LIGO Laboratory / LIGO Scientific Collaboration

LIGO-E1400166-v3 9/30/2014

LGV7 Containment Vessel Installation Plan

M. Zucker

Distribution of this document:
LIGO Vacuum Review Board

This is an internal working note
of the LIGO Laboratory.

California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – NW22-295
185 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 1970
Mail Stop S9-02
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

http://www.ligo.caltech.edu/

1 Introduction & scope

An external containment vessel will pull external vacuum around the stem and mechanism of 48" gate valve LGV7, located at the midpoint of the Livingston Y arm. This will eliminate air leakage through an inaccessible compound leak that has evidently developed somewhere inside the stem.

Requirements and boundary conditions are described in E1300891; a review weighing design options is summarized in G1400042. The evolved enclosure design is documented in D1400035 and subassemblies. Mechanical support for this enclosure is shown in D1400008 and subassemblies. Detailed geometry and tolerancing for the critical bottom interface seal are described in T1400193.

This document provides detailed plans and procedures for installing, testing and operating the enclosure.

9/30/2014: UPDATED FOR VRB INSTALLATION READINESS REVIEW INCORPORATING LESSONS FROM 9/23-26 FIT CHECK AND DRY RUN EXERCISE

2 Initial preparations

2.1 Prepare lab environment

2.1.1 Scaffold, railings, ladders *completed*

2.1.2 Overhead jib crane *completed*

2.2 Prepare valve to receive enclosure

2.2.1 Remove gear motor and encoder *completed*

2.2.2 Record baseline valve support deflection *completed*

- *We saw during the 9/23-26 test, with nearly full mass installed, that load-related deflection was at most 15% of daily diurnal change in height (presumably due to tube thermal cycling). Deflection monitoring is no longer required.*

3 Install containment vessel

3.1 Install steel support frame

- Refer to D1400008 and D1400032
- Clamp the Ion Pump Risers (D1400008 item 7) to the uppermost valve trunk stiffening ribs at locations shown in elevation view (measured from the West end of stiffener rib).
- Omit 1/2" interface plates shown between Riser and valve ribs; Risers should rest directly on the ribs.

- *Omit West "L" angle bracket* (D1400032 item 10). East bracket may be installed now.
- *Omit diagonal braces* on both sides for now.
- *Install upper horizontal braces in optional lower position* temporarily. Firm up but do not final torque these fasteners.

3.2 Prep valve stem & weld lower seal O-ring(s)

3.2.1 Clean exposed parts and surfaces

- Solvent wipe all exposed surfaces from stem nipple upward.
- Take care not to redistribute lubricants or contaminants, by changing wipes frequently.
- Do not allow liquid solvent or residues to pool or drip into bearing housing.
- Repeat until wipes come clean, especially on lubricated surfaces

3.2.2 Dress tube seam weld and lap sealing face ***not required***

- *On close examination surface finish looks adequate without dressing. In particular the seam weld, while visually apparent, is smooth and within nominal conformal capacity of the compressed o-ring. We may revisit this in the unlikely event the nozzle gets scratched somehow, but otherwise feel it is more prudent to leave it alone.*

3.2.3 Weld up lower o-ring(s) in place

- Mark three 6" stem seal o-rings with equatorial alignment line, using silver Sharpie, then cut each with razor blade.
- Clean tube and install welding fixture D1400145 on valve stem nipple at convenient working height.
- Place seal blank in fixture, insuring equatorial marks line up (no twist).
- Apply adhesive[1].
- Tension fixture to make up joint
- After cure, release fixture; roll and inspect joint to certify complete fusion
- Trim and dress joint squeezeout with fine abrasive paper as required to recover uniform o-ring cross section
- Clean with isopropanol
- Roll and inspect again for proper fusion; cut and discard if failed
- Repeat until three good o-rings are stacked on stem nipple (two spares)
- Remove welding fixture
- Lightly lubricate o-rings with Apiezon L compound
- Slide welded o-rings to bottom of nipple; cover with UHV foil for protection during subsequent assembly

[1] Loctite #404, McMaster 7569A22

3.3 Install and bond seal plate assembly

3.3.1 Prepare for assembly

- Clean and inspect joint face and upper and lower seal faces of narrow seal plate D1400017 and wide seal plate D1400018.
- Install 3/16" dowel pins in narrow plate D1400017
- Apply wrap of thin poly tape (mold release) to the stem nipple in vicinity of plate joint at the temporary assembly position, to protect nozzle from adhesive squeezeout.
- Also apply tape on horizontal frame braces near joint area to prevent sticking if there are drips.
- Spread plastic sheeting below work area to catch any stray drips.
- Position wide plate D1400018 on west side of nozzle, resting on the horizontal braces.
- Temporarily fit narrow plate D1400017 to insure it can pull tight against the wide plate D1400018 without interference.
- Remove both seal plates.

3.3.2 Bond and fasten seal plate parts together

- Prepare and catalyze 25g of Stycast 2850 FT adhesive according to manufacturer's instructions, using precision balance for proportioning.
- Degas catalyzed mixture in vacuum degassing chamber until foaming ceases.
- Transfer catalyzed epoxy to applicator syringe, taking care to avoid entraining air bubbles
- Using #17 needle on syringe, apply a uniform, continuous 2.5 mm bead to bottom of adhesive groove in wide plate's joint face
- Deposit sample beads on scrap material to monitor cure.
- Position wide plate D1400018 on horizontal braces and slide up against nozzle
- Mount narrow plate D1400017 and install flange fasteners
- NOTE: End fasteners near ribs require small-diameter washers; insure that all washers lie flat against flange face
- While checking for and removing excess adhesive squeezeout, progressively tighten fasteners to specified torque in alternating pattern
- Remove excess joint squeezout with spatula. *DO NOT scrape flush* in the area of groove endpoints at upper or lower seal faces.
- Residual adhesive should remain slightly convex at these four points, to permit dressing the joint flush after cure.
- Insure that adhesive groove is completely filled and slightly convex (overfilled) at the four o-ring crossings, without bubbles or cavities; if joint face appears concave, carefully add a drop of epoxy from syringe
- Remove any excess adhesive from stem nipple before it cures, using acetone on cotton swabs
- Monitor adhesive sample beads for cure. *NOMINAL CURE 16-24h @ 25° C*

- Place one sample bead in oven at 65C for 2-hour "accelerated cure" test. *Failure to harden at elevated temperature in two hours indicates that the catalyst has failed or mixture was incorrect*. If this happens, immediately disassemble D1400017 from D1400018 and clean uncured adhesive off thoroughly with acetone.

3.3.3 Dress & inspect sealing faces

- Wait 24 hours to complete curing.
- Verify that adhesive has cured to machinable hardness.
- To prevent lap tilt or gouging of adjacent areas, temporarily protect surrounding metal near the seal transitions with thin plastic packing tape.
- Using flat metal backing block and wet/dry abrasive paper, lubricated with water, lap excess adhesive parallel to the plane of base metal at the four adhesive channel endpoints.
- On the lower seal face, use a radiused block conforming to the nozzle shape, and trim the abrasive paper as required to finish the plate as close as possible to the nozzle OD.
- Once adhesive has been dressed flush, down to thickness of protective tape, remove the tape, clean thoroughly and switch to fine abrasive; continue dressing.
- Clean and inspect seal faces under magnification with glancing illumination; touch up as required
- Lightly grease upper and lower seal faces with Apiezon L

3.4 Raise and level seal plate

- Carefully raise integrated D1400017/D1400018 assembly as high as it will go on valve stem nozzle; hold in position.
- *CAUTION: Be careful not to ding or scratch stem nozzle surface!*
- Install West "L" angle bracket (D1400036 item 10) onto support frame.
- Slide Enclosure Supports, Front and Rear (D1400028 and D1400029, respectively) into position beneath D1400017/18 assembly and install 6 bolts with washers, *finger tight only*.
- Set assembly (D1400017/18 with D1400028 and D1400029 attached) down onto support frame L brackets
- Test gap between seal plate ID and stem nozzle OD with feeler gages at several points around circumference. Average radial clearance should be about .015" but this will vary, as the nozzle is not cylindrical.
- Choose appropriate thickness of plastic shimstock and cut a 2" strip about 18" in length. Temporarily insert strip into gap from above. These will maintain plate centering and protect the nozzle from damage during leveling. Shims must be removed after plate leveling, don't lose them down the gap.
- Raise an o-ring into position against bottom of D1400017/18 assembly.
- Install Lower Seal Ring (D1400019) on nozzle. Check that drill point mark in the upper surface is facing North, and that ring split is aligned with the leak check

groove on the GV7 stem nozzle triple flange. Check that ring gaps are both closed and ring is not binding on stem nozzle.

- Insert bolts to fasten Lower Seal Ring to D1400017/18 assembly bolt circle. *Finger tighten only*.
- Check vertical gap to insure o-ring is in uniform contact with plate and with conical sealing ring surface. Sealing should rest parallel to seal plate.
- Unbolt and reinstall upper frame horizontals (D1400032 item 5) at final assembly height.
- Clock rotation of D1400017/18 assembly around nozzle axis so its edges lie parallel with the edges of the GV7 Motor Mount Plate above. Angle tolerance is +/- 1/32" over longest dimension.
- Using slop in mounting bolt connections, slide Enclosure Support plates withe respect to Seal Plate assembly until mounting holes line up with holes in frame (5/16 slots in L angle, and 3/8 holes in upper frame horizontals). Take care to maintain angle and position of seal plate assembly with respect to nozzle and Motor Mount plate.
- Do not apply pressure on the stem nozzle or allow fasteners to bind; if insufficient fasteners engage freely, omit some and/or open up holes in the steel frame members (removed one at a time for rework, insuring load is properly borne by remaining pieces). Install fasteners loosely with 1/4" head clearance.
- Torque 3/8 fasteners binding aluminum plates D1400028 and D1400029 to seal plate assembly D1400017/18. These now form a unit.
- Using precision level on the D1400017/18 assembly seal face, find the highest corner. Insert steel shim packs under aluminum plates D1400028 and D1400029 as appropriate to bring the other three corners to this level.
- *Add 0.100" additional shim height under South edge* (so the assembly tilts slightly to the North). This compensates for misalignment in the 4.62" Conflat accepting the Ballscrew Tube Cover, thus improving clearance around the top of the screw.
- Temporarily tighten fasteners binding D140017/18/28/29 assembly to the support frame.

3.5 Install Vacuum Enclosure Box (lower housing)

- Inspect, grease and install o-ring in lower flange Vacuum Enclosure Box (D1400016).
- Lower box over the ballscrew, bearing tube, and motor housing plate; check that it rests uniformly on the vessel base plate assembly.
- Install flange fasteners loosely.
- Inspect o-ring through gap all around to insure it remained in the groove.
- Torque vessel lower housing/ base plate flange fasteners in specified pattern.
- *REMOVE PLASTIC SHIMS* between seal plate ID and stem nozzle OD.

3.6 Install Vacuum Enclosure Box Cover (upper housing)

- Inspect, grease and install o-ring in upper flange of Enclosure Box D1400016.
- Lower Box Cover D1400015 into place and install fasteners loosely.

- Check o-ring status through gap all around.
- Progressively torque flange fasteners to specification.

3.7 Install Ballscrew Tube Cover and adjust leveling

- Install 4.63" OD CF annealed copper gasket on Ballscrew Tube Cover flange.
- Lower Ballscrew Tube Cover D140009 over GV7 ballscrew onto gasket.
- Tilt the top of the Tube Cover gently in each direction to check internal clearance from ballscrew.
- Adjust shims under base plate assembly if necessary to insure adequate clearance between ballscrew and cover in all directions.
- Measure gaps between support frame members and aluminum plates D1400028/29 at locations of remaining fasteners (those on "L" angle brackets D1400036 item 10, or on upper frame horizontals D1400032 item 5). Make up and insert shim packs to fit each gap (tolerance -0.000"/+0.005") to insure each fastener will tighten without flexing the frame or enclosure supports.
- Progressively torque mounting bolts locking assembly to frame while rechecking enclosure clearances.
- Evenly tighten flange bolts in Lower Seal Ring to compress o-ring against stem nozzle and Seal Plates. Check periodically for even gap around circumference.
- Insert fasteners and tighten 4.62" CF joint to secure Ballscrew Cover Tube to Vacuum Enclosure Box Cover (use nominal CF tightening procedure).

3.8 Install ion pump & instruments

- Install Ion Pump Adjustment plate as shown in D140008.
- Install non-rotatable end of Conflat Nipple D1400022 onto Enclosure. Use annealed 8" OD CF copper gasket. Fasten with plate nuts behind Enclosure flange (hex nuts & washers will not fit, and you couldn't wrench them if they did).
- On workbench, assemble ion pump with 6" ID gate valve per nominal CF procedure. Also assemble Ion Pump Brackets D1400023 to ion pump (note metric M8 fasteners go into pump body).
- Put polyethyene cap over gate valve nozzle to protect it from impact during installation.
- Crane IP/gate valve assembly into position atop Ion Pump Adjustment Plate D1400020, inserting Ion Pump Shim Plates D1400027 under Ion Pump Brackets. Thread in fasteners, but keep loose to permit alignment of flanges.
- Adjust laterally and jack vertically, using ball-ended SHSS in corners of Adjustment Plate, to align Conflat Nipple flange to gate valve bolt circle. Insert annealed copper gasket in gap. Insert threaded studs into gate valve body.
- Continue adjustments until flanges mate with no residual stress or torque.
- Make up Conflat joint per nominal torque procedure.
- Lock Ion Pump Adjustment Plate to support frame using two 1/2-13 hex cap screws provided.
- Install 1.5" isolation valve and Pump/Purge/Instrumentation assembly onto Enclosure port (Figure 1).

- Install turbopump and connect flex foreline to scroll pump.
- Attach and test all pump and gauge power and signal connections.
- Close the 1.5" enclosure isolation valve and He MSLD leak test all connections outside the enclosure. Repair any leaks as necessary.
- Test pumps, gauges, controllers, and data logging.
- Shut down, vent lines and reopen 1.5" enclosure isolation valve.

4 Evacuate & test

4.1 Establish baseline beamtube vacuum state

4.1.1 Baseline leak rate *completed*

- Measure arm leak rate total using accumulation procedure comparable to T1400161 , *OR establish that steady-state pressure is consistent, within nominal instrument uncertainties, with prior measurements under similar conditions.*

4.1.2 Baseline RGA

- Measure residual gas spectrum at MY.
- Set MY RGA to continuously log major indicator species (air, water vapor, helium, argon, and signal HC fragments).

4.1.3 Beamtube valve & pumping configuration

- Install SS500 pump stations at Y2-1 and Y1-6. Spin up and test according to E1300563.
- Hard-close GV4 and GV9 for remainder of installation, test and commissioning procedure. *This is to limit collateral damage in case of catastrophic air dump.*
- SS500 pumps will remain spinning but isolated; beam tube will not be pumped during procedure to prevent masking of any change in leak signatures.

4.2 Gross leak test @ + 1 PSIG internal

- Set up He MSLD with accessory nozzle for ambient-pressure sniffing
- Assemble 1.5" metal flex line to IP pumpout valve on 6" gate trunk (this will be the exhaust)
- Arrange sufficient flex extensions to bring free exhaust outside lab environment
- Install O_2 deficiency monitor or Schweppotron™ concentration meter in exhaust line flow
- Assemble metering valve and low pressure regulator to supply He gas at 1 psig to vessel purge valve
- Open gate valve and both angle valves and purge vessel with He until exhaust monitor indicates outflow is predominantly He.
- Close exhaust (on 6" gate trunk), allowing enclosure to equilibrate at 1 psig internal pressure.
- Close inlet (pumpout valve) and remove helium source
- Ventilate the lab aggressively with fans

- Check MSLD background
- Sniff test around three o-ring joints, bottom plate assembly flange, valve bonnets, and all conflats, periodically rechecking MSLD background.
- If a leak is found, investigate and repair.
- Note: this process will saturate the o-rings with helium. The gas will persist after evacuation, degrading the subsequent fine leak check. Because we are reluctant to cycle the enclosure back to atmosphere once under vacuum, we're deliberately trading away sensitivity of the final fine leak check in order to minimize the chance of starting the pumpdown with a gross leak.

4.3 Purge enclosure with dry N_2

- Remove helium source and substitute dry nitrogen gas
- Open exhaust valves and purge enclosure thoroughly with flowing nitrogen for at least 30 minutes.
- Insure slight positive pressure (throttle the outlet) to exclude atmospheric water vapor
- Test outflow gas for residual He with MSLD sniffer; if significant He remains, continue purge.
- Close 6" gate.
- Close 1.5" angle valves.
- This process will help to clear residual He; but more importantly, it insures that if the internal leak changes during the evacuation procedure, only dry N_2 gas will enter the tube, thus minimizing any potential for damage.

4.4 Pump down

- Refer to Figure 1. All valves should be closed except V7, V9 (automatic), V1 and V4.
- Insure personnel on Y2-1 and Y1-6 SS500 stations are in clear communication.
- SS500 stations should be at nominal operation with tube isolation valves *closed*.
- Establish pressure trends:
    - PT624, PT723, PT753;
    - Both SS500 inlet CC gauges (PT978, PT964);
    - Enclosure pressure G1;
    - Enclosure scroll pump foreline pressure G3;
    - Enclosure turbo rotor speed (while operating);
    - Enclosure turbo motor current (while operating)
- Shut down unnecessary machinery, HVAC, fans etc. in midstation to reduce ambient sound.
- Start scroll pump SP1.
- Crack open pumpout valve V5 slightly and evacuate to approximately 600 Torr as reported by G1.
- Reclose V5.
- Shut down scroll pump SP1 to make lab quiet.

- Listen near vessel seals and flanges for gross leak sounds.
- Monitor G1 briefly for pressure recovery.
- If no faults are indicated, restart SP1.
- Crack V5 open to resume pumpdown at gradual rate.
- When G1 registers 200 Torr, fully open pumpout valve.
- When G1 registers 2 Torr, accelerate turbopump.

- **Fine leak test**

- After turbo reaches steady operation with foreline pressure G3 < 0.1 Torr, isolate SP1 by closing V7 and direct turbo exhaust to MSLD connected to V8.
- He leak test containment vessel seals and joints.
- If no leaks are detected, valve out MSLD by closing V8 and restore scroll pump connection by opening V7.
- After reestablishing equilibrium, briefly isolate vessel from turbo by closing V5 for a fixed period (1 to 5 minutes) to measure rate of pressure rise in enclosure.
- Restore turbo by reopening V5. Continue pumping to hard vacuum

4.5 Evaluate impact on beamtube vacuum

- Plot total gauge and RGA species partial pressures.
- Repeat residual gas spectrum measurement and compare with baseline.
- (eventually) Repeat total pressure accumulation and compare with baseline.

4.6 Transition to ion pump operation & long-term maintenance

- Note: It is hard to predict how long it will take before outgassing declines to a point where the IP can hold (and survive a reasonable length of time). We are therefore presuming we may have to maintain unattended turbo operation indefinitely.
- After gross leak test, the isolated IP can be started at any convenient time by conventonal auxiliary turbo, connected to the pumpout on the 6" gate trunk.
- The containment vessel's internal outgassing and leak rates should periodically be estimated by isolating the turbo and measuring the rate of pressure rise.
- After the rate achieves an acceptable threshold, approximately 3e-4 Tl/s, the 6" gate valve can be opened to engage the ion pump.
- When ion current and vessel pressure are observed to stabilize, the turbo/scroll pump can be isolated and shut down
- IP current and gauge pressure should be logged continuously to monitor the health of the ion pump.
- Due to likelihood of internal contamination, the IP and gauge set should be placed on a periodic maintenance/replacement schedule, irrespective of apparent performance. Extreme contamination can cause either or both to falsely indicate good vacuum, or to fail catastrophically without warning.

- The safe "hold time[2]" in event of power or equipment fault is in principle very long, assuming the internal leak conductance does not change and the containment vessel stays intact. Restoration of containment pumping is thus unlikely to pose an urgent recovery priority. However, periodic reassessment may be warranted to update leak and outgassing rates, and thus bound the worst-case hold time. If required, site emergency shutdown procedures may be updated to include relevant indications and protective measures.

[2] Defined as length of pumping interruption before the containment vessel pressure causes the embedded leak to compromise interferometer performance, water adsorption, or hydrocarbon contamination.

5 Appendix A: Related documents

G1400042	GV7 recovery team meeting, 16 Jan 2014
E1400364	LGV7 Containment Vessel Installation: Hazard Analysis
E1300891	LGV7 Leak Neutralization
D1400035	GV7 Vacuum Box Enclosure Assembly
D1400008	GNB Gate Valve Enclosure Assembly
D1400145	Flouroelastomeric annulus de-disintegrator (F.A.D.D.)

6 Appendix B: Risk assessment

In addition to nominal risks associated with operations on or near the LIGO beamtubes, to be managed in more or less conventional ways, there are peculiar risks associated with our imperfect knowledge about the leak. A summary table is provided in E1400364.

6.1 Water vapor from a triggered dump or leak acceleration

Test data indicate the internal fault is a compound leak, with diffusion through some material forming at least part of the gas impedance. Our best guess for this material is the lubricating grease from the lead screw mechanism. A viscous material like this could flow under mechanical or thermal influence[3]. Removing the existing atmospheric pressure gradient across the leak (the objective of our task) could disturb the material, perhaps dislodging a "plug" or bursting a bubble of dissolved gas[4].

Suppose that by such a mechanism, the act of evacuating the containment vessel inadvertently removes the obstruction that was, up to that point, the *dominant* gas impedance. That is, the leak conductance rises sharply from its current value (about 10^{-7} l/s), while the enclosure is still substantially at or near atmospheric pressure.

Given the enclosure volume (~ 120 liters), this event admits about 10^5 Torr-liters of air into the tube, raising the mean pressure to 2 mTorr.

At nominal ambient humidity and temperature, about 2,000 Tl of water vapor would be admitted with the air. This exceeds by a factor of five our nominal "lifetime water dose" criterion of 400 Tl per tube (T990186).

For this reason, we will limit the initial humidity inside the containment vessel. In the above procedure, we purge the housing with dry nitrogen before evacuation. This is

[3] The possibility is partly responsible for our reluctance to cut, weld, or otherwise modify the existing valve assembly, even though such restrictions complicated the containment vessel design.

[4] Indeed, Weiss observed a bubble that formed and popped, opening a "hole," during his test of grease permeation (T1400183).

expected to reduce water vapor concentration by approximately two decades. The accidental water vapor dose is thus limited to a manageable 20 Tl.

We will also eventually add ion pumps on this tube, to deal with water vapor already admitted with the mouse leak since 2008; so there is some additional margin.

6.2 Hydrocarbons

The lubricating grease and various paints, coatings and elastomers in the remnants of the valve mechanism will produce a rich spectrum of hydrocarbon molecules. Based only on the grease sample test, Weiss estimates an initial rate for ~100 AMU HC's of order 1 Tl/s, declining to .05 Tl/s after a few hours (T1400183). We don't have sufficient data to say whether the outgassing conforms to a simple power law, or how long until the source is depleted.

The initial "pulse" in the event of an accident, as for water, depends on the initial conditions. Purging the enclosure before evacuation should help here also.

In the steady state, for any given fixed gas evolution rate the fraction entering the tube will depend on the ratio of internal leak conductance to external pump conductance. The enclosure's turbo connection will conduct of order 20 l/s, whereas the ion pump net speed should be closer to 200 l/s.

Presuming constant 0.05 Tl/s evolution, the *existing* steady-state leak rate[5] would thus bleed 2.5×10^{-10} Tl/s of HC into the tube under turbo pumping, and 2.5×10^{-11} Tl/s on the ion pump.

By comparison, the beamtube outgassing *goal* for AMU 100 hydrocarbons, met at commissioning, was set at 5×10^{-18} Tl/s/cm^2 (G1100105). Integrated over the 3.1×10^{8} cm^2 tube area this corresponds to a total gas load of 1.5×10^{-9} Tl/s. Our *requirement* was relaxed by a further factor of 10^3.

However, as before, adsorption and desorption are expected to be strongly peaked near the leak, i.e., near the location of maximum phase noise impact. And again, if the leak rate increases upon evacuation, the conductance balance could change radically. Indeed, we *expect* the conductance to change eventually, since the grease will dry out with time. As a result, the apparent safety margin of less than a decade (on turbo) may be adequate, but is not overwhelming.

Anticipating this motivated us to close-couple the largest ion pump that can physically fit onto the containment vessel (even though it is vast overkill with respect to managing the original air leak). At the same time, we have to acknowledge that the ion pump can't even

[5] This is not entirely self-consistent. On one hand, in this scenario the leak itself is effectively "made of" the goo in question; on the other hand, its net permeability for 100 AMU molecules should be less than its permeability for air.

be brought online (with a reasonable forecast lifetime) until outgassing falls at least a decade below Weiss' measurement. If the observed degassing proves "stiff" and long-lived, we may consider substituting a close-coupled turbopump and/or cryotrap to replace or augment the ion pump.

Mirror contamination at the stations (2000m in each direction) due to hydrocarbon contamination is not a concern. HC molecules are expected to "stick" within a few tube diameters of where they are admitted; irrespective of such adsorption, tube conductance introduces a steep gradient for heavy molecules; and the LN_2 cryopumps afford a final protective buffer. The surviving HC flux at the interferometer optics should be some orders of magnitude smaller than the ambient HC flux due to local detector components.

7 Appendix C: Piping & Instrumentation

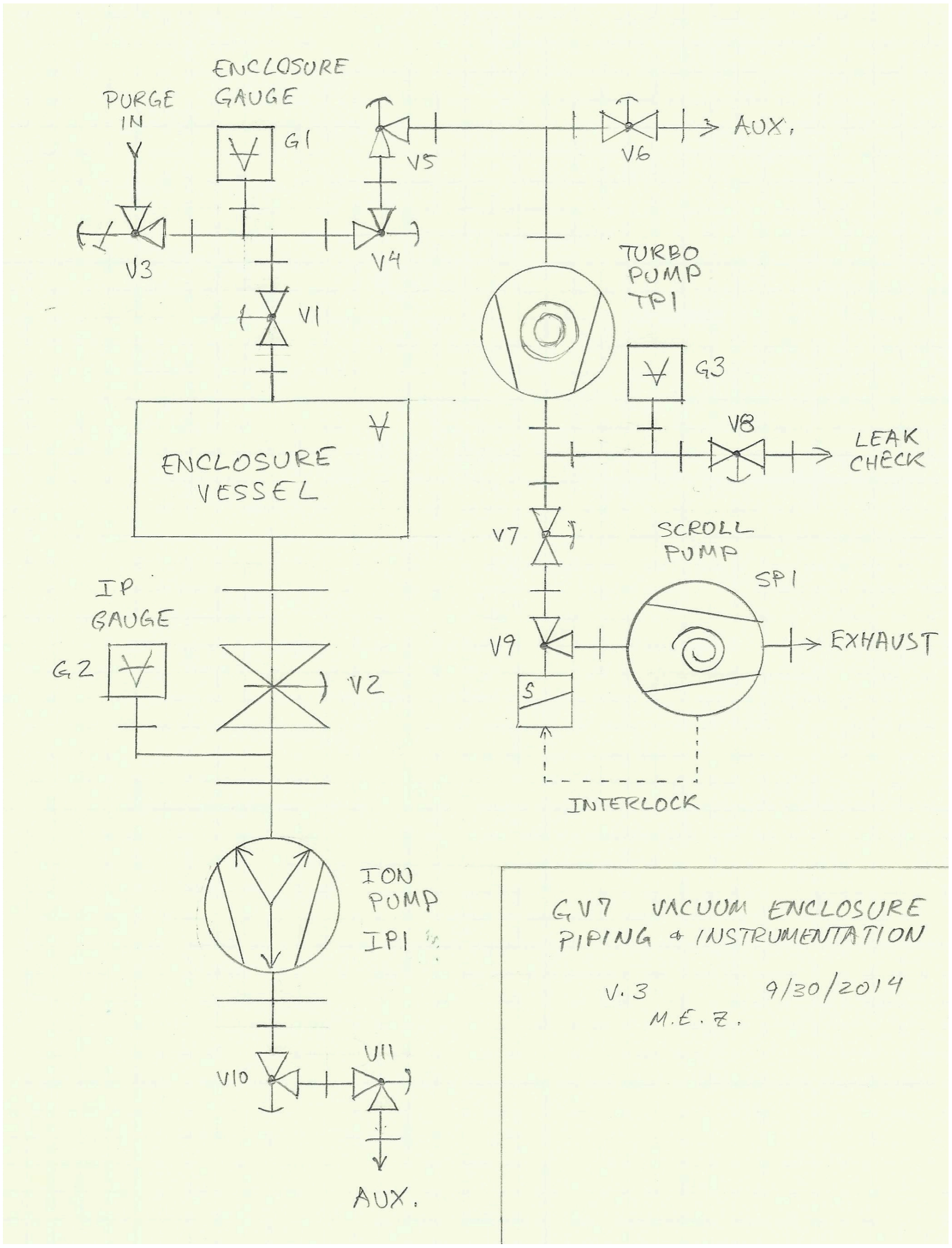


Figure 1: Piping & instrumentation schematic for LGV7 vacuum enclosure

ID	***description***	***detail***	***comments/signal***
V1	isolation valve	1.5" metal	
V2	IP gate valve	6" viton	
V3	purge metering valve	1.5" metal	
V4	pumpout valve	1.5" metal	
V5	pumpout valve (backup)	1.5" viton	
V6	aux port valve	1.5" viton	
V7	foreline valve	1.5" viton	
V8	leak check valve	1.5" viton	
V9	safety valve	solenoid NC	local interlock to SP1
V10	IP pumpout valve	1.5" metal	
V11	IP pumpout (backup)	1.5" viton	
G1	enclosure gauge	wide-range	CDS readout (P)
G2	IP gauge	wide-range	CDS readout (P)
G3	foreline gauge	pirani	CDS readout (P)
IP1	ion pump	Gamma 300I	CDS readout (I, V)
TP1	turbomolecular pump		CDS readout (OK bit)[6]
SP1	scroll pump		CDS readout (OK bit)[7]

Table 1: Equipment list (referred to Figure 1)

[6] planned (TBD)
[7] planned (TBD)

8 Appendix D: Tools and Materials

8.1 Tools & fixtures

- PPE as required
- Precision cleaning supplies
- Rigging equipment, slings & hardware
- Vacuum flange assembly tools
- Abrasive metal finishing tools
- Adhesive mixing tools
- Adhesive degassing chamber and vacuum pump
- Regulated oven for accelerated-cure epoxy mix test
- Precision balance (5 mg resolution)
- Adhesive weighing & mixing receptacles
- Adhesive syringes & needles
- O-ring trimming & welding fixture D1400145
- Precision level (Starrett #98-12 or equivalent)
- Digital caliper (Mitutoyo #500-197-20 or equivalent)
- Feeler gage set (Starrett #66T or equivalent)
- Taper gap gages (Starrett #270 and #269A or equivalents)
- Combination square (McMaster 2108A31 or equivalent)
- Die grinder[8] (DeWalt DW887 or equivalent)
- Carbide burr set (McMaster 4308A12 or equivalent)
- Magnetic drill[9] (Milwaukee 4270-20 or equivalent)
- Annular cutter set (Milwaukee 49-22-8410 or equivalent)

8.2 Materials

- Epoxy adhesive and catalyst[10]
- Viton cyanoacrylate adhesive[11]
- Threaded fasteners, nuts & washers per LIGO drawing BOM's
- Annealed copper ConFlat gaskets (8" OD, 4.62" OD, 2.75" OD CF)
- ConFlat flange hardware (8", 4.62", 2.75")
- Blank stem seal o-rings[12]
- Plastic packing tape
- Polyethylene sheet
- PVC tape
- Gaffer tape
- Stainless steel shim assortment (McMaster 97235K82 or equivalent)

[8] For 'adjusting' holes in mounting frame

[9] For 'seriously adjusting' holes in mounting frame

[10] Emerson & Cuming Stycast 2850FT and Catalyst 9 (distributed by Ellsworth Adhesives)

[11] Loctite #404, McMaster 7569A22

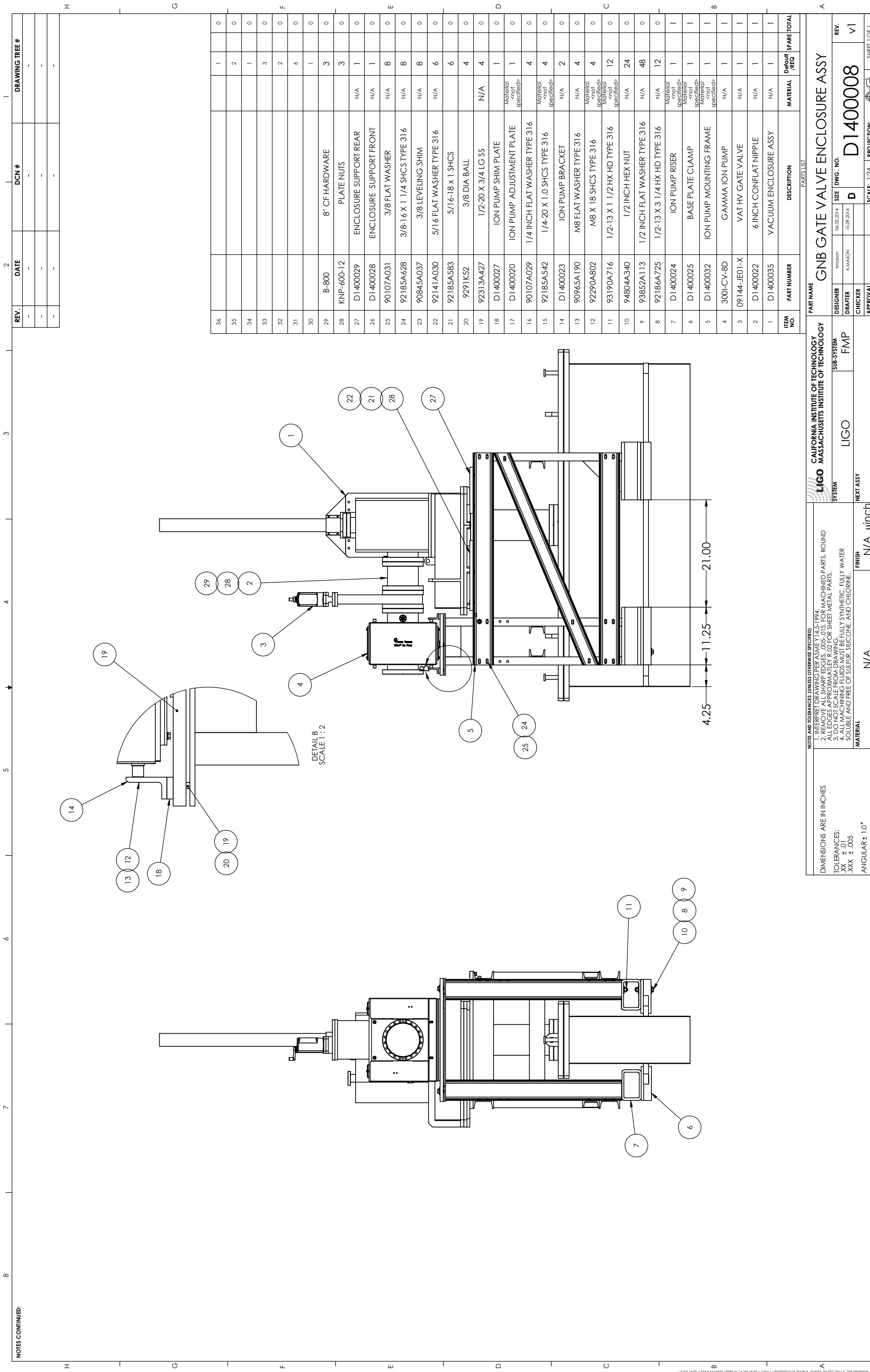
[12] AS568A--437, McMaster 9464K674, 6" ID x 1/4" nominal Viton, A75 durometer

- Plastic shim stock assortment (McMaster 9513K42 or equivalent)

8.3 Instrumentation

- He MSLD leak tester with sniffer probe accessory
- Helium supply, regulators & test valves
- GN_2 purge supply, regulators & test valves

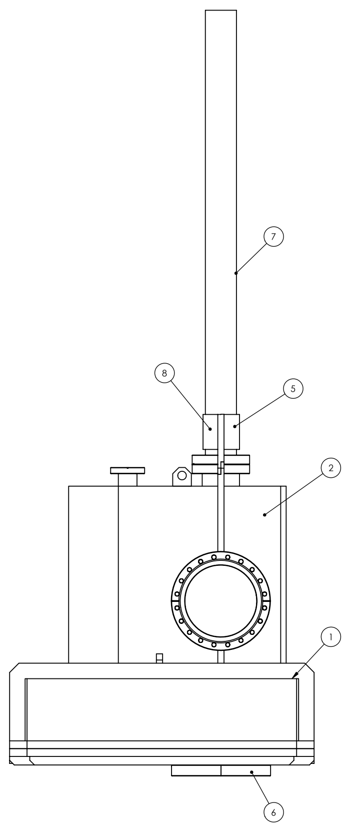
9 Appendix E: Assembly Drawings

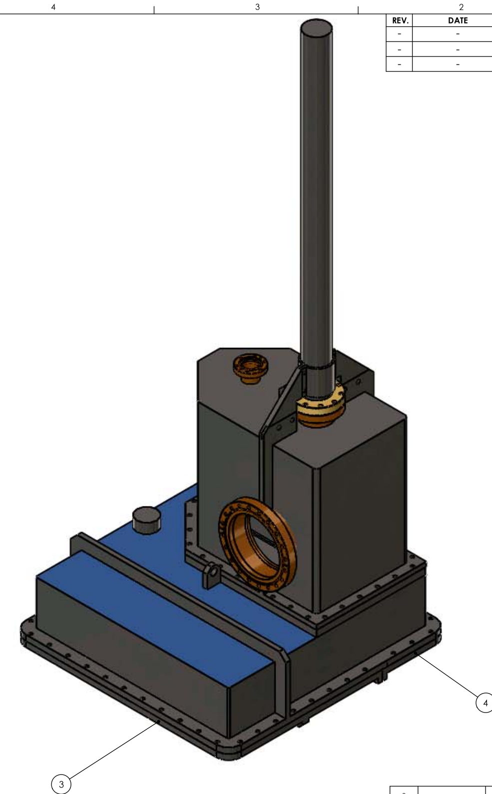


NOTES CONTINUED:

4. APPROXIMATE WEIGHT = 240.0 LBS.

REV.	DATE	DCN #	DRAWING TREE #
-	-	-	-
-	-	-	-
-	-	-	-





ITEM NO.	PART NUMBER	DESCRIPTION	MATERIAL	REQ	SPARE	TOTAL
9				2		2
8	D1400011	ball screw tube clamp bracket	AISI 304	1		1
7	D1400009	Vacuum Enclosure Ball Screw Tube Cover	AISI 304	1		1
6	D1400019	Lower Seal Plate	AISI 304	2		2
5	D1400010	Ball screw tube clamp	AISI 304	1		1
4	D1400017	Narrow Plate Positive Seal	AISI 304	1		1
3	D1400018	Bottom wide seal plate	AISI 304	1		1
2	D1400015	Vacuum Enclosure Box Cover	AISI 304	1		1
1	D1400016	Vacuum Enclosure Box	AISI 304	1		1

PARTS LIST

DIMENSIONS ARE IN INCHES

TOLERANCES:
.XX ± .01
.XXX ± .005

ANGULAR ± 1.0°

NOTES AND TOLERANCES: (UNLESS OTHERWISE SPECIFIED)

1. INTERPRET DRAWING PER ASME Y14.5-1994.
2. REMOVE ALL SHARP EDGES, .005-.015, FOR MACHINED PARTS, ROUND ALL EDGES APPROXIMATLEY R.02 FOR SHEET METAL PARTS.
3. DO NOT SCALE FROM DRAWING.
4. ALL MACHINING FLUIDS MUST BE FULLY SYNTHETIC, FULLY WATER SOLUBLE AND FREE OF SULFUR, SILICONE, AND CHLORINE.

MATERIAL: N/A

FINISH: N/A µinch

LIGO CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SYSTEM

SUB-SYSTEM

NEXT ASSY: D1400008

PART NAME: GV7 GATE VALVE VACUUM ENCLOSUR ASSY.

DESIGNER

DRAFTER: K.MASON 9.03.2014

CHECKER

APPROVAL

SIZE: D

DWG. NO.: D1400035

REV.: v2

SCALE: 1:8

PROJECTION:

SHEET 1 OF 1

D1400035-v2_VAC_vacuum box enclosure assembly, PART PDM REV: X-000, DRAWING PDM REV: