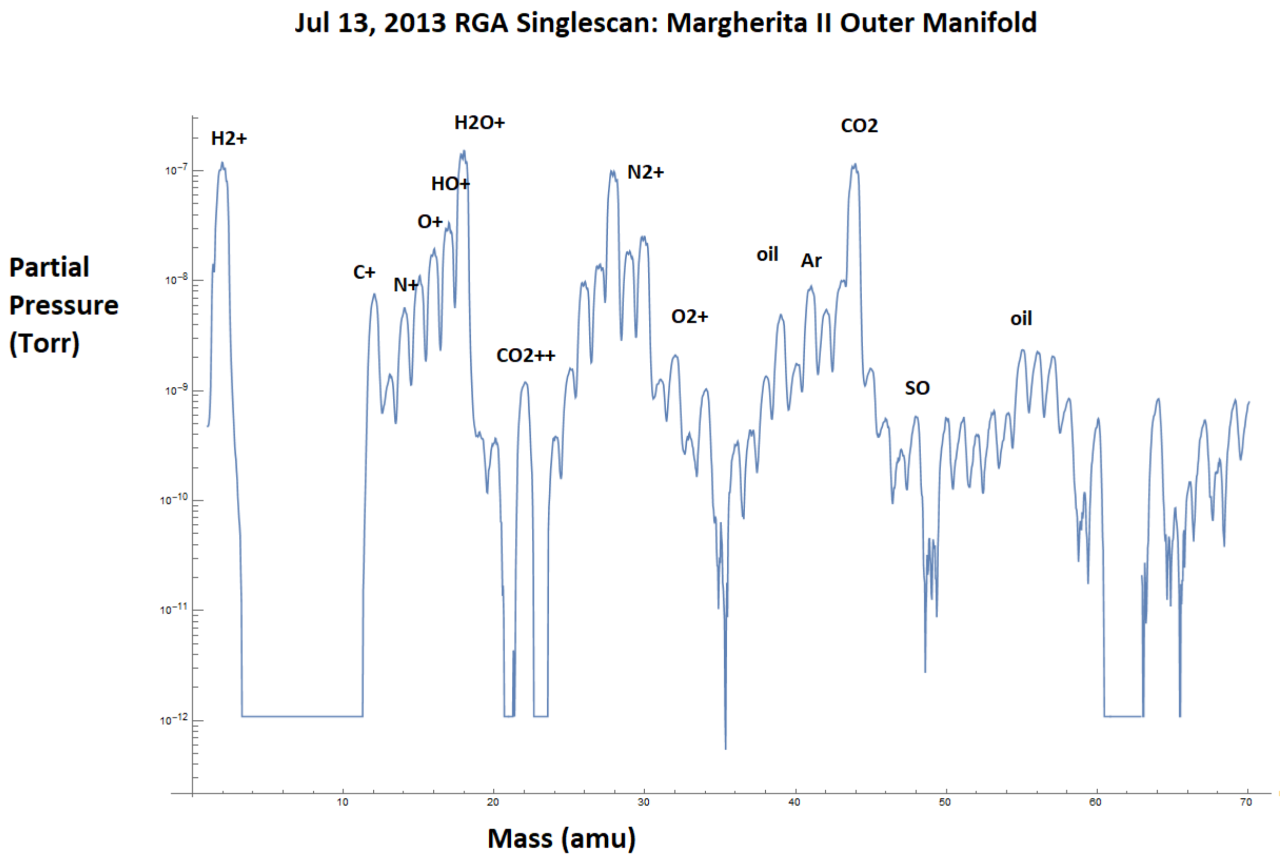

Figure 11: The initial Residual Gas Analyzer "single-scan" of the newly vacuum-sealed Margherita Outer Manifold, pre-bakeout (July 13, 2017). A high level of contaminants are observed in the plot of the partial pressure peaks at various areas in the mass spectrum, in which ionized species or their contaminant sources are labeled.

7 Fiberglass Thermal Insulation

Fiberglass Pipe Insulation [17] (Fig. 12) was cut and fitted to the tubing of the large tube manifold, while loose insulation was arranged in a cake-like, foil-covered prism insulating the small tube manifold (Fig. 13).

Junctions in which fiberglass pipes intersect without exposing any CF tubes were constructed. Viewed from directly above, at each fitting, one pipe has a triangle projection cut at 45-degrees; the piece into which it fits is cut as its negative. Projected onto the cylindrical piping, these lines become sine functions on the pipe surface, which are then cut out with a razor blade held in the same vertical planes designed from the overhead view. The result is a network of fiberglass pipe on the large tubes which minimizes heat loss Long sleeves, gloves, and inhalation protection are strongly recommended when working with fiberglass insulation.

[17] https://expressinsulation.com/

Figure 12: Fiberglass piping used to construct a thermal insulation system for the large tube manifold. When fiberglass is handled, skin should be covered and respiratory precautions should be taken. Suction clean the work area once fiberglass insulation has been installed.

8 Heating System and Preparation for Bakeout

Twenty-four calibrated thermocouples monitor the outer manifold, and six control thermocouples provide the Omega PID controllers with feedback for temperature control via OmegaLux heaters which are wrapped and integrated into the outer manifold under the thermal insulation. Thermocouples are calibrated at room temperature on Pi41 [18] and saved as additive offsets; further calibration is possible but unnecessary for our desired level of precision. Fig. 14 shows the location of the thermocouples on the outer manifold, and Fig. 15

[18] A Raspberry Pi 2 now located on Margherita 2 for Labjack DAQ (IP address 205.208.20.41)

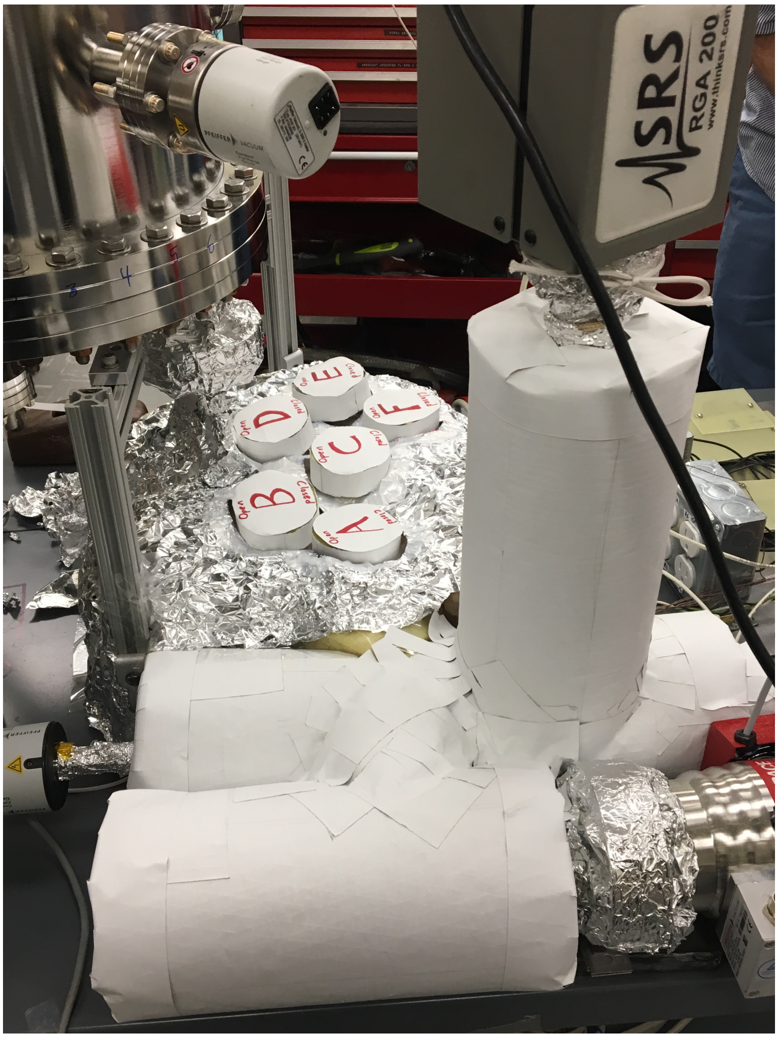

Figure 13: Thermal Insulation on Outer Manifold, with measurement equipment attached to take pre-bakeout readings. The red letters label the Swagelok valves on the Small Tube Manifold.

9 Next on the To-Do List

Future reports will document internal fixture installation, bakeout of the entire Margherita 2 system, qualitative RGA scans, new dark box design and construction, minimizing thermocouple noise, and anode readout connection to PSEC4A.

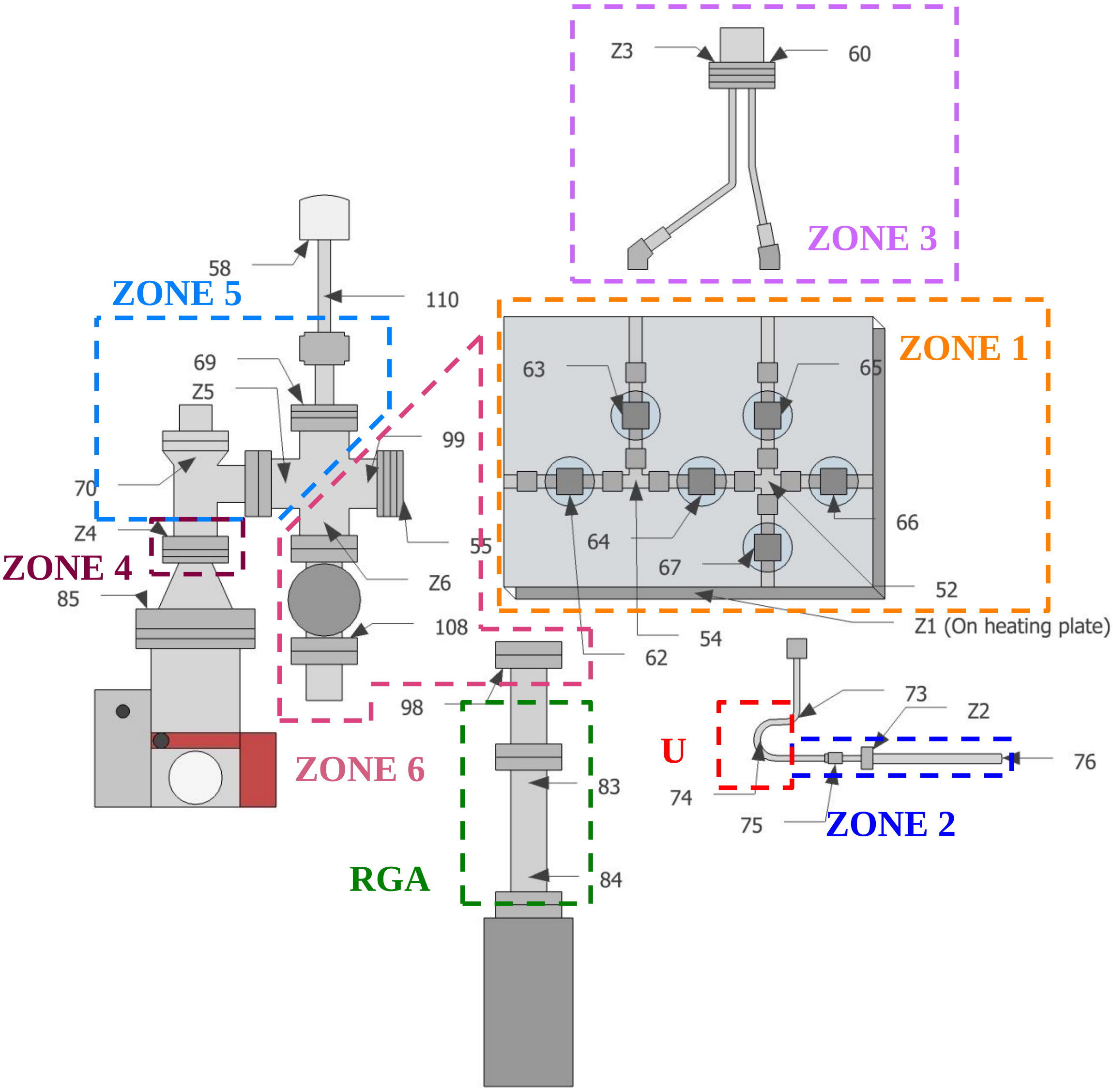

Figure 14: Schematic diagram of the thermocouples that monitor and feedback the heating system. Labels refer to AIN channels unless the thermocouple is a control thermocouple for an OmegaBox heater controller, in which case the label is by zone number. (diagram courtesy of Hannah Tomlinson).

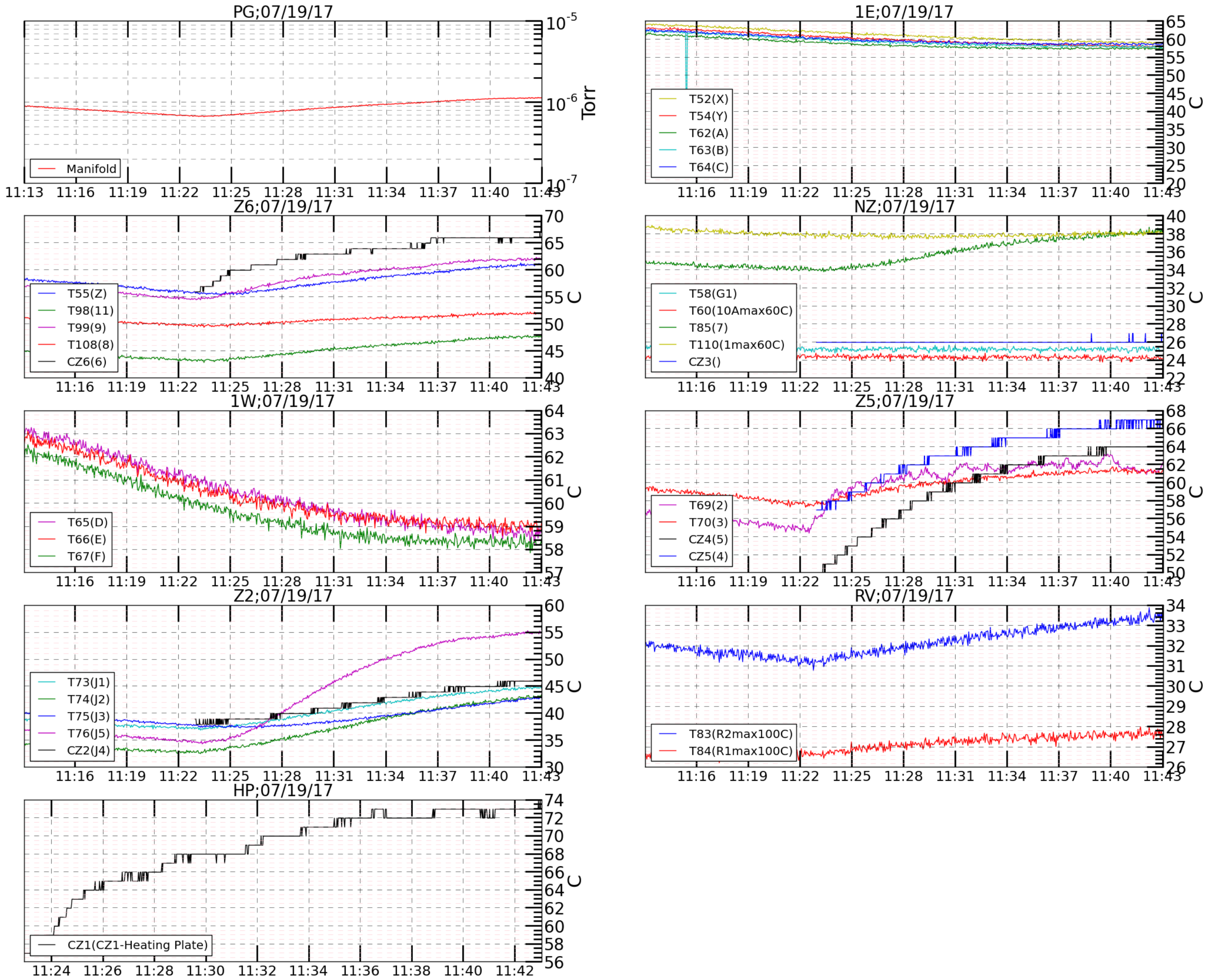

Figure 15: July 19 plots during heating system tests. The heaters were driven to setpoints at 40 C at 11:23. At these low temperatures, the concern is not temperature precision but rather uniformity on the large tubes, as well as keeping the RGA and pressure gauge below 100C and 60C, respectively, as the outer manifold is heated. As temperatures continued to be driven up to 250 degrees C, the differences in temperature across valves and CF flanges were plotted. Monitoring these differences to ensure that they stay below 60 C is critical to CF valve and flange seal health. Further bakeout will be documented in future reports.

Margherita 2 Internal Construction: Fixture Assembly and Heater Installation

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August 18, 2017

Abstract

The authors' previous report covered the construction, insulation, DAQ, and heating of the Margherita 2 cesium transport system, the outer manifold. This report documents the construction of the Margherita 2 internals. The bell jar was removed for access to the lightbox-tile site. Parts were rigorously cleaned. Heaters, thermocouples, press bars, and a dummy tile were placed in the newly-constructed light box, which was surrounded by reflective stainless steel foil. The bell jar was then sealed for bakeout.

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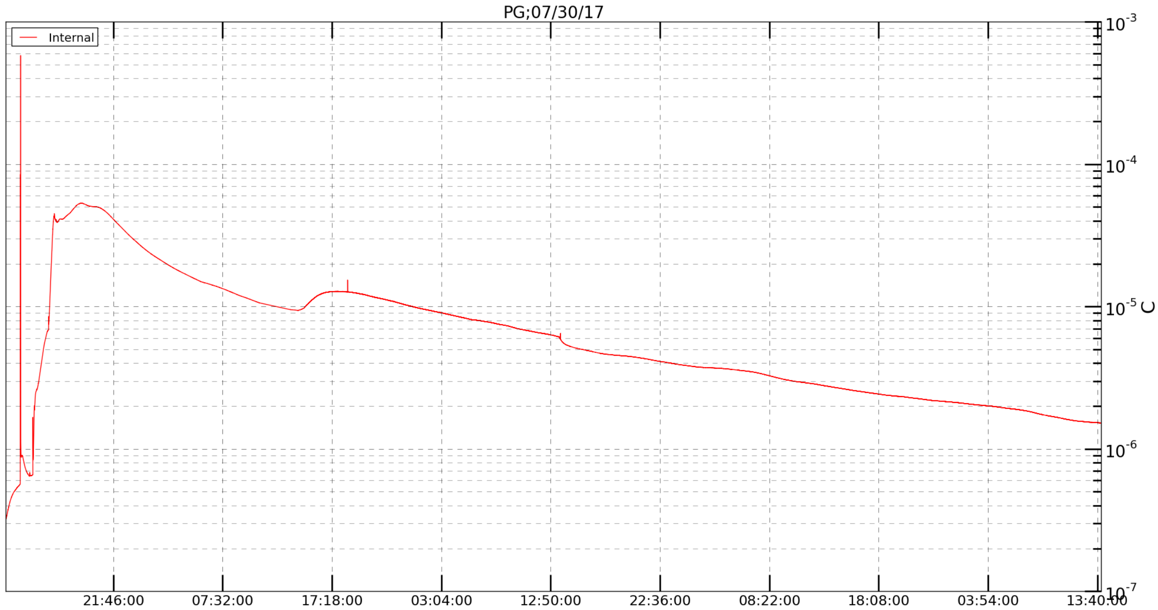

Figure 1: Pressure of the Margherita 2 Internals during its initial weeklong heating via radiative Ni-Chrome lamps. The pressure initially increased due to heating; high temperature was maintained over the July 26 - July 30 period, during which a steady pressure decline suggested outgassing and decontamination. Heat lamps were shut off at 19:00 on July 30. By the morning of July 31, the pressure had stabilized at 1.5×10^{-8} Torr.)

1 Margherita 2 Internal Construction

1.1 Bell Jar Removal Procedure

1. Follow recipe to stop the Turbo Pump and vent the Margherita 2 chamber safely.

2. Remove and collect in a container the 36 bolts and 36 nuts of the bottom flange of the Margherita 2.

3. Prepare a small cart or other flat, appropriately stable and wheeled surface with paper and several layers of aluminum foil as a landing and temporary storage area for the bell jar.

4. Move the crane and Margherita 2 cart so that the bell jar is accessible. Fasten the crane to the bell jar lifting hooks with a rope[1].

5. With a team of at least three people, slowly raise the bell jar with the handle pump while at least two members stabilize the bell jar, wearing surgical masks.

[1]This recipe was written for removal procedure in the old HEP building. Crane procedure will differ for the new building.

Figure 2: Removal of Bell Jar

1.2 Cleaning Procedure with Ultrasonic Bath

1. Prepare the sonicator:

   a. Fill with 4% by mass Micro-90 in deionized water.

   c. De-gas for 10 minutes.

2. Place all parts in independent fixturing (small parts in wire baskets, larger ones with wire handles and aluminum foil).

3. Place basket of parts into the sonicator, turn on at 50°C for 8-10 minutes.

   Fold the basket's handles inwards so that the lid closes fully.

4. During this time, boil 1 liter deionized water in the tea kettle.

   If sonicator finishes before water is done boiling, leave parts in bath.

5. Take basket of parts out of sonicator, hang over the plastic tray.

   Make sure that it is not submerged in or close to the water level of the tray.

6. Rinse parts by pouring deionized water over them.

   A lack of bubbles indicates that all detergent has been rinsed off.

   Pay special attention to holes, pockets, etc. in parts.

7. Dry parts

   For steel/ceramic

   Transfer parts (one at a time) to small pizza oven

   Make sure that no part surfaces are touching oven surfaces

   Bake

   Stainless steel: 200° C for 30 minutes

   Ceramic: 350° C for 2 hours

   For copper

   Blow-dry with nitrogen

8. Remove parts, store/install

   For aluminum

   instead of the above procedure: use Alconox Detergent[2] (stored in the ACC building as of Aug. 2017) with the Branson Sonicator[3]. Follow the bath's instructions, then proceed with the boiling deionized water rinse. Bake at 150 C for 30 min to dry.

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[2] Alconox Powdered Precision Cleaner, https://alconox.com/product-catalog/

[3] Branson 2510 Ultrasonic Cleaner https://www.marshallscientific.com/Branson-2510-Ultrasonic-Cleaner-p/br-uc.htm

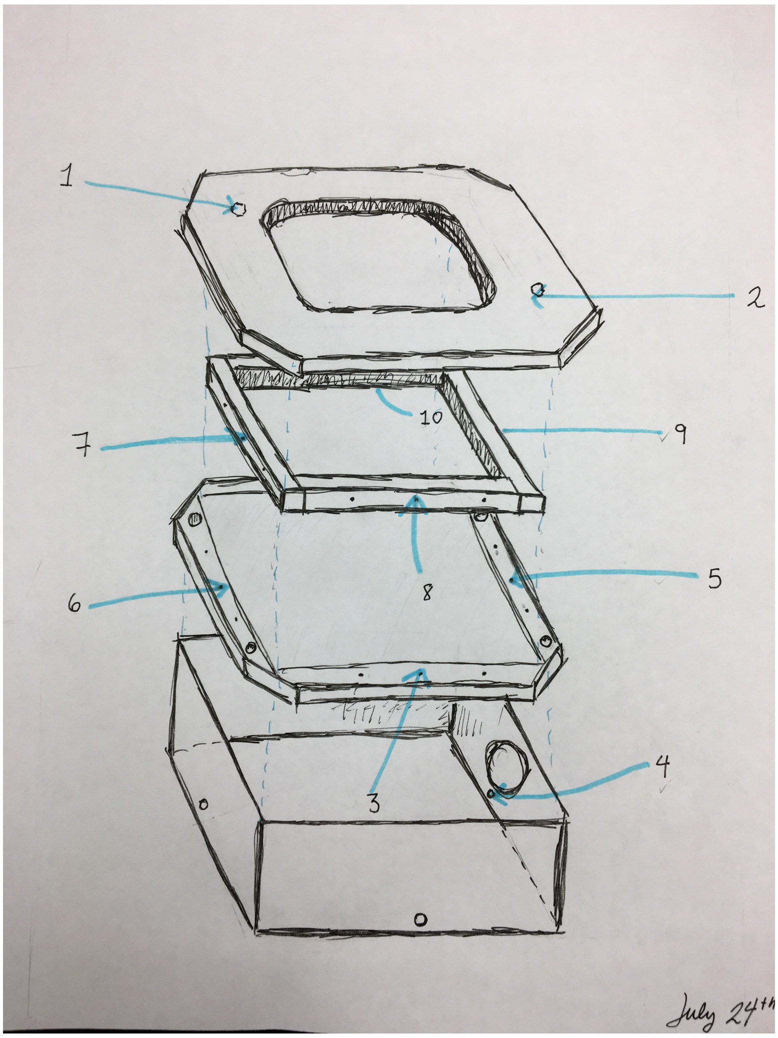

Figure 3: Custom-built thermocouples were attached to the fixture at the points indicated in the sketch, drawn by H. Tomlinson

1.3 Sealing the Large Chamber Flange

Replace the large copper gasket if necessary. Each large gasket can be used three times; this usage is tracked in black marker on the side of the bell jar. After the bell jar has been replaced (follow the bell jar removal instructions in reverse order, taking care that steel foil insulation is straightened at frequent intervals when the crane lowering is paused), follow these instructions to seal the large flange:

1. Place in all 36 bolts and nuts, tightening by hand.

2. Tighten about 1/8 turn past finger-tightness torque, in any order. 9/16 inch wrenches are necessary.

3. With a group of two people, each with a torque wrench, begin tightening bolts to 150 ft-lbs starting with the four bolts labeled "1." Tighten in a cross-pattern; your partner should always be tightening the bolt that is 180 degrees opposite from the one you are tightening. Tighten in order from "1" to "9" in this cross pattern for all thirty-six bolts.

4. Next, find out how many times the copper gasket has been used by looking at the side of the bell jar, where markings read "Lower gasket 250 300 350." Each time the gasket is sealed, one of the three numbers is crossed out; the number itself indicates the torque in ft-lbs at which the flange was sealed (the seal must be progressively tighter as the gasket get successively flattened). Select the appropriate torque on the torque wrenches.

5. Repeat step 3 with the higher torque.

6. Repeat step 5 twice more for a total of three passes at the higher torque. Despite applying the same torque each time, the bolts should tighten slightly because tightening one bolt slightly loosens its neighbors.

7. Using a black marker, cross out the appropriate number on the bell jar. The pump and pressure gauge should next be connected so that the new seal can be checked for leaks–see Pump Operation and Leak Detection.

2 Lightbox installation

2.1 Ni-Chrome Lamp Heaters

1. Connect 4 heater power wires to inside of Marg2 electric feedthru pins A,B (heater 1)[4] and pins K,J (heater 2). These will supply AC power from the Variac's output.

2. Insulate the power wires/thermocouples with ceramic beads (Fig.4. Connect to strain-relief terminals, then to screws on pillars.

3. Mount Ni-chrome heaters and connect the power wires. (Fig.6. Install walls, one of which has a vent hole.

4. Build the upper layers; install press bars. Calibrate the press bar spring mechanism with an approximate 5 pound weight (Fig.2.

5. Install ten sheets of stainless steel foil, on all four sides of and on top of the fixtures. Replace and seal bell jar.

[4] Refer to M2 Vol. 1 Page 4-5

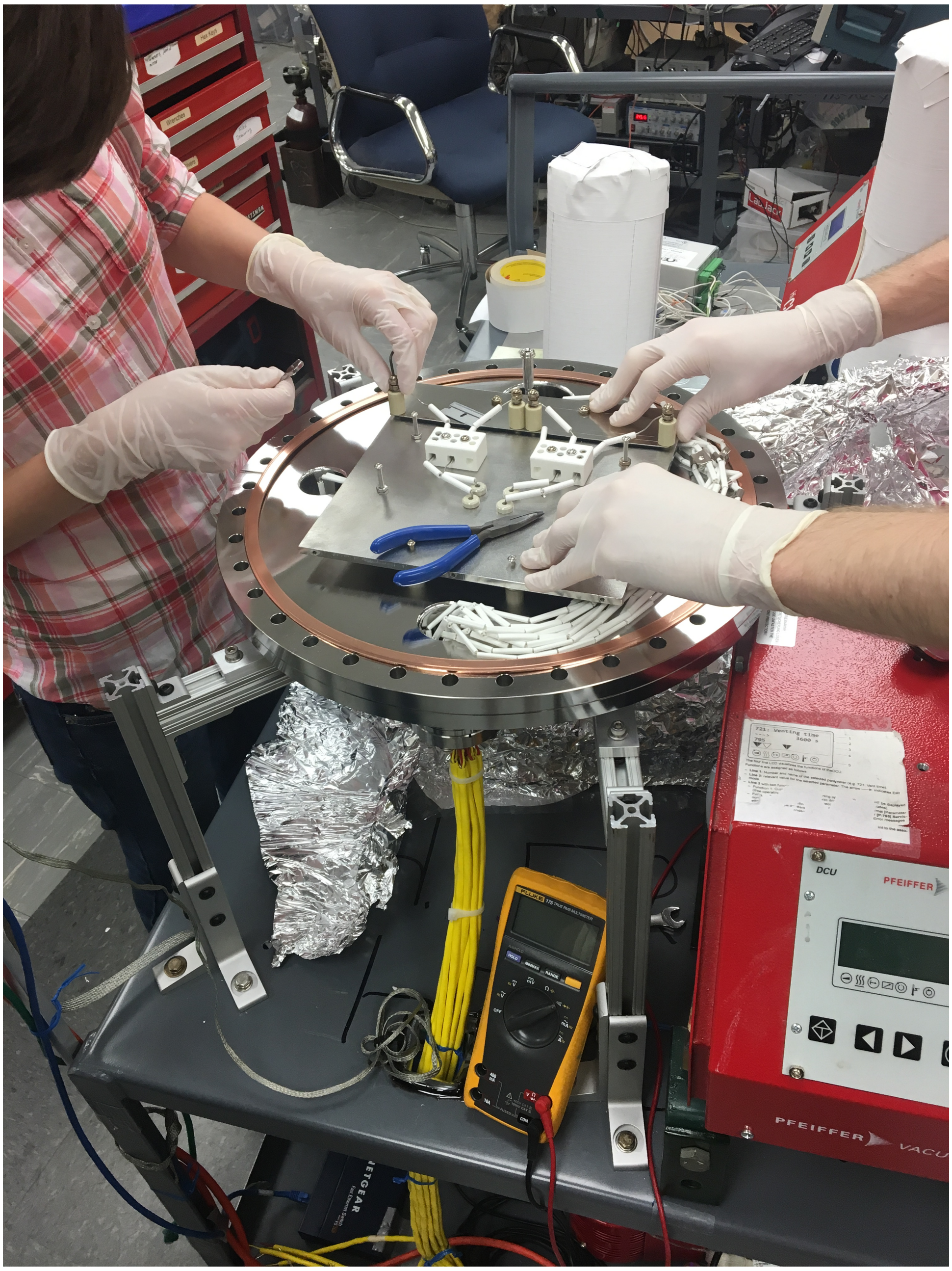

Figure 4: Electrical connections are made as the base of the fixture is installed. Care should be taken to avoid short circuits, and screw terminals such as the white boxes in the figure should be deployed for strain relief.

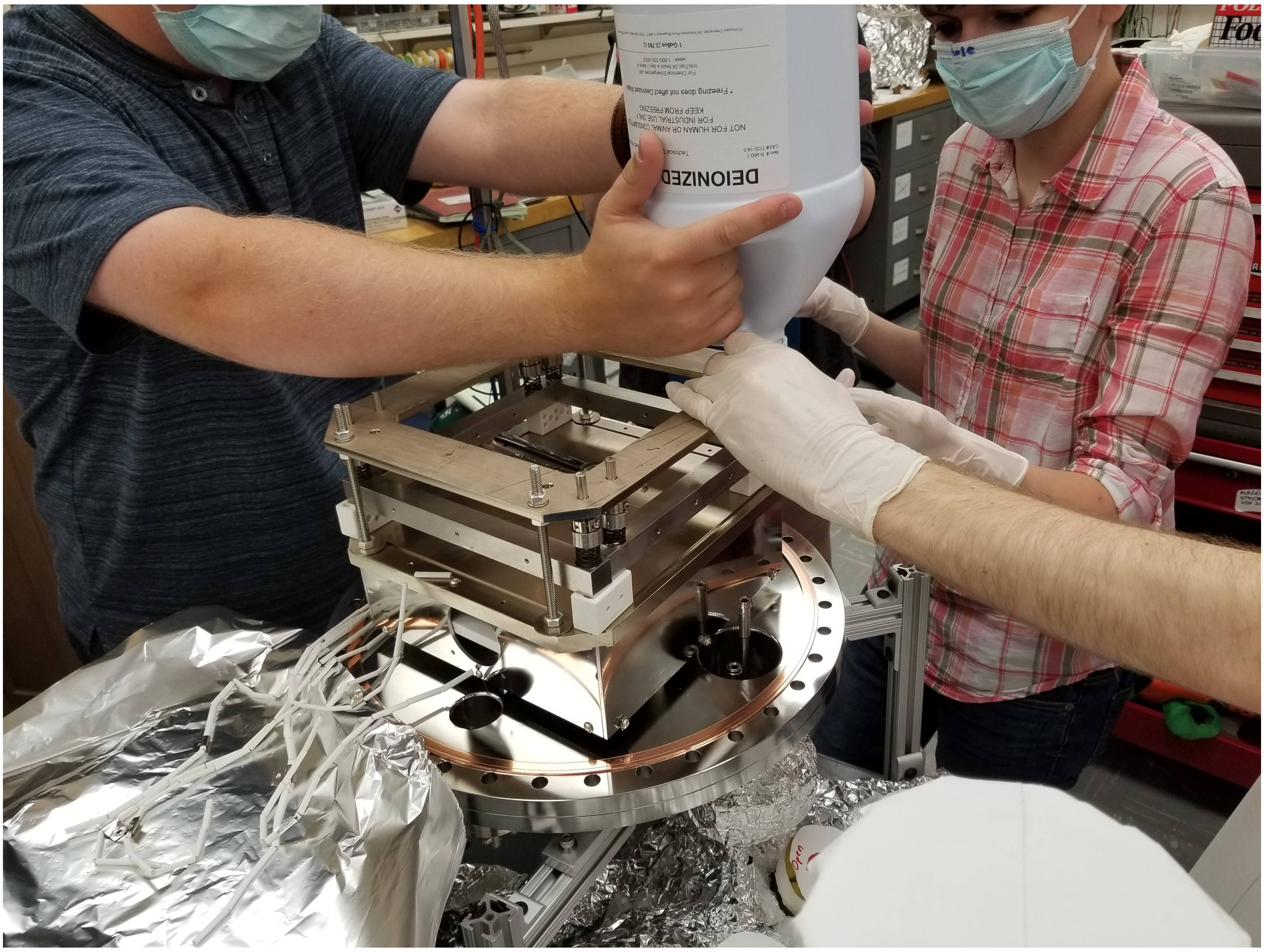

Figure 5: Spring-loaded press bars apply constant pressure to the tile, even as the indium solder flattens as it melts, which causes the height of the tile to slightly decrease. In order to maintain this constant pressure, then the press bars are spring loaded and calibrated with a five pound weight as shown in the figure. A bottle of deionized water which is approximately five pounds was used for this step.

Figure 6: The fixture contains two white Ni-chrome heaters at its lowest level. Since these heaters operate in ultra-high vacuum, they are largely radiative. Thus, stainless steel foil acts as a reflective insulation. Ten thermocouples monitor the internal temperature.