E950073-04-B

	IDENTIFICATION			
	ALI-1			
TITLE INITIAL & FINAL ALIGNMENT DURING INSTALLATION OF LIGO BEAM TUBE MODULES USING GPS SYSTEM PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	REFERENCE NO. 930212		SHT 1 OF 10	
	OFFICE RSE		REVISION 4	
	MADE BY SDH	CHKD BY SWP	MADE BY SDH	CHKD BY SWP
	DATE 12/28/93	DATE 12/29/93	DATE 3/31/94	DATE 5/18/95

1.0 SCOPE:

This procedure defines the method of establishing the LIGO Beam Tube alignment during construction activities and through final alignment after bake out and testing. This procedure uses Global Positioning System (GPS) techniques with jigs and fixtures unique to LIGO requirements. Procedures are detailed for Beam Tube Layout, Initial Alignment and Final Inspection of Beam Tube Support positions.

2.0 REFERENCES:

The alignment maintenance procedures for the Beam Tube Module are based on the following references:

1) Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, Caltech; Feb-92.
2) LIGO Project Safety Manual.
3) Manufacturer's Procedures for Global Positioning System (GPS) Equipment and Computer Software.

3.0 EQUIPMENT:

The following is a listing of alignment equipment selected for use in establishing and maintaining the LIGO beam tube clear aperture of 1.07 meter diameter.

1) Global Positioning System Package consisting of the following:
   a. Base station receivers
   b. Radio, software, modem system, stands, etc.
   c. Antenna accessories
   d. 386 (min.) computer, DOS format
2) Target reference rod and antenna adapter.
3) Beam Tube Reference Point Attachment Layout Fixture (Sketch ALI-1).
4) Beam Tube Reference Point Attachment Fixture (Sketch ALI-2).
5) Alignment work sheet and data recorder.
6) Miscellaneous tools including flashlights, shop lights, wrenches, screwdrivers, etc.
7) Personnel transportation (bicycle, motor-scooter, golf cart, etc.).

4.0 DOCUMENTATION:

The receiving, recording, calculation and use of data is controlled by data logging forms that will be documented in both hard copy and on 3.5" diskettes formatted to DOS.

4.1 Forms shall be standardized and used to record all data including all dimensional and atmospheric measurements, and will include instrument information including calibration dates, instrument serial numbers and field calibration anomalies.

4.2 Data used to process coordinate points, atmospheric conditions, and instrument information shall be in-put to a spread sheet computer program with abilities to sort for ranges and specific text references.

4.3 Forms are indexed below:

1) Inspection Report
2) Data Record
3) Spreadsheet
4) Project Data Index

4.4 All project documentation shall be signed by the responsible technician and dated with the date of that signing and the date of the actual recordings.

5.0 EXECUTION:

The alignment process begins when the LIGO foundation matte surface is in place. The layout of the beam tube supports, rail track system, and general reference points is detailed below:

5.1 Layout of beam tube reference points shall be performed per the following steps:

1) Set-up receiver base station at the base monument and log in for satellite communication.

2) Locate beam tube support reference points at detailed intervals using the roving GPS antenna and data collector. Record the designated identification on the data record for the specific LIGO location.

3) Adequately mark the position "area" on the concrete slab.

4) Continue steps for all reference points. Assure reference points are adequately marked.

5.2 Installation of beam tubes and supports shall be performed per the following steps:

NOTE:
Assure the support is in the MID position of adjustment before bolting to the foundation.

1) Pull a string line from two beam tube support reference points. Measure the distance from the beam tube reference point along the string line and mark the open tube end distance calculated per the data record. The first beam tube assembly and support shall be positioned by locating the open end of the tube to the layout reference and centering the weld end to the beam tube support plate punch mark. This mark may be extended in the same string line fashion as noted previously.

2) Secure the beam tube support to the foundation mat per the engineering detail.

3) Fine adjust the lateral and vertical position of the tube before the clean room is moved into place.

4) Repeat step 5.3 for each beam tube installation.

5) During the installation activities, the beam tube support may be positioned using a temporary support. Align the beam tube to best condition until the tube's permanent support is installed. Repeat the steps after installation of the permanent support.

6) Mount the Beam Tube Reference Point Attachment Fixture (ALI-1) and level the fixture to Earth. Mark with a punch a 1 (mm) diameter point on the outside diameter (OD) of the machined support ring. Recheck the point.

7) Mount the Beam Tube Reference Fixture (ALI-2) with the punch sight attachment and set-up on the punch mark made in step 5.2.6). Attach the GPS antenna and input reference point data into the GPS computer. Record the location, elevation and all other applicable data into the data collector.

8) Perform these steps for all beam tube support reference points.

5.3 Installation of "Through the Cover" Target Reference Rod Assemblies after beam tube covers are installed:

1) Lay out reference mark on beam tube machined stiffener using beam tube layout fixture. Determine its position using the as-built dimensions. In-put data into RTK-GPS data logger.

2) Locate and cut, drill, and/or bore each designated access penetration above the support and install the weather cover. Apply gasketing as required.

3) Install and level the beam tube reference point fixture to the machined stiffener. Assure that the fixture is properly located and level to the punchmark located on the machined stiffener.

4) Attach a stainless steel tag in the area of the stiffener mark with the proper reference point serial number stamped into the tag.

5) Mount the GPS antenna to the fixture connection and fine adjust level.

6) Input reference rod data into the GPS computer and record location.

5.4 Final Inspection and Adjustment of Beam Tube Modules

The inspection and maintenance of beam tube alignment is divided into two steps. These are (1) verification of beam tube support stiffener centerline positions, (2) adjustment of beam tube supports and (3) Final verification of beam tube support stiffener centerline positions.

5.4.1 Verification of beam tube support stiffener centerline positions is performed in the following steps:

1) Set-up receiver base station and log in for satellite communication.

2) Attach the beam tube reference fixture (ALI-2) to the beam tube stiffener and align to the layout punch mark. Install the GPS antenna. Record the position serial number and location on the data collector.

3) Level the fixture on the tube stiffener to within 0.001 in/ft. Record the position serial number and location on the data collector. The data collector shall log calculate the beam tube rotation in degrees, minutes and seconds for analysis.

4) Using the levelness value and the target coordinates, calculate the location of all support alignment positions.

5) Determine adjustments for each location. Input adjustments into data logger program.

5.4.2 Inspection of beam tube alignment and adjustment of beam tube supports shall be performed per the following steps:

1) Set-up receiver base station and log in for satellite communication.

Elevation Movement

2) Level the fixture(ALI-2) on the tube stiffener to within 0.001 in/ft. Record the position serial number and location on the data collector. The data collector shall provide position correction factors(off-sets) for adjusting beam tube centerlines.

3) Attach dial indicators, at all jack locations, to monitor the movements between the beam tube and the fixed support brackets. Set the dial indicators to monitor vertical and horizontal movements.

4) Install jacks between the concrete slab and support frame, and or between the support brackets and the support frame at the designated jacking points. The jacks are to be placed at equal distances from the tube centerline and the hydraulic lines manifolded together so that the jacks will apply equal forces on the supports when raising or lowering. This is done so the jacks will not apply an off center loading to the support and twist the beam tube while raising or lowering the support.

5) Note that the jacks have only 1/2" stroke. Add or remove shims as necessary when the jacks must be re-located to provide additional movement.

6) Re-Zero all dial indicators and slowly loosen the "U" clamps holding the support frame to the fixed support brackets.

7) Extend the jacks until contact the beam tube and pressurize to 100 P.S.I. This will apply a nominal force to the jacks.

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DO NOT REMOVE THE "U" CLAMPS.
ONLY LOOSEN NUTS ENOUGH
TO REMOVE CLAMPING FORCES
TO PERMIT MOVEMENT OF THE SUPPORT BEAM.

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8) Raise or lower the support frame to the specified movement. Use the dial indicators to measure the amount of movement made during the jacking operation.

<u>Lateral Movement</u>

9) Repeat steps 5.4.2.2) and 5.4.2.3).

10) Install the lateral jacking cylinder between the support frame and the fixed support brackets.

11) Zero all dial indicators and slowly loosen the "U" clamps holding the support frame to the fixed support brackets.

12) Extend the hydraulic cylinder and pressurize to 100 P.S.I. to apply a nominal force to the jacks.

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ONLY LOOSEN NUTS ENOUGH
TO REMOVE CLAMPING FORCES
TO PERMIT MOVEMENT OF THE SUPPORT BEAM.

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13) Move the support frame laterally with the hydraulic cylinder to the specified movement. Use the dial indicators to measure the amount of movement made during the jacking operation.

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DO NOT MOVE THE BEAM TUBE IN ANY ONE DIRECTION GREATER THAN 3 CENTIMETERS, WITHOUT ASSESSING THE AMOUNT THAT THE BEAM TUBE WILL BE BENT DURING THE ALIGNMENT PROCESS. THE TUBE CAN BE OVERSTRESSED BY APPLYING TOO MUCH FORCE DURING ALIGNMENT. PRESSURE IN THE HYDRAULIC CYLINDER WILL BE USED TO MONITOR THE AMOUNT OF STRESS BEING APPLIED TO THE BEAM TUBE.

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ROTATION MOVEMENT

14) Repeat steps 5.4.2.2) and 5.4.2.3).

15) Check the beam tube rotation by setting the alignment fixture on the stiffener and locking it to the reference punch mark. Note the level of the fixture and rotate the beam tube using the leveling jacks. Each of the leveling jacks has a valve that can be closed to permit differential leveling and twist the beam tube.

16) Re-clamp the support frames to the fixed support brackets and confirm that the support has been moved as specified.

FINAL VERIFICATION

5.4.3 Final verification of Beam Tube Support Stiffener centerline positions is performed in the following steps:

1) Set-up receiver base station and log in for satellite communication.
2) Attach the Beam Tube Reference fixture(ALI-2) to the beam tube stiffener and align to the layout punch mark. Install the GPS antenna. Record the position serial number and location on the data collector.
3) Level the fixture on the tube stiffener to within 0.001 in/ft. Record the position serial number and location on the data collector. The data collector shall log calculate the beam tube rotation in degrees, minutes and seconds for analysis.
4) Calculate the location of all support and baffle alignment positions and document as-built beam tube centerline.

6.0 CALIBRATION:

Since the GPS equipment under goes a calibration during each use, the formal documents recording the calibrations are suggested to be a check list type file attached to the alignment report. The equipment shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.

7.0 ATTACHMENTS:

1) Sketch ALI-1 : Beam Tube Reference Point Attachment Layout Fixture.

2) Sketch ALI-2 : Beam Tube Reference Point Attachment Fixture.

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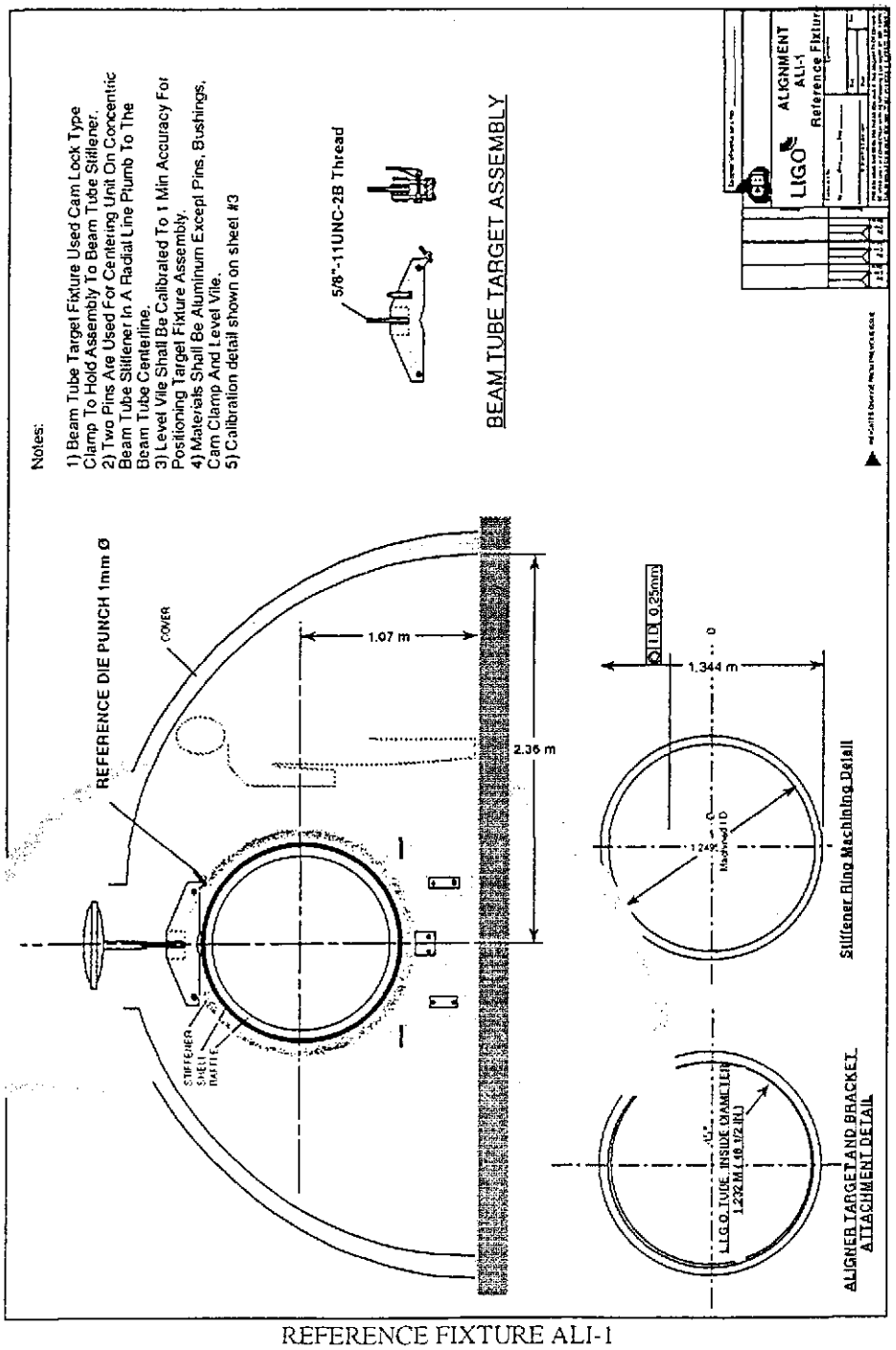

REFERENCE FIXTURE ALI-1

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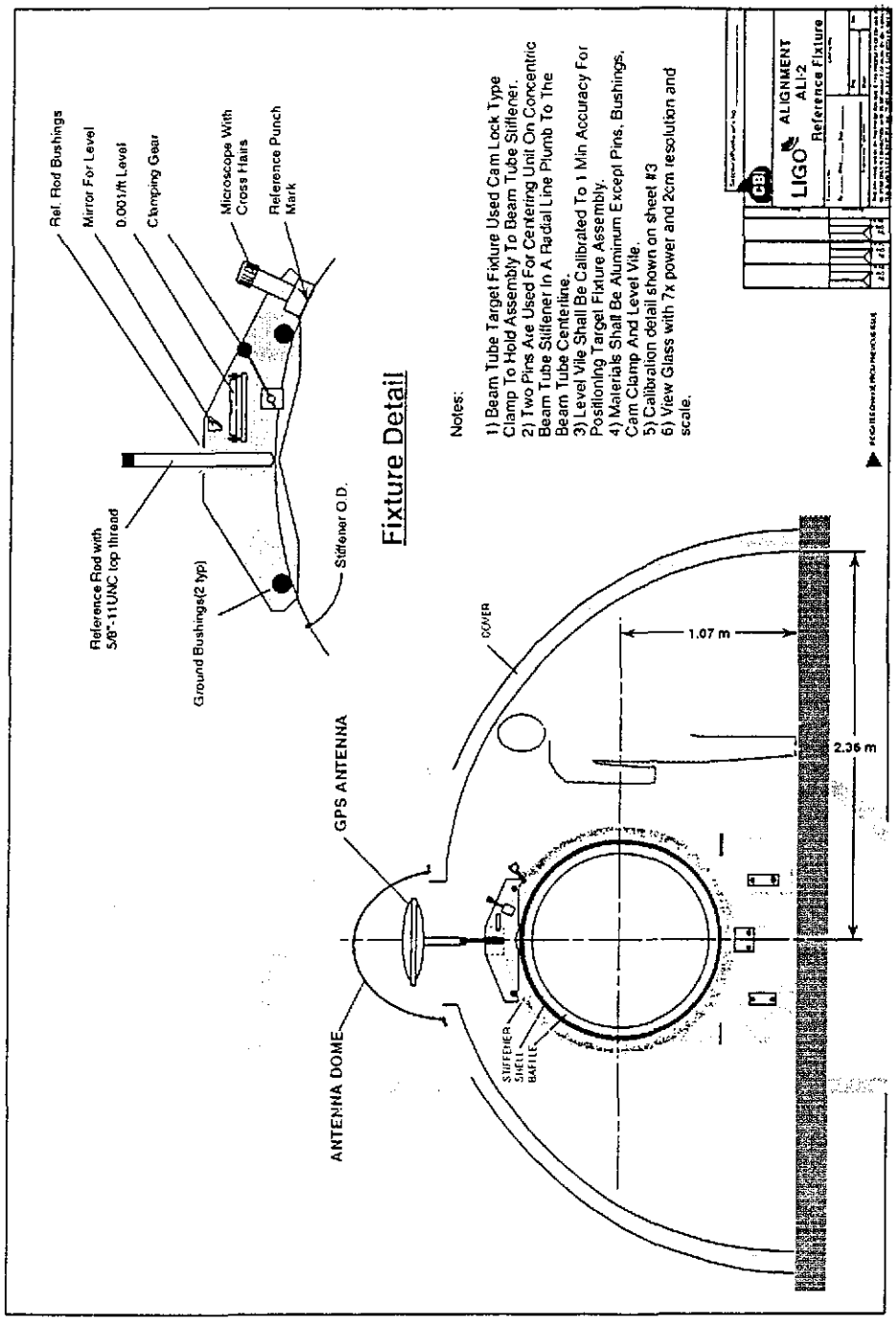

REFERENCE FIXTURE ALI-2