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LIGO Design Review Report

LIGO BEAM TUBE MODULES UPDATED DESIGN REVIEW

Title

Review Board: A. Abramovici, W. Althouse (Chairman), F. Dylla, T. Eagar, A. Lazzarini, B. Lucas, O. Matherny, W. Tyler
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This is an internal working note of the LIGO Project

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REPORT ON THE UPDATED DESIGN REVIEW OF THE LIGO BEAM TUBE MODULES

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REPORT ON THE UPDATED DESIGN REVIEW OF THE LIGO BEAM TUBE MODULES

The LIGO Beam Tube Modules were designed by Chicago Bridge & Iron, Inc. (CBI), under contract to the LIGO Project. CBI also fabricated and tested a qualification test model of the beam tube. Both the design work and the qualification test results were reviewed by groups whose members included many of the present review board. A contract was subsequently awarded to CBI for the fabrication and installation of the beam tubes at the two LIGO sites in Livingston Parish, LA and Hanford, WA. The contract included requirements to update the design in certain areas (some due to recommendations from the qualification test review). These later efforts are the subject of the present review.

The Updated Design Review for the LIGO Beam Tube Modules was conducted on March 27, 1996, at CBI's facility in Plainfield, Illinois. This report documents the observations and recommendations made by the review board. The review board membership and charter are provided in LIGO-L960176 (Attachment I). The agenda for the review are provided in Attachment II.

The review consisted of presentations by CBI on their fabrication and installation plans and design modifications, with questions and answers intermixed with the presentations. During the review, board members were encouraged to record their observations, concerns and recommendations by completing a "Recommendation for Action" (RFA) form and submitting to the review board chairman. At the end of the presentations, the review board met in executive session and discussed each RFA. These consensus discussions serve as the basis for this report and are summarized below.

SUMMARY RESPONSE TO THE REVIEW BOARD CHARTER

We summarize the review board charter (Attachment I) and our responses below. Please see the following section for our report on detailed observations and specific recommendations.

- **Assess CBI's fabrication and installation plans, and advise whether CBI's responses to the Qualification Test Review board report are adequate to begin construction.**

The overall fabrication and installation plans are well thought out and reflect an appropriate balance of the technical and logistical tradeoffs needed to optimize the end-to-end process. We detected very few weaknesses, which we noted below and which are judged to be minor and easily corrected. With minor exceptions (also noted below), the recommendations of the Qualification Test Review board report have been satisfactorily addressed.

•Make an independent judgement of the risks involved in CBI's fabrication and installation approach.

CBI has put considerable effort into planning the fabrication and installation activities, and the resulting plans present no extraordinary technical risks. The recommendations made in this report are intended to enhance the quality of beam tubes and mitigate those (in our opinion, unnecessary but minor) technical risks which remain.

•Identify any concerns or other factors which might affect the success of the LIGO Project.

All concerns of this review board are noted in this report. As hinted at above, all of our concerns can fairly be labelled "minor." We found a positive, productive "can-do" attitude on the part of the participants in this review and would fully expect CBI's endeavors to be successful.

OBSERVATIONS AND RECOMMENDATIONS

Fabrication:

CBI plans on fabricating the beam tube sections in a facility which they are currently setting up about 15 miles from the LIGO Hanford site (a LA fabrication facility has not yet been identified, but a similar arrangement is planned). Cylindrical tubing will be formed from coil stock on a custom-built spiral tube mill. After stiffening rings, support rings, expansion joints and pump ports are welded on, the tube section ends will be expanded to a standard diameter and machined square for field welding. The completed tube sections will be leak checked to 10^{-10} atm-cc/sec (of helium), and repaired if necessary. The sections will then be stockpiled. They will be moved to a cleaning station and cleaned about two days before needed for installation, in order to minimize the exposure of cleaned tubes.

The follow observations lead to the recommendations which immediately follow. (There are separate discussions below of welding and cleaning processes.)

- When steel coils are delivered, the truck is backed into the facility for unloading near the spiral tube mill. The truck's exhaust is allowed to freely mix with air in the fabrication facility, and presents an unnecessary source of potential contamination.
- CBI relies on positive differential air pressure in the testing and cleaning rooms, provided by local HVAC systems, to prevent shop contaminants (such as welding fumes) from reaching these areas. However, no means of verifying the differential pressure is planned.

- The make-up air to create the differential pressure is picked up from outside the facility, but CBI could not verify that the air pick-ups are away from potential contamination sources, such as loading dock vehicle exhaust fumes.
- After tube sections leave the spiral tube mill, they are placed on pairs of wheeled "bogies" (one at each end) and rolled on a ground rail system to the area where stiffening rings are attached. CBI has not evaluated the stresses experienced by the tube section during this operation. We are concerned that, without the stiffening rings installed, the tube may be exposed to excessive stresses which might lead to buckling failure.
- CBI plans an adequate organization for the field fabrication operation. Although the organization charts for fabrication and installation didn't explicitly show a safety function, CBI explained their philosophy for ensuring safety and we are satisfied that this was just an omission on the charts.

Recommended actions:

1. CBI should provide positive removal of vehicle exhaust to the outside of the facility.
2. CBI should monitor and record the differential air pressures between the facility ambient environment and pressures in the test room and the cleaning room.
3. CBI should review the locations of intake air pickups for the testing and cleaning rooms and ensure that access to the areas near these pickups is adequately controlled to prevent accidental contamination of the air supply.
4. CBI should calculate the buckling loads on the tube sections experienced during transport from the spiral tube mill storage area to the stiffener welding area and compare with the theoretical buckling load capacity; take corrective action (such as distributing the support points along the section length) if the predicted loads are excessive.
5. CBI should add safety representation to the fabrication organization chart.

Welding:

The spiral welding process is different from that used for the qualification testing, where problems in achieving full penetration were experienced. The spiral welding equipment is new and appears to be well matched to the need. The revised spiral welding procedure has not been qualified for H_2 outgassing. The current plan calls for LIGO to test the H_2 outgassing of samples taken directly from the new spiral mill with the new welding equipment. CBI plans to characterize the variable parameters of this new equipment to find the optimum operating conditions and tolerance to variations in the parameters, but this has not yet been done. CBI recognizes that each time the spiral tube mill is stopped and restarted, the weld parameters may not exactly track the spiral mill motions and repairs may be required. We also note that even when the equipment is set up optimally, weld penetration may vary due to variations in the properties of individual coils of stainless steel (this variation applies to all weld processes, not just spiral welding).

The laser trackers used to control the new spiral welding equipment provide a video image for real-time monitoring. Recording these images may provide an inexpensive QA resource later to help establish a time-tagged record of welder performance, and possibly to locate and characterize local anomalies which are subsequently detected during leak testing.

CBI apparently has an established procedure for the weld process used to splice coil ends together, however this procedure has not been reviewed and approved by LIGO.

Finally, We note that a recommendation from the Qualification Test Review regarding a repair procedure for welds with copper inclusion has not yet been implemented.

Recommended actions:

6. Before LIGO approves the spiral welding procedure, CBI should establish the acceptable range of each controlled weld parameter for the spiral weld equipment.
7. CBI should consider amending the spiral weld procedure to specify that an integral number of tube sections are completed between planned stops and starts of the spiral tube mill, and removing and discarding the short stub containing any start-up flaws.
8. CBI should perform test(s) on a sample of each stainless steel coil that establishes that acceptable penetration will be achieved within the controlled range of each weld process (spiral, coil splice, girth, port installation, etc.).
9. CBI should document and submit to the LIGO project for review/approval the welding procedure for splices between coil ends.
10. CBI should consider video tape recording the laser tracker image for future QA reference. Time-of-day/date labelling, commonly provided automatically with most commercial VTRs, would be sufficient to provide later traceability, provided that date and time-of-day information for each tube section serial number was recorded in the fabrication QA log.
11. CBI should include a paragraph in all weld procedures to declare copper contamination of welds as unacceptable.

Cleaning:

Like the spiral weld process, the cleaning process is also different from that used for the qualification testing. The revised procedure replaces a room temperature bath in a diluted detergent (Mirachem) tank (used during qualification testing) with a high temperature/high pressure sprayed application of Mirachem mixed with steam, a method tested by CBI on oil-soiled coupons during preparations for the qualification test, and similar to the method used to apply an acid/steam mixture in the earlier "Beam Tube Demonstration" test performed by LIGO before CBI's involvement. CBI has modified the spray apparatus (used for steam rinsing during the qualification testing) to improve its reach over the expansion joint and to add two more nozzles to increase the flow rate. These are both positive improvements, but we doubt CBI's conclusion that doubling the flow rate will permit cutting the cleaning and rinse times in half. The permissible cleaning rate can be judged from the FTIR results obtained from the first few tube sections.

The follow observations lead to the recommendations which immediately follow.

- Prior experience with the spray apparatus failing to rotate might recur during the cleaning process.
- Cleaning will take place in a cleaning room within the fabrication facility which has its own air supply (see comments above under "Fabrication"). However, the careful design of this separate area may be compromised by contaminants brought into the area when tube sections are moved in and out through 10 ft. doors.
- The deionized water system will be leased, but specifications for the deionized water quality were not available for review.
- The effluent from the cleaning process collects on the lower side and end of the tube, and the possibility for residue contamination is greatest here. CBI's plans for removing the effluent are adequate, but nonetheless it may be useful to note the tube orientation for future reference.
- The cleaning operation is quantitatively verified by pouring a solvent through the cleaned tube section, collecting the solvent run-off at the lower end, and sending the sample to an independent laboratory for FTIR testing. During the qualification testing, some test results were suspected to be in error due to prior contamination of the sample collection bottles.
- After the first ten tube sections are cleaned and installed, FTIR samples are taken for each 10th tube section. The FTIR test results may not be available until after several tube sections have been installed. CBI has no specific obligations other than to collect the samples and send them for testing. The LIGO Project needs to develop a strategy for dealing with an FTIR result

which exceeds the established criteria.

- LIGO is to furnish completed and cleaned optical baffles to CBI for installation in the beam tube. During this review, we discovered that a protective "safety guard" which is furnished with the baffle and removed by CBI after installation is not yet subject to cleanliness controls, and represents a potential conduit for contamination to the inside of the beam tube.

Recommended actions:

12. CBI should add a feature to provide a positive indication of proper rotation of the steam spray apparatus.
13. CBI should add a provision to protect the cleaning area from unnecessary contamination introduced during ingress and egress through the doors, for example by segregating the entry/exit area with a heavy plastic curtain acting as a temporary partition. Remove gross or loose contamination from the tube sections before moving them to the cleaning station.
14. CBI should prepare a specification to control the quality of deionized water for LIGO review and approval. The specification should include limits on impurity content, not just a resistivity measurement.
15. CBI should identify and record the tube orientation during cleaning.
16. CBI should establish a procedure to verify that sample bottles are clean before use. Apply permanent ID markings to each sample bottle, and record this ID in the tube cleaning log when samples are taken for evaluation.
17. The LIGO Project should develop a contingency plan for use in the event that data from cleanliness samples show unacceptable contamination.
18. All baffle-related processes should be reviewed to ensure cleanliness, including cleanliness of auxiliary parts such as the baffle "safety guard" and cleanliness assurance during baffle installation.

Installation:

The installation process includes three-stage graded clean room entries to control the introduction of contaminants into the portable clean rooms. These graded entries look like they will be very effective. A CBI worker, garbed in clean room clothing, will enter the free end of the tube to place the interior purge dam used during girth seam welding and weld leak checking, and later to remove the purge dam, inspect the weld and install the optical baffles. There are no plans to equip this worker with any communication aids, and the worker, 65 feet deep into the beam tube module, might have difficulty maintaining synchronization with the operations on the outside. In addition, we are concerned that the working environment inside the tube may be quite uncomfortable (hot and cramped), making it difficult to control contamination from perspiration or through abrasion of the clothing. CBI indicates that they have considerable experience in this area, and prefer to work out the details in response to the specific conditions encountered in the field. Consequently we make no recommendations regarding this concern, other than suggesting that all parties remain vigilant during the operation.

CBI plans to use (hydrocarbon) lubricated bolts and nuts for installing pump port components. Silver-plated stainless steel bolt and nuts (or any other lubricant-free approach) should be used to avoid the possibility of hydrocarbon contamination inside the vacuum system.

CBI is building a new semi-cylindrical vacuum box for leak testing the girth seams. The new design appears to solve many of the problems experienced with the test box used during the qualification testing. The new test box should be tried out at the earliest opportunity to verify that these problems have indeed been solved. None of the review board members had any experience with the particular sealing putty (Nashua #102) planned for sealing the leak test box, and it may migrate on the surface and inadvertently plug a real leak.

Recommended actions:

19. CBI should provide adequate lighting and communications capability to persons working inside tube.
20. CBI should use a lubricant-free alternative to lubricated bolts for installing items at the pump port locations.
21. LIGO should perform a migration test of the "Nashua #102" sealing putty to ensure that it doesn't creep along the surface and contaminate potential leaks
22. CBI should add safety representation to the installation organization chart.

Design:

The details of the ground connection to the beam tube are lacking. A ground stake driven under the beam tube will not be serviceable after years of corrosion. Locating the stake outside the beam tube enclosure should be considered.

At LIGO's request, CBI has updated some details of design in the areas of module terminations and length, and pump port hardware. In addition, CBI has proposed additional detailed changes in the beam tube supports (both "guided" and fixed). We reviewed these modifications for functional compatibility with the stated objectives of the beam tubes (L. Jones, Beam Tube Technical Manager, certified the technical accuracy and fit compatibility). All of CBI's design modifications appear to meet the mark. However, some interface details between the vacuum equipment and beam tube, as currently planned, seem incomplete and may lead to problems. According to CBI, the beam tube termination anchors were not designed to facilitate easy adjustment while carrying a vacuum load on the end. The alignment details need to be revisited to ensure that problems which can be anticipated do not interfere with the field mating of the vacuum equipment and the beam tube, noting that either system may be installed first.

Recommended actions:

23. LIGO should define and document the procedure for adjusting the termination supports while the beam tube is under vacuum load.
24. LIGO should review the accumulation of tolerances at the beam tube/vacuum equipment interface in order to minimize alignment matching and fit-up problems. For example, a common set of local (inside the building) fiducials might be used for installing the vacuum equipment and the beam tube terminations.
25. The details of the beam tube grounding should be clarified, including grounding stake location and connection details.

Acceptance testing:

CBI's plan appears to up to the job of demonstrating performance in accordance with their contractual obligations, although the allocated schedule time of only a few days for acceptance testing seems optimistic. However, LIGO needs to develop an extended acceptance test plan which covers not only CBI's obligations (leak-free, adequate clear aperture, verification that all steel preparation and cleaning processes have been followed) but also establishes the initial prebake outgassing condition of the beam tube module. Several weeks may be required to carry out the full testing.

No recommended actions.

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LIGO BEAM TUBE MODULES UPDATED DESIGN REVIEW

Title

Review Board: A. Abramovici, W. Althouse (Chairman), F. Dylla, T. Eagar, A. Lazzarini, B. Lucas, O. Matherny, W. Tyler

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The Updated Design Review for the LIGO Beam Tube Modules was conducted on March 27, 1996, at CBI's facility in Plainfield, Illinois. This report documents the observations and recommendations made by the review board. The review board membership and charter are provided in LIGO-L960176 (Attachment I). The agenda for the review are provided in Attachment II.

The review consisted of presentations by CBI on their fabrication and installation plans and design modifications, with questions and answers intermixed with the presentations. During the review, board members were encouraged to record their observations, concerns and recommendations by completing a "Recommendation for Action" (RFA) form and submitting to the review board chairman. At the end of the presentations, the review board met in executive session and discussed each RFA. These consensus discussions serve as the basis for this report and are summarized below. F. Dylla was unable to attend the review meeting but reviewed the presentation material and reviewed and approved this report.

SUMMARY RESPONSE TO THE REVIEW BOARD CHARTER

We summarize the review board charter (Attachment I) and our responses below. Please see the following sections for our report on detailed observations and specific recommendations.

- **Assess CBI's fabrication and installation plans, and advise whether CBI's responses to the Qualification Test Review board report are adequate to begin construction.**

The overall fabrication and installation plans are well thought out and reflect an appropriate balance of the technical and logistical tradeoffs needed to optimize the end-to-end process. We detected very few weaknesses, which we note below and which are judged to be minor and easily corrected. With minor exceptions (also noted below), the recommendations of the Qualification Test Review board report have been satisfactorily addressed.

- **Make an independent judgement of the risks involved in CBI's fabrication and installation approach.**

CBI has put considerable effort into planning the fabrication and installation activities, and the resulting plans present no extraordinary technical risks. The recommendations made in this report are intended to enhance the quality of beam tubes and mitigate those minor technical risks which remain.

•Identify any concerns or other factors which might affect the success of the LIGO Project.

All concerns of this review board are noted in this report. As stated above, all of our concerns can be labeled "minor." We found a positive, productive "can-do" attitude on the part of the participants in this review and would fully expect CBI's endeavors to be successful.

OBSERVATIONS AND RECOMMENDATIONS

Fabrication:

CBI plans on fabricating the beam tube sections in a facility which they are currently setting up about 25 miles from the LIGO Hanford site (a LA fabrication facility has not yet been identified, but a similar arrangement is planned). Cylindrical tubing will be formed from coil stock on a custom-built spiral tube mill. After stiffening rings, support rings, expansion joints and pump ports are welded on, the tube section ends will be expanded to a standard diameter and machined square for field welding. The completed tube sections will be leak checked to 10^{-10} atm-cc/sec (of helium), and repaired if necessary. The sections will then be stockpiled. They will be moved to a cleaning station and cleaned about two days before needed for installation, in order to minimize the exposure of cleaned tube sections.

Our recommendations arise from the following observations. (There are separate discussions below of welding and cleaning processes.)

- When steel coils are delivered, the truck is backed into the facility for unloading near the spiral tube mill. The truck's exhaust is allowed to freely mix with air in the fabrication facility, and presents an unnecessary source of potential contamination.
- CBI relies on positive differential air pressure in the testing and cleaning rooms, provided by local HVAC systems, to prevent shop contaminants (such as welding fumes) from reaching these areas. However, no means of verifying the existence of a differential pressure is planned.
- The make-up air to create the differential pressure is picked up from outside the facility, but CBI could not verify that the air pick-ups are away from potential contamination sources, such as loading dock vehicle exhaust fumes.
- After tube sections leave the spiral tube mill, they are placed on pairs of wheeled bogies (one at each end) and rolled on a ground rail system to the area where stiffening rings are attached. During transport, the tube sections lack strength in certain modes because the stiffening rings are not yet installed, and we are concerned that the stress induced by a sudden shock (from, for example, a bogie wheel stopping against an errant tool lying on the tracks) might be severe enough to lead to buckling failure. CBI has not evaluated the stresses which might be experienced by the tube section during this operation.
- CBI plans an adequate organization for the field fabrication operation. Although the organization charts for fabrication and installation didn't explicitly show a safety function, CBI explained their philosophy for ensuring safety and we are satisfied that this was just an omission on the charts.

Recommended actions:

1. CBI should provide positive removal of vehicle exhaust to the outside of the facility.
2. CBI should monitor and record the differential air pressures between the facility ambient environment and pressures in the test room and the cleaning room.
3. CBI should review the locations of intake air pickups for the testing and cleaning rooms and ensure that access to the areas near these pickups is adequately controlled to prevent accidental contamination of the air supply.
4. CBI should evaluate the loads which might lead to buckling of the tube sections during transport from the spiral tube mill storage area to the stiffener welding area and compare with the theoretical buckling load capacity; take corrective action if the predicted loads are excessive.
5. CBI should add safety representation to the fabrication and installation organization charts.

Welding:

The spiral welding process is different from that used for the qualification testing, where problems in achieving full penetration were experienced. The spiral welding equipment is new and appears to be well matched to the need. The revised spiral welding procedure has not yet been qualified for H_2 outgassing, but LIGO will test the H_2 outgassing of samples taken directly from the new spiral mill with the new welding equipment. Our observations:

- CBI plans to characterize the variable parameters of the new spiral welding equipment to find the optimum operating conditions and tolerance to variations in the parameters, but this has not yet been done. CBI recognizes that each time the spiral tube mill is stopped and restarted, the weld parameters may not exactly track the spiral mill motions and repairs may be required. If the opportunity arises to synchronize the start/stop areas with the tube section ends, then these areas could be discarded rather than repaired.

- Even when the equipment is set up optimally, weld penetration may vary due to variations in the properties of individual coils of stainless steel (this variation applies to all weld processes, not just spiral welding).

- The laser trackers used to control the new spiral welding equipment provide a video image for real-time monitoring. Recording these images may provide an inexpensive QA resource later to help establish a time-tagged record of welder performance, and possibly to locate and characterize local anomalies which are subsequently detected during leak testing. Time-of-day/date labelling, commonly provided automatically with most commercial VTRs, would be sufficient to provide later traceability, provided that date and time-of-day information for each tube section serial number was recorded in the fabrication QA log.

- CBI apparently has an established procedure for the weld process used to splice coil ends together, however this procedure has not been reviewed and approved by LIGO.

- A recommendation from the Qualification Test Review regarding a repair procedure for welds with copper inclusion has not yet been implemented.

Recommended actions:

6. Before LIGO approves the spiral welding procedure, CBI should establish the acceptable range of each controlled weld parameter for the spiral weld equipment.
7. CBI should perform test(s), in accordance with procedures prepared by CBI and approved by LIGO, on a sample of each stainless steel coil that establishes that acceptable penetration will be achieved within the controlled range of each weld process (spiral, coil splice, girth, port installation, etc.).
8. CBI should consider recording the laser tracker image on video tape for future QA reference.
9. CBI should document and submit to the LIGO project for review/approval the welding procedure for splices between coil ends.
10. CBI should include a paragraph in all weld procedures to declare copper contamination of welds as unacceptable.

Cleaning:

Like the spiral weld process, the cleaning process is also different from that used for the qualification testing. In addition to deleting a final alcohol rinse, the revised procedure replaces a room temperature bath in a diluted detergent (Mirachem) tank (used during qualification testing) with a high temperature/high pressure sprayed application of Mirachem mixed with steam. This revised method was tested by CBI on oil-soiled coupons during preparations for the qualification test, and is similar to the method used to apply an acid/steam mixture in the earlier "Beam Tube Demonstration" test performed by LIGO before CBI's involvement. CBI has modified the spray apparatus (used for steam rinsing during the qualification testing) to improve its reach over the expansion joint and to add two more nozzles to increase the flow rate. These are both positive improvements, but we doubt CBI's conclusion that doubling the flow rate will permit cutting the cleaning and rinse times in half. The success of the cleaning procedure must ultimately be judged from the FTIR results obtained from the first few tube sections. Our observations:

- Prior experience with the spray apparatus failing to rotate might recur during the cleaning process.
- Cleaning will take place in a cleaning room within the fabrication facility which has its own air supply (see comments above under "Fabrication"). However, the careful design of this separate area may be compromised by contaminants brought into the area when tube sections are moved in and out through 10 ft. doors.
- The deionized water system will be leased, but specifications for the deionized water quality were not available for review.
- The effluent from the cleaning process collects on the lower side and end of the tube, and the possibility for residue contamination is greatest here. CBI's plans for removing the effluent are adequate, but nonetheless it would be useful to note the tube orientation during cleaning for future reference.
- The cleaning operation is quantitatively monitored by pouring a solvent through the cleaned

tube section, collecting the solvent run-off at the lower end, and sending the sample to an independent laboratory for FTIR testing. During the qualification testing, some test results were suspected to be in error due to prior contamination of the sample collection bottles.

- After the first ten tube sections are cleaned and installed, FTIR samples are taken for each 10th tube section. The FTIR test results may not be available until after several tube sections have been installed. CBI has no specific obligations other than to collect the samples and send them for testing. The LIGO Project needs to develop a strategy for dealing with an FTIR result which exceeds the established acceptance criteria.

- LIGO is to furnish completed and cleaned optical baffles to CBI for installation in the beam tube. Few details of the baffle installation were available at the time of the review. The baffle preparation and installation processes collectively present a potential conduit for introducing contamination to the inside of the beam tube, and plans should be carefully reviewed when the details become available.

Recommended actions:

11. CBI should add a feature to provide a positive indication of proper rotation of the steam spray apparatus.
12. CBI should add a provision to protect the cleaning area from unnecessary contamination introduced during ingress and egress through the doors, for example by segregating the entry/exit area with a heavy plastic curtain acting as a temporary partition. Remove gross or loose contamination from the tube sections and transport bogies before moving them to the cleaning station.
13. CBI should prepare a specification to control the quality of deionized water for LIGO review and approval. The specification should include limits on impurity content, not just a resistivity measurement.
14. CBI should identify and record the tube orientation during cleaning.
15. CBI should establish a procedure to verify that sample bottles are clean before use. Apply permanent ID markings to each sample bottle, and record this ID in the tube cleaning log when samples are taken for evaluation.
16. The LIGO Project should develop a contingency plan for use in the event that data from cleanliness samples show unacceptable contamination.
17. All baffle-related processes should be reviewed to ensure cleanliness, including cleanliness of auxiliary parts (such as protective covers, etc.) and cleanliness assurance during baffle installation.

Installation:

The installation process includes three-stage graded clean room entries to control the introduction of contaminants into the portable clean rooms. These graded entries appear to be very effective. Our observations:

- A CBI worker, garbed in clean room clothing, will enter the free end of the tube to place the interior purge dam used during girth seam welding and weld leak checking, and later to remove the purge dam, inspect the weld and install the optical baffles. There are no plans to equip this worker with any communication aids, and the worker, 65 feet deep into the beam tube module, might have difficulty maintaining synchronization with the operations on the outside.

- Specific safety procedures were not available to determine if proper consideration was given to all safety requirements of the installation process. It is noted that CBI does have a good general safety program that most likely will address this area very well but, until the specific safety procedures are available for review by the LIGO Safety Officer we cannot state that safety is adequate.
- The working environment inside the tube may be quite uncomfortable (hot and cramped), making it difficult to control contamination from perspiration or through abrasion of the clothing. CBI indicates that they have considerable experience in this area, and prefer to work out the details in response to the specific conditions encountered in the field. This approach will require extra attention toward cleanliness concerns during the early period when the procedural details are worked.
- CBI plans to use (hydrocarbon) lubricated bolts and nuts for installing pump port components. Silver-plated stainless steel bolt and nuts (or other suitable lubricant-free approach) should be used to avoid the possibility of hydrocarbon contamination inside the vacuum system while ensuring future serviceability of the hardware.
- CBI is building a new semi-cylindrical vacuum box for leak testing the girth seams. The new design appears to solve many of the problems experienced with the test box used during the qualification testing. The new test box should be tried out at the earliest opportunity to verify that these problems have indeed been solved. None of the review board members had any experience with the particular sealing putty (Nashua #102) planned for sealing the leak test box, and there is concern that it may migrate on the surface and inadvertently plug a real leak.

Recommended actions:

18. CBI should provide adequate lighting and communications capability to persons working inside the tube.
19. CBI should provide their specific job safety analysis associated with the installation procedures for review before the installation begins.
20. LIGO QA, in coordination with CBI QA, should direct special attention to the practices employed to prevent contamination generated by the work environment inside the tube.
21. CBI should use a lubricant-free alternative to lubricated bolts for installing items at the pump port locations.
22. LIGO should perform a migration test of the "Nashua #102" sealing putty to ensure that it doesn't creep along the surface and contaminate potential leaks

Design:

At LIGO's request, CBI has updated some details of design in the areas of module terminations and length, and pump port hardware. In addition, CBI has proposed additional detailed changes in the beam tube supports (both "guided" and fixed). We reviewed these modifications for functional compatibility with the stated objectives of the beam tubes (L. Jones, Beam Tube Technical Manager, certified the technical accuracy and fit compatibility). All of CBI's design modifications appear to meet the mark. However, some interface details between the vacuum equipment and beam tube, as currently planned, seem incomplete and may lead to problems.

- According to CBI, the beam tube termination supports were not designed to facilitate easy adjustment while carrying a vacuum load on the end.
- The alignment details need to be revisited to ensure that problems which can be anticipated do not interfere with the field mating of the vacuum equipment and the beam tube, noting that either system may be installed first.
- The details of the electrical ground connection to the beam tube are lacking. A grounding stake driven under the beam tube will not be serviceable after years of corrosion. Locating the stake outside the beam tube enclosure should be considered.

Recommended actions:

23. LIGO should define and document the procedure for adjusting the termination supports while the beam tube is under vacuum load.
24. LIGO should review the accumulation of tolerances at the beam tube/vacuum equipment interface in order to minimize alignment matching and fit-up problems. For example, a common set of local (inside the building) fiducials might be used for installing the vacuum equipment and the beam tube terminations.
25. The details of the beam tube electrical grounding should be clarified, including grounding stake location and connection details, and added to the appropriate interface control drawing.

Acceptance testing:

CBI's plan appears to be up to the job of demonstrating performance in accordance with their contractual obligations, although the allocated schedule time of only a few days for conducting the acceptance tests seems optimistic.

However, the acceptance testing to be performed by CBI is not sufficient to ensure successful operation of the LIGO facility. LIGO needs to develop an extended acceptance test plan which covers not only CBI's obligations (leak-free, adequate clear aperture, certification that all steel preparation and cleaning processes have been followed) but also establishes that the beam tube meets all of its technical requirements (this would include determining the outgassing condition of the beam tube module). LIGO intends to bake out the beam tube modules, and these additional steps might fall naturally into the bakeout plan, but the bakeout (which is not part of the CBI contract and was not reviewed at this meeting) has not yet been planned in detail.

Recommended actions:

26. LIGO should develop an acceptance test plan and acceptance criteria for the beam tube modules.

BATCH START

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CBI Services
LIGO Project
POB 160
Richland WA 99352

May 3, 1996

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California Institute of Technology
LIGO Project
Ms. Linda Turner / Mr. Larry Jones - Mail Stop 51-33
391 So. Holliston Ave.
Pasadena CA 91125

Reference: Caltech Contract No. PC181520
LIGO Beam Tube Modules

Subject: CFBI Comments on Updated Design Review LIGO Doc. T960078-01-P 4/26/96
CBI-CT-2.2/0078

CBI received the draft report referenced above April 29, 1996. In overview, we appreciate the positive and constructive comments contained in the report.

We have the following comments regarding specific observations and recommendations: (Each number in the report is referenced under each section.)

Fabrication:

1. We suggest the vehicle exhaust be controlled by procedure. We would propose the truck engines be stopped immediately upon positioning in the building and not restart until the truck is prepared to exit. It would require considerable time and expense to install an exhaust blower and metal flex hose system in addition to the labor required to implement the operation of the equipment. We understand the concern regarding potential contamination of the exposed surfaces of tubes in process, but since the completed tubes are capped and sealed after testing and cleaning, we do not see this source of contamination as significant.

2. The interest in the testing room boundary is primarily related to helium background control, and only secondarily to maintenance of atmospheric cleanliness. In our opinion the degree of control required and the consequences of loss of the atmosphere control in the testing room do not justify continuous air pressure monitoring or record keeping.

With regard to the cleaning room, the maintenance of a positive pressure is beyond what CBI considers to be necessary to provide a suitable environment for the cleaning operations.

3. With regard to the air intakes at the Hanford manufacturing facility, we have checked and these sources are isolated from sources of contamination. We suggest a statement to this effect can be included in the Fabrication Plan.

4. CBI checked the beam tube for static loads during the Design and Qualification test. The methods proposed for tube handling during fabrication and installation do not increase the loads on the beam tube. In the opinion of CBI, no additional checks are required.

5. The organization charts for the Fabrication and Installation plans will be revised to indicate the Weld Supervisors also function as safety representatives. This is common practice on CBI contracts and the Weld Supervisors are trained for this function.

Welding:

6. We expect we will be able to narrow the range or relate the range to the travel speed.

7.In our opinion additional tests on each coil are not required. The chemistry of the coil material is being controlled to minimize potential variability that might affect weldability. The high amperage Weldlogic equipment will further minimize the risk of not achieving full penetration. In addition, welding of the coil splice will serve as preliminary evaluation of weldability and finally sectioning of the first tube welded will provide a confirmation of weldability.

8. We are checking into the possibility or recording the laser tracking image and will give this further consideration.

9. No comment.

10. We suggest this be added to V18X, not in a weld procedure. A draft has been prepared and submitted.

Cleaning:

11. We intend to evaluate the spray apparatus during shake down and qualification testing and will evaluate these needs and respond accordingly.

12. We do not expect to have gross contamination of the tube sections or the transport bogies. The tube sections and transporters will be cleaned as required prior to movement into the cleaning room.

13. In our opinion LIGO should provide the water quality specification. CBI plans to treat the incoming water used in the cleaning of the beam tube sections with a commercially available process system.

14. CBI intends to clean all tubes with the 0 degree cardinal in the up (12 o'clock) position.

15. CBI intends to establish a procedure to identify and control sample bottles.

16. At this time there is no established acceptance criteria. Implementation of a contingency plan could impact our performance shedule. The contingency plan would need to be prepared for immediate use without any lost production time.

17. Regarding the comments relating to the availability of baffle installation details, please note the baffle installation procedure was submitted prior to the Design Review and the steps of baffle installation, including the receipt of the baffles from Caltech and the stepped process of removing the double bagging and introducing the baffle into the clean room, were included in the review.

Installation:

18. As a normal course of work, we would set up lighting and communication between the inside and outside of the tube to perform our work properly, safely and efficiently.

19. CBI intends to prepare specific job safety analysis associated with the installation process prior to the commencement of work activity. The JSA's will be available for review but we do not expect they will be subject to formal approval prior to the start of work.

20. No comment.

21. No comment.

22. LIGO may choose to conduct tests as stated, however the use of "Duct Seal " is referenced in the Contract, DRD No. 03 item h, as an acceptable seal material. A change to an Apiezon product would certainly add to the cost of the tests.

Design:

23. CBI recommends the termination not be adjusted when the beam tube is under vacuum.

24. No comment.

25. CBI will provide grounding details.

Acceptance Testing:

Comment on allocation of schedule time:

The project schedule has each of the four module leak tests as activities with durations in days, (30 to 45 days). The activity duration includes setting up equipment, module pumpdown, and acceptance testing. The completion of the acceptance test is a milestone which has a duration of

0 day. No duration has been included for leak localization and any leak chasing will impact the schedule. The completion of the fourth module is the conclusion of the hardware acceptance testing.

The Completion Review is a milestone and follows the completion of the fourth acceptance test. The project schedule currently shows the Completion Review Meeting milestone immediately following the fourth module acceptance test milestone, however this will be changed allow time to assemble the Data package and schedule the meeting.

26. No comment.

Regards,

L. C. Buboltz
Project Manager

bcc: P.A.LoBello-Concord Sales
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FAX TRANSMITTAL SHEET is page #1 of 3 pages.

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COMMENTS:

REPORT ON THE UPDATED DESIGN REVIEW OF THE LIGO BEAM TUBE MODULES

Signature page

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FAX COVER PAGE

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FAX NUMBER:	
VOICE NUMBER:	
REFER TO:	LIGO-T960078-A
SUBJECT:	Signature page
NUMBER OF PAGES FAXED INCLUDING THIS COVER SHEET:	2

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REPORT ON THE UPDATED DESIGN REVIEW OF THE LIGO BEAM TUBE MODULES

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	LIGO-T960078-A	**-P**	5/3/96
Document Type	*Doc Number*	*Group-Id*	*Date*

__LIGO Design Review Report__

LIGO BEAM TUBE MODULES UPDATED DESIGN REVIEW

Title

Review Board: A. Abramovici, W. Althouse (Chairman), F. Dylla, T. Eagar, A. Lazzarini, B. Lucas, O. Matherny, W. Tyler
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This is an internal working note of the LIGO Project

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REPORT ON THE UPDATED DESIGN REVIEW OF THE LIGO BEAM TUBE MODULES

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REPORT ON THE UPDATED DESIGN REVIEW OF THE LIGO BEAM TUBE MODULES

The LIGO Beam Tube Modules were designed by Chicago Bridge & Iron, Inc. (CBI), under contract to the LIGO Project. CBI also fabricated and tested a qualification test model of the beam tube. Both the design work and the qualification test results were reviewed by groups whose members included many of the present review board. A contract was subsequently awarded to CBI for the fabrication and installation of the beam tubes at the two LIGO sites in Livingston Parish, LA and Hanford, WA. The contract included requirements to update the design in certain areas (some due to recommendations from the qualification test review). These later efforts are the subject of the present review.

The Updated Design Review for the LIGO Beam Tube Modules was conducted on March 27, 1996, at CBI's facility in Plainfield, Illinois. This report documents the observations and recommendations made by the review board. The review board membership and charter are provided in LIGO-L960176 (Attachment I). The agenda for the review are provided in Attachment II.

The review consisted of presentations by CBI on their fabrication and installation plans and design modifications, with questions and answers intermixed with the presentations. During the review, board members were encouraged to record their observations, concerns and recommendations by completing a "Recommendation for Action" (RFA) form and submitting to the review board chairman. At the end of the presentations, the review board met in executive session and discussed each RFA. These consensus discussions serve as the basis for this report and are summarized below. F. Dylla was unable to attend the review meeting but reviewed the presentation material and reviewed and approved this report.

SUMMARY RESPONSE TO THE REVIEW BOARD CHARTER

We summarize the review board charter (Attachment I) and our responses below. Please see the following sections for our report on detailed observations and specific recommendations.

- **Assess CBI's fabrication and installation plans, and advise whether CBI's responses to the Qualification Test Review board report are adequate to begin construction.**

The overall fabrication and installation plans are well thought out and reflect an appropriate balance of the technical and logistical tradeoffs needed to optimize the end-to-end process. We detected very few weaknesses, which we note below and which are judged to be minor and easily corrected. With minor exceptions (also noted below), the recommendations of the Qualification Test Review board report have been satisfactorily addressed.

- **Make an independent judgement of the risks involved in CBI's fabrication and installation approach.**

CBI has put considerable effort into planning the fabrication and installation activities, and the resulting plans present no extraordinary technical risks. The recommendations made in this report are intended to enhance the quality of beam tubes and mitigate those minor technical risks which remain.

•Identify any concerns or other factors which might affect the success of the LIGO Project.

All concerns of this review board are noted in this report. As stated above, all of our concerns can be labeled "minor." We found a positive, productive "can-do" attitude on the part of the participants in this review and would fully expect CBI's endeavors to be successful.

OBSERVATIONS AND RECOMMENDATIONS

Fabrication:

CBI plans on fabricating the beam tube sections in a facility which they are currently setting up about 25 miles from the LIGO Hanford site (a LA fabrication facility has not yet been identified, but a similar arrangement is planned). Cylindrical tubing will be formed from coil stock on a custom-built spiral tube mill. After stiffening rings, support rings, expansion joints and pump ports are welded on, the tube section ends will be expanded to a standard diameter and machined square for field welding. The completed tube sections will be leak checked to 10^{-10} atm-cc/sec (of helium), and repaired if necessary. The sections will then be stockpiled. They will be moved to a cleaning station and cleaned about two days before needed for installation, in order to minimize the exposure of cleaned tube sections.

Our recommendations arise from the following observations. (There are separate discussions below of welding and cleaning processes.)

- When steel coils are delivered, the truck is backed into the facility for unloading near the spiral tube mill. The truck's exhaust is allowed to freely mix with air in the fabrication facility, and presents an unnecessary source of potential contamination.
- CBI relies on positive differential air pressure in the testing and cleaning rooms, provided by local HVAC systems, to prevent shop contaminants (such as welding fumes) from reaching these areas. However, no means of verifying the existence of a differential pressure is planned.
- The make-up air to create the differential pressure is picked up from outside the facility, but CBI could not verify that the air pick-ups are away from potential contamination sources, such as loading dock vehicle exhaust fumes.
- After tube sections leave the spiral tube mill, they are placed on pairs of wheeled bogies (one at each end) and rolled on a ground rail system to the area where stiffening rings are attached. During transport, the tube sections lack strength in certain modes because the stiffening rings are not yet installed, and we are concerned that the stress induced by a sudden shock (from, for example, a bogie wheel stopping against an errant tool lying on the tracks) might be severe enough to lead to buckling failure. CBI has not evaluated the stresses which might be experienced by the tube section during this operation.
- CBI plans an adequate organization for the field fabrication operation. Although the organization charts for fabrication and installation didn't explicitly show a safety function, CBI explained their philosophy for ensuring safety and we are satisfied that this was just an omission on the charts.

Recommended actions:

1. CBI should provide positive removal of vehicle exhaust to the outside of the facility.
2. CBI should monitor and record the differential air pressures between the facility ambient environment and pressures in the test room and the cleaning room.
3. CBI should review the locations of intake air pickups for the testing and cleaning rooms and ensure that access to the areas near these pickups is adequately controlled to prevent accidental contamination of the air supply.
4. CBI should evaluate the loads which might lead to buckling of the tube sections during transport from the spiral tube mill storage area to the stiffener welding area and compare with the theoretical buckling load capacity; take corrective action if the predicted loads are excessive.
5. CBI should add safety representation to the fabrication and installation organization charts.

Welding:

The spiral welding process is different from that used for the qualification testing, where problems in achieving full penetration were experienced. The spiral welding equipment is new and appears to be well matched to the need. The revised spiral welding procedure has not yet been qualified for H_2 outgassing, but LIGO will test the H_2 outgassing of samples taken directly from the new spiral mill with the new welding equipment. Our observations:

- CBI plans to characterize the variable parameters of the new spiral welding equipment to find the optimum operating conditions and tolerance to variations in the parameters, but this has not yet been done. CBI recognizes that each time the spiral tube mill is stopped and restarted, the weld parameters may not exactly track the spiral mill motions and repairs may be required. If the opportunity arises to synchronize the start/stop areas with the tube section ends, then these areas could be discarded rather than repaired.

- Even when the equipment is set up optimally, weld penetration may vary due to variations in the properties of individual coils of stainless steel (this variation applies to all weld processes, not just spiral welding).

- The laser trackers used to control the new spiral welding equipment provide a video image for real-time monitoring. Recording these images may provide an inexpensive QA resource later to help establish a time-tagged record of welder performance, and possibly to locate and characterize local anomalies which are subsequently detected during leak testing. Time-of-day/date labelling, commonly provided automatically with most commercial VTRs, would be sufficient to provide later traceability, provided that date and time-of-day information for each tube section serial number was recorded in the fabrication QA log.

- CBI apparently has an established procedure for the weld process used to splice coil ends together, however this procedure has not been reviewed and approved by LIGO.

- A recommendation from the Qualification Test Review regarding a repair procedure for welds with copper inclusion has not yet been implemented.

Recommended actions:

6. Before LIGO approves the spiral welding procedure, CBI should establish the acceptable range of each controlled weld parameter for the spiral weld equipment.
7. CBI should perform test(s), in accordance with procedures prepared by CBI and approved by LIGO, on a sample of each stainless steel coil that establishes that acceptable penetration will be achieved within the controlled range of each weld process (spiral, coil splice, girth, port installation, etc.).
8. CBI should consider recording the laser tracker image on video tape for future QA reference.
9. CBI should document and submit to the LIGO project for review/approval the welding procedure for splices between coil ends.
10. CBI should include a paragraph in all weld procedures to declare copper contamination of welds as unacceptable.

Cleaning:

Like the spiral weld process, the cleaning process is also different from that used for the qualification testing. In addition to deleting a final alcohol rinse, the revised procedure replaces a room temperature bath in a diluted detergent (Mirachem) tank (used during qualification testing) with a high temperature/high pressure sprayed application of Mirachem mixed with steam. This revised method was tested by CBI on oil-soiled coupons during preparations for the qualification test, and is similar to the method used to apply an acid/steam mixture in the earlier "Beam Tube Demonstration" test performed by LIGO before CBI's involvement. CBI has modified the spray apparatus (used for steam rinsing during the qualification testing) to improve its reach over the expansion joint and to add two more nozzles to increase the flow rate. These are both positive improvements, but we doubt CBI's conclusion that doubling the flow rate will permit cutting the cleaning and rinse times in half. The success of the cleaning procedure must ultimately be judged from the FTIR results obtained from the first few tube sections. Our observations:

- Prior experience with the spray apparatus failing to rotate might recur during the cleaning process.
- Cleaning will take place in a cleaning room within the fabrication facility which has its own air supply (see comments above under "Fabrication"). However, the careful design of this separate area may be compromised by contaminants brought into the area when tube sections are moved in and out through 10 ft. doors.
- The deionized water system will be leased, but specifications for the deionized water quality were not available for review.
- The effluent from the cleaning process collects on the lower side and end of the tube, and the possibility for residue contamination is greatest here. CBI's plans for removing the effluent are adequate, but nonetheless it would be useful to note the tube orientation during cleaning for future reference.
- The cleaning operation is quantitatively monitored by pouring a solvent through the cleaned

tube section, collecting the solvent run-off at the lower end, and sending the sample to an independent laboratory for FTIR testing. During the qualification testing, some test results were suspected to be in error due to prior contamination of the sample collection bottles.

- After the first ten tube sections are cleaned and installed, FTIR samples are taken for each 10th tube section. The FTIR test results may not be available until after several tube sections have been installed. CBI has no specific obligations other than to collect the samples and send them for testing. The LIGO Project needs to develop a strategy for dealing with an FTIR result which exceeds the established acceptance criteria.
- LIGO is to furnish completed and cleaned optical baffles to CBI for installation in the beam tube. Few details of the baffle installation were available at the time of the review. The baffle preparation and installation processes collectively present a potential conduit for introducing contamination to the inside of the beam tube, and plans should be carefully reviewed when the details become available.

Recommended actions:

11. CBI should add a feature to provide a positive indication of proper rotation of the steam spray apparatus.
12. CBI should add a provision to protect the cleaning area from unnecessary contamination introduced during ingress and egress through the doors, for example by segregating the entry/exit area with a heavy plastic curtain acting as a temporary partition. Remove gross or loose contamination from the tube sections and transport bogies before moving them to the cleaning station.
13. CBI should prepare a specification to control the quality of deionized water for LIGO review and approval. The specification should include limits on impurity content, not just a resistivity measurement.
14. CBI should identify and record the tube orientation during cleaning.
15. CBI should establish a procedure to verify that sample bottles are clean before use. Apply permanent ID markings to each sample bottle, and record this ID in the tube cleaning log when samples are taken for evaluation.
16. The LIGO Project should develop a contingency plan for use in the event that data from cleanliness samples show unacceptable contamination.
17. All baffle-related processes should be reviewed to ensure cleanliness, including cleanliness of auxiliary parts (such as protective covers, etc.) and cleanliness assurance during baffle installation.

Installation:

The installation process includes three-stage graded clean room entries to control the introduction of contaminants into the portable clean rooms. These graded entries appear to be very effective. Our observations:

- A CBI worker, garbed in clean room clothing, will enter the free end of the tube to place the interior purge dam used during girth seam welding and weld leak checking, and later to remove the purge dam, inspect the weld and install the optical baffles. There are no plans to equip this worker with any communication aids, and the worker, 65 feet deep into the beam tube module, might have difficulty maintaining synchronization with the operations on the outside.

- Specific safety procedures were not available to determine if proper consideration was given to all safety requirements of the installation process. It is noted that CBI does have a good general safety program that most likely will address this area very well but, until the specific safety procedures are available for review by the LIGO Safety Officer we cannot state that safety is adequate.
- The working environment inside the tube may be quite uncomfortable (hot and cramped), making it difficult to control contamination from perspiration or through abrasion of the clothing. CBI indicates that they have considerable experience in this area, and prefer to work out the details in response to the specific conditions encountered in the field. This approach will require extra attention toward cleanliness concerns during the early period when the procedural details are worked.
- CBI plans to use (hydrocarbon) lubricated bolts and nuts for installing pump port components. Silver-plated stainless steel bolt and nuts (or other suitable lubricant-free approach) should be used to avoid the possibility of hydrocarbon contamination inside the vacuum system while ensuring future serviceability of the hardware.
- CBI is building a new semi-cylindrical vacuum box for leak testing the girth seams. The new design appears to solve many of the problems experienced with the test box used during the qualification testing. The new test box should be tried out at the earliest opportunity to verify that these problems have indeed been solved. None of the review board members had any experience with the particular sealing putty (Nashua #102) planned for sealing the leak test box, and there is concern that it may migrate on the surface and inadvertently plug a real leak.

Recommended actions:

18. CBI should provide adequate lighting and communications capability to persons working inside the tube.
19. CBI should provide their specific job safety analysis associated with the installation procedures for review before the installation begins.
20. LIGO QA, in coordination with CBI QA, should direct special attention to the practices employed to prevent contamination generated by the work environment inside the tube.
21. CBI should use a lubricant-free alternative to lubricated bolts for installing items at the pump port locations.
22. LIGO should perform a migration test of the "Nashua #102" sealing putty to ensure that it doesn't creep along the surface and contaminate potential leaks

Design:

At LIGO's request, CBI has updated some details of design in the areas of module terminations and length, and pump port hardware. In addition, CBI has proposed additional detailed changes in the beam tube supports (both "guided" and fixed). We reviewed these modifications for functional compatibility with the stated objectives of the beam tubes (L. Jones, Beam Tube Technical Manager, certified the technical accuracy and fit compatibility). All of CBI's design modifications appear to meet the mark. However, some interface details between the vacuum equipment and beam tube, as currently planned, seem incomplete and may lead to problems.

- According to CBI, the beam tube termination supports were not designed to facilitate easy adjustment while carrying a vacuum load on the end.
- The alignment details need to be revisited to ensure that problems which can be anticipated do not interfere with the field mating of the vacuum equipment and the beam tube, noting that either system may be installed first.
- The details of the electrical ground connection to the beam tube are lacking. A grounding stake driven under the beam tube will not be serviceable after years of corrosion. Locating the stake outside the beam tube enclosure should be considered.

Recommended actions:

23. LIGO should define and document the procedure for adjusting the termination supports while the beam tube is under vacuum load.
24. LIGO should review the accumulation of tolerances at the beam tube/vacuum equipment interface in order to minimize alignment matching and fit-up problems. For example, a common set of local (inside the building) fiducials might be used for installing the vacuum equipment and the beam tube terminations.
25. The details of the beam tube electrical grounding should be clarified, including grounding stake location and connection details, and added to the appropriate interface control drawing.

Acceptance testing:

CBI's plan appears to be up to the job of demonstrating performance in accordance with their contractual obligations, although the allocated schedule time of only a few days for conducting the acceptance tests seems optimistic.

However, the acceptance testing to be performed by CBI is not sufficient to ensure successful operation of the LIGO facility. LIGO needs to develop an extended acceptance test plan which covers not only CBI's obligations (leak-free, adequate clear aperture, certification that all steel preparation and cleaning processes have been followed) but also establishes that the beam tube meets all of its technical requirements (this would include determining the outgassing condition of the beam tube module). LIGO intends to bake out the beam tube modules, and these additional steps might fall naturally into the bakeout plan, but the bakeout (which is not part of the CBI contract and was not reviewed at this meeting) has not yet been planned in detail.

Recommended actions:

26. LIGO should develop an acceptance test plan and acceptance criteria for the beam tube modules.

CALIFORNIA INSTITUTE OF TECHNOLOGY

Laser Interferometer Gravitational Wave Observatory (LIGO) Project

To/Mail Code: Distribution
From/Mail Code: G. Sanders/51-33
Phone/FAX: 395-2997/304-9834
Refer to: LIGO-L960176
Date: March 8, 1996

Subject: LIGO Beam Tube Modules Updated Design Review

The review board for the updated Design Review of the Chicago Bridge & Iron, Inc. (CBI) subcontract for fabrication and installation of LIGO Beam Tube Modules will consist of the following individuals:

W. Althouse, Chairman	LIGO Technical Configuration Manager
A. Abramovici	LIGO Detector Group
F. Dylla	CEBAF
T. Eagar	MIT
A. Lazzarini	LIGO Systems Engineer
B. Lucas	LIGO ES&H Officer
O. Matherny	LIGO Facilities Group
W. Tyler	LIGO QA Officer

Other LIGO representatives will attend, and D. Berley, LIGO Program Manager for NSF, will be invited to attend.

REVIEW BOARD CHARTER

The review board will assess CBI's fabrication and installation plans, and advise whether CBI's responses to the Qualification Test Review board report are adequate to begin construction.

In arriving at its recommendations, the review board will consider the objectives, scope, schedule and technical specifications in the CBI contract. The review board will also make an independent judgement of the risks involved in CBI fabrication and installation approach, and identify any concerns or other factors deemed pertinent which affect the success of the LIGO Project.

gs:bb

Distribution:

Review Board Members
F. Asiri
B. Barish
D. Berley
L. Buboltz, CBI
M. Coles
D. Coyne
E. Jasnow
L. Jones
P. Lindquist
F. Raab
A. Sibley
G. Stapfer
R. Vogt
R. Weiss
S. Whitcomb
J. Worden
M. Zucker
Chronological File
Document Control Center

Agenda
LIGO Beam Tube Design Review
March 27, 1996
8:00AM
CBI Plainfield Facility, Training Room B

Private Review Board Session	8:00AM-8:15AM	W. Althouse
Greetings and Introductions	8:15AM-8:20AM	L. C. Buboltz
Overview Project Status	8:20AM-8:30AM	L. C. Buboltz
Fabrication Plan	8:30AM-8:50AM	K. F. Drake
Spiral Weld & Monitoring	8:50AM-9:10AM	R.A. Johnson
Leak Check Caskets	9:10AM-9:25AM	D. W. DeGraaf/P. B. Shaw
Cleaning Equipment & Monitoring	9:25AM-9:45AM	S. W. Peters
Break	9:45AM-10:00AM	
Installation Plan	10:00AM-10:20AM	V. F. Gervais
Baffle Installation	10:20AM-10:35AM	V. F. Gervais
GPS Alignment Procedure	10:35AM-10:50AM	S. D. Hand
Field Enclosures	10:50AM-11:05AM	S. D. Hand
Girth Seam Vacuum Box	11:05AM-11:20AM	D. W. DeGraaf/P. B. Shaw
Concluding Questions & Discussion Fabrication and Installation	11:20AM-12:00M	
Lunch	12:00M-1:00PM	
Module Termination Design	1:00PM-1:15PM	A. R. Libby
Termination ICD/Module Length	1:15PM-1:30PM	M. L. Tellalian
Alternate Supports	1:30PM-1:45PM	M. L. Tellalian
Pump Port Hardware Design/ICD's	1:45PM-2:00PM	W. A. Carpenter

Acceptance Test & Outgas Measurement Plan	**2:00PM-2:15PM**	**W. A. Carpenter**
Concluding Questions/Discussion	**2:15PM-2:45PM**	**Group**
Break	**2:45PM-3:00PM**	
Private Review Board Session	**3:00PM-4:00PM**	**W. Althouse**
Final Review Board Comments	**4:00PM-4:25PM**	**Group**
Closing Remarks	**4:25PM-4:30PM**	**L. C. Buboltz**