Title

Fabrication Procedure for the Old TPC Magnet

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PROGRAM — PROJECT — JOB

PEP-4 EXPERIMENT

THIN SUPERCONDUCTING SOLENOID COIL

TITLE

FABRICATION PROCEDURE FOR THE OLD TPC MAGNET

This Engineering Note is a combination of two procedure notes written on October 13, 1978 and May 29, 1979. The procedure notes were used as a guide by the shop during the construction of the TPC magnet between October 1978 and March 1980. The original notes were never formally issued. This note has been updated to reflect the procedure used during the construction of the old coil. Perhaps this Engineering Note can be used as a rough guide during the reconstruction of the coil. I invite the comments of others particularly the people from the LBL Assembly shop.

The procedures which are described in this note are: 1) The preparation of the bore tube; 2) the winding of the ultra pure aluminum layer; 3) the vacuum impregnation of the ultra pure aluminum layer; 4) the winding of the coil and the cooling tubes; 5) the vacuum impregnation of the coil and the cooling tubes; 6) the assembly of coil package (plumbing, electrical leads and instrumentation); 7) the preparation and testing of the cryostat vacuum vessels; 8) the assembly of the liquid nitrogen shields and preparation for final assembly; 9) the final assembly of the entire TPC magnet.

Preparation of the Bore Tube Procedure

1. Mount the bore tube on the winding machine so that it will turn without wobbling. Measure the basic dimensions of the bore tube.

2. Scribe the bore tube every 30° on one end flange. Designate this end flange as the North end. Mark this end flange as the face of the clock starting with 1 and ending with 12 in a clockwise fashion. Scribe the other end of the bore tube every 30°. The scribe marks on the opposite end flange shall correspond exactly to those on the North end. (A line drawn from a scribe mark on the North end to the corresponding scribe mark on the opposite end shall be paralled to the axis of the bore tube.) The opposite end of the bore tube shall be designated as the South end. The numbering of the South end scribe marks will correspond to the numbering of the North end (12 o'clock at the South end corresponds to 1 o'clock at the North end and so on). Clearly mark each scribe mark as to its clock position and clearly mark which end is the North end and which end is the South end.

3. Mark with blue paint the position to be occupied by the support brackets in accordance with LBL Drawing numbers 19C3406 and 19C3416. This designates a no mans land where no holes may be drilled. Positions at 1, 5, 7 and 11 o'clock will have radial support brackets, the no mans strip should be 8.5 inches (216 mm) wide. Position at 3 and 9 o'clock will have anti rotation support brackets, the no mans strip should be 18.0 inches (457 mm) wide.

4. Map the surface of the bore tube to determine out of roundness and the position and topography of hills and valleys on the bore tube surface. The topography of hills and valleys will be transferred to the appropriate LBL Drawing, (number 19C3384).

5. Remove all burrs from the bore tube surface.

6. Drill the holes in the bore tube end flanges for current inlets and outlets, ultra pure aluminum inlets and outlets in accordance with LBL Drawing numbers 19C3406 and 19C3416. Deburr and smooth the holes. Cut slots for the oval cooling tube in accordance with LBL Drawing numbers 19C3406 and 19C3416. Make sure the slot has smooth parallel walls so that a machined piece of metal can be inserted later to insure bore tube rigidity. The slots will be located at the 2, 6 and 10 o'clock positions at both ends of the bore tube. Drill five 11/16 inch diameter holes through the bore tube flange at the North end for electrical wire feedthroughs. These holes are to be drilled in accordance to LBL Drawing number 19C3406. Drill and tap the holes needed to hold the electrical connectors to the flange (see LBL Drawing 19C3406).

7. Drill the 24 bore tube holes for introducing the epoxy. (See LBL Drawing number 19C3384).

8. Insert the RL fittings in the 24 holes for epoxy introduction to the magnet.

9. Locate and drill ten indentation holes in the bore tube. These holes are to be 3/4 inch in diameter and 1/8 inch deep. They must be drilled with a flat bottomed drill so that the holes have a flat bottom. The holes, which contain a NEMA G10 insulator for the Q coils are located in accordance with LBL Drawing number 19C3486.

10. Fabricate NEMA G-10 cups which hold the Q coils and glue them into the 1/8 inch deep holes described in paragraph 1 of this section.

11. Fill the valleys in the bore tube profile with Devcon to insure roundness and a smooth winding surface.

12. Fabricate from NEMA G-10 the superconductor and ultra pure aluminum lead feedthrough (caution, remember that one can not bend the ultra pure aluminum excessively).

13. Fabricate from NEMA G-10 strip the ground plane insulation on the bore tube flange. Glue the strips on the flange insuring no cracks between the region where the superconductor is wound and the bore tube flange. Devcon the gap between the flange and the bore tube. Devcon can help glue the ground plane insulation.

14. Drill and tap holes in the bore tube for the Silicon Diode Thermometers. There will be three such holes (see LBL Drawing number 19C3486).

15. Clean and sandblast the bore tube surface in preparation for ultra pure aluminum windings.

Winding of the Ultra Pure Aluminum Layer

1 Glue the stripes of NEMA G-10 which form the epoxy channels on the bore tube surface. The stripes should parallel the axis of rotation of the bore tube. The strips should be placed so as to not impede the flow of epoxy from any of the 24 fill holes. The strips should not be continuous along the bore tube. There should be breaks to allow circumferential flow of epoxy around the tube. The exact pattern of the strips will be determined later.

2 Glue 1/8 thick piece of NEMA G-10 in the strip at the ends of the bore tube and at the center of the bore tube. Allow room for epoxy flow, silicon diode insertion, Q coil insertion, and cross overs for the ultra pure aluminum coil. (See LBL Drawing Number 19C3486).

3 Insert and glue the Q coils to the NEMA G-10 provided on the bore tube. The Q coils are attached to twisted pair leads of the appropriate length. The center Q coil wires go to Connector 1 the north Q coil wires go to Connector 2.

4. Insert the silicon diodes in the taped holes on the bore tube. Wire the diodes to twisted pair leads of the correct length. Put a large spot of epoxy on the diode to protect it. The diode wires go to Connector 3.

5 . Wind a layer of half lapped fiberglass tape over the bore tube and it's epoxy channel strips. The tape should be wound so that the NEMA-G10 strip is visible as a lump under the glass. There should be a channel for the ultra pure aluminum to be wound in when it crosses the region with the NEMA G-10 strips.

6 . Wind the ultra pure aluminum along with a dacron fishline cord. The cord and the ultra pure aluminum should be wound together so that alternating cord and aluminum turns are formed (see LBL Drawing number 19C3384). The ultra pure aluminum must be wound with no tension. The aluminum is easily deformed. The cord can be wound under tension; the spool may be well away from the bore tube. Avoid deforming the aluminum. Splices in the aluminum may be made with soft solder. See that the joints are at least 6.0 m long (20 feet) aluminum layer. We ask that there be no turn to turn short in the aluminum layer. The position of cross overs across the strips containing epoxy parts, Q coils, and diodes is shown in LBL Drawing Number 19C3486.

7. Record the following data about the ultra pure aluminum layer:

   a) The number of turns in the coil.

   b) The location of bad spots.

   c) The location of coil splices.

8. Scotch tape NEMA-G10 strips which form epoxy channels over the ultra pure aluminum coil. Wind the half lapped glass cloth over the strips. Remove the scotch tape once the strips have been captured by the glass cloth.

9. Record the thickness of all layers of tape, ultra pure aluminum and NEMA G-10 strips. Check for shorts in the aluminum coil.

10. Solder the Q coil wires to the appropriate pins on electrical connectors 1 and 2. Solder the silicon diode wires to the appropriate pins on electrical connector 3. Glue with epoxy the back of the connectors 1 through 3. Insert a teflon plug with mold release on it into the holes in the flange for electrical connectors 4 and 5. Seal around the teflon plugs with dux seal.

Vacuum Impregnation of the Ultra Pure Aluminum Layer

1. Prepare and build a shround, which is vacuum tight, that goes around the outside of the ultra pure aluminum coil package. Two approaches can be used; they are:

   a) A shroud can be made from metal sheet. This form does not fit every nook and cranny in the coil. No visual sighting of the epoxy is possible with this system.

   b) A plastic film can be used. It must be backed with a coarse meshed hardware cloth screen. The screen permits one to see the epoxy. This shroud will conform to various nooks and crannies in the coil.

   Fabrication of the shroud is difficult to specify in advance. W. Wenzel of the Assembly Shop, will be given a great deal of latitude in the selection of shroud material and the construction technique for the shroud. The shroud should be fabricated from 1/16 inch thick aluminum sheet which is welded together in the sheet metal shop. The shroud should have 26 ports in it in order to introduce the epoxy. The location of 24 of these ports should correspond to the location of the holes in the bore tube. The other two holes should be located near the first (bottommost) fill hole. The inner surface of the shroud should be coated with mold release.

2. The shroud should be wrapped with 1/2 OD or equivalent hose or tube to carry the hot water used to heat the bore tube and epoxy. The hose should be wrapped so that there is one turn every couple of inches. Check for shorts in the aluminum coil.

3. Seal all leaks in the shroud and between the shroud and the bore tube. Vacuum leak check. Repeat the sealing procedure; leak check and so on until mold is vacuum tight. Caution the procedure will take weeks. Check for shorts in the aluminum coil.

4. The finished mold should be insulated with 4 inch thick fiberglass insulation and aluminized mylar (to reduce radiation heat transfer). The insulation should be put around the outside and on plywood discs mounted on the ends of the bore tube.

5. When the mold is vacuum tight and insulated, pot the coil according to the procedure given in LBL Specification M20 and LBL external report LBL-7931. Any variations proposed for the potting process must be approved by Don Coyle or Walt Wenzel in the Assembly Shop.

6. Remove the shroud from the outside of the coil. Inspect the outside surface for voids and cracks.

7. If the epoxy pour was uneven, the epoxy potting process must be re-evaluated. Corrective measures can be taken. Small voids or bubbles can be filled with Devcon or epoxy. Clearly, this is a step we don't want to deal with. Check for shorts in the ultra pure aluminum coil.

The Winding of the Coil and the Cooling Tube

1. Check the ultra pure aluminum layer for turn and turn to bore tube shorts. Clear any shorts that are found.

2. Map the surface of the bore tube to determine out of roundness and the position of hills and valleys.

3. Clean and sandblast the surface of the potted ultra pure aluminum.

4. Fill the valleys in the bore tube profile with Devcon to insure roundness.

5. Drill out the holes in the RL fitting through which epoxy was poured into the ultra pure aluminum. The 24 drilled out holes permit epoxy to be poured into the inside of superconducting coil.

6. Clean and sandblast the surface of the Devconed bore tube.

7. Glue NEMA G-10 strips which form the epoxy channels on the surface of the bore tube with the ultra pure aluminum on it. The strips should be parallel to the axis of rotation of bore tube. The strips should not impede the flow of epoxy from any of the 24 fill holes. The strips should not be continuous along the bore tube. There should be breaks in the epoxy to allow circumferential flow of epoxy around the tube. The exact pattern of the strips is to be determined later.

8. Wind a layer of half lapped fiberglass tape over the epoxy channel strips.

9. Wind the first layer of the superconducting coil over the glass tape layer. The turns density of the coil must be uniform. It is suggested that the coil be divided into ten parts. Each of the ten parts should have the same number of turns (about 87 or 88 turns). Splices in the coil will be lap joints which are 60 cm long soldered with Sn 62 solder. The coil conductor shall be wound under a tension of 155 lbs. (690 N). All solder joints will be insulated by fiberglass sleeve. The joint should be painted with fast drying laequer before the sleeve is pulled over the joint. Care should be excercised in bringing the conductor through the North end. A pigtail which is 3 feet long shall be left at the North end. The coil shall be wound from North to South on the first layer. The pigtail at the South end is the center tap winding. The center tap is spliced as a lap joint on to the first layer as it makes a transition to the second layer. Do not start winding the second layer until after the center tap is insulated and Step 10 is completed. The insulation of the center tap is handled just like a normal coil lap splice. The center tap pigtail shall be 3 feet long. Make sure tension is maintained at all times. Check for shorts continuously.

10. Wind a layer of half lapped fiberglass tape over the first layer of the coil.

11. Wind the second layer of the superconducting coil just as given in 9, except that the second coil layer is wound from South to North. Make splices as in 9, the final pigtail at the North end shall be 3 feet long. Make sure tension is maintained at all times. Make sure the turns density of the second layer is identical to the first coil layer. Check for shorts continuously.

12. Wind a layer of half lapped fiberglass tape over the second layer of the coil.

13. Check for shorts in the coil.

14. Five P coils will be wound evenly from end to end along the top of the glass tape covering the superconducting coil. These coils will have 100 turns which are evenly distributed along the length of the coil between the bore tube flanges. Each coil will be wound with relatively fine insulated wire the color of the insulation of each coil wire will be different. The leads from these coils will be connected to the pins of electrical connector number 4.

15 . Check for shorts in the coil.

16 Glue NEMA G-10 strips to form epoxy channels as in Step 7 of this section.

17. Wind the flattened aluminum cooling tube on to the coil.

    a) Insert one end of the cooling tube into the slot at the 2 o'clock position. Wind the first tube so that two other tubes can fit in the slot between the turns. The final turn is then passed through the flange at the 6 o'clock position at the opposite end. Wind the tube from North to South. (This tube will be marked yellow.)

    b) Insert one end of the second tube into the slot at the North end at the 6 o'clock position. Wind the tube next to the first turn leaving space for the third turn. The final turns are passed through the flange at the 10 o'clock position at the South end. (This tube will be marked blue.)

    c) Insert one end of the third tube into the slot at the North end at the 10 o'clock position. Wind the tube from North to South between the first and second tubes. The tube will exit at the south end in the two o'clock position. (This tube will be marked red.)

    d) Each tube should have a 2 foot long pigtail at each end.

18. Check for shorts in the coil.

19. Mark the tubes with paint which will not desolve in epoxy. Color each of the three tubes a different stripe so that one can see the stripes through the epoxy when the potting is complete.

20. Insert the machined pieces which hold the tubes as they pass through the flange.

21. Wind a layer of coarse weave, half lapped glass tape over the squashed aluminum cooling tube.

22. Check for shorts in the coil.

<u>Vacuum Impregnation of the Coil and Cooling Tube</u>

1. Prepare the shroud as in the previous potting operation. Put this shroud around the outside of the coil package. The shroud should have 26 ports in it as in the previous potting operation.

2. No hose is necessary, one of the cooling tubes will carry the hot water to control the temperature of the epoxy during the pour.

3. Check for shorts in the coil.

4. Seal all leaks as in Step 3 of the previous potting operation.

5. Insulate the mold as in Step 4 of the previous potting operation.

6. Check for shorts in the coil.

7. Once the mold is vacuum tight, follow the potting procedure given in Step 5 of the previous potting operation.

8. Pray to the God of your choice.

9. Once the curing operation is complete, remove the shroud from the outside of the coil and inspect the surface for void, cracks and missing epoxy.

10. If the cast is a good one, open a bottle of champagne and thank the god of your choice. If the cast is not good, curse the god of your choice. Prepare for any action which is appropriate. In other words "PUNT".

11. When the cast has been inspected and found good and smooth on the outside surface, apply a glaze coat of epoxy.

12. Map the surface of the coil package to determine out of roundness and the hills and valleys which might exist. Check for shorts in the coil, check for shorts in the ultra pure aluminum coil.

The superconducting coil is finished except for the installation of helium leads, electrical leads, the nitrogen shields and the cryostat vacuum vessel.

Assembly of the Coil Package

1. Check the superconducting coil, the ultra pure aluminum coil and all instrumentation wiring for shorts. Note the defective instrumentation circuits. Check the resistance of the coil from end to end and from ends to center tap. Check the resistance of the ultra pure aluminum circuit.

2. Hi-pot the superconducting coil to ground; try to take the coil up to 10kV without breakdown. Hi-pot the ultra pure aluminum coil to ground; try to take the ultra pure aluminum coil to 5kV. Hi-pot the superconducting coil to the ultra pure aluminum coil; try to take the coil up to 10kV without breakdown.

3. Fit the support brackets to the coil end flange. Use Devcon if necessary to insure a good fit. The large brackets go at 3 and 9 o'clock positions at both ends. The small brackets go at the 1, 3, 5, 7 and 11 o'clock positions at both ends. Mark each bracket to indicate its fitted position.

4. Match drill the bracket and flange holes for the screws and dowel pins. For God sakes don't drill the horizontal holes in the end flange too deep, you will screw up the coil if you do. Tap the screw holes for the Keenserts.

5. Insert the dowel pins for the brackets. Insert the screw Keenserts in the end flange for the bracket.

6. Install the brackets, do a final Devcon fit if it is necessary to insure a good fit.

7. Fabricate and install the 1/4-inch thick 6061 aluminum strips between the brackets. Be careful where holes are drilled in the flange. Avoid drilling into tubes, instrumentation wires, superconductor and ultra pure aluminum. The strips may extend 3-inches into where the tubes are. Holes may only be drilled in the red tube. The red tube is the tube for mounting, use only the red tube.

8. Cut the red tube flush with the coil end flange. Remember, all you color-blind people, the red tube goes in at 10 o'clock at the North end and leaves at 2 o'clock at the South end. Don't plug the ends of the red tube.

9. Pressurize and leak check the blue and yellow tubes. These tubes can be taken to 1,000 psi on a mixture of helium, nitrogen and freon. Sniff for leaks. A mass spectrometer leak check can be done also.

10. Cut the blue tube so that about 6-inches sticks out beyond the place where the tube enters the flange. Make sure the blue tube is rigidly supported at either end. Remember, the blue tube goes in at 6 o'clock at the North end and leaves at 10 o'clock at the South end. Remember, the blue tube is the spare helium circuit.

11. Attach the return tube from the South to North end of the yellow tube near the 6 o'clock position (don't go more than halfway between 6 and 7 o'clock). Use a pre-bent flattened 3/4-inch OD tube with 0.080-inch walls. Weld the tube to the stub of yellow tube coming out of the South end at 6 o'clock. Remember, the yellow tube enters the north end at 2 o'clock and leaves the South end at 6 o'clock. Brackets for mounting the tube which traverses from the South end the North end may only be screwed into the red tube. An aluminum to stainless transition piece is to be welded to the tube which crosses from South to North at the North end.

12. Fabricate a 12-inch long bus bar assembly for the center tap wire. Hard solder a 3/4-inch OD copper tube onto the bus bar. Make sure the copper tube sticks out at least 1-inch beyond the end of the bar; this bus bar can become a current lead to the coil if one has to use the center tap. Fabricate a continuous NEMA G-10 insulator which goes under the bus bar (measure the mass of the bus bar assembly). Drill and tap the screw holes for the bus bar (see the drawing for the method of insulating the screws from the bus bar). Soft solder the center tap superconductor to the bus bar.

13. Connect the high voltage cable to the center tap bus bar. Run the cable along the flange then along the cooling tube running from South to North. Make sure the cable is well supported to the end flange and the red tube Magnetic forces can be quite large on this cable during a quench.

14. Fabricate two 6-inch long bus bars to attach the ultra pure aluminum wires to. Pre-tin the ultra pure aluminum wires with an ultrasonic solder bath. Fabricate NEMA G-10 insulating stubs to insulate the ultra pure aluminum from the bore tube. Measure the mass of the bus bar assembly. Install the bus bars. Using the same insulating screw set up used on other bus bars. Soft solder the tinned ultra pure aluminum wires to the 6-inch long bus bars.

15. Ground the ultra pure aluminum bus bar to the bore tube at the South end with a copper grounding strap. Allow for the attachment of the stainless steel lead to the North end bus bar.

16. Make up cable connectors which connect the five 10-pin instrumentation connectors on the coil flange to cable connector on the North end of the cryostat at the 2:30 position at the North end. Allow for a copper piece to thermally short the cables to the liquid nitrogen shield cooling system.

17. Fabricate the bus bars for the main electrical leads with the 3/4 inch OD copper pipe mounted on it. Hard solder the bus bar and lead assembly together and check the vacuum tightness of the helium tubes through the bus bar and through the gas cooled tampax type leads. The whole assembly should be hard soldered together not soft soldered together.

18. Build up the NEMA-G10 insulators between the lead assembly and the coil end flange. Match drill the screw holes and fabricate the pieces. Fabricate the cover insulation system for the leads and bus bars. Make sure all machined NEMA G-10 pieces have been coated with epoxy to prevent the absorption of water into the fiberglass epoxy. Measure the mass of the electrical lead, bus bar and insulation assembly.

19. Make up the plumbing from the entry position of the North end at about the 6:45 position. This plumbing can be fabricated from copper. This plumbing can be fabricated from copper. This plumbing will include the tube, and a high voltage insulator. The tube is to go behind the support brackets rather than over them. The insulator is to be located near the 9 o'clock position. The tube from the insulator to where it connects to the 9-11 o'clock position lead assembly is to be insulated from the bore tube end flange. The tube should be wrapped with Mylar or plasma sprayed with Teflon to provide insulation. Support bracket should be made from NEMA G-10 check plumbing assembly for leaks (hard solder joints only).

20. Make up the plumbing from the 11-1 o'clock position lead assembly to the cooling tube entry at 2 o'clock (this is the North end entry for the yellow tube). The plumbing assembly will include an insulator, copper tube, an aluminum to stainless transition piece and aluminum tube. The insulator will probably be behind the 1 o'clock position support bracket. Note the tube between the 11-1 o'clock position electrical bus bar to the insulator is to be insulated from the bore tube. Use the same insulation procedure as in Step 19. Check the assembly for vacuum leaks. Note all joints are either hard soldered or welded.

21. Install the electrical lead bus bars and lead assemblies on the bore tube with their insulators; these assemblies go between 9-11 o'clock and between 11-1 o'clock. Soft solder the superconductor to the bus bar assembly. Install all of the appropriate insulation. Be sure to electrically insulate the electrical leads, the cable blocks, the bus bars and the cables themselves. Tighten down on the screws.

22. Hi-pot the superconducting coil to ground with the installed electrical leads and center tap bus bar. The potting should go up to 10kV. Hi-pot the superconducting coil to the ultra pure aluminum coil, this hi-pot should go to 10kV. Hi-pot the ultra pure aluminum coil to ground; try to go to 5 kV. Check the resistance of the superconducting coil and the ultra pure aluminum coil. Check the instrumentation wiring for shorts or open circuits.

23. Connect the plumbing from the lead assembly to the pieces of plumbing from 6:45 and 2 o'clock. There should be four open holes. One is at 6:30 on the North end on the helium return pipe which connects into the coil at 6 o'clock on the South end (the yellow circuit). The second is the helium inlet pipe at 6:45 on the North end. There are the two gas holes which come out of the cable blocks at the room temperature end of the electrical leads.

24. Vacuum leak check with a mass spectrometer entire assembly from the helium inlet to the coil inlet and from the helium outlet back to the coil outlet at the South end. Note the yellow tube circuit is connected to all of the plumbing. Vacuum leak check the blue tube (make sure there are no screws screwed into it).

25. Remove the frames inside the magnet and record the change of radius of the coil package. The coil should sit in cradle. Cut off the RL fitting used to feed epoxy into the coil on the inside. Grind the epoxy feedpoints and inside welds on the coil flush with the inside of the bore tube. Clean up and sandblast the inside of the bore tube; the final rinse should be alcohol or some other safe organic solvent.

26. Measure the dimensions of the finished coil package. These include length, diameter, out-of-roundness at various places and thicknesses. Measure the mass of the finished coil assembly.

Preparation and Testing of the Vacuum Vessels

1. Grind the high spots down on the inner vessel welds to prepare the vessel for pressure testing.

2. Measure the length, circumference and out-of-roundness of the inner vessel for pressure testing.

3. Hydrostatically test the inner vessel to an internal pressure of at least 247 psig at the hightest point in the vessel. Hold the pressure for about 10-minutes. Release the pressure and measure the volume of water which leaves the vessel as it is depressurized.

4. Remeasure the length of the vessel, note any permanent set. Remeasure the circumference of the vessel at the same three places shown in Step 2. Complete the permanent deformation (less than 0.05 percent) and the vessel withstood the hydrostatic test in Step 3, the vessel is certified to 165 psi. The certification test has to be witnessed by at least 3 people, one of whom must be Ed McLaughlin who will certify the vessel as being safe. (See LBL Engineering Note M5305.)

5. Ship the inner vessel back to Caral Inc. to have the high voltage feedthrough pipe installed and have the holes for final assembly with the outer vessel drilled.

6. Both vessels will be shipped to LBL with the holes for fastening the vessels together drilled and the Keenserts inserted. Inspect both the inner and outer vessels for flaws in welding.

7. Measure the length, circumference and out-of-roundness of the outer vessel. This is particularly important on the OD of the section which is under the outer drift chambers. Measure how much the weld sticks up from the surface of the indented section. If the welds are within our allowable tolerance leave them alone. They will help contribute to buckling stability. Grind the welds on the outer vessel where it is necessary.

8. Fabricate the instrumentation feedthroughs, high voltage feedthroughs and lead feedthroughs for ultra pure aluminum circuits and the center tap. Fabricate vacuum pumping ports and ports which must weld into the vessel. Leak check before installation.

9. Weld any of the appendages to the outer vessel which are available, for example, the installation of the feedthroughs on the vessel for instrumentation. Install all parts up to the aluminum to stainless transition piece where this is applicable. Install the vacuum pumping ports. Sandblast and clean both vessels.

10. Assemble the inner and outer vessels together. Seal all of the ports on the flats. Seal the two seams with epoxy, RTV, or Dux seal. Pump the assembled cryostat vessel down and check the vessel for vacuum tightness. Use a mass spectrometer on its most sensitive scale. Repair any of the bad welds in the vessel. Photograph the assembly at this stage.

13. Remove the socket plates from the outer vessel. Drill out the hole to create a socket for the end ball at the room temperature end of the support rods. When all of the sockets have been fabricated, reinstall the socket plate. Make sure the correct socket plate goes into the correct socket plate hole.

14. After the support pad or socket plates are installed, put the coil assembly back into the outer vessel. Position the coil assembly as in Step 12. Insert the NEMA support rod with balls through the plug holes. Insert the plugs, tighten the plug onto the rods until the coil assembly is supported by the rods. Measure deflection of the coil and the outer rings as this process proceeds.

15. Tighten the support rod until designed prestress is obtained and the coil assembly is centered in the desired position. Measure the position of the plugs and the rods so that the right position can be obtained later.

16. Photograph the coil inside the outer cryostat. Photograph the support system assembly at the South end.

17. Measure the position of the coil inside the outer vessel, use this information to design the shield. Disassemble the magnet coil from the outer vessel.

18. Drill and tap the holes for the molecular sieve canisters at the North and South ends of the coil package.

Assembly of the Liquid Nitrogen Shields and Preparation for Final Assembly

1. Check the twelve copper nitrogen temperature shields. Check their dimensions and vacuum check the copper tube soldered to these shields.

2. Fabricate the G-10 spacers which separate the copper shields to the magnet. Check the fit of these spaces.

3. Drill holes in the copper shields for the support system pins, electrical leads, helium gas pipes, instrumentation leads, ultra pure aluminum circuit leads, and helium cryogenic system pipes.

4. Fit the copper shield to the magnet checking the alignment of all holes and the liquid nitrogen piping.

5. Mount the magnet with the copper shields attached into the cryostat. Check fit around the high voltage lead through. Check radial and longitudinal clearances to see if there is enough room for the super-insulation.

6. Match drill holes in the copper shield with holes in the corrugated aluminum inner and outer shields.

7. Assemble the aluminum shields to the copper shield to check for fit.

8. Assemble the copper shields to the magnet and then install the aluminum shields. Check the dimensions of the aluminum shields as they are assembled on the coil package.

<u>Final Assembly of the Entire TPC Coil Cryostat Package</u>

1. Make up NEMA G-10 boxes which attach to the G-10 under the bus bars at the main electrical leads, center tap leads and the ultra pure aluminum circuit leads. Make sure there is plenty of room for superinsulation inside and outside these boxes. Make sure the copper nitrogen shield fit properly over these boxes.

2. Wrap aluminized Mylar with alternating layers of fine mesh bridal veil around the center portion of the gas cooled electrical leads. Wrap the insulation with clear Mylar film, 10-layers of superinsulation is sufficient.

3. Insulate with Mylar the regions around the main electrical lead, center tap leads, and the ultra pure aluminum leads. Make sure the Mylar completely covers all exposed metal which may be electrically hot. Install the NEMA G-10 boxes around the various leads and bus bars.

4. Install the copper strap onto the final support rods. The edge of the strap should be about 52 mm from the cold end of the short rods and about 77 mm from the cold end of the long rods (there are a total of 8-rods of each type). The strap should be glued and clamped onto the rods. Install the berrylium copper end balls onto the ends of each rod. Use glue to keep the balls from falling off. Wrap the center section of the support rods with 10-alternating layers of aluminized Mylar and bridal veil netting. There should be a couple of layers of netting under the first layer of aluminized Mylar there should be one layer of netting over the aluminized Mylar. Yellow sticky tape can be used to hold the whole thing together. Photograph the support rods at this stage.

5. Install the coil onto the motor driven spindel. Wrap 20-layers of crinkled aluminized Mylar around the outside of the coil package. Be careful not to disturb instrumentation wiring. There should be bridal veil netting between Mylar layers about every third layer. Be sure to overlap the superinsulation enough to insure there is no heat leak path between the shield and the coil. Allow at least 15-inches of superinsulation to stick out from the ends of the coil package. Slit this superinsulation (making sure the slits do not line up from layer to layer). Fold each individual layer of insulation over the end of the coil package and tape the insulation to the inside of the coil. This technique will insure that there is no part of the coil package which sees either the bare 80K shield or a room temperature. Surface wrap the outside of the insulated coil with knotted dacron cord. Hi-pot the coil, check the wiring. Photograph the coil assembly at this stage.

6. Install the canisters of Linde 5a Molecular sieve into the threaded holes at the North and South end of the coil package.

7. Wrap the superinsulation over the molecular sieve canisters. Tape the superinsulation to the inside of the bore tube.

8. Install the copper liquid nitrogen shields connect the liquid nitrogen system together using the swage lock fittings. Install the outer corrugated aluminum shields.

9. Wrap 30 layers crinkled aluminized Mylar around the nitrogen shield. Be careful not to distrub the various wiring. There should be a layer of bridal veil for every three layers of superinsulation. Allow at least 20 inches of superinsulation to hang over the ends of the coil. Slit the superinsulation at holes for the support rods, electrical leads, instrumentation wiring and insulated helium and liuqid nitrogen transfer lines.

10. Slide the superinsulated coil package into outer cryostat vacuum vessel making sure that all of the penetrations are lined up properly. Instrumentation wiring is to be fed out of the appropriate North end openings and main electrical leads are fed out of their openings; the helium piping is lined up. Insert the compression rods once the coil package is aligned to the proper position. Attach the compression rod straps to the shield at both ends. Tighten the compression rods until the coil package is self supporting in the correct position. Remove the frame inside the coil. Put the compression rods under the right prestress. Make sure the coil is properly aligned. Make sure the coil assembly is clean.

11. Adjust and measure the position of coil package within the outer cryostat vacuum vessel until the coil is in the correct position.

12. Assemble the main electric cables, make up the O'ring joints. Make the gas cooled helium lead cooling final connections. Hi-pot the coil and check the connections.

13. Make up all of the instrumentation wiring connections, the high voltage connections, the center tap connections and connections for the ultra pure aluminum circuit connections and the center tap connections have been thermally tied to the shield. Make sure all instrumentation wiring is tied to the shield.

14. Make the final welds to the cryostat outer vessel for the helium transfer pig tails. Make up the final helium transfer line cold joints (helium piping). Vacuum leak check all joints in the helium circuit. Repair any leaks make up the final liquid nitrogen pipe joints. Vacuum leak check all joints in the nitrogen line. Superinsulate the helium line joints where they are cold. Superinsulate the nitrogen joints.

15. Stuff superinsulation in all regions of the coil which are not covered with superinsulation except the inside 3.0-meters of surface. Hi-pot the coil and aluminum circuit check all instrumentation connections. Check the resistance of the coil and the aluminum circuits from the outside. Photograph the assembly at this stage.

16. Install the superinsulation blankets on the inside of the coil package bore tube. Hold the blanket in with NEMA-G 10 spring clips. Install the inner corrugated nitrogen temperature shields. Tape the superinsulation from the outside to the corrugated aluminum shields. Make sure the inner shields are clear of burrs and snages. Make sure the sheet metal screw which screw the corrugated aluminum shields to the copper shields are covered with yellow sticky Mylar tape.

17. Wrap the inner vacuum vessel with 30-layers of crinkled aluminized Mylar. Every third layer will have bridal veil netting between it. Make sure the high voltage feedthrough pipe is wrapped with superinsulation. Wrap the insulated inner vessel with knotted dacron cord.

18. Slide the superinsulated inner cryostat vessel into the inner shield. Check clearances; tailor the insulation so that the inner vessel fits properly. Photograph the inner vessel assembly as it goes together.

19. Install the bolts at the joints. Install the soft aluminum seal strips on the outside seal and weld it to the vessel on either side of the bolt circle and crack. Install the soft aluminum seal strip on the inside seal and weld it to the vessel on either side of the bolt circle and crack.

20. Vacuum check the outside joints with a mass spectrometer leak detector. Repair leak. Pressurize the internal piping to 50 atm or so. Leak check for minor leaks. Pray to the God of your choice there are no leaks.

21. Hi-pot the coil to ground to at least 5kV. Hi-pot the coil to the ultra pure aluminum circuit to at least 5kV. Check all of the instrumentation wiring. Measure the resistance of the coil and the ultra pure aluminum circuits.

22. Photograph the finished coil assembly in Building 77 along with the people who built the magnet.

23. Build a heavy timber frame to support the coil as it is being shipped and to hold the coil during the Building 64 tests. The TPC magnet outer supports can be incorporated as part of this assembly. Ship the finished coil assembly to Building 64.

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