LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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SPECIFICATION for ELECTRICAL CONTRACTOR SERVICES for the BEAM TUBE BAKEOUT at the LIGO HANFORD OBSERVATORY

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1. Purpose

This document defines the requirements for the LIGO beam tube bake out power equipment materials, assembly and installation. Each beam tube module is to be powered by equipment in accordance with this specification. The objective of the equipment is to provide AC and DC power to the beam tube and test equipment to heat the tube to a high temperature for bake out.

2. Applicable Documents

The following overall Beam Tube Module bake out drawings apply as well as reference drawings from Chicago Bridge & Iron (CBI) the beam tube fabrication and installation Contractor. Individual assembly drawings are referenced in each section.

Description	Drawing
Portable Power Cable Specification	LIGO-E970193
Portable Electrical Power Panelboard Assemblies	LIGO-E980008
Heating Blanket Relay Panel Assemblies	LIGO-E980006
Beam Tube Bake Out Preliminary Design	LIGO-T970148
Distribution Transformer 13.4 kV/480 V 45 & 500 kVA	LIGO-T980012
Power Supply Instruction Manual	LIGO-T980011
Overall layout and module configuration (CBI)	LIGO-D950031
Beam Tube section configuration and dimensions (CBI)	LIGO-D950034
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Corner Station LVEA Receptacle & Power Plan, Y Arm (Parsons WA-E-504)	LIGO-D960433
Typical End or Mid Station Single Line Diagram (Parsons WA-E-008)	LIGO-D960393

3. Description

3.1 Overview

The LIGO project beam tube modules are 2,000 m (6,500 ft) 49" diameter stainless steel tubes that must be evacuated. To achieve low vacuum levels the tube must be heated to a temperature of 150^{o} C (300^{o} F) for 30 days. This process "bakes out" the water vapor and other gasses in the tube as it is pumped out. The tube will be heated by passing a DC current through it and heating it by the resistance of the steel. The tube has been constructed to electrically isolate it from the tube supports allowing it to be energized. This scope of work is to assist the LIGO project at the Hanford site in setting up each module for bake out, moving equipment between modules as they are baked and preparing the assemblies for shipment to a second LIGO site at Livingston, LA.

3.2 Module Bake Out Plan

Each beam tube is to be baked out in modules of about 2,000 m each. These occur between the corner and mid stations and between the mid and end stations on each arm of the project (see site map and layout, Appendix A). This creates four modules at each site, for a total of eight module bake outs for both sites. The ends of the 2 km long modules are terminated by large gate valves. There are nine 10 inch diameter pumping ports distributed at approximately 800 ft (250m) intervals along the module. The beam tube is in an enclosed concrete protective cover with access doors at each pump port location. There are also smaller emergency access doors midway between the pump ports. A road parallels the beam tube enclosure.

The bake out process involves the following:

1. One time assembly at Hanford of electrical equipment to be used for the bake out.
2. Set up of electrical distribution equipment for the first bake out.
3. Assisting LIGO staff during a module bake out.
4. Coordination and moving of equipment between bake outs.
5. Partial disassembly and packaging for shipment of materials to the Louisiana site.

Each module to be baked out contains 9 ports along the tube length. Two ports are at the ends in the stations with seven ports between stations along the beam tube enclosure. The ports will be fitted with special low vacuum level pumps which will be operated as the tube is baked out. Cold plate cryogenic pumps will operate on eight ports, with the two end ports receiving turbo molecular pumps as well (see Beam Tube Bakeout Preliminary Design, LIGO-T970148-00-E).

Analytic equipment for characterizing the tube vacuum will be connected at the center port of each module. The tube will also be outfitted with a data collection and temperature monitoring system that will track conditions during and after each module bake out along the entire length of the beam tube.

To support the pumps and heating equipment, power must be supplied to each port area (see conceptual schematics, Appendix B). The seven ports along the tube enclosure will receive a 12.47 kV/120-208 V three phase skid mounted transformer. The transformers serve a 208 V panel and outlet board assembly mounted with the transformer. Cord sets will be plugged into the distribution panel to serve various equipment at each port vestibule area.

The tube will be heated by a DC power system. The DC system is divided into two power supply units, with each serving one half of a tube module (see Appendix B). The supplies will have a common point at the center of the module. The power supplies utilize a 12 pulse solid state converter to transform 480 V three phase power into DC power. The expected output voltage will range between 70 and 90 VDC. The output power will vary depending on the ambient temperature over the bake out period. Peak current requirements in extreme winter Hanford conditions (-30^{o} C) will not exceed 4,500 A with summer

conditions (45^{o} C) expected to require 3,800 A. The current from the power supply will be split at the connection to the beam tube with about half flowing in each direction. The return currents to complete the electrical circuit will be carried by portable cabling laid outside along the beam tube enclosure. The DC power supplies will be served by an additional transformer at the two ports with the power supplies. AC power usage will be monitored at these locations. The two end ports will receive their power from the building distribution system already in place. Enough power assemblies, including the DC power supplies, will be provided to allow for the next module to be setup while the previous one is baking out. However, only one set of DC return cables will be used.

The beam tube has been insulated with fiberglass insulation along the entire length. Additional heating at the pump locations and DC tube connections will be required. This will be supplied with heating blankets custom fitted for each location. The blankets all operate on 120 V AC power. Except for the DC power supplies, the blankets make up the bulk of the electrical power demand. Each blanket, or group of blankets, will be controlled by a solid state temperature controller using thermocouple inputs. The Contractor will be responsible for positioning the temperature control units and connecting power to the controllers. The blanket installation and their final power connection will be provided by others. Only one set of heating blankets and controls will be used for each bake out. This set of blanket and controls must then be moved and setup at the next module for continued bake out.

See drawing LIGO D980097 for a typical assembly arrangement on a module. Also see LIGO technical document LIGO-T970148 for specific bake out technical details.

3.3 General Requirements

Installation

All materials shall be installed in accordance with the best industry practices by skilled workers regularly engaged in this type of work.

All materials shall be installed in accordance with manufacturer’s recommendations, applicable building codes and industry standards.

The Contractor shall be responsible for obtaining any required permits and arranging any required inspections. Coordination and scheduling to group inspections with the State Electrical Inspector will be required.

Materials Furnished by Contractor

All materials furnished by the Contractor incorporated into the construction shall be of the highest grade, free from defects and imperfections, of recent manufacture, and unused. Materials shall be of respective kinds, classifications, and grades designated on drawings and in these specifications. They shall be the standard products of recognized, reputable manufacturers.

The total estimated quantities necessary to complete the work as specified are listed on the "Bill of Materials" contained in the project documents.

These quantities are estimates only. The Contractor will be required to furnish and place the entire quantities necessary to complete the work specified, be they more or less than the quantities estimated.

The Contractor shall furnish to LIGO material safety data sheets (MSDS) on all materials provided or used by the Contractor except those materials provided by LIGO.

Materials Furnished by LIGO

The quantity and type of LIGO furnished materials are listed on the assembly drawings.

LIGO furnished materials and equipment will be available at the LIGO corner station warehouse in lay-down areas nearby, and must be moved to the project site by the Contractor.

The Contractor shall execute a receipt for all items he receives which are furnished by LIGO. Execution of said receipt without reservation incorporated therein shall bar a subsequent claim by the Contractor that the items were received in a damaged condition, provided, however, the Contractor shall not be responsible for any damage or expense resulting from the latent defect in materials, tools, and equipment. The materials and equipment shall be assumed to be in good working order unless noted otherwise by the Contractor. Upon receipt by the Contractor of materials furnished by LIGO, the Contractor shall become solely responsible for their care and protection.

In the event that the quantities of materials furnished by LIGO are not sufficient to complete the project as shown on the drawings and specifications, the Contractor shall advise LIGO in writing of the shortage. If LIGO determines that the shortage is not due to carelessness or wastefulness on the part of the Contractor, the additional material required will be furnished by LIGO.

If materials, tools, equipment or reels furnished by LIGO are damaged, lost, stolen or destroyed by reason of any cause, whether within or beyond the control of the Contractor, other than the existence of latent defect, they shall be repaired or replaced entirely at the Contractor's expense.

The Contractor shall return to the LIGO laydown area, or warehouse, as directed by LIGO, all materials not incorporated in the completed work, inclusive of materials determined salvageable by LIGO. Materials returned shall be boxed, crated or packaged in a manor similar to the manor in which they were received by the Contractor.

3.4 Schedule

Appendix C shows the proposed bake out schedule. The work will revolve around intense setup and moving periods with less work during the bake out periods.

4. Hanford First Time Assembly

4.1 AC Power Outdoor Assemblies

The AC power assemblies comprise four types, three for outside along the beam tube enclosure and one for indoors in the corner, mid and end stations. The units must be assembled from their component parts, typically a panel board that must be mounted to a frame and mated with a transformer.

The Contractor shall assemble the units according to the drawings and the specifications for each assembly unit. The Contractor shall provide all materials not specifically called out on the material lists as provided by LIGO and all labor, tools, equipment and coordination needed to assemble the following units.

Description	Specification
Assembly A1 is used for 120/208 V service outdoors at the majority of the port locations	LIGO-E980023
Assembly A3 is used for 120/208 V service at the stations that have analytic instrumentation	LIGO-E980025

The component parts for these assemblies will be available at the LIGO storage warehouse near the corner station, in the corner station or storage in laydown areas near the corner station. The Contractor shall move

the LIGO provided material to a working area or to the first bake out module locations for assembly. The LIGO warehouse will not be available for Contractor assembly.

Contractor supplied equipment will be required to move the power transformers which weigh approximately 4,500 lb. for the 500 KVA unit and 2,000 lb. for the 45 KVA unit.

4.2 Blanket Heater Control Assemblies

The blanket heater control assemblies require placing a temperature control panel onto a frame. The heater control assemblies are not outdoor rated and will be provided with indoor assembly and interim storage space at LIGO.

The Contractor shall assemble the units according to the drawings and the specifications for each assembly unit. The Contractor shall provide all materials not specifically called out on the material lists as provided by LIGO and all labor, tools, equipment and coordination needed to assemble the following units.

Description	Specification
Assembly H1 is used for temperature control of port hardware and cable connections needing a single channel controller.	LIGO-E980006 No Assembly Required
Assembly H2 is used for multi. channel control at the beam tube module ends.	LIGO-E980029
Assembly H3 is used for multi. channel control at the beam tube module ends.	LIGO-E980029
Assembly H4 is used for multi. channel control at the beam tube module ends.	LIGO-E980029

The Contractor shall also fabricate connector plates to allow H2, H3, and H4 to be bolted together at the frame bases. The plate fabrication and drilling is permitted in the assembly area, but not in the LIGO Vacuum Equipment areas.

4.3 Corner/Mid/End Station Power Assemblies

Assembly A2 is used for 120/208 V three phase service in the station areas. The units will plug into existing 480 V three phase outlets. The A2 unit features a 480/208 V step down transformer and panel board. The A2 power assembly is not outdoor rated and will be provided with indoor assembly and interim storage space at LIGO.

The Contractor shall assemble the units according to the drawings and the specifications for each assembly unit. The Contractor shall provide all materials not specifically called out on the material lists as provided by LIGO and all labor, tools, equipment and coordination needed to assemble the following units.

Description	Drawing
Assembly A2 120/208 V Service with 480 V transformer.	LIGO-E980024

4.4 DC Power Supplies

Assembly B2 is used for 480 V service to the DC power supplies and the assembly of the power supply related equipment into a shipping container. The DC power supplies themselves weigh about 5,900 lb. and are a delicate piece of electronic equipment. Extreme care shall be exercised in moving, connecting to and working around the power supply units. See unit instruction manual in the assembly package.

The Contractor shall assemble the units according to the drawings and the specifications for each assembly unit. The Contractor shall provide all materials not specifically called out on the material lists as provided by LIGO and all labor, tools, equipment and coordination needed to assemble the following units.

Description	Drawing
Assembly B2 is used for 480 V to DC service outdoors with container, with metering.	LIGO-E980026

4.5 DC Cable Management

The Contractor shall develop a cable management system to allow for expeditious placement and take up of the DC cabling system. The positive lead utilizes a parallel run of (8) 500 kcmil type W copper portable cables. The return leads are parallel runs of (4) 500 kcmil type W copper portable power cable. The cable will be supplied on reels. See LIGO-E970193-A-W for cable specification. Note that project drawings and the cable specification have the following correlation: cable RT1=A, Cable RT2=B, cable RT3=C, and cable RT4=D. The Contractor shall permanently label both ends of each cable at the first installation.

The cables will require relocation from one module to the next during the brief down time between module bake outs. See the schedule included with this document.

4.6 DC Tube Connection

The DC tube connection assembly utilizes a connection box to transition the type W power cable to high temperature cable and custom connectors for attachment to the beam tube. Beam tube attachment will be made at certain stiffening rings on the tube as shown on the drawings. The transition box, high temperature wire and connectors will require assembly prior to the first module bake out.

The Contractor shall assemble the units according to the drawings and the specifications for each assembly unit. The Contractor shall provide all materials not specifically called out on the material lists as provided by LIGO and all labor, tools, equipment and coordination needed to assemble the following units.

Description	Drawing
Assembly D Beam Tube Connection	LIGO-E980028

5. Module Preparation

Drawings LIGO-D980097 and LIGO-D980098 show the equipment arrangement for the first module (Y-2) to be baked out. Drawings LIGO-D980096, LIGO-D980094, and LIGO-D980095 show the arrangement for subsequent modules. The following general priority shall be followed for the order of equipment layout:

1. Establish AC power 120/208 V at all ports
2. Layout and connect AC cord sets all ports
3. Layout heating control equipment all ports
4. Establish DC power supplies
5. Layout DC cabling and connect to beam tube
6. Assist in ongoing AC equipment connection

5.1 AC Power Assemblies

The Contractor shall place the assemblies as shown on the drawings and specifications for the first module to be baked out. The Contractor shall provide all materials not specifically called out on the material lists as provided by LIGO and all labor, tools, equipment and coordination needed to place, energize and operate the AC power assemblies and cord sets. The Contractor shall coordinate with other Contractor's work and LIGO in the execution of the work. The Contractor shall provide barricades as required by code authorities or as directed by LIGO. Electrical cords shall be routed to the extent possible to provide physical protection for the cords and to maintain a safe, neat and orderly environment. The Contractor shall provide and install cable ties or other bundling means as required to train the cords.

The Contractor shall connect the power for the turbo molecular pumps at the port ends. These pumps will plug into existing LIGO 40 A outlets. The Contractor shall take precautions to ensure that all equipment is off and circuit breakers deenergized prior to plugging in or disconnecting all connections other than 20 A receptacles. The connecting equipment is not rated as a disconnecting means and therefore cannot be utilized hot.

The Benton County PUD will provide and install the AC primary cabling, termination, primary load break elbows and make connection to the primary voltage system. The Contractor shall coordinate the placement of primary conduit with the PUD, arrange for PUD to make the primary connections, and install the pulling loop cover assembly E after cabling has been installed.

5.2 DC Cabling

The Contractor shall supply all labor, material not specifically called out on the material lists as provided by LIGO, equipment, and coordination to unreel and place the DC cabling systems along the beam tube enclosure as shown on the drawings. Return and supply DC cables shall be terminated at the DC power supply container. Cables shall lay on the ground and be placed as close to the beam tube enclosure as possible. The cables shall be lifted and placed on the vestibule enclosure roof at pump ports to allow unrestricted access. Provide strain relief as necessary to prevent cable damage. Cables shall be handled with reasonable care to prevent damage to the insulation or the conductor. Cables shall not be dragged on the ground or pulled through their developed length as a means of installation. Coordinate with LIGO to develop acceptable installation options at the X-1 road way bridge obstruction. The cable lengths provided by LIGO have been selected to function over the longest distances required. At some modules, excess cable length will occur. The Contractor shall develop a system to manage the excess cable lengths in these instances such that access to the project equipment and the beam tube is maintained.

Also the Contractor should note that the positive connection of the PS2 (power supply 2) is approximately 40 m from the pump port vestibule where the equipment is located. The supply cables will require the full

length provided and shall be routed outside of the beam tube enclosure, penetrate the enclosure through Contractor provided core drills, and connect to assembly “D”. Extra long power cords are also required here to power lights and equipment at the beam tube connection ring. On the X-2 and Y-2 modules this offset will require the DC return cables to cross over two vestibule areas before reaching the power supply. The Contractor shall adjust the lay of the DC return cable RT4 in these locations to develop the straightest possible length and allow connection to the power supply.

The DC tube connections at the module ends will be in the indoor tube area of the corner, mid and end stations. The beam tube enclosure is separated from the indoor area by sheet metal panels arranged around the beam tube and extending out to the enclosure. The Contractor will be required to remove a few of these panels to allow for the DC return cables to exit out to the beam tube enclosure. The Contractor shall provide packing material to seal the cable penetration while bake out occurs. The packing material shall be non-friable to prevent compromise of the clean environment of the stations. The DC cable shall be supported and protected to prevent any damage at the penetration. The Contractor shall plan to have the penetration open a minimal amount of time to help prevent dust infiltration to the stations.

The Contractor shall splice, repair or patch any damaged DC cable.

5.3 Beam Tube Connection

The Contractor shall provide the labor and material required to connect assembly D to the beam tube stiffening rings.

There may be bake out monitoring equipment, instruments, heater blankets, wiring, thermocouples and beam tube insulation in the area of the cable connections. The Contractor shall take care to prevent damage to this equipment during the connector and cable installation.

Prevention of leaks or potential leaks into the beam tube is of paramount importance. The stainless steel wall of the beam tube is subject to long-term stress-induced corrosion due to chemical attack. No glues or adhesives may be used around the beam tube without coordination with LIGO. Also the use of any tools and particularly power tools that could potentially damage the 1/8” thick tube wall must be coordinated with LIGO. The Contractor shall take measures to ensure that tools cannot accidentally damage the beam tube.

5.4 Beam Tube Enclosure Core Drilling

The Contractor shall provide concrete core drilled or cut penetrations to route the DC cabling and the AC cable sets into the beam tube enclosure for connection. Coordinate with LIGO on the placement of the penetrations. Generally, the DC cables should be routed through the beam tube enclosure wall, and the AC cables through the pump port vestibule side walls. Cables shall not be routed through the beam tube enclosure doorways. Cores or cutouts shall be left at the penetration site for sealing and grouting by others after bake out is complete. Separate holes shall be provided for primary AC, secondary AC, DC cabling, data and signal cables, and cryopump helium lines.

5.5 Grounding

The Contractor shall establish all grounds as shown on the drawings and as required by the NEC or the local authority. In particular, this covers service grounds at each transformer and grounding of the power supply units. Grounding is also required at the beam tube DC return connections as required in assembly unit I. This is the only place that the beam tube will be grounded. At other locations the tube will be at some DC potential between 0 and 90 V during the bake out. Care shall be taken to prevent equipment or any conductive material from contacting the beam tube surface. The Contractor shall verify that equipment cord connected to the beam tube is electrically insulated from the beam tube as part of the setup procedure.

5.6 Heater Controls

The Contractor shall arrange and place the units according to the drawings and the specifications for each assembly unit. The Contractor shall provide all materials not specifically called out on the material lists as provided by LIGO and all labor, tools, equipment and coordination needed to arrange, place and connect the controls. Assemblies H2, H3, H4 shall be bolted together once placed at the module ends. The assemblies shall be placed such that the temperature controls are all visible from one side. See LIGO-D980098 for arrangement details.

5.7 Instrument Trailer

The Contractor shall move the instrument trailer into place as shown on the drawings. The Contractor shall also assemble the power connections for the trailer unit.

5.8 Data Distribution Cables

The Contractor shall lay the data distribution cables (one electrical, one fiber optic) into place along the beam tube module. The data distribution cables shall be furnished by LIGO.

6. Bake Out Sequence

The first beam tube module to be baked will be Y-2. According to the current plan, the modules will be baked out as Y-1, X-1, X-2. There are two sets of AC portable panelboards ("A" assemblies), DC power supply assemblies ("B2" assemblies) and AC power cord sets ("C" assemblies), but only one set each of DC power return cables (with junction boxes and tube connectors, the "D" assemblies) and heating blanket relay panels ("H" assemblies). The equipment deployment sequence is illustrated in Appendix D.

6.1 First Module Bake Out/Second Module Preparation

Once the first module is prepared as outlined above, LIGO will begin the bake out process. The beam tube will be energized and gradually ramped up in temperature until 150^{o} C is reached. The Contractor shall assist and support LIGO in verifying operation of the electrical equipment, troubleshooting connections and equipment failures, consulting with LIGO on the operation and adjustment of equipment and connections and arrangement as needed or directed by LIGO. The first bake out energization will be the commissioning run of all the power equipment and many of the LIGO components. The Contractor shall have staff available on site during this period to assist with issues as they arise.

The sequence for the module bake out allows for preparation of the next module as the present one is baked. Once the first module is prepared and substantially complete, preparation of the second module should begin. The second set of the power equipment will be commissioned during the second module bake out. The Contractor shall provide all materials not specifically called out on the material lists as provided by LIGO and all labor, tools, equipment and coordination needed to arrange, place and connect the second module bake out equipment as outlined in the first module preparation section above. The Contractor shall provide all labor and equipment required to move the heater controls from the first bake out to the second module bake out. Some LIGO equipment will remain on the first module as it cools.

Specifically, a residual gas analyzer (RGA) unit and the associated trailer will be located at port 5 during the bake out. An additional unit and trailer will be located at port 4 for post bake monitoring. Once the bake out is over, the port 5 "bake" RGA will be moved to next module along with the other bake equipment. The port 4 RGA and trailer will also move to the next module but not until post bake monitoring is complete. The Contractor shall provide labor and equipment to move each trailer and its power connection to the new locations.

6.2 Second Module Bake Out/Third Module Preparation

The Contractor should note that the beam tube modules are mirror images of each other. For instance, the Y-2 and Y-1 modules are mirrored about the mid station. The equipment for the second bake out shall be installed as shown on the drawings and allowing for the mirroring effect. However, the primary voltage power supply conduit was not mirrored in the construction. This connection will always be on the right hand side of the port vestibules when viewed from the roadway. The mirroring affect also takes place between the two arms of the beam tube.

The second module to be baked out will require the same commissioning, testing, trouble shooting as outlined above for the first module. As the second module is baked, the power equipment (except the DC return cables) from the first module shall be moved to the third module, set up, tested, and turned over for LIGO use.

6.3 Third Module Bake Out/Fourth Module Preparation

The Contractor shall move the equipment from the second module to the fourth module to prepare for the final Hanford site bake out. The requirements for the third bake out will be substantially the same as for the first. The Contractor shall provide the same support as outlined above for the first and second modules.

6.4 Fourth Module Bake Out/Shipping Preparation

The equipment for the fourth module bake out shall be set up and commissioned the same as required above for the first three modules. The equipment from the third module bake out shall be moved and prepared for shipment to Louisiana. When the fourth module has been baked, that equipment shall also be prepared for shipment. The time period allowed for final packing of equipment is one week. The Contractor shall provide the labor required to support this quick pack effort. The Contractor shall take care to prevent damage to equipment, particularly cord connectors and electronics.

7. Packaging for Shipment to Louisiana

The Contractor shall pack the equipment with protective wrappings, crating and other packaging to prevent damage while in shipment. The equipment shall be secured into shipping containers and/or shipping trailers as provided by LIGO. The Contractor shall follow the direction of LIGO in handling and packing the equipment. When the fourth module has been baked, that equipment shall also be prepared for shipment. The time period allowed for final packing of equipment is one week. The Contractor shall provide the labor required to support this quick pack effort. The Contractor shall take care to prevent damage to equipment, particularly cord connectors and electronics. Some equipment such as water coolers and the power supplies may require freeze protection measures to prevent damage from low temperatures while in transit. The Contractor shall keep an inventory record of all material packed and in which containers an item is placed.

8. Site Conditions

8.1 Water

No water service is available at the site. The Contractor shall make all arrangements for water supply at his own expense and shall pay all charges incurred during the life of the contract.

8.2 Sanitation

No sanitation facilities will be available to the Contractor. The Contractor shall be responsible for providing all sanitation facilities required.

8.3 Electrical Service

No electrical service will be available along the beam tube until installation of power assemblies by the Contractor. The Contractor shall be responsible for providing any electrical service required for the work prior to assembly installation. It shall be the Contractor's responsibility to arrange with LIGO access to the electrical equipment that may be available inside the corner, mid and end stations. Any modifications to the existing electrical service determined necessary by the Contractor shall be approved by LIGO. All expense for construction power will be born entirely by the Contractor. Upon completion of the contract, electrical equipment shall be returned to a satisfactory state as required by LIGO.

8.4 Telephone Service

No telephone service is available on site. If determined necessary by the Contractor, additional temporary telephone service may be installed entirely at the Contractor's expense. Cellular telephone service is suggested.

8.5 Underground Utilities

The drawings and specifications may not give the precise location of all drainage systems, electrical conduit, ground grids or other structures. It shall be the responsibility of the Contractor to ensure that no damage to said utilities or foundations is incurred during excavation. If any damage does occur it shall be the responsibility of the Contractor, at his expense, to repair or replace at the discretion of LIGO, damaged systems.

8.6 Fasteners

No charge or powder driven fasteners shall be used at this site. Other fastener systems shall be approved and coordinated with LIGO prior to installation.

8.7 Laydown Areas

A laydown area near the corner station, approximately 5 acres in size, is available to the Contractor. Additional smaller areas nearer the beam tube entrances may be made available upon request from the LIGO Construction Manager on site. The laydown area may be available for a job site trailer if desired by the Contractor.

8.8 Lighting

There is no lighting inside the beam tube enclosure. The bake out Contractor shall be responsible for providing temporary lighting as needed to install the equipment.

8.9 Confined Space

LIGO considers the beam tube enclosure to be a confined space. The Contractor shall be responsible for furnishing adequate lighting and ventilation in the work area and providing for other safety considerations according to a safety plan submitted by the Contractor and approved by LIGO.

8.10 Coordination of Activities

The Contractor is required to coordinate his activities with the other Contractors on site and with the LIGO staff. The Contractor shall not block the roadways at any time.

LIGO facilities are unique. All activities which physically modify the facilities shall be coordinated with LIGO to prevent inadvertent damage or compromise in the function of the project.

8.11 Indoor Assembly Area

The Contractor will be provided use of an approximate 20'x 20' work area near the corner station. The work area is in a maintenance building at the mechanical equipment area near the water tower. It is anticipated that the area will only be needed for the first time assembly of indoor rated units. As units are assembled, they should be moved to their respective staging areas. The Contractor shall be responsible for maintenance of the assembly area in an orderly manner while in use. The area shall be cleared once assembly is complete and returned in the same condition as which it was received. 120 V power is available for use in the assembly area.

8.12 Corner/Mid/End Station Clean Room Equipment Areas

The beam tube area inside the corner/mid and end stations is maintained as a clean room type area. Elimination of dust and dust infiltration prevention is achieved by air locks in the facility design. The Contractor shall clean all indoor rated equipment of surface dust prior to introduction to the beam tube area. Also any assembly activities which may create airborne dusts or particles are prohibited in these areas. The indoor assembly area shall be used for these types of activity. Coordinate with LIGO staff on any actions that the Contractor feels may compromise the clean room type environment.

9. Clean Up

The Contractor shall remove all debris and scraps of material from the job site.

10. Safety

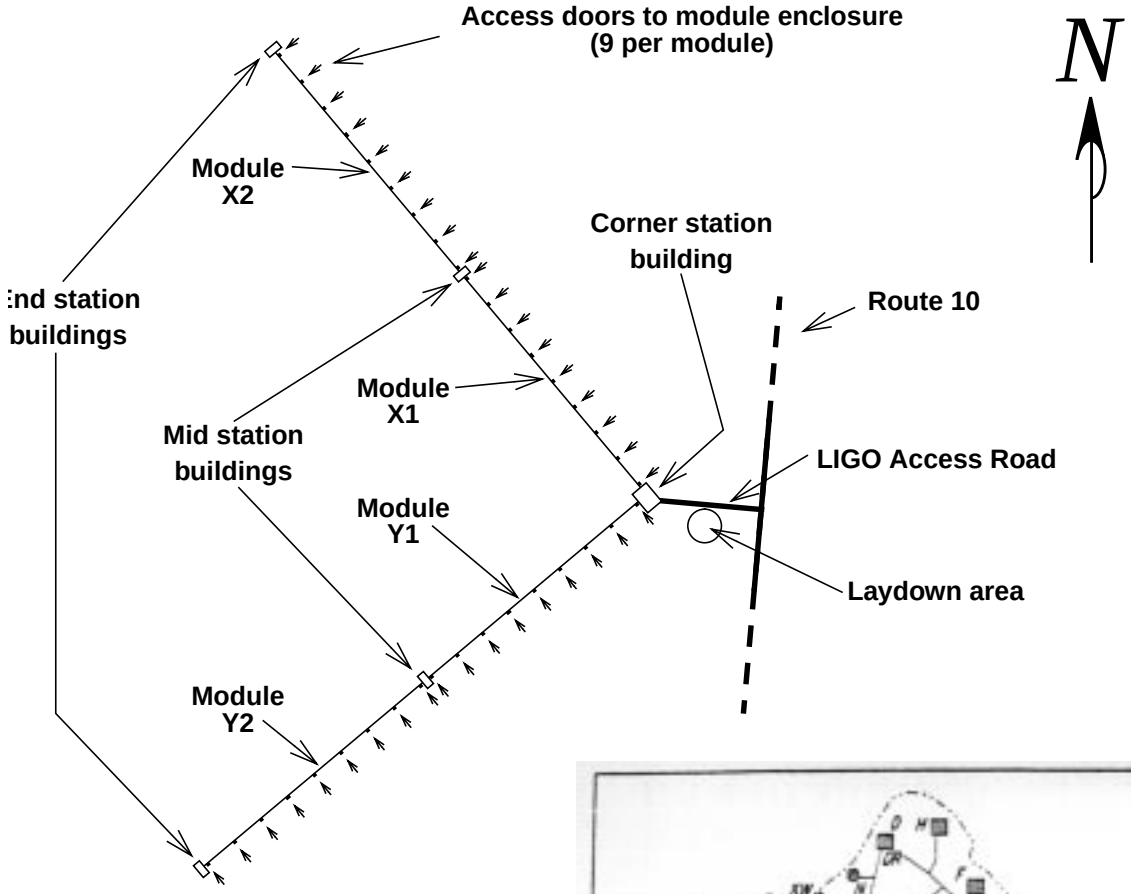
The Contractor shall furnish the On-site Safety Plan and safety procedures which the Contractor shall comply with during the performance of this work. The Contractor shall use the LIGO Lockout/Tagout procedure for all work performed on site.

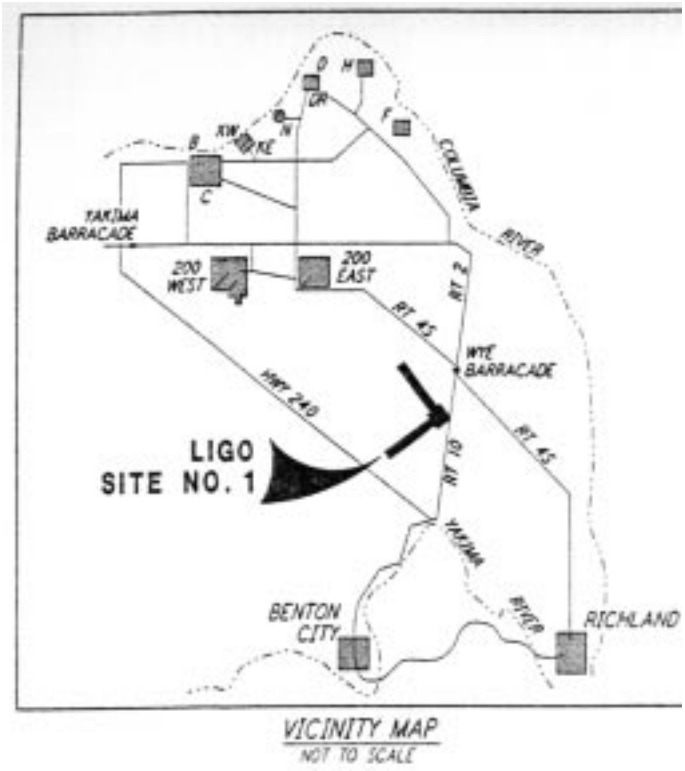
11. Quality Assurance

The Contractor shall furnish supplier's certifications of compliance to specifications for all purchased materials.

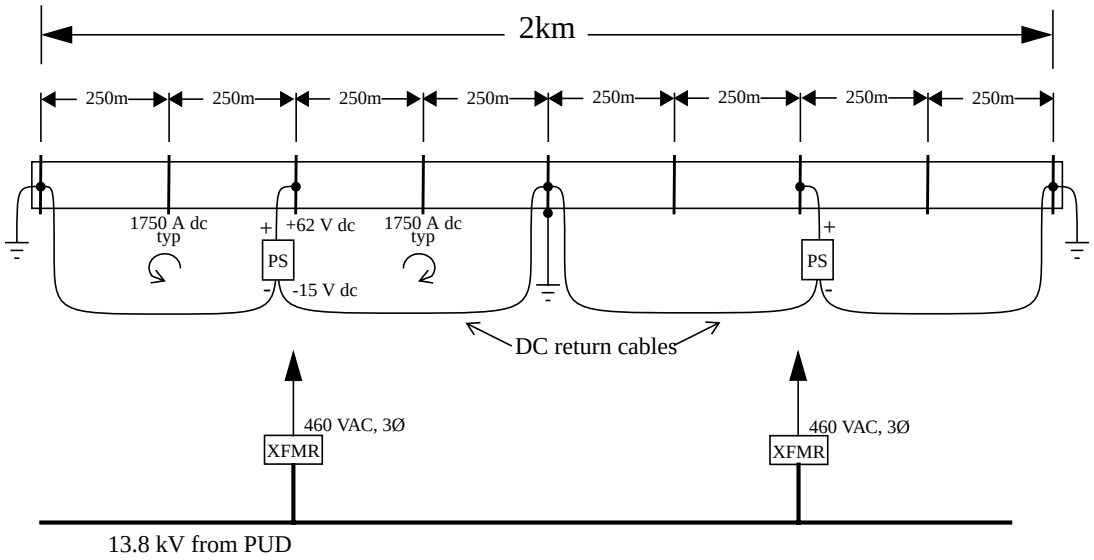
Finished assemblies shall be subject to inspection by a LIGO representative prior to moving into place in indoor areas. Outdoor assemblies shall be subject to inspection by a LIGO representative prior to use and after receipt of a notice of assembly completion from the Contractor.

APPENDIX A
SITE LAYOUT AND MAP (not to scale)



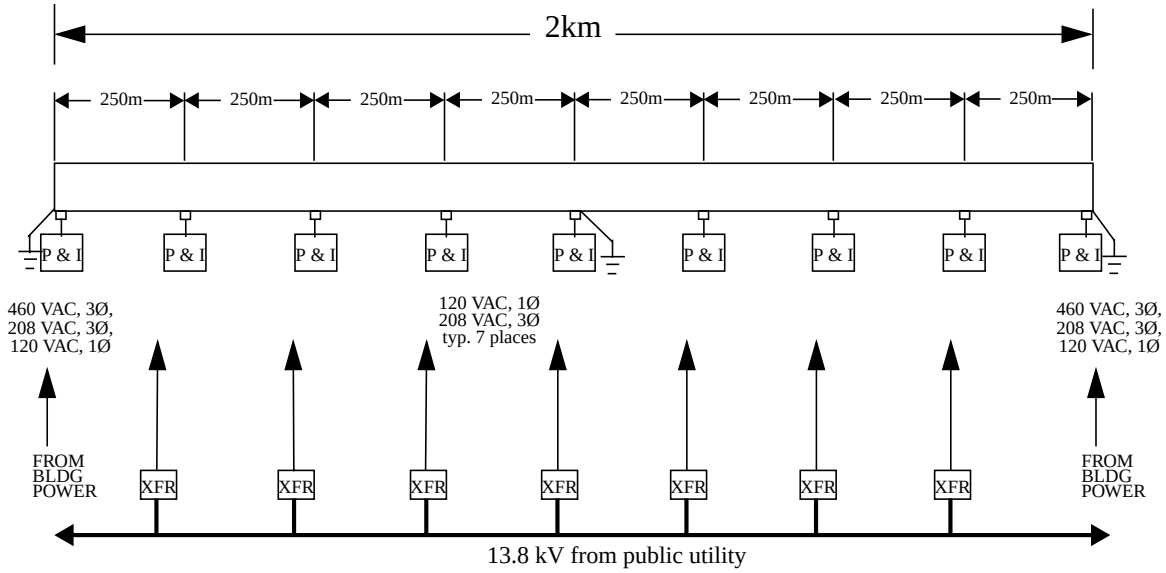


APPENDIX B
CONCEPTUAL SCHEMATICS



NEED FOR TUBE HEAT[1] -
2 x 400 kVA = 800 kVA (summer days)
2 x 460 kVA = 920 kVA (summer nights)
2 x 505 kVA = 1010 kVA (winter nights)
2 x 550 kVA = 1100 kVA (coldest winter nights)
[1]Additional power required for pumps, instrumentation, auxiliary heating

Legends:
PS Low voltage, high current DC power supply
XFMR Power Transformer



Legends:
Pump Port
P & I Pumps & Instrumentation

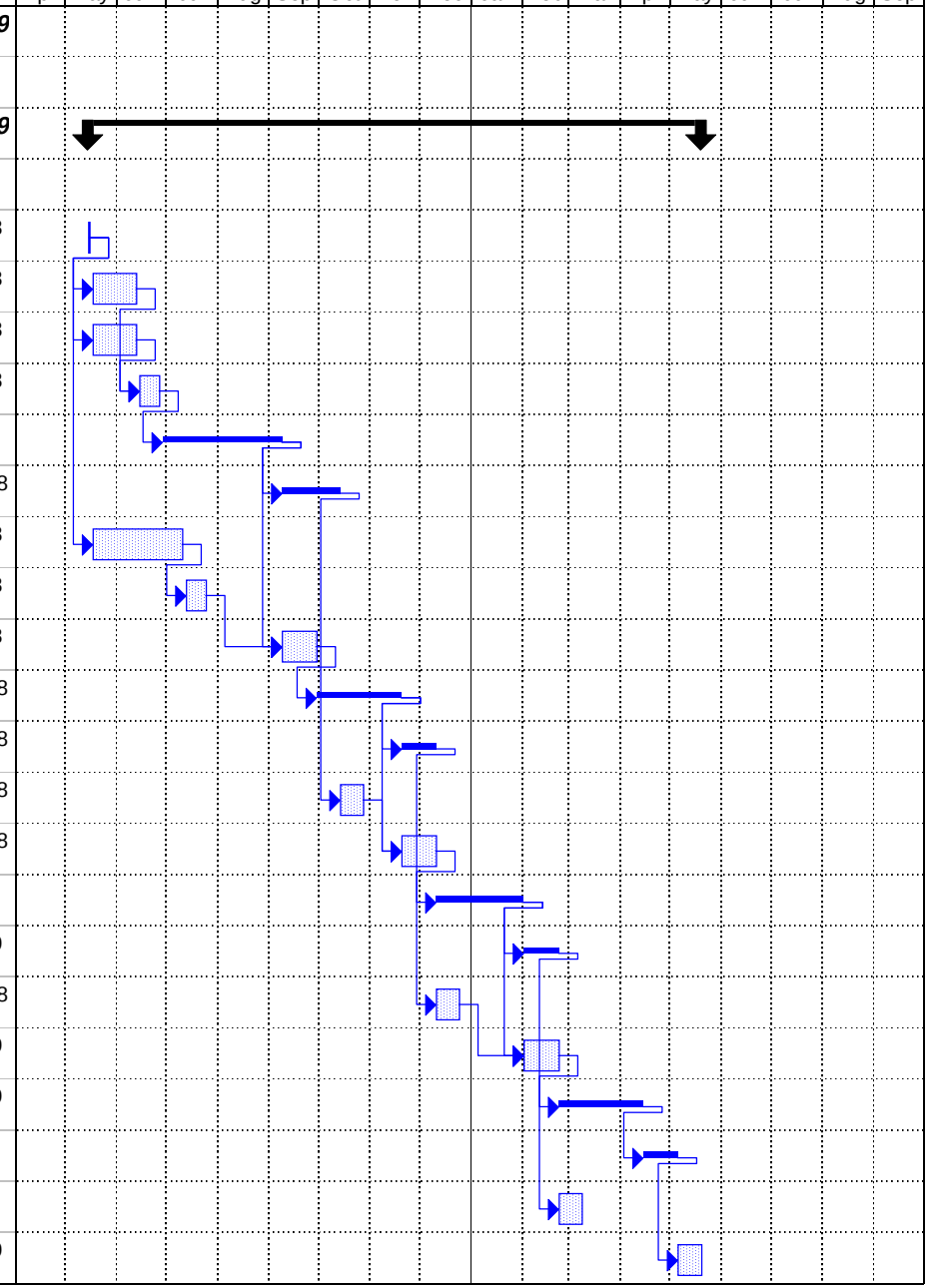
DC power supply layout (top); AC power distribution for heater jackets, pumps and instrumentation (bottom)

APPENDIX C
SCHEDULE

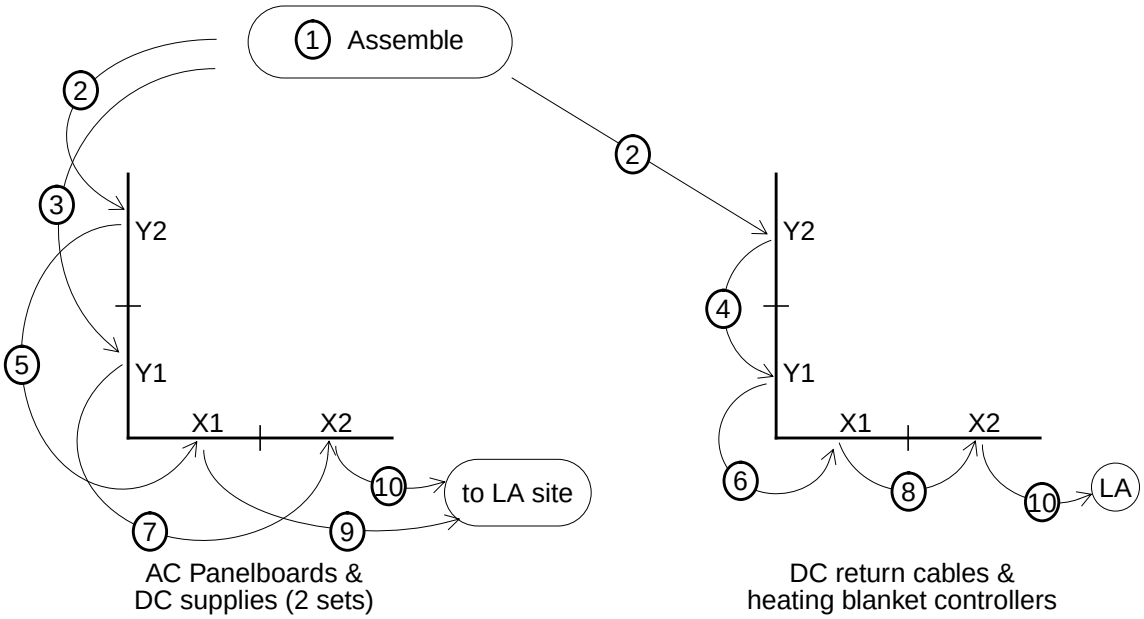
LIGO Hardware Installation and Commissioning Summary Schedule

5/13/98

ID	Task Name	Duration	Start	Finish
1	***BEAM TUBE BAKEOUT - LIGO HANFORD OBSERVA***	***264d***	***5/15/98***	***5/19/99***
2				
3	***Electrical Services for Bakeout***	***264d***	***5/15/98***	***5/19/99***
4				
5	Award Electrical Services Contract	1d	5/15/98	5/15/98
6	Assemble AC/DC Power set 1, Cables, Heater Controls	20d	5/18/98	6/12/98
7	Install and Connect AC/DC Power atY2	20d	5/18/98	6/12/98
8	Install Pumps, Controls at Y2	10d	6/15/98	6/26/98
9	Bakeout Y2	52d	6/29/98	9/8/98
10	Evaluate Y2 bake	25d	9/9/98	10/13/98
11	Assemble AC/DC Power set 2	40d	5/18/98	7/10/98
12	Install AC/DC Power @Y1	10d	7/13/98	7/24/98
13	Move Cables, Pumps, Controls to Y1	15d	9/9/98	9/29/98
14	Bakeout Y1	37d	9/30/98	11/19/98
15	Evaluate Y1 bake	15d	11/20/98	12/10/98
16	Move AC/DC Power set 1 to X1	10d	10/14/98	10/27/98
17	Move Cables, Pumps, Controls to X1	15d	11/20/98	12/10/98
18	Bakeout X1	37d	12/11/98	2/1/99
19	Evaluate X1 bake	15d	2/2/99	2/22/99
20	Move AC/DC Power set 2 to X2	10d	12/11/98	12/24/98
21	Move Cables, Pumps, Controls to X1	15d	2/2/99	2/22/99
22	Bakeout X2	37d	2/23/99	4/14/99
23	Evaluate X2 bake	15d	4/15/99	5/5/99
24	Pack AC/DC Power set 1, ship to LA	10d	2/23/99	3/8/99
25	Pack AC/DC Power set 2 and other equip, ship to LA	10d	5/6/99	5/19/99



APPENDIX D
TASK SEQUENCE



TASK NO.	TASK DESCRIPTION
1	Assemble portable equipment
2	Install 1st set of equipment at Y2
3	Install 2nd set of AC/DC power supplies at Y1
4	Move DC cables and heater blanket controllers to Y1
5	Move 1st set of AC/DC power supplies to X1
6	Move DC cables and heater blanket controllers to X1
7	Move 2nd set of AC/DC power supplies to X2
8	Move DC cables and heater blanket controllers to X2
9	Prepare 1st set of AC/DC power supplies for shipment to LA
10	Prepare remaining equipment for shipment to LA

APPENDIX E
ASSEMBLY SPECIFICATIONS AND DRAWINGS

Drawing List

(**BOLD** entries = LIGO supplied items)

E980022	Specification for Electrical Contractor Services
E980031	Assembly Summary
D980097	Plan view - Bakeout Equipment Arrangement - Y2 Module
D980096	Plan view - Bakeout Equipment Arrangement - Y1 Module
D980094	Plan view - Bakeout Equipment Arrangement - X1 Module
D980095	Plan view - Bakeout Equipment Arrangement - X2 Module
D980098	Bakeout Equipment Details
E980030	Beam Tube Grounding During Bakeout - Assembly 'I'
E970193	**Portable Power Cable - NEC Type W**
E980006	**Heater Relay Panel Assemblies**
E980008	**Portable Power Panelboard Assemblies**

There are two complete sets of AC portable panelboards, DC power supply assemblies and AC cord sets as follows:

E9800023	Specification for Electrical Panelboard Assembly 'A1'
D980047	Assembly 'A1' - 120/208 Volt 3 Phase Service
D980048	Riser Diagram - Assembly 'A1'
D980049	Bill of Materials - Assembly 'A1'
D980050	**Subassembly 'A1-1' - Panel 'A1' (part of E980008)**
D980051	**Panel Schedule for Panel 'A1' (part of E980008)**
D980052	**Bill of Materials - Subassembly 'A1-1' (part of E980008)**
E980024	**Specification for Electrical Panelboard Assembly 'A2'**
D980053	**Assembly 'A2' - 120/208 Volt 3 Phase Service**
D980055	**Bill of Materials - Assembly 'A2'**
D980056	**Subassembly 'A2-1' - Panel 'A2' (part of E980008)**
D980057	**Panel Schedule for Panel 'A2' (part of E980008)**
D980058	**Bill of Materials - Subassembly 'A2-1' (part of E980008)**
E980025	Specification for Electrical Panelboard Assembly 'A3'
D980059	Assembly 'A3' - 120/208 Volt 3 Phase Service
D980060	Riser Diagram - Assembly 'A3'
D980061	Bill of Materials - Assembly 'A3'
D980062	**Subassembly 'A3-1' - Panel 'A3' (part of E980008)**
D980063	**Panel Schedule for Panel 'A3' (part of E980008)**
D980064	**Bill of Materials - Subassembly 'A3-1' (part of E980008)**

E980026	Specification for DC Power Supply Assembly ‘B2’
D980079	Portable DC Power Supply with 277/480 V, 3ϕ Metered Service
D980087	Riser diagram - Assembly ‘B2’
D980088	Panel ‘B2’ Metering cabinet
D980089	Bill of Materials - Assembly ‘B2’
D980090	**Subassembly B2-1 Schematic Diagram (part of E980008)**
D980080	DC Shunt Cabinet - Assembly ‘G’
D980081	DC Shunt Cabinet - Splice Plate Item #212
D980101	DC Shunt Cabinet - Splice Plate Item #213
D980082	DC Shunt Cabinet - Splice Plate Item #214
D980054	Bill of materials - Assembly ‘G’
D980066	**120/240 V, 50 A Weatherproof Power Cord Set Assembly ‘C1’**
D980065	**Bill of Materials - Assembly ‘C1’**
D980067	**Bill of Materials - Misc. Cord Sets and Adapters ‘C2-C12’**
E980027	Specification for 15 kV Transition Box Assembly ‘E’
D980072	15 kV Transition Box - Assembly ‘E’
D980073	Bill of Materials - Assembly ‘E’

There is one set of DC return cable junction boxes and connectors to the beam tube as follows:

E980028	Specification for Beam Tube DC Connections Assembly ‘D’
D980077	Tube Bakeout DC Tube Connection (Assembly ‘D’)
D980078	Bill of Materials - Assembly ‘D’
D980068	Tube Bakeout DC Connector - Subassembly ‘D-1’
D980069	**Tube Bakeout DC Connection Ring Extension - 306T**
D980070	**Tube Bakeout DC Connection Ring Extension - 306B**
D980071	**Bill of Materials - Subassembly ‘D-1’**
D980083	Tube Bakeout DC Connection Box (Subassembly ‘D-2’)
D980084	Splice plate
D980085	Bill of Materials

There is one set of heater jacket controllers as follows:

E980029 Heater Blanket Relay Panel Installation - Assembly ‘H’
D980021 Heating Blanket Relay Panel Box ‘H1’ Ass’y (part of E980006)
D980022 Assembly ‘H1’ Connection Diagram (part of E980006)
D980023 Assembly ‘H1’ Schematic Diagram (part of E980006)
D980038 Bill of Materials - Assembly ‘H1’ (part of E980006)

D980024 Heating Blanket Relay Panel Assembly ‘H2’
D980039 Bill of Materials - Assembly ‘H2’
D980025 Subass’y ‘H2-1’ Heating Blanket Panel ‘H2’ (part of E980006)
D980026 Subass’y ‘H2-1’ Connection Diagram (part of E980006)
D980027 Subass’y ‘H2-1’ Schematic Diagram (part of E980006)
D980091 Controller Display & Equip. Connector Details (part of E980006)
D980040 Bill of Materials - Subass’y ‘H2-1’ (part of E980006)

D980028 Heating Blanket Relay Panel Assembly ‘H3’
D980041 Bill of Materials - Assembly ‘H3’
D980029 Subass’y ‘H3-1’ Heating Blanket Panel ‘H2’ (part of E980006)
D980030 Subass’y ‘H3-1’ Connection Diagram (part of E980006)
D980031 Subass’y ‘H3-1’ Schematic Diagram (part of E980006)
D980091 Controller Display & Equip. Connector Details (part of E980006)
D980042 Bill of Materials - Subass’y ‘H3-1’ (part of E980006)

D980032 Heating Blanket Relay Panel Assembly ‘H4’
D980043 Bill of Materials - Assembly ‘H4’
D980033 Subass’y ‘H4-1’ Heating Blanket Panel ‘H2’ (part of E980006)
D980034 Subass’y ‘H4-1’ Connection Diagram (part of E980006)
D980035 Subass’y ‘H4-1’ Schematic Diagram (part of E980006)
D980091 Controller Display & Equip. Connector Details (part of E980006)
D980044 Bill of Materials - Subass’y ‘H4-1’ (part of E980006)

D980036 Heating Blanket Cord Set Assembly ‘HC’ (part of E980006)
D980045 Bill of Materials - Assembly ‘HC’ (part of E980006)

D980099 Heating Blanket-Junction Box Cord Set ‘HC1’ (part of E980006)
D980100 Bill of Materials - Assembly ‘HC1’ (part of E980006)

D980037 6-Way Junction Box Assembly ‘HJ1’ (part of E980006)
D980046 Bill of Materials - Assembly ‘HJ1’ (part of E980006)

D980092 2-Way Junction Box Assembly ‘HJ2’ (part of E980006)
D980093 Bill of Materials - Assembly ‘HJ2’ (part of E980006)