LIGO Seismic Isolation System:
Fabrication Process Specification

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1. SCOPE

This specification covers aspects important to the fabrication, cleaning, handling and shipping of all the fabricated parts for the Seismic Isolation System (SEI) for the LIGO program, for which HYTEC is responsible, with the exception of the vacuum bellows, springs, and spring seats. They will be covered by other specifications.

2. PRECEDENCE

In the event of conflict, the order of precedence is

1) The Purchase Order

2) The Drawing

3) This Specification

4) Any Referenced Specification

3. SPECIFICATION ORGANIZATION

3.1 COMPONENT CATEGORIES

The equipment covered by this specification is divided into two categories.

Category 1 equipment used inside the ultra-high vacuum

Category 2 equipment used outside the vacuum

The detail drawings will refer to this specification and will specify the category to which the part belongs. The applicable paragraphs for the two categories are indicated in Table 1.

Table 1. Application of Specification Paragraphs to Components Within, and Outside of, the Vacuum

Category	Applicable Paragraphs
1	3.2, 4.1 through 5.9, 5, 6, 7
2	4.1, 4.4, 4.5, 4.8, 4.10, 5.2.3, 6 (except 6.5), 7

3.2 PROCESS SEQUENCE

The sequence of process steps required by this specification for category 1 components (i.e. components intended for use in vacuum) is as indicated in Figure 1.

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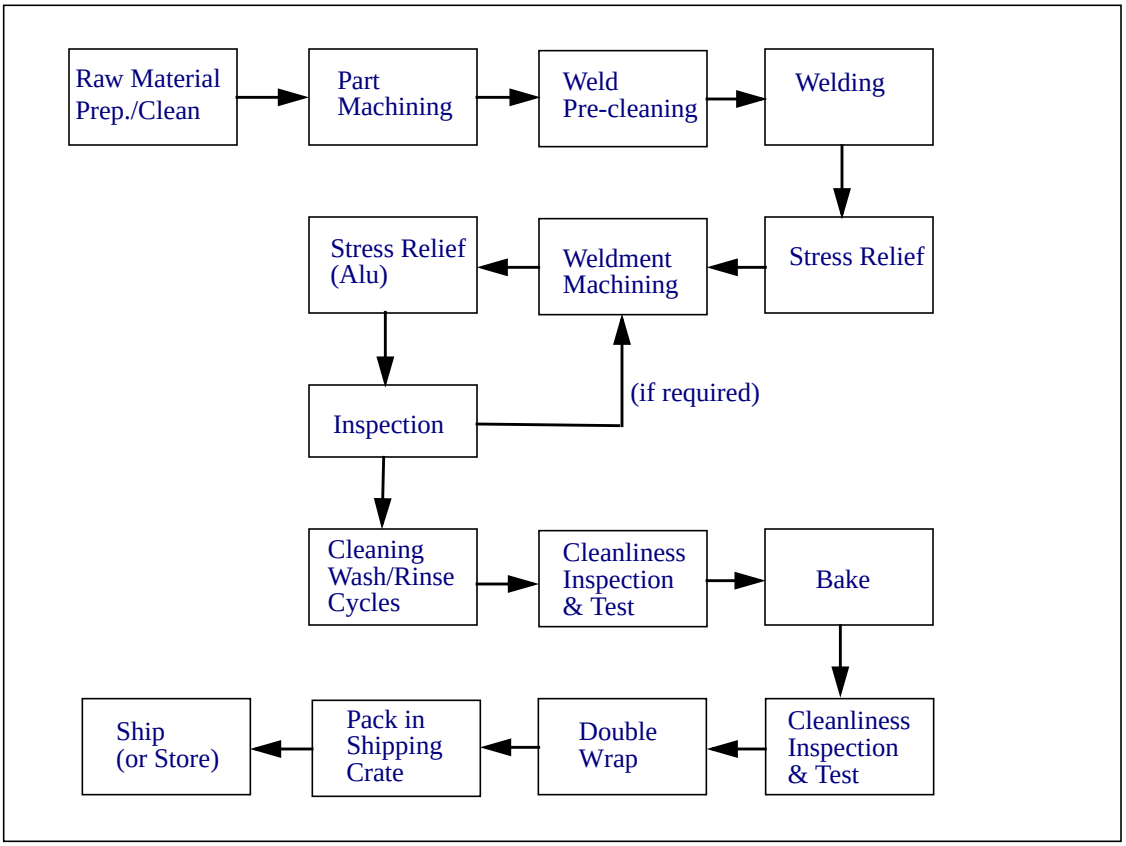
Figure 1: Process Sequence for Category 1 Parts
(Additional in-process steps are likely to be required by the fabricator.)



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4. GENERAL REQUIREMENTS

4.1 RAW MATERIAL REQUIREMENTS, PREPARATION & HANDLING

The specific alloy used shall be in accordance with the appropriate drawing.

Material certification is required for all material used for fabricating SEI components and shall be included in the component traveller records.

4.1.1 Aluminum

4.1.1.1 Raw aluminum material stock shall be cleaned in accordance with standard shop practice prior to part machining operations. After cleaning no hydrocarbons should come into contact with the material other than as specified in this document. The material shall be wrapped and covered at all times when the material is not being processed to minimize possible exposure to contaminants.

4.1.1.2 Anodized surfaces are not permitted.

4.1.1.3 Surfaces should not have deep oxidation layers (e.g. indicative of long exterior exposure).

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

4.1.2 Stainless Steel

4.1.2.1 In order to preclude surface contamination of stainless steel (SST) stock by carbon steel, all raw SST material intended for use in the LIGO Seismic System 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.

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

4.1.3 Carbon Steel

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

4.2 PROTECTION FROM CONTAMINATION

Contact of category 1 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 category 1 material at any time. This includes fluids such as machining lubricants and paints.

No carbon steel hooks, fork lift forks, grapples or chains shall be allowed to contact the category 1 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 Section 5.6. For raw material, polyethylene sheet or teflon or clean stainless steel or aluminum pieces may be used as spacers.

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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 category 1 components.

4.3 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.

4.4 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.

4.5 SMOKING AND AIRBORNE CONTAMINATION

Smoking is not allowed in any LIGO 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 category 1 part may be exposed (prior to double wrapping).

4.6 LIQUID CONTAMINANTS

Liquids containing hydrocarbons or other contaminants shall not be allowed to come into contact with category 1 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.

4.7 GRINDING & ABRASIVE CLOTH/PAPER

Grinding (with abrasive wheels, cloth, or stones), or use of abrasive cloth or paper, is not permitted on category 1 components.

4.8 MACHINING LUBRICATION

No lubricant may be used which might result in material contamination that cannot be removed by the cleaning method described in Section 5.5 of this specification. The use of cutting fluids or lubricants which contain sulfur or silicone compounds is prohibited. Acceptable lubricants are listed in the Appendix, section 8.6.

4.9 CONFLAT PROTECTION

The knife edge of a conflat flange, intended for high vacuum sealing with a metal gasket, is extremely susceptible to damage if impacted. A teflon cap shall be used to protect the knife edge whenever possible. Minute damage (scratches or dents) to the knife edge and the adjacent sealing surfaces of the conflat flange will require re-machining or, if already welded, possible rejection of (scrapping) a finished weldment.

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4.10 PAINT

Only category 2 components may be painted. The paint to be used is a medium textured beige Sherwin Williams (D13 Polane® T-Plus, polyurethane enamel, F63 series) #SW-F63TX-H-1651-5864.

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5. SPECIFIC REQUIREMENTS

5.1 PRIOR TO WELDING

5.1.1 Remove gross contamination from all surfaces by steam cleaning with a portable steam system.

5.1.2 Remove ink markings such as material designations with acetone.

5.1.3 Perform a single wash/rinse cycle of all parts which comprise the weldment per the cleaning process in section 5.5 prior to welding.

5.2 WELDING

5.2.1 Comply with the welding environment requirements of Section 4.5.

5.2.2 Perform the pre-welding steps defined in Section 5.1.

5.2.3 Welders must be certified to American Welding Society (AWS) or American Society of Mechanical Engineering (ASME) standards.

5.2.4 All welds for category 1 components are full penetration.

5.2.5 Welds in category 1 components should not be subsequently ground.

5.2.6 An inert shield gas (e.g. Argon) must be used in all category 1 welding.

5.3 STRESS RELIEVING

5.3.1 Aluminum

5.3.1.1 The aluminum category 1 parts comprise the final elements in the isolation system. It is imperative that they be as free of residual stresses as possible. After welding, the aluminum parts shall be held at 204C (400F) for 2 hours.

5.3.1.2 After all subsequent machining operations, the above parts are to be stress relieved at 177C (350F) for 6 hours.

5.3.2 Stainless Steel STRESS RELIEVING

5.3.2.1 The Stainless Steel (SST) category 1 parts comprise elements in the isolation system. It is important that they be as free of residual stresses as possible. After welding, the SST parts shall be held at 488C (900F) for 4 hours per inch of thickness, and slow cooled.

5.4 CLEANING

5.4.1 General Notes

5.4.1.1 The cleaning procedure is to be used subsequent to all machining and welding operations and prior to the bake (i.e. the bake is the final cleaning processing

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step, performed only on the completed parts and weldments).

5.4.1.2 This process is applicable to either stainless steel or aluminum.

5.4.1.3 Comply with the cleaning environment requirements of section 4.4

5.4.1.4 Comply with the handling requirements of section 4.2, 4.6 and 5.6

5.4.1.5 Do not let any surface dry between the start of washing and the end of final rinse.

5.4.2 Cleaning Requirements

5.4.2.1 The following cleaning process can be implemented with either of the two following cleaners (see the appendix for sources):

a) a 5% concentration Inpro-Clean 1300 solution (9.8 pH), or
b) Mirachem 500 and deionized water solution in a 1:30 mix.

5.4.2.2 Perform the rinse with deionized water at 65C (150F).

5.4.2.3 Application of the cleaning fluids is via a steam spray at 65C (150F).

5.4.2.4 Spray wash and rinse for the duration and number of cycles[1] indicated in Table 2.

Table 2. Wash and Rinse Requirements

Component Area	Minimum Duration per Cycle (minutes)[a]		Number of Wash/Rinse Cycles	Final D.I. Rinse Duration (minutes)
	Spray Wash	Spray Rinse		
Exterior Surfaces	3	3	3	5
Interior Cavity Surfaces (e.g. optics table eggcrate cavities)	3	3	5	10
Thru Holes (tapped or clear)	3	3	5	10
Blind Holes (tapped or clear)	3	3	10	20

a.Alternatively, if the time required to raise the temperature of the part to 130F (from room temperature) is shorter, then this temperature criteria can be used to set the duration.

5.4.2.5 The cleaning solution must be sprayed at a high rate onto every surface, into each hole (blind or through), vented sandwich core volume and each tapped (through or blind) hole.

5.4.2.6 A cleaning apparatus must be developed and used to deliver, via steam spray-

1. The wash and rinse cycle duration and repetition is an estimate; These values will be verified or revised in the cleaning qualification task.

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ing, the cleaning solutions and deionized water used in the rinse.

5.4.2.6.1 For general surface cleaning, the fluid should be delivered at a rate of *5 gal/min **(TBR)***[2] with an array of nozzles which each have a full cone spray pattern (> 60 degree cone angle) which overlaps. The spray pattern cannot be static; the spray heads or part should rotate and/or translate so that the spray jets move relative to the component being cleaned.

5.4.2.6.2 A special cleaning apparatus must designed to be capable of simultaneously spraying the numerous blind tapped holes in the optics tables while the table is inverted, i.e. so that debris and chips from the tapping operations are flushed out of the blind holes. The spray should be delivered to the tapped holes via 0.125 inch diameter tubes which are inserted 1/2 of the depth of the blind tapped holes. The spray capacity should be 0.5 gal/min (***TBR)***[3] in/s. The spray pattern should include four lateral and one axial jet.

5.4.2.6.3 The trapped volumes of the category 1 weldments (e.g. the eggcrate cavities of the optics tables and the interior of the downtube structure) shall be washed and rinsed with a high impact, rotary type tank nozzle. The spray capacity must be 5 gal/min (***TBR)***[4]

5.4.2.7 Allow for sampling of recirculated fluids for analysis, confirmation of cleanliness and quality control.

5.4.2.8 Drying is accomplished by blowing Class 100 clean air or dry nitrogen, filtered at the nozzle, over the component before allowing it to cool. If necessary trapped pools of cleaning solution (prior to rinse cycle) or pools of water (after rinse) can be patted (not wiped) with a clean, lint free cloth suitable for clean room practice.

5.4.2.9 Inspection and Testing

5.4.2.9.1 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 and rinse cycle 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.

5.4.2.9.2 Perform water-sheeting inspection. Filtered deionized water (e.g. from fi-

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[2] The flow rate of the steam spray for general surface cleaning of category 1 components will be established in the cleaning qualification task.
[3] The flow rate of the steam spray for cleaning holes in category 1 components will be established in the cleaning qualification task.
[4] The flow rate of the steam spray for trapped cavities in category 1 components will be established in the cleaning qualification task.

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nal rinse) should sheet or cover a flat surface. If the water beads up or avoids areas on the surface, either the surface is still contaminated or the detergent has not been adequately removed in the rinse. Repeat the wash and rinse cycles until the water sheets.

5.4.2.9.3 Perform a visual inspection (no magnification) and blacklight inspection (360 nm wavelength, 12 to 18 inches from the surface). No visible contamination shall be detected with the naked eye under both natural and ultraviolet light. The presence of any hydrocarbon or fingerprints shall be cause for rejection, and the part must go through at least one more wash and rinse cycle before repeating a check of the cleanliness.

5.4.2.9.4 Obtain an alcohol sample for FTIR analysis from 10 representative blind tapped holes in the optics table, from the surface of an internal cavity and from an external surface of each weldment. The precise location, amount of alcohol and the method of application and collection will be developed ***(TBD)***[5]. Compare the FTIR results to the limits to be established as part of the cleaning qualification process ***(TBD)***.[6]

5.4.2.9.5 After inspection and testing (5.4.2.10), 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.

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

5.5 BAKING

After verification of a successful FTIR result (from 5.5.2.10.4), the component can proceed to the bake, the final hydrocarbon cleaning step.

5.5.1 The cleaning environment external to the air bake chamber shall be as defined in Sections 4.2 and 4.3.

5.5.2 The air bake oven must be extremely clean and supplied with a ***TBD***[7] low flow rate of class 100, charcoal filtered air, with a hydrocarbon level of less than 15 ppm. The SEI category 1 components must be the only components within the oven during the bake. In addition, once the oven is cleaned, inspected and approved for use in baking SEI components, it must be dedicated to the SEI category 1 component bake activity. If it is used for any other purpose, it must be re-cleaned, re-inspected and re-approved for use in baking SEI components.

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5. The method of sampling, the number of samples and the precise locations for sampling will be determined in the course of qualifying the cleaning process.
6. The cleaning process qualification task will result in definitive FTIR acceptance levels.
7. The flow rate of replenishing air into the bake oven will be established during the cleaning qualification task.

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5.5.3 Bake aluminum components in a clean air oven at 120C (248F) and maintain for 24 hours.

5.5.4 Bake stainless steel components in a clean air oven at 200C (392F) and maintain for 24.

5.5.5 Perform a cleanliness inspection and test per section 5.4.2.9. Use ethanol to spot clean any fingerprints.

5.5.6 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.

5.5.7 After cleaning and after baking, category 1 component surfaces shall not be touched by skin or other contaminants; only C.P. Stat plastic sheet and Nitrilite gloves are acceptable. All category 1 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.

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

5.6 CLEAN/BAKE HANDLING

5.6.1 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.)

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

6. QUALITY ASSURANCE/CONTROL

6.1 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.

6.2 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.

6.3 TRAVELERS

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

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6.4 IDENTIFICATION

Identification of the material shall be maintained through all manufacturing processes. Each component shall be uniquely identified. The identification shall enable the complete history of each component to be maintained (in association with Documentation “travelers”). A record for each component shall indicate all weld repairs and fabrication abnormalities.

Marking the finished materials with marking fluids, die stamps and/or electro-etching is not permitted A vibratory tool with a minimum tip radius of 0.005” is acceptable for marking on surfaces which are not hidden from view. Engraving is also permitted.

6.5 CLEANING PROCESS SPECIFICATION

A process specification shall be developed by the vendor with specific QA/QC provisions to insure that this cleaning process is followed, and that the detergent solution and the particulate filters are maintained, and that the quality of the de-ionized water and detergent solutions are monitored. The QA process plan must include a cleaning log indicating part numbers (including revision number), serial numbers, comments, observations, cleaning process variables (e.g. flow rate, pressures, durations, temperatures, cycles, etc.) and a record of inspections.

6.6 DIMENSIONAL QC

A QC procedure for 100% inspection of all key finished dimensions of the components shall be developed and submitted for approval. The QC dimensional inspection shall be performed after all machining and stress relief operations.

6.7 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.

7. SHIPPING

7.1 CRATES

Crates shall be designed and constructed to best commercial practice. The following points should be observed in the construction of crates:

7.1.1 Rubbing strips of 4" thick lumber shall be installed on the underside of the crate bases to provide for sling and forklift truck handling.

7.1.2 Sufficient reinforcing joists of proper size shall be on the crate tops in the center of balance area to prevent crushing of the crate when it is lifted with a single set of slings.

7.1.3 Crate liners shall be applied between the sheathing and the frame member of sides, ends and top. The liner material shall be low density polyethylene film at least 6 mils thick or any other approved waterproof material.

7.1.4 No ventilation holes shall be provided in the crates.

7.1.5 The crates should be designed to be resistant to entry by rodents.

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7.1.6 Drain holes shall be provided in the crate bases

7.1.7 Use nylon slings for lifting. The use of chains is prohibited.

7.2 VEHICLES

All components shall be transported on tractor/trailer combinations equipped with air ride suspensions.

8. APPENDIX A: SOURCES

8.1 C.P. STAT PLASTIC FILM FOR WRAPPING & 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

8.2 INPRO-CLEAN 1300 FOR CLEANING SST AND ALUMINUM

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

8.3 MIRACHEM 500 FOR CLEANING SST AND ALUMINUM

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

8.4 NITRILE GLOVES FOR HANDLING HARDWARE

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

8.5 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

8.6 ALLOWABLE CUTTING FLUIDS

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

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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
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		

9. APPENDIX B: ABBREVIATIONS

FTIR	Fourier Transform Infra-Red, a standard laboratory test method for determination of chemical constituents in a sample
LIGO	Laser Interferometer Gravitational-wave Observatory
SEI	Seismic Isolation System
TBD	To Be Determined
TBR	To Be Reviewed

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