CBI

TITLE	BEAM TUBE CAN SECTION INSTALLATION SEQUENCE	IDENTIFICATION: INSTALLSEQ LIGO-E950049-07-B			
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		OFFICE LIGO		REVISION 7	
PRODUCT	LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY KLW	CHKD BY KHF	MADE BY RER	CHKD BY LCB
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CBI — DATE 11/4/98

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1.0 Scope

This procedure outlines the sequences to be followed during the installation of the beam tube sections. Detail or supporting procedures for welding, cleaning, testing, alignment, etc. are referenced as required. See Section 6.0 for listing.

2.0 Starting Terminations

2.1 Layout the twenty holes for the termination support base plates. Drill the twelve 15/16" diameter holes only for pieces 20-11 (the short 7/8" diameter anchors) with a depth of 7 1/2" to 7 3/4" deep from the top of the foundation, not the base plate. Drill the eight 1 1/16" diameter holes only for pieces 20-10 (the long 1" diameter anchors) with a depth of 1'- 0 3/8" to 1'- 0 5/8" deep from the top of the foundation.

2.2 Locate and anchor the soft support bearing plate to the concrete valve foundation. The centerlines of the bearing plate must be placed within 1/4" of the final valve centerline location. Drill 5/8" diameter holes, 2" deep for the drop-in anchor. Blow out the holes, and insert the anchors using the proper setting tool. Setting tool to be driven into anchor until setting tool shoulder meets top of anchor. Tighten the anchor bolts to about 11 ft-lb (22 ft-lb max).

2.3 Roughen the foundation surface (where the base plates for the termination support will sit) by chipping, sand blasting or other mechanical means to remove any laitance or weak surface layer.

2.4 Adjust the support pads (by means of the adjusting bolts) on the valve temporary support frame so that the pads are centered and square with the frame. Place the valve temporary support frame on the concrete valve foundation. To easily achieve an accurate placement, line up the centerline of the support pads with the centerlines of the soft support bearing plate which has already been accurately placed. The valve temporary support pads can be adjusted 1" in any direction.

2.5 Adjust the 1" studs on the valve temporary support frame so that the when the valve is placed on the pads the height of the valve centerline will be close to its final location and level. The four 1" studs should all be contacting the concrete at this time (snug each stud by hand to insure contact is made).

2.6 In accordance with the valve manufacturer's handling procedures, lift the valve from the shipping crate, rotate the valve to the vertical position and center the valve over the soft support plate centerlines. Lower the valve onto the valve temporary support frame pads. Hold the valve vertically with the crane until temporary angle tie backs are installed and adjusted to hold the valve in the vertical position. After the valve is secured in position, remove all rigging/lifting equipment from the valve.

Note: Do not remove the cap from the valve stub at this time.

2.7 Clean bottom of base plate (Pc Mk. 20-9) to remove dirt and contamination. Wipe surface with isopropyl alcohol to degrease the surface.

2.8 Position and level the base plate using shims. A minimum clearance between the base plate and the foundation of 1/2" is required (use 3/4" nominal) over the entire base plate.

2.9 Clean holes with a wire brush and then blow out hole using a pump, blow out bulb or compressed air.

2.10 Install the epoxy anchors per the manufacturer's instructions, noting the following precautions/steps:

1. Use Hilti HIT-HY 150 adhesive epoxy. Store the epoxy in a cool (41°F to 77°F), dry location, away from direct sun light.
2. When installing the epoxy anchors, the temperature of the beam tube slab must be at least 23°F, the slab may be heated to achieve the desired temperature. The temperature of the epoxy must be at least 41°F.
3. After rejecting the first two trigger pulls of a new epoxy refill pack or new nozzle, inject the epoxy into the hole, filling from the bottom and slowly withdrawing the nozzle until the hole is at about 2/3 full. Care should be taken to avoid forming air pockets in the epoxy.
4. Insert the anchor into the hole, twisting slightly during installation. Assure the anchor projects vertical. Do not disturb the anchor after the gel time and until the epoxy is fully cured. Do not load the anchor until the epoxy is fully cured (see the table below).

Foundation Temperature (°F)	Cure Time	Gel Time
23	6 hours	25 minutes
32	3 hours	18 minutes
41	1.5 hours	13 minutes
68	50 minutes	5 minutes
86	40 minutes	4 minutes
104	30 minutes	2 minutes

2.11 Clean up the area around the valve and beam tube termination. If the permanent building is not completed, cover the valve to protect it from the weather. To use as a temporary weld shelter and provide a controlled atmosphere, erect an enclosure around the area of the seam between the beam tube termination section and the valve stub. The temporary enclosure shall protect the tube from contamination by airborne dust, flying insects and shall keep floor dust from becoming airborne. Control the atmosphere in this temporary weld shelter by connecting it to the Weld Shelter system, BDF or through the use of HEPA filters.

2.12 Set the beam tube termination section on temporary, adjustable supports and roll it into the temporary weld shelter.

2.13 Position the Weld Shelter over the termination tube section as close to the valve/beam tube interface as possible. If the permanent building has been erected, this will be outside of the exterior wall, or at the end of the first concrete beam tube cover section if it has been installed. The Weld Shelter HVAC system will be used to provide clean, filtered air to the temporary weld shelter.

2.14 Clean the ends of the valve stub and beam tube section in accordance with procedure CCP-1 until all visible contamination has been removed. Clean the inside of the temporary weld shelter to remove all visible contamination, and wet down the floor.

2.15 Confirm that the temporary shelter is clean and insect free. Remove the cap from the valve stub and request the LIGO representative to take their measurements of the valve gate gap. Align the valve optically to the established reference points. Adjust the elevation, axial and lateral positions, perpendicularity and rotation to the beam tube axis, using the

adjustments provided by the temporary valve support. Minimize the length of time that the cap is off the valve stub by doing as much of the alignment process as possible before the cap is removed or after the cap has been reinstalled.

2.16 Confirm that the temporary weld shelter is insect free, then remove the cap from the end of the beam tube termination section and move the beam tube termination section toward the valve until it is in its final position. Align the free end of the beam tube section and begin aligning the circumferential seam using the special CBI fit-up clamp.

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Warning

Do not perform any welding or tacking at this time.

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2.17 Move or roll the Clean Room into position over the end of the beam tube section, in accordance with the steps outlined in sections 3.10 and 3.11 below.

2.18 Remove the end cap from the end of beam tube section now inside the Clean Room. Personnel entering the Clean Room and tube shall meet the conditions and clothing requirements of CRWA-1. Personnel entering the beam tube shall take precautions to prevent contamination of the beam tube by bodily fluids. During warm weather, "cool vests" shall be worn to control excess sweating. Personnel who have signs of a cold or flu shall not enter the beam tube.

2.19 Complete required checks and records for non-permit confined space entry, and verify safe entry is feasible. Initiate the tube entry inventory record.

2.20 While maintaining the free end of the beam tube termination section in its correct position, align, fit and weld the circumferential seam between the beam tube termination section and the valve in accordance with the steps outlined in sections 3.15 through 3.24 below.

2.21 Leak test the completed circumferential seam in accordance with the steps outlined in sections 3.25 through 3.34 below.

2.22 Once the circumferential seam is successfully tested, the temporary weld shelter may be removed. The valve must be protected from the weather at all times.

Note: Sections 2.23 through 2.25 may be completed later during the continuing beam tube installation process (see sections 3.39 through 3.42).

2.23 Install any required internal baffles in accordance with the Internal Baffle Installation procedure BFL.

2.24 Inspect and clean beam tube interior as the workman "backs out" of beam tube from the completed circumferential seam.

2.25 Immediately upon completion of baffle installation, cleaning, and exiting from the Clean Room end of the beam tube, install the tube access plug in the Clean Room end of the just installed beam tube termination section.

2.26 Install and secure a cap on the clean room end of the beam tube termination section, and cover with a clean protective bag.

2.27 At this point, installation of the beam tube termination section is complete and beam tube installation may be started.

2.28 Position the termination support frame sections. Align and bolt the two halves together. Torque the bolts in accordance with the drawings. Align the frame and connect the beam tube termination section to the termination support per the drawings.

2.29 Install valve soft support referencing drawing #22, note #2 for installation sequence.

2.30 Remove the temporary valve support and angle tie back braces. Confirm the valve position.

2.31 If the permanent building has not been erected and enclosed, erect a temporary weather enclosure over the valve upon removal of the temporary weld shelter and installation of the termination support.

2.32 While **maintaining cleanliness**, connect the Blower/Dryer/Filter (BDF) system to the pump port, and start the flow of air into the beam tube when the next beam tube section is placed, see step 3.13 below.

Note: The following steps are done upon completion of the module during final alignment.

2.33 Verify the valve is in its proper position.

2.34 Install piece 20-14, lubricate the anchor bolts and then install the Belleville washers and the nuts on the 1" diameter anchor bolts. Reference drawing #20 (sheet #2 and note #10 of sheet #1) for installation instructions. To achieve proper tension in the bolts, note the torque required to flatten the Belleville washers, and then tighten the bolts to 1.5 times that torque (do not exceed a torque of 208 ft-lbs).

2.35 Weld pieces 20-13 to the base plates (Pc Mk 20-9). To achieve the desired gap, make sure the mating edges of pieces 20-13 and 20-12 are free of any dirt or other material which may prevent a close fit. Fit piece 20-13 tightly against piece 20-12. To minimize opening of the gap during welding, weld the ends of piece 20-13 to the base plate first, and then weld the long edge of 20-13 to the base plate. After the welding of pieces 20-13 is complete, check the resulting gaps between pieces 20-13 and 20-12.. If the sum of the gaps for the two pieces 20-13 on the same side of the beam tube exceeds the allowable per drawing 20 sheet 2, shim the gaps to be less than the maximum allowable.

2.36 Provide forms to contain the grout under the base plate. Use "Five Star Speed Epoxy Grout" or equal to fill the space between the base plate and the foundation. Ensure that the grout fills the spaces between the anchor bolts and the base plate to the top surface of the base plate.

2.37 Only after the anchor bolt adhesive is fully cured and base plate grout has cured for 24 hours, install washer and two nuts on each 7/8" anchor bolt. Tighten the bottom nut and "snug" the top nut against the bottom nut.

3.0 Installation Sequence

See the "Beam Tube Can Section Fabrication Sequence" procedure (Doc ID "FabSeq") for the specific sequences and procedures that are followed during the fabrication sequence.

The beam tube sections are delivered to the installation site in a tested and internally cleaned condition with sealed end caps and double plastic protective bags installed on both ends, and wrapped with sun shield tarps. Beam tube sections with pump port nozzles will have the valve and the "H" pump port hardware attached in the shop prior to shipment and sealed with plastic covers, and protected for shipment.

Limit contamination of the beam tube module inner surfaces during installation.

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Reference

See
"Contamination Control for Construction Activities During Beam Tube Installation"
Doc ID "CCP-1"

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Additionally, the previously installed beam tube sections are maintained under a positive clean air flow at all times that the construction end of the beam tube is open during installation activities.

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Reference

See
"Positive Blower/Dryer/Filtration System Installation & Maintenance"
Doc ID "BDF1"

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3.1 Receive the beam tube sections from the fabrication facility, unload and store the beam tube section on temporary supports along side the beam tube slab. The sun shield shall cover the beam tube sections while in transit and temporary storage at the installation site.

Note: The installed beam tube sections outside of the concrete beam tube covers shall be covered with a sun screen before a differential of the temperature of any two points on the beam tube surface exceeds 100°F.

3.2 Move or roll the Clean Room and associated equipment forward allowing sufficient space to place the next beam tube section into position.

3.3 Move the Weld Shelter along the completed beam tube section until the end of the completed beam tube section is inside the Weld Shelter Outer Room nearest the Clean Room.

3.4 After verifying the correct orientation of the ends, position the next beam tube section on temporary, adjustable supports on the beam tube slab, with the end of the beam tube section inside the Outer Room of the Weld Shelter and near the end of the completed beam tube section.

3.5 Following visual inspection of the next beam tube section (this inspection may be done prior to setting the next beam tube section in place), move the Weld Shelter further along until the beam tube ends are in the Ante Room.

Note: During inclement weather, prior to moving the Weld Shelter, while still under the Outer Room, remove the first protective bag from the end of the next beam tube section and wipe any contamination from the remaining bag and tube end.

3.6 Inside the Weld Shelter Ante Room, remove the protective bags from the ends of both the next and the completed beam tube sections. Remove any visible contamination from the beam tube ends, in accordance with procedure CCP-1, and move the Weld Shelter further along the beam tube until the ends are inside the Fit-Up Room of the Weld Shelter.

3.7 After verifying that the ends of the tubes and the interior of the Weld Shelter Fit-Up Room are at the desired level of cleanliness in accordance with procedure CCP-1, remove the end caps of both beam tube sections at the circumferential seam to be made and position the next beam tube section to the completed beam tube section.

3.8 Using a centering head, rotate the next beam tube section into proper alignment with the completed beam tube section and start aligning the circumferential seam using special CBI fit-up clamp. See drawing ER45 for details of the fit-up clamp.

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Warning

Do not perform any welding or tacking at this time.

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Reference See "Fitting/Purge Procedure for Circumferential Butt Welds for *LIGO*" Doc ID "FPCircumferential"

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3.9 Align beam tube section centerline and elevation to the previously marked alignment reference points.

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Reference See "Initial and Final Alignment During Installation of LIGO Beam Tube Modules using GPS System" Doc ID "ALI-1"

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3.10 Move the Clean Room back so the Ante Room is over the end of the beam tube and remove the protective bags. Remove any visible contamination from the end of the beam tube section in accordance with procedure CCP-1.

Note: During inclement weather, stop the Clean Room so the Outer Room is over the end of the beam tube. Remove the first protective bag and remove any visible contamination from the remaining bag and end of the beam tube section, in accordance with procedure CCP-1, prior to continuing movement of the Clean Room so the Ante Room is over the end of the beam tube for removal of the second protective bag.

3.11 After verifying that all visible contamination has been removed from the end of the beam tube section and the Clean Room and seal area, move the Clean Room into position over the end of the beam tube section. Pressurize the inflatable seal to seal the tube to the Clean Room.

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Reference
See
"Clean Room Transporting,
Storage and Maintenance Procedure"
Doc ID"CRTSM"
for specific procedures
to be adhered to when using
the clean room.

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3.12 Remove end cap from end of beam tube section now inside Clean Room. Personnel entering the Clean Room and tube shall meet the conditions and clothing requirements of CRWA-1. Personnel entering the beam tube shall take precautions to prevent contamination of the beam tube by bodily fluids. During warm weather, "cool vests" shall be worn to control excess sweating. Personnel who have signs of a cold or flu shall not enter the beam tube.

3.13 Start the air flow from the BDF into the beam tube by closing the bypass valve to the atmosphere and opening the valve to the pump port.

3.14 Verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non-permit confined space entry. Initiate the tube entry inventory record.

3.15 Install the inflatable purge ring, centered on the circumferential seam, and place the stainless steel purge line inside the tube section.

Note: Purge lines shall be stainless steel tube or sheathed with metal braid for cleanliness and protection.

3.16 Using the quick disconnects and flexible connection lines, connect the purge line to the breathing air supply and to the inflatable purge ring outer seals. Inflate the purge ring seals by opening the valve to the breathing air supply line, while maintaining the purge

ring centered on the circumferential seam. Do not exceed a pressure of 25 psi in the purge ring seals.

3.17 After the purge ring is sealed against the tube, close the breathing air supply valve. Disconnect the purge line from the inflatable purge ring seals, and connect the purge line to the purge ring annular space. At this time all personnel must evacuate the beam tube section.

No one is allowed inside the beam tube during the purging operation!

3.18 Inside the Clean Room, disconnect the purge line from the breathing air supply line and connect the purge line to the Argon purge gas supply line. Purge the annular space by fully opening the Argon gas supply valve, allowing the flow of purge gas through the annular space and out the vent port into the beam tube. Purge until the annular space contains less than 1.0% oxygen, as verified by the remote read out from the oxygen sensor connected directly to the purge ring annular space. Upon reaching 1.0% oxygen or less, establish the Argon flow rate at the minimum value (light positive flow) necessary to maintain oxygen level between 0.5% and 1.0%.

3.19 Complete fit-up of the circumferential seam. Tack welding is allowed at this step.

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Reference
See
"Welding Procedure Specification
for Circumferential Welds"
Doc ID "WPS-ER308L/Circ".

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3.20 Set up and position the weld equipment and complete the welding of the circumferential seam.

3.21 Close the Argon purge gas supply valve and move the flexible connector hose from the Argon purge gas supply line to the breathing air supply line. Open the breathing air supply valve and vent the Argon purge gas from the purge ring annular space until the acceptable oxygen level is achieved in the annular space as verified by the oxygen sensor.

3.22 After venting of the purge ring annular space is complete, verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non-permit confined space entry. Personnel entering the beam tube shall meet the conditions and clothing requirements of LIGO Procedure, CRWA-1.

3.23 Enter the beam tube and deflate the purge ring by venting the purge ring seals. Move the inflatable purge ring clear of the circumferential seam.

3.24 Visually inspect the outside and inside of the completed circumferential seam weld in accordance with Visual Inspection Procedure VI8X. If any welded repairs are necessary, perform the repairs in accordance with WPS-ER308L/REPAIR. For any repairs not requiring welding, use repair procedure GR8X. When the seam is acceptable, proceed to step 3.39.

Note: During any repairs in the interior of the beam tube, steps must be taken to contain and remove particulate matter.

- Any grinding or chipping shall be performed with a portable tool inside a clean containment box.
- Weld repairs shall be made with a portable 110 volt GTAW (TIG) power source, (Maxstar 91 or equal).
- The glove box interior and exposed tube wall shall be vacuumed in place prior to removal from the beam tube. The vacuum shall vent outside the beam tube and Clean Room, or exhaust through a HEPA filter.
- The repaired area shall be inspected and cleaned in accordance with procedure CL3N.

Note: The following steps 3.25 through 3.34 are for vacuum testing the circumferencial seams. Typically they are done on the previously completed seam concurrently with the fitting and welding of the next beam tube section, steps 3.15 through 3.24.

No one is allowed inside the beam tube during the purging operations for the external welding, nor the leak testing!

3.25 Position the inflatable purge ring over the circumferential seam. Confirm that the purge line is connected to the breathing air supply and the purge ring outer seals. Inflate the purge ring outer seals by opening the valve to the breathing air supply line, while maintaining the purge ring centered on the circumferential seam. Do not exceed a pressure of 25 psi in the purge ring seals.

3.26 After the test purge ring is sealed against the tube, close the breathing air supply valve. Disconnect the purge line from the inflatable purge ring seals, and connect the purge line to the purge ring annular space. At this time all personnel must evacuate the beam tube section.

No one is allowed inside the beam tube during the helium leak test purging operation!

3.27 Inside the Clean Room, disconnect the purge line from the breathing air supply line and connect the purge line to the Helium test gas supply line.

3.28 After positioning the Test Shelter over the seam, install the 360 degree vacuum box, connect the Helium Mass Spectrometer, and test the circumferential seam.

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Reference
See
"Helium Mass Spectrometer Hood Testing
of Closing Weld Joints Between Beam
Tube Can Sections"
Doc ID "HMST2N"

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3.29 If a leak is detected, vent, locate, repair and re-test in accordance with the applicable steps of procedure HMST2N.

3.30 Remove the 360 degree vacuum box from the circumferential seam exterior.

3.31 Close the valve to the Helium test gas supply. Disconnect the purge line from the Helium test gas supply line and reconnect it to the breathing air supply line. Open the breathing air supply valve and vent the Helium test gas from the purge ring annular space through the

vent port and into the beam tube until the acceptable oxygen level is achieved in the annular space.

3.32 After venting of the test purge ring annular space is complete, verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non-permit confined space entry. Personnel entering the beam tube shall meet the conditions and clothing requirements of LIGO Procedure, CRWA-1.

3.33 Enter the beam tube and deflate the test purge ring by venting the purge ring seals. Leave the purge ring at the seam until it is time to move it to the next seam for testing. If necessary for baffle installation, move the test inflatable purge ring away from the seam.

3.34 Disconnect and remove the stainless steel purge line.

3.35 Steps 3.36 through 3.38 are for installation and testing of valve at the pump port. Generally the pump port valve and "H" type pump port hardware will be installed and tested in the shop prior to shipping to the installation site. Skip these steps if not applicable to a specific beam tube can section.

3.36 Temporarily enclose the pump port area. The temporary enclosure shall protect the port from contamination by airborne dust, flying insects and shall keep floor dust from becoming airborne. Remove the pump port cover and locally clean the area associated with pump port with isopropyl alcohol. Extreme caution must be used to prevent damage to the pump port knife edge sealing surfaces.

3.37 Immediately after cleaning the pump port area, place a gasket on the pump port flange on the beam tube section. Carefully install the valve and the type H pump port hardware.

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Reference
See
"Helium Mass Spectrometer Hood Test
of Valve and Blind Flange Seals to Pump Ports"
Doc ID "HMST3N"

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3.38 Perform helium mass spectrometer test of installed valve and pump port hardware.

3.39 Install the required internal baffles in the previously completed beam tube section in accordance with the Internal Baffle Installation procedure BFL.

3.40 Remove tube access plug from the end of the previously completed area.

3.41 Inspect and clean beam tube interior as the workman "backs out" of beam tube from completed area. Power cords for equipment, such as the vacuum cleaner, shall be sheathed with metal braid, or other acceptable material for cleanliness and protection.

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Reference
See
"Final Cleaning and Inspection of
Beam Tube Module Inner Surfaces "
Doc ID "CL3N"

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3.42 Install tube access plug near the end of the just completed area immediately upon completion of baffle installation, cleaning, and exit from that area of the beam tube towards the Clean Room.

3.43 Perform initial alignment during construction and installation of beam tube section per procedure ALI-1.

3.44 Stop the air flow from the BDF into the beam tube by closing the valve to the pump port and opening the bypass valve to the atmosphere.

3.45 Install an end cap on the clean room end of the beam tube and secure in position with band. Place the protective bag over the end cap and end of the tube section and secure with a stretchable cord.

3.46 At this point, the beam tube section installation is complete and the next beam tube section installation may be started. Revert to paragraph 3.2.

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Note

Do not move clean room from end of installed beam tube until just prior to installation of next beam tube.

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4.0 Support Installation

The contract structural supports are installed on the beam tube sections which have been welded in place and after the fit-up/welding rolling equipment has been moved forward of structural support point. The longitudinal position of the beam tube supports is established based on the position of the support stiffeners on the installed beam tube sections with the appropriate compensation for the temperature at the time of installation. The design of the beam tube calls for the expansion joints to be in their neutral position when the temperature of the beam tube is 106 °F. The installation sequence for all fixed and guided supports consists of the following steps proceeding from fixed support to fixed support.

4.1 After the beam tube fit-up/welding/testing rolling equipment has moved clear of the next installed beam tube section with a fixed support, attach the fixed support bracket assemblies (Pc Mk 6-B) to the beam tube support stiffener ring. Then connect the frame assembly (Pc Mk 6-A) to the bracket assemblies per drawing 6.

4.2 To locate the longitudinal position of the fixed support and the corresponding beam tube circumferential seam, the two beam tube sections and the expansion joint, forward of the previous fixed support, must be adjusted longitudinally for the current position and temperature by stretching the expansion joint and moving the leading beam tube section.

For a length of 130' between fixed supports, the expansion joint must be stretched to move the fixed support stiffener forward in the direction of construction a distance equal to the amount based on the measured temperature per the table shown below, plus or minus the amount the expansion joint varies from it's theoretical free length of 25 inches (add the variation to the temperature base amount if the expansion joint is less than it's theoretical free length of 25 inches, subtract the variation if it is more than it's free length). For fixed supports adjacent to terminations, the amounts shown in the table must be reduced by the ratio of the length between the termination support and the fixed support to 130'.

The following chart represents the number to be added to 25 inches to get the final length for the expansion joint at that temperature after stretching.

Measured Temperature	Longitudinal Adjustment
106 °F	0"
98 °F	1/8"
90 °F	1/4"
82 °F	3/8"
74 °F	1/2"
66 °F	5/8"
58 °F	3/4"
50 °F	7/8"
42 °F	1"
34 °F	1 1/8"
26 °F	1 1/4"
18 °F	1 3/8"
10 °F	1 1/2"
2 °F	1 5/8"
- 6 °F	1 3/4"
-14°F	1 7/8"
-22°F	2"

Note: The expansion joint length may be further adjusted to compensate for variations in the lengths of the beam tube sections in order to maintain the ends of the beam tubes within the tolerances necessary for the location of the pump ports and termination point. The final length of two adjacent expansion joints may not vary by more than 1/4" when measured at the same temperature.

4.3 To establish the longitudinal adjustment, determine the average temperature of the beam tube sections between the previous fixed support and the fixed support being installed. The temperature should be taken on the top, bottom, and on each side of the tube sections using a digital surface thermometer. If conditions, such as a portion of the beam tube being covered, create areas of differing temperatures, additional measurements will be taken along the axis at each of the different areas. Once the average temperature is determined, calculate the amount of the longitudinal adjustment per step 4.2 above and immediately

mark the longitudinal position of the fixed support lug assembly (Pc Mk 8-A or 8-B) in relation to the corresponding frame assembly (Pc Mk 6-A).

4.4 Once the required position is known, anchor the fixed support lug assembly (Pc Mk 8-A or 8-B) to the concrete in the correct position longitudinally and laterally based on the beam tube alignment reference marks and the calculated longitudinal adjustment. The holes for the anchors should be 5/8" diameter and a minimum of 4 1/4" deep. Blow out the hole. Insert the anchor stud using a hammer making sure that some threads are below the top surface of the base plate. Install and tighten the nuts on the anchor bolt.

4.5 With the fixed support lug assembly anchored in the proper position, a space will exist between it and the fixed support frame assembly. If this space does not exceed 1-3/8", (plus the variation of the expansion joint from it's free length if it is less than the free length, or minus the variation if it is greater than the free length), use the four 1" diameter clamping bolts (Pc Mk 8-6) to draw the frame assembly and tube section to the anchored lug assembly, closing the gap. The 1-3/8" space, plus or minus the adjustment, corresponds to the maximum allowable longitudinal load on the anchored lug assembly. If the space exceeds this amount at the time the expansion joint is being stretched, additional assistance, in the form of additional temporary anchors to pull against, is necessary to close the space. Once the cross member of the frame assembly is pulled to the lug assembly and the space closed, and the beam tube adjusted laterally and for elevation to the preliminary reference point, tighten the four 1" diameter clamping bolts to prevent movement until final alignment is done later.

4.6 If the beam tube temperature is expected to fall below 14 °F, the last beam tube fixed support must be restrained with additional means to prevent excessive anchor bolt uplift loads until the next fixed support is installed.

4.7 Assemble the guided support at the expansion joint in accordance with drawing 19 and adjust the cables to support the beam tube at the proper elevation.

4.8 After the two adjacent fixed supports are installed, and verifying that the guided support is centered axially about the expansion joint, locate and drill (using the base plates as a template) eight 9/16" diameter holes with a depth of 4-1/4" to 4-1/2" from the top of the beam tube slab, not the base plate. Clean the holes with a wire brush and then blow out the

holes using a pump, blow out bulb or compressed air. The holes should be drilled as nearly vertical as possible, due to interferences, the holes may not be exactly vertical.

4.9 Install the epoxy anchors per the manufacturer's instructions, noting the following precautions/steps:

1. Use Hilti HIT-HY 150 adhesive epoxy. Store the epoxy in a cool (41°F to 77°F), dry location, away from direct sun light.
2. If necessary to make the anchor vertical, "prebend" the anchor prior to setting it in the hole in the epoxy.
3. When installing the epoxy anchors, the temperature of the beam tube slab must be at least 23°F, the slab may be heated to achieve the desired temperature. The temperature of the epoxy must be at least 41°F.
4. After rejecting the first two trigger pulls of a new epoxy refill pack or new nozzle, inject the epoxy into the hole, filling from the bottom and slowly withdrawing the nozzle until the hole is at about 2/3 full. Care should be taken to avoid forming air pockets in the epoxy.
5. Insert the anchor into the hole, twisting slightly during installation. Assure the anchor projects vertical. Do not disturb the anchor after the gel time and until the epoxy is fully cured. Do not load the anchor until the epoxy is fully cured (see the table below).

Foundation Temperature (°F)	Cure Time	Gel Time
23	6 hours	25 minutes
32	3 hours	18 minutes
41	1.5 hours	13 minutes
68	50 minutes	5 minutes
86	40 minutes	4 minutes
104	30 minutes	2 minutes

4.10 After the anchor bolt adhesive is fully cured, install a washer and one nut on each 1/2" anchor bolt. Tighten the bottom nut to anchor the base plate to the concrete. Loosely install piece 19-6, the Belleville washers and the nuts on the 1/2" diameter anchor bolts. Reference drawing #19 sheet #3 for details.

Note: **Do not anchor the guided support to the base plate or the concrete beam tube slab at this time**. The guided support must remain loose until the concrete covers are installed, to allow the beam tube and support frame to move during temperature changes.

4.11 The temporary supports near the permanent fixed or guided supports can be removed as soon as the permanent support is installed and supports the beam tube.

4.12 After the concrete beam tube covers have been placed, position the guided support frame and beam tube in the proper location using the reference marks. Use the 4-way hydraulic tensioner, as described in procedure SUP-ADJUST, to obtain equal tension in the horizontal cables, and in the vertical hanger cables. The beam tube should be centered laterally in the guided support frame by adjusting the horizontal cables. Position the guided support frame along the beam tube so that the hanger cables on each side of the expansion joint are symmetrical, they should both be vertical or both be slanted away from the expansion joint an equal amount. Tighten the nuts and Belleville washers in accordance with drawing #19, note #5 to anchor the guided support frame and beam tube in position.

5.0 Ending Terminations

5.1 Prior to placing the last beam tube section, layout the twenty holes for the termination support base plates. Drill the twelve 15/16" diameter holes only for pieces 20-11 (the short 7/8" diameter anchors) with a depth of 7 1/2" to 7 3/4" deep from the top of the foundation, not the base plate. Drill the eight 1 1/16" diameter holes only for pieces 20-10 (the long 1" diameter anchors) with a depth of 1'- 0 3/8" to 1'- 0 5/8" deep from the top of the foundation. Prepare the concrete surface and position and install the base plates as described in steps 2.3, and 2.7 through 2.10.

Note: Steps 5.2 through 5.10 are applicable if the corner or end station building has not been erected to the extent of blocking the continued use of the Clean Room. If the building construction status prevents the use of the Clean Room on the last two tube sections and valve proceed to step 5.11.

5.2 Prior to completion of the next to last beam tube section, prepare temporary supports and track to allow movement of the Clean Room past the end of the valve foundation block.

5.3 Prior to completion of the next to last beam tube section, locate and anchor the valve soft support base plate as described in step 2.2.

5.4 Adjust the support pads on the valve temporary support frame so that the pads are as far away from the beam tube section as possible. This will provide 2 1/2" of axial movement toward the beam tube section with the valve in place. Adjust the 1" studs on the valve temporary support frame so that when the valve is placed on the pads, the height of the valve centerline will be close to it's final location and level.

5.5 After installation and welding of the last beam tube section, move the Clean Room forward and place the soft support and temporary support frame on the concrete valve foundation. Position the frame to allow approximately 2" of axial movement of the valve toward the beam tube when the valve is placed in the frame.

5.6 In accordance with the valve manufacturer's handling procedures, lift the valve from the shipping crate, rotate the valve to the vertical position and center the valve over the soft support plate centerlines. Lower the valve onto the valve temporary support frame pads. Hold the valve vertically with the crane until the temporary angle tie backs are installed and adjusted to hold the valve in the vertical position. After the valve is secured in position, remove all rigging/lifting equipment from the valve.

Note: Do not remove the cap from the valve stub at this time.

5.7 Position the Weld Shelter near the end of the beam tube termination section. To use as a temporary weld shelter and provide a controlled atmosphere, erect an enclosure around the area of the seam between the beam tube termination section and the valve stub. The temporary enclosure shall protect the tube from contamination by airborne dust, flying insects and shall keep floor dust from becoming airborne. Control the atmosphere in this temporary weld shelter by connecting it to the Weld Shelter or Clean Room system.

5.8 Clean the temporary weld shelter by vacuum and wiping down the surfaces. Clean the end of the valve stub and beam tube section in accordance with procedure CCP-1 to remove all visible contamination on the ends and surrounding surfaces. Any tools or material taken into the temporary weld shelter shall be cleaned first.

5.9 Move or roll Clean Room into position near the vacuum equipment side of the valve. After cleaning and verifying that all visible contamination has been removed, place a short section of tube between the Clean Room and the valve to span this gap. This consists of a short section of excess beam tube material with a flange for bolting it to the face of the valve. Protect the valve face with a gasket made of 1/8 inch thick Red Buna-N Rubber. The end of the short tube projects into the Clean Room penetration as a normal tube section. Pressurize the inflatable seal to seal the Clean Room to this make-up tube section.

5.10 Proceed to step 5.27.

Note: Steps 5.11 through 5.26 are applicable if the corner or end station building has been erected to the extent of preventing the continued use of the Clean Room on the last two tube sections and the valve.

5.11 After installation and welding of the third tube from the end, remove the Clean Room and associated equipment from the beam tube slab.

5.12 Place the last two tube sections on the beam tube slab in their approximate positions.

5.13 Position the Weld Shelter over the seam between the last two tube sections. After removing all visible contamination from the ends of the beam tube sections and the surrounding area, remove the end caps and align and fasten the two sections together by pulling them together with come-alongs connected to temporary lugs clamped to the support stiffener rings. Seal the seam with plastic stretch-wrap film.

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Warning
Do not perform any welding
or tacking at this time.

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5.14 Move the Weld Shelter over the seam between the second and third tube sections. After removing all visible contamination from the ends of the beam tube sections and the surrounding area, remove the end caps and begin aligning the circumferential seam with the special CBI fit-up clamp.

****

Warning
Do not perform any welding
or tacking at this time.
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5.15 To use as a temporary clean room/ante room and provide a controlled atmosphere for entry into the beam tube, erect a two section enclosure over the end of the last beam tube section. The temporary enclosure shall protect the tube from contamination by airborne dust, flying insects and shall keep floor dust from becoming airborne. Control the atmosphere in this temporary shelter by connecting it to the Weld Shelter system or through the use of HEPA filters. Clean the temporary shelter by vacuum and wiping down the surfaces. Personnel entering this temporary clean room and the beam tube shall meet the conditions and clothing requirements of CRWA-1. Personnel entering the beam tube shall take precautions to prevent contamination of the beam tube by bodily fluids. During warm weather, "cool vests" shall be worn to control excess sweating. Personnel who have signs of a cold or flu shall not enter the beam tube.

5.16 After verifying that all visible contamination has been removed from the end of the last beam tube section and the temporary clean room in accordance with CCP-1, remove the end cap. Start the air flow from the BDF unit into the tube, verify positive airflow exists and that safe entry is feasible. Complete required checks and records for non-permit confined space entry. Initiate the tube entry inventory record.

5.17 Align, fit and weld the second beam tube section to the last beam tube section in accordance with steps 3.15 through 3.24 above.

5.18 After moving the Weld Shelter back over the seam between the second and third beam tube sections and verifying that all visible contamination has been removed from beam tube seam and surrounding area, align, fit and weld this seam in accordance with steps 3.15 through 3.24 above.

5.19 Leak test each of the seams completed in steps 5.17 and 5.18 in accordance with steps 3.25 through 3.34 above. If not installed in the shop prior to shipping, install and test the pump

port valve in accordance with steps 3.36 through 3.38 above. Complete internal baffles, divert air flow from the BDF unit, and cap the beam tube end in accordance with steps 3.39 through 3.45 above.

5.20 Adjust the support pads on the termination valve temporary support frame so that the pads are as far away from the beam tube section as possible. This will provide 2 1/2" of axial movement toward the beam tube section with the valve in place. Adjust the 1" studs on the valve temporary support frame so that when the valve is placed on the pads, the height of the valve centerline will be close to it's final location and level.

5.21 Open the temporary clean room, or move it forward, to allow installation of the termination valve. Place the soft support bearing plate and temporary support frame on the concrete valve foundation. Position the frame to allow approximately 2" of axial movement of the valve toward the beam tube when the valve is place on the frame.

5.22 In accordance with the valve manufacturer's handling procedures, lift the valve from the shipping crate, rotate the valve to the vertical position and center the valve over the soft support plate centerlines. Lower the valve onto the valve temporary support frame pads. Hold the valve vertically with the crane until temporary angle tie backs are installed and adjusted to hold the valve in the vertical position. After the valve is secured in position, remove all rigging/lifting equipment from the valve.

Note: Do not remove the cap from the valve stub at this time.

5.23 Position the Weld Shelter over the termination tube section as close to the building as possible.

5.24 Prepare a temporary weld shelter over the beam tube termination section to valve seam.

5.25 Clean the end of the valve stub and beam tube section in accordance with procedure CCP-1 until all visible contamination has been removed from the ends and in the surrounding atmosphere.

5.26 Enclose to the temporary clean room by sealing it to the valve body. Remove all visible contamination from the temporary clean room and valve in accordance with procedure CCP-1.

5.27 Remove the caps from the beam tube end and the valve stub, and request the LIGO representative to take their measurements of the valve gate gap. Remove the cap from the valve flange. **CAUTION: Read GNB Valve Operation Instructions Prior to Opening** Valve!! Open the valve in accordance with the valve manufacturer's specifications. CAUTION: Before entering the valve area request a LIGO lockout/tagout for the mechanical interlock and visually confirm that the interlock is engaged and that the padlock is properly positioned. Verify that the valve seat area contains no visible contamination, place the internal sleeve inside the valve to protect the valve seat area from damage and contamination. CAUTION: Take extreme care not to drop material or contamination into the valve seat area. This internal sleeve consists of an aluminum plate 1/8 inch thick, 18 inches wide and 4 feet long rolled to fit the inside radius of the valve opening. The sleeve covers a minimum of 120 degrees of the valve seat area and is bolted to a tab that is welded to the short tube section described in step 5.9 to prevent movement. Personnel entering this temporary clean room and tube shall meet the conditions and clothing requirements of CRWA-1.

5.28 After verifying that the current position of the end of the final beam tube section is such that the seam will be within all allowable tolerances of its theoretical position after adjustment, move the valve into position to close the gap with the end of the beam tube section and align the valve optically to the established reference point. Adjust the elevation, axial and lateral positions, perpendicularity and rotation to the beam tube axis, using the adjustments provided by the temporary valve support. Begin aligning the weld joint using the special CBI fit-up clamp.

5.29 Start the air flow from the BDF unit into the beam tube, verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non-permit confined space entry. Initiate the tube entry inventory record.

5.30 Align, fit and weld the valve to the beam tube termination section in accordance with the steps outlined in sections 3.15 through 3.24 above.

5.31 Leak test the completed seam in accordance with the steps outlined in sections 3.25 through 3.34 above. If not installed in the shop prior to shipping, install and test the pump port valve in accordance with sections 3.36 through 3.38 above.

5.32 Install any remaining required internal baffles in accordance with the Internal Baffle Installation procedure BFL.

5.33 Remove the tube access plug from the end of the previously completed beam tube section. Immediately upon completion of cleaning and baffle installation, exit from the beam tube through the clean room.

5.34 Inspect and clean beam tube interior as workman "backs out" of beam tube from completed final beam tube area.

5.35 Remove the internal sleeve, close the valve, and place and secure the cover on the valve flange.

5.36 Remove the Clean Room, or temporary clean room, and temporary weld shelter. The valve must be protected from the weather at all times.

5.37 Complete installation of the beam tube termination support. Position the termination support frame sections. Align and bolt the two halves together. Torque the bolts in accordance with the drawings. Align the frame and connect the beam tube termination section to the termination support per the drawings.

5.38 Complete installation of the valve soft support referencing drawing #22, note #2 for installation sequence.

5.39 Remove the temporary valve support frame and angle tie back braces.

5.40 If the permanent building has not been erected and enclosed, erect a temporary weather enclosure over the valve upon removal of the temporary weld shelter, Clean Room or temporary clean room, and installation of the termination support.

Note: The following steps are done upon completion of the module and final alignment.

5.41 Verify the valve is in its proper position.

5.42 Install piece 20-14, lubricate the anchor bolts and then install the Belleville washers and the nuts on the 1" diameter anchor bolts. Reference drawing #20 (sheet #2 and note #10 on sheet #1) for installation instructions. To achieve proper tension in the bolts, note the torque required to flatten the Belleville washers, and then tighten the bolts to 1.5 times that torque (do not exceed a torque of 208 ft-lbs).

5.43 Weld pieces 20-13 to the base plates (Pc Mk 20-9). To achieve the desired gap, make sure the mating edges of pieces 20-13 and 20-12 are free of any dirt or other material which may prevent a close fit. Fit piece 20-13 tightly against piece 20-12. To minimize opening of the gap during welding, weld the ends of piece 20-13 to the base plate first, and then weld the long edge of 20-13 to the base plate. After the welding of pieces 20-13 is complete, check the resulting gaps between pieces 20-13 and 20-12. If the sum of the gaps for the two pieces 20-13 on the same side of the beam tube exceeds the allowable per drawing 20 sheet 1, shim the gaps to be less than the maximum allowable.

5.44 Provide forms to contain the grout under the base plate. Use "Five Star Speed Epoxy Grout" or equal to fill the space between the base plate and the foundation. Ensure that the grout fills the spaces between the anchor bolts and the base plate to the top surface of the base plate.

5.45 Only after the anchor bolt adhesive is fully cured and base plate grout has cured for 24 hours, install washer and two nuts on each 7/8" anchor bolt. Tighten the bottom nut and "snug" the top nut against the bottom nut.

6.0 Referenced Procedures and Specifications

This installation sequence is to be used in conjunction with the following procedures and/or specifications:

6.1 Blower-Dryer Filtration System Operation and Maintenance
Doc ID "BDF1"

6.2 Initial and Final Alignment During Construction and Installation of Beam Tube Modules using GPS System
Doc ID "ALI-1"

6.3 Helium Mass Spectrometer Hood Test of Closing Weld Joints Between Beam Tube Cans
Doc ID "HMST2N"

6.4 Helium Mass Spectrometer Hood Test of Valve and Blind Flange Seals to Pump Ports
Doc ID "HMST3N"

6.5 Cleanroom Transporting, Storage and Maintenance Procedure
Doc ID "CR1TSM"

6.6 Final Cleaning and Inspection of Internal Surfaces Including Baffles
Doc ID "CL3N"

6.7 Fitting/Purge Procedure for Circumferential Butt Welds for LIGO
Doc ID "FPCIRCUMFERENTIAL"

6.8 Welding Procedure Specification for Circumferential Welds
Doc ID "WPS-ER308L/CIRC"

6.9 Contamination Control for Construction Activities During Beam Tube Installation
Doc ID "CCP-1"

6.10 Internal Baffle Installation, Doc ID "BFL"

6.11 Adjustment of Fixed and Guided Supports, Doc ID "SUP-ADJUST"

7.0 Summary Diagrams

See attachment, INSTALLSEQ (ATTACH).