



IDENTIFICATION

ALM-B

LIGO-E950074-03-B

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| TITLE ALIGNMENT MAINTENANCE USING GLOBAL POSITIONING SYSTEM (GPS) PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY | REFERENCE NO. 930212 | | SHT 1 OF 8 | |
| | OFFICE RSE | | REVISION 3 | |
| | MADE BY SDH | CHKD BY SWP | MADE BY SDH | CHKD BY SWP |
| | DATE 12-21-93 | DATE 12-29-93 | DATE 10/23/95 | DATE 10/23/95 |

1.0 SCOPE:

This procedure defines the method of maintaining the LIGO tube alignment using the Global Positioning System(GPS). Detailed are procedures for reference verification, set-up and inspection of tube positions at each support.

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, CAL TECH; Feb-92.
- 2) LIGO Project Safety Manual.
- 3) Manufacturer's Procedures for Global Positioning System(GPS) Equipment and Computer Software.
- 4) LIGO Procedure "Initial and Final Alignment during Installation of LIGO Beam Tube Modules Using GPS System," ALI-1.

3.0 EQUIPMENT:

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

- 1) Global Positioning System Package consisting of the following:
 - a. Base Station Receiver.
 - b. Radio link system, Tribracs, Stands, Etc.
 - c. Antenna Accessories and fixtures.
 - d. Personal Computer workstation formatted for DOS and MS Windows®. The computer must have a math co-processor as a minimum with RAM and storage capability required based on the manufacturer's recommendations.
 - e. Data Collector
 - f. Real Time and Static Software.
 - g. Satellite Positioning Almanac and Forecasting Software with modem.
 - h. Target Reference Rod and antenna positioner

APPROVED

 11/10/95

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- 2) Equipment Required for Positioning and Adjustments:
 - i. Beam Tube Reference Point Layout and Antenna Support Fixture(**ALI-1, Figure 5.2a**)
 - j. Tools including flashlights, shop lights, wrenches, impact drivers, equipment carts and personell transportation.
 - k. Jacking equipment consisting of Pumps, Cylinders, Valves, Manifold and High Pressure Hose(**Figure 5.3a**).

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.

- 1) Forms shall be standardized and used to record all data including dimensional and atmospheric measurements, and will include instrument information including calibration dates, instrument serial numbers and field calibration anomalies.
- 2) Data used to process coordinate points, atmospheric conditions, and instrument information shall be in-put to a spread sheet computer program having capabilities to sort for ranges and specific text references.
- 3) Standardized Documents are indexed below:
 - a. Daily GPS Field Report(See LIGO Procedure ALI-1, Figure 4.3a)
 - b. Data Record(See LIGO Procedure ALI-1, Figure 4.3b)
 - c. GPS Inventory/Calibration Log(See LIGO Procedure ALI-1, Figure 4.3c)
- 4) All documentation should include the name of the responsible technician and the date the inspection/calculations were completed.
- 5) A plotting format should be used to provide a graphic representation of layout and alignment conditions when advantageous in determining relationships in visual observations.

5.0 EXECUTION:

The Beam Tube Alignment Maintenance activities will be performed in an similar manner as the final alignment activity noted in the LIGO Procedure ALI-1. The



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following steps are suggested for future beam tube centerline inspections and adjustments.

5.1 Set-up for GPS alignment activities.

- 1) Perform pre-planning by analyzing the satellite conditions and PDOP quality. Assess the daily accuracy level and schedule layout activities. Begin the "**Daily GPS Field Report**" by completing the applicable sections of the report as noted in LIGO Procedure ALI-1, Figure 4.3a.
- 2) Set-up the reference receiver at a selected LIGO Control Point and log in for satellite communication. Follow the GPS Equipment Manufacturers' guide for performing this activity. Locate the site control points and verify position to assure set-up is correct and repeatable.

5.2 Verification of Beam Tube Support Stiffener centerline positions is performed in the following steps:

- 1) Locate the first support point and verify location and I.D. number. Input data in to the Data Collector.

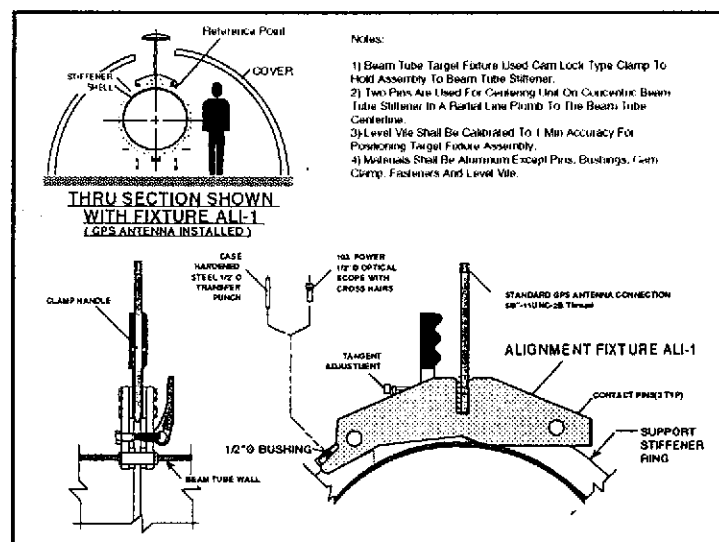


Figure 5.2a



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- 2) Attach the Beam Tube Reference antenna fixture to the beam tube stiffener and level (**Figure 5.2a**). Inspect layout mark on beam tube stiffener for location to the fixture cross hair. Record the off-set in the data collector.
- 3) Mount the GPS antenna to the fixture connection and fine adjust level.
- 4) Input antenna height data into the data collector and record location.
- 5) Take GPS reading. Keep the antenna located on the point for a time required to obtain static data for post processing. Real time positions should be recorded on the field copy of the "**Data Record**" (LIGO Procedure ALI-1, Figure 4.3b) for a quick reference, however no beam tube support adjustments should be made until the static data is post-processed.
- 6) Post-processing shall be performed by first obtaining the corrected satellite positions and clock corrections via modem from the NOAA. Data will be downloaded to the hard drive of the GPS work station computer.
- 7) Position data obtained shall be post-processed using actual satellite position and clock corrections. GPS Manufacturer provided software shall be used to post process data and determine actual corrected positions.
- 8) A spreadsheet program shall be used to calculate a "corrected" beam tube centerline condition and compare the line with each beam tube support ring position. Off-sets shall be calculated and those outside of the corrected centerline tolerance zone shall be highlighted for adjustments.
- 9) Quantified Beam Tube support adjustments shall be input into the data collector for real time inspections at each out-of-tolerance support. This will aid the field personnel during beam tube centerline maintenance activities.

5.3 Adjustment of Beam Tube Supports shall be performed per the following steps:

PRECAUTION

**WHEN JACKING BEAM TUBE SUPPORT POINTS:
SUPPORT LOAD LIMITS**

DO NOT EXCEED 6750 lbs TOTAL LOAD AT ANY TIME

Actual Jacking Pressure Reading = TBD



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**OVERSTRESSING OF THE EXPANSION JOINT WILL RESULT
IF THE TUBE IS ROTATED IN EXCESS OF $\pm 3\text{mm}$
(Radial @ Support Ring O.D.).**

Elevation Movement

- 1) Level the fixture(ALI-1) 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.
- 2) 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.

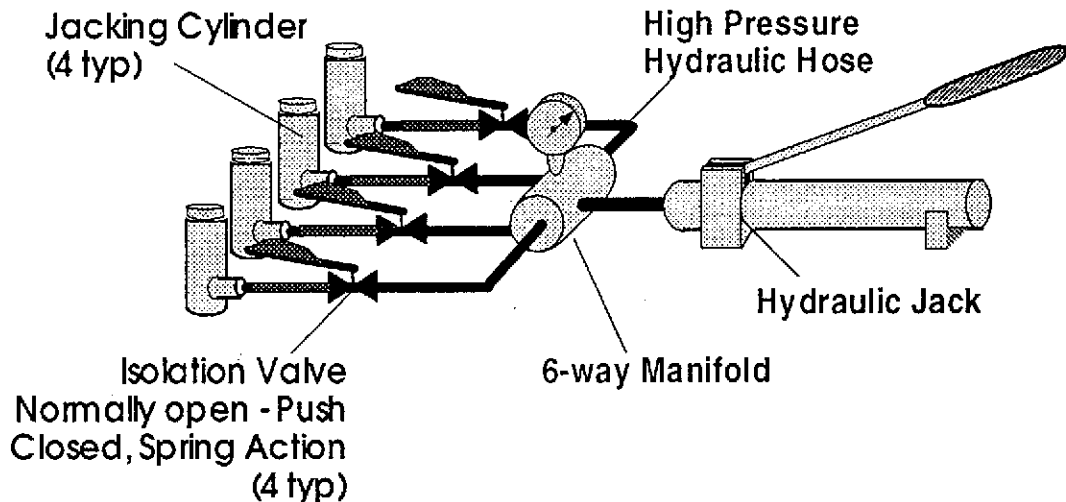


Figure 5.3a

- 3) Set-up the jacking system for either fixed support or guided support adjustments. The fixed support system requires two(2) jacking cylinders. The guided supports require four(4) cylinders. A detail is shown in **Figure 5.3a**. 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 manifold together so that



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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. Before jacking, assure the jack isolation valves for the operating cylinders are in the "open" position. When adjusting a fixed support, close the two isolation valves feeding the two un-used cylinders.

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

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

- 5) Extend the jacks until contact the beam tube and pressurize to 100 P.S.I. This will apply a nominal force to the jacks.
- 6) Loosen the "U" Clamps to 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.
- 7) Use a light prying effort between the horizontal support and the base to move the support when friction is encountered at the support.

Lateral Movement

- 8) Install the lateral jacking cylinder between the support frame and the fixed support brackets.
- 9) 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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**OVERSTRESSING OF THE EXPANSION JOINT WILL RESULT
IF THE TUBE IS ROTATED IN EXCESS OF ± 3 mm.
(Radial @ Support Ring O.D.)**

ROTATION MOVEMENT

- 1) Re-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 first by loosening the "U" bolts and allowing the tube to relax back into its non-stressed condition. If this does not re-align the beam, then rotate using the leveling jacks. Each of the leveling jacks has a normally open valve that has to be held down to permit differential leveling and twist the beam tube. **DO NOT ROTATE THE TUBE IN EXCESS OF +/- 3millimeters radial at the support ring O.D.**
- 2) Re-clamp the support frames to the fixed support brackets and confirm that the support has been moved as specified.

5.4 Final Inspection of Beam Tube Support Positions shall be performed per the following steps:

5.4.1 Set-up for GPS alignment activities repeat steps noted in paragraph 5.1.

5.4.2 Verification of Beam Tube Support Stiffener centerline positions is performed by repeating steps in paragraph 5.2

5.4.3 Additional Adjustments of Beam Tube Supports shall be performed per steps detailed in paragraph 5.3.

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

1. Repeat all steps noted in paragraphs 5.1 and 5.2 as necessary to assure clear aperture is available.



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6.0 CALIBRATION:

Since the GPS equipment under goes a calibration during each use, the formal documents recording the calibrations will be recorded on each "Daily GPS Inspection 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 maintenance and calibrations shall be documented in the "GPS EQUIPMENT INVENTORY/CALIBRATION LOG"(LIGO Procedure ALI-1, Figure 4.3c).