LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY (LIGO)

CALIFORNIA INSTITUTE OF TECHNOLOGY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Specification	**LIGO-E960022-v25**	**03 July 2112**

LIGO Clean and Bake Methods and Procedures

LIGO Systems Engineering

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This is an internal working note

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CHANGE RECORD

Revision	*Date*	*Authority*	*Description*
A	28 Jan 2000	Initial Release	Initial Release
B/v1	13 Mar 2003	DCN E030125	
C/v2	21 May 2004	Limited distribution	• integrate cleaning/air bake/FTIR sampling and evaluation used on large parts • add a qualified increase in the bake temperatures for 6061-T6 aluminum • define safe procedure for use of methanol in ultrasonic cleaning • define safe procedures for gross cleaning with acid, trichloroethane and acetone. • switch from a callout of “Ameristat poly sheet”, an obsolete term, to a generic description of an acceptable bag material
D/v2	Oct 2007	Limited distribution	• added cleaning procedures based on discussions and advice received while cleaning parts for the AdLIGO BSC prototype at LASTI • added bake time and temp for Indium & picomotors
v3	21 Jul 2009	see DCC record	• added responsibilities section which defines the roles of the VRB, VRT, cognizant engineer, etc. • dropped reference to provisionally approved materials • defined two separate FTIR sampling methods (alcohol rinsate and Freon swiping) • explicitly added a “gross” cleaning step (only obliquely mentioned in previous versions), derived from LIGO-E048225-v1 • added spray and parts cabinet washer procedures • separated wet cleaning from baking instructions
V4		see DCC record	• reorganized Section 10 as site technicians were having trouble navigating
v5	Feb 2010	see DCC record	• Section 10 Added ICS wherever PT was called out • Removed Equipment operations Section 10.6.1.3 as this info is in SOPs, listed in Reference Document Table • Elaborated on large washing equipment instructions, ref. SOPs • Removed 2 person requirement from Precision Cleaning steps • Removed Parts Cleaning Request Contam Control Doc specifies how to request cleaning/baking • Removed Vacuum Baking Procedure Form – LHO vacuum team reported that form was out dated and never used.

CHANGE RECORD

Revision	*Date*	*Authority*	*Description*
V6	26 Feb 2010	see DCC record	• Clarification to the cleaning solution dilution ratios in Table 2
V7	29 Mar 2010	See DCC record	• Clarified that section B.4, "Sensor/Actuator "Pigtail" Cables, applies to OSEM, A-OSEM and B-OSEM cables only
V8	5 May 2010	See DCC record	• Many component additions. More clarifications.
V9	Nov 2010	See DCC record	• Clarification in Sect 10. • Added Masterbond EP30 Section • Corrected numbering scheme at end of Section 12
V10	Dec 2010	See DCC record	• Added section for Glass processing • Updated AOSEM bake duration from 48 hours to 96 hours. • Added statement in large 0-ring step to vacuum bake after processing per E960159.
V11	29 Mar 2011	See DCC record	• Added Electro-polish section • Added Sapphire Prisms section
V12	29 Mar 2011	See DCC record	• Clarified bake procedures for fluoroelastomers (Viton™ and Fluorel™) in section 12.15 • Clarified free fluorine extraction process" for fluoroelastomers (Viton™ and Fluorel™) in section 12.15
V13	30 Mar 2011	See DCC record	Section 12.15: • Noted that the free fluorine extraction process (aka "Walker" process) is not needed for large vacuum equipment o-rings • Noted that small loads of fluoroelastomer can go directly from the free fluorine extraction process into a VBO • Defined the temperature of the Liquinox cleaning step for the free fluorine extraction process • Clarified the vacuum baking options
V14	22 May 2011	See DCC record	• Added section on granite processing as per email instructions Coyne May 22, 2011. • Added notes on magnet handling. • Added section on EP30-2 gluing on Glass Masses.
V15	28 Jun 2011	See DCC record	• Added a section 7.1 defining Class A and B (consistent with E0900047), and noting that section 11 has instructions for cleaning class B parts • Moved the section on granite to be under the Class B cleaning instructions in section 11 (not within the class A instructions) • Added instructions for Class B cleaning of Nylon and Delrin

CHANGE RECORD

Revision	*Date*	*Authority*	*Description*
v16	11 Jul 2011	See DCC record	• Added cleaning instructions for Filter Glass in section 12.17.3
v17	25 Aug 2011	See DCC record	• Added section on NOT cleaning or baking hygroscopic crystalline optics such as DKDP or RTP (language similar to v2) • Made clarifications in the section on Vac-Seal
v18	26 Aug 2011	See DCC record	• Added general stipulations in section 12.2 such as for design applications where dimensional control is extremely important or tolerances are exceedingly tight, it is the responsibility of the design engineer to (a) establish a basis for baking parts at temperatures lower than the default temperatures recommended herein, and (b) get a waiver for a lower temperature bake from the LIGO Vacuum Review Board. • Corrected indium entry • Combined copper and copper alloys (such as aluminum bronze, phosphor bronze and beryllium copper) into a single section
v19	24 Sep 2011	See DCC record	• Added section regarding Class B cleaning and baking of Viton
v20	19 Oct 2011	See DCC record	• Changed section 12.27.8 to show updated cleaning procedure for viewports
V21		See DCC record	• Changed Section 12.27.8 (again) to show updated viewport cleaning procedures • Clarified and updated section regarding electrical feedthroughs
V22	26 March 2012	See DCC record	• Clarified responsibilities of cognizant engineer and VRB • Added section about DI water and inspection of DI water systems that supply Clean and Bake facilities • Augmented fluoroelastomers section with reminder to maximize surface exposure and minimize surface contact during baking and made it explicit that CIT is the default site for baking ALIGO Viton, etc. • Clarified OSEM cables and sensor probe sections • Removed note about not using water on electro-polished parts • Clarified labeling section to mention ICS generated labels • Added explicit note about oven ramp up and cool down times for feed-throughs • Updated optics cleaning and baking section to indicate VRB acceptance of “no bake” proposal

CHANGE RECORD

Revision	*Date*	*Authority*	*Description*
			• Added section about Clean and Bake requests including link to CNB Ticketing System • Clarified cleaning process for Macor • Added process for cleaning Optics Lens Caps • Added link to CNB of Siskiyou Mirror Mounts • Added Zerodur and Invar clean and bake instructions • Stuff that still needs to be done: clean and bake of anodized Al, clarification of CNB of taps, CNB of PEEK cable clamps, etc.
v23	13 Apr 2012	see DCC record	• Viewports section updated to reflect the following: -Commercial viewports being solvent cleaned (isopropanol followed by methanol if required) rather than Liquinox-ed and -Custom viewport glass being cleaned according to Freon Wipe Procedure (E1200266), which states that no FTIR is required. • Link to M1200015 (LIGO Lab Disposal of Solvent Contaminated Materials) added to Solvent Cleaning section
v24	27 Jun 2012	see DCC record	• Clarified rules regarding mixed material bake loads (section 13.2)
V25	03 Jul 2012	See DCC record	• Split Vacuum Compatibility and Qualification Procedures from Clean and Bake Methods as the document was getting cumbersome. E960022 will remain the Clean and Bake reference and VE Qual will become a different document shortly. • The body of E960022 now contains general information regarding clean and bake procedures and the appendices contain information regarding specific materials and assemblies. As new procedures for specific materials/components are developed, they will be added to the appropriate appendix rather than the body of the document. • Appendix 1: Acronyms and Definitions • Appendix 2: Links to Related Documents (Incomplete at this point but should be completed soon.) • Appendix 3: Class B • Appendix 4: Class A Materials • Appendix 5: Class A Assemblies

Contents

Section 1.0: Background and Scope

The goal of this document is to provide approved processes for cleaning and baking parts that will reside within the ultra-high vacuum (UHV) systems of LIGO interferometers. (This document is not intended to provide guidance for passivation or phosphate-based acid cleaning of austenitic stainless steels.) Following these procedures provides reasonable assurance against the inadvertent introduction into the LIGO vacuum envelope of material which could contaminate optics and/or produce excess phase noise by forward scattering. Table 1 outlines the integrated processes required to minimize possible contamination of the UHV systems and optics. It is intended that the total optical contamination produced by detector components placed into the LIGO vacuum envelope shall be limited to < 0.5 ppm/yr/optic absorption and < 10 ppm/yr/ optic scatter.

All materials/parts (commercial and custom designed) must undergo vacuum out-gassing and contamination evaluation to ensure compatibility with operation in high-power laser cavities within UHV systems. Please see LIGO Vacuum Compatibility and Qualification (LIGO XXXXXX) for additional details.

The cleaning procedures identified herein were developed to accomplish the cleaning of hardware as defined in the Appendix of MIL-STD-1246 with an emphasis on using low-hazard (biodegradable) critical cleaning detergents.

All items to be installed inside LIGO vacuum equipment or onto beam tube pump ports shall conform to this policy for preparation, handling, cleaning, baking, and storage prior to assembly and during assembly. These items are considered Class A hardware. (For definition of Class A hardware, see Glossary.) Cleaning, baking, storage and handling of LIGO components shall be performed in accordance with recognized and accepted cleaning practices. Some of these cleaning procedures are generic: for example, T6061 Aluminum and stainless steel are very commonly used materials for LIGO parts. Other procedures have been developed to handle specialized or oversized components that could otherwise not be cleaned. Generally, baking will be carried out at the maximum temperature permissible for a given material: however, there are many special cases.

Section 2.0: Approved Materials

LIGO maintains an updated list of materials considered safe to use in LIGO vacuum systems. This approved list is LIGO-E960050. New material must go through the prescribed screening process before it may be added to this list.

In cases where any of the cleaning procedures cannot be followed due to considerations such as material durability or sensitivity to elevated temperatures, a waiver shall be completed and submitted to the Vacuum Review Board for consideration and approval. The waiver shall be accompanied by an alternative preparation procedure which has been demonstrated to achieve the desired cleaning effects.

Section 3.0: LIGO Roles and Responsibilities

3.1: Vacuum Review Board (VRB)

The Vacuum Review Board (VRB) makes recommendations on policy affecting the LIGO UHV system. When new materials or processes are contemplated, they shall be submitted to the VRB for review and acceptance. VRB members are selected by the Systems Engineering and the Detector Systems group management.

The VRB will recommend the disposition of issues where policy and schedule are in conflict. The VRB members are listed on the (secure) VRB wiki page.

3.2 : Vacuum Review Team (VRT)

The test data (either RGA scans or FTIR results) which is used to verify that a Class A part is acceptable for LIGO UHV use must be reviewed and approved by a Vacuum Review Team (VRT) member. The VRT is comprised of at least one member from each of the LIGO Laboratory sites at which UHV preparation work is performed. The intent is that the local VRT member serves principally to review and approve the Class A parts prepared at their local site. The other VRT members may be called upon to review and approve another site's Class A parts if the local representative is absent. If the verification test data is difficult to interpret or in some way questionable, or if a waiver on process or acceptance criteria is wanted (for example for expedience of schedule), then the VRT must refer the matter to the VRB.

The RGA scan or FTIR results should be attached to the appropriate bake load in ICS.

The VRT members are listed on the (secure) VRB wiki page.

3.3: Cognizant Engineer (CE)

It is the responsibility of the Cognizant Engineer for a subsystem or assembly intended for UHV service, to make certain that:

- only approved materials are used. Please see E12XXXX, LIGO Vacuum Compatibility and Qualification for details. (Calum's engineering spec??)
- only approved cleaning processes are used by contractors performing UHV cleaning services. Please see E12XXXX, LIGO Vacuum Compatibility and Qualification for details.
- A procedure to clean and bake any new materials or unique combinations of approved materials has been approved by the Chief Engineer **prior** to submitting a Clean and Bake Request.

3.4: System Engineer (SE)

It is the responsibility of the System Engineer to review/approve cleaning and baking procedures for new materials.

3.5: Clean and Bake Coordinator (CBC)

It is the responsibility of the Clean and Bake Coordinator to work with CEs/vendors to develop cleaning and baking methods for new materials or unique combinations of approved materials, assign parts to the Clean and Bake queue according to LIGO vacuum-bake and air-bake ovens availability and schedule priority, prioritize the FTIR queue, and to maintain this document. All Clean and Bake Requests should be submitted through the CNB Ticketing System.

3.6: Vacuum Prep Team (VPT)

Only individuals who have been trained on the procedures defined in this document and have been approved to use the equipment and chemicals associated with the procedures may carry out the preparation of LIGO parts for UHV service. In general, this work is performed by a small team (Vacuum Prep Team-VPT) of individuals at each LIGO site. Untrained or unqualified staff should not presume to enter Vacuum Prep cleanrooms, operate cleaning equipment or handle clean parts.

Section 4.0: Cleaning and Preparation of Materials

4.1: By LIGO VPT

All materials/parts (both commercial and LIGO-produced) must be scrutinized for vacuum cleanliness/compatibility before being accepted for utilization with the LIGO vacuum system. LIGO shall clean all components intended for UHV service in accordance with the procedures referenced or defined within this document. Cleaning procedures shall be defined for all materials on the LIGO approved materials list. These procedures are listed in Appendices 3, 4 & 5 and will be updated as new materials or cleaning procedures are approved.

Tables and work areas for cleaning, packing/unpacking, assembly, alignment and testing of cleaned parts are to be made of stainless steel that is cleaned daily. (Procedure for cleaning outlined in E0900047.) If a stainless table is not available, then a Class sacrificial B plate may be substituted. If (and only if) a Class B sacrificial plate is not available, other surfaces may be lined or covered with fresh contamination-free foil or Ameristat immediately before starting work. Ameristat shall not be used if a solvent incompatible with the film is involved in the assembly or cleaning process. Final assembly of any small subassembly or component intended for installation in LIGO shall be assembled under a Class 100 laminar flow bench. Assemblies too large for handling on laminar flow benches shall be unwrapped and assembled in soft-sided clean rooms.

CLASS A hardware is defined as any item that will be exposed to vacuum. Such hardware maybe temporarily or permanently mounted inside of, or on, the inner surfaces of the interferometer vacuum equipment. Materials for Class A components are strictly limited to those listed in E960050 and for the specific approved applications noted.

CLASS B hardware is defined as any item that will come into contact with CLASS A hardware or the interior surfaces of the interferometer vacuum equipment. Materials which comprise Class B components are less restricted, but should generally be from the materials listed in E960050 in order to minimize cross-contamination of the UHV system.

4.2: By Commercial Vendor

If a vendor is required to provide clean components, then the vendor shall use recognized UHV practices. The vendor shall submit to LIGO a description of the practices for prior approval by LIGO as part of the quote or proposal for the work in accordance with the procurement process, if we have the time for LIGO Lab to qualify the contractor's proposed process. Otherwise, the contractor shall use one of the processes already approved by the LIGO Laboratory.

For commercially produced components with potentially many materials used in the construction, a detailed accounting of all materials and the amounts used shall be submitted for review. It may be necessary to require certifications (per article or serial number) for the materials employed in their manufacture, so that material substitutions by the manufacturer are visible to LIGO. The vendor shall notify LIGO of any material substitutions which occur after the agreed-upon list of materials has been determined. LIGO QA shall have oversight to ensure such notification is obtained. Where practicable, a first article screening using an RGA scan and out-gassing measurement shall be performed by LIGO prior to receiving shipment of all other components.

4.3: By Collaboration between LIGO VPT and Commercial Vendor

There are a number of components that are assembled clean by vendors: for instance, SEI actuators and mirror mounts. In this case, close cooperation between the cognizant/responsible engineer, the Clean and Bake Coordinator and the vendor is required. Generally, the vendor sends basic components to LIGO for Class B cleaning, then LIGO returns the cleaned parts to the vendor for either partial or complete clean assembly, and finally, the vendor sends the assemblies to LIGO for a Class A vacuum-bake. Refer to E1200245, Siskiyou Mirror Mounts, for a more detailed explanation of this process.

Section 5.0: Clean and Bake Requests

During iLIGO, clean and bake requests were dealt with using a “traveler system” and during eLIGO, most clean and bake requests were sent via email to a site clean and bake coordinator. aLIGO demanded a more structured and transparent system due to the complexities of coordinating Clean and Bake (CNB) activities at three sites: CIT, LHO, and LLO. A web-based CNB Ticketing System was developed and is the primary method for submitting any CNB Request. If you have any questions or need help filling out the on-line form, please contact your local site CNB person, Jodi Fauver, Calum Torrie, or Jonathan Hanks.

Table 1: Integrated Cleanliness Processes for LIGO Parts

Design and Fabrication: LIGO Document XXXXX
Must use Approved Materials and Processes or get permission from the System Engineer (SE)

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Shipping and Handling: LIGO Document XXXXX
Must use Approved Materials and Processes or get permission from the Quality Assurance (QA)

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Pre-Cleaning Storage: LIGO Document XXXXX
Store parts destined to be Class A or Class B inside temperature-controlled space

↓

Inventory Control System (ICS) Data: Entered by Cognizant Engineer (CE) or designee
Parts must be in ICS to generate Clean and Bake request

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Clean and Bake Request through Ticketing System: Submitted by CE or designee
Must have Approved Clean and Bake Process
If not, consult System Engineer (SE) or Clean and Bake Coordinator (CBC)

↓

Cleaning @ CIT, LHO, LLO: Assigned by CBC or designee and recorded in ICS
Must used Approved Materials and Processes
Gross Cleaning (if required) → **Precision Cleaning** (All Class A and Class B parts)

↓

Baking @ CIT, LHO, LLO: Assigned by CBC or designee and recorded in ICS
Must use Approved Equipment and Processes
Class B = Air Bake **Class A** = Air Bake or Vacuum Bake

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Testing/QA: Performed VPT, approved by VRT, and recorded in ICS
Must use Approved Materials and Processes
Class A Air Bake = FTIR **Class A Vacuum Bake** = RGA

↓

Wrap-Bag-Tag: Requested by CE or designee
Must use Approved Materials and Processes

↓

Post-Cleaning Storage or Assembly: Requested by CE and recorded in ICS
Must use Approved Materials and Processes

Section 6.0: Safety Related Issues:

Although much effort has been taken to the hazard of cleaning parts, the techniques and materials described herein have health, safety and environmental impacts. Consult the appropriate Material Safety Data Sheets (MSDS) of the products to be used before performing any process specified herein. MSDS are on file in each building at the sites where detergents and solvents will be used. Good industrial hygiene and safety practices shall be employed at all times. At a minimum, the use of the following personal safety equipment is recommended during all cleaning activities: gloves, safety glasses and an apron.

When dealing with hazardous chemicals/solvents, it is critical to minimize worker exposure. Therefore, workers shall wear the following: splash goggles, aprons, and additional layers of gloves. Care should be taken during solvent transport: each LIGO VPT has been provided with solvent transport devices to minimize the risk of bottle breakage. Solvents shall be dispensed into Right-to-Know (RTK) dispensing bottles. Workers shall dispose of solvent contaminated materials in specified waste cans as outlined in M1200015.

Become familiar with the SOPs for the Large Parts Washer (LPW), and the ultrasonic cleaners used to process Class A and Class B parts. The SOPs contain instructions for necessary cycling of the wash and rinse baths which happen regularly, as well as maintenance and parameter settings of the equipment.

Section 7.0: Cleaning Related Issues:

7.1: Background

Ideally, all parts received by LIGO from its contractors/fabricators are quite clean, i.e. free of scales, welding slag, particulates, greases, oils, minerals, etc. The parts must be inspected by the VPT to determine what level of cleaning is required. In most cases, LIGO's contracts have some level of cleanliness or cleaning defined, though usually not to the level of UHV readiness. Even if a shipment of parts is supposed to be quite clean, all of the parts must be examined as a quality assurance (QA) check and to insure that contamination has not occurred during shipment.

In some cases, preliminary cleaning is required in order to remove "gross" contamination. Gross contamination includes weld slag, scale or oxidation (perhaps due to heat treatment or on an as-received, non-machined surface), soil or grease/oils, inks, etc. The surface cleanliness/condition of the received parts should be cited in ICS and brought to the attention of the CE for the parts. If it is determined that the parts will not be sent back to the manufacturer, then the VPT must perform appropriate gross cleaning processes to remove the contamination before beginning the "precision" cleaning processes. See Table 2 in Section xxx below, for a list of gross cleaning processes applicable to various materials. Precision Cleaning shall always be performed after Gross Cleaning for Class A and Class B parts.

7.2: General Cleaning Expectations

VPT members participating in any clean and bake activities are expected to conform to the following standards:

- Handle each part or assembly with appropriate care and clean gloves;
- Those washing parts shall use the cleaning materials specified in Table 4, shall garb appropriately (bouffant cap, mask, frock, shoe covers and at least one set of cleanroom gloves) and shall not let any surface dry between start of washing and end of final rinse;
- Those handling cleaned parts shall garb appropriately (bouffant cap, mask, frock, shoe covers and at least one set of cleanroom gloves); and
- Those using equipment (HULK, LPW, LABO, G-M Oven, etc.) shall be familiar with the appropriate SOP before operating equipment.

VPT members should prepare fresh cleaning solutions per the recommended solution dilution stated on the bottle. Table 2 is a summary of the recommended cleaning solution parameters from Alconox, the vendor who supplies many of the LIGO approved cleaning chemicals. Cleaning solutions prepared for manual and ultrasonic processes should be discarded after a few loads or when the solution appears dirty. In some cases, the solution may need to be switched after every load but it is a judgment call by the VPT. Solution life extension maybe accomplished as directed by the manufacturer, as required.

Table 2: Cleaning Solution Parameters

(Note that not all detergents are compatible with all cleaning equipment, so follow the table carefully.)

Product	Equipment	Dilution	Amount	Wash Temperature	Manual Precautions		
	Compatibility	%	Oz/Gal	Degrees F	Hand	Eye	Clothing
Citranox®	Ultrasonic/manual	1 to 2	1 – 3 Oz : 1 Gal	140	Yes	Yes	Yes
Citrajet®	LPW	1 to 2	1 – 3 Oz : 1 Gal	140	Yes	Yes	Yes
Alconox	Ultrasonic/manual	1	1 – 2 Oz : 1 Gal	Warm	Yes	Yes	No
Alcojet	LPW	1	1 – 2 Oz : 1 Gal	Hot	Yes	Yes	No
Liquinox®	Ultrasonic/manual	1	1 – 2 Oz : 1 Gal	Hot	Yes	Yes	No

7.3: Gross Cleaning

7.3.1: General Information

Unless otherwise specified, Gross Cleaning shall be performed in a facility (building or room) that is isolated from general shop practices (e.g. machine operations, welding or aerosol

applications). Some gross spot cleaning is permitted in the clean areas of the clean and bake facilities: consult with the VPT leader. Isolation should also include separate air handlers to minimize re-contamination. When an isolated facility is not available, suitable isolation may be accomplished using a soft-wall cleanroom or a flow bench.

The following supplies are required to support the procedures specified herein. All equipment used to perform the cleaning procedures identified herein shall be pre-cleaned using the cleaning materials and procedures identified below. A list of vendor information regarding these and additional handling supplies can be found in the Contamination Control Plan E0900047.

1. Stainless Steel Tanks, Containers and/or Pails
2. Stainless Steel Brushes with ABS[1] handles
    - Scouring Brushes
    - Finishing Brushes (for soft metals)
    - Tube Cleaning Brushes (for holes)
3. Stainless Steel Metal Wool or Gauze
4. ConTec PNHS Clean Room Wipes
5. Right-to-Know Solvent Dispenser Bottles
6. Solvents and detergents specified in Section xx

Note that if a brush or stainless steel wool has been used for a specific material (for example: aluminum) then it should NOT be used for other types of materials (for example: copper).

If any special tools or fixtures are required for the cleaning processes, they shall be designated and approved by the CE.

All parts subjected to Gross Cleaning shall be free from all visible tape, inks, and other residues not identified in the engineering drawing. All residues shall be removed using a solvent and a low-lint wipe such as ConTec PNHS-99. LIGO approved solvents are isopropanol, methanol, and acetone.

Separate parts in groups according to material and then by the extent of contamination. For example, sort all aluminum parts from stainless steel parts. Then, determine which aluminum parts need heavy, medium, light, or no gross cleaning. Gross clean each subset of aluminum parts appropriately and then work on gross cleaning the stainless steel parts.

The recommended gross cleaning processes for selected materials and surface conditions are identified in Table xx. Cleaning processes will normally be accomplished in order from left to

right depending on the level of cleaning required for the parts, starting from an appropriate step as determined by the VPT. For example, if the part does not have heavy scale (usually true for LIGO parts) or welding slag, then the Mechanical Cleaning process can be skipped. However, if the part appears to have an oil film then the Solvent Cleaning step should be undertaken.

Chemical cleaning agents must be compatible to prevent excessive material attack or latent degradation. Check material compatibility before proceeding with cleaning procedures. Consult with the cognizant and/or system engineer.

Parts that have been gross cleaned and dried shall be identified and stored appropriately.

Table 3 outlines the Suggested Gross Cleaning Steps and should be used to guide VPT members through Gross Cleaning. Use the Table by starting at an appropriate level and then moving on the next step if required. For instance, start at Step A if a particular part needs Aggressive Mechanical Cleaning.

7.3.2: After Gross Cleaning: Rinsing and Drying Parts

Tap water rinsing is used to remove residual material left by any of the gross cleaning processes. (*Note-While tap water is appropriate for rinsing during gross cleaning processes, it IS NOT acceptable for rinsing during or after precision cleaning.) Subject parts to an initial running water rinse with ambient or warm (120F) tap water. The rinse water should contact all surfaces and hole details for a minimum of 20 seconds on each surface. Where a running water rinse is not practical, a series of three (3) or more agitated soak/rinse tanks or at least two (2) counter-flow cascade rinse tanks is required. Immediately dry parts per section XXX or proceed to subsequent operations.

The drying process after gross cleaning is used to minimize the impurities from rinse water that can be deposited on the part during evaporation. Physically remove rinse water from all surfaces using cleanroom wipes and/or clean nitrogen gas.

7.3.3: Description of Approved Gross Cleaning Processes

7.3.3.1: Acidic Cleaning

This process uses acidic cleaning agents to remove inorganic contamination, trace metal and oxide such as scale, calcium and magnesium salt and where general metal brightening is required. Ideally, this is accomplished with a phosphate-free acid. However, a mild phosphoric acid may be used on aluminum parts. Acidic cleaners will cause eye and skin burns if operators do not take appropriate precautions; therefore, eye and hand protection are mandatory.

Acidic cleaning is effective when the part is submerged in the appropriate solution; therefore, manual scrubbing, wiping, soaking or ultrasonic cleaning would work. Use the

appropriate acidic cleaner listed in Table XXX, given the material being cleaned and the application used. 10 minute soaks or cycles should be sufficient.

7.3.3.2: Aggressive Mechanical Cleaning

This process is used to remove scale and heavy oxide by abrasive action and should only be used when physical damage to the items being cleaned is not a concern. During the mechanical cleaning process, ensure that the resulting surfaces are smooth and meet workmanship requirements.

Remove all weld splatters, slag, scale, discoloration, and carbonization using mechanical cleaning methods (such as scrubbing with metal brushes, stainless steel wool, etc.) and a DI water/detergent solution and/or solvents. Tools used for mechanical cleaning shall be clean and previously used only on the same material.

7.3.3.3: Detergent Pre-Cleaning

This process is used for the removal of organic contamination such as oil, fat, shop soil and grease. Using a standard Citranox solution, run the parts in a designated dirty ultrasonic cleaner (3 minutes for Aluminum, 10 minutes for stainless steel) for one cycle. Increase Citranox concentration if needed and run another cycle. Repeat as needed until parts are visually clean then rinse parts thoroughly.

7.3.3.4: Solvent Cleaning

This process uses acetone, methanol, and/or isopropanol to remove organic contamination such as oil, grease, hydrocarbon fuel and ink. Proper precautions should be taken when using and disposing of solvents or solvent contaminated materials. Please see LIGO-M1200015 for details.

Solvent cleaning shall be performed using controlled application methods (e.g., saturated ConTec wipes or swabs) and prioritizing on threads and holes while finishing with the main surfaces. Technical wipes and swabs will be discarded when there is visible evidence of contamination.

7.3.3.5: Steam Cleaning

A high pressure, high temperature steam clean process is used to remove loose debris and contaminants from the surface. Follow the instructions that come with the steam cleaner.

Table 4: Gross Cleaning

*Note: **Personal Protective Equipment (PPE)**: Hand=H, Eye=E, Clothing=C

** Solvent degrease does not require tap water rinse or drying step

Material	Surface Condition	A. Aggressive Mechanical Clean (detergents + steel wool, brushes)	B. **Solvent degrease Meth/Acet PPE Required*		C. Acidic Cleaning (acidic solution + ultrasonic cleaning) PPE Required*	D. Detergent Pre-Cleaning (Liquinox + ultrasonic cleaning)	Tap Water Rinse	Drying
Aluminum	Machined		X	X	Citrajet, Citranox, Protex	X	X	X
	Rolled		X	X	Citrajet, Citranox, Protex	X	X	X
	Weld Scale, Corrosion, or Oxidation	X	X	X	Citrajet, Citranox, Protex	X	X	X
Brass Copper Phosphor-Bronze	Machined		X	X		X	X	X
	Corrosion or Oxidation		X	X	Citrajet, Citranox, Protex	X	X	X
Stainless Steel	Machined		X	X		X	X	X
	Weld Scale, Corrosion, or Oxidation	X	X	X	Citrajet, Citranox, Protex	X	X	X
	Electro-Polished		X	X		X	X	X
Maraging Steel	Machined, Rolled		X	X				
	Corrosion or Heat Oxidation		X	X	Citrajet, Citranox, Protex			
Polymers			X	X				

7.4: Precision Cleaning

7.4.1: General Information

Precision cleaning is to take place in a cleanroom facility with workers donning the appropriate garb. (See E0900047 for cleanroom areas, protocol set up at the sites and contamination control supplies that may be used in the following processes.)

The quality of the DI water used for precision cleaning and rinsing is very important in meeting the LIGO cleanliness requirement. A resistivity gauge should be part of the system and should be checked on a regular basis. (Ideally, DI water resistivity should be independently verified using a resistivity meter once a month.) All filters, hoses, and storage tanks that are part of the system supplying DI water for precision cleaning and rinsing should be inspected on a regular basis (every three to six months depending on the number of loads processed). Be aware of water spots on parts: they are the leading indicator that the system needs a clean-out.

Parts should be processed in manageable lots of identical materials (i.e., aluminum with aluminum).

The choice of approved cleaning processes (manual, ultrasonic, pressure washer or large parts cabinet washer) depends on the part size and on judgment from engineering and technical staff.

In some cases, a manual washing or ultrasonic wanding of suspect areas (e.g. blind holes, tapped holes, blackened/oxidized regions, etc.) will be required before automated washing.

Approved Class B Cleaning Processes for Specific Materials and Components may be found in Appendix 3.
Approved Class A Cleaning and Baking Processes for Specific Materials and Components may be found in Appendix 4.

7.4.2: After Precision Cleaning: Rinsing, Drying and Inspecting Parts

Parts can be rinsed by hand with DI water equipment or in the LPW. Appropriate rinse cycles are as follows:

- When lifting items out of the ultrasonic cleaner, use a DI water spray to rinse the parts (draining back into the ultrasonic) for a thorough rinse of 20 sec over the entire surface.
- Parts could be transferred to the sink for DI hand rinsing the surface for 20 seconds.

- After loading washed parts in the LPW, parts can be hand rinsed there utilizing the LPW rinse wand for 20 second surface treatment
- After loading the LPW, set the machine for a 10 minute rinse cycle (and 0 minute wash cycle).

The goal should be to have 3 of the above rinses, whether all the same type, or mixing types.

Drying after precision cleaning is used to minimize water induced corrosion and/or water borne impurities. Drying can be accomplished by blowing clean air over the component before allowing it to cool or exhausting/ venting the parts cabinet washer so that all surfaces dry before the part is cool. It is also acceptable to lay parts out on clean racks (ideally in a dedicated cleanroom or flowbench) to let the water evaporate. Complex parts may take several hours to dry, in which case, heat lamps may be used to speed up the process.

Parts should be dried as quickly as possible so that they can be stored. However, parts should be thoroughly dry before wrapping, or staining occurs.

Inspect components (or close up the vessel) as soon after drying as possible. (Inspection shall be done (before removing the piece from the washing cabinet) using a black light (such as Bayco UVR-9012B) on all interior surfaces or flange faces. No visible contaminant of any form shall be detected when viewed with the naked eye under both natural and ultraviolet light.??? Talk to Dennis about this!)

A visual inspection shall be made of exterior surfaces. The presence of any hydrocarbon or fingerprints or other contamination shall be cause for rejection. Parts found to be contaminated shall be re-cleaned.

7.4.3: Description of Approved Precision Cleaning Processes

7.4.3.1: CO2 Cleaning

In dry ice cleaning (or blasting), dry ice pellets are hurled at a surface to be cleaned at high speed. The pellets strip the surface of the contaminants, sublimate into the atmosphere, and leave behind no toxic gases. The only residual is the dirt or paint left behind for disposal.

CIT, LHO, and LLO have CO2 generators on portable carts for use in CO2 cleaning. Set up and compressor charging require significant lead time and any use should follow vendor instructions, the applicable SOP and LIGO-E990316.

7.4.3.2: Electropolishing

In electro polishing, an electric current is applied to metal surfaces using an electrolytic bath in a process that is the reverse of plating. The metal part becomes the anode in an

electric circuit. Because projections dissolve faster than flat surfaces and crevices, burrs and sharp edges are removed and the surface is left flat, smooth, and brilliant.

LIGO parts may be electropolished to remove contaminants such as abrasives, to passivate a surface, to deburr parts, and/or to achieve surface cleanliness that requires little or no preparation for subsequent treatment or use. Electropolishing also minimizes loss of high-temperature creep-rupture strength.

7.4.3.3: Large Parts Washer

When the Large Ultrasonic cleaner cannot be used, use the Large Parts Washer (LPW) wash cycles.

1. Setup the LPW with wash solution as per its SOP (M1000027).
2. When loading parts into the washer, make sure that they do not overlap, or rub against each other causing damage. Utilize SST parts baskets such that parts can be accessed easily. Basket lids and SST tie-down wire may be required to hold light weight parts in place during the cycle.
3. A typical wash cycle is 10 minutes. Actual durations will depend on the size and complexity of the parts. The parts may need to be rotated after the cycle and the cycle re-run such that all surfaces are exposed to the wash fluid. Consult with engineering staff.
4. Rinse and dry entire part as identified in the following sections.

7.4.3.4: Manual Cleaning

Manual cleaning is sometimes needed for objects which do not fit into the washing machines, etc. Manual cleaning shall be performed in accordance with the following procedure:

1. Prepare cleaning solution in a stainless steel container or tank.
2. Transfer prepared cleaning solution in a stainless tank or container (bucket).
3. Submerge the part or incremental sections until all surfaces have been exposed to cleaning solution.

a. Clean the entire part using soaked clean wipers/brushes, prioritizing on blind and through holes, while finishing with the main surfaces. Cleaning solution should not be allowed to dry on part during cleaning operations.

b. Rinse and dry entire part thoroughly as identified in the following sections.

7.4.3.5: Pressure Washer

Pressure washing is unlikely on-site but likely at an outside vendor and shall be performed in accordance with the following procedure:

1. Prepare cleaning solution in a stainless tank or container.

2. Transfer prepared solution into pressure washer.

   Clean entire part prioritizing on blind and through holes, while finishing with the main surfaces (changing nozzles as necessary to facilitate). Cleaning solution should not be allowed to dry on part during cleaning operations. Alternate between spray wash and spray rinse cycles as indicated in Table 3.

3. Perform a final DI rinse of the entire part as identified below.

Table 3: Pressure Wash and Rinse Guidelines

Component Area	Minimum Duration per Cycle (minutes)		Number of Wash/Rinse Cycles	Final DI Rinse Min. Dur. (minutes)
	Spray Wash	Spray Rinse		
Exterior Surfaces	3	3	3	5
Interior Cavity Surfaces	3	3	5	10
Through Holes	3	3	5	10
Blind Holes	3	3	10	20

7.4.3.6: Ultrasonic Cleaning

Ultrasonication is the preferred method of cleaning LIGO parts/assemblies prior to bake-out. Ultrasonic cleaning uses high frequency sound waves to agitate a liquid. The bubbles created by the agitation act on contaminants adhering to materials like metal, glass, Viton, and ceramics. The bubbles also penetrate holes, cracks, and recesses. The intention is to thoroughly remove all traces of contamination tightly adhering or embedded onto solid surfaces.

A liquid (DI water, acetone, isopropanol, metyhanol) is used in an ultrasonic tank. The choice of liquid depends on the type of contamination and the part/assembly being cleaned. Contaminants can include cutting fluid. Tapping fluid, dust, oil, rust, grease, polishing compounds, fingerprints, and mold release agents. Ultrasonic cleaning can be used for a wide range of part shapes, sizes and materials: It may not be necessary for an assembly to be taken apart prior to cleaning.

LIGO Clean and Bake facilities use various sizes of ultrasonic cleaners which are described below. Most parts are sonicated in a large (~110 gallon) tank, affectionately known as the HULK, using a DI water/Liquinox solution. However, smaller tanks (5.5 gallon, 2.5 gallon, 1.5 gallon) are also used especially for delicate parts or where solvents are the liquid of choice. In addition, an ultrasonic wand is used on small areas such as blind and tapped holes when needed. Which ultrasonic tank is most appropriate to use is a judgment call of the VPT but the output of transducers should be considered before a decision is made. Further information regarding ultrasonic tank vendors, etc. may be found in the Contamination Control document, E0900047.

Ultrasonic cleaning shall be performed in accordance with all vendor safety recommendations, , the appropriate SOP, and the following procedure.

1. Immerse parts: clean racks or baskets may be used to ease handling.
2. Set the ultrasonic cleaner for cycles according to the material you are cleaning. (Note that Aluminum discolors in the HULK when left in too long, hence the shorter duration.)

Stainless	Aluminum
10 minutes	10 minutes in small tanks 3 minutes max in HULK

3. Rinse and dry entire part as identified in section XXX.

7.4.3.7: Wipe Down

Wipe down is used when a part is so big and/or cumbersome that there is no other way to clean it. It may also be used if a part has already been through clean and bake but has been cleanly modified, dropped, or otherwise lightly contaminated. (However, this is not best practice and should be avoided if possible.) Wipe down is accomplished with solvents (usually acetone followed by isopropanol), swabbing holes first and then using a ConTec wipe on the surfaces. Wipe down should be unidirectional and have a starting point or landmark to confirm that the entire part has been cleaned.

Section 8.0: Baking Related Issues

8.1: Background

For a part/ assembly to be baked, it must have cleared numerous hurdles that are designed to protect the integrity of the LIGO Vacuum System and core optics. The part must be made from approved and certified materials (LIGO xxxxxx). The fabricator must contract to adhere to LIGO specifications for cleanliness during manufacture, storage and shipping (LIGO xxxxxx). The part/assembly must be "gross cleaned", if necessary, "precision cleaned", dried, and inspected according to the procedures outlined above. Next, the part/assembly must be baked to drive off any hydrocarbons or other undesirable substances. Any deviation from these procedures must be cleared with the VRT with an approved waiver and the waiver attached to the ICS Bake Load. Bake-out is the most stringent "gate-keeper" in the protective clean and bake system and acceptable cleanliness level is documented by testing: RGA for vacuum bakes (LIGOXXXXXX) and FTIR (LIGOXXXXXX) for air bakes. Vacuum baking is preferred since an RGA scan can provide a direct measure of outgassing from the parts. If the parts are too large to fit into a LIGO UHV oven, then the parts must be FTIR swiped and then air baked.

Stated more formally, RGA and FTIR QA screening provide the measurement of hydrocarbon outgassing of the subject components after appropriate vacuum preparation. The RGA levels for a pre-determined and specified group of species masses which represent hydrocarbon fragments is compared to those obtained in the material qualification step. Excess RGA levels indicate inadequate cleaning and preparation of the component under test. Reliance on RGA scans for screening is required to provide a faster process to accommodate fabrication schedules. The alternative method of screening parts too large for practical vacuum baking is the FTIR swipe of the components followed by an air bake. Samples must be taken prior to air bake due to sensitivity limitations of the FTIR analysis process. Swipe samples are sent to JPL for analysis and the results must meet the published acceptance criteria (LIGO xxxxxx) unless waived by the VRT. Any waiver must be documented and attached to the ICS Bake Load.

For design applications where dimensional control is extremely important or tolerances are exceedingly tight, it is the responsibility of the DESIGN ENGINEER to (a) establish a basis for baking parts at temperatures lower than the default temperatures recommended herein, and (b) get a waiver for a lower temperature bake from the LIGO Vacuum Review Board.

The baking procedures outlined below are consistent with:

1) Bake-out is at the maximum temperature possible for the material(s); and,
2) the achievement of the summed mass pressure limit.

8.2: Air Bake for Class B

Recall that Class B parts are NOT destined for UHV service, although they come in contact with parts that ARE destined for UHV service. That means that Class B parts need to be clean but not extremely clean and Class B bake-out reflects this difference. Class B parts follow the same

cleaning procedures and bake temperatures as Class A parts of the same materials but the bake is performed in an air bake oven and for about half the dwell time of a Class A bake. Bake time for Class B loads is 24 hours unless otherwise specified. Class B bakes may be done in either small or large ovens. There are several small (~2'x3') and one large (~10'x10') air bake ovens at each Observatory. VPT members should follow the appropriate SOP when using air bake ovens.

In general, VPT members should look at Appendices 4 and 5 for clean and bake guidance including bake temperature. However, Appendix 3 contains guidance for some materials/assemblies that do not have Class A instructions. For example, bronze is not a UHV approved material so it is not listed in Appendix 4 but since bronze can be used for tooling, guidance is provided in Appendix 3.

8.3: Air Bake for Class A

With large components, which it may not be feasible to bake under vacuum, an air bake will be considered acceptable providing cautions are taken to preclude contamination from the ambient air and cleanliness is documented by an acceptable FTIR result. Both LHO and LLO have large air bake ovens that are used for Class A bake-out of large seismic isolation plates, VE septa, suspension weldments, etc. These large ovens have specific SOPs that VPT members should be familiar with prior to use. Occasionally, LIGO may use an approved vendor oven for baking/oxidizing specialty components like baffles. In general, VPT members should look at Appendices 4 and 5 for clean and bake guidance including bake temperature.

8.4: Vacuum Bake for Class A

Vacuum baking is the default bake-out procedure for LIGO parts/assemblies and is the limiting factor in preparing parts for UHV service. Vacuum baking requires relatively long lead times and close coordination with the CBC to ensure timely availability of parts. The variables that contribute to long lead times are: research and development needs, VBO availability, load cycle length, material segregation, and documentation requirements.

All bakes shall be performed in LIGO-approved ovens; these may be located at vendors. The location, number, and size of LIGO VBOs is as follows: CIT-4 small ovens; LHO-1 small, 1 upright, 2 large ovens; LLO-1 upright, 2 large ovens; and MIT-0 ovens.

Vacuum bake loads generally consist of a single material (for example, stainless steel) but mixed bake loads are permitted as long as NO POLYMERS (for example, PEEK, Viton, Kapton) are in the mixed load. The reasoning is that we do not want to compromise the cleanliness of parts by baking at the lowest temperature defined for the materials in a mixed load. (Of course, it is never acceptable to bake a material at a temperature higher than its specified maximum temperature.) In addition, polymers generally outgas a lot of material which can "plate down" on the surfaces of non-polymer parts. Exceptions can be made (at the discretion of the installation leader, chief engineer or project management) for small and urgent loads. A mixed load's bake temperature should be determined by the material with the lowest temperature threshold.

Loading a VBO correctly is crucial to bake-out effectiveness. Parts should be as dry as possible before being loaded: this may require an air bake. Excess water or solvent will slow pump down and may damage the VBO. Ideally, bake loads should consist of a single material type to allow the highest bake temperature possible. However, mixed loads are permissible as long as appropriate dwell time and temperature requirements are met. VPT members should consult with a VRT member and document load specific instruction in the ICS notes. In addition, care should be taken to minimize contact between flat surfaces and maximize exposure of surface area to facilitate outgassing under heat and pressure. Clean wire, nuts, blocks, tooling and fixtures are useful in maintaining optimum contact/distance between parts during bake-out.

Please refer to Appendix 4 for clean and bake guidance regarding Class A Materials.

Please refer to Appendix 5 for clean and bake guidance regarding Class A Assemblies.

Section 9: Handling and Storage Related Issues

9.1: Background

Handling and storing cleaned and baked parts appropriately ensures that the high cleanliness level needed to maintain UHV-service compatibility is maintained. This is the final step in the clean and bake process. Handling baked parts requires appropriate garb (bouffant cap, mask, frock, shoe covers/dedicated cleanroom shoes, double gloves). Unless otherwise indicated, gloves are to be changed when proceeding to handle components at different stages of processing. Tools and fixtures which may contact cleaned parts in assembly or transport are to be cleaned and baked as Class B material: see section XXXX.

Tables and work areas for cleaning, packing/unpacking, assembly, alignment and testing of cleaned parts are to be lined or covered with fresh contamination-free foil or CPstat immediately before starting work. CPstat shall not be used if a solvent incompatible with the film is involved in the assembly or cleaning process. Final assembly of any small subassembly or component intended for installation in LIGO shall be assembled under a Class 100 laminar flow bench. Assemblies too large for handling on laminar flow benches shall be unwrapped and assembled in portable clean rooms assembled around open chambers.

9.2: Wrap-Bag-Tag

Processed parts shall be prepared for transport and storage using the following wrap-bag-tag procedure. Please refer to LIGO XXXXX for a list of approved supplies and LIGO XXXXXX for specific information on wrapping large items.

(a) Wrap large or awkward part(s) in clean C-3 fabric: door covers work well for this purpose. Class B stainless steel or glass containers are preferred for small parts. If the above options will not work, or two (2) layers of UHV quality aluminum foil may be used but foil is known to particulate once it is crumpled so its use should be minimized.

(b) Place part(s) into a zipper bag made of Class 100 clean, anti-static, poly sheeting. If the part(s) are too large or awkward for zipper bags, then wrap them in Class 100 clean, anti-static, poly sheeting.

(c) Compress the bag tightly around the part(s) to purge excess air and then zip the bag closed. If a zipper bag is not available, then fold down the top of the bag at least twice and then tape the folded top to the bag to provide a complete seal.

(d) Place the part(s) into a second anti-static polyethylene bag or second layer of sheeting, as specified above, remove excess air, and then zip or tape shut. Outer CPStat bags should NOT be in cleanrooms since they are dirty: they have touched lots of contaminated things and they have paper labels.

(e) A self-adhesive label must be used on the outer layer of all bagged components. The label must contain the following: (i) a warning stating: "UHV CLEAN PART -- HANDLE ONLY WITH PROPERLY GLOVED HANDS" and (ii) a part description/identification. Ideally, the standard labels generated by ICS for Bake loads should be used as they contain all required information.

All empty fields on the ID label shall be filled in with the relevant information; use “N/A” rather than leaving a field blank. ????

(f) Place the double bagged part(s) in an appropriate shipping /storage container, using care to not puncture or cut the bags. Seal the shipping container closed. Attach a label with the LIGO part number (drawing number(s), including revision letter) and serial number(s) to the outside of the container.

The shipping/storage containers must be such that they insure that the double bags do not get punctured and that the parts are properly supported during transit.

Appendix 1: Glossary nomenclature and acronyms

ABO	Air-Bake Oven
AMU	Atomic Mass Unit
Bake-out	The process of applying elevated temperature for an appropriate amount of time to drive off contaminants; used in combination with cleaning to prepare parts/assemblies for UHV service.
CBC	Clean and Bake Coordinator
CE	Cognizant Engineer
CIT	California Institute of Technology
Class A	Hardware (components, parts, assemblies, tooling, etc.) that is intended for UHV service
Class B	Hardware (tools, tooling, fixtures) which comes into contact with Class A objects
CO_2	Carbon Dioxide
CVP	Commercial Viewport: Off-the-shelf "window" that is assembled by the manufacturer
DI	De-ionized: most often used to describe the type of water used in cleaning LIGO parts
FTIR	Fourier Transform Infra-Red : Spectroscopic method for determining Hydrocarbon contamination levels, QA test for Class A parts that are air baked
HC	Hydrocarbons
HULK	Huge Ultrasonic Liquid "Kleaner", 110 gallon ultrasonic tank
HVP	High-quality Viewport: "window" that is assembled at LIGO
ICS	Inventory Control System
JPL	Jet Propulsion Laboratory: Analyzes FTIR samples
LHO	LIGO Hanford Observatory in Washington state
LLO	LIGO Livingston Observatory in Louisiana
LIGO	Laser Interferometer Gravitational Wave Observatory
MEC	Mechanical Cleaning
OFHC	Oxygen Free High-Conductivity Copper
NEO	Neodymium Iron Boron (A type of magnet)
PFA	Perfluoroalkoxy fluoropolymer (Du Pont)
PTFE	Polytetrafluorethylene (Du Pont)
PZT	Lead-Zircomate-Titanate

RGA	Residual Gas Analyzer: Small mass spectrometer designed for contamination monitoring in vacuum systems; attached to LIGO VBOs
SE	System Engineer
SEI	Seismic Isolation System
Sonication	The process of ultrasonic cleaning parts/assemblies prior to bake-out
SUS	Suspensions
TBD	To Be Determined
TBW	To Be Written
UHV	Ultra High Vacuum
VBO	Vacuum Bake Oven
VPT	Vacuum Prep Team
VRB	Vacuum Review Board
VRT	Vacuum Review Team

Appendix 2: Related Document Links

Document Title	*ID Number*
Project System Safety Plan (Advanced LIGO General Safety Plan)	LIGO-M950046
Project QA Plan (Advanced LIGO QA Plan)	LIGO-M970076
Vacuum Compatible Materials List	LIGO-E960050
Seismic Isolation System: Fabrication Process Specification (Advanced LIGO Version?)	LIGO-E970063
Specification for the LIGO Bake-out Ovens	LIGO-T980008
General Optics Cleaning Procedure	LIGO-E1100439
Cleaning Procedures for LIGO Commercial Optics (Other Than Core or IO Optics)	LIGO-E000007
Process Specification: CO_2 Cleaning Procedures	LIGO-E990316
Cleaning and Baking Viewports Latest documents	LIGO-E990190
Advanced LIGO Contamination Control Plan (supersedes LIGO Hanford Observatory Contamination Control Plan, LIGO-M990034)	LIGO-E0900047
Specification for Cleaning Procedure for LIGO Vacuum Equipment, Hanford & Livingston (PSI V049-2-015, Rev 2)	LIGO-E970004
RGA Test Qualification for the BSC Suspension Structures	LIGO-E080177
Astro Pak's Precision Cleaning Procedure	LIGO-C1102328
Standard Operating Procedure for Large Parts Washer	LIGO-M1000027
Standard Operating Procedure for Large Air Bake Oven	LIGO-M1000028
Standard Operating Procedure for Large Ultrasonic Parts Cleaner	LIGO-M1000029
SOP for Galli-Morelli Oven	
Disposal of Solvent-Contaminated Waste	M1200015

Appendix 3: Approved Class B Cleaning Procedures for Specific Materials and Components

The following sub-sections give Class B cleaning instructions for materials that are not permitted for Class A components, but may be used for Class B components, as long as shedding or abrasion of the Class B component is prevented.

Specific Materials

Brass

Use acetone with a ConTec PNHS-99 wipe and a stainless steel or brass bottle brush (for internal threads) or stainless steel wool over the threaded areas.

Ultrasonic clean in isopropanol for 10 minutes at room temperature in a fume hood.

Blow dry the parts with dry N2

Store in an appropriate Class B container or wrap in UHV aluminum foil

Do not use water or water-based cleaners since this will cause an oxide layer on the brass part.

DO NO BAKE brass since it may contaminate the oven (vacuum or air oven) with lead.

Delrin

Delrin® (acetyl homopolymer) is a registered trademark/material by DuPont. Delrin has excellent chemical resistance to isopropanol, methanol, acetone and soap solutions so both solvent and/or aqueous cleaning is acceptable.

The deflection temperature (1.80 MPa per the ISO 75-1/-2 test) for Delrin® is slightly, or somewhat, higher than 90C. One source cites a maximum, continuous service temperature of 85C. Consequently, air bake at 80C for 24 hr.

Granite

"Gross" (or initial) cleaning with either (1) manual or ultrasonic cleaning with Liquinox(R) or (2) manual cleaning with a granite or stone cleaner such as DuPont(TM) StoneTech(R) Professional Stone & Tile Cleaner, which is a dilute mixture of isopropyl alcohol & alcohol ethoxylate (<5%) and water (>90%). The alcohol ethoxylate is a surfactant. Only a cleaner should be used -- without any sealers or "protecting" agents (such as silicone). If one is unsure of the composition of the stone cleaner, then DO NOT USE IT. After cleaning, the stone should be thoroughly rinsed with water and allowed to dry.

"Precision" clean by wiping thoroughly with isopropyl alcohol. If the stone is small enough to be air baked (and not bonded to other materials), then bake at 200C for 12 hr. If this is impractical, then repeat the isopropyl alcohol wiping twice more.

Nylon

Nylon has excellent chemical resistance to isopropanol, methanol, acetone and soap solutions. Nylon does swell due to exposure to water but the diffusion time is much longer than the duration of the cleaning step and it is reversible by baking so both aqueous and/or solvent cleaning is acceptable.

Nylon has a maximum, continuous operation/service temperature ranging from 80 to 140 C, depending on grade or type. Consequently, air bake at 80C for 24 hr.

Viton

The Class B process may be used as long as the Viton will not be staying in the vacuum envelope AND will not come in direct contact with optics. In this case, optics are defined as glass that has been coated to reflect or absorb light.

1. Walkerizing is NOT required.
2. Clean Viton using standard Liquinox solution for 10 minutes in an ultrasonic cleaner.
3. Bake for 24 hours in 180 degree C air bake oven.

Specific Components

Solid Stack T1000057

1. Setup LPW with a 2% Citrajet (4 gallons Citrajet to 200 gallons DI water) at 120F.
2. Place Solid Stack parts on LPW basket so they are not overlapping or touching each other and cannot move during the wash cycle.
3. Run a 10-minute wash cycle with a 2-minute drain.
4. Run a 10-minute rinse cycle with a 2-minute drain, in DI water with a starting temperature of 120F.
5. After the rinse cycle (be sure to wait for the 2-minute drain cycle to end) give the parts a final wand rinse with clean DI water to remove any leftover soap film.
6. Dry parts by hand and place on LABO cart.
7. Cover parts with clean C-3 or foil until cart is ready to be placed into LABO for bake.

PETG Lens Caps T1200149

1. Initial Clean (with NO FTIR and NO BAKING)
    a. Large Parts Washer - Clean using Spray nozzle and rack from the Large Parts washer
    b. Water Jet - Use Water jet (1500 psi) working at 6ft away on the fine spray setting (i.e. not jet setting.) A dish rack (or equivalent) should be used to mount the lens caps during this step. Safety glasses should be worn when using the water jet. This step requires 2 people.
2. Ultrasonic - Ultrasonic cleaned in small ultrasonic cleaner using just DI water for a 15 minute cycle.
3. CO2 gun - Use CO2 (99.998% pure) gun in a clean-room environment. The gun should be operated at least 6'' away from the part. Both the front and the back should be sprayed down. The Lens Cap can be set on foil and held via the foil while spraying the gun. Safety glasses should be worn when using the snowgun. This step requires 2 people.
4. Place cleanroom wipe on surface that will contact optic then wrap-bag-tag as usual.
5. Re-clean (should be done prior to ANY use of lens cap on optic) Soak approved clean room wipes (ConTec PNHS or TX1010) with IPA and wipe down surfaces.

Appendix 4: Approved Class A Cleaning and Baking Processes for Specific Materials

Aluminum

Tempered aluminum is very sensitive to reheat; and can lose significant yield strength with excessive bake temperature or time. The following time and temperature cycles will keep strength losses to less than 5%:

- Type 6061-T6: Bake at 150 C° for 48 hours.
- All others: Bake at 120 C° for 48 hours.

Brass

DO NOT bake brass since it may contaminate the oven (vacuum or air oven) with lead. See notes in Appendix 3 when processing Brass.

Bronze

See Brass section above.

Ceramics (including Macor and Zerodur)

Lacking better information, clean with Liquinox in an ultrasonic cleaner (preferably a small one). Treat small parts very gently as they may be brittle or fragile. Bake at $200C^0$.

Copper and Copper Alloys

Acceptable copper alloys are listed in E960050 and T0900368. All materials must comply with the limits set on high vapor pressure elements defined in L080072 and must be wrought (not cast). Acceptable alloys can be found from the following material types:

- Copper (including OFHC)
- Beryllium copper
- Aluminum bronze
- Phosphor bronze

The cleaning procedure is as follows:

- Clean using a compatible procedure from section

Fluorelastomers (including Viton and Fluorel)

Note: The only fluoroelastomers approved for use in the LIGO UHV system are specific grades of Fluorel™ (3M product) and Viton™ (DuPont product), except for small o-rings - See E960050 for details.

Free fluorine extraction processing must be performed on all Fluorel and Viton parts which will be used inside LIGO vacuum (as part of a subassembly, for example) with the exception of the large o-rings used for sealing the vacuum vessels. This includes off-the-shelf commercial parts as well as custom procured molded parts. (Note: E960050 stipulates which Fluorel and Viton formulations are approved.)

To perform Fluorine extraction, follow the steps below (similar to the steps specified in the technical summary of processing detailed by Walker & Sons in L990205):

1) Ultrasonic or agitated clean in warm (about 120F) Liquinox solution for 10 minutes.
2) Rinse with DI water
3) Pressure cook in DI water at 15 psi for 2 hours (*Note-Be sure to place the parts on a shelf or rack within the pressure cooker and not on the bottom of the pressure cooker where the temperature can get much higher due to contact with the heated bottom.)
4) Repeat steps 2 and 3 four (4) times
5) Rinse in DI water 3 times
6) Dry in oven for 4 to 5 hours. (*Note-If the load is small it can go directly into a VBO. However if the load is large, it should be dried prior to going into the VBO or it may choke the turbo pump.)

If the above steps cannot be performed in-house, Walker & Sons Enterprises[1] can perform the work. Contamination control and handling specifications will need to be sent at the time of request for this work.

Glass (including Black Glass aka Welder's Glass, Filter Glass and Silica Carbide)

- Wipe edges with a methanol saturated ConTec wipe
- Lean glass against a clean surface or have someone hold it up by the edges and rinse the surfaces with methanol
- Inspect for spotting, etc. Repeat methanol rinse as necessary to produce clean surface.
- Vacuum bake at 200 C^0

[1] Walker & Sons Enterprises, Inc. 105 SE 16th Street, Newcastle, OK 73065 (405) 392-4721

Indium

The cleaning process to remove oils and hydrocarbons from the surface of indium is as follows:

- ultrasonically clean with acetone
- If the indium is to be used for cold welding or soldering/fusing, then an acid etch process to remove the oxide film is required. (See document XXXXX for the procedure.)

Magnets (NEO35, NdFeB, Sm-Co)

Warning: Some LIGO magnets are very strong so care should be taken during all handling. Some magnets chip very easily when they make uncontrolled contact with other surfaces. For example, some magnets chip when they snap to another object a few inches away. To aid in handling through clean and bake, use metal mesh to hold magnets in pairs away from one another. Place one magnet on one side of the mesh attracted to another, barrel to barrel, to maximize surface area exposed for cleaning and baking.

NdFeB, nickel plated

- Mount magnets on metal screen to minimize flat surfaces being trapped during cleaning.
- Ultrasonic clean in Liquinox solution for 3 minutes
- Thoroughly DI rinse
- Bake in vacuum at 80 C° for 48 hrs.

NEO 35

- Mount magnets on metal screen to minimize flat surfaces being trapped during cleaning
- Ultrasonic clean in methanol for 10 minutes
- Bake in vacuum at 80 C° for 48 hrs
  When the magnets became part of a magnet/standoff assembly, after sanding, and prior to bonding, clean using a CO_2 cleaning system (LIGO-E990316).

Sm-Co, permanent

- Ultrasonic clean in methanol for 10 minutes
- Bake in vacuum at 177 C° for 96 hours

Masterbond (EP30-2)

Assemblies glued with EP30 should be cured and vacuum baked as per E1000386. (*Note-some assemblies can be found in the Appendix 5: instructions there take precedence over these basic instructions for EP30.)

- Clean assembly parts prior to applying EP30 according to appropriate instructions in Section 10.
- Apply as little EP30 as possible to provide adequate bonding.
- Cure according to E1000386 – see specific components below.
- Vacuum bake assemblies at 145C° if appropriate for all assembly materials. If not, bake at the temperature of the material with the lowest bake temp. For example, some Aluminum alloys require a bake temp of 120C°. If EP30 is used on an Aluminum assembly, then the bake temp should be at 120 C° not 145C°.

PEEK

See Appendix 5 for specific assemblies.

PFA-440

*Note: Only PFA 440 HP grade Teflon is approved. Parts requiring high dimensional tolerances are not to be made of PFA 440 HP grade Teflon (see E960050).

- Ultrasonic clean in acetone for 10 minutes
- Ultrasonic clean in methanol for 10 minutes
- Bake in vacuum at 120 C° for 48 hours

PZT piezoelectric ceramics

- Ultrasonic clean in methanol for 10 minutes.
- Bake in vacuum at 80 C° for 24 hrs.

Sapphire, Ruby (Prisms, etc)

- Ultrasonic clean in DI water for 20 minutes.
- Ultrasonic clean in Liquinox and DI water for 20 minutes.
- Ultrasonic rinse in DI water for 20 minutes.
- Ultrasonic clean in isopropanol for 20 minutes.

Silica, Fused aka Glass including Non-Core Optics aka mirrors

The VRB approved a proposal (L1100046) to allow optics to be installed in vacuum without being baked as long as they are cleaned in accordance with the appropriate COC cleaning procedure and NO FTIR is required.

For completely polished mirrors from REO (edges also polished!), no baking required. Clean as per E1200266.

For mirrors with ground edges clean as per E1200266, no baking required.

*Note: Optics that have items bonded to them with a polymer adhesive (e.g. magnets, wire stand-off prisms) must be baked to cure the adhesive.

Solder (Lead-tin, Kester 6337)

- Same as the base metal, but flux is to be removed first by spraying Deflux solution.

Stainless Steel (including Invar)

- Liquinox, ultrasonic 10 minutes
- Bake at 200 C° for 48 hours

Vac-Seal

As of March 2008, the LIGO qualified adhesive product known as "Vac-Seal" and manufactured by Tra-Con[2], (now part of Emerson & Cuming, a division of Henkel) is no longer available. Note that there is another product called Vacseal from SPI, which we have not qualified for use. For a replacement (for LIGO purposes of staking parts only and not "sealing"), see EP30-2 Masterbond.

For the historical record, our cleaning and baking protocol for the Vac-Seal adhesive was:

- Ultrasonic clean in methanol for 10 minutes.
- Bake in vacuum at 80 C° for 48 hrs.

[2] In previous versions of this document it was erroneously reported that VacSeal was manufactured by Perkin Elmer.

Appendix 5: Approved Class A Cleaning and Baking Processes for Specific Assemblies

Actuators (SEI ISI electromagnetic)

See LIGO-E0900257.

Blades (Nickel-Plated Maraging Steel)

Ni Plated Maraging Steel Blades fabricated as per E090023 should only be handled with gloves. Soak blades for 3 minutes in isopropanol, wiping surface to treat problematic areas. For larger blades, soaking may not be applicable, so thoroughly wipe all surfaces and flush holes.

Cables (PEEK shielded Kapton cables with various SST or PEEK connectors)

This procedure applies to the sensor cables for the various Optical Sensor and Electro-Magnetic Actuator (OSEMs) assemblies and SEI assemblies.

- Ultrasonic clean in isopropanaol for 10 minutes
- Let wet cables drain on clean UHV foil on a flow bench then check for detritus. If there is visible detritus, repeat step 1 until the cables are detritus-free.
- Once the cables are detritus-free, ultrasonic in methanol for 10 minutes.
- Dry under heat lamp for at least 48 hours.
- Air bake at 80 C° for at least 48 hours.
- Bake in vacuum at 120C° for 48 hours.

Capacitive Position Sensors (CPS by ADE) with Kapton-coated wire

- Ultrasonic clean in methanol for 10 minutes.
- Soak in isopropyl alcohol for 10 minutes agitating regularly.
- Dry under heat lamp for at least 48 hours.
- Air bake at 100 C° for 48 hours (max temp of 100 C° per ADC, supplier of probes)
- Bake in vacuum at 100 C° for 48 hours. *(max temp of 100 C° per ADE, supplier of probes)*

Crystalline Optics (Hygroscopic)

Hygroscopic crystalline optics such as:

- KDP (potassium dihydrogen phosphate)
- DKDP (deuterated potassium dihydrogen phosphate or KD2PO4),
- KTP (potassium titanyl phosphate)
- RTP (rubidium titanyl phosphate)

shall NOT be cleaned and shall NOT be baked. DO NOT let water, detergent or solvent contact the crystals at all. DO NOT expose the crystals to solvent fumes: keep open containers of solvent at least 2 meters from crystals and keep containers closed whenever possible.

If there is some dust particles on the surface, use a clean, dry gas source (e.g. liquid nitrogen boil-off) to blow the particulates away.

Earthquake Stops

See E1000752. Cure EP30 glue bonds via heat lamp for 16-24 hours.

Electronic Components

- Clean with Liquinox solution and rinse with DI water.
- Bake in vacuum at highest temperature compatible with manufacturer's maximum rating.
- Special guidance from Rich Abbot in email to JLF dated 20 Dec 2011

  1. Items containing only Kapton film with no multi-layer Kapton circuit boards (for example, those bonded by Pyralux adhesive), and no solder bake at **200C** (for example, the in-vacuum cable assemblies with D-25 on both ends)
  2. Items containing soldered joints bake at **170C** (a possible example is the SEI magnet actuator cables, although I'm not sure they are soldered)
  3. Items containing multi-layer Kapton circuit boards bake at **120C** (for example, the QPD harnesses used within ISC that have the little circuit boards to plug in photodiodes)

Electropolished Components

- If parts are simple, ultrasonic clean in standard Liquinox solution. Items with difficult holes or complex geometries should be ultrasonic cleaned in DI water alone after the HULK or other ultrasonic machine has been cleaned out to remove Liquinox residue. As a last resort, parts may be ultrasonically cleaned in isopropanol under a fume hood.
- Vacuum bake parts for 48 hours. Temperature is determined according to the material. (i.e. Stainless steel is baked at 200 C)

Feedthroughs, Electrical

A Picture Guide to ALIGO Electrical Feethroughs may be found in document LIGO-1200250.

- Leak check ALL feedthroughs prior to Clean and Bake.
- Ultrasonically clean all feedthroughs in isopropanol for 10 minutes.
- Bake feedthroughs in an oven that has a programmed ramp up and ramp down of 120 C° in 6 hours (20 degrees per hour)
- Carefully load feedthroughs into oven so as to avoid damage, especialy to connectors and knife edges, while at the same time maximizing loads.
- Bake at 150 C° for 48 hour.
- DO NOT force cooling of oven when feedthroughs are in the load.
- Leak check all feedthroughs after Clean and Bake.

Flag Assemblies

Cure via heat lamp instructions in E1000386 for 16-24 hours and then vacuum bake at 120 C°.

HAM SUS Metal Masses with D070334 magnet/standoffs:

Cure via airbake instructions in E1000386 at 100C° for 2-4 hours. Check that magnets can tolerate this temp/duration (although it has been determined that SmCo can).

Mass Dampers???

Mirror Mounts (ISC)

A technical write-up of the procedure used to provide LIGO with almost completely assembled mirror mounts suitable for vacuum baking is outlined in LIGO-E12002245.

Music Wire

SUS utilizes steel music wire in many assemblies. The wire does not get baked, prior to use. Spools should be kept in a dry area, preferably with the desiccant wrapping provided by the vendor.

Cleaning: After removing a wire segment from the spool, wipe the entire segment with acetone until no more residue comes off of the wire onto the wipe. Once the acetone wipe comes away clean, change gloves and wipe entire segment length three (3) times with methanol using a clean wipe each time.

Optics (LOS)

- Use flashlight and inspect every cavity; if contaminated send out for another pickle and passivate (using local vendor who has experience in handling and wrapping per our procedures).
  Note: A few areas of reddish surface contamination (rust) in the interior is acceptable.

- Check all threaded holes with UHV cleaned and baked silver-plated, stainless screws to confirm that the threads are clear; if necessary chase the threads with a clean tap using no lubricant except DI water or approved solvents.
- Wipe all exposed surfaces with a clean room cloth (not a clean room paper/tissue) and isopropanol.
- Flush thoroughly with DI water using stainless steel brushes; turn the structure end-over-end and on all sides to clear as much of the particulate from the interior cavities as possible.
- Blow dry (as much as possible) with N_2 (do not allow the water to sit and dry).
- Wipe the exposed surfaces again with a clean room cloth (not a clean room paper/tissue) and isopropanol to see if any particulates have been flushed out of the cavities and onto the exterior; flip the structure end-over-end.
- Vacuum bake at 200 C° for 48 hours.
- Spot check after the vacuum bake for particulates as the structure is turned end-over-end; wipe any particulates off with a clean room cloth (not a clean room paper/tissue) and isopropanol.

OSEMS (A and B types)

- **iLIGO OSEM Complete Assembly:**
  Ultrasonic clean in methanol for 10 minutes.
  Soak in isopropyl alcohol for 10 minutes agitating regularly.
  Bake in vacuum at 80 C° for 48 hours.
- **AOSEM Complete Assembly with loosened or removed assembly screws:**
  Soak in isopropyl alcohol for 10 minutes agitating regularly.
  Bake in vacuum at 145 C° for **96** hours.
- **BOSEM Complete Assembly:**
  Soak in isopropyl alcohol for 10 minutes agitating regularly.
  Bake in vacuum at 120 C° for 48 hours.

PEEK

Cable Clamps: See LIGO D0900004.

Connectors/Kapton cabling/wire harnesses: See **Cables** above.

Zip Ties: Ultrasonic clean in methanol for 10 minutes then vacuum bake at 200 C° for 48 hours.

Picomotors (OMC)

Maximum survival temperature of 100 C° so bake at 80 C°for 24 or 48 hours?

Plates (SEI ISI at vendor)

Initial LIGO SEI large in-vacuum components were cleaned per the procedure outlined in LIGO-E970063. Advanced LIGO SEI large in-vacuum components will be cleaned by subcontract per the procedure outlined in LIGO-

Silica Earthquake Tips

- Clean in standard Liquinox solution for 10 minutes using a small ultrasonic machine with Contec wipes in the bottom to prevent the tips from moving around too much.
- Rinse thoroughly per usual protocol.
- Vacuum bake at 200C. These parts can be baked in a stainless steel load, no waiver required.

Stages (Commercial)

- Disassemble and clean parts in ultrasonic cleaner with Liquinox for 10 minutes.
- Rinse in DI water.
- Clean in ultrasonic cleaner with methanol for 10 minutes.
- Replace all plastic parts with appropriate metal or Teflon replacement part (Teflon PFA 440 HP pieces).
- Remove Teflon parts and clean thoroughly.
- Reassemble stages.
- Bake in vacuum at 120 C° for 24 hours.

Target Faces (Polished Al)

DO NOT TOUCH THE POLISHED SURFACE WITH ANYTHING BUT THE LIQUIDS DESCRIBED BELOW.

DO NOT PLACE THIS PART IN AN ULTRASONIC CLEANER: This will cause surface pitting.

The only acceptable method for removing contamination on the surface is by flowing liquids over the surface. When performing the process described below, take care not to touch the polished surface and not to let the polished surface come in contact with any other surface.

Is it important to have more than one person involved in this process?

1) Immerse the part into a 1% Liquinox solution and stir the solution to keep it flowing over the part. Do not let the polished surface contact any other surface. Remove the part after 3 minutes (maximum) in the Liquinox bath. (How do you keep it from contacting any other surface if you put it into a container of Liquinox? Are you holding it in your hand?)
2) Immediately rinse the part in DI water for 5 minutes, with the DI water flowing/moving over the part surfaces.
3) Place the part into spectrometer grade (not reagent grade) Methanol and stir for about 1 minute.
4) Air dry the part in a cleanroom or flow bench.

Viewports

Commercial: aLIGO and iLIGO
(aka CVP, Metal-to-glass directly sealed view port assemblies, off-the-shelf view ports)

- Clean all the metal parts and welded grooves with isopropanol then drag wipe the optical surfaces with spectroscopic methanol.
- If there is a large amount of dust on the optics, try to get the big pieces off by spraying with methanol and immediately drying with an ion gun to avoid scratching. (Take proper safety precautions when using ion gun.)
- Drag wipe with Freon to clean optic
- Vacuum bake at 200 C° for 48 hours
- Send to QA for proof before install

High-quality: aLIGO
(aka HVP, custom O-ring sealed viewport assemblies, custom dichroic viewports)

- Clean and bake stainless steel parts according to standard procedure
- Clean and bake O-rings according to standard procedure
- Clean fused-silica according to E1200266.
  (Freon wipe followed by First Contact with NO BAKE and NO FTIR.)
- Assemble the clean parts in a clean space
- Send to QA for proof before install