TITLE

LARGE OPTICS SUSPENSION SPECIFICATION

APPROVALS:	DATE	REV	DCN NO	BY	CHK	DCC	DATE
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1 INTRODUCTION

1.1. Objectives and Scope

This document is divided into two parts: the specifications for the fabrication of the LOS Structure Assembl and the Height Adapter and the specifications for the preparation and suspension of an optic in the LOS Assembly.

The objectives and scope of this document is to specify how to fabricate, identify, clean and assemble a Large Optic Suspension. It also details how to assemble a Large Optic Suspension (LOS) including how to prepare an optic for installation into the suspension structure and how to hang and balance that optic.

1.2. Applicable Documents

LIGO-D960132: Large Optic Suspension Assembly, LOS1
LIGO-D960133: LOS Structure Assembly, LOS1
LIGO-D960145: LOS Height Adapter Assembly

LIGO-E960022: LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures
LIGO-T960074: Suspension Preliminary Design
LIGO-T950011: Suspension Design Requirements
LIGO-T970158: Large Optics Suspension Final Design (Mechanical System)
LIGO-L970196: Part Numbers and Serialization of Detector Hardware
LIGO-E970132: Large Optic Suspension Assembly Quality Conformance Worksheet

2 SPECIFICATION FOR FABRICATION

2.1. Physical Configuration

According to

LIGO-D960132: Large Optics Suspension Assembly
LIGO-D960133: LOS Structure Assembly
LIGO-D960145: LOS Height Adapter Assembly

2.2. Fabrication Specification

2.2.1. Process Sequence

The sequence of process steps for the fabrication of the LOS Structure Assembly required by this specification is as indicated in Figure 1. These process steps are the same for the Height Adapter.

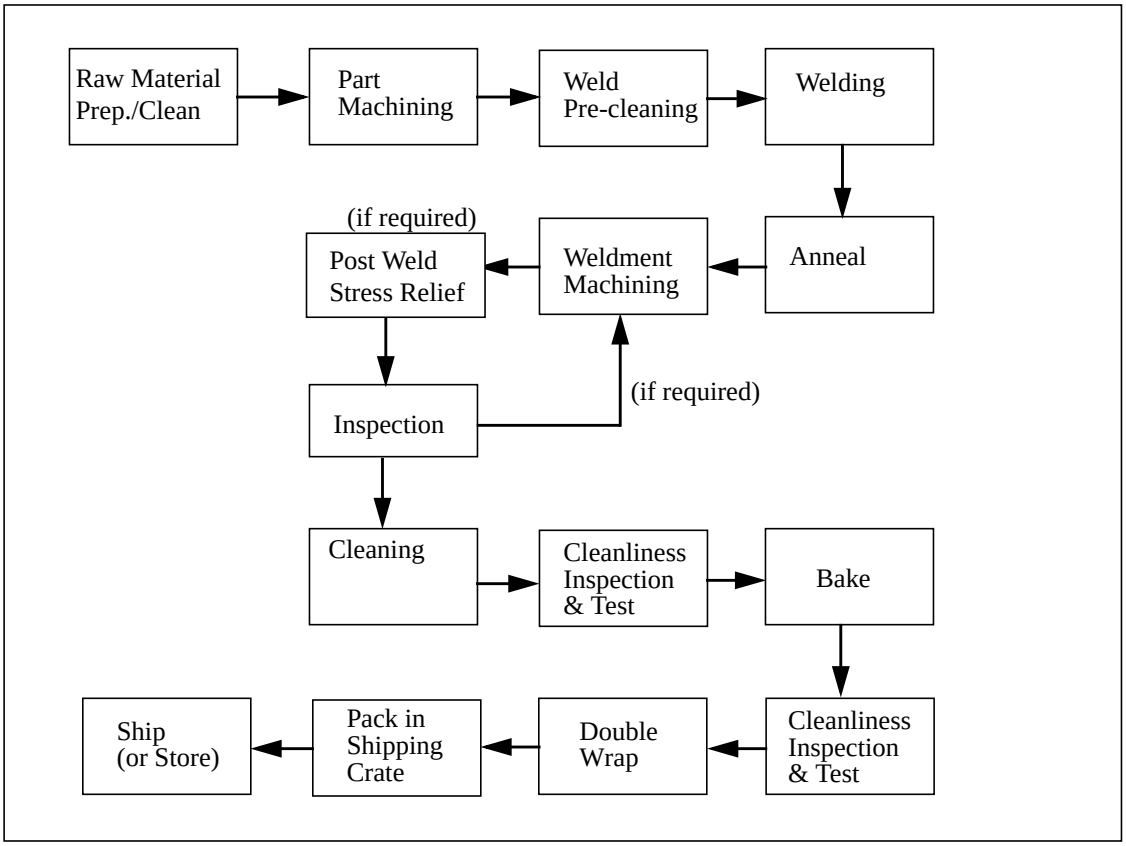

Figure 1: Process Sequence

2.2.2. Raw Material Preparation and Cleaning

- **Preparation and Handling**

In order to preclude surface contamination of stainless steel (SST) stock by carbon steel, all raw SST material intended for use in the Large Optics Suspension shall be cleaned and pickled prior to subsequent operations. Careful control on the pickled SST shall be imposed so that carbon steel contamination, as well as hydrocarbon contamination, is prohibited.

No weld splices or repair welding is permitted without explicit approval.

- **Protection From Contamination**

Contact of suspension material by uncontrolled and/or un-allowed materials shall be avoided. This includes materials such as work gloves, work boots and unprotected shop floors. Liquids, gases or vapors containing hydrocarbons or other contaminants shall not be allowed to come into contact with the suspension material at any time. This includes fluids such as machining lubricants (except those specified in Appendix 1.)

No carbon steel hooks, fork lift forks, grapples or chains shall be allowed to contact the suspension material. Raw materials shall not be stored in direct contact with materials of different composition, but shall be separated by suitable spacers or sheeting, depending on the part's level of cleanliness (raw material vs. cleaned part). For cleaned parts follow procedures listed under Clean/Bake Handling. For raw material, polyethylene sheet or Teflon or clean stainless steel or aluminum pieces may be used as spacers.

Stored materials (raw materials or work-in-process) shall be protected from the shop atmosphere when not being handled (or worked on) by plastic sheets or similar protective covers. Prior to cleaning and baking, polyethylene plastic sheet is acceptable. After cleaning, only CP Stat plastic and Nitrilite (gloves) can touch the suspension components. See Appendix for information about the plastic and gloves.

- **Cleaning environment**

Cleaning is to be performed in a Class 100 cleanroom environment per FED-STD-209B. If the vendor does not have a dedicated Class 100 cleanroom facility for performing the cleaning operations, then an area of the facility must be isolated from the rest of their operations, cleaned up and used to house a portable Class 100 cleanroom. The atmosphere for this "clean manufacturing area" must not exchange directly with a shop floor area with potential hydrocarbon emissions. The air must also be carbon filtered and monitored with a hydrocarbon meter to assure that the level of hydrocarbons in the air is less than 15 ppm.

2.2.3. Part Machining

- **Fabrication environment**

Raw materials shall be protected from contamination throughout the fabrication process. All welding and fitting shall be done in clean manufacturing space (Class 100,000 to 200,000) with outside air purge to minimize contamination. Welding gases shall be collected in exhaust systems and vented outside.

- **Smoking and Airborne Contamination**

Smoking is not allowed in any suspension storage or manufacturing area.

Gases and vapors containing hydrocarbons shall be limited to 15 ppm, as measured by a hydrocarbon meter, in environments in which a cleaned suspension part may be exposed (prior to double wrapping).

- **Liquid contaminants**

Liquids containing hydrocarbons or other contaminants shall not be allowed to come into contact with suspension material at any time. This includes fluids such as machining lubricants (other than those specified in this document) and paints. All machining fluids shall be water soluble and low in chlorides.

- **Grinding & Abrasive Cloth/Paper**

Grinding (with abrasive wheels, cloth, or stones), or use of abrasive cloth or paper, is not permitted on suspension components, except where noted.

- **Machining Lubrication**

No lubricant may be used which might result in material contamination that cannot be removed by the cleaning method described in this specification or referred to in this document. The use of cutting fluids or lubricants which contain sulfur or silicone compounds is prohibited. Acceptable lubricants are listed in Appendix 1.

2.2.4. Weld Pre-cleaning

Remove ink markings such as material designations with acetone. Clean parts according to LIGO-E960022, LIGO Vacuum Compatibility, Cleaning Methods and Qualifications.

2.2.5. Welding

Comply with the welding environment requirements listed under Smoking and Airborne Contamination. Perform the pre-welding steps defined in the section titled Prior to Welding. Welders must be certified to American Welding Society (AWS) or American Society of Mechanical Engineering (ASME) standards. All welds for suspension components are full penetration. Welds in suspension components should not be subsequently ground. An inert shield gas (e.g. Argon) must be used in all suspension welding.

2.2.6. Annealing

The Large Optic Suspension Structure Assembly shall be annealed at 2000 degrees F. for TBD hours and then allowed to slowly cool in air. Prospective heat treatment companies shall provide proposed number of hours for annealing operation in bid package.

There are a number of post-weld, post-anneal machining operations called out on the LOS Structure Assembly drawing, including flatness to .002” for the top and bottom plates. If this machining causes further warpage such that achieving these dimensional/flatness requirements is difficult, a post machining stress relief operation will be required. The structure shall be held at 488C (900F) for 4 hours per inch of thickness and slow cooled

2.2.7. Cleaning and Baking

All procedures listed herein must be performed while suited up in clean room clothing including, but not limited to: coat, booties, bonnet, gloves, facial mask. This applies to anyone handling or near clean pieces or pieces being cleaned. The structure assembly to be cleaned and baked in preparation for installation according to LIGO-E960022, LIGO Vacuum Compatibility, Cleaning Methods and Qualifications.

- **Cleaning Inspection and Testing**

Sample check the cleanliness of blind tapped and through tapped holes with a clean Q-tip dampened with alcohol for a minimum of 10% of the holes. If any discoloration of the Q-tip is evident, then the part must go through at least one more wash before repeating a check of the cleanliness. If any machining chips are found:

(a) a HEPA filtered vacuum cleaner may be used to remove the chips from the holes, and
(b) the holes must be cleaned with a solvent dampened Q-tip wipe.

After inspection and testing , double bag the component in C.P. Stat plastic film. Tie or band the inner bag(s) closed. Do not use tape or heat sealing on the inner bag. Purge the bag with dry nitrogen (class 5 or better) before closing. The outer bag should be heat sealed, after purging with dry nitrogen.

A log of the cleaning procedure shall be kept and form part of the component traveler.

- **Baking Inspection and Testing**

Sample check the cleanliness of blind tapped and through tapped holes with a clean Q-tip dampened with alcohol for a minimum of 10% of the holes. If any discoloration of the Q-tip is evident, then the part must go through at least one more wash before repeating a check of the cleanliness. If any machining chips are found:
(a) a HEPA filtered vacuum cleaner may be used to remove the chips from the holes, and
(b) the holes must be cleaned with a solvent dampened Q-tip wipe.

Use ethanol to spot clean any fingerprints.

After inspection, double bag the component in C.P.Stat plastic film. Purge the bag with dry nitrogen (Grade 5 or better) before closing. Tie or band the inner bag(s) shut. Do not use tape or heat sealing. The outer bag should be heat sealed, after purging with dry nitrogen.

A log of the baking procedure shall be kept and form part of the component traveler

- **Clean/Bake Handling**

During and subsequent to the cleaning initiation, all personnel in the clean room must wear complete clean room garb, including a lab coat, face mask, hair net/cap, shoe covers and clean room gloves. (This applies to anyone handling or near clean pieces or pieces being cleaned.)

Use nitrile gloves (see Appendix 1) for handling cleaned parts. During cleaning of parts, use a fabric Vidaro Glove (see Appendix 1) over the nitrile glove.

After cleaning and after baking, suspension component surfaces shall not be touched by skin or other contaminants; only C.P. Stat plastic sheet and Nitrilite gloves are acceptable. All suspension parts shall be double bagged (C.P.Stat plastic) or protected by a Class 100 cleanroom atmosphere. Small components can be bagged together with other small pieces.

2.3. Quality Assurance/Control

2.3.1. Identification

Assembly part number and serial number to be marked on the top of the base of the assembly, [detail part name, LOS Bottom Plate, P/N D960505] with laser marking or acid etch techniques. Also, a vibratory tool with a minimum tip radius of 0.0005” is acceptable for marking on surfaces which are not hidden from view. Engraving is also permitted. The marked area shall be cleaned thoroughly after marking with the appropriate solvents listed in the LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022.

Machined piece parts of the assembly shall be marked and serialized according to the document titled Part Numbers and Serialization of Detector Hardware, LIGO-L970196. This document allows for “bag-and-tag” type of identification for small parts. The sensor/actuator heads shall be identified by this method along with the finished sensor/actuator head assemblies.

2.3.2. Serial Number

The Serial number shall be of the format:
Dxxxxxx-x S/N *nnn* Where

Dxxxxxx-x is the LIGO piece part or assembly drawing number, including the revision letter to which the hardware item was built, and

nnn is the sequential serial number, 001 through 999, in the order produced.

2.3.3. Quality Assurance Provisions

A first article fabrication and assembly shall be inspected for form and fit and workmanship. An inspection report shall be issued using JPL inspection report form, U.S. Government Printing Office 1995-680-304. These forms may be provided by LIGO.

Measure the strength of the magnets using an F. W. Bell Model 9200 Portable Gaussmeter with a Gaussmeter Probe, P/N HTB92-0608 and the Magnet Strength Fixture, P/N D970169, -1 for magnet testing. Collect 8 magnets that have comparable strengths, to within +/- 5%, record the manuf. name, P.O. number, serial/lot number, magnet strength of each magnet and set them aside for one suspension. Use the Large Optic Suspension Assembly Quality Conformance Worksheet to record this data.

Measure the strength of the coils in the sensor/actuator head assemblies using an F. W. Bell Model 9200 Portable Gaussmeter with a Gaussmeter Probe, P/N HTB92-0608 and the Magnet Strength Fixture, P/N D970169, -2 for sensor/actuator head assembly testing. Collect six sensor/actuator head assemblies (five needed and one spare) that have comparable strengths, to within +/- 1%, record serial numbers and strengths of each assembly and set them aside for one suspension. Use the Large Optic Suspension Assembly Quality Conformance Worksheet to record this data.

Inspect the mechanical parts and fixtures of the Large Optics Suspension to their respective drawings using the Large Optic Suspension Assembly Quality Conformance Worksheet.

To ensure Quality Conformance for the assembly, complete and file the Large Optic Suspension Assembly Quality Conformance Worksheet, E970132, and keep it with the traveler record for the assembly.

2.3.4. Purchaser Access

Non-escort privileges for the buyer, owner, government and owner representatives to all areas of the facilities where work is being performed shall be arranged. This will include access to all areas where material is being processed and stored. The purchaser shall have the right to witness all manufacturing processes.

2.3.5. QA Approval

LIGO QA reserves the right to inspect and approve vendor/fabricator QA plan and processes. The processes and procedures used for cleaning the parts must be qualified before application to the production items. The qualification shall be the same as the acceptance testing and shall be done for every large item. Small parts may be sample tested to insure that the process is controlled. In the event that a cleanliness acceptance test fails, all products between the last test and the failed test shall be recleaned and retested.

2.3.6. Travelers

QA travelers shall accompany all material from delivered raw stock to final components and assemblies.

2.3.7. Welding QC

A QC procedure for 100% inspection of all welded joints shall be developed and submitted for approval. This QC procedure shall be used to verify that all welds called out on the drawings have been accomplished and that the weld penetration is complete and that the weld quality is acceptable.

3 SPECIFICATION FOR ASSEMBLY AND BALANCING

3.1. Physical Configuration

According to

LIGO-D960132: Large Optics Suspension Assembly
LIGO-D960133: LOS Structure Assembly

LIGO-D960145: LOS Height Adapter Assembly

- **Cleaning and Baking**

All procedures listed herein must be performed while suited up in clean room clothing including, but not limited to: coat, booties, bonnet, gloves, facial mask. This applies to anyone handling or near clean pieces or pieces being cleaned. The structure assembly to be cleaned and baked in preparation for installation according to LIGO-E960022, LIGO Vacuum compatibility, Cleaning Methods and Qualifications.

3.2. Fixtures

D961412: Set Screw Tool
D970074: Magnet-to-Dumbbell Standoff Fixture
D960050: Magnet/Standoff Assembly Fixture
D960147: Guide Rod Fixture Assembly
D960763: Fixture, Test Mass (often called the Dummy Mass)
38427: Edmund Scientific, Pocket Measuring Microscope
D960016: Microscope Bushing
PZT Buzzer
D950126: LED Fixture
D970180: Winch Fixture
D960145: Height Adapter
D960753: Fixture, Wire and Optics

- **Set Screw Tool**

Used to ease in the installation of the spring plungers in the Sensor/Actuator Plates.

- **Magnet-to-Dumbbell Standoff Fixture**

Used to configure and bond the magnets to the dumbbell shaped aluminum standoffs.

- **Magnet/Standoff Assembly Fixture**

Used to position and epoxy the magnet/standoff assemblies to the face of the optic.

- **Guide Rod Fixture**

Used to position and bond a guide rod, a wire standoff and side magnet/standoff assemblies to the side of the optic.

- **Fixture, Test Mass**

Used for the prototype test. This aluminum “optic” has the same size, wedge, chamfer and approximate mass as the fused silica optic.

- **Measuring Microscope**

Used to align the sensor/actuator plates to the magnet/standoff assemblies glued on the optic or dummy mass.

- **Microscope Bushing**

Mounted on the bore of the measuring microscope and used to adapt the bore of the microscope to the bore of the holes for the sensor/actuator head assemblies in the sensor/actuator plates. This bushing is also used to align the centerline of the microscope (crosshairs) to the centerline of the outside diameter of the bushing.

- **PZT Buzzer**

Used for sliding the wire standoff along the side of the optic to change the pitch balance of the optic. It is a rod or tube to which a PZT is attached. The PZT is driven while the vibrating rod is placed against the end of the standoff to produce small displacements of the standoff.

- **LED Fixture**

Used to position and mount the LED relative to the photodiode in the sensor/actuator head. Use of this fixture will be covered in another document

- **Winch Fixture**

Just as the name implies, this fixture is used to microposition the suspension wire vertically.

- **Height Adapter**

Used to adapt suspension to its correct vertical position relative to the laser beam.

- **Fixture, Wire and Optics**

Used to position the wire and to protect and move the optic into position in the suspension support structure.

3.3. Assembly/Balancing Specification

3.3.1. Assembly Sequence

1. Suspension Assembly
2. Optic and Dummy Mass Preparation
3. Optic Hanging and Balancing
4. Sensor/Actuator Head Installation

3.3.2. Suspension Assembly

1. Clean and bake all components of the suspension assembly per LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022
2. Screw in the 8 Wedge Stops and the 8 3/8” bolts into their respective brackets until they protrude past the inside of the bracket by about .25”.

3. Install the spring plungers, or the alternate socket head set screws, into the Sensor/Actuator Brackets in preparation for the installation of the Sensor/Actuator Assemblies. The Set Screw Tool may be used with the cross head spring plungers instead of a regular screw driver.
4. Install the suspension block with its hardware. Do not install the clamps on the suspension block just yet.
5. At this point, it is best to prepare a dummy mass for suspending using the fixtures and procedure below.

3.3.3. Optic and Dummy Mass Preparation

3.3.3.1 Magnet-to-Dumbbell Standoff

- **Materials**

D960501: Magnet
D970075: Dumbbell Standoff
D960149: LOS Side Standoff
Perkin Elmer Vac-Seal epoxy resin
D970074: Magnet-to-Dumbbell Standoff Fixture
solvents; methanol, acetone, isopropyl alcohol
6” length of 20 to 30 ga insulated wire
800 grit sandpaper
cellophane tape
aluminum foil
lint-free wipes
microscope
ultrasonic agitator

- **Adhesive Procedure**

1. Clean 8 magnets and 8 standoffs, separately, per LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022. Lightly sand both ends of each magnet with 800 grit sandpaper. Use cellophane tape to remove the grit. Using a microscope, examine the sanded magnet ends to make sure that all grit has been removed. Clean the magnets in an ultrasonic agitator with acetone. Check the ends of the standoffs under the microscope to make sure that each surface is clean, flat and without burrs. If a surface looks unsatisfactory, follow the magnet sanding instructions for both ends of the standoffs.
2. Strip off about.5” of insulation from the wire. Splay conductors and clip off all but one. Clean conductor with acetone and alcohol with lint-free wipe.
3. Mix the two epoxy components of a Vac Seal “bipax” together thoroughly, approximately 2 minutes. Dispense from the middle of the container onto clean aluminum foil.
4. Insert eight magnets into the magnet-to-dumbbell standoff fixture after it has been cleaned thoroughly with methanol and acetone. The magnets have to be positioned on the optic so that their polarities are alternated. It is best to make five magnet/standoff assemblies of one polarity and three of the other polarity. The easy way to do this is to line up the eight magnets to be used with this fixture. Insert five magnets in five holes (the fixture may be marked to indicate polarity), and then turn the magnets in your hand 180 degrees, and then insert the last three in the remaining holes. Be sure to note which magnets are which polarity.
5. Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on

the wire to the end of a standoff. Optimum adhesive thickness is.003" [.08mm] or a volume of 3.9×10^{-6} in^3 [.06mm^3]. Epoxy should only cover a diameter of about.02" [.5mm]with a height of .01"[.3mm]. Insert standoff carefully into fixture, making sure not to get adhesive on fixture. Repeat this for seven remaining standoffs, making sure to use 2 or 3 longer dumbbell standoffs for the side magnets, as shown on the LOS Assembly parts list. Lightly tap the standoffs against the magnets.

6. Leave the assembly, standoff side up, for 24 hours or more. Vac Seal cures in 72 hours so if that time is available, it should be used to allow the assemblies to fully cure.
7. Use a blunt, clean, non-magnetic instrument to tap the magnets and remove the assemblies. Take care to move each assembly away from the fixture, and apart from each other, after loosening. Move the assemblies onto a clean, flat plate. Take great care when handling these glued assemblies as they are extremely fragile.
8. Place plate with magnet/standoff assemblies into an ultrasonic agitator filled with isopropyl alcohol for 10 minutes.

3.3.3.2 Magnet/Standoff Assembly Fixture

- **Materials**

8 magnet/dumbbell standoff assemblies, from instructions above.
Perkin Elmer Vac-Seal epoxy resins
D970050: Magnet/Standoff Assembly Fixture
D960147: Base Plate of Guide Rod Fixture Assembly
D960763: Fixture, Test Mass (Dummy Mass) or Optic
solvents; methanol, acetone, isopropyl alcohol
6" length of 20 to 30 ga insulated wire
aluminum foil
lint-free wipes

- **Fixture Assembly**

1. Clean base plate and magnet/standoff assembly fixture thoroughly per LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022.
2. Place the optic or dummy mass onto the base plate with the side up that will have the magnet/standoff assemblies epoxied to it. Configure the optic such that its outer diameter lines up evenly with the circle etched onto the base plate. Using the arrow on the side of the optic, rotate the optic until the arrow lines up with the horizontal and/or vertical lines of the base plate, whichever is appropriate for the positioning of the optic with respect to the face magnets. See T970 for magnet configuration data.
3. Clean the magnet/standoff assembly fixture per LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022. Make sure the two #4-40 screws that hold the two pieces of the fixture together are in place and tightened. Install the three #10-32 set screws on the side of the bottom piece of the fixture (called the holding ring) until the tips are flush with the inside diameter of the holding ring. Position the two screws with knobs so that the tip of the screws just touch the holding ring. Mark a line on the top of each knob from the centerline to the outside diameter to determine initial rotation position. The lines on the knobs should be parallel to each other.
4. Carefully lower both onto the face of the optic such that the top piece of the fixture (called the positioning ring) registers onto the top surface of the optic. Align the lines on the outside diameter of the fixture with

the etched lines on the side of the optic. Using the three side set screws, position the fixture such that its centerline is coincident with the centerline of the optic as close as possible. This is done by incrementally advancing the set screws. Make sure that the fixture doesn't slip from its alignment with the lines on the optic.

5. Strip off about .5" of insulation from the wire. Splay conductors and clip off all but one. Clean conductor with acetone and alcohol with lint-free wipe.
6. Mix the two epoxy components of a Vac Seal "bipax" together thoroughly, approximately 2 minutes. Dispense from the middle of the container onto clean aluminum foil.
7. Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the end of a standoff. Optimum adhesive thickness is .003" [.08mm] or a volume of 3.9×10^{-6} in^3 [$.06mm^3$]. Epoxy should only cover a diameter of about .02" [.5mm] with a height of .01"[.3mm]. Insert standoff carefully into fixture, making sure not to get adhesive on fixture. Repeat this for three more magnet/standoff assemblies. Make sure that the magnet's poles are in opposite configuration to the magnet next to it in the circle. For example, see Figure 2 below. Lightly tap the top of the magnets. The magnets are placed so that polarities of the magnets alternate; this is to prevent the mass from being shaken in position and orientation, by time-varying ambient magnetic fields.
8. Leave the assembly for 24 hours or more. Vac Seal cures in 72 hours so if that time is available, it should be used to allow the assemblies to fully cure.
9. After curing, remove the two #4-40 screws that hold the positioning ring to the holding ring. Incrementally turn the knobs of the two #10-32 screws, at the same time, so that the positioning ring slowly rises above the holding ring without tilting. When the positioning ring has cleared the magnet/standoff assemblies, carefully set it aside and again, carefully, remove the holding ring from the optic. Try to maintain the position of the optic on the base plate as it will need to be in this position for the guide rod fixture assembly procedures, below.

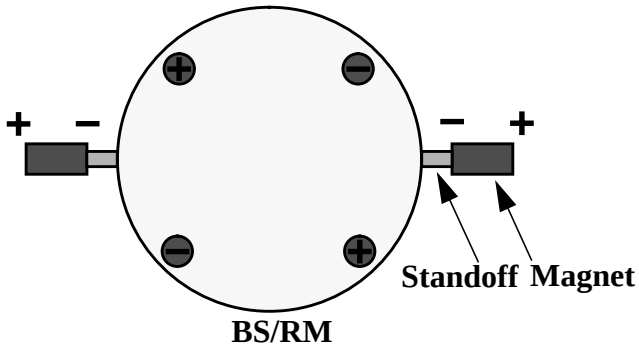

Figure 2: Configuration of the magnet/standoff Assembly.

3.3.3.3 Guide Rod Fixture

- **Materials**

Dummy Mass or Optic with four magnet/standoff assemblies glued to its face
2 or more magnet/standoff assemblies of the same pole configuration that use the side (longer) dumbbell standoff
D960146: Guide Rod
Perkin Elmer Vac-Seal epoxy resins
D960147: Guide Rod Fixture Assembly - which includes:
Base Plate
Left Block, Top
Right Block, Top
solvents; methanol, acetone, isopropyl alcohol
6” length of 20 to 30 ga insulated wire
aluminum foil
lint-free wipes

- **Fixture Assembly**

1. Check to make sure that the optic or dummy mass is centered in the etched circle on the base plate. If the parts are separate, review step #2 of the magnet/standoff fixture assembly, above.
2. Clean the blocks of the guide rod fixture thorougly per LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022. Clean and bake the guide rod and wire standoff per the same specification.
3. Carefully slide the two top pieces; left block, top and right block, top along the wedges of the base plate. Snug them up against the side of the optic. Notice the etched lines on the top blocks. Those etched lines should be aligned with the etched arrows on the side of the optic or dummy mass. Once this alignment is made, tighten the screws that hold the top blocks to the base plate to finger tightness.
4. Check that the magnet/standoff assemblies that will be used with this fixture are of the same pole configuration (i.e. the positive pole is glued to the standoff) as shown in Figure 2.
5. Strip off about .5” of insulation from the wire. Splay conductors and clip off all but one. Clean conductor with acetone and alcohol with lint-free wipe. If using an adhesive applicator that was previously used, be sure to clean off all old, cured adhesive.
6. Mix the two epoxy components of a Vac Seal “bipax” together thoroughly, approximately 2 minutes. Dispense from the middle of the container onto clean aluminum foil.
7. Position the guide rod in the smaller vertical v-groove. If there is difficulty inserting the guide rod into the v-groove, move the top block down a bit, along the wedge, insert the guide rod, and then cinch the block back into position, holding the guide rod in the v-groove securely. Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the vertical line of contact between the guide rod and the optic that is furthest away from the magnet/standoff assembly. Be sparing in epoxy at this point as more glue will be used later to secure this guide rod. Take care in not getting epoxy on the fixture. Insert the wire standoff in the other vertical v-groove and apply epoxy in the same way. Be sure to apply epoxy to the vertical line of contact between the wire standoff and the optic that is furthest away from the magnet/standoff assembly.

8. Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the end of a side (longer) dumbbell standoff. Optimum adhesive thickness is.003" [.08mm] or a volume of 3.9 x 10^{-6} in^3 [.06mm^3]. Epoxy should only cover a diameter of about.02" [.5mm] with a height of .01"[.3mm]. Push magnet/standoff assembly slowly and carefully along the larger horizontal v-groove, making sure not to get adhesive on fixture. Repeat this for the magnet/longer standoff assembly on the other side of the optic. Lightly tap the end of the magnets.
9. If preparing an optic rather than a metal dummy mass, look through the optic at the four glue joints and make sure that the contact area is visible.
10. Leave the assembly for 24 hours or more. Vac Seal cures in 72 hours so if that time is available, it should be used to allow the assemblies to fully cure.
11. After curing, unscrew the fasteners that hold the top blocks to the base plate, one side at a time, and slowly, carefully, move the top blocks down the wedges and out of the way of the magnet/standoff assemblies and the guide rod and wire standoff.

3.3.4. Optic Hanging and Balancing

- **Materials**

Optic or dummy mass with 6 magnet/standoff assemblies and 1guide rod and 1 wire standoff glued to it.
Large Optic Suspension Structure
.012" diameter suspension wire
D960755: wire standoff
D970180: Winch fixture
HeNe laser
Quad photodiode
Table level
Perkin Elmer Vac-Seal epoxy resins
6" length of 20 to 30 ga insulated wire
aluminum foil
lint-free wipes
38427 Edmund Scientific, Pocket Measuring Microscope
D960016: Microscope Bushing
PZT Buzzer
D960753: Fixture, Wire and Optics
Base Plate
Cradle
Teflon Bracket
Metal Brackets
Teflon Strap
18 1/4-20x1.50 long stainless, SHCS
18 1/4-20 stainless lock washers
18 1/4-20 stainless flat washers
18 1/4-20 hex nuts
solvents: methanol, acetone

LARGE OPTICS SUSPENSION SPECIFICATION

- **Assembly**

1. Clean and bake the suspension wire and the other wire standoff per LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022.
2. Level the optical table that's being used for this suspension work, using a mechanical bubble type level, within +/- 0.05 mrad. Set up an optical lever, using a small HeNe laser and a quad cell photodiode, and level the beam within +/- 0.05 mrad. This is done by placing the photodiode near the output of the laser and centering the photodiode to the laser beam. Then move the photodiode down the table and measure the angular displacement of the beam. Make the lever arm as long as possible to increase the accuracy of the alignment.
3. Using oversize washers and a 1/4-20x1.25" long screw, attach the winch to one of the threaded holes on the top of the suspension block, with the rocker of the winch closest to the front of the suspension block. Attach one top suspension block clamp to the top of the suspension block with its screws tightened finger tight. Attach the other suspension block clamp to the face of the winch, tightening the screw finger tight. Attach the bottom two suspension block clamps to the suspension block with its screws, leaving the clamp loose.
4. Clean the wire and optics fixture components. Thoroughly clean suspension wire with methanol and acetone to remove rust after baking. Place the wire in the groove in the cradle of the fixture. Take care not to twist the wire. Any twist in the wire will greatly affect the balance. Make sure that the base plate is positioned under the cradle. Carefully sit the optic in the cradle over the wire, such that the face of the optic that has the magnets/standoff assemblies glued to it is pushed up against the back-stop of the cradle. Clamp the optic in place with the Teflon bracket, the metal brackets and the Teflon strap on top. Slowly push the cradle into the suspension structure. Using the safety stops under the optic, support the optic and remove the brackets. Move the cradle out of the way, moving it away from you. Screw in the chamfer stops so that there is a 1-2mm gap between the optic and the end of the chamfer stop.
5. String the wire up to the suspension block and under the bottom two suspension block clamps. Secure the wire with the clamps, finger tight, such that it is touching the inside of the dowel pins pressed into the suspension block. Remember that it is undesirable to have any twist in the wire.The purpose of the two bottom suspension block clamps at this point is only to keep the wire against the face of the suspension block. In the process of threading the wire, be sure to keep the wire clear of the magnet as the wire is magnetic. Slip the wire under clamp on the suspension block and tighten the clamp's screws. Slip the other end of the wire under the winch clamp, making sure to snug the wire against the dowel pin. Tighten the screws for the clamp mounted to the winch after lightly pulling on the wire.
6. Position the wire such that it is slightly taut by threading in or backing off of the winch's 1/4-20 screw. By eye, align the centerline of the magnets with the centerline of the holes in the sensor/actuator plates. Insert a wire standoff below the guide rod, making sure that the wire sits in the v-groove of both of the wire standoffs. The wire standoff may be inserted above the guide rod and then moved down over the guide rod into place below it. If this approach is used, be sure to loosen the wire a bit so that the wire will not break or the guide rod will not break off due to increased tension in the wire.
7. Slowly, lower the safety stops that support the bottom of the optic and suspend the mass. Try backing off the face safety stops to determine which direction the wire standoff needs to slide along the guide rod to balance the optic/dummy mass. Use the PZT buzzer to micro-position the wire standoff so that the optic/dummy mass will hang stationary. When repositioning the wire standoff, be sure to clamp the optic/dummy mass with the safety and chamfer stops. Again, check the position of the optic making sure that the centerlines of the magnet/standoffs on the face of the optic line up with the centerline of the holes for the sensor/

actuator head assemblies in the sensor/actuator plates. Adjust the height of the optic with the winch if necessary. Check often that the wire is still in the grooves of the wire standoffs.

8. Align the centerline of the microscope to the centerline of the microscope bushing. To do this, start by mounting the bushing onto the microscope bore as evenly as possible, using one row of set screw holes. Position the bushing in an optical mount so that the other row of set screws is accessible. Mount a fiber optic beam delivery cable, connected to a high intensity lamp, into another optical mount and position it so that the light passes through the microscope and illuminates the cross hairs at the focal length. Remember that this type of microscope will show an inverted image. Use a piece of paper, mounted on a flat vertical plate, to image the cross hairs at the focal length. Slowly rotate the microscope to determine the magnitude of the displacement between the centerline of the microscope cross hairs and the centerline of the bushing outer diameter. Using the accessible set screws, reduce the displacement as much as possible between the two centerlines. Use a threadlocker or tape on/around the adjustment set screws to indicate that this alignment has been performed.
9. Mount the bushing/microscope assembly into one of the holes for the sensor/actuator head assembles and view the position of the magnet relative to the position of the sensor/actuator hole. Insert the bushing/microscope in the hole next to it and determine the position of the magnet/standoff assembly relative to the sensor/actuator hole. Carefully rotate the optic to line up the magnets with the holes.'
10. Refer to T970 to determine the proper optic orientation. Using the optical lever, balance the optic such that the unbalance is **within +/- .5 mrad**. Test the balance by rotating the mass around the optical axis. Before rotating the optic, be sure to move the safety stops below the optic into position such that the optic is lightly supported by these stops. This will allow the wire to loosen a bit when the optic is rotated. After rotating the optic a number of times, check the balance. Use the microscope in the sensor/actuator holes to align the optic to the holes.
11. When the optic is balanced, gently move the face safety stops near the face of the optic, <u>just until contact is made</u>. Make sure that the alignment doesn't change. [If the optic is <u>fully</u> clamped, the alignment will change upon the adhesive curing.]
12. Strip off about .5" [12mm] of insulation from the wire. Splay conductors and clip off all but one. Clean conductor with acetone and alcohol using a lint-free wipe.
13. Mix the two epoxy components of a Vac Seal "bipax" together thoroughly, approximately 2 minutes. Dispense from the middle of the container onto clean aluminum foil.
14. Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the top side and ends of the wire standoff. Apply epoxy to the unglued end of the opposite wire standoff to secure it better.
15. Let the suspension sit for 72 hours or more.
16. If balancing an optic (rather than a dummy mass) for installation into an interferometer, remove the optic and clean and bake it, being careful not to break off the magnet/standoff assemblies or the guide rod or wire standoffs in handling. The Core Optics handling tool should be used to remove the optic from the suspension. Try not to break the suspension wire upon removal of the optic. Clean and bake per LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022. Care should be taken to keep the solvents away from all glue joints as acetone will dissolve Vac Seal.
17. Rehang the optic, with the same suspension wire, and make sure it is has maintained its balance using the optical lever.
18. Determine if this alignment is satisfactory by assuming a maximum vertical positional offset is 500 microns

and the maximum horizontal offset is 300 microns. These offset assumptions are valid for a sensor/actuator head assembly that has the LED and photodiode oriented vertically. If the optic is still misaligned vertically from the sensor/actuator plates, use the winch to adjust its vertical position. If the optic is misaligned rotationally, prop it up with the safety stops under it, and gently rotate about the centerline of the optic. The optic may have to be rotated a number of times to position the wire in the same way it was before baking the optic.

19. Tighten the screws for the bottom suspension block clamps. Tighten the top suspension block clamp. Remove the clamp from the winch and screw it into the suspension block, aligning the wire against the dowel pin. Remove the winch. Recheck all clamp screws to make sure the wire is secure.
20. Clean and bake the height adapter per LIGO-E960022 and bolt it to the Large Optic Suspension Assembly with the hardware listed above. Make sure that the hardware has been cleaned and baked per LLIGO-E960022. Torque all fasteners to 100 in lb.

3.3.5. Sensor/Actuator Head Installation

- **Materials**

suspension
D960011: Sensor/Actuator Assembly
Kapton sensor/actuator cables
solvents; methanol, acetone, isopropyl alcohol
solder and flux
deflux spray

- **Assembly**

1. Install the sensor/actuator pin plates on the back side of the sensor/actuator heads, if not already done. Clean the assemblies along with the cables per LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022.
2. Install the 4 cleaned and baked #10-32 set screws or spring plungers in the threaded holes that will hold the sensor/actuator assemblies in place until they are flush with the inside diameter of the sensor/actuator assembly mounting hole in the sensor/actuator plate. Solder the cables to the wires coming out of the pins on the pin plates. Deflux the solder joints.Mount the sensor/actuator assemblies in the proper configuration, making sure that the optic/dummy mass is fully clamped. Slowly, slide the sensor/actuator assemblies into the holes in the plate until about 2mm of sensor/actuator assembly protrudes beyond the back of the sensor/actuator plates.
3. Using an oscilloscope, optimally position the sensor/actuator assemblies with respect to the magnet/standoff assemblies on the optic. This is done by measuring the voltage of the unblocked photodiode and then positioning the sensor/actuator head such that the magnet shadows the photodiode and produces half of the unblocked voltage. Use the set screws to clamp the sensor/actuator assemblies in their optimum positions. **Always check the position of the safety stops as a gap of 1mm must be maintained to protect the magnet/standoff assemblies during this procedure**.
4. Check the calculated vertical resonance for the wire. The orientation of the LED/photodiode pair in each sensor/actuator head affects the magnitude of this resonance's coupling into the pitch and yaw resonant frequencies. While moving the sensor/actuator head assemblies near the magnets on the optic, check the ori-

entation of the sensor/actuator head assemblies. Generally, the optimum position is near to vertical, in that the photodiode is directly over the LED in a vertical orientation. If the oscilliscope shows a sharp spike around the calculated vertical resonance, slowly rotate the head assembly until the spike is at a minimum. Generally this is within 20 degrees of the vertical.

5. Check that the sensor/actuator assemblies damp properly and that critical damping may be achieved.

LARGE OPTICS SUSPENSION SPECIFICATION

APPENDIX 1

- **C.P. Stat Plastic Film for wrapping and bagging**

C.P. Stat 100 ESD sheeting,
1 roll 48" wide by 1000 ft. long,
with CFC certification that it passes
JPL's specifications.

Caltex Plastics, Inc.
P.O. Box 58546
2380 E. 51st St.
Los Angeles, CA 90058
213-583-4140

- **Inpro-Clean 1300 for cleaning stainless steel**

Oakite Products, Inc.
Berkeley Heights, NJ
800-899-8074

- **Mirachem 500 for cleaning stainless steel**

The MIRACHEM Corporation
2113 East Fifth Street
Tempe AZ 85281-3034
800-662-0333

- **Nitrile Gloves for handling hardware**

Ansell Edmont Industrial, Inc.
Coshocton, OH 43812
614-622-4311

- **Vidaro gloves for use with solvent cleaning**

part nos. 2-MY-31K4-2 or 2-WY-31K4-2
Vidaro Corporation
Kent OH 44240
330-673-0228

- **Allowable Cutting Fluids**

The following list shows all the approved products for use in machining of Ultra-High Vacuum components. Vendor should check with contractor prior to deviating from the cutting fluid recommended on the face of the drawing.

Aqua Syn 55	Cimcool 5 Star 40	Cimperial #1011
Cutzol EDM 220-30	Dip Kool 868	Dip KUT 819H
Haloform CW-40	Kool Mist #88	No Sul #6871

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Rapid Tap	RD2-195	Pearl Kerosene by Chevron Chem Co.
Relton A-9	Rust-Lick G-25-J	Sunnen MAN-852 Honing Oil
Tap Magic	Tapmatic #1	Tapmatic #2
Tool Saver by Do All Corp.	Trim Tap	Vytron Concentrate
Wheelmate #203		

LARGE OPTICS SUSPENSION SPECIFICATION

TITLE

LARGE OPTICS SUSPENSION SPECIFICATION