LIGO VACUUM EQUIPMENT
FINAL DESIGN REPORT
CDRL 03
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LIGO PHASE B
FINAL DESIGN
CDRL 03
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Volume IV
Vacuum Equipment Installation/Commissioning

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1.0 INSTALLATION PLAN SUMMARY

1.1 General

The installation/commissioning plan has been developed to efficiently execute the Site phase of the LIGO Vacuum Equipment contract with minimum risk to project performance goals, project schedule and personnel safety.

The installation/commissioning program will be executed under strict quality control and safety requirements. Raw materials and finished components will be protected from contamination throughout the installation and commissioning process.

As part of the Final Design effort, PSI has evaluated the installation options for the vacuum equipment system. PSI has elected to hire a general contractor to install the vacuum equipment at each site. The LIGO Vacuum Equipment systems will be installed by a site installation contractor working under PSI's direction. PSI will maintain a site supervisor at each site for the duration of the installation/commissioning program.

PSI engineering staff members will participate on a rotating basis to monitor construction activities and to validate the installation process.

During the Final Design Phase, PSI has evaluated various options for aligning the vacuum equipment to the Beam Tube centerline. PSI has hired Metrowest Engineering Co. to assist PSI in selecting laser alignment equipment and developing the required procedures. The alignment plan is detailed in the following section of this volume.

Site commissioning will be executed using PSI personnel with labor assistance from the site contractor. Each site will be commissioned in phases and acceptance of individual vacuum equipment stations is envisioned to be on a staged basis.

Detailed acceptance test procedures are included in this volume. These procedures will validate the system and equipment performance and form the basis for LIGO's acceptance of the vacuum equipment.

Prior to the start of installation at each site, a LIGO/PSI Installation Readiness Review will be held.

After the site acceptance tests are complete, an LIGO/PSI Acceptance Test Review meeting will be held to closeout the contractual requirements at each site.

1.1.1 Installation Control Plan

Planning/Scheduling

Installation plans and schedules are developed by the project manager and the site manager in conjunction with the project team.

Installation scheduling is performed on a computer software package from Primavera Systems called SureTrack Project Scheduler. SureTrack is a comprehensive project control software. It produces critical path schedules and various reports used for resource planning. The schedule is updated periodically to show status and current critical path tasks.

Installation Schedule updates will be provided to LIGO during the monthly progress meetings.

1.1.2 Technical Performance Measurements

Technical performance shall be measured during the installation/commissioning portion of Phase 'B' by the following means:

- PSI Internal Design Reviews of Installation Documentation
- PSI/LIGO Design Reviews (Installation Readiness Review)
- Initial Vessel Alignment Review
- Leak Testing Results
- Cleanliness Check Results
- Final Vessel Alignment
- Final Acceptance Testing

Each of these measures will validate the design and installation of the vacuum equipment system.

1.2 Site Material Control

Material Control at the installation site will be executed in accordance with the following documents:

V049-2-119	Contamination Control Plan
V049-2-120	Raw Material Handling Procedure
V049-2-124	Control of Non-Conformance

All material (both PSI shipped components and supplies as well as vendor shipments) received at the site will be inspected prior to acceptance. Deliveries will be inspected for shipping damage, contamination and component accuracy versus the shipping or purchase order.

Materials that are required to be identified and traceable to its source are verified at this time.

After inspections, the materials or items are tagged either "Accept" or "Reject". When they are determined to be acceptable, they are transferred to the Site Contractor. All rejected material is marked and returned to the vendor. It is not stored with the accepted project material. Discrepancy reports shall be written for all rejected material and routed to the PSI site supervisor for resolution.

Where it is necessary to maintain permanent markings or identification on materials and items, they are marked vibro-etching. All major items are visibly marked with a mark number either on the item or on an attached nameplate or tag. No marking is allowed on vacuum surfaces.

1.3 Control of Special Processes

All installation special processes (welding, cleaning, alignment, etc.), are controlled by documented procedures issued through the Document Control Department. Special processes are numbered and called out on manufacturing drawings as applicable.

All required inspections and tests are performed utilizing properly calibrated measuring and test equipment. All calibrated test equipment has calibration stickers, indicating when the calibration was done, when the next calibration is due and the initials of the person who performed the calibration. Each piece of equipment has a serial number which also appears on the calibration record for tractability to recognized National Standards.

1.4 Change Control

Controlled documents and drawings are issued from PSI's Westborough, MA, office to the site supervisor. The PSI site supervisor issues documents and/or drawings to the Site Contractor. When a new revision is issued, it is the PSI supervisor's responsibility to pickup or mark "void" the out-of-date revision and issue the latest revision. All engineering copies of documents and drawings are issued as uncontrolled copies.

It is the responsibility of the PSI site supervisor to check the working documents and drawings being used by the Site Contractor to determine if the latest revision of each is in use.

All requests for change initiated after the final design approval will be controlled by PSI procedures SOP-006-001 "Request for Change". (See Volume I)

1.5 Quality Assurance Program

It is the responsibility of the PSI site supervisor to monitor and control quality assurance during the installation/acceptance testing phase of the program.

A rotating group of home office Q.A. and engineering staff will be used to support the installation Q.A. program.

The overall Q.A. plan will be executed per V049-2-029 (See attachment).

Components and materials will be installed via detailed PSI procedures and checklists. Contractor hold points will be established to verify installation alignment, cleanliness and general workmanship.

1.6 Safety Program

The detailed safety program will be established for PSI and contractor personnel at each LIGO site. The PSI program will be instituted per PSI Procedure V049-2-023 "Safety Plan" (See attachments).

The PSI site supervisor is responsible for implementing the site safety program.

All members of the PSI project team (and associated contractors) are responsible for executing the project in a manner that minimizes risk to personnel, facilities and equipment.

1.7 Training/Qualification

As part of the LIGO Project Execution, PSI will conduct personnel training and qualification in various specialty areas for site installation personnel. The following is a list of the planned training/qualification activities:

PAW Welding Process

GTAW Welding Process

UHV Installation

Cleanroom Protocol

UHV Cleaning

Leak Checking

1.8 Schedule

The following is a summary schedule of the Vacuum Equipment Fabrication Schedule. The schedule has been timed to support the planned installation sequence.

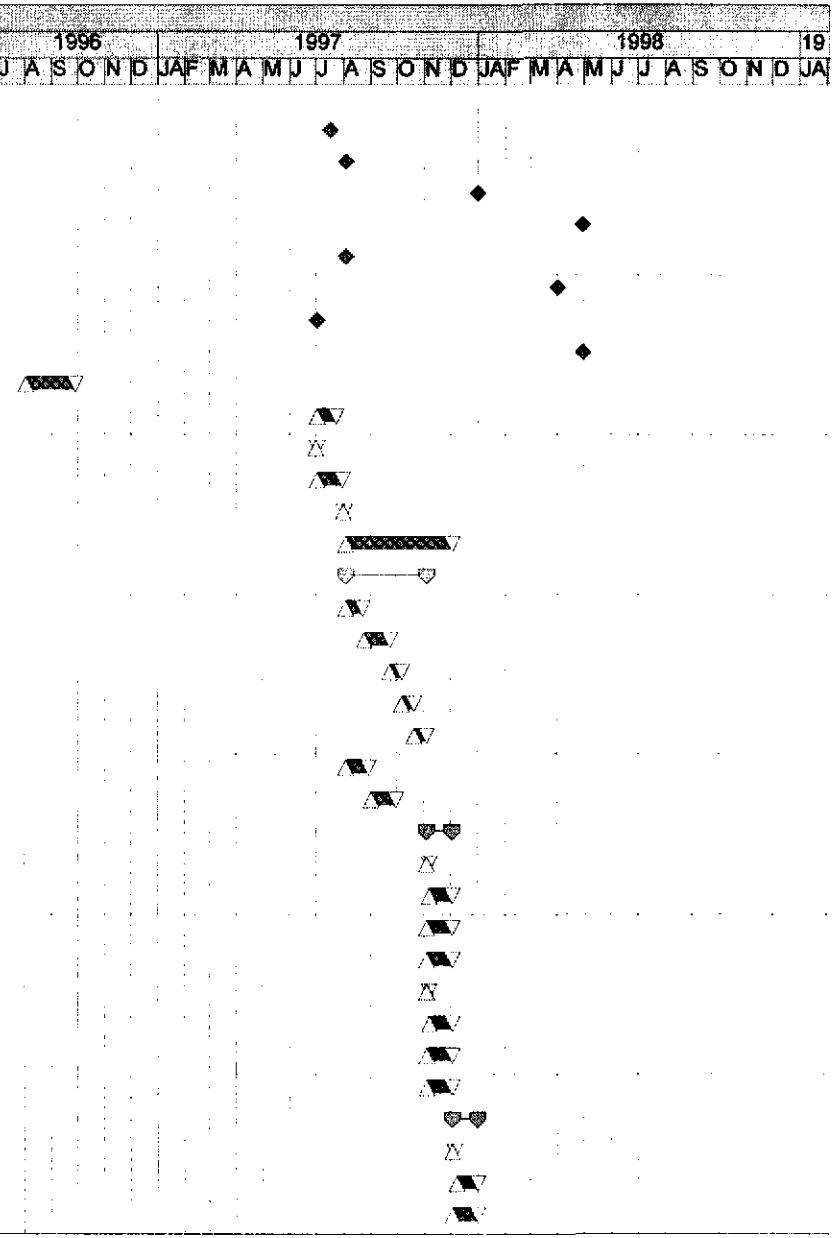
INSTALLATION/ACCEPTANCE TESTING SCHEDULE

(Sorted by Site/Activity ID)

INSTALLATION / ACCEPTANCE TESTING SCHEDULE

(Sorted by Site / Activity ID)

Act ID	Description	Orig Dur	Early Start	Early Finish	Percent Complete
Hanford, Washington Installation / Testing					
18	Delivery of Bakeout System to WA Site	0		16JUL97	0
20	Begin Installation At Washington Site	0	04AUG97		0
22	Mechanical Completion At Washington Site	0		31DEC97	0
25	Complete WA Acceptance Test Review Package	0		28APR98	0
36	Begin Installation - Washington Site	0	04AUG97		0
38	Complete Acceptance Testing - Washington Site	0		31MAR98	0
44	Installation Readiness Review - Washington	0		01JUL97	0
46	Acceptance Test Review - Washington	0		29APR98	0
798	Bid & award Washington installation subcontract	40	02AUG96	27SEP96	0
799	WA Site - Installation subcontractor mobilize	15	02JUL97	23JUL97	0
801	Conduct installation readiness review - WA site	1	01JUL97 *	01JUL97	0
802	Verify interfaces & as-built site conditions -WA	20	02JUL97	30JUL97	0
803	Joint occupancy of WA site	1	01AUG97 *	01AUG97	0
804	WA Site - Receive/store/set eqt in all stations	85	04AUG97	02DEC97	0
810	WACS installation	65 *	04AUG97	03NOV97	0
811	WACS - Offload, clean, & position all components	15	04AUG97	22AUG97	0
812	WACS - Install vertex components	20	25AUG97	22SEP97	0
814	WACS - Install right beam manifold components	10	23SEP97	06OCT97	0
816	WACS - Install diagonal components	10	07OCT97	20OCT97	0
817	WACS - Install left beam manifold components	10	21OCT97	03NOV97	0
818	WACS - Install mechancial room eqt/piping/wiring	20	04AUG97	29AUG97	0
819	WACS - LN2 supply systems installation	20	02SEP97	29SEP97	0
820	WA Arm 1 (left) - Install mid/end station eqt	20 *	04NOV97	02DEC97	0
821	Left WAMS - Offload, clean, position components	3	04NOV97	06NOV97	0
822	Left WAMS - Install components	17	07NOV97	02DEC97	0
824	Left WAMS - Install mechanical room eqt/wiring	20	04NOV97	02DEC97	0
825	Left WAMS - LN2 supply systems installation	20	04NOV97	02DEC97	0
826	Left WAES - Offload, clean, position components	3	04NOV97	06NOV97	0
827	Left WAES - Install components	17	07NOV97	02DEC97	0
828	Left WAES - Install mechanical room eqt/wiring	20	04NOV97	02DEC97	0
829	Left WAES - LN2 supply system installation	20	04NOV97	02DEC97	0
830	WA Arm 2 (right) - Install mid/end station eqt	20 *	03DEC97	31DEC97	0
831	Right WAMS - Offload, clean, position components	3	03DEC97	05DEC97	0
832	Right WAMS - Install components	17	08DEC97	31DEC97	0
834	Right WAMS - Install mechanical room eqt/wiring	20	03DEC97	31DEC97	0



Early start point
Early finish point
Early bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

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LIGO Vacuum System Project

Installation / Test Schedule 1Aof3A

Data date 01MAY96

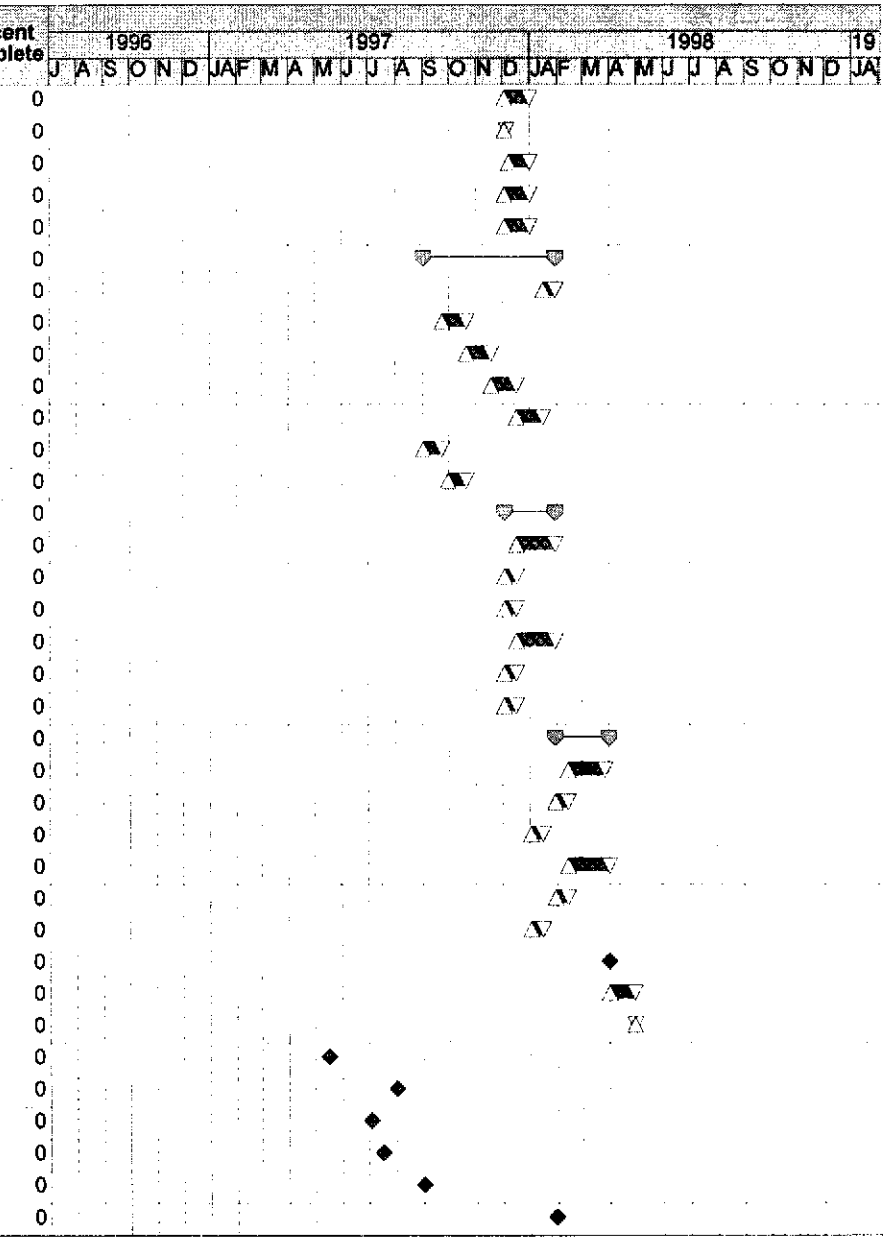
Run date 03MAY96

Filter Installation Activities Only

Layout Sort by Location

Date	Revision	Checked	Approved
03MAY96	Final Design Pkg	PFH	REB

Act ID	Description	Orig Dur	Early Start	Early Finish	Percent Complete
835	Right WAMS - LN2 supply systems installation	20	03DEC97	31DEC97	0
836	Right WAES - Offload, clean, position components	3	03DEC97	05DEC97	0
837	Right WAES - Install components	17	08DEC97	31DEC97	0
838	Right WAES - Install mechanical room eqt/wiring	20	03DEC97	31DEC97	0
839	Right WAES - LN2 supply system installation	20	03DEC97	31DEC97	0
910	WACS - Test/commission station	105 *	02SEP97	29JAN98	0
911	WACS - Complete station commissioning	10	16JAN98	29JAN98	0
912	WACS - Test/commission vertex section	20	23SEP97	20OCT97	0
914	WACS - Test/commission right beam manifold	20	21OCT97	17NOV97	0
916	WACS - Test/commission diagonal section	20	18NOV97	16DEC97	0
917	WACS - Test/commission left beam manifold	20	17DEC97	15JAN98	0
918	WACS - Test/commission mechanical room equipment	15	02SEP97	22SEP97	0
919	WACS - Test/commission LN2 supply systems	15	30SEP97	20OCT97	0
920	WA Arm 1 (left) - Test/commission mid/end sta's	40 *	03DEC97	29JAN98	0
922	Left WAMS - Test/commission station components	30	17DEC97	29JAN98	0
924	Left WAMS - Test/commission mechanical room eqt	10	03DEC97	16DEC97	0
925	Left WAMS - Test/commission LN2 supply systems	10	03DEC97	16DEC97	0
927	Left WAES - Test/commission station components	30	17DEC97	29JAN98	0
928	Left WAES - Test/commission mechanical room eqt	10	03DEC97	16DEC97	0
929	Left WAES - Test/commission LN2 supply system	10	03DEC97	16DEC97	0
930	WA Arm 2 (right) - Test/commission mid/end sta's	43 *	30JAN98	31MAR98	0
932	Right WAMS - Test/commission station components	30	13FEB98	26MAR98	0
934	Right WAMS - Test/commission mechanical room eqt	10	30JAN98	12FEB98	0
935	Right WAMS - Test/commission LN2 supply systems	10	02JAN98	15JAN98	0
937	Right WAES - Test/commission station components	33	13FEB98	31MAR98	0
938	Right WAES - Test/commission mechanical room eqt	10	30JAN98	12FEB98	0
939	Right WAES - Test/commission LN2 supply system	10	02JAN98	15JAN98	0
940	Complete acceptance testing - WA site	0		31MAR98	0
945	Prepare acceptance test report for WA site	20	01APR98	28APR98	0
946	Conduct acceptance review meeting - WA site	1	29APR98	29APR98	0
17A	WA Corner Station Major Vessel Delivery	0		16MAY97	0
17C	WA End Station Major Vessel Delivery	0		01AUG97	0
17E	WA Mid Station Major Vessel Delivery	0		03JUL97	0
17F	WA LN2 Dewars Delivery At Site	0		16JUL97	0
24A	Start Acceptance Testing At Washington Site	0	02SEP97		0
24C	Complete Acceptance Test - WA Corner Station	0		29JAN98	0



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LIGO Vacuum System Project

Installation / Test Schedule 2Aof3A

Data date 01MAY96

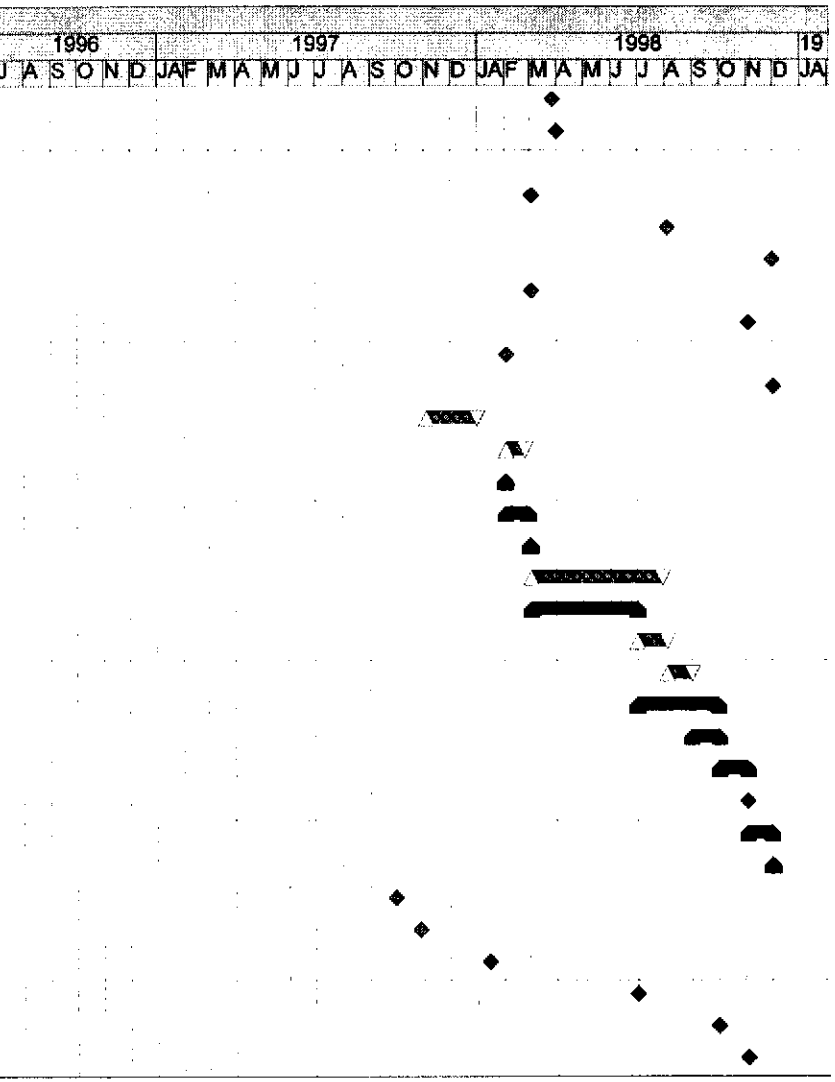
Run date 03MAY96

Filter Installation Activities Only

Layout Sort by Location

Date	Revision	Checked	Approved
03MAY96	Final Design Pkg	PFH	REB

Act ID	Description	Orig Dur	Early Start	Early Finish	Percent Complete
24E	Complete Acceptance Test - WA Mid Stations	0		26MAR98	0
24F	Complete Acceptance Test - WA End Stations	0		31MAR98	0
Livingston, Louisiana Installation / Testing					
21	Begin Installation At Louisiana Site	0	03MAR98		0
23	Mechanical Completion At Louisiana Site	0		03AUG98	0
26	Complete LA Acceptance Test Review	0		30NOV98	0
37	Begin Installation - Louisiana Site	0	03MAR98		0
39	Complete Acceptance Testing - Louisiana Site	0		02NOV98	0
45	Installation Readiness Review - Louisiana	0		02FEB98	0
47	Acceptance Test Review - Louisiana	0		01DEC98	0
848	Bid & award Louisiana installation subcontract	40	04NOV97	31DEC97	0
849	LA Site - Installation subcontractor mobilize	15	03FEB98	23FEB98	0
851	Conduct installation readiness review - LA site	1	02FEB98 *	02FEB98	0
852	Verify interfaces & as-built site conditions -LA	19	03FEB98	27FEB98	0
853	Joint occupancy of LA site	1	02MAR98	02MAR98	0
854	LA Site - Receive/store/set eqt in all stations	105	03MAR98	29JUL98	0
860	LACS installation	85	03MAR98	30JUN98	0
870	LA Arm 3 (left) - Install end station eqt	23	01JUL98	03AUG98	0
872	LA Arm 4 (right) - Install end station eqt	20	04AUG98	31AUG98	0
960	LACS - Test/commission station	64	01JUL98	30SEP98	0
970	LA Arm 3 (left) - Test/commission end station	22	01SEP98	01OCT98	0
972	LA Arm 4 (right) - Test/commission end station	22	02OCT98	02NOV98	0
980	Complete acceptance testing - LA site	0		02NOV98	0
985	Prepare acceptance test report for LA site	19	03NOV98	30NOV98	0
986	Conduct acceptance review meeting - LA site	1	01DEC98	01DEC98	0
17B	LA Corner Station Major Vessel Delivery	0		29SEP97	0
17D	LA End Station Major Vessel Delivery	0		27OCT97	0
17G	LA LN2 Dewars Delivery At Site	0		14JAN98	0
24B	Start Acceptance Testing At Louisiana Site	0	01JUL98		0
24D	Complete Acceptance Test - LA Corner Station	0		30SEP98	0
24G	Complete Acceptance Test - LA End Stations	0		02NOV98	0



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LIGO Vacuum System Project

Installation / Test Schedule 3Aof3A

Data date 01MAY96

Run date 03MAY96

Filter Installation Activities Only

Layout Sort by Location

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1.9 System Turnover

It is anticipated that Vacuum Equipment at each site will be turned over to LIGO in three phases associated with the right arm (a mid and end station), the corner station and the left arm (a mid and corner station).

Acceptance testing for the vacuum equipment is planned on a building by building basis since the vacuum equipment for each building is isolated by gate valves. After each building is performance tested and accepted by LIGO, an acceptance test report will be prepared by PSI and submitted to LIGO for approval.

PSI shall also submit an acceptance test data review package prior to the LIGO/PSI Acceptance Test Review meeting.

The test reports and Acceptance Test Review meetings will be separate for each site.

The Acceptance Test Review meeting will then be held to closeout remaining contract issues for that site.

2.0 INSTALLATION SUMMARY

2.1 General

The Vacuum Equipment will be installed by the selected site installation contractor under the direction of the PSI site supervisor.

The Vacuum Equipment installation will be scheduled and controlled to minimize possible contamination to the vacuum system.

The LIGO Vacuum Equipment installation will consist of several different phases.

1. Laser surveying and grid mapping of LVEA areas.
2. Setting of mechanical room equipment in place.
3. Setting vacuum vessels and components in place.
4. Installing and commissioning the clean air skid and cleanrooms.
5. Aligning and installation of vacuum vessels and component by section.
6. Installation of vacuum pumping systems.

Some of these activities will be accomplished in parallel to reduce the installation time.

The overall strategy is to commission the clean air systems and clean rooms as soon as possible to provide clean purge gas for vessel assemble. This will require some temporary clean air lines to be run until the fixed clean air headers can be installed.

The major vessels and components are installed and connected for each major vacuum equipment section (vertex, diagonal, etc.) first. After the vessels are installed, the piping headers and electrical systems are installed under the vessels.

The actual installation sequence is detailed in Section 3.0.

2.2 Control of Contamination

All vacuum boundary components will have been shop cleaned at PSI prior to being shipped to the site. At the site, all vacuum components will remain sealed until they are ready for installation.

Whenever vacuum boundary components are to be opened, they will be purged with Class 100 air and protected by Class 100 clean rooms. Clean room operation shall conform to V049-2-118 "Procedure for Clean Room Activities".

2.3 Vacuum Equipment Alignment

Prior to placing vacuum alignment in the LVEA areas, a detailed laser survey and grid mapping will be conducted by PSI at each station. This survey will establish accurate beam tube centerlines and offset reference lines. This survey would use monuments supplied by LIGO to accurately establish the beam line.

These reference marks will also allow PSI to set the vessels close to their final position as they are moved into the building.

A laser alignment system will be used to accurately install the vacuum beam line vessels and components. At the present time, the actual system has not been selected. A typical system which is being considered is an Euclid model 300 (see Section 7.3). This system uses a laser source, a reference target and a portable target.

Once the laser source and reference target are properly aligned, the portable target would be moved to the vessel beam tube nozzle cover (special alignment cover) to accurately align the nozzle centerline. This procedure would be repeated until all components were aligned.

The actual laser alignment procedure will be developed after the laser alignment system is selected.

2.4 Vessel Installation and Precision Alignment

PSI will use a specially built dolly system to lift and accurately position the vessels for installation. (See Section 7.2).

Once the vessel has been aligned, the floor will be marked for boring using the vessel leg anchor plates as a template. The vessel will then be rolled aside and the anchor bolt holes will be drilled. After the anchor bolts cement has cured, the vessel will be lifted over the bolts and realigned.

The special dolly system has a calibrated lift system to aide in realigning the vessel.

3.0 STATION INSTALLATION SEQUENCE

3.1 General

The vacuum system components will be installed in the following general sequence. Some activities will occur in parallel (i.e. mechanical room and LVEA laser survey) to expedite the schedule. Class 100 clean rooms will be assembled and commissioned as required to support the installation.

3.2 Corner Station Installation

3.2.1 Vertex Section

Position WCP1, WCP2, WGV5, WGV7, 2ea. BE4, and 2ea. A1.

Position spools 2ea. BE9, BE5, 2ea. B1, 2ea. B8, BE6, BE2, BE3 and A13.

Position WHAM7 and WHAM12.

Position WHAM1 and WHAM6.

Position 2ea. Mode Cleaner Tubes B2A.

Position Mode Cleaner Tubes B3A and B5A.

Position WHAM2 and WHAM3.

Position WHAM11 and WHAM10.

Position WHAM9 and WHAM8.

Position spools A13 and BE3.

Position WBSC4, WBSC8, WBSC7, WBSC3, WBSC1 and WBSC2.

Position WHAM4 and WHAM5.

Position spools 2ea A15, 2ea A3, A6, B7, B4, A12, 2ea BE2, BE3 and BE3A.

Assemble and position 2ea. BSC Clean Rooms.

Install WBSC2, WHAM4, WHAM5, WHAM6 (Anchor bolts - no grout).

Install Mode Cleaner B5 (Anchor bolts - no grout).

Install Pipe Bridge.

Install WBSC3, WGV2, WBSC7 and WGV2 (Anchor bolts - no grout).

Install WBSC1, WBSC8, WBSC4 and WGV1 (Anchor bolts - no grout).

Install WHAM3, WHAM2, WHAM1 and B3A (Anchor bolts - no grout).

Install Mode Cleaner Tube B3 to WHAM2 (Anchor bolts - no grout).

Install 2ea. BE3 at WBSC2.

Install 2ea. BE2 at WBSC2.

Install Ion pumps WIP3, WIP4 and gauges at WHAM5.

Install A3 at WBSC3 and A3 at WBSC1.

Install Ion Pumps WIP1, WPI2 and gauges at WHAM2 and WHAM5.

Install Ion gauges.

Install Roughing and Turbo pump hand valves 6" - 10".

Install Main Roughing Pumps and anchor bolts.

Install Main Turbo Pumps and anchor bolts.

Install Electrical distribution systems, Vacuum piping and Clean Air piping.

Install Vertex I/O wiring to LIGO CVS rack.

Grout all components

3.2.2 Washington Corner Station-Right Beam Manifold

Assemble and set-up portable Clean Room.

Install WCP2, WGV7, A1, and BE4 (Anchor bolts - no grout).

Install Beam Tube manifold A13, B8, B1, BE5 and B9 (Anchor bolts - no grout).

Install adapters A13, A12, B4 to WGV4 and B7.

Install 6" and 10" hand valves.

Install WRC2 and WTC2 at B7 anchor bolt to floor.

Install Electrical distribution systems, Vacuum piping and Clean Air piping.

Install Right Beam Manifold I/O wiring to LIGO CVS rack.

Install Ion gauges.

Grout all components.

3.2.3 Washington Corner Station-Diagonal Section

Assemble and set-up portable Clean Rooms.

Install WHAM9, WHAM8 and WHAM7 (Anchor bolts - no grout).

Install WHAM10, WHAM11 and WHAM12 (Anchor bolts - no grout).

Install WGV3, B4 and B6.

Install Mode Cleaners 2ea. B2A (Anchor bolts - no grout).

Install 6" hand valve at B6.

Install adapters A6 and BE3.

Grout all components.

Install Electrical distribution systems, Vacuum piping and Clean Air piping.

Install Diagonal I/O wiring to LIGO CVS rack.

Install Ion pumps WIP7 at WHAM11, WIP8 at WHAM8.

Install Ion gauges.

Install Roughing and Turbo pump hand valves 6" - 10".

3.2.4 Washington Corner Station-Left Beam Manifold

Assemble and set-up portable Clean Room.

Install WCP1 and WGV5 (Anchor bolts - no grout).

Install Beam Tube manifold between WGV5 and WBSC8 (Anchor bolts - no grout).

Install spools A1, A13, B8, B1, BE6 and B9 (Anchor bolts - no grout).

Install 6" and 10" hand valves at BE6.

Install WRC1 and WTC1 at BE6 anchor bolt to floor.

Install Ion gauges.

Install Electrical distribution systems, Vacuum piping and Clean Air piping.

Install Left Beam Manifold I/O wiring to LIGO CVS rack.

Confirm the Corner Station Oxygen monitoring system is operational (supplied by the Owner).

Grout all components.

3.2.5 Corner Station Mechanical Room

Install Main Roughing and Turbo Backing pumps.

Install Clean Air compressor (and commission A.S.A.P.)

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install condensate blow down lines.

Install Air Drier blowdown vent line.

3.2.6 Washington Corner Station LN2 Supply System Installation

Install Right Beam Manifold LN2 tank, GN2 equipment and LN2 vaporizer.

Install VJ piping to WCP2.

Pressure test LN2 system.

Install Left Beam Manifold LN2 tank, GN2 equipment and LN2 vaporizer.

Install VJ piping to WCP1.

Confirm the Corner Station oxygen monitoring system is operational. (Supplied by owner).

Pressure test LN2 system.

Commission and test WCP1.

3.2.7 Corner Station Laydown Area Requirements

Equipment laydown areas to support the Corner Station equipment installation activities will be needed outside of the Large Item Access Airlock on the north side of the LVEA. This area will run west to east. The approximate size is (later).

Incoming equipment will be positioned in a manner which will not encumber access to the LVEA, LN_2 system or other site activities in this area.

3.3 Right Mid Station Installation

3.3.1 Vacuum Vessels

Assemble and install portable clean room.

Install WBSC5 (Anchor bolts - no grout).

Install WCP5 (Anchor bolts - no grout).

Install WCP6 and BE4 (Anchor bolts - no grout).

Install 10" hand valve.

Install WGV14 and spools A1, A7.

Install spool BE4 between WCP5 and WGV13.

Install WGV15 and spool A14.

Install WIP10.

Install pump carts and anchor bolt.

Install Ion gauges.

Install Electrical distribution systems, Vacuum piping and Clean Air piping.

Install Right Mid Station I/O wiring to LIGO CVS rack.

Grout all components.

3.3.2 Right Mid Station Mechanical Room

Install and Turbo Backing pumps.

Install Clean Air compressor.

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install condensate blow down lines.

Install Air Drier blowdown vent line.

3.3.3 Right Mid Station LN_2 Supply Systems

Install Right Mid Station LN2 tanks, GN2 equipment and LN2 vaporizers.

Install VJ piping to WCP5 and WCP6.

Confirm the Right Mid Station oxygen monitoring system operational.

Commission LN2 systems.

Commission and test WCP5, WCP6.

3.3.4 Right Mid Station Laydown Area Requirements

Equipment laydown areas to support the Right Mid Station equipment installation activities will be needed outside of the Inspection/Shipping/Receiving area on the east side of the Right Mid Station. This area will run south to north. The approximate size is (later).

3.4 Left Mid Station Installation

3.4.1 Vacuum Vessels

Assemble and install portable clean room.

Install WBSC6 (Anchor bolts - no grout).

Install WCP3 (Anchor bolts - no grout).

Install WCP4 (Anchor bolts - no grout).

Assemble and install portable clean room.

Install spools and WGV10.

Install spool A1 between WGV9 and WCP3.

Install spool A14 and WGV11.

Install spool BE4 between WCP4 and WGV12.

Install WIP9.

Install hand valves.

Install pump carts.

Install Ion gauges.

Install Electrical distribution systems, Vacuum piping and Clean Air piping.

Install Left Mid Station I/O wiring to LIGO CVS rack.

Grout all components.

3.4.2 Left Mid Station Mechanical Room

Install Turbo Backing pumps.

Install Clean Air compressor.

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install condensate blow down lines.

Install Air Drier blowdown vent line.

3.4.3 Left Mid Station LN_2 Supply Systems

Install Left Mid Station LN_2 tanks, GN_2 equipment and LN_2 vaporizers.

Install VJ piping to WCP3 and WCP4.

Confirm the Left Mid Station oxygen monitoring system operational.

Commission LN_2 systems.

Commission and test WCP3 and WCP4.

3.4.4 Left Mid Station Laydown Area Requirements

Equipment laydown areas to support the Left Mid Station equipment installation activities will be needed outside of the Inspection/Shipping/Receiving area on the south side of the Left Mid Station. This area will run west to east. The approximate size is (later).

3.5 Right End Station Installation

3.5.1 Vacuum Vessels

Assemble and install portable clean room.

Install WCP8 (Anchor bolts - no grout).

Install WBSC9 (Anchor bolts - no grout).

Install WGV20 and spools A1, A7.

Install spool BE4 between WCP8 and WGV19.

Install hand valves.

Install pump carts anchor bolt.

Install WIP12.

Install Ion gauges.

Grout all components per specification.

Install Electrical distribution systems, Vacuum piping and Clean Air piping.

Install Right End Station I/O wiring to LIGO CVS rack.

3.5.2 Right End Station Mechanical Room

Install and Turbo Backing pumps.

Install Clean Air compressor.

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install condensate blow down lines.

Install Air Drier blowdown vent line.

3.5.3 Right End Station LN_2 Supply System

Install Right End Station LN2 tank, GN2 equipment and LN2 vaporizer.

Install VJ piping to WCP8.

Confirm the Right End Station Oxygen monitoring system operational.

Commission LN2 system.

Commission and test WCP8.

3.5.4 End Station Laydown Area Requirements

Equipment laydown areas to support the Right End Station equipment installation, activities will be needed outside of the Inspection/Shipping/Receiving area on the east side of the Right End Station. This area will run south to north. The approximate size is (later).

3.6 Left End Station Installation

3.6.1 Vacuum Vessels

Assemble and install portable clean room.

Install WBSC10 (Anchor bolts - no grout).

Install WCP7 (Anchor bolts - no grout).

Assemble and install portable clean room.

Install spool A1 and WGV18.

Install spool BE4 between WCP7 and WGV17.

Install WIP11.

Install hand valves.

Install pump carts anchor bolt.

Install Ion gauges.

Install Electrical distribution systems, Vacuum piping and Clean Air piping.

Install Left End Station I/O wiring to LIGO CVS rack.

Grout all components.

3.6.2 Left End Station Mechanical Room

Install Turbo Backing pumps.

Install Clean Air compressor.

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install blow down lines.

3.6.3 Left End Station LN_2 Supply System

Install Left End Station LN_2 tank, GN_2 equipment and LN_2 vaporizer.

Install VJ piping to WCP7.

Confirm the Left End Station oxygen monitoring system operational.

Commission LN_2 system.

Commission and test WCP7.

3.6.4 Left End Station Laydown Area Requirements

Equipment laydown areas to support the Left End Station equipment installation activities will be needed outside of the Inspection/Shipping/Receiving area on the south side of the Left End Station. This area will run west to east. The approximate size is (later).

3.7 Grouting Requirements

Base plate grout shall be the flowable type and it shall meet with the requirements of ASTM C1107 for nonshrink, nonmetallic grout.

Tests required by other applicable ASTM specifications shall be performed including strength tests.

The minimum grout strength shall be 7000 psi at 28 days.

Acceptable grout products are:

1. Five Star Grout - manufactured by: Five Star Products.
2. Masterflow 928 - manufactured by: Masterbuilders
3. Masterflow 713 - manufactured by: Masterbuilders

Application:

The undersides of all base plates shall be clean and the concrete surface be clean and dampened prior to placing grout.

Grout shall be mixed, placed and cured in accordance with the manufacturers instructions.

Curing shall continue for a minimum of 7 days.

Grout test and QC inspection reports shall be provided to the Owner.

3.8 Vessel and Component Laser Alignment

All vessels and components will be aligned in accordance with Laser Alignment Procedure (later).

3.9 Anchor Bolt Installation

All anchor bolts will be installed in accordance with Anchor Bolt Installation Procedure V049-1-101.

4.0 COMMISSIONING SUMMARY

4.1 General

The vacuum equipment commissioning program will be scheduled and controlled to minimize possible contamination to the vacuum system. PSI personnel will execute the commissioning program with labor support from the site contractor.

Some components (ion pumps, roughing and turbo pumps, etc.) will have been performance tested at the vendors facility prior to shipment. Vacuum vessels, spools, mode cleaner tubes, etc. will have been vacuum leak tested at PSI prior to shipment and will have met LIGO requirements. These tests will not be repeated at the site.

The clean air systems and the Class 100 clean rooms will be commissioned first to provide contamination control for the installation of vacuum components.

As each isolatable section is mechanically completed, commissioning will commence on that section. Annulus systems will be pumped down and their vacuum integrity verified. The roughing headers will be partially installed and capped to allow initial pumpdown of the first isolatable section.

As each new isolatable section is completed, the vacuum headers will be extended and the electrical systems installed. The newly completed section will then be initially pumped down.

By using a three point laser system (source, portable target, and reference target) the source can be moved to the end of the completed isolotable section (and aligned on the beam centerline). This allows the gate valves to remain closed for initial pumping of the completed section while still allowing alignment of new components.

Section 5.0 provides summaries of each acceptance test. The detailed acceptance test procedures for each component and system are included in the attachments to this volume.

4.2 Control of Contamination

All vacuum boundary components will have been shop cleaned at PSI prior to being shipped to the site. At the site, all vacuum components will remain sealed until they are ready for installation.

Whenever vacuum boundary components are to be opened, they will be purged with Class 100 air and protected by Class 100 clean rooms. Clean room operation shall conform to V049-2-118 "Procedure for Clean Room Activities".

4.3 Acceptance Testing

Formal LIGO Acceptance Testing will be done on a station by station basis for each site. The Acceptance Test (and signoffs) will be executed as detailed in each component and system test procedure (see Attachment 18 and 19).

After testing, acceptance test reports will be prepared and submitted. In addition, an Acceptance Data Review Package will be submitted for review.

The LIGO/PSI Acceptance Test Review meeting will then be held to closeout remaining contract issues.

5.0 ACCEPTANCE TESTING

This section details how each major LIGO component and system will be acceptance tested.

Some components (ion pumps, roughing and turbo pump, etc.) are performance tested at the vendors facility. Vacuum vessel and tube sections have been vacuum leak tested at PSI and have met LIGO requirements. These tests will not be repeated during site testing.

The actual component and station acceptance test procedures are included as attachments to this volume.

The following is a summary of the acceptance test plan.

5.1 Component Acceptance Tests

5.1.1 Chamber and Tube Section Leak Test Plan

Chambers (BSC, HAM, 80K) and tube sections will have been shop tested at PSI and will have met LIGO's component leakage requirement (less than 1×10^{-9} torr - l/s of helium) prior to arriving at the site. These tests will not be repeated during site acceptance testing (unless a vessel leak has developed during shipment). O-ring joints that have been made in the field will be tested (via pumpdown) as part of the isolatable section testing.

5.1.1.1 Prerequisites

The individual vacuum enclosures have completed their manufacturing cycle and have been cleaned ,baked, factory leak tested, sealed and evacuated for shipment. O-ring annulus volumes are back filled with pure nitrogen gas and valved off. The unit is then wrapped and packaged for shipment.

Upon arrival at the installation site, the unit will be visually inspected for any shipping damage or vacuum seal disturbance that may have occurred during transit. The vacuum level in the chamber is then measured and compared to the pre-shipment levels. The measured vacuum level in the chamber will be corrected for expected o-ring permeation. The pressure level in the o-ring annulus will also be measured. If the measured pressure levels in the chamber or annulus indicate that a leak has opened up during transit, the unit will be leak checked and repaired at or near the site.

5.1.2 Vacuum Pump Acceptance

Acceptance tests for the Main Roughing, Main Turbomolecular, and Auxiliary Turbomolecular vacuum pumps will be performed at the Edwards High Vacuum Inc. (EHVI) factory located in Grand Island, N.Y. EHVI is ISO 9001 certified and the vacuum systems for the LIGO project are designed and manufactured in accordance with the documentation and quality assurance programs required by ISO9001.

Each vacuum system will be acceptance tested prior to shipment. In addition to quality, workmanship, and dimensional inspections, the systems are tested for pumping speed, ultimate pressure, leakage, and operation of protective features.

5.1.2.1 Main Roughing (Ref. Specification V049-2-001 Rev. 3)

The Main Roughing system's individual vacuum pumps will be atmospheric air speed tested by EHVI at the point of manufacture in the U.K. A test certificate is provided with each pump. Main Roughing system functional tests will be done at EHVI's Grand Island, N.Y. facility. The minimum required pumping speed at 1 torr = 236 l/s, at 0.1 torr = 472 l/s. The roughing pump set must be capable of evacuating a volume of 200 cubic meters from atmosphere to 1 torr in 4 hours or less. The Main Roughing Pumps are designed for continuous duty service at full load and will pump down a 2000 cubic meter volume from atmosphere to 1 torr without overheating.

5.1.2.2 Turbo Pumps

The Main and Auxiliary turbomolecular pump systems are speed tested in accordance with American Vacuum Society AVS 4.1; Recommended procedure for measuring pumping speeds as revised in October 1986. The speed test is performed across the normal working range of the turbomolecular pump, from $1x10^{-6}$ torr to $1x10^{-3}$ torr.

5.1.2.2.1 Main Turbomolecular Pump Sets (Ref. Specification V049-2-002 Rev. 4)

The minimum required pumping speed at the inlet port of the Main Turbo pump = 1400 l/s N2 at an inlet pressure = $1x10^{-3}$ torr. The minimum required backing pump throughput = 5 torr-l/s with a backing pressure = 1 torr. The Main Turbo Pump sets are designed for continuous duty service at full load and will pump down a 2000 cubic meter volume from 1 torr to $1x10^{-6}$ torr without overheating.

5.1.2.2.2 Auxiliary Turbomolecular Pump Sets (Ref. Specification V049-2-003 Rev. 3)

The minimum required pumping speed at the inlet port of the Auxiliary Turbo pump = 50 l/s N2 at an inlet pressure = $1x10^{-3}$ torr. The Auxiliary Turbo pump set will be speed tested per AVS 4.1 procedure.

5.1.2.3 Ion Pumps

5.1.2.3.1 Main Ion Pumps

a. Check for physical damage to the pump, controller and HV cables.

b. Prior to pump installation, verify that it still is under vacuum.

c. After pump installation, vacuum leak check it with isolation valve closed. Refer to PSI leak test procedure V049-2-067.

d. Install the controller, hook up control wires and HV cable(s) to the controller and feedthru(s). Then test controller functionality and all interlocks.

e. Speed test as documented in Specification V049-2-004 will be performed at the factory for only the first manufactured ion pump.

5.1.2.3.2 Annulus Ion Pumps

Refer to Section 5.1.2.3.1 (Main Ion Pumps).

5.1.3 Valves

5.1.3.1 Large Gate Valves (Refer to Specification V049-2-107)

The large gate valves will be acceptance tested at the manufacturer's shop prior to shipment.

All valves will be inspected for dimensional conformance to approved assembly drawings. Each valve will be inspected for cleanliness by black light. Valves will be recleaned if any contamination is found.

Each valve will be functionally tested. Prior to final gate seal leak testing, operation of each valve for 20 cycles will be demonstrated. The valves will be shown to be capable of stroking in either direction in 5 minutes or less.

Each valve shall be tested for leakage (using oil-free pumping equipment and leak detector) prior to shipment from the manufacturer. Each valve will be baked at 150 C prior to leak checking. For dual gate seals and end seals, each seal will be individually tested. For the end seals, the Vendor's test fixture will allow testing of each seal individually. An RGA with calibrated leak will be used in performing the leak testing. Partial pressures of hydrocarbons greater than 2.0×10^{-10} Torr for any species will be cause for rejection. Body and flange leakage will be measured to be less than 10^{-10} torr liter/sec of helium before shipment. Leak checking procedures will conform to ASTM E498.

One valve of each size and type of actuation will be tested for shock. The valve will be tested in the vertical position resting on a pad that deflects at least 0.1" under the static load of the valve, so as not to simulate a "hard mount". Testing will be done both at atmospheric pressure and with the valve under vacuum. An accelerometer will be mounted near a connecting flange (or weld stub) on the valve housing or near the edge of one of the flange covers. Separate measurements will be taken in each of the three axes. Valve actuation will be shown to induce no more than 0.01g peak-to-peak acceleration at any point on the valve mounting flanges or weld stubs.

The following documentation will be provided prior to shipment:

- Leak test procedure and report (including data).
- Shock test procedure and report (including data)
- Manufacturer's standard QA reports (including final functional test reports)

5.1.3.2 6", 10" and 14" Gate Valves (Refer to Specification V049-2-108)

Each valve will be inspected for cleanliness by black light. Valves will be recleaned if any contamination is found.

All 6", 10" and 14" gate valves will be leak tested (using oil-free pumping equipment and leak detector). An RGA with calibrated leak will be used in performing the leak testing. Leak checking procedures will conform to ASTM E498. Valve body and flange total leakage will be measured to be less than 10^{-10} torr liter/sec of helium before shipment. Gate seal leakage will be shown to be less than 1x 10^{-9} torr liter/sec of helium.

One valve of each size and type of actuation will be tested for shock. The valve will be tested in the vertical position resting on a pad that deflects at least 0.1" under the static load of the valve, so as not to simulate a "hard mount". Testing will be done both at atmospheric pressure and with the valve under vacuum. An accelerometer will be mounted near a connecting flange on the valve housing or near the edge of one of the flange covers. Separate measurements will be taken in each of the three axes. Valve actuation will be shown to induce no more than 0.01g peak-to-peak acceleration at any point on the valve mounting flanges.

The following documentation will be provided prior to shipment:

- Leak test procedure and report (including data).
- Shock test procedure and report (including data).
- Manufacturer's standard QA reports (including final functional test reports).

5.1.3.3 Other Small Valves (Refer to Specification V049-2-111)

Each valve will be inspected for cleanliness by black light. Valves will be recleaned if any contamination is found. The vendor's standard inspections will be performed.

All 6", 10" and 14" gate valves will be leak tested (using oil-free pumping equipment and leak detector). The vendor's standard leak checking procedures will be used. Valve body and flange total leakage will be measured to be less than 10^{-9} torr liter/sec of helium before shipment, or less if the vendor's standard is lower. Gate seal leakage will be shown to be less than 1x 10^{-9} torr liter/sec of helium, or less if the vendor's standard is lower.

The manufacturer's standard QA reports (including final functional test reports) will be submitted.

5.1.4 80K Cryopump System Site Acceptance Test

5.1.4.1 80K Pump Field Joint Leak Test

The specification requires all leaks greater than $1x10^{-9}$ torr-l/s of helium to be repaired in accordance with LIGO approved procedures. Prior to shipment to the site, the 80K pump will have been leak checked and all objectionable leaks will have been repaired. Fabrication Test Plan V049-2-129 describes the method by which this is done for the cryopump reservoir. Leak checking of the cryopump vacuum vessel and all joints and flanges on cryopump which are assembled in the field will be leak checked per the methods described in V049-2-014.

5.1.4.2 LN2 Dewar, Regeneration Heater, and Cryopump Site Acceptance Tests

Detailed plans have been developed for field acceptance tests of each of these systems. They are to be found in document number V049-2-102.

5.1.5 Clean Air Supplies (Refer to Specification V049-2-109)

Each compressor system will be functionally tested. A comprehensive operational test plan will be developed and used to demonstrate proper operation of the compressors. Tests will include normal operation plus simulation of unusual events (component failure, etc.) to ensure that individual skid controls bring the system to a safe condition.

For one of each size system, the delivered flowrate will be shown to be at least 50 CFM or 200 CFM, the dewpoint shown to be no higher than -60 C (at atmospheric pressure), and hydrocarbon content shown to be no higher than the ambient air. In addition, a particle count of the delivered air will be taken to confirm that it conforms to Class 100. (As part of the system acceptance in the field, the hydrocarbon content and particle count will be repeated to confirm cleanliness of the installed piping system.

5.1.6 Portable Soft-Wall Cleanrooms (Refer to Specification V049-2-110)

One of each size portable cleanroom will be fully assembled at the manufacturer's shop. It will be inspected for dimensional specifications and the presence and proper operation of the windows to seal to the beam tube or nozzles, and to the BSC dome. Rigidity of both the frame and of the removable ceiling unit will be verified. The operation of the sealing system used to mate two cleanrooms together will be checked.

The cleanroom will be operated and certified to produce a Class 100 environment.

A system assembly and operating manual will be provided.

5.1.7 Bakeout System Blankets And Carts

a. All bakeout carts will be tested per PSI fabrication specification V049-2-068 prior to shipment to the site.

b. All blankets will be tested for operation and performance at PSI during bakeout of all vacuum vessels.

Vacuum vessels will be cleaned, baked out, evacuated, and sealed prior to shipment to the site.

5.2 System Acceptance Testing

5.2.1 Isolatable Section Leakage Testing

Individual vacuum components are assembled into isolated sections which will be leaked checked as an independent volume. The procedures used to leak check the isolated sections are similar to the procedures used for individual components and in general follow the guidelines of ASTM E498.

Each isolated section has basically two types of vacuum volumes; the main chamber volumes and the annulus volume between the dual o-ring seals. The annulus systems will be leak checked by pumping down each annulus system as it is completed. If the annulus pumps down in the calculated time frame, significant leaks are not present.

The main vacuum sections will be leak tested using an air signature test. The test criteria is given in leak testing procedure V049-2-014. If an unacceptable leak rate is detected, the section will be leak checked in accordance with leak check procedure V049-2-14.

5.2.2 Pumpdown Time and Ultimate Pressure

The Pumpdown and ultimate pressure tests is performed on the largest isolatable section with an 80K pump. In the case of the Washington corner station the isolatable sections would be: 1. The Vertex section with one of the Beam Manifolds, and 2. The Diagonal section with one of the Beam Manifolds. In the case of the Louisiana corner station the isolatable section would be the Vertex section with one of the Beam Manifolds. The End/Mid stations have only one isolatable section. Before a pumpdown/ultimate pressure test is performed, the sections that make up the largest isolatable section must be baked.

5.2.2.1 Annuli Pumpdown

The annuli on the flanges will have been pumped during installation for leak checking. Any remaining flange annuli at atmosphere will be pumped prior to start of bakeout.

5.2.2.2 Vacuum Equipment

The roughing carts, and main turbomolecular pumping system and main ion pump system will have been tested already. The main ion pumps will be evacuated and baked after installation onto the vacuum envelope with their isolation valve closed. The main ion pumps will then be started to ensure proper operation.

5.2.2.3 Residual As Analysis Prior To Bakeout

Data will be taken prior to start of bakeout as a reference for checking outgassing rates/leaks after the bakeout.

5.2.2.4 System/Isolatable Section Bakeout

The bakeout system will be installed on the isolatable section and the section will be baked out according to the bakeout procedures. Prior to the start of bakeout the system will be evacuated using the roughing system. The main turbomolecular cart will be used to pump on the isolatable section during the bake.

The isolatable section will be heated to 150°C and soaked for 48 hours at 150°C±20°.

Cooldown of the system will be carried out with the heating system operating to maintain temperature uniformity. This is done by ramping down the setpoints to ambient temperature.

Since the pumpdown tests will be carried on a isolatable section with a 80K cryopump, the beam manifold section will also need to be baked prior to vacuum pumpdown tests in the case of the corner stations. Execute bakeout for other sections as required.

5.2.2.5 Residual Gas Analysis After Bakeout And Cooldown

With the system baked and cooled down, a residual gas analysis will be carried out to determine the presence of any air leaks and cleanliness of the system.

5.2.2.6 Backfill with dry nitrogen

The system will be back filled with dry nitrogen (grade 0, to avoid hydrocarbon contamination) prior to vacuum pumpdown test.

5.2.2.7 Pumpdown Of Isolatable Section With 80K Cryopump

Corner Station: **Vertex & Beam Manifold**

Once two isolatable sections, a vertex section and beam manifold section have been baked and backed filled, the vacuum pumpdown test can be initiated.

End/Mid Station: **There Is Only One Isolatable Section.**

5.2.2.7.1 Pumpdown From Atmosphere To 0.1 Torr Using The Roughing System

Corner Stations:

The isolatable section will be pumped using one main roughing system to a pressure below 0.1 torr. The requirement is to be able to turn on the turbo pump in less than four hours. Acceptance will be when a pressure of 0.1 torr is reached in less than 4 hours and the roughing system can be turned off and the turbo pump can be turned on.

End/Mid Stations:

The isolatable section will be pumped using the backing pump of the main turbo pump to a pressure of 0.2 torr. Acceptance will be when a pressure of 0.2 torr is reached in 15 hours and when the turbo pump can be turned on.

5.2.2.7.2 Pumpdown From 0.1 Torr To 10^{-6} Torr Using The Main Turbomolecular System

Corner Stations:

The isolatable section will be pumped using two main turbomolecular pump system. to a pressure of less than $5x10^{-6}$ torr. Acceptance will be when the pressure of less than $5x10^{-6}$ torr is reached in 24 hours.

End/ Mid Stations:

One main turbomolecular pump system is used to pump the isolatable section to a pressure of less than $5x10^{-6}$ torr. The pumps will be started once a pressure of 0.2 torr has been reached. Acceptance will be when the pressure of less than $5x10^{-6}$ torr is reached in 24 hours.

5.2.2.7.3 80K Cryopump

The cryopump will be turned on when a pressure of less than $5x10^{-6}$ torr has been reached. To minimize cryotrapping of CO_2, the cryopump should be cooled down as late as possible.

5.2.2.7.4 Main Ion pumps.

The main ion pumps will be turned on after the cryopump is cold and has been pumping for several hours. (Between 24 hours to 30 hours into the pumpdown).

5.2.2.8 Ultimate Pressures after 100 hours.

The isolatable section shall attain a total pressure of $2x10^{-8}$ torr, measured at the ion pumps after 100 hours of pumping. The partial pressure shall be measured with an RGA at an main ion pump pumpout port. If the hydrogen content of the steel prevents the attainment of this value, then the total pressure of the gasses, other than H_2 and H_2O shall not exceed $6x10^{-9}$ torr.

The partial pressure goals of the following gasses shall be adjusted to reflect results that are consistent with the prototype chamber and design margins required for reliable implementation, but shall not be less than shown in the following table.

Table 5.2.2.8

Gas Species	Partial Pressure Goals Torr	Partial Pressure Acceptance Torr
H_2O	$5 X 10^{-9}$	
H_2	$5 X 10^{-9}$	
Total H_2O, H_2	**$1 X10^{-8}$**	
N_2	$5 X 10^{-10}$	
CO	$5 X 10^{-10}$	
CO_2	$2 X 10^{-10}$	
CH_4	$2 X 10^{-10}$	
All others	$5 X 10^{-10}$	
Total other	**$1.9 X10^{-9}$**	**$6X10^{-9}$**
Total	**$1.2 X10^{-8}$**	

Partial pressure of H_2O is expected to be higher at the ion pump because the ultimate pressure calculation is based on pressure of water at the cryopump. It is proposed to measure the partial pressure of water near the inlet of the cryopump.

5.2.3 Interface To The CDS

All CDS cabinets are supplied and installed by LIGO. PSI will terminate all VE instruments and other system interlocks as shown on PSI electrical drawings. CDS cabinet locations are shown on the following drawings:

V049-3-123 (4 sheets)

V049-3-108 (2 sheets)

V049-3-308 (2 sheets)

V049-3-408 (1 sheets)

V049-3-508 (1 sheets)

Acceptance test for instrument loops and other wiring installed by PSI and terminated in the CDS's, will be performed as follows:

a. Check point to point continuity of each conductor to insure that wiring is intact and terminated at the proper place at both ends.

b. Verify wire connections are made in accordance with terminal wiring diagrams and schedules.

c. Using highlighter (transparent marker), indicate on terminal wiring diagram sheets that each wire and connection has been verified. These sheets will be made available to the buyer.

d. Replace defective wiring and retest.

e. Additional testing requirements are listed in V049-2-022 (Electrical and Instruments Construction Work).

6.0 VIBRATION/NOISE/SHOCK MEASUREMENT

6.1 General

In order to evaluate the effectiveness of the first order remediation measures designed into the vacuum equipment, direct measurements of noise, shock, and vibration will be conducted at the LIGO sites during the commissioning process. The LIGO specification has identified the HAM and the BSC chambers as locations where shock and vibration response are important. These tests have been included as part of the System Acceptance Test Plans for the corner, mid, and end stations (document numbers V049-2-113, -114. and -115). The measurements are informational only however, and may be used to develop measures to improve performance should LIGO deem that it is necessary or desirable to do so. Further details of the tests may be found in the referenced documents.

6.2 Vibration Measurements

Specialized research accelerometers will be used (Wilcoxon models WR731A and WR 916BTO-1) to measure vibration amplitudes at the HAM and BSC chambers. While it appears from manufacturer's data that they are sensitive enough to measure acceleration amplitudes below specification compliance limits above 10 Hz, electronic noise from the measuring equipment or ambient vibration may reduce the accelerometer sensitivity. For this reason, the vibration measurements should be viewed as complementary to the analytical models.

6.3 Noise Measurements

Cambridge Acoustical Associates has done some acoustical modeling of the interferometer end station for preliminary predictions of compliance with the LIGO specification with respect to noise (NC-20 at any location within the vacuum equipment and laser areas). This preliminary analysis predicts excellence of the specification at the BSC by amounts which depend on the octave band of interest. Final results require the measurement of sound pressure levels in the vacuum equipment area at the LIGO sites. As previously stated, these measurements have been included in the station System Acceptance Test Plans.

6.4 Shock Measurements

The LIGO specification requires that valve actuation induce no more than 0.01 g peak-to-peak acceleration at any point within 1 meter of any BSC or HAM chamber. To satisfy this requirement, PSI has placed a requirement in the valve specifications that this acceleration be met at the valve with a verifying factory test. The valve manufacturers have agreed to this with one exception - the manufacturer of the large pneumatically-actuated gate valves has not been confident that they will pass this test. He has expressed confidence, however that the valve will come close. The valve will nevertheless be factory tested for shock. Since the pneumatically - actuated valves are located at a considerable distance from either a HAM or BSC, with intervening bellows, even if the shock measured at the valve is somewhat higher than .01g, the risk of inducing a shock greater than .01g at a chamber appears low. This will be verified with a shock test for a representative pneumatic valve actuation conducted at the LIGO site.

7.0 SPECIAL EQUIPMENT REQUIREMENTS

7.1 GENERAL

Various special devices/systems will be used to install and commission the LIGO Vacuum Equipment. These devices/systems are detailed in this section.

7.2 Vessel Alignment Dollies

Special alignment dollies are being designed and fabricated by PSI to install the vacuum equipment vessels.

These dollies are capable of lifting and accurately aligning the vessel during anchor bolt installation. They can also be used to move the vessel around the station. (See attached drawings).

PROCESS SYSTEMS INTERNATIONAL
DOCUMENT REVIEW CHECKLIST
PROJECT NAME:
PSI DOC. NO.

CHK		BY / DATE
	PROJECT ENG.	
	MECHANICAL	
	STRESS	
	ELECTRICAL	
	PROCESS	
	MFG. ENG.	
	MANUF.	
	Q.A.	
	DRAFTING	

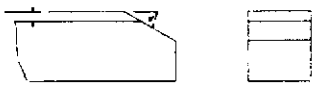
PROCESS SYSTEMS INTERNATIONAL
DOCUMENT APPROVAL CHECKLIST

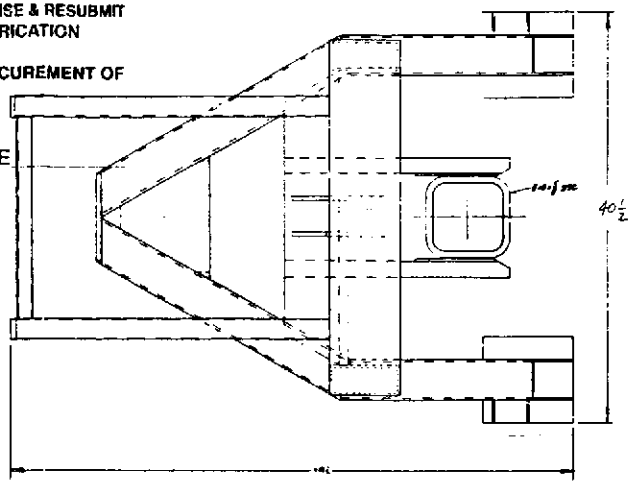
PROJECT NAME: LTGD
PSI DOC. NO.

NOTE: THIS REVIEW DOES NOT RELIEVE THE SELLER OR CONTRACTOR OF ANY OBLIGATIONS UNDER THE P.O. OR CONTRACT

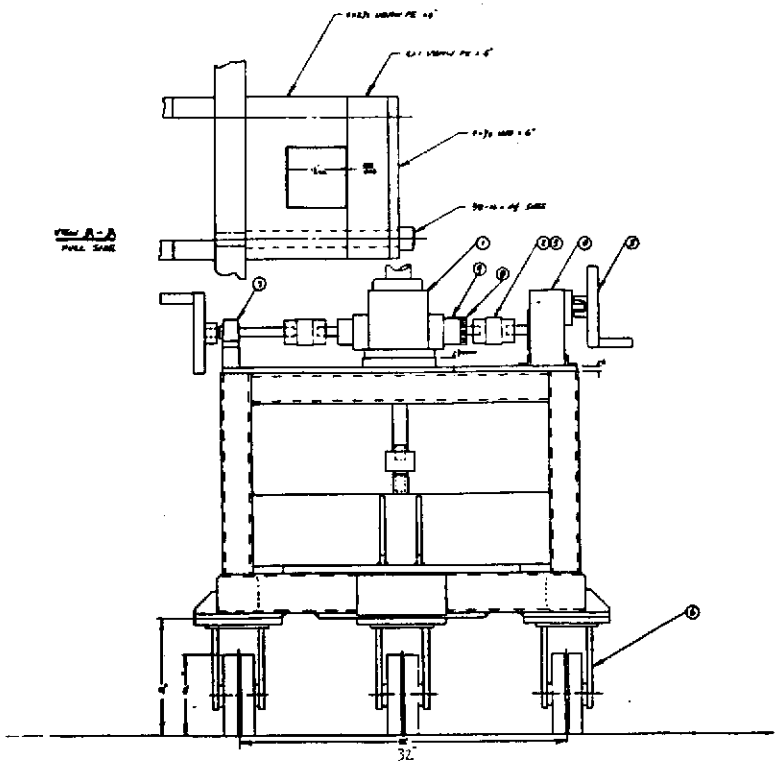
____ FA = FINAL APPROVAL
____ AS = APP'D AS NOTED - REVISE & RESUBMIT
____ AF = APPROVED FOR FABRICATION
____ NA = NOT APPROVED
____ RP = RELEASED FOR PROCUREMENT OF MATERIALS ONLY
____ RR = REVISE & RESUBMIT

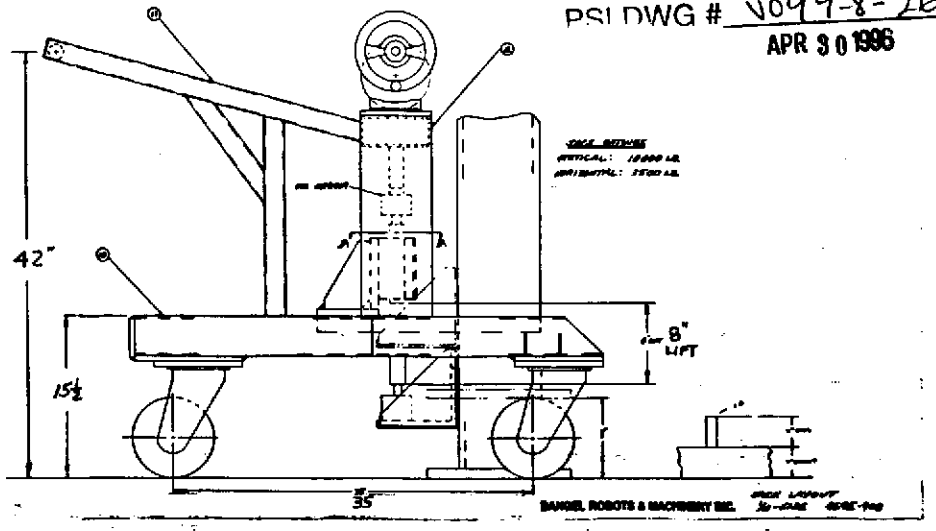
BY_____ DATE_____





VENDOR NAME: Daniel Webster
REVISION NO: 1
SUBMITTAL NO:
STATUS: Review & Approved





PSI DWG # V049-8-260
APR 30 1996

PROCESS SYSTEMS INTERNATIONAL
DOCUMENT APPROVAL CHECKLIST

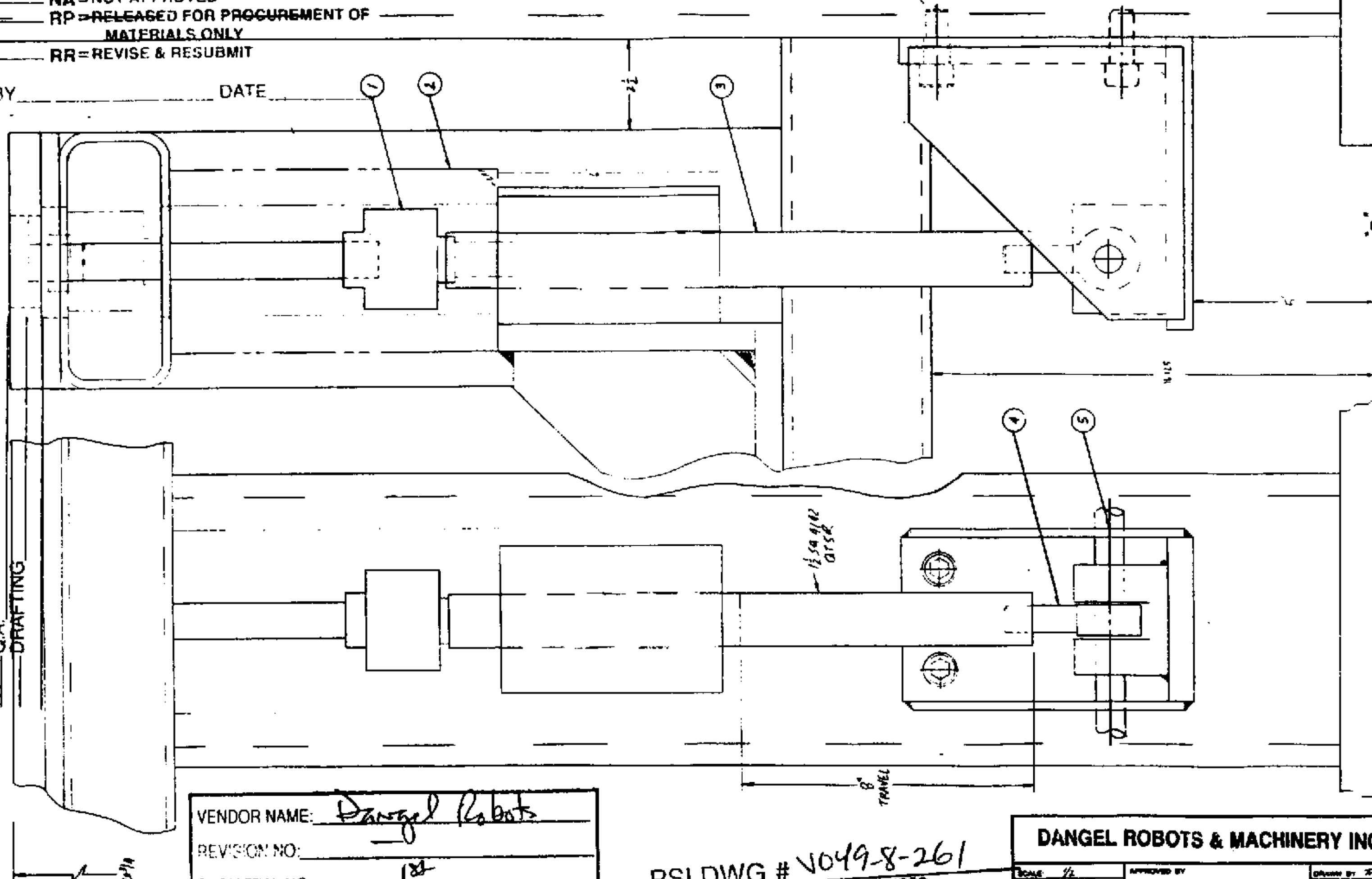
PROJECT NAME: LIGO

PSI DOC. NO. ______

NOTE: THIS REVIEW DOES NOT RELIEVE THE SELLER OR CONTRACTOR OF ANY OBLIGATIONS UNDER THE P.O. OR CONTRACT.

- ____ **FA** = FINAL APPROVAL
- ____ **AS** = APP'D AS NOTED - REVISE & RESUBMIT
- ____ **AF** = APPROVED FOR FABRICATION
- ____ **NA** = NOT APPROVED
- ____ **RP** = RELEASED FOR PROCUREMENT OF MATERIALS ONLY
- ____ **RR** = REVISE & RESUBMIT

BY ______ DATE ______



DOCUMENT REVIEW CHECKLIST

PROJECT NAME: ______

PSI DOC. NO. ______

CHK	BY / DATE
PROJECT ENG	
MECHANICAL	
STRESS	
ELECTRICAL	
PROCESS	
MFG. ENG.	
MANUF	
Q.A.	
DRAFTING	

VENDOR NAME: Dangel Robots

REVISION NO: 0

SUBMITTAL NO.: 1st

STATUS: Review & Approval

PSI DWG # V049-8-261

APR 30 1996

DANGEL ROBOTS & MACHINERY INC.

SCALE: 1/2 | DATE: 4-11-96 | APPROVED BY | DRAWN BY

LIGO PROJECT

BSC LIFTING LAYOUT

DRAWING NUMBER: 469C-909

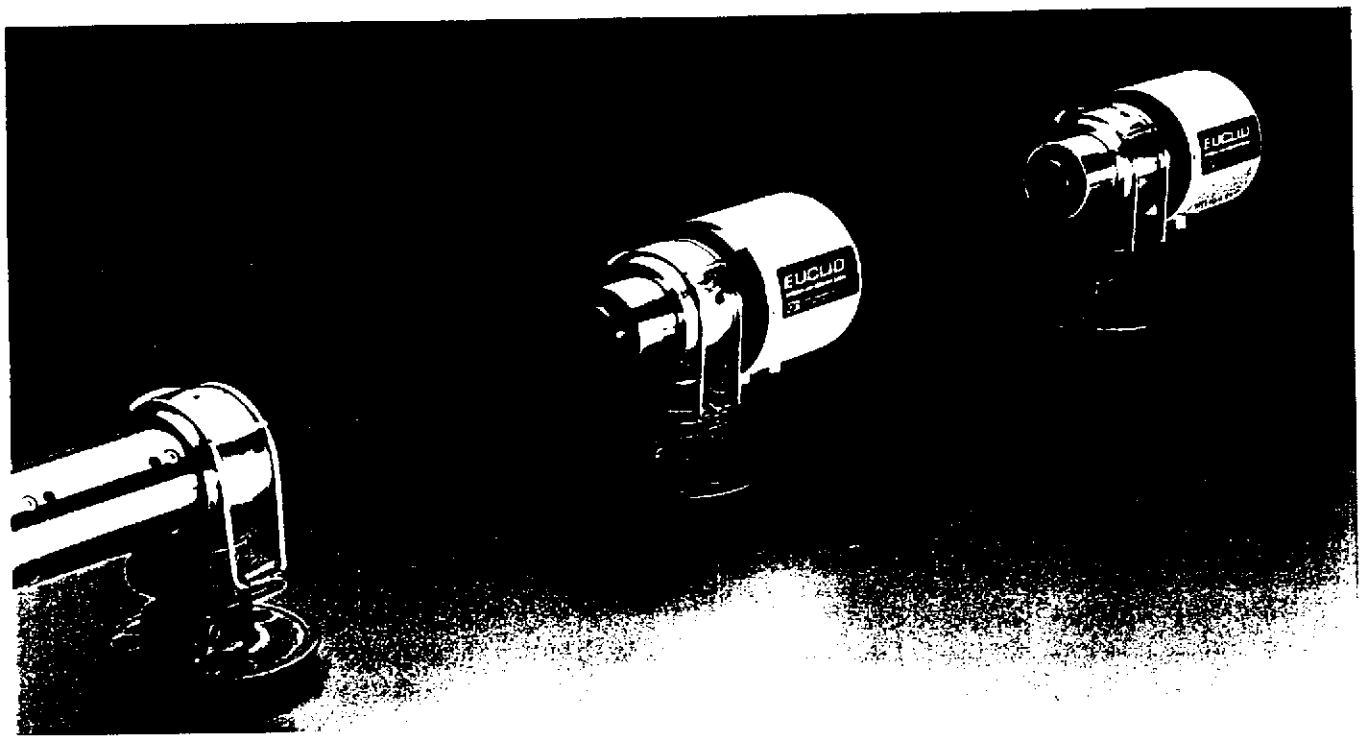
7.3 Laser Alignment System

7.3.1 The attached laser alignment system is under consideration for aligning the vacuum equipment at the site. This system utilizes a laser source, a reference target and a portable target. By moving the portable target form component to component, the beam tube centerline can be accurately aligned to the vessel nozzle.

EUCLID™

Model 300

Intelligent Laser Alignment System



A New Concept in Laser Alignment

The *EUCLID* Model 300 is a new concept in laser-based alignment that has demonstrated great savings in time, labor, and costs in an industrial environment. By eliminating the effects of beam vibration and laser pointing errors, the operator can now quickly and accurately align objects over distances of 150 feet. This lightweight, rugged, and portable system employs an advanced *see-through* Alignment Target system and an imbedded microprocessor that automatically compensates for laser movement in real time. The operator no longer has to deal with dithering numbers caused by a vibrating laser beam.

Eliminates Effects of Beam Wander and Vibration

The experienced operator knows how troublesome beam wander and drift can be in a conventional laser alignment system. The laser beam must frequently be checked to determine whether it has drifted away from the target center; if it has, previous adjustments may be invalid. This can cause time-consuming and costly delays in a work schedule. In a high-vibration environment, it is almost impossible to get a stable reading from a conventional digital position display. The operator must "guess" when the target is properly aligned with the laser. The *EUCLID* system solves these problems by employing a Reference Target that continually monitors the position of the laser beam and transmits this information to the hand-held Pendant or a computer for real-time alignment compensation.

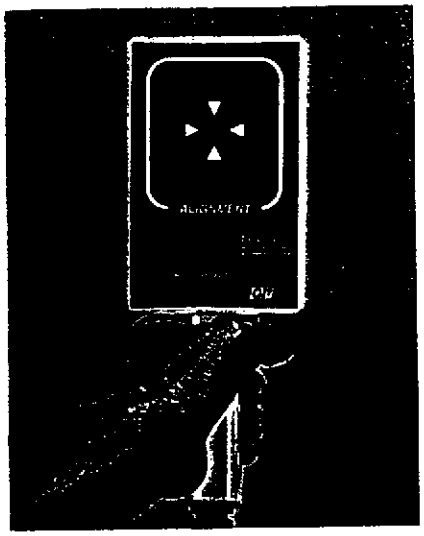
Quick Setup, No Repeated Laser Adjustments

The *EUCLID* system is quick to setup and simple to operate. The laser and targets fit standard NAS tooling spheres. Because the precisely calibrated Reference Target monitors laser position, the operator only needs to position the alignment laser beam within 0.1 inch of its center. This process is quickly accomplished by monitoring the real time display on the Pendant or a computer. The operator is then ready to start the alignment process. Since the Reference Target allows the system to constantly track the position of the laser, no further laser adjustments are necessary.

QUEST
INTEGRATED, INC.

Simple, User-Friendly Operation

The power of the *EUCLID* system is the combination of high-speed microprocessor-based laser alignment and simplicity of operation.



The *EUCLID* system comes equipped with easy-to-use software for setup and operation. The system is programmed prior to use for application-specific parameters such as data rate, target distances, and tolerance thresholds. Up to 20 alignment target positions can be programmed into the Pendant or computer. Once programmed, the Pendant parameters remain stored in memory until a new set is required for a different task. The graphical display on the Pendant assists the operator in conducting the alignment process. When all four green arrows are illuminated, the target is within acceptable tolerances, and the operator may proceed to the next station. The *EUCLID* system will notify the operator if a problem has occurred, such as a blocked laser beam or an unplugged cable. If the operator wishes to monitor numerical alignment information, a computer may be used. Either way, the process is quick, simple, and precise.

Logs Alignment Data Over Extended Periods of Time

The *EUCLID* system can also be used to acquire and store alignment data over long periods of time. By using the *EUCLID* system with the computer, a machine or a process can be continually monitored for up to four days. The *EUCLID* system's data logging function can be used to monitor and correlate movement with temperature, time of day, traffic or even the tides. Simply attach the targets to the structure and let the computer store alignment data to a file. A permanent record is available for QC or archival purposes.

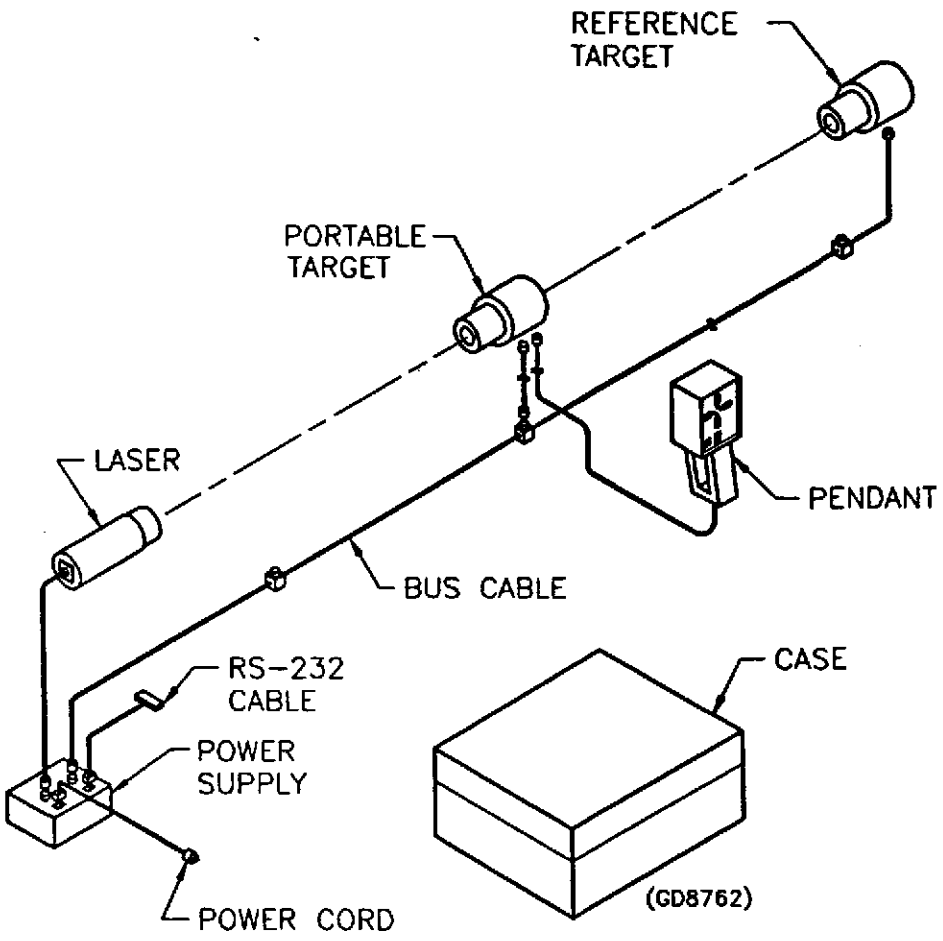
Industry Applications

- Aerospace
- Civil Engineering
- Maintenance
- Machine Tool
- Plant Operations
- Automotive
- Laboratory/Scientific
- Material Handling
- Structures

System Specifications

Laser:	Class IIA (<1 mW, visible red)
Operational Range:	up to 150 feet (standard)
Temperature Range:	0 to 40°C
Resolution:	0.0001 inch
System Accuracy:	± 0.003 inch
Target Active Area:	0.2 inch (radius from center)
Target Accuracy:	± 0.001 inch
Power:	110 VAC, 60 Hz
Shipping Case:	25L x 19W x 12H (inches)
Weight:	57 lb
Computer (minimum):	386/25 MHz, 640K RAM, 2MB available disk space DOS 3.1 or higher
Mechanical Interface:	NAS tooling sphere

QUEST INTEGRATED, INC. 21414 68th Ave. S., Kent, WA 98032 1-800-233-3345 Fax: (206) 872-8967


REFERENCE
TARGET
PORTABLE
TARGET
LASER
PENDANT
BUS CABLE
RS-232
CABLE
POWER
SUPPLY
POWER CORD
CASE
(GD8762)

GD8762

7.3.2 Metrowest Preliminary Alignment Report

May 2,1996

Process Systems International, Inc.
20 Walkup Drive
Westborough, Massachusetts 01581-5003

Re: Procedure for vessel alignment for the LIGO project.

We at MetroWest Engineering, Inc. are pleased to have the opportunity to assist Process Systems International in the development of a methodology and procedure for the alignment of the manufactured vessels for the LIGO project. Because of the exacting specifications involved in the alignment of the vessels, some specialized equipment will be needed to achieve this goal. We will be reviewing several options, not only in the selection of the equipment available but also in the procedures involved. The tasks will proceed as follows:

1. Equipment selection:
A. Report on available equipment, including advantages and disadvantages of each device. The price to purchase and or lease the device along with any recommendations.

2. Vessel alignment procedures:
A. Baseline procedures for end station units.
B. Baseline procedures for mid station units.
C. Baseline procedures for corner station units.

3. Recommendations:
A. Procedure for initial installation of vessels in approximate locations.
B. Procedure for final measurements to align and position the vessels.

1. Equipment selection:

Sokkia NET2 3-D Station:
This is an extremely accurate instrument with the capabilities to measure large structures. The instrument has the ability to interface directly with an electronic field book or a personal computer. Sokkia ® has developed an industrial measurement software called AccuNET ™ which when combined with the instrument and target system, provides non-contact measurement and analysis of large objects to sub-millimeter accuracy. The AccuNET ™ system displays measured coordinates, performs a best fit shape analysis using least squares and analyzes lines, planes, circles, spheres, cylinders and parabolas to give an accurate 3-dimensional picture of the object. The system software runs under Microsoft Windows ™ on a personal computer. You can merge external data to the data collected by importing the design coordinates through a DXF or ASCII file.
Horizontal angle accuracy is 2" with a display resolution to 1".
Distance accuracy is ±1mm + 2 ppm with a display resolution to 0.0001 m.

Advantage:
The instrument has an automatic dual-axis liquid tile sensor compensator.
The package comes with adhesive targets, available in a variety of sizes, which eliminates the need for the conventional glass prisms. The smallest target size is 10 mm x 10 mm.
The instrument meets the needs of the precision requirements.

Disadvantage:
There will be a learning curve to this system for both operating the instrument and implementing the software.
The minimum electronic measuring range is 2 meters (6.6 feet).
The targets need to be set by hand which introduces human error in to the equation.

Topcon GTS-700:
This instrument is a highly accurate total station capable of measuring both horizontal and vertical angles and distances to within the required precision.
Horizontal angle accuracy is 1" with a minimum reading to 0.5".
Distance accuracy is ± 2 mm + 2 ppm with a minimum reading to 0.2 mm.

Advantage:
The instrument is equipped with a dual-axis compensator which features a tilt sensor indicator and electronic plumb line adjustment.
The ability to exchange data with a personal computer along with the ability to write your own custom data collection programs on MS-DOS ® based computers.
The instrument has internal data collection and the ability to manipulate that data by the performing of coordinate geometry, differential and trigonometric leveling.
Icon driven menus are used for easy use and a minimal learning curve.
The minimum focusing distance is 1.3 meters (4.3 feet).

Disadvantage:
Measurements are by the conventional glass prism. This either requires a second person to operate the prism or that the prism itself is mounted on the vessel.
The distance accuracy is what we would consider barely acceptable for this project.

Topcon DL-101 Electronic Digital Level:

An electronic level complete with a digital readout which has the ability to achieve first order leveling. Minimum units for reading is 0.01 mm.
Accuracy is 0.4 mm with an Invar staff.

Advantage:
The fully automatic measuring ability and digital display excludes any reading errors, writing mistakes and other human errors in recording measurements.
Standard RS-232C port provides an instant communications link to a data collector or a direct output to a personal computer.
The ability to also measure distances although not to the accuracy needed for this project.

Disadvantage:
The minimum measuring range is 2 meters (6.6 feet).
Requires a consistent area to position the rod which introduces human error.

EUCLID ™ Intelligent Laser Alignment System

Quest Integrated Inc. - Kent, Washington.
This lightweight rugged and portable system employs an advanced see through alignment target system and an imbedded microprocessor that automatically compensates for laser movement in real time. By eliminating the effect of beam vibration and laser pointing errors, the operator can quickly and accurately align objects. The system employs a reference target that continually monitors the position of the laser beam and transmits this information to a hand held Pendant or a computer for real-time alignment compensation. The laser unit and targets fit standard NAS tooling spheres. The system comes with the software for setup and operation which is programmed prior to use for application-specific parameters such as data range, target distance and tolerance thresholds. The Pendant, which is a hand held device, has a graphic display which assists the operator in conducting the alignment process. When all four arrows are illuminated on the Pendant, the target is within acceptable tolerances.
System accuracy is ± 0.08 mm (± 0.003")
Target accuracy is ± 0.025 mm (± 0.001")

Advantage:
A minimum number of people are needed to operate the system.
The system is extremely accurate.

Disadvantage:
The vessels would need to be tooled to accept the laser unit and targets.
This system is not for rent and must be bought.

The Model L-723 Triple Scan™ Laser

Hamar Laser Instruments, Inc. - Wilton, CT.

The ability to measure flatness, straightness and squareness simultaneously with a single setup. The unit is completely self contained and can be used as is, or with a tilt and leveling base. The Model L-120 leveling base provides a complete and accurate way to level the unit while the Model L-104A Lift Stand allows the user to raise or lower the laser in controlled, accurate increments to any desired height from 20 to 60 inches. The unit is powered by a 9VDC battery pack attached to the unit or a 115VAC adapter is available. Three laser turrets positioned 90° apart are set in either a scanning or through-beam mode. In the scanning mode, rotating laser turrets simultaneously sweep three completely flat planes calibrated to be perpendicular to one another. With a slight adjustment on each rotating laser turret the laser beams project straight through the center of each turret and form a virtual x,y,z axis in space.

Advantage:

Extremely accurate.

Unit is small, lightweight and very portable. It weighs only 4.25 lbs.

Can operate as 1,2 or 3 beams and or 1,2 or 3 scanned planes in any combination.

Disadvantage:

A visible diode beam is used with a beam diameter of 4 mm.

Limited to an effective operating distance of 100 feet.

2. Vessel alignment procedures.

A. Baseline procedures for end station units.

(see accompanying sketch)

This section offers the least amount of encumbrances in laying out the vessels. The challenge is fitting the relatively large vessels into a relatively small building while maintaining a high degree of accuracy. Because the project is non-directional, we will refer to building walls as left, right, near and far based on the preliminary sketches provided to us by PSI. The work area is confining and does not afford us the luxury of establishing long offset lines; we therefore recommend several baselines be established. First and foremost, the beam line should be established and marked on the ground. This line should also be extended until it intersects with the right wall establishing a reference mark on said wall preferably at the finish grade height of the end vessel. The beam tube itself will establish one end of the beam line as it enters through the left wall and a reference mark should be established on the beam tube indicating its center point. Reference marks should be made along the beam line baseline at the two vessel locations, WCP8 and WBSC9, in addition to the two gate valve locations, WGV19 and WGV20 resulting in four reference marks. Three additional reference marks should be made available along this line. These marks should be made for a distance of thirty feet at ten foot intervals, extending beyond the center of the end vessel WBSC9, toward the right wall. The beam line baseline should then be offset in two directions. One offset line should be established ten (10) feet toward the far wall while the second offset line should be established fifteen (15) feet toward the near wall. The reference marks should mirror the locations established on the beam line baseline with the inclusion of the location of the end of the beam tube, preferably at the weld line. This will give you a minimum of three reference points at each major junction. Three points are necessary because if one point is skewed you will not know if you only had two points to work from. Coordinate values can then be calculated for each reference mark, offering a very tight triangular network which is essential in determining the final location of the vessels. Because of the tight working quarters and the height of the structures, we recommend a mark be established on each vessel at the time of manufacturing which references the center of the unit in both a horizontal and vertical plane. Since you will not be able to see the top of the vessels from the baselines we suggest a reference mark on the vessel be established no higher than eight feet from the floor. This will allow technicians to comfortably view the marks from the offset baselines. Vertical reference marks should also be made available. The beam line appears to be 6'-1" off the floor. This would make a good reference elevation and markings should be made on the near wall, far wall and the right wall. Again a combination of vertical and horizontal alignment could be referenced with the same point on the right wall while the beam tube itself offers the vertical alignment coming in from the left wall. Because of the precision required, the reference marks need to be narrow enough to be accurate yet large enough to be visible. In the unlikely event a vessel becomes missaligned it would be advantageous to be able to use the now existing horizontal offset baselines to rectify the problem. It is therefore suggested the offset baselines be permanently monumented with brass discs set in the floor of the building.

These discs are about three inches in diameter, and an X-mark would designate the actual offset point on the disc. The discs would be set at the previously suggested locations. We recommend the vertical reference mark to be a small reflective, flat target. The target affords the luxury of using a laser alignment and or laser leveling system in the setting of the vertical confines of the vessel while maintaining the ability to use more conventional methods in establishing the vertical datum.

B. Baseline procedures for mid station units.

(see accompanying sketch)

The mid station units offer much the same challenge as the end station units with the exception of having to fit an additional chamber within the building. This section does not afford us the luxury of extending the beam line baseline to an intersecting wall. In this section the beam tube will be entering through both the left and right walls and again the ends of the beam tubes should have a reference mark establishing their respective center points, giving you the horizontal and vertical location of the beam line. As in the previous section the beam line should be established as a baseline with the center of the vessels WCP5, WBSC5 and WCP6 being marked on this line. In addition the gate valves WGV13, WGV14, WGV15 and WGV16 should also be marked. This baseline should be offset in two directions, ten (10) feet toward the far wall and fifteen (15) feet toward the near wall, and again mirror the location of the vessels and gate valves established on the beam line baseline. The ends of the beam tube, at the weld line, should also be marked on the offset lines. The vertical reference marks should be established on the near wall and the far wall, with the beam tubes themselves acting as a proper vertical reference. The same logic applies to this situation in establishing a permanent offset baseline using the brass discs with X-marks. The monumenting of the vertical reference should also remain the same as the procedure for the end station.

C. Baseline procedures for corner station units.

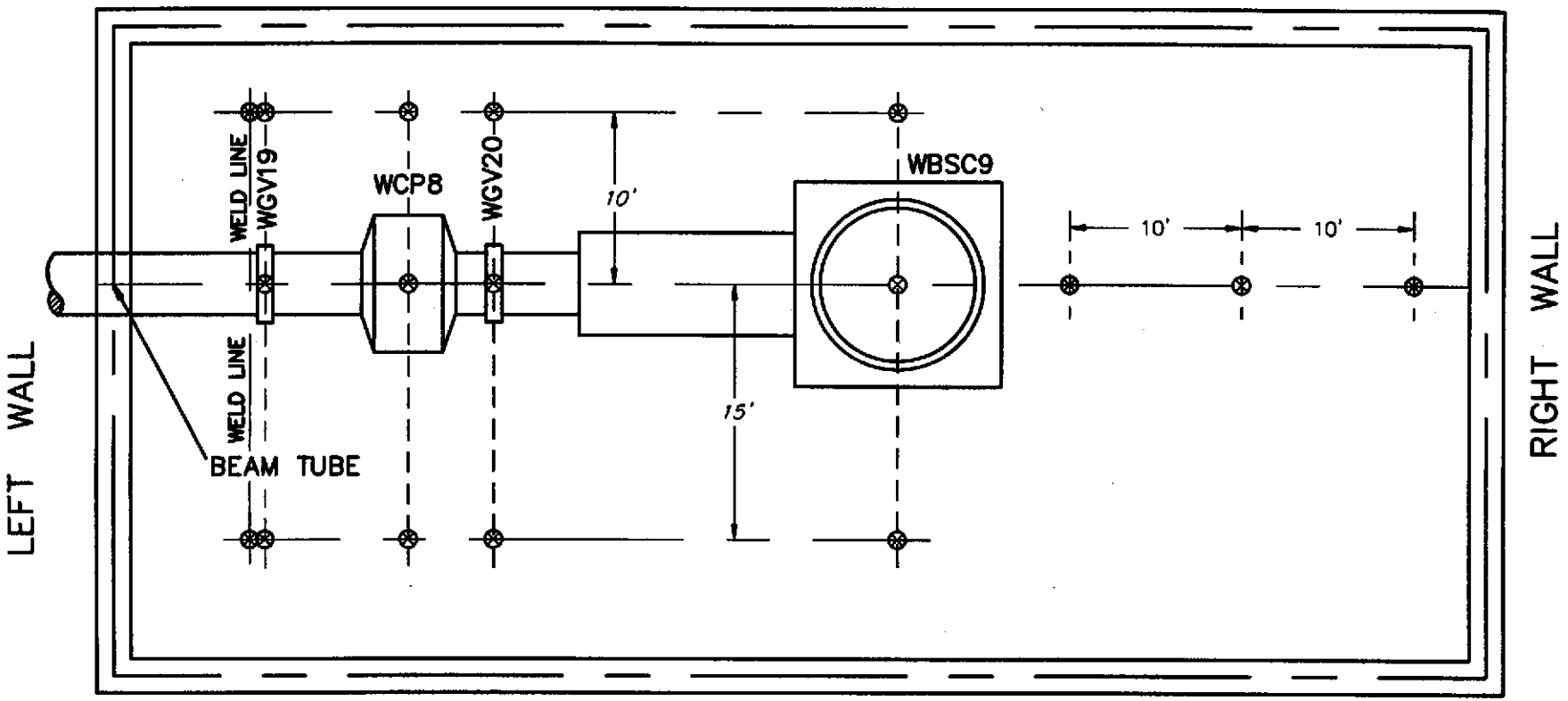
(see accompanying sketch)

This area offers the biggest challenge. There are four separate beam lines that need to be established and offset. The beams are parallel and perpendicular to each other which will aid in the offsetting of the baselines. Again the beam line baselines should be established with the critical vessel locations marked. The baselines should be extended at least thirty feet with markings at ten foot intervals and preferably until they intersect with the left wall and the near wall. This would be the beam line baseline extending from unit WHAM1 toward the left wall and the beam line baseline extending from unit WHAM6 toward the near wall. The beam tubes will again mark the end points of these baselines. The shorter beam line baselines should also be extended. From unit WHAM7 that baseline should be extended until it intersects with the right wall, with markings at ten foot intervals. From unit WHAM12, that baseline should be extended until it intersects with the far wall, again with markings at ten foot intervals. The intersection points of the shorter beam line baselines with the longer beam line baselines need not be marked as this will only add an already confusing situation. You do not want the intersection of these baselines to be confused with the center of the vessels. These shorter baselines

should end at their respective gate valve locations. The baselines can then be offset a distance equal to one half the distance between the beam lines. For example if the beam lines are thirty feet apart, the offset baseline would be fifteen feet. The main beam line baseline running through WHAM1, 2 and 3 would be offset toward the far wall while the beam line baseline running through WHAM4, 5 and 6 would be offset toward the right wall. Because of the many units involved within this corner section, it would not be sensible to attempt to offset each individual unit. Instead we recommend the two baselines be marked off in twenty foot intervals, in both directions, starting with the intersection of the two baselines. The offset points can then be assigned a coordinate value along with the vessels. The vessels can then be set in place using either multiple instrument triangulation or a total station equipped with distance measuring capabilities. Again because of the number of units involved, it is suggested the shorter beam line vessels be put in place first. You will want to maintain as long a sight line as possible while installing the vessels, for as long as possible. Once you have installed the units WBSC3 and WBSC1, you will have limited your line of sight toward the near wall and left wall respectively. However, we do not foresee this as a problem as long as the line of sight is maintained toward the rear wall and the right wall. The connecting tubes between vessels WBSC8, WBSC4 and WBSC1 should be the last thing installed, again due to the fact that you will want to maintain that sight line. Vertical reference marks should be consistent with the previous recommendations for the end station units and mid station units. Vertical reference marks should be established somewhere along each wall of the building. The intersection of the beam line baselines with the near wall and the left wall offer excellent positions for a combined horizontal and vertical reference mark. The beam tubes offer the vertical reference at the far wall and the right wall. Because of the cluster of units involved within the center of the building, additional vertical reference marks should be made available to insure a clear sight between the technicians and the vessels. The wall corners nearest to units WBSC4, WBSC8, WBSC2 and WBSC7 should also have a vertical reference mark made available. Again we recommend that targets be used in referencing the vertical marks and brass discs be used for the offset baseline.

3. Recommendations / Action Items:

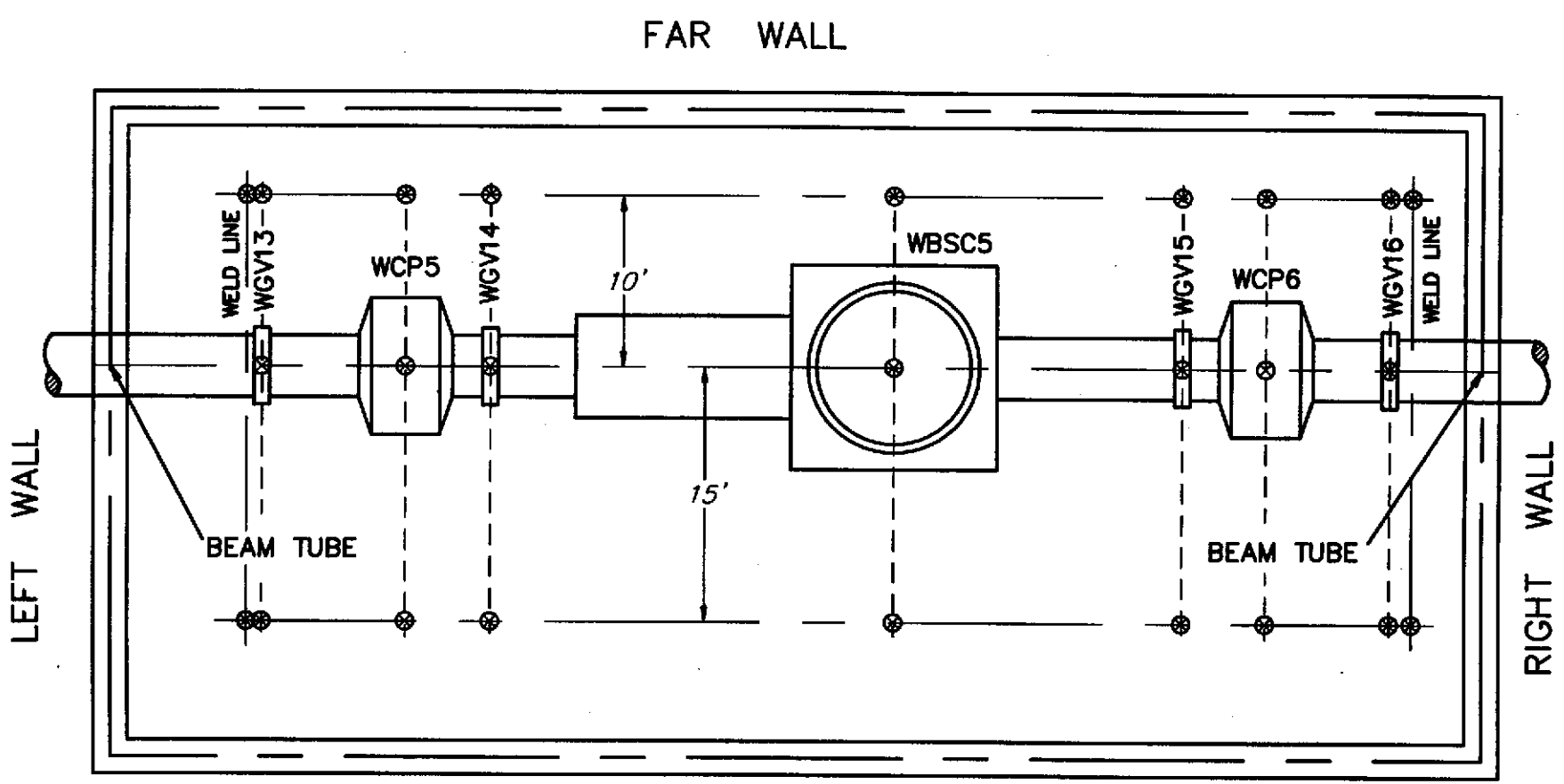
We anticipate receiving additional instrument information from companies such as Leica™ which has a T3000 theodolite and a N3 spirit level, K&E ™ who manufactures an array of optical alignment equipment and Nikon ™ with their DTM-700 series total station instruments. In addition to that and based on telephone conversations with the company representatives we will be receiving additional information on other laser alignment systems. Some of the other manufacturers are Leica, On-Track Photonics, Inc. and Cubic Precision. These systems sound very promising and we would be remiss in excluding them from our evaluation process. Once the additional information is received we will be making our final recommendations on equipment selection and respective vessel alignment procedures.



⊗ DENOTES PROPOSED TARGET LOCATION

PRELIMINARY SKETCH OF END STATION UNITS

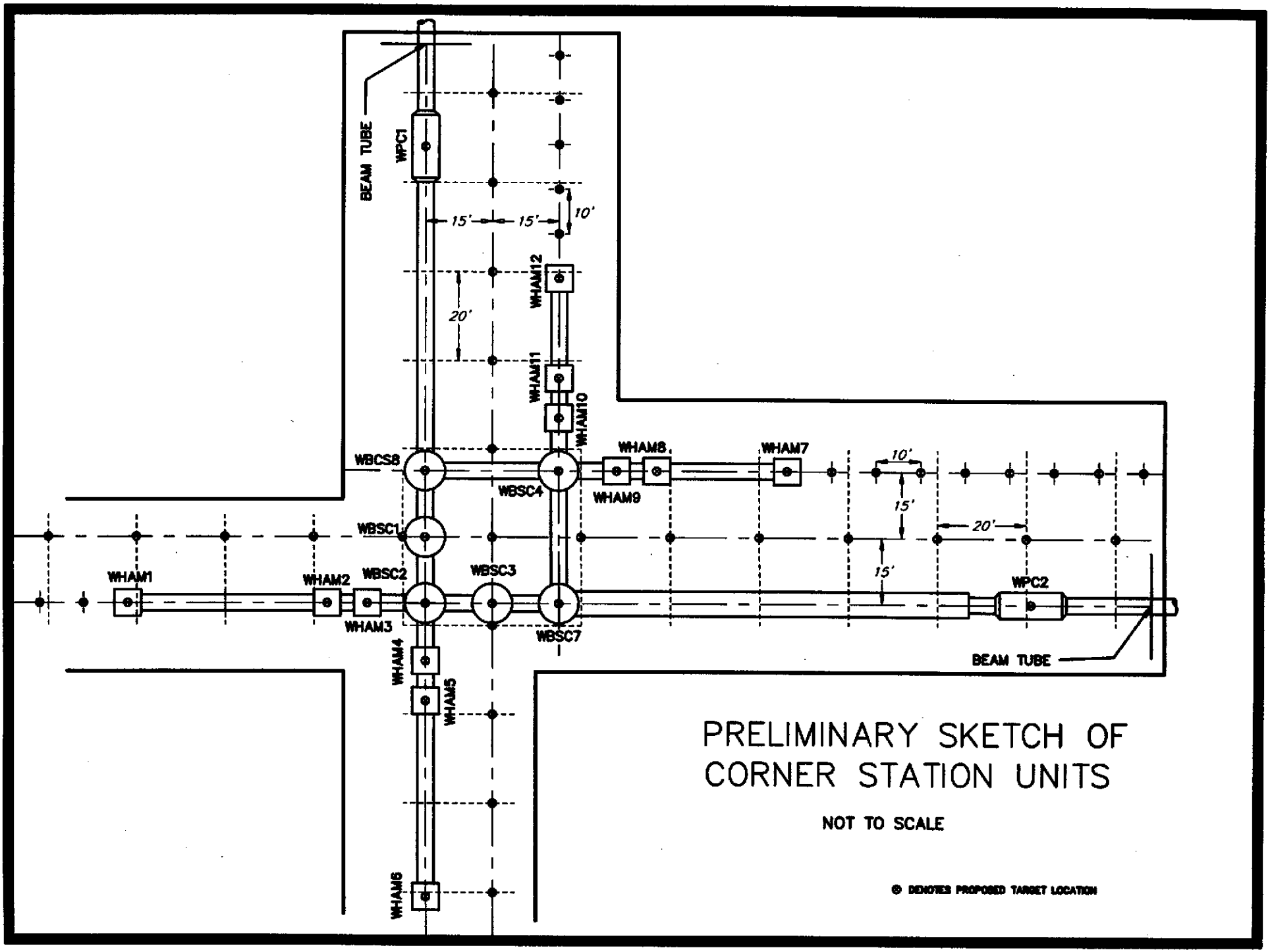
NOT TO SCALE



⊗ DENOTES PROPOSED TARGET LOCATION

PRELIMINARY SKETCH OF MID STATION UNITS

NOT TO SCALE


BEAM TUBE
WPC1
15'
15'
10'
20'
WHAM12
WHAM11
WHAM10
WBCS8
WBSC4
WHAM8
WHAM9
WHAM7
10'
15'
20'
WBSC1
15'
WHAM1
WHAM2
WBSC2
WBSC3
WPC2
WHAM3
WBSC7
WHAM4
WHAM5
BEAM TUBE
WHAM6
PRELIMINARY SKETCH OF
CORNER STATION UNITS
NOT TO SCALE
⊕ DENOTES PROPOSED TARGET LOCATION

FDR VOLUME IV

ATTACHMENTS

1.	General Construction Spec.	V049-2-021
2.	Electrical and Instrument Construction Spec.	V049-2-022
3.	Project Q.A. Plan	V049-2-029
4.	Project Safety Plan	V049-2-023
5.	Laser Alignment Procedure	(Later)
6.	Leak Check Procedure	V049-2-014
7.	Welding Procedures	V049-2-070
		V049-2-071
		V049-2-072
		V049-2-073
8.	Material/Welding Repair Procedure	V049-2-074
9.	Visual Inspection Procedure	V049-2-128
10.	Raw Material Handling Procedure	V049-2-120
11.	Control of Non-Conformance	V049-2-124
12.	Contamination Control Plan	V049-2-119
13.	Site Piping Cleaning Procedure	V049-2-131
14.	Site Vacuum Surface Re-Cleaning Procedure	V049-2-132
15.	Clean Room Activities	V049-2-118
16.	Black Light Test Procedure	V049-2-130
17.	Isolatable Section Bakeout Procedure	V049-2-116

18. Component Acceptance Tests Procedures

80K Pumps	V049-2-102
Roughing Pumps	V049-2-104
Turbomolecular Pumps	V049-2-105
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Large Gate Valves	V049-2-107
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SPECIFICATION

FOR

GENERAL CONSTRUCTION AND INSTALLATION

VACUUM AND ASSOCIATED EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT MANAGER: Richard Bayless

STRUCTURAL : Raymond S. Curtis

ELECTRICAL/CONTROL : Vachi Bark.

PROJECT : D. A. McWilliams

INSTALLATION MANAGER: DAVE EVERS/REB

REV LTR	BY—DATE	APPD—DATE	DESCRIPTION OF ACTION
Ø	B.E. 5/6/96	REB 5/6/96	RELEASED PER DEO 177 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED BY / DATE	APPROVED BY / DATE	Number	Rev
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1 PROJECT LOCATION

1.1 The location for the Scope of Work of this specification is: Hanford, Washington

2 DEFINITIONS

2.1 Where the word "Buyer" is used in this specification, it shall be understood as referring to Process Systems International, Inc. (PSI).

2.2 Where the word "Owner" is used in this specification, it shall be understood as referring to US Government.

2.3 Where the word "Contractor" is used in this specification, it shall be understood as referring to the Successful Bidder designated by the Buyer to supply all items required to successfully complete the Scope of Work.

2.4 Where the word "Scope of Work"/"Work" is used in this specification, it shall be understood as referring to all items of work required to complete the work defined in this specification, indicated on the project drawings, or enumerated in the project specifications.

2.5 Where the word "Subcontractor" is used in this specification, it shall be understood as referring to any party designated by the Contractor to supply items required to complete the scope of work, subject to Buyer's acceptance.

3 SITE VISIT

3.1 The Contractor shall visit the job site and familiarize himself with the site conditions and proposed facilities, carefully examining local conditions, together with investigating possible conditions that may affect his costs, complicate, delay, or otherwise obstruct the progress of his Work and include costs associated with such conditions in the Lump Sum.

The planned building drawings are included in this package.

4 CONTRACTOR CONTACTS

4.1 Should the Contractor have questions he should contact:
Mr. David Evers
Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581
Phone: (508) 366-9111

5 PERMITS AND CODES

5.1 Before starting work on this project, it shall be the responsibility of the Contractor to make certain that permits and approvals are obtain at the site. Where regulations require that permits be obtained, the Contractor shall obtain the permits at his own expense and furnish copies to the Buyer.

5.2 The Contractor shall include in his Lump Sum Bid all costs associated with performing the work in compliance with Federal, State, and Local codes governing the Work.

5.3 CODES AND STANDARDS

5.3.1 Unless otherwise required, material and workmanship shall conform to and comply with current editions and the latest revisions of applicable codes and standards.

5.3.2 The following codes and standards, as applicable, shall be followed for the procurement, installation and testing of the equipment and piping:

AISC - American Institute of Steel Construction
ANSI - American National Standards Institute

16.1 Cast Iron Pipe Flanges
16.5 Steel Pipe Flanges
31.1 Also For Utilities
31.3 Chemical Plant and Petroleum Refinery Piping

ASME - American Society of Mechanical Engineers

Section VIII, Pressure Vessels
Division I Boiler and Pressure Vessel Code
Section IX, Welding Qualifications

ASTM - American Society for Testing Materials
AWS - American Welding Society Welding Symbols
NEMA - Motors and Generators, MG-1
OSHA - Occupational Safety and Health Act Noise Standard
SSPC - Structural Steel Painting Council

5.4 SPECIFICATION COMPLIANCE

5.4.1 Work shall comply with drawings, data sheets, standards, codes and specifications referred to or attached as part of this specification. Applicable national, state or local codes, or regulations shall be considered as part of this specification. The Contractor is responsible for compliance with such standards, specifications, codes or regulations.

5.4.2 The Buyer's Installation Manager or his designee shall witness all inspections by regulatory agencies.

5.4.3 Conflicts between documents shall be brought to the attention of the Buyer and resolved at the time of quotation.

6 SAFETY REGULATIONS

6.1 A site specific safety plan shall be developed, complying with Federal OSHA regulations.

6.2 The Contractor shall also comply with the Owner's on-site Construction Safety,Health and Environmental Management program.

6.3 The Contractor shall be fully responsible for providing first aid equipment and other safety equipment required for his personnel.

6.4 The Contractor shall designate a person at each site to responsible for safety management at that site. He shall conduct weekly safety meetings.

6.5 To ensure safety, the Contractor is responsible for supporting and bracing partially installed equipment.

7 GENERAL REQUIREMENTS

It is the intent that the Work be executed in accordance with the Project Drawings and Project Specifications and in the best qualified manner. It is not intended that the Project Drawings, Project Specifications including this Specification enumerate every possible eventuality that the Contractor may encounter before completing the Work. The Contractor represents that he has practical construction knowledge and experience in performing the Work. Therefore, the Contractor shall review and inspect all facilities and equipment and materials supplied to him to ensure correctness and suitability for interfacing with the Contractor's scope of Work. Additionally, the Contractor shall provide materials required (beyond what is identified in contract documents as furnished by others) to complete the Scope of Work. Interferences among pipe, conduit, steel, etc., where occurring in limited instances, shall be considered normal working circumstances and to have been included in the Contractor's Lump Sum Bid and, therefore, shall not be reimbursable by the Buyer. Minor errors or interferences due to lack of field verification or error shall be corrected at the Contractor's expense.

7.1 Bid shall state what the Contractor intends to subcontract and his proposed subcontractors. The Contractor will assume the responsibility for supervising such subcontracts. Prevailing Davis-Bacon Rates shall be used to develop the proposal cost. Any rate increases at a later date will be a change order to the contract.

7.2 The Contractor shall be responsible for examination and inspection of his Subcontractors' work to assure that it complies to the specifications and the Buyer standards and that the work performed is of good workmanship quality.

7.3 The Buyer's written acceptance will be required of subcontract Work and specific acceptance of each Subcontractor.

7.4 The unsuccessful Bidders shall return specifications, drawings, and documents issued to them under this exhibit after notification that Work was awarded to others.

7.5 In the case of conflicting or incomplete technical information, it shall be the responsibility of the Contractor to bring conflicts or deficiencies to the Buyer's attention prior to the submission of the proposal. The more stringent requirements shall apply until resolution is provided by the Buyer.

7.6 "Hold" or "Later" shown on Drawings indicate that final dimensions and details have not been determined. Contractor shall not exclude these areas from his Scope of Work or Bid Proposal.

7.7 The Contractor's Work must be coordinated in the field through the Buyer's Installation Manager.

7.8 The Contractor shall be responsible for daily cleanup and removal of debris, rubbish, etc. as the result of the Work from the job site. Rubbish and debris resulting from the Work shall be removed and legally disposed. Before project completion, the contractor shall remove equipment, scaffolding, tools, temporary services and utilities. If the Contractor refuses, the Buyer shall take necessary steps to cleanup the Contractor's debris, rubbish, etc. and charge associated costs to the Contractor's account.

7.9 By submitting a bid, Contractor agrees that time is of the essence.

7.10 Contractor shall furnish with the bid a detailed construction and staffing plan and schedule which specifies the resources and time required to complete the Work. The Installation and Staffing Plan is to be updated weekly during the installation.

7.11 During the course of the job, the Contractor shall submit a weekly forecast of activities planned for the next two weeks.

7.12 A representative of the Contractor will be required to attend weekly progress meetings. Progress meetings will be conducted by the Contractor with the Buyer personnel to review past week's progress and next week's planned activity. A Two Week Look Ahead Schedule, updated weekly will be provided at weekly Progress Meetings, which are tentatively set for Monday mornings.

7.13 Buyer's field representatives and the Owner shall have the right to review Contractor's work, material, equipment, or review procedures as is applicable to ensure the Work is in compliance with the Specifications. The Contractor shall provide tools, instruments, etc. necessary to facilitate these reviews.

7.14 The Contractor shall cooperate with Buyer's field representative in establishing a schedule of the various reviews or verifications to be performed during the progress of the Work. Buyer's field representative shall designate which occasion he wishes to participate or witness, and the Contractor shall furnish an agreed upon amount of notification prior to the start of each week.

7.15 Contractor's field representative shall confirm by examination and tests, specified or usually used for such purposes, and report to the Buyer that the material, equipment and field installation Work conforms to the requirements of the Contract Documents including, but not limited to:

a) The Contract.
b) The Specifications.
c) Applicable Codes and Standards.

7.16 It is not intended that the presence or activity of the Buyer's field representative shall relieve the Contractor in any way of his obligation to maintain an adequate inspection program of his own or of other obligations under this specification. Furthermore, the fact that Buyer's field representative may inadvertently overlook a deviation from some requirement of this specification shall not constitute a waiver of that requirement, of the Contractor's obligation to correct the condition when it is discovered, or of other obligations under this specification.

7.17 Buyer's field representative has the authority and responsibility to stop any portion of the Work which, if continued, would make compliance with some other requirements of the specifications difficult or impossible.

7.18 Contractor will ensure that a safety meeting is scheduled weekly.

7.19 The Contractor is responsible for manning the project with the number of people necessary for the Work to achieve the completion dates indicated on the approved schedule and, if it is necessary, shall include costs for shift work and overtime to meet the completion dates in the Contractor's Lump Sum Price.

7.20 The Contractor's approved progress curve will be monitored on a daily or weekly basis by the Buyer. If it becomes apparent during the monitoring of the progress by the Buyer that a slippage in the progress has occurred, the Buyer shall direct and the Contractor shall provide at no increase in cost, additional people, overtime and shift work to achieve the schedule. The Contractor shall maintain the corrective measure taken until the Buyer has agreed that the current progress agrees with the original project progress curve.

7.21 The Contractor shall include in his lump sum bid:

7.21.1 Costs of moving his equipment around the site.

7.21.2 Costs for receiving and cleaning vessels and equipment prior to moving them into the buildings.

7.21.3 Cost of erecting a temporary wood and plastic shelter to clean equipment.

7.21.4 Costs for layouts required to properly locate and set equipment and the work.

7.22 Contractor shall, at all times, have a competent Superintendent on the premises to represent him and to whom instructions may be given until final acceptance of the Work has been obtained from the Buyer.

7.23 The Contractor's work including tests shall be subject to Buyer's review. The Contractor shall maintain records of tests made during the course of the job and transfer these records to the Buyer at the end of the job. The Contractor shall maintain quality control to ensure that quality requirements are met. Contractor shall submit proposed QC/QA procedures no later than one month after he has been awarded the contract.

7.24 The Contractor shall take measurements to avoid damaging all structures, cables, conduits, pipelines, wells, fences, paving and other facilities within or adjacent to the work site. Damages shall be promptly repaired by the Contractor at his expense, including all premium time, to the satisfaction of the Buyer.

7.25 The Contractor's material storage shall be confined to those areas which Buyer designates as construction laydown areas. Laydown, fabrication, and painting activities are limited to areas specifically designated by the Buyer.

7.26 Contractor and Contractor's subcontractors shall abide by the rules and procedures the Owner has in effect at the job site pertaining to the performance of the workers, materials, tools, and equipment. Contractor shall be responsible for personnel in his employment and shall take appropriate disciplinary action, including dismissal for the violations to these rules and procedures. These rules and procedures include, but are not limited to, the following:

7.26.1 Prior to installation, the Contractor and his personnel shall become familiar with the safety guidelines of the Owner.

7.26.2 Firearms or other weapons of any kind are strictly prohibited within or around the job site.

7.26.3 No alcohol or drugs of any kind will be allowed within or around the job site.

7.27 During the course of the job, the Contractor will submit a weekly report, indicating the progress of each phase of the job and the overall progress.

7.28 MAINTAIN RECORD DRAWINGS AS FOLLOWS:

7.28.1 At the site, maintain a set of prints marking them to accurately reflect the actual installation including changes in sizes, locations, and dimensions as the work progresses.

7.28.2 On a daily basis, trace over the prints with a highlighter (marker) to indicate work installed. Make these prints available to Owner's and the Buyer's representatives.

7.28.3 At completion of project, transfer information from your marked prints onto mylars and deliver drawings including marked prints to the Buyer's project manager.

7.29 CONSTRUCTION INSTALLATION REVIEW

7.29.1 The responsibility for inspection rests with the Contractor; however, the Buyer or his representative reserves the right to review equipment at any time during installation to ensure that the materials and workmanship are in accordance with Specification and Drawings.

7.29.2 The Contractor shall submit a detailed inspection plan and a quality control program for review by the Buyer or his representative prior to the start of construction.

7.30 DOCUMENTATION

7.30.1 The Buyer will issue to the Contractor, one (1) set of prints of Drawings and Specifications. "C" size and larger drawings will be issued as a reproducible vellum.

7.30.2 Equipment/material identification tags shall not be removed.

7.31 TEMPORARY CONSTRUCTION WATER

A source of water for construction purposes will be available to the Contractor.

7.32 TEMPORARY SANITARY FACILITIES

7.33 The Contractor may be required to provide and maintain temporary sanitary toilets for the use of personnel employed by the Contractor, Subcontractor and others engaged in the work. These facilities shall conform to the requirements of all state, county and local ordinances.

7.34 TEMPORARY STORAGE FACILITIES

7.35 The Buyer's representative will designate areas and locations for the temporary storage of materials, tools and equipment, and will designate areas where debris may be accumulated. Parking areas must be kept clean and neat at all times.

7.36 TEMPORARY MAINTENANCE SERVICE

7.37 It shall be the responsibility of the Contractor to maintain and administer, in accordance with ultra high vacuum practice, a program of temporary maintenance, repair, protection and the preservation of work installed under the applicable Specifications and Drawings until the total completion of the Work.

7.38 DISPOSITION OF DEBRIS AND CLEANUP

7.38.1 No debris shall be allowed to accumulate in or be in contact with existing equipment or in such a manner as to interfere with normal, convenient and safe operations of the Work.

7.38.2 The Contractor shall remove and dispose of construction debris from the work areas, including temporary facilities and utility connections, unless otherwise directed by the Buyer's representative.

7.38.3 This cleanup phase of the Work shall be accomplished before construction will be considered complete.

7.39 FINAL ACCEPTANCE

7.39.1 Final acceptance of the Work required by the Specifications shall be of the total job. This acceptance shall be given after cleanup operations and final performance tests have been completed.

7.39.2 Prior to final acceptance, the Contractor shall supply Buyer with a waiver of lien stating that no outstanding debts exist pertaining to this job.

7.39.3 Mechanical completion shall be declared in writing by the Buyer Installation Manager. The Contractor and Buyer shall develop a deficiency checklist ("Punch List").

7.40 BILLING

7.40.1 Invoices for work performed under this specification shall be clearly identified with the Job Title, Job Number and Contract or Purchase Order Number. Prior to issuance of invoices, they will be reviewed by the Buyer Installation Manager for progress achieved during the billing period.

7.40.2 Approved invoices shall then be submitted for payment of Work completed (percent progress) to:

Mr. David Evers
Process Systems International
20 Walkup Drive
Westborough, MA. 01581-5003

7.41 The Buyer will, during the bidding period, advise Bidders by letters of changes to the Work. These changes shall become a part of the bid documents as if originally submitted. Contractor shall acknowledge receipt of these addenda in their proposals.

8 SCOPE OF WORK

8.1 GENERAL

The Contractor shall include all costs associated with providing labor including supervision; transportation, labor; materials; construction equipment; tools, construction supplies; consumables; required warehousing; temporary facilities and services to receive, warehouse; and complete the installation of the equipment, piping and miscellaneous structural steel work (pipe supports etc.) and all other required Work indicated in the Specifications and Drawings to the satisfaction of the Buyer.

The Contractor shall receive, clean, inspect, assemble as required, erect, place and precision align, install anchor bolts, shim, and bolt down all required equipment as shown on P&ID.

The Contractor shall also assist in the commissioning and testing of the LIGO vacuum system on a time and material basis. The Bidder shall state in their proposal the applicable T&M rates.

All vacuum equipment must be installed and commissioned in a clean room environment. Any time a vessel is to be opened (for inspection, bolting to other equipment, etc.). It must be protected by a portable class 100 clean air system. These systems require 4-8 hr to clean up a class 100,000 environment (normal building environment) to class 100 after the class 100 clean room system is started. Portable clean rooms will be provided by the Buyer.

8.1.1 Lifting of major equipment items will be performed in accordance with specific requirements and shall be consistent with notes or vendor drawings. Equipment sizes and weights are detailed on the Assembly Drawings of Equipment to be installed.

8.1.2 Equipment may be shipped under a vacuum and care should be taken when breaking any fitting in preparation for installation of interconnecting piping.

8.1.3 The Contractor shall detail, fabricate and deliver miscellaneous structural steel and pipe supports as required in accordance with Contract Documents.

8.2 EQUIPMENT RECEIVING AND PRELIMINARY CLEANING

8.2.1 The Contractor will receive and offload LIGO vessels and equipment at the site.

The Contractor shall pre-clean all vacuum vessels and components in the designated clean area before equipment is pre-positioned in Corner, Mid and End Stations.

Temporary shipping braces shall be removed prior to moving the equipment into the buildings.

8.2.2 The Contractor shall receive, handle and store all material in accordance with the following:

V049-2-120 Raw Material Handling

V049-2-119 Contamination Control Plan

V049-2-124 Control of Non-Conformance

8.3 EQUIPMENT SETTING AND PRECISION ALIGNMENT

8.3.1 Equipment shall be aligned using laser optical alignmemt equipment (provided by the Buyer).

8.3.2 The Contractor shall set and align the LIGO vacuum system per the Buyers installation drawings and installation plan. The center line of all beam tube nozzles must be aligned ± 2 mm in both transverse directions and to within 25 mm of the design position in the axial direction. Extreme care shall be used while setting and aligning to avoid damage to the flange surfaces.

8.3.3 Ports shall be pre-cleaned and protected by a class 100 portable clean room anytime ports are opened. Vessels shall be wiped down after the clean room is in place. The clean room environment must be at class 100 levels for 1 hour before opening any vessel or piece of vacuum beam line equipment. The vacuum system assemblies shall be prepared and assembled in accordance with Buyer's Installation Specification.

8.3.4 After alignment, anchor bolts shall be installed and vessels shall be bolted into place and grouted.

8.3.5 Base plate grout shall be the flowable type and it shall meet with the requirements of ASTM C1107 for nonshrink, nonmetallic grout.

Tests required by other applicable ASTM specifications shall be performed including strenth tests.

The minimum grout strenth shall be 7000 psi at 28 days.

Acceptable grout products are:

1. Five Star Grout - manufactured by : Five Star Products.

2. Masterflow 928 - manufactured by : Masterbuilders

3. Masterflow 713 - manufactured by : Masterbuilders

Application:

The undersides of all base plates shall be clean and the concrete surface be clean and dampened prior to placing grout.

Grout shall be mixed, placed and cured in accoerdance with the manufacturers instructions.

Curing shall continue for a minimum of 7 days.

Grout test and QC inspection reports shall be provided to the Owner.

8.4 VACUUM AND UTILITY PIPING

8.4.1 Vacuum and utility piping shall be installed per attached drawing list. In the vacuum building, vacuum and utility piping is run under the vacuum equipment. Piping shall be tested per this Specification. All field piping will be supplied by the Buyer.

8.5 80K PUMP SYSTEM

Vacuum jacketed piping shall be installed by the contractor. Vacuum jacketed lines will be supplied by the Buyer. LN_2 lines outside buildings shall be standard SCH 5S stainless steel. Lines that require mechanical insulation shall be insulated with material and thickness as indicated on the P&ID's.

The Contractor shall install the 80K pump system LN_2 supply and return, regeneration, etc. per PSI DWG _____.

8.6 TESTING

The contractor shall assist the Buyer in testing and commissioning the LIGO vacuum system on a time and material basis.

8.7 ELECTRICAL WORK

Electrical work shall be accomplished per the attached electrical construction Specification V049-2-022 (see Attachment A).

8.8 PIPING

The Scope of Work includes, but is not limited to, the fabrication and installation of various piping systems as shown on the Project Drawings and P&ID's. Utility an vacuum piping to be installed in accordance with ANSI B31.3

8.8.1 The Contractor shall supply all necessary welding procedures. Welding procedures shall be submitted by the Contractor to the Buyer for acceptance prior to commencement of welding. The Buyer shall not be responsible or shall there be a schedule extension due to the Contractor's failure to submit acceptable welding procedures.

8.8.2 The Contractor shall protect piping systems from the entrance of moisture and foreign materials.

8.8.3 Vacuum Jacketed (VJ) Piping System materials will be furnished by Buyer. It is the responsibility of the Contractor to install these systems and perform appropriate testing.

8.8.4 The Contractor is responsible for locating and making necessary pipe penetrations through building walls, and providing pipe supports as required.

8.8.5 The Contractor shall qualify welding procedures and welders in accordance with ASME Boiler and Pressure Vessel Code, Section IX, latest edition.

8.8.6 The Contractor shall notify the Buyer, who will witness all tests, two (2) hours prior to test readiness. Test readiness means Contractor has verified system is leak-free. After testing, the Contractor shall safely vent test media from piping (pressure tests).

8.8.7 Piping systems shall be cleaned by the Contractor as directed by the Buyer.

8.8.8 The Contractor is responsible for inspecting materials furnished by others to ensure they are free of defects and damages.

8.8.9 The Contractor shall pneumatically test the utility piping systems including; but not limited to; vents, drains, pipe caps, flanges and blind flanges. The contractor shall provide, bolts, gaskets and test gases.

8.8.10 Material and equipment provided by the Contractor shall be new and standard products of manufacturer's who are regularly engaged in its production and, unless otherwise specified, shall be of the manufacturers latest design and subject to review by the Buyer.

8.8.11 The Contractor is responsible for installing Buyer furnished valves and actuators as indicated on the Buyer lists.

Valves with socket weld or butt weld connections are to have their seats and seals removed prior to installation in accordance with manufacturers requirements.

8.9 EQUIPMENT AND PIPING INSULATION

8.9.1 Insulation shall be provided on equipment and piping as indicated on the Piping and Instrumentation Diagrams(P&ID's) and line list.

8.9.2 Insulation and jacketing are to be applied to piping and equipment as indicated on the general arrangement drawings, piping isometrics, P&ID's, line list and sketches in the Insulation Specification. Contractor shall insulate furnished equipment, and piping as well as Contractor provided piping.

8.10 UTILITIES

The Contractor is to provide hookups to on-site utility source for electrical, gas, compressed air, etc.

8.11 PIPE CLEANING

All vacuum headers and class 100 air piping shall be supplied cleaned by the Buyer.

9 TESTING

Required tests shall be conducted in the presence of the Buyer's representative. The Buyer's representative shall be notified at least 4 hours prior to the performance of a test. The Buyer shall determine if test results are acceptable. Costs for repairing failed items and re-testing shall be by the Contractor.

9.1 THE CONTRACTOR SHALL CONDUCT THE FOLLOWING TEST

9.1.1 Piping pneumatic test (in accordance with ANSI B31.3 requirements utilities).

9.1.2 Equipment alignment checks.

9.1.3 Helium Leak Tests

9.2 THE CONTRACTOR SHALL ASSIST THE BUYER IN THE FOLLOWING TESTS ON A T&M BASIS

9.2.1 Helium leak check

9.2.2 Vacuum pump down testing.

9.3 TESTING EQUIPMENT/SUPPLIES

9.3.1 The Contractor shall provide equipment and gases/supplies required for testing.

9.4 LEAK TESTING AFTER REWORK

9.4.1 After the leaks have been located and repaired, the applicable test procedure shall be repeated as if the part, assembly or system were newly received.

9.5 ACCEPTANCE BASIS

9.5.1 When the leak rate is equal to or less than the value specified for the service, the part, assembly or system shall be acceptable.

9.6 TEST RECORDS

9.6.1 Written records in the form of log book entries or reports of leak detection tests will be made and retained for transfer to Buyer after acceptance.

10 MATERIAL / SERVICES PROVIDED BY CONTRACTOR

10.1 Unless specified as furnished by the Buyer, the Contractor shall provide materials, equipment, etc., including but not limited to the following:

10.1.1 Materials indicated on the Drawings or required by the Specifications and not indicated as by others.

10.1.2 Materials required to perform pneumatic testing.

10.1.3 Equipment and materials required to perform leak detection by Helium Sensitive Mass Spectrometer (supplied by the Buyer).

10.1.4 Commodities required for the electrical work.

10.2 The following shall also be provided by the Contractor:

10.2.1 Consumables such as weld filler materials, backing gases and test gases.

10.2.2 Radiographic equipment, film, magnetic particle, equipment with consumables and liquid penetrate consumables if required.

10.2.3 Cranes, hoists, welding machines, and other construction equipment and tools including small tools and expendable items.

10.3 The Contractor shall be responsible for receiving and storing materials, including those supplied by Buyer, associated with this Work. Material receiving reports shall be made available to the Buyer at his request.

11 MATERIALS FURNISHED BY OTHERS/BUYER

11.1 Major Equipment items as shown on P&ID's.

11.2 Control valves and relief valves hand valves, rupture ducts, automatic on/off - shown on P&ID's, Piping Drawings and Project Documents.

11.3 Hand valves - shown on P&ID's, Piping Drawings and Project Documents.

11.4 Special materials (SP's) shown on P&ID's, Piping Drawings and Project Documents.

11.5 Vacuum jacketed piping systems as shown on piping Drawings and project Documents.

11.6 Contractor shall return to the Buyer any surplus materials furnished by Buyer.

11.7 Piping and Materials shown on Drawings specifically called out by a ballooned Item Number are to be supplied by the Buyer. Items will be delivered to the Contractor as assemblies as shown on contract drawings except where shipping or Installation requirements require otherwise.

11.8 Class 100 air piping and vacuum header piping.

12 PROJECT DOCUMENTS LIST

The Contract Documents shall be as shown in Attachment A.

13 SCHEDULE OF THE WORK

13.1 Due to owner requirements, the installation phase shall be completed in 26 weeks starting August 1997.

14 BASIS OF BID

14.1.1 Lump Sum: The Contractor shall formulate his firm Lump Sum Price for supplying materials as required by this Specifications, Drawings, and not stated as furnished by others.

14.1.2 The Firm Total Lump Sum Bid (not subject to escalation) is to include direct and indirect costs, including all profit associated with performing the Scope of Work associated with the project specifications, together with each and every item of expense for all supervision, tools, construction equipment, labor, materials, and other services necessary to perform the Work.

Labor rates use by the Contractor are supplied by the Buyer (see Attachment B). Changes in labor rates from these levels will form a basis for charges to the lump sum price.

Note that the indirect costs above shall include costs for overhead such as, but not necessarily limited to, salaries and benefits of Contractor's executive officers and other home office and branch office personnel directly or indirectly associated and working on the project; expenses incurred in conjunction with Contractor's main office, branch office, or other facilities, including expenses for real estate rentals or purchases, accounting, payroll, purchasing, expediting, engineering, legal and data processing services, telephone, telegraph, office furniture, office equipment, interest for capital employed or money borrowed, association membership fees and fund contributions, and other administrative expenses of any kind required to perform the Work, including bonuses or any types of incentive payments to supervisory and non-supervisory personnel.

14.1.3 Price is to be lump sum fixed, valid for a period of 2 years from time of submittal to the Buyer.

14.1.3.1 The Lump Sum Fixed Price shall give the breakdown between Material (M), Labor (L) and Equipment (E) and Taxes. Each building's work shall be broken out separately. The Contractor will submit, as a requirement separate Price Breakdowns for items listed under Scope.

14.1.3.2 Firm Unit prices (not subject to escalation) are to be provided and shall be utilized for evaluating and costing any revisions, additions, and deletions and new drawings issued to the Contractor's scope to provide.

15 SELECTION OF THE CONTRACTOR

Will be made from proposals submitted under this inquiry with special consideration given to the ability of the Contractor to schedule and complete the Work in accordance with the Schedule. Bidders in consideration may be required to review their estimate in the Buyer's office prior to contract award. The review will include a review of takeoff quantities sufficient to assure Buyer that the Contractor understands the Scope of Work. The Buyer reserves the right to reject any and all bids for any reason.

Title: **SPECIFICATION FOR ELECTRICAL & INSTRUMENT CONSTRUCTION WORK**

PRELIMINARY
NOT for CONSTRUCTION

SPECIFICATION

FOR

ELECTRICAL & INSTRUMENT CONSTRUCTION WORK

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY Daniel J. Parenti Jr. 4/29/96
WA PE Reg 32541 (exp 5/12/98)
LA PE Reg E-26566 (exp 3/31/98)

ELECTRICAL Fadi Barbar

QUALITY ASSURANCE C.R. Braddock

TECHNICAL DIRECTOR D.A. Williams

PROJECT MANAGER Rachel Bayley

REV LTR	BY—DATE	APPD—DATE	DESCRIPTION OF ACTION
Φ	DP 4/29/96	RES 4/29/96	Released for Review & Comments per DCN#0149

PROCESS SYSTEMS INTERNATIONAL, INC				SPECIFICATION	
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1.1 Process Systems International General Provisions

1.2 General Construction Specification V049-2-021

1.3 Attachments to the Specification (see Table of Contents).

2 SCOPE OF WORK

2.1 Provide labor, tools, materials, and equipment necessary for a complete installation of the Work as specified and as indicated on Drawings.

2.2 Receive, store, and handle equipment furnished by others and required to be installed under this Contract.

2.3 Through the PSI's representative, coordinate Work activities provided under this Contract with work provided by others.

2.4 SUMMARY OF ELECTRICAL WORK

2.4.1 Work as indicated on the Drawings takes place at two sites. The Washington site consists of one corner station, two mid stations, and two end stations and the Louisiana site one corner station and two end stations.

- Provide power, instrument, and control wiring installed in conduit or cable tray; receptacles and outlets; and equipment connections as indicated.
- Panelboards and below grade conduits are provided by others unless otherwise indicated.

2.4.2 Install gages, switches, electronic transmitters, and other instruments that are not already skid mounted; control cabinets; and other equipment furnished by others (see ATTACHMENT B: *FURNISHED ELECTRICAL EQUIPMENT LIST*).

2.4.3 Provide instrument air/gas tubing between pneumatically operated devices and supply lines and connections as indicated. Provide process tubing between electronic transmitters and process points and connections as indicated.

2.4.4 Field Tests

- Test power wiring for grounds and shorts.
- Test motors for correct shaft rotation.
- Test instrument and control wiring for point-to-point continuity, grounds, and shorts.
- Check instrument gas and process tubing for leaks.
- Field Calibrations by PSI

3 INTENT

3.1 Intent of the Drawings and Specification is to assist and guide the Contractor and to establish minimum requirements.

3.2 Drawings indicate arrangement and approximate location of equipment. When necessary to deviate from the arrangement indicated to meet structural conditions or to clear other work, inform PSI's representative of proposed deviation before proceeding.

3.3 Comply with specific, detailed requirements indicated in lieu of generally stated requirements.

3.4 Portions of these Drawings and Specification are abbreviated and may include incomplete statements. Deduce the omitted words or phrases such as *the Contractor shall, shall be, as indicated on the drawings, in accordance with details, a, the*, and *all*.

3.5 Drawings and Specification do not undertake to indicate every item necessary to produce a complete installation of the Work indicated or specified.

4 DEFINITIONS (ALSO SEE THE GENERAL CONDITIONS & THE NEC)

By Others	Work not under this Contract.
Contractor	Company doing electrical and instrumentation work as defined in the Contract Documents.
PSI	Process Systems International, Inc
Indicated	Shown or noted.
Install	Place, secure, and connect.
Labeled	Equipment marked with an identifying symbol authorized by a nationally recognized testing company such as UL, FM, ETL indicating sample of product has been tested and determined it complies with their safety standards.
Owner	US Government
Owner's Representative	Persons designated by Owner
Permitted	As by code, Contract Documents, or PSI.
Provide	Furnish and install.
Required	As by code, Contract Documents, or prevailing conditions.
Submittal	Information required to show that the proposed equipment complies with project requirements.
Use	Provide material or equipment referenced.
Work	Material and equipment and their installation and other requirements as established in the Contract Documents.
Wire (Verb)	Connect to equipment indicated and provide wiring required for connection.
Wiring	Conductors, raceways, and accessories as required for a complete installation.

5 CODES, STANDARDS, AND PERMITS

5.1 Comply with authorities having legal jurisdiction and applicable parts of the latest (unless otherwise required) publications by the following jurisdictions and organizations:

- Applicable federal, state, and local codes.
- Federal Occupational Safety and Health Act (OSHA)
- American National Standards Institute, Inc. (ANSI)
- National Fire Protection Association (NFPA)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- Insulated Cable Engineers Association (ICEA)
- Underwriter's Laboratories (UL), Factory Mutual Engineering Corp (FM), Electrical Testing Laboratories, Inc (ETL), or other nationally recognized testing companies' equipment and installation safety standards

5.2 The Drawings and Specification do not undertake to repeat requirements written in the above codes, ordinances, and standards.

5.3 Arrange and pay for necessary permits, licenses, inspections, and certificates applicable to the performance of the Work. At conclusion of the Project, deliver certificates of inspection to the PSI's representative.

6 LABELED EQUIPMENT

Provide labeled equipment and assemblies where recognized national testing company safety standards exist.

7 INSTALLATION RESTRICTIONS

7.1 Do not cut structural members without written acknowledgment from the Owner obtained via the PSI's representative.

7.2 Do not weld supports and equipment to building steel without written acknowledgment from the Owner obtained via the PSI's representative.

7.3 Arrange equipment to allow accessibility to installations likely to need inspection, calibration, repair, and maintenance.

8 SPECIFIED EQUIPMENT AND SUBSTITUTIONS

8.1 The manufacturer of the equipment specified is used as the basis of the design and to establish quality required for this project. Unless no substitutions is stated, other manufacturers of equivalent equipment may also be proposed by the Contractor.

8.2 The description following a catalog number is basically to identify the product, but the description may also call for accessories, options, and modifications which are beyond the cataloged product.

8.3 Submit proposed substitutions to the electrical engineer for acceptance via PSI's representative. With submittal, provide details of necessary changes to accommodate substitutions. Submit samples if requested.

9 PROPOSED EQUIPMENT SUBMITTALS

Before delivering equipment to the job site and installing it, complete the submittal process as follows:

9.1 Equipment List: As soon as practicable, submit for review a list of equipment proposed for installation with each item identified by Specification paragraph number or where applicable by Drawing number. Include manufacturer's name with catalog or model number for each item.

9.2 Product Data: Where required by specification of the product, submit catalog data sheets or other published materials showing appearances, electrical ratings, performance characteristics, dimensions, installation methods, and space requirements of proposed equipment.

9.3 Shop Drawings: Where required by specification of the product, submit shop drawings, drawn to scale, indicating physical size and arrangement, construction details, provisions for conduits, access requirements for installation and maintenance, finishes, and materials used in fabrication. Supplement shop drawings with wiring diagrams and information as previously described under product data.

9.4 Mark submittals to clearly identify proposed equipment including accessories, options, and features and to exclude parts not applicable to the Project.

9.5 If proposed equipment deviates from the Specification or Drawings, indicate those differences and provide sufficient data to justify acceptance.

9.6 Provide products of one manufacturer for each classification of equipment.

9.7 Stamp submittals indicating that they have been checked and that they comply with Project requirements including physical restrictions before submitting.

9.8 Submittals reviews by PSI does not relieve the contractor from the responsibility of complying with the Specification and Drawings.

9.9 Unless otherwise required, provide two copies of submittals and deliver to PSI's project manger. Where practicable submit all product data and shop drawings at one time. Arrange submittal in three-ring binders with loose-leaf dividers separating categories of equipment.

9.10 At the job site, maintain the latest equipment submittals showing the action taken by PSI's project manager. Make these submittals available to Owner's and PSI's representatives.

10 TEMPORARY POWER

10.1 The Owner will provide electrical power, without charge. Make connections to the Owner's system where permitted.

10.2 Provide transformers, wiring, panelboards, distribution boxes, extension cords, and accessories as project needs require.

10.3 When temporary power is no longer required, remove that portion provided under this Contract.

11 RECORD DRAWINGS

11.1 At the site, maintain a set of prints marking them to accurately reflect the actual installation including changes in sizes, locations, dimensions, and circuiting as the work progresses.

11.2 On a daily basis, trace over the prints with a highlighter (transparent marker) to indicate work installed. Make these prints available to Owner's and PSI's representatives.

11.3 At completion of project, deliver marked prints to PSI's project manager.

EQUIPMENT AND INSTALLATION

12 CABLE TRAY SYSTEMS

Where indicated, provide cable trays as follows:

12.1 MANUFACTURERS: PW Industries, B-Line, or MP Husky.

12.2 TRAYS: NEMA VE1; channel and latter type trays as indicated; latter tray with rungs on 12 inch centers less unless otherwise indicated.

12.3 MATERIAL: 6063-T6 aluminum or 5052-H32 steel with ASTM's hot dip galvanized after fabrication standards.

12.4 LOAD AND SPAN: rated for 50 pounds per linear foot or more and span to suit tray supports.

12.5 ACCESSORIES:

12.5.1 expansion fittings in accordance with manufacturer's recommendations to accommodate building expansion joints and thermal expansion of tray to in ambient temperature range of 0°C to 50°C

12.5.2 bonding jumpers

12.5.3 end plates where applicable

12.5.4 drop-out fittings where conduit is not required

12.5.5 divider strips (barriers) where indicated with curved fittings and hold-down clips

12.5.6 other fittings to best suit each application

12.6 SUBMITTALS

12.6.1 Provide product data of each cable tray component.

12.6.2 Provide shop drawings of fabricated support brackets.

12.6.3 Provide dimensioned diagrams indicating where expansion joints are proposed.

12.7 INSTALLATION

12.7.1 Support horizontal and vertical trays by each rail using hold-down clamps to prevent lateral or vertical displacement. Provide support brackets, channels/struts, $^{3}/_{8}$ inch or larger hanger rods, and fittings to best suit installation (see *SUPPORTS*, Article 22, p.13).

12.7.2 Ensure that trays are effectively bonded to electrical equipment served by wiring in cable tray.

- Where applicable, bond tray to building steel with #2 AWG copper conductor at two locations.
- Bonding jumpers at expansion and adjustable fittings.

12.7.3 At approximate 20-foot intervals, identify power, instrument, and control cable trays with vinyl, self-adhesive signs with one inch high lettering or, similarly, with stencil and paint.

12.7.4 At approximate 10-foot intervals, identify channel tray with high voltage, ion pump wiring with *DANGER—HIGH VOLTAGE—DO NOT TOUCH.*

13 CONDUIT SYSTEMS
(ELECTRICAL RACEWAY OF CIRCULAR CROSS SECTION)

13.1 RIGID METAL CONDUIT (RMC, also RGS): Provide galvanized steel RMC conforming to ANSI C80.1 and UL 6 standards unless otherwise specified.

13.2 INTERMEDIATE METAL CONDUIT (IMC): At indoor locations, galvanized IMC conforming to UL 1242 standard may be provided in lieu of RMC unless otherwise required.

13.3 ELECTRICAL METALLIC TUBING (EMT): At indoor locations, EMT conforming to ANSI C80.3 and UL 797 standards may be provided in lieu of RMC or IMC unless otherwise required.

13.4 FLEXIBLE METAL CONDUIT (FMC): At connections to motors, transformers, and other vibrating equipment and instruments, provide thermoplastic covered, liquidtight FMC conforming to UL 360 standard and fittings to best suit application.

13.5 ACCESSORIES:

13.5.1 Provide fittings to best suit each application.

13.5.2 Provide expansion fittings as required in accordance with manufacturer's recommendations to accommodate building expansion joints indoors and thermal expansion of conduit in ambient temperature range of 0°C to 50°C.

13.6 INSTALLATION:

13.6.1 Restrictions: Where practicable, keep instrument wiring at least 12 inches away from other wiring and minimize paralleling instrument wiring with power or control wiring.

13.6.2 Arrangement: Make raceway offsets and bends symmetrically and uniformly.

13.6.3 Supports:

- Fasten conduits to building with one-hole malleable iron conduit clamps with screw or bolt.
- Where applicable and where two, three, or more

conduits are routed together, provide trapeze hangers made of 3/8 inch minimum hanger rods and channels/struts with conduit clamps.

- Support 11/2 inch or larger suspended conduits with 3/8 inch minimum hanger rods with conduit clamp.
- Provide supports as specified under *SUPPORTS*, Article 22, p.13.

13.6.4 Pull boxes: Provide pull boxes required for proper conductor installation in addition to boxes indicated.

13.6.5 Terminating conduits:

- Attach RMC and IMC to equipment by threading into integral cast hub, compression fitting, or double locknuts with bushing.
- Attach EMT with either set-screw or compression type fittings and connectors with integral insulating liners.

13.6.6 Flexible conduit connections:

- Connect to motors, transformers, and other vibrating equipment with 18 to 30 inches of FMC.
- At equipment mounted on vibrating isolators, provide 90° bend in the FMC connection.
- Connect to instruments with 18 to 30 inches of FMC.

13.6.7 Grounding: Where grounding conductor or bonding is applicable at locknut installations, provide threaded bushings with insulating liner and grounding lug.

13.6.8 Close openings: Keep conduits closed when not accessing them to prevent rain, dirt, and debris from entering.

14 BOXES, CONDUIT BODIES, AND WIREWAYS

14.1 PULL AND SPLICE BOXES:

14.1.1 Where indicated and as required to install wiring without damaging insulation or stretching conductors, provide sheet steel, galvanized or finished with gray baked enamel boxes with screw-on covers unless otherwise required.

14.1.2 Where applicable, provide sheet steel, galvanized or finished with gray baked enamel box barriers to maintain separation of wiring systems.

14.2 OUTLET AND JUNCTION BOXES

14.2.1 Provide cast-metal boxes with threaded hubs unless otherwise specified.

14.2.2 At outdoor locations, provide covers with gaskets.

14.2.3 At indoor locations, sheet-metal boxes may be provided in lieu of cast-metal boxes and conduit bodies unless otherwise required.

14.3 CONDUIT BODIES:

14.3.1 Where applicable, cast-metal conduit bodies with threaded hubs may be used in lieu of boxes unless otherwise required.

14.3.2 At outdoor locations, provide covers with gaskets.

14.4 WIREWAYS AND AUXILIARY GUTTERS:

14.4.1 Where required, provide sheet steel, galvanized or finished with gray baked enamel wireways and gutters with screw-on covers unless otherwise required.

14.4.2 Where applicable, provide sheet steel, galvanized or finished with gray baked enamel box barriers to maintain separation of wiring systems.

14.5 ACCESSORIES: Provide fittings to best suit each application.

14.6 INSTALLATION:

14.6.1 General requirements:

- Arrange boxes neatly and symmetrically to adjacent components and architectural features.
- Identify wire and cables by tag numbers within box with indelible felt tipped marker pen or as specified under wiring systems.
- Provide supports as specified under *SUPPORTS*, Article 22, p.13.
- When not accessing, close equipment to prevent rain, dirt, and debris from entering.

14.6.2 Wireway and gutters: Bond each section of wireways and gutters with #12 or larger conductor.

14.6.3 Pull and splice boxes: Provide supports to prevent conductors from resting on removable bottom covers.

14.6.4 Outlet and junction boxes: Rigidly fasten boxes directly to structure, to support channels/struts, or in framed constructions to bar hangers.

15 WIRE AND CABLE

15.1 POWER WIRE (up through 600 volts):

15.1.1 Provide #12 AWG or larger single; stranded copper; type THHN, THHN-THWN, THWN, or XHHW conductors rated 90°C, 600 volts unless otherwise specified.

Use colored coded insulation in sizes up to #8 AWG, except up to #6 AWG for grounding conductors, and black insulated conductors in larger sizes (see *WIRING IDENTIFICATION*, Article 16).

15.2 CONTROL WIRE (discrete signals):

15.2.1 120 VAC: Provide #14 AWG or larger, stranded copper, type THHN-THWN, multiconductor cable rated 90°C, 600 volts unless otherwise indicated.

15.2.2 24 VDC: Provide #18 AWG or larger, stranded copper, multiconductor cables rated 90°C and 300 volts unless otherwise indicated.

15.3 INSTRUMENT WIRE (analog signals):

15.3.1 4-20mA: Provide #18 AWG or larger, stranded copper, individually shielded twisted pairs, single or multipair cables rated 90°C, 300 volts unless otherwise indicated.

15.3.2 Thermocouple: Provide #16 AWG single pair and #20 AWG multipair ANSI type (as indicated), solid thermocouple extension cable shielded, rated 105°C, 300 volts.

15.4 TRAY CABLE: In addition to above, provide cable tray installations with cable labeled for cable tray use.

15.5 SUBMITTALS: Provide product data of each wire and cable.

15.6 INSTALLATION:

15.6.1 Where practicable, keep instrument wiring at least 12 inches away from other wiring and minimize paralleling instrument wiring with power or control wiring

15.6.2 Without splices, install wiring in conduit or cable tray unless otherwise indicated.

15.6.3 Install simultaneously conductors and multiconductor cables to occupy same conduit .

15.6.4 Where necessary, use labeled pulling lubricant that is approved by the cable manufacturer.

15.6.5 Use woven cable grips.

15.6.6 Be cautious not to exceed manufacturer's recommended pulling tension and cable bending radius.

15.6.7 After installation, seal cables exposed to weather or other harmful environments until cable is terminated.

15.6.8 Provide sufficient wire length at each end of pull to permit grouping and training the wires and cables. Where applicable, use self-locking nylon wire ties; cut off loose ends. Take care not to exceed manufacturer's wire bending radii. Do not allow wiring to bear against edges of enclosures. Replace wiring cut too short to meet installation requirements.

15.7 See *TESTING*, Article 23, p.14.

16 WIRING IDENTIFICATION

16.1 POWER WIRE:

16.1.1 Color code single conductors as follows:

Line	208/120V	480/277V
A	Black	Brown
B	Red	Orange
C	Blue	Yellow
N	White	Gray
G	Green	Green

16.1.2 Where applicable, color code conductors using one-inch wide colored plastic adhesive tape wrapped with two full turns.

16.1.3 Identify each conductor end with panel designation and circuit number or with applicable identification to suit other type of circuits. Use printed, adhesive wire marker strips.

16.2 INSTRUMENT AND CONTROL WIRE:

16.2.1 Tag each end of single conductors and cable pairs with schematic wire number unless otherwise directed.

16.2.2 Tag each spare cable end with unique identification.

16.2.3 Use printed sleeve markers.

16.3 SUBMITTALS: Provide product data of printed sleeve markers.

17 WIRING TERMINATIONS

17.1 POWER WIRE:

17.1.1 Splices:

- #10 AWG and smaller conductors, provide insulated spring connectors.
- #8 AWG and larger conductors, provide either compression (crimp) connectors using matching installing tool or mechanical screw type connectors. Cover splices with insulating material made for connector where available; otherwise, cover with at least three layers of electrical, vinyl tape to attain insulation rating equivalent to that of the conductor.

17.1.2 Terminations:

- #10 AWG and smaller conductors to buses, enclosures, and similar applications, provide compression (crimp) terminals.
- #8 AWG and larger conductors, provide either compression (crimp) connectors using matching installing tool or mechanical screw type connectors.
- Where more than one conductor requires termination and terminals are not provided as part of the equipment, provide screw or pressure type insulated terminal blocks.

17.1.3 Motor Leads: To connect to motor leads, use split-bolts connectors. Cover splices with insulating material made for connector where available; otherwise, cover with at least three layers of electrical, vinyl tape to attain insulation rating equivalent to that of the conductor.

17.1.4 Where applicable, tighten screw type hardware in accordance with manufacturer's published torque values. If not available, comply with UL 486A standards.

17.2 INSTRUMENT AND CONTROL WIRE:

17.2.1 At instrument end of cable, strip and cutoff shielding back to edge of overall jacket. Then wrap two full turns of electrical plastic tape or placed heat shrinkable insulating sleeve half on conductors and half on overall jacket . At other end of cable, secure shielding to junction box terminal. (Shielding connects only to a single ground reference point at the electrical source.)

17.2.2 Coil, insulate, and label ends of spare conductors.

17.2.3 Remove insulation from ends of conductors using mechanical or electric heat type stripper.

18 WIRING DEVICES

Provide devices as indicted on the Drawings.

19 GROUNDING

19.1 EQUIPMENT GROUNDING: Bond each end of equipment grounding conductors to the grounding bushing, the grounding bus, grounding lug, or the enclosure, respectively.

19.2 GROUNDING CONNECTIONS:

19.2.1 Use mechanical connectors to make grounding connections.

Completely remove paint, dirt, and corrosion down to bare metal at connection areas, and coat surfaces with anti-oxidant electrical joint compound.

20 INSTRUMENT AIR/GAS AND PROCESS TUBING

Where indicated, provide the following:

20.1 INSTRUMENT AIR/GAS TUBING: Provide $^1/_4$ inch, type L, or larger copper tubing, brass compression connectors, and copper clips.

20.2 PROCESS TUBING: Provide $^1/_4$ inch, 0.035 WT, or larger 304 stainless steel, seamless tubing, stainless steel compression connectors, and stainless steel clips

20.3 INSTALLATIONS: Arrange tubing neatly and symmetrically to adjacent components. Use bending tools to make bends in tubing.

20.4 SUBMITTALS: Provide product data of tubing and accessories.

21 EQUIPMENT FURNISHED BY OTHERS
(SEE — **ATTACHMENT *B: FURNISHED ELECTRICAL EQUIPMENT LIST*)**

21.1 Receive, store (in clean, dry location), and handle equipment furnished by others and required to be installed under this Contract.

21.2 Rig large, heavy equipment in place and bolt free standing equipment to floor as specified under *SUPPORTS*, Article 22, p.13.

21.3 Make power, instrument, and control wiring and tubing connections as indicated.

21.4 Where practicable, keep instrumentation wiring 12 inches away from other wiring and minimize paralleling instrument wiring with power or control wiring.

21.5 Where necessary, cut holes to accommodate conduit, cable, and tubing connections.

22 SUPPORTS

22.1 Where applicable, provide steel channels/struts with galvanized or painted finish.

22.2 Fasten equipment and supports with corrosion resistant hardware.

22.3 Provide support systems of suitable strength to hold intended equipment in place.

22.4 Fabricate supports from structural steel or steel channels/struts rigidly welded or bolted. Paint cut ends of supports with rust inhibitor matching existing finish.

22.5 Secure free-standing equipment to concrete pad or floor with at least four $^{5}/_{8}$ inch or larger bolts. Provide drilled concrete anchors where applicable.

22.6 Secure surface-mounted panels and cabinets with at least four $^{1}/_{2}$ inch or larger bolts.

23 TESTING

23.1 No equipment shall be energized without consent of PSI's representative.

23.2 It is the Contractor's responsibility to conduct tests without damage to equipment.

23.3 POWER WIRE TESTING (up through 600 volts):

23.3.1 Test each new conductor installed and existing conductor reconnected to ground using 1000-volt megger.

23.3.2 Provide written test report listing resistance by feeder and branch circuit.

23.3.3 Replace conductors measuring less than 25 megohm and retest.

23.4 CONTROL AND INSTRUMENT WIRE TESTING:

23.4.1 Check point-to-point continuity of each conductor to ensure that wiring is intact and terminated at the proper place at both ends. After wiring has been terminated,

1. lift one conductor at a time off of its terminal at both ends;
2. establish an isolated return path (not ground, but may be one of the cable conductors);
3. check conductor continuity;
4. reconnect wire to terminals, or if defective, correct, recheck, and reconnect;
5. with highlighter, mark wiring diagram or schedule to indicate that wire and connection has been verified; and
6. proceed to next conductor.

23.4.2 Using highlighter, indicate on terminal wiring diagrams or schedules that each wire and connection has been verified. Make these sheets available to Owner's and PSI's representatives.

23.4.3 Replace defective wiring and retest.

23.5 MOTORS TESTING:

23.5.1 Before connecting, measure motor winding resistance and ground resistance.

23.5.2 PSI will test each three-phase motor for proper rotary direction. Where necessary, correct circuit connections at motor box.

23.6 RECEPTACLES TESTING: Test polarity and grounding of each receptacle device used with equipment furnished under this Work. Report deficiencies to PSI's representative.

23.7 INSTRUMENT GAS AND PROCESS TUBING TESTING:

23.7.1 Check tubing and connectors for leaks.

23.7.2 Check gas operated valves for proper opening and closing or positioning of pneumatically operated device.

23.7.3 Make repairs as necessary and retest.

23.8 VALVES TESTING:

23.8.1 Valve cycling to verify proper operation of limit switches, pneumatic operators, and positioning operators is by PSI.

23.8.2 At defective installation, make electrical and pneumatic repairs as necessary and retest.

23.9 SCHEDULING, NOTIFYING, AND WITNESSING TESTING: Provide the PSI's representative with at least three days notification of scheduled testing. With the notification, include a list of proposed tests and the expected time to perform these tests.

24 CALIBRATING—BY PSI

—END—

ATTACHMENT "A"

DRAWING LISTS

Washington Site only

DRAWING	DESCRIPTION
V049-3-002	OVERALL SITE PLAN
V049-3-101	INSTRUMENT PLAN—VERTEX SECTION
V049-3-102	INSTRUMENT PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-103	INSTRUMENT PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-104	INSTRUMENT PLAN—DIAGONAL SECTION
V049-3-106	CABLE TRAY PLAN—VERTEX SECTION
V049-3-107	CABLE TRAY PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-108	CABLE TRAY PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-109	CABLE TRAY PLAN—DIAGONAL SECTION
V049-3-111	INSTRUMENT/ELECTRICAL PLAN—VERTEX SECTION
V049-3-112	INSTRUMENT/ELECTRICAL PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-113	INSTRUMENT/ELECTRICAL PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-114	INSTRUMENT/ELECTRICAL PLAN—DIAGONAL SECTION
V049-3-116	POWER PLAN—VERTEX SECTION
V049-3-117	POWER PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-118	POWER PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-119	POWER PLAN—DIAGONAL SECTION
V049-3-123	CDS INTERFACE DIAGRAM—CORNER STATION (4 SHEETS)
V049-3-124	CONDUIT STUB-UP PLAN—CORNER STATION (2 SHEETS)
V049-3-125	VACUUM CART INTERFACE PLAN—CORNER STATION (3 SHEETS)
V049-3-126	CONDUIT SCHEDULE—CORNER STATION
V049-3-127	DATA HIGHWAY PLAN— VERTEX STATION
V049-3-128	DATA HIGHWAY PLAN— LEFT BEAM MANIFOLD STATION
V049-3-129	DATA HIGHWAY PLAN— RIGHT BEAM MANIFOLD STATION
V049-3-130	DATA HIGHWAY PLAN— DIAGONAL STATION

Washington Site only

DRAWING	DESCRIPTION
V049-3-131	DATA HIGHWAY INTERCONNECT DIAGRAM— CORNER STATION
V049-3-201	INSTRUMENT PLAN—LEFT MID STATION
V049-3-202	CABLE TRAY PLAN—LEFT MID STATION
V049-3-203	INSTRUMENT/ELECTRICAL PLAN—LEFT MID STATION
V049-3-204	POWER PLAN—LEFT MID STATION
V049-3-206	VACUUM CART INTERFACE PLAN—LEFT MID STATION (2 SHEETS)
V049-3-208	CDS INTERFACE DIAGRAM—LEFT MID STATION
V049-3-209	CONDUIT SCHEDULE—LEFT MID STATION
V049-3-301	INSTRUMENT PLAN—RIGHT MID STATION
V049-3-302	CABLE TRAY PLAN—RIGHT MID STATION
V049-3-303	INSTRUMENT/ELECTRICAL PLAN—RIGHT MID STATION
V049-3-304	POWER PLAN—RIGHT MID STATION
V049-3-305	CONDUIT STUB-UP PLAN—RIGHT MID STATION
V049-3-306	VACUUM CART INTERFACE PLAN—RIGHT MID STATION (2 SHEETS)
V049-3-308	CDS INTERFACE DIAGRAM—RIGHT MID STATION
V049-3-309	CONDUIT SCHEDULE—RIGHT MID STATION
V049-3-308	CDS INTERFACE DIAGRAM—RIGHT MID STATION (2 SHEETS)
V049-3-401	INSTRUMENT PLAN—LEFT END STATION
V049-3-402	CABLE TRAY PLAN—LEFT END STATION
V049-3-403	INSTRUMENT/ELECTRICAL PLAN—LEFT END STATION
V049-3-404	POWER PLAN—LEFT END STATION
V049-3-406	VACUUM CART INTERFACE PLAN—LEFT END STATION (2 SHEETS)
V049-3-408	CDS INTERFACE DIAGRAM—LEFT END STATION
V049-3-409	CONDUIT SCHEDULE—LEFT END STATION
V049-3-408	CDS INTERFACE DIAGRAM—LEFT END STATION
V049-3-501	INSTRUMENT PLAN—RIGHT END STATION
V049-3-502	CABLE TRAY PLAN—RIGHT END STATION

ATTACHMENT "A"

Number A V049-2-022 Rev 4

Washington Site only

DRAWING	DESCRIPTION
V049-3-503	INSTRUMENT/ELECTRICAL PLAN—RIGHT END STATION
V049-3-504	POWER PLAN—RIGHT END STATION
V049-3-505	CONDUIT STUB-UP PLAN—RIGHT END STATION
V049-3-506	VACUUM CART INTERFACE PLAN—RIGHT END STATION (2 SHEETS)
V049-3-508	CDS INTERFACE DIAGRAM—RIGHT END STATION
V049-3-509	CONDUIT SCHEDULE—RIGHT END STATION

ATTACHMENT "A"

Number A V049-2-022 Rev 4

Louisiana Site only

DRAWING	DESCRIPTION
V049-3-003	OVERALL SITE PLAN
V049-3-601	INSTRUMENT PLAN—VERTEX SECTION
V049-3-602	INSTRUMENT PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-603	INSTRUMENT PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-606	CABLE TRAY PLAN—VERTEX SECTION
V049-3-607	CABLE TRAY PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-608	CABLE TRAY PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-611	INSTRUMENT/ELECTRICAL PLAN—VERTEX SECTION
V049-3-612	INSTRUMENT/ELECTRICAL PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-613	INSTRUMENT/ELECTRICAL PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-616	POWER PLAN—VERTEX SECTION
V049-3-617	POWER PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-618	POWER PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-623	CDS INTERFACE DIAGRAM—CORNER STATION (4 SHEETS)
V049-3-624	CONDUIT STUB-UP PLAN—CORNER STATION (2 SHEETS)
V049-3-625	VACUUM CART INTERFACE PLAN—CORNER STATION (3 SHEETS)
V049-3-626	CONDUIT SCHEDULE—CORNER STATION
V049-3-627	DATA HIGHWAY PLAN—VERTEX STATION
V049-3-628	DATA HIGHWAY PLAN— LEFT BEAM MANIFOLD STATION
V049-3-629	DATA HIGHWAY PLAN— RIGHT BEAM MANIFOLD STATION
V049-3-630	DATA HIGHWAY PLAN— DIAGONAL STATION
V049-3-631	DATA HIGHWAY INTERCONNECT DIAGRAM— CORNER STATION
V049-3-701	INSTRUMENT PLAN—LEFT END STATION
V049-3-702	CABLE TRAY PLAN—LEFT END STATION
V049-3-703	INSTRUMENT/ELECTRICAL PLAN—LEFT END STATION
V049-3-704	POWER PLAN—LEFT END STATION

ATTACHMENT "A"

Number	Rev
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Louisiana Site only

DRAWING	DESCRIPTION
V049-3-706	VACUUM CART INTERFACE PLAN—LEFT END STATION (2 SHEETS)
V049-3-708	CDS INTERFACE DIAGRAM—LEFT END STATION
V049-3-709	CONDUIT SCHEDULE—LEFT END STATION
V049-3-801	INSTRUMENT PLAN—RIGHT END STATION
V049-3-802	CABLE TRAY PLAN—RIGHT END STATION
V049-3-803	INSTRUMENT/ELECTRICAL PLAN—RIGHT END STATION
V049-3-804	POWER PLAN—RIGHT END STATION
V049-3-805	CONDUIT STUB-UP PLAN—RIGHT END STATION
V049-3-806	VACUUM CART INTERFACE PLAN—RIGHT END STATION (2 SHEETS)
V049-3-808	CDS INTERFACE DIAGRAM—RIGHT END STATION
V049-3-809	CONDUIT SCHEDULE—RIGHT END STATION

ATTACHMENT "A"

Number	Rev
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Washington & Louisiana Sites

DRAWING	DESCRIPTION
V049-3-001	GENERAL NOTES & LEGEND
V049-3-006	ELECTRICAL INSTALLATION DETAILS
V049-3-007	ELECTRICAL INSTALLATION DETAILS
V049-3-008	ELECTRICAL INSTALLATION DETAILS

REFERENCE DRAWING LIST*

DRAWING	DESCRIPTION
V049-3-004	ION CONTROLLER CABINET (2 SHEETS)
V049-3-121	PNL-100A & 100B ASSEMBLY
V049-3-122	PNL-100A & 100B WIRING DIAGRAM
V049-3-207	PNL-200 WIRING DIAGRAM
V049-3-307	PNL-300 WIRING DIAGRAM
V049-3-407	PNL-400 WIRING DIAGRAM
V049-3-507	PNL-500 WIRING DIAGRAM
V049-3-622	PNL-600A & 600B WIRING DIAGRAM
V049-3-707	PNL-700 WIRING DIAGRAM
V049-3-807	PNL-800 WIRING DIAGRAM

* Reference drawings, used by others to fabricate equipment, are furnished to supplement installation details and indicate wiring terminations.

ATTACHMENT "A"

Number	Rev
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ATTACHMENT "B"

FURNISHED ELECTRICAL EQUIPMENT LIST

Washington Site only

ITEM	INSTRUMENT TAG/EQUIPMENT DESIGNATION	V INDICATES VACUUM ENVIRONMENT LOCATION	DESCRIPTION (INDICATED ON DRAWING/SHEET)
1	FI-104	—	CRYOPUMP WCP1 FLOW INDICATOR (V049-3-102)
2	FI-154	—	CRYOPUMP WCP2 FLOW INDICATOR (V049-3-103)
3	FI-204	—	CRYOPUMP WCP3 FLOW INDICATOR (V049-3-201)
4	FI-254	—	CRYOPUMP WCP4 FLOW INDICATOR (V049-3-201)
5	FI-304	—	CRYOPUMP WCP5 FLOW INDICATOR (V049-3-301)
6	FI-354	—	CRYOPUMP WCP6 FLOW INDICATOR (V049-3-301)
7	FI-404	—	CRYOPUMP WCP7 FLOW INDICATOR (V049-3-401)
8	FI-504	—	CRYOPUMP WCP8 FLOW INDICATOR (V049-3-501)
9	LT-100	—	CRYOPUMP WCP1 LEVEL TRANSMITTER* (V049-3-102)
10	LT-105	—	CRYOPUMP WCP1 DEWAR LEVEL TRANSMITTER* (V049-3-102)
11	LT-150	—	CRYOPUMP WCP2 LEVEL TRANSMITTER* (V049-3-103)
12	LT-155	—	CRYOPUMP WCP2 DEWAR LEVEL TRANSMITTER* (V049-3-103)
13	LT-200	—	CRYOPUMP WCP3 LEVEL TRANSMITTER* (V049-3-201)
14	LT-205	—	CRYOPUMP WCP3 DEWAR LEVEL TRANSMITTER* (V049-3-201)
15	LT-250	—	CRYOPUMP WCP4 LEVEL TRANSMITTER* (V049-3-201)
16	LT-255	—	CRYOPUMP WCP4 DEWAR LEVEL TRANSMITTER* (V049-3-201)
17	LT-300	—	CRYOPUMP WCP5 LEVEL TRANSMITTER* (V049-3-301)
18	LT-305	—	CRYOPUMP WCP5 DEWAR LEVEL TRANSMITTER* (V049-3-301)
19	LT-350	—	CRYOPUMP WCP6 LEVEL TRANSMITTER* (V049-3-301)
20	LT-355	—	CRYOPUMP WCP6 DEWAR LEVEL TRANSMITTER* (V049-3-301)
21	LT-400	—	CRYOPUMP WCP7 LEVEL TRANSMITTER* (V049-3-401)
22	LT-405	—	CRYOPUMP WCP7 DEWAR LEVEL TRANSMITTER* (V049-3-401)

* Furnished with accessories.

Washington Site only

ITEM	INSTRUMENT TAG/EQUIPMENT DESIGNATION	V INDICATES VACUUM ENVIRONMENT LOCATION	DESCRIPTION (INDICATED ON DRAWING/SHEET)
23	LT-500	—	CRYOPUMP WCP8 LEVEL TRANSMITTER* (V049-3-501)
24	LT-505	—	CRYOPUMP WCP8 DEWAR LEVEL TRANSMITTER* (V049-3-501)
25	PNL-100A	—	CORNER STATION ION CONTROLLER PANEL (V049-3-116)
26	PNL-100B	—	CORNER STATION ION CONTROLLER PANEL (V049-3-116)
27	PNL-200	—	LEFT MID STATION ION CONTROLLER PANEL (V049-3-204)
28	PNL-300	—	RIGHT MID STATION ION CONTROLLER PANEL (V049-3-304)
29	PNL-400	—	LEFT END STATION ION CONTROLLER PANEL (V049-3-404)
30	PNL-500	—	RIGHT END STATION ION CONTROLLER PANEL (V049-3-504)
31	PT-101	—	CRYOPUMP WCP1 PRESSURE TRANSMITTER* (V049-3-102)
32	PT-151	—	CRYOPUMP WCP2 PRESSURE TRANSMITTER* (V049-3-103)
33	PT-201	—	CRYOPUMP WCP3 PRESSURE TRANSMITTER* (V049-3-201)
34	PT-251	—	CRYOPUMP WCP4 PRESSURE TRANSMITTER* (V049-3-201)
35	PT-301	—	CRYOPUMP WCP5 PRESSURE TRANSMITTER* (V049-3-301)
36	PT-351	—	CRYOPUMP WCP6 PRESSURE TRANSMITTER* (V049-3-301)
37	PT-401	—	CRYOPUMP WCP7 PRESSURE TRANSMITTER* (V049-3-401)
38	PT-501	—	CRYOPUMP WCP8 PRESSURE TRANSMITTER* (V049-3-501)
39	TE-103A	—	CRYOPUMP WCP1 THERMOCOUPLE (V049-3-102)
40	TE-153A	—	CRYOPUMP WCP2 THERMOCOUPLE (V049-3-103)
41	TE-203A	—	CRYOPUMP WCP3 THERMOCOUPLE (V049-3-201)
42	TE-253A	—	CRYOPUMP WCP4 THERMOCOUPLE (V049-3-201)
43	TE-303A	—	CRYOPUMP WCP5 THERMOCOUPLE (V049-3-301)
44	TE-353A	—	CRYOPUMP WCP6 THERMOCOUPLE (V049-3-301)
45	TE-403A	—	CRYOPUMP WCP7 THERMOCOUPLE (V049-3-401)
46	TE-503A	—	CRYOPUMP WCP8 THERMOCOUPLE (V049-3-501)

* Furnished with accessories

ATTACHMENT "B"

Number A V049-2-022 Rev

Louisiana Site only

ITEM	INSTRUMENT TAG/EQUIPMENT DESIGNATION	V INDICATES VACUUM ENVIRONMENT LOCATION	DESCRIPTION (INDICATED ON DRAWING/SHEET)
1	FI-604	—	CRYOPUMP LCP1 FLOW INDICATOR (V049-3-602)
2	FI-654	—	CRYOPUMP LCP2 FLOW INDICATOR (V049-3-603)
3	FI-704	—	CRYOPUMP LCP3 FLOW INDICATOR (V049-3-701)
4	FI-754	—	CRYOPUMP LCP4 FLOW INDICATOR (V049-3-801)
5	LT-600	—	CRYOPUMP LCP1 LEVEL TRANSMITTER* (V049-3-602)
6	LT-605	—	CRYOPUMP LCP1 DEWAR LEVEL TRANSMITTER* (V049-3-602)
7	LT-650	—	CRYOPUMP LCP2 LEVEL TRANSMITTER* (V049-3-603)
8	LT-655	—	CRYOPUMP LCP2 DEWAR LEVEL TRANSMITTER (V049-3-603)
9	LT-700	—	CRYOPUMP LCP3 LEVEL TRANSMITTER* (V049-3-701)
10	LT-705	—	CRYOPUMP LCP3 DEWAR LEVEL TRANSMITTER* (V049-3-701)
11	LT-800	—	CRYOPUMP LCP4 LEVEL TRANSMITTER* (V049-3-801)
12	LT-805	—	CRYOPUMP LCP4 DEWAR LEVEL TRANSMITTER* (V049-3-801)
13	PNL-600A	—	CORNER STATION ION CONTROLLER PANEL (V049-3-616)
14	PNL-600B	—	CORNER STATION ION CONTROLLER PANEL (V049-3-616)
15	PNL-700	—	LEFT END STATION ION CONTROLLER PANEL (V049-3-704)
16	PNL-800	—	RIGHT END STATION ION CONTROLLER PANEL (V049-3-804)
17	PT-601	—	CRYOPUMP LCP1 PRESSURE TRANSMITTER* (V049-3-602
18	PT-651	—	CRYOPUMP LCP2 PRESSURE TRANSMITTER* (V049-3-603)
19	PT-701	—	CRYOPUMP LCP3 PRESSURE TRANSMITTER* (V049-3-701)
20	PT-851	—	CRYOPUMP LCP4 PRESSURE TRANSMITTER* (V049-3-801)
21	TE-603A	—	CRYOPUMP LCP1 THERMOCOUPLE (V049-3-602)
22	TE-653A	—	CRYOPUMP LCP2 THERMOCOUPLE (V049-3-603)
23	TE-703A	—	CRYOPUMP LCP3 THERMOCOUPLE (V049-3-701)
24	TE-803A	—	CRYOPUMP LCP4 THERMOCOUPLE (V049-3-801)

*Furnished with accessories.

ATTACHMENT "B"

Number A V049-2-022 Rev 0

ATTACHMENT "C"

SUBMITTAL LIST

Submit for review the proposed equipment submittals and reports as required under the Specification and listed below:

1. Equipment substitutions (Article 8.3, page 6)

   Submit proposed substitutions to the electrical engineer for acceptance via PSI's representative. With submittal, provide details of necessary changes to accommodate substitutions. Submit samples if requested.

2. List of proposed equipment (Article 9.1, page 6)

   As soon as practicable, submit for review a list of equipment proposed for installation with each item identified by Specification paragraph number or where applicable by Drawing number. Include manufacturer's name with catalog or model number for each item.

3. Cable tray (Article 12.6, page 7)

   Provide product data of each cable tray component.
   Provide shop drawings of fabricated support brackets.
   Provide dimensioned diagrams indicating where expansion joints are proposed.

4. Wire and cable (Article 15.5, page 11)

   Provide product data of each wire and cable.

5. Wiring identification (Article 16.3, page 12)

   Provide product data of printed sleeve markers.

6. Instrument air/gas and process tubing (Article 20.4, page 13)

   Provide product data of tubing and accessories.

7. Testing (Article 23.3.2, page 14)

   Provide written test report listing resistance by feeder and branch circuit.

SPECIFICATION FOR

PROJECT QUALITY ASSURANCE PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

MANUFACTURING ENGINEER: Phillip Palmer

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D A M C Williams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	4/24/96		RELEASED PER DEC 137

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-029	Rev. 0
	ALB	4-24-96	REB	4/24/96		

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1.0 PURPOSE

The purpose of the QA Plan is to establish the quality requirements for the scope of work intended. This plan contains the PSI quality standards that will be imposed on the LIGO High Vacuum System.

2.0 GENERAL

The outlined plan will be imposed at PSI as well as all major component vendors.

3.0 RESPONSIBILITIES

The manager of Quality Assurance and the assigned Project Manager are responsible for the implementation of this plan.

4.0 PROCEDURE

4.1 Quality Review And Planning

4.1.1 Prior to fabrication the Quality Assurance Engineer will establish the hold/witness points from the Customers specification; the PSI inspection points and the applicable PSI procedures for the contract. From this information, the QAE will prepare a PSI Quality Plan, for each chamber or assembly built at PSI. The Quality Plan will define all of the inspection steps that require witness and/or verification during the course of manufacturing and assembly at PSI. Subcontractual work will be subject to the same planning, by the subcontractor, at his plant with witnessed HOLD points and inspections by PSI.

4.2 Receiving Inspection

4.2.1 All raw materials that are procured with Material Test Reports will be receipt inspected prior to use.

4.2.2 Procured components and items will be inspected at the vendor's plant. If inspection is not performed at the vendors plant, they will be receipt inspected upon arrival.

4.3 Material Certification

4.3.1 All vacuum chamber and flange materials will be procured with Material Test Reports. Other nozzle, small parts, small flange nozzles and bolting materials will be procured with a Certificate of Compliance. At receiving inspection, the materials will be verified against the Purchase Order for quantity, material markings and the Material Test Report will be verified to the applicable ASME and/or ASTM material specification for compliance.

4.3.2 If primary vacuum boundary materials are purchased from foreign (outside of USA), PSI will conduct independent lab analysis to verify material composition.

4.4 In-Process Inspection

4.4.1 QA/QC will verify material traceability throughout the manufacturing cycle. They will monitor the quality of welding and the qualifications of personnel, verify the final cleaning and verify/witness the testing required by the customers specification.

4.5 Cleaning

4.5.1 All materials will be cleaned free of grease, oil, rust and foreign matter prior to welding. After the welding and machinery operations, the assemblies will be cleaned to the required level, for the intended service.

4.5.2 Final cleaning will be performed in accordance with the LIGO cleaning procedure.

4.6 Welding

4.6.1 All welding exposed to the vacuum will be performed by the PAW or the GTAW (TIG) welding process, with a 100% Argon shield gas or plasma arc welding with 100% Argon shield gas. All open or closed root, butt welding will be purged with 100% Argon (backing gas). Slip-on-flanges and lap joint designs that allow for fillet welds will not require baking gas. All vacuum welding will performed utilizing ASME Section IX qualified welding procedures and qualified welders.

4.6.2 Welding operations will be monitored on a daily basis by the QA/QC department for compliance with the LIGO Project Procedures and the applicable codes.

4.7 Final Inspection

4.7.1 Final inspection will be accomplished on all components prior to shipment. This inspection will include but is not limited to the following: serialization of components, final cleaning, final acceptance testing and packaging for shipment.

4.8 Testing

4.8.1 Vacuum components shall meet pumpdown and helium leak rates per the LIGO Project Procedures.

4.8.2 Pumps and valves will be performance tested at the vendor plant. These tests will be witnessed by PSI.

4.8.3 All testing will be performed in accordance with LIGO Project procedures. All shop testing performed will be witnessed/verified by QA/QC.

4.8.4 Written test reports will be generated for all testing and will be included in the final documentation package.

4.9 Documentation

4.9.1 Final documentation on this project will consist of signed off Quality Plans, Material Test Reports for vacuum chamber and flange materials, certificates of conformance of all nozzle materials, small parts and bolting materials, final cleaning certificate, Helium leak test reports, pumpdown test report and a Certificate of Conformance to the codes and standards.

4.10 Vendor Surveillance

4.10.1 Prior to fabrication, each vacuum vessel fabricator shall submit quality plans to PSI for approval. PSI QA and engineering will set mandatory hold points and perform periodic inspections at the vendor's plant. The vendor shall provide final documentation as detailed in the procurement specification for all PSI fabricated components, documentation shall be provided as shown in Attachment 1 "Final Documentation Summary".

4.10.2 For major purchased components, QA requirements are detailed in "QA Requirements Summary" form attached to each procurement specification.

4.11 Engineering Plan Review

4.11.1 QA will be part of the design review team as the design develops.

4.12 Procurement Specification Review

4.12.1 QA will be part of the review team for all major component specifications.

Attachment 1
V049-2-029

LIGO VACUUM EQUIPMENT
FINAL DOCUMENTATION SUMMARY

Component
Model No.:
Serial No.:

Date:
Prepared By:

1.	Quality Plan Doc. No.:		Rev.
2.	Material Test Reports:		Date
3.	Certification of Conformance:		
4.	Heat Treat Charts:		
5.	Final Cleaning Certification:		
6.	Bakeout Certification:		
7.	Final Vacuum Leak Reports:		
8.	Non-Conformance Reports:		
9.	Certificate of Conformance:		

Number

Rev.

Notes:

SPECIFICATION		
Number A	V049-2-029	Rev.

PROJECT SAFETY PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

QUALITY ASSURANCE: Allan L Bradbook

LIGO SAFETY OFFICER: James M Eaves

PROJECT MANAGER: Richard Boyle

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	4/24/96		RELEASED PER DEO 137

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-023	Rev. 0
	JMC	15APR96	RBB	4/24/96		

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ATTACHMENTS

1.0 PURPOSE

This plan defines and establishes the safety requirements for the LIGO Project vacuum equipment supply and installation. The program requirements include safety management systems as well as safety engineering controls necessary to ensure the identification and resolution of all safety issues relative to this project.

This program provides for the review and approval of all operations, facilities equipment, and manpower application for safety and environmental controls necessary to provide maximum protection and to minimize risk of personnel, facilities, and hardware/equipment, etc.

2.0 SCOPE

The requirements as stated herein, will apply to all PSI facilities and construction sites.

3.0 APPLICABLE DOCUMENTS

The current revisions of the following documents dictate the requirements relative to the implementation of this plan.

a. 29 CFR Occupational Safety and Health Administration (OSHA) General Industry Standards

b. 40 CFR Environment Protection Agency (EPA) Protection of Environment

c. 49 CFR Department of Transportation (DOT) Transportation

d. National Fire Protection Association (NFPA) Fire Codes, Handbook Of Fire Protection, Life Safety Code Handbook, National Electrical Code.

e. American National Standards Institute (ANSI) Safety Standards.

f. National Safety Council (NSC) Accident Prevention Manual for Industrial Operations.

g. Toxic Substances Control Act (TSCA).

PSI has in place safety policies to meet general OSHA, Government and State requirements (regulations) which have been qualified by implementations/audits and by on-site visitation of these agencies.

4.0 PLAN MAINTENANCE

During the execution of this program, PSI's safety philosophy will be dictated by its Safety Policy Statement.

PSI is committed to providing a safe workplace for all employees. Program objectives are the prevention of injury, an the prevention of injury, and the prevention of employee and visitor exposure to hazardous conditions or materials. In order to achieve these objectives, environmental health and safety issues will be addressed as integral components of our business strategy. Our goal is to provide quality products and services while actively conserving our human and natural resources. It is our belief that accidents and undesirable environmental incidents are preventable by active participation from each employee.

All managers and leaders are responsible for ensuring that each employee receives the training and instruction necessary to perform his job safely. Each employee has the responsibility to comply with the company work rules following safe work practices and procedures established to protect the environment, and for reporting to leaders and managers all unsafe acts and hazardous conditions which may impact the environment. PSI's scope of operations range from manufacturing facilities to administrative offices. Therefore, safety programs will be tailored to each situation.

All PSI employees are required to read and follow the PSI Safety Manual as a condition of employment. (See Attachment I.)

6.0 SAFETY OBJECTIVES

6.1 To carry out the PSI safety policy, the following objectives have been identified relative to the Safety Program.

a. All work will be performed in the safest possible manner to reduce accidents involving personal injury, environmental impact, and equipment, facility or product damage.

b. A formal safety program has been established to define safety responsibilities, safety management controls, procedures, industrial safety requirements, industrial hygiene requirements, environmental functions, and other provisions to meet regulatory agency requirements. (See PSI Safety Manual.)

c. The PSI Safety program has the active support of all PSI employees. All levels of management will support the program and the concept of individual responsibility for safe operations will be established and reinforced.

d. The primary responsibility for safe operations will rest with the supervisor, who supported by the Safety Committee, is charged with conducting assigned tasks in the safest possible manner. Each supervisor will assure that organizational procedures provide safe working conditions and that team members comply with all Safety Committee requirements associated with the task.

e. The value of personnel training and certification as an accident preventive measure will be emphasized. Employees will be trained to be familiar with the systems, equipment and facilities which are required for the safe performance of their assigned tasks.

f. The Safety Program will be responsible for all safety related contractual directions.

g. To ensure site safety programs comply with PSI Safety Standards.

6.2 Organization

To accomplish the safety objectives relative to this program, a Safety Committee has been established at PSI. The Safety Committee has been designated and charged with the responsibility of coordinating the safety program to meet company and contractual safety requirements. The committee reports to the President of PSI. There are 12 to 14 people on the safety committee representing each PSI department including Humor Resources. The committee normally meets every two weeks. Special meetings may be called by the chairman if required.

6.3 Responsibilities

Throughout the performance of this project, responsibilities have been established to carry out the requirements of this plan. The Safety Committee chairman (or individual members) are responsible for informing the President of PSI if an unsafety condition is allowed to exist at PSI after it has been identified.

a. Each PSI department has the responsibility for identifying potential hazardous operations, facilities and equipment; for providing required documentation and information incorporating safety requirements for continuing the safe conduct of activities; and for developing procedures and controls necessary for the safe processing of fabricated articles/items throughout all phases of manufacturing and delivery of products.

b. Supervisors/Team Leaders are responsible for assuring safe workmanship practices, including training, certification and qualification of personnel to approved training requirements.

c. All involved personnel are responsible for reporting to any potential unsafe condition throughout the performance of their duties/responsibilities - to the Safety Committee Chairman for resolution.

7.0 MAINTENANCE OF SAFETY CONTROLS

7.1 The Safety Manual, which is available to all personnel, will be revised/updated when new information is obtained, or when new development of processes/equipment dictate changes, and for training/qualification of personnel as determined by growth/expansion/development, etc.

7.2 Safety meetings will be held based on a "need to know" basis and as a minimum quarterly.

8.0 SITE SAFETY PLAN

Weekly safety meetings are mandatory on all PSI jobsites, and are administered by the PSI site manager. PSI subcontractors will be required to maintain a formal safety program. Site specific safety plans will be developed inconjunction with the selected PSI installation contractor. This will result in a cohesive document that has been proved to be successful in application. It also results in more familiarity by the people performing and supervising the work.

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

SPECIFICATION FOR LEAK CHECK PLAN
FOR LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROCESS ENGINEER R T Jones

PROJECT ENGINEER S Mottus

QUALITY ASSURANCE Alan L Bradbury

TECHNICAL DIRECTOR D. O. McWilliams

PROJECT MANAGER Rabel Bagley

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Φ	SM 5/4/96	RE B 5/4/96	INITIAL RELEASE DCO 0162 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED SM	DATE 5/4/96	Approved RE B 5/4/96 DATE	Number: A V049-2-014 / Rev. 0

1.0 PURPOSE

The purpose of this procedure is to define the necessary steps to ensure that equipment fabricated by Process Systems International (PSI) meets the leak rate specification for each component. The procedure includes proposed methods for leak checking welded joints and the double O-ring /pumped annulus flange joints. Where required ,additional data will be gathered and tests will be performed to confirm the methods.

2.0 GENERAL

This specification will be periodically updated to reflect the latest leak check test data that becomes available from prototype and production component testing.
The leak testing methods will make use of a Residual Gas Analyzer and a dry (oil free) Helium Mass Spectrometer Leak Detector. All leak testing methods and calibration will be derived from A.S.T.M. E498 Standard Test Methods for Leaks Using the MSLD or RGA in Tracer Probe Method

3.0 RESPONSIBILITY

This procedure is applicable to PSI Testing Department and its personnel.

4.0 PROCEDURE

4.1 Joint Categories:

Category I
Welded joint located away from the double O-ring flange assembly .

Category II
Welded joint located near the double O-ring flange assembly .

Category III
CF flange joint.

Category IV
Atmospheric O-ring. (O-ring between atmosphere and annulus channel.)

Category V
UHV O-ring. (O-ring between annulus channel and UHV chamber.)

4.2 Leak Checking Welded Joints

Category I
Welded joint located away from the double O-ring flange assembly .

These leaks can be detected using standard MSLD leak detection procedures with He as the tracer gas. The leak detector is sensing the vacuum chamber and He is sprayed external to the vessel. If there are multiple or large leaks the potential problem of building a high He background level in the vessel exists.

Category II
Weld joint located near a double O-ring flange assembly .

Helium leak detection procedures are still preferred. The proposed method is to bag the O-ring flanged joint and introduce a pure nitrogen purge into the bag. This will keep the concentration of helium in the bag low in order to minimize permeation or leakage of He through the atmospheric O-ring seal.Maintaining a vacuum in the O-ring annulus will also help by removing helium before it can permeate the UHV O-ring and enter the vacuum chamber.

4.3 Leak Checking Conflats

Category III
Conflats.

The conflats can be leak checked using standard Helium MSLD procedures.As in Category II leak detection,nearby O-ring flange assemblies may need bagging and nitrogen purging.

4.4 Leak Checking O-rings

Category IV
Atmospheric O-ring. (O-ring between atmosphere and annulus channel.)

Leak checking method

The dual O-ring sealed flanged joint to be tested must first be bagged .The bag is then purged and filled with the tracer gas.The detector will be sensing the pumped annulus volume between the atmospheric O-ring seal (Cat.IV) and the UHV O-ring (Cat.V).Tracer gas that leaks across or diffuses through the atmospheric O-ring seal will be pumped by the annulus pumping system .The maximum allowable leak rate across the O-ring seal must be less than the expected diffusion rate through the seal.The expected order of magnitude for the diffusion rate of air through the Viton seal is 10^{-5} Torr-L/s.Since helium will diffuse through Viton much quicker than air, the diffusion rate through the O-ring for helium will be higher than 10^{-5} Torr-L/s. An alternate tracer gas to helium may be required for the O-ring seal leak detection. Since diffusion data for Viton is limited, it will be necessary to test other gasses. Preferably, a gas which has a diffusion rate slow enough to yield a gas load smaller than the leak rate we are testing for.In order to minimize background interference due to O-ring outgassing, the trace gas should not be a gas abundant in air.Leaks greater in magnitude than the diffusion value will be repaired.

Possible candidates for tracer gases:

Argon	Able to use if the diffusion rate is small compared to leak size. Testing would be required. Literature data indicate that Argon diffuses faster than nitrogen.
Neon	Same as Argon. Diffusion rate unknown
Krypton	Same as Argon. Diffusion rate unknown
Helium	May still be useful since it is a very light gas and would pass relatively quickly through the leak. More time is required for the diffusion to occur, thus if the leak is large enough it could be distinguished from diffusion.
Air signature	For small leaks this could become difficult, the outgassing background could vary too much.

Category V
UHV O-ring. (O-ring between UHV space and annulus channel.)

This O-ring has essentially the same problems as the atmospheric O-ring, however the atmospheric O-ring has one advantage over the UHV O-ring; the volume on the detection side of the atmospheric O-ring (annulus volume) is much smaller than the volume on the detection side of the UHV O-ring (chamber). It is therefore preferable to also leak check the UHV O-ring via the annulus system.

Leak checking method

Pump down the vacuum chamber and backfill with dry tracer gas to a pressure of approximately 10 Torr.The reason not to backfill to 1 atmosphere pressure is to simulate the normal operating pressure

force on the UHV O-ring seal (almost balanced), and to keep the consumption of tracer gas to a minimum.
The detector will be sensing the pumped annulus volume between the atmospheric O-ring seal (Cat.IV) and the UHV O-ring (Cat.V).Tracer gas that leaks across or diffuses through the UHV O-ring seal will be pumped by the annulus pumping system . Seal leakage criteria is set by the diffusion rate through the seal.The maximum allowable leak rate across the O-ring seal must be less than the expected diffusion rate through the seal.

Optional Leak Detection Methods

Option 1. Leak checking with atmosphere on both sides of the flange seals.

This method may be used if it is determined that the UHV O-ring's sealing integrity will not be altered when the UHV side is cycled between atmospheric pressure and vacuum.

Since both seals are exposed to air, each O-ring should produce the same gas load (diffusion, outgassing, and leakage) if the seals are performing properly. If approximately twice the expected gas load for one O-ring is detected, then both seals are considered acceptable.. If a leak is suspected, establishing an air signature will be time consuming, a quicker method may be to spray one side of the joint with a tracer gas previously determined as being suitable for distinguishing between diffusion and leakage. If the sprayed O-ring does not appear to be leaking, then the unsprayed O-ring must be tested.Prior to spraying the suspect O-ring, the annulus system must be sufficiently evacuated to reduce the background from the first leak check The suspect seal is then sprayed with the same tracer gas. If a second suitable tracer gas is available, the second tracer gas may be used instead of the original tracer to spray the suspect O-ring.

Outgassing of O-Rings

Air contains approximately 1% Argon , 5 ppm Helium, 18ppm Neon.Outgassing of these gasses from the O-ring will contribute to the background levels during leak checking.
The solubility for these individual gasses in Viton is unknown, therefore actual outgassng levels for these gasses will have to be determined experimentally.
As an estimate , the outgassing load from the O-ring is 10^{-11} Torr-L/sec for Helium and Neon, and 10^{-8} Torr-L/sec for Argon.

LEAK TEST DATA SHEET

	1	2	3
Component Name			
Model Number			
Serial Number			
Drawing Number			
Detector Name			
Model Number			
Serial Number			
Detector Calibration			
Expiration Date			
Standard Leak Rate			
Background			
Standard Response			
Leak Test Data			
Location /Date			
Tracer Gas			
Pressure			
Duration			
Response			
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By :	Date :		
Witnessed By :	Date :		
Signature :	Date :		
Title :			

Remarks : _____

_____

BSC LEAK TEST SUMMARY SHEET

Name							
Model No.							
Serial No.							
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
		Torr-L/s	Torr-L/s				
Annulus-1	IV		$1x10^{-5}$				
Annulus-2	IV		$1x10^{-5}$				
Annulus-3	IV		$1x10^{-5}$				
Annulus-4	IV		$1x10^{-5}$				
Annulus-5	IV		$1x10^{-5}$				
Annulus-1	V		$1x10^{-5}$				
Annulus-2	V		$1x10^{-5}$				
Annulus-3	V		$1x10^{-5}$				
Annulus-4	V		$1x10^{-5}$				
Annulus-5	V		$1x10^{-5}$				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				
Comments							
Witnessed Signature Title Date							

HAM LEAK TEST SUMMARY SHEET

Name							
Model No.							
Serial No.							
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
		Torr-L/s	Torr-L/s				
Annulus-1	IV		$1x10^{-5}$				
Annulus-2	IV		$1x10^{-5}$				
Annulus-3	IV		$1x10^{-5}$				
Annulus-4	IV		$1x10^{-5}$				
Annulus-1	V		$1x10^{-5}$				
Annulus-2	V		$1x10^{-5}$				
Annulus-3	V		$1x10^{-5}$				
Annulus-4	V		$1x10^{-5}$				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				
Comments							
Witnessed Signature Title Date							

SPOOL SECTION LEAK TEST SUMMARY SHEET

Name							
Model No.							
Serial No.							
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
		Torr-L/s	Torr-L/s				
Annulus-1	IV		$1x10^{-5}$				
Annulus-2	IV		$1x10^{-5}$				
Annulus-1	V		$1x10^{-5}$				
Annulus-2	V		$1x10^{-5}$				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				
Comments							
Witnessed Signature Title Date							

SPECIFICATION

Number: V049-2-014 A	Rev.0

LIGO- V049-2-070

Rev. A

Process Systems International, Inc.
20 Walkup Drive Westborough, MA 01581
WELDING PROCEDURE SPECIFICATION (WPS)

WPS No.: 150 Date: 02/08/96 Revision No.: A Date: 04/23/96
Supporting PQRs: 150 H48

BASE METAL (QW-403, QW-405)	JOINT (QW-402)
P No. 8 to P No.:8	Joint design Groove/Fillet(see pg 2)
Thickness range. 0.1875" to 1.0000"	Backing..... With or without backing
Position(s).All positions	Backing Matl Optional
Progression.Vertical Up	Fillet Weld Size All (QW-451.4)
notes	notes

PREHEAT (QW-406)	POSTWELD HEAT TREATMENT (QW-407)
Minimum Temperature. 60 Degrees F.	Temperature range None
Interpass Temp. Max. 350 Degrees F.	Time range None
Preheat Maintenance. None	notes

	All pass(es)	None
Process / type	PAW / manual	
Process thickness limit.	0.1875" to 1.0000"	None
GAS (QW-408)		
Shielding Gas / CFH.....	75% Argon, 25% He./ 20-30	None / -
Trailing Gas / CFH.....	None / -	None / -
Backing Gas / CFH.....	100% Argon / 9-24	None / -
Plasma Gas / CFH.....	100% Argon / 1-3	None / -
FILLER METAL (QW-404)		
AWS classification.....	ER308L	None
SFA Spec. No. & F No....	SFA#: 5.9 F#: 6	SFA#: None F#: -
A No. or Chem. Comp.....	8	None
Filler metal trade name.	SOLID FILLER METAL	None
SAW flux trade name/type	N/A / -	None / -
Elec./Wire size (in) ...	1/16 | 3/32 | 1/8	- | - | -
ELECTRICAL (QW-409)		
Welding amperage range..	30-100 | 75-160 | 100-200	- | - | -
Welding voltage range...	12-18 | 14-21 | 16-26	- | - | -
Travel speed (ipm).....	Var. | Var. | Var	- | - | -
Max. Heat Input (J/in)..	None	None
Tungsten Type/Size.....	EWTh-2 / 1/16" - 3/16"	N/A / -
Current & Polarity.....	DCEN (straight)	N/A
TECHNIQUE (QW-410)		
String / weave bead.....	String & Weave Bead	N/A
Orifice / gas cup.....	3/8" to 5/8"	None
Contact tube to work....	N/A	None
Oscillation.....	Transverse	None
Mult./Single electrode..	Single Electrode	N/A
Other Technique Notes...	Keyhole & Melt-in used	None

Multiple or Single Pass (per side).... Multiple Passes
(n1)No Pass > 1/2" t
(n2)No supplementary filler metal will be used with this procedure.
(n3)
(n4) WELD WIRE SHALL BE CLEANED SPECIAL AND HANDLED WITH POLY GLOVES.
(n5) GRINDING WITH ABRASIVE WHEELS IS "NOT ALLOWED.
(n6) WIRE BRUSHING IS "NOT ALLOWED".
(n7) DEFECT REMOVAL MUST BE ACCOMPLISHED WITH A CARBIDE BURR CUTTER.

WPS No.: 150 Date: 02/08/96 Revision No.: A Date: 04/23/96

JOINT (QW-402)

Single-V groove Backing : no backing Root Opening: .125-.1875 max. Groove Angle: 50 degree min. Root Face : .030-.060 max.	Single-Bevel groove Backing : no backing Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-060 max.
Single-V groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 50 degree min. Root Face : .030-.060 max.	Double-Bevel groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-.060 max.
Double-V groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-.060 max.	Single/Double Fillet Backing : Root Opening: 1/32" max. Weld Size : Required fillet plus root opening
Square groove Backing : T-joint Root Opening: 1/32" max.	Square groove Backing : no backing Root Opening: 3/32" max.

WELD JOINT DESCRIPTIONS SHOWN ARE NOT INCLUSIVE OF ALL OF THOSE FOUND ON THE JOB. WELD JOINT DESIGN REFERENCE IN AN ENGINEERING SPECIFICATION OR DESIGN DRAWING SHALL TAKE PREFERENCE OVER WELD JOINTS SHOWN IN THIS WPS.

Initial cleaning shall be in strict compliance with special job procedures. Method of back gouging must be accomplished with a carbide burr cutter.

(a) NON-FUSABLE RETAINERS MAY BE USED.

(b) WELD WIRE SHALL BE CLEANED SPECIAL IN ACCORDANCE WITH SPECIFIC JOB PROCEDURES. SEALED IN BAGS AND HANDLED WITH POLY GLOVES AT ALL TIMES.

(c) GRINDING AND WIRE BRUSHING ARE "NOT ALLOWED" ON THE LIGO JOB. DEFECT REMOVAL MUST BE ACCOMPLISHED WITH A CARBIDE BURR CUTTER.

(d) WELDING STARTS & STOPS MUST RAMP GRADUALLY UP & DOWN TO AVOID CRACKING. THE WELDER SHALL PROVIDE A POST (AFTER FLOW) GAS FLOW OF 10 SECONDS.

(e)

We certify that the statements in this record are correct and in accordance with the requirements of Sections IX and VIII of the ASME Code.

Prepared By: A Rollins (04/23/96) Weld Specialist

Accepted By: Mary Bandbook (04/23/96) QA Manager:

Process Systems International, Inc.
20 Walkup Drive Westborough, MA 01581
Procedure Qualification Record (PQR)

PQR No.: 150 H48 Date: 2/ 8/96 WPS No.: 150 Rev A

JOINT DESIGN (QW-402) WELD JOINT CONFIGURATION Single-V groove Gas backing was used Groove Angle : 75 Degrees Root Opening : 0-125" Inches Root Face : 030-062" Inches note:	BASE METAL (QW-403) Material form. Plate Material Spec. SA-240, Type 304L To ..... SA-240, Type 304L P No. 8 Gr. 1 to P No. 8 Gr. 1 Thickness (in) 0.5000 HEAT TREATMENT (QW-406, QW-407) Preheat Temperature: 60 Degrees F. Preheat Maintenance: None Interpass Temperature: 350 Degrees F. PWHT temperature ... : None Degrees F. PWHT Holding time(hr): None note:
POSITION (QW-405) Position of Joint : 1G - Flat Progression: N/A note:	

	All pass(es)			None	
Weld Process / type	PAW / manual				
GAS (QW-408)					
Shielding Gas / CFH.....	75% Argon, 25% He./ 20-30			None / -	
Trailing Gas / CFH.....	None / -			None / -	
Backing Gas / CFH.....	100% Argon / 10-20			None / -	
Plasma Gas / CFH.....	100% Argon / 1-3			None / -	
FILLER METAL (QW-404)					
AWS Classification.....	ER308L			None	
SFA Spec. No. & F No....	SFA#: 5.9		F#: 6	SFA#: None	F#: -
A No. or Chem. Comp.....	8			None	
Filler Metal Trade Name.	SOLID FILLER METAL				
SAW Flux Trade Name/Type	N/A / -			None / -	
Weld Deposit 't' (in)...	0.5000			None	
Elec./Wire Size (in)....	1/16	3/32	1/8	-	-	-
ELECTRICAL (QW-409)					
Amperage USED	30-100	75-160	100-200	-	-	-
Voltage USED	12-18	14-20	16-26	-	-	-
Travel Speed (ipm).....	Var.	Var	Var	-	-	-
Max. Heat Input (J/in)..	None			None	
Tungsten Type & Size....	EWTh-2 / 3/32" - 3/16"			N/A / -	
Current Type/Polarity...	DCEN (straight)			N/A	
TECHNIQUE (QW-410)					
String or Weave Bead....	String & Weave Bead			N/A	
Orifice/Gas Cup Size....	1/2" - 5/8"			None	
Contact Tube to Work....	N/A			None	
Oscillation.....	Transverse			None	
Mult./Single Electrodes.	Single Electrode			N/A	
Other Technique Notes...	Keyhole & Melt-in used			None	

Multiple or Single Pass (per side).... Multiple Passes

(n1) No supplementary filler metal will be used with this procedure.
(n2)
(n3)
(n4)
(n5)

Procedure Qualification Record (PQR)

PQR No.: 150 H48

TENSILE TEST (QW-150)

Specimen No.	Width (in.)	Thick. (in.)	Area (sq.in.)	Ultimate total load (lb)	Ultimate stress (psi)	Type of failure and location
1	0.748	0.497	0.372	33550	90200	Weld metal
2	0.750	0.505	0.379	34350	90600	Weld metal

GUIDED BEND TEST (QW-160)

Figure No. and Type	Result	Figure No. and Type	Result
QW-462.2 Side bend	No defects	QW-462.2 Side bend	No defects
QW-462.2 Side bend	No defects	QW-462.2 Side bend	No defects

TOUGHNESS TEST (QW-170)

Spec. No.	Notch Location	Notch Type	Test Temp. (F)	Impact Values (ft-lbs)	Lateral exp.		Drop weight break
					Shear %	Mils	
None							

HARDNESS TEST - No hardness test

Base metal	-1-	-2-	-3-	HAZ	-1-	-2-	-3-	WM	-1	-2-	-3-

(Heat Affected Zone=HAZ, Weld Metal=WM)

Notes:

Stamp: H48 Welder's Name: Kennedy, Dan ID:
Tests conducted by: CONAM INSPECTION INC. Laboratory Test No: 14082
PQR was done & welding of coupon was witnessed by : Process Systems

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Code.

Prepared By: A Rollins (2/ 8/96) Weld Specialist

Certified By: Allan R Bendlook (2/ 8/96) QA Manager:

LIGO- V049-Z-071

REV. A

Process Systems International, Inc.
20 Walkup Drive Westborough, MA 01581
WELDING PROCEDURE SPECIFICATION (WPS)

WPS No.: 151 Date: 02/16/96 Revision No.: A Date: 04/23/96
Supporting PQRs: 151-H48

BASE METAL (QW-403, QW-405) P No. 8 to P No.:8 Thickness range. 0.1875" to 1.0000" Position(s).All positions Progression.Vertical Up notes	JOINT (QW-402) Joint design Groove/Fillet(see pg 2) Backing..... With or without backing Backing Matl Optional Fillet Weld Size All (QW-451.4) notes
PREHEAT (QW-406) Minimum Temperature. 60 Degrees F. Interpass Temp. Max. 350 Degrees F. Preheat Maintenance. None	POSTWELD HEAT TREATMENT (QW-407) Temperature range 625-675 DEG. F. Time range 4 notes

	All pass(es)	None
Process / type	PAW / manual	
Process thickness limit.	0.1875" to 1.0000"	None
GAS (QW-408)		
Shielding Gas / CFH.....	75% Argon, 25% He./ 20-30	None / -
Trailing Gas / CFH.....	None / -	None / -
Backing Gas / CFH.....	100% Argon / 9-24	None / -
Plasma Gas / CFH.....	100% Argon / 1-3	None / -
FILLER METAL (QW-404)		
AWS classification.....	ER308L	None
SFA Spec. No. & F No....	SFA#: 5.9 F#: 6	SFA#: None F#: -
A No. or Chem. Comp.....	8	None
Filler metal trade name.	SOLID FILLER METAL	None
SAW flux trade name/type	N/A / -	None / -
Elec./Wire size (in) ...	1/16 | 3/32 | 1/8	- | - | -
ELECTRICAL (QW-409)		
Welding amperage range..	30-100 | 75-160 | 100-200	- | - | -
Welding voltage range...	12-18 | 14-21 | 16-26	- | - | -
Travel speed (ipm).....	Var. | Var. | Var.	- | - | -
Max. Heat Input (J/in)..	None	None
Tungsten Type/Size.....	EWTh-2 / 1/16"-3/16"	N/A / -
Current & Polarity.....	DCEN (straight)	N/A
TECHNIQUE (QW-410)		
String / weave bead.....	String & Weave Bead	N/A
Orifice / gas cup.....	3/8" to 5/8"	None
Contact tube to work....	N/A	None
Oscillation.....	Transverse	None
Mult./Single electrode..	Single Electrode	N/A
Other Technique Notes...	Keyhole & Melt-in used	None

Multiple or Single Pass (per side).... Multiple Passes
(n1)No pass > 1/2" t.
(n2)No supplementary filler metal will be used with this procedure.
(n3)WELD WIRE SHALL BE CLEANED SPECIAL AND HANDLED WITH POLY GLOVES.
(n4)GRINDING WITH ABRASIVE WHEELS IS "NOT ALLOWED".
(n5)WIRE BRUSHING IS "NOT ALLOWED".
(n6)PWHT Ramp up to 300 deg.f.then 100 deg.f./hr. up to 650 deg. f.
(n7)PWHT Ramp down at 100 deg.f./hr. to room temp.

WPS No.: 151 Date: 02/16/96 Revision No.: A Date: 04/23/96

JOINT (QW-402)

Single-V groove
Backing : no backing
Root Opening: .125-.1875 max.
Groove Angle: 50 degree min.
Root Face : .030-.060 max.

Single-Bevel groove
Backing : no backing
Root Opening: .125-.1875 max.
Groove Angle: 45 degree min.
Root Face : .030-.060 max.

Single-V groove
Backing : gouged & back welded
Root Opening: .125-.1875 max.
Groove Angle: 50 degree min.
Root Face : .030-.060 max.

Double-Bevel groove
Backing : gouged & back welded
Root Opening: .125-.1875 max.
Groove Angle: 45 degree min.
Root Face : 3/16" max.

Double-V groove
Backing : gouged & back welded
Root Opening: .125-.1875 max.
Groove Angle: 45 degree min.
Root Face : .030-.060 max.

Single/Double Fillet
Backing :
Root Opening: 1/32" max.
Weld Size : Required fillet plus root opening

Square groove
Backing : T-joint
Root Opening: 1/32" max.

Square groove
Backing : no backing
Root Opening: 3/32" max.

WELD JOINT DESCRIPTIONS SHOWN ARE NOT INCLUSIVE OF ALL OF THOSE FOUND ON THE JOB. WELD JOINT DESIGN REFERENCE IN AN ENGINEERING SPECIFICATION OR DESIGN DRAWING SHALL TAKE PREFERENCE OVER WELD JOINTS SHOWN IN THIS WPS.

Initial cleaning shall be in strict compliance with special job procedures. Method of back gouging must be accomplished with a carbide burr cutter.

(a) NON-FUSABLE RETAINERS MAY BE USED.

(b) WELD WIRE SHALL BE CLEANED SPECIAL IN ACCORDANCE WITH SPECIFIC JOB PROCEDURES. SEALED IN BAGS AND HANDLED WITH POLY GLOVES AT ALL TIMES.

(c) GRINDING AND WIRE BRUSHING ARE "NOT ALLOWED" ON THE LIGO JOB. DEFECT REMOVAL MUST BE ACCOMPLISHED WITH A CARBIDE BURR CUTTER.

(d) WELDING STARTS & STOPS MUST RAMP GRADUALLY UP & DOWN TO AVOID CRACKING. THE WELDER SHALL PROVIDE A POST (AFTER FLOW) GAS FLOW OF 10 SECONDS.

(e)

We certify that the statements in this record are correct and in accordance with the requirements of Sections IX and VIII of the ASME Code.

Prepared By: A Rollas (04/23/96) Weld Specialist

Accepted By: Alan Bradford (04/23/96) QA Manager:

Process Systems International, Inc.
20 Walkup Drive Westborough, MA 01581
Procedure Qualification Record (PQR)

PQR No.: 151-H48 Date: 02/16/96 WPS No.: 151 Rev A

JOINT DESIGN (QW-402) WELD JOINT CONFIGURATION Single-V groove Gas backing was used Groove Angle : 75 Degrees Root Opening : 062-125 Inches Root Face : 030-062 Inches note:	BASE METAL (QW-403) Material form. Plate Material Spec. SA-240, Type 304L To ..... SA-240, Type 304L P No. 8 Gr. 1 to P No. 8 Gr. 1 Thickness (in) 0.5000 HEAT TREATMENT (QW-406, QW-407) Preheat Temperature: 60 Degrees F. Preheat Maintenance: None Interpass Temperature: 350 Degrees F. PWHT temperature ... : 650 Degrees F. PWHT Holding time(hr): 4.00 note: PWHT TEMP.= +/-25 DEG. F.
POSITION (QW-405) Position of Joint : 1G - Flat Progression: N/A note:	

	All pass(es)					None		
Weld Process / type	PAW / manual							
GAS (QW-408)								
Shielding Gas / CFH.....	75% Argon, 25% He./ 20-30					None / -		
Trailing Gas / CFH.....	None / -					None / -		
Backing Gas / CFH.....	100% Argon / 10-20					None / -		
Plasma Gas / CFH.....	100% Argon / 1-3					None / -		
FILLER METAL (QW-404)								
AWS Classification.....	ER308L					None		
SFA Spec. No. & F No....	SFA#: 5.9 F#: 6					SFA#: None F#: -		
A No. or Chem. Comp.....	8					None		
Filler Metal Trade Name.	SOLID FILLER METAL					None		
SAW Flux Trade Name/Type	N/A / -					None / -		
Weld Deposit 't' (in)...	0.5000					None		
Elec./Wire Size (in)....	1/16	3/32	1/8			-	-	-
ELECTRICAL (QW-409)								
Amperage USED	30-100	75-160	100-200			-	-	-
Voltage USED	12-18	14-20	16-26			-	-	-
Travel Speed (ipm).....	Var.	Var	Var			-	-	-
Max. Heat Input (J/in)..	None					None		
Tungsten Type & Size....	EWTh-2 / 3/32"-3/16"					N/A / -		
Current Type/Polarity...	DCEN (straight)					N/A		
TECHNIQUE (QW-410)								
String or Weave Bead....	String & Weave Bead					N/A		
Orifice/Gas Cup Size....	1/2"-5/8"					None		
Contact Tube to Work....	N/A					None		
Oscillation.....	Transverse					None		
Mult./Single Electrodes.	Single Electrode					N/A		
Other Technique Notes...	Keyhole & Melt-in used					None		

Multiple or Single Pass (per side).... Multiple Passes

(n1) No supplementary filler metal will be used with this procedure.
(n2)
(n3)
(n4) PWHT Ramp up to 300 Deg.F.then 100 Deg.F/Hr.up to 650 Deg.F.
(n5) PWHT Ramp down at 100 Deg.F./Hr. to room temp.

Procedure Qualification Record (PQR)

PQR No.: 151-H48

TENSILE TEST (QW-150)

Specimen No.	Width (in.)	Thick. (in.)	Area (sq.in.)	Ultimate total load (lb)	Ultimate stress (psi)	Type of failure and location
1	0.752	0.502	0.378	34100	90330	Weld metal
2	0.751	0.510	0.383	34000	88800	Weld metal

GUIDED BEND TEST (QW-160)

Figure No. and Type	Result	Figure No. and Type	Result
QW-462.2 Side bend	No defects	QW-462.2 Side bend	No defects
QW-462.2 Side bend	No defects	QW-462.2 Side bend	No defects

TOUGHNESS TEST (QW-170)

Spec. No.	Notch Location	Notch Type	Test Temp. (F)	Impact Values (ft-lbs)	Lateral exp. Shear %	Lateral exp. Mils	Drop weight break
None							

HARDNESS TEST - No hardness test

Base metal	-1-	-2-	-3-	HAZ	-1-	-2-	-3-	WM	-1	-2-	-3-

(Heat Affected Zone=HAZ, Weld Metal=WM)

Notes:

Stamp: H48 Welder's Name: Kennedy, Dan ID:
Tests conducted by: CONAM INSPECTION INC. Laboratory Test No: 14086
PQR was done & welding of coupon was witnessed by : Process Systems

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Code.

Prepared By: A Rollas (02/16/96) Weld Specialist

Certified By: Alan L Bradlock (02/16/96) QA Manager:

LIGO- V049-2-07Z
Rev. A

Process Systems International, Inc.
20 Walkup Drive Westborough, MA 01581
WELDING PROCEDURE SPECIFICATION (WPS)

WPS No.: 153 Date: 02/23/96 Revision No.: A Date: 04/23/96
Supporting PQRs: 153-H48

BASE METAL (QW-403, QW-405) P No. 8 to P No.:8 Thickness range. 0.1875" to 1.0000" Position(s).All positions Progression.Vertical Up notes	JOINT (QW-402) Joint design Groove/Fillet(see pg 2) Backing..... With or without backing Backing Matl Optional Fillet Weld Size All (QW-451.4) notes
PREHEAT (QW-406) Minimum Temperature. 60 Degrees F. Interpass Temp. Max. 350 Degrees F. Preheat Maintenance. None	POSTWELD HEAT TREATMENT (QW-407) Temperature range 650 Time range 4 - n6, n7 notes STRESS RELIEF +/-25 DEG.F.

	All pass(es)			None				
Process / type	GTAW / manual							
Process thickness limit.	0.1875" to 1.0000"			None				
GAS (QW-408)								
Shielding Gas / CFH.....	100% Argon / 18-36			None / -				
Trailing Gas / CFH.....	None / -			None / -				
Backing Gas / CFH.....	100% Argon / 9-24			None / -				
FILLER METAL (QW-404)								
AWS classification.....	ER308L			None				
SFA Spec. No. & F No....	SFA#: 5.9		F#: 6	SFA#: None		F#: -		
A No. or Chem. Comp.....	8			None				
Filler metal trade name.	SOLID FILLER METAL			None				
SAW flux trade name/type	N/A / -			None / -				
Elec./Wire size (in) ...	1/16	3/32	1/8	-	-	-		
ELECTRICAL (QW-409)								
Welding amperage range..	30-120	80-180	100-225	-	-	-		
Welding voltage range...	n/r	n/r	n/r	-	-	-		
Travel speed (ipm).....	Var.	Var.	Var.	-	-	-		
Max. Heat Input (J/in)..	None			None				
Tungsten Type/Size.....	EWTh-2 / 1/16" - 3/16"			N/A / -				
Current & Polarity.....	DCEN (straight)			N/A				
TECHNIQUE (QW-410)								
String / weave bead.....	String & Weave Bead			N/A				
Orifice / gas cup.....	# 5 to # 10			None				
Contact tube to work....	N/A			None				
Oscillation.....	N/A			None				
Mult./Single electrode..	Single Electrode			N/A				
Other Technique Notes...				None				

Multiple or Single Pass (per side).... Multiple Passes
(n1)No Pass > 1/2" t
(n2)
(n3)WELD WIRE SHALL BE CLEANED SPECIAL AND HANDLED WITH POLY GLOVES.
(n4)GRINDING WITH ABRASIVE WHEELS IS "NOT ALLOWED".
(n5)WIRE BRUSHING IS "NOT ALLOWED".
(n6)PWHT (STRESS RELIEF) Ramp up to 300 deg.f.then 100 deg.f./hr.to 650 deg.f.
(n7)PWHT (STRESS RELIEF) Ramp down at 100 deg.f./hr.to room temp.

WPS No.: 153 Date: 02/23/96 Revision No.: A Date: 04/23/96

JOINT (QW-402)

Single-V groove Backing : no backing Root Opening: .125-.1875 max. Groove Angle: 50 degree min. Root Face : .030-.060 max.	Single-V groove Backing : no backing Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-.060 max.
Single-V groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 50 degree min. Root Face : .030-.060 max.	Double-Bevel groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-.060 max.
Double-V groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-.060 max.	Single/Double Fillet Backing : Root Opening: 1/32" max. Weld Size : Required fillet plus root opening
Square groove Backing : T-joint Root Opening: 1/32" max.	Square groove Backing : no backing Root Opening: 3/32" max.

WELD JOINT DESCRIPTIONS SHOWN ARE NOT INCLUSIVE OF ALL OF THOSE FOUND ON THE JOB. WELD JOINT DESIGN REFERENCE IN AN ENGINEERING SPECIFICATION OR DESIGN DRAWING SHALL TAKE PREFERENCE OVER WELD JOINTS SHOWN IN THIS WPS.

Initial cleaning shall be in strict compliance with special job procedures. Method of back gouging must be accomplished with a carbide burr cutter.

(a) NON-FUSABLE RETAINERS MAY BE USED.

(b) WELD WIRE SHALL BE CLEANED SPECIAL IN ACCORDANCE WITH SPECIFIC JOB PROCEDURES. SEALED IN BAGS AND HANDLED WITH POLY GLOVES AT ALL TIMES.

(c) GRINDING AND WIRE BRUSHING ARE "NOT ALLOWED" ON THE LIGO JOB. DEFECT REMOVAL MUST BE ACCOMPLISHED WITH A CARBIDE BURR CUTTER.

(d) WELDING STARTS & STOPS MUST RAMP GRADUALLY UP & DOWN TO AVOID CRACKING. THE WELDER SHALL PROVIDE A POST (AFTER FLOW) GAS FLOW OF 10 SECONDS.

(e)

We certify that the statements in this record are correct and in accordance with the requirements of Sections IX and VIII of the ASME Code.

Prepared By: A Rollas (02/23/96) Weld Specialist

Accepted By: Mary Bradbury (02/23/96) QA Manager:

Process Systems International, Inc.
20 Walkup Drive Westborough, MA 01581
Procedure Qualification Record (PQR)

PQR No.: 153-H48 Date: 02/23/96 WPS No.: 153 Rev A

JOINT DESIGN (QW-402) WELD JOINT CONFIGURATION Single-V groove Gas backing was used Groove Angle : 75 Degrees Root Opening : 0-125 Inches Root Face : 030-062 Inches note:	BASE METAL (QW-403) Material form. Plate Material Spec. SA-240, Type 304L To ..... SA-240, Type 304L P No. 8 Gr. 1 to P No. 8 Gr. 1 Thickness (in) 0.5000 HEAT TREATMENT (QW-406, QW-407) Preheat Temperature: 60 Degrees F. Preheat Maintenance: None Interpass Temperature: 350 Degrees F. PWHT temperature ... : 650 Degrees F. PWHT Holding time(hr): 4 note: STRESS RELIEF 650 +/-25 DEG.F.
POSITION (QW-405) Position of Joint : 1G - Flat Progression: N/A note:	

	All pass(es)					None		
Weld Process / type	GTAW / manual							
GAS (QW-408)								
Shielding Gas / CFH.....	100% Argon	/	20-30			None	/	-
Trailing Gas / CFH.....	None	/	-			None	/	-
Backing Gas / CFH.....	100% Argon	/	10-20			None	/	-
FILLER METAL (QW-404)								
AWS Classification.....	ER308L					None		
SFA Spec. No. & F No....	SFA#: 5.9		F#: 6			SFA#: None		F#: -
A No. or Chem. Comp.....	8					None		
Filler Metal Trade Name.	SOLID FILLER METAL							
SAW Flux Trade Name/Type	N/A	/	-			None	/	-
Weld Deposit 't' (in)...	0.5000					None		
Elec./Wire Size (in)....	1/16"	3/32"	1/8"			-	-	-
ELECTRICAL (QW-409)								
Amperage USED	30-120	80-180	100-225			-	-	-
Voltage USED	n/r	n/r	n/r			-	-	-
Travel Speed (ipm).....	Var.	Var	Var			-	-	-
Max. Heat Input (J/in)..	None					None		
Tungsten Type & Size....	EWTh-2 / 3/32"-3/16"					N/A / -		
Current Type/Polarity...	DCEN (straight)					N/A		
TECHNIQUE (QW-410)								
String or Weave Bead....	String & Weave Bead					N/A		
Orifice/Gas Cup Size....	# 8					None		
Contact Tube to Work....	N/A					None		
Oscillation.....	N/A					None		
Mult./Single Electrodes.	Single Electrode					N/A		
Other Technique Notes...						None		

Multiple or Single Pass (per side).... Multiple Passes

(n1) No Pass > 1/2" t
(n2)
(n3)
(n4) PWHT (STRESS RELIEF) Ramp up to 300 deg.f.then 100 deg.f./hr to650 deg.f.
(n5) PWHT (STRESS RELIEF) Ramp down at 100 deg.f./hr. to room temp.

Procedure Qualification Record (PQR)

PQR No.: 153-H48

TENSILE TEST (QW-150)

Specimen No.	Width (in.)	Thick. (in.)	Area (sq.in.)	Ultimate total load (lb)	Ultimate stress (psi)	Type of failure and location
1	0.745	0.504	0.375	33800	90100	Weld metal
2	0.750	0.506	0.380	34150	89900	Weld metal

GUIDED BEND TEST (QW-160)

Figure No. and Type	Result	Figure No. and Type	Result
QW-462.2 Side bend	No defects	QW-462.2 Side bend	No defects
QW-462.2 Side bend	No defects	QW-462.2 Side bend	No defects

TOUGHNESS TEST (QW-170)

Spec. No.	Notch Location	Notch Type	Test Temp. (F)	Impact Values (ft-lbs)	Lateral exp. Shear %	Lateral exp. Mils	Drop weight break
None							

HARDNESS TEST - No hardness test

Base metal	-1-	-2-	-3-	HAZ	-1-	-2-	-3-	WM	-1	-2-	-3-

(Heat Affected Zone=HAZ, Weld Metal=WM)

Notes:

Stamp: H48 Welder's Name: Kennedy, Dan ID:
Tests conducted by: CONAM INSPECTION INC. Laboratory Test No: 14087
PQR was done & welding of coupon was witnessed by : Process Systems

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Code.

Prepared By: A Rollas (02/23/96) Weld Specialist

Certified By: Alan Bradbrook (02/23/96) QA Manager:

LIGO - V049-2-073

Process Systems International, Inc.
20 Walkup Drive Westborough, MA 01581
WELDING PROCEDURE SPECIFICATION (WPS)

REV. A

WPS No.: 073-3 Date: 05/29/74 Revision No.: A Date: 04/23/96
Supporting PQRs: 073-H9

BASE METAL (QW-403, QW-405) P No. 8 to P No.:8 Thickness range. 0.0625" to 0.7500" Position(s).All positions Progression.Vertical Up notes	JOINT (QW-402) Joint design Groove/Fillet(see pg 2) Backing..... With or without backing Backing Matl Optional Fillet Weld Size All (QW-451.4) notes
PREHEAT (QW-406) Minimum Temperature. 50 Degrees F. Interpass Temp. Max. 350 Degrees F. Preheat Maintenance. None	POSTWELD HEAT TREATMENT (QW-407) Temperature range None Time range None notes

	All pass(es)			None				
Process / type	GTAW / manual							
Process thickness limit.	0.0625" to 0.7500"			None				
GAS (QW-408)								
Shielding Gas / CFH.....	100% Argon	/	15-25	None	/	-		
Trailing Gas / CFH.....	None	/	-	None	/	-		
Backing Gas / CFH.....	100% Argon	/	9-30	None	/	-		
FILLER METAL (QW-404)								
AWS classification.....	ER308L			None				
SFA Spec. No. & F No....	SFA#: 5.9		F#: 6	SFA#: None		F#: -		
A No. or Chem. Comp.....	8			None				
Filler metal trade name.	SOLID FILLER METAL			None				
SAW flux trade name/type	N/A	/	-	None	/	-		
Elec./Wire size (in) ...	1/16	3/32	1/8	-	-	-		
ELECTRICAL (QW-409)								
Welding amperage range..	70-150	80-180	130-275	-	-	-		
Welding voltage range...	n/r	n/r	n/r	-	-	-		
Travel speed (ipm).....	Var.	Var.	Var.	-	-	-		
Max. Heat Input (J/in)..	None			None				
Tungsten Type/Size.....	EWTh-2 / 1/16" - 3/16"			N/A /		-		
Current & Polarity.....	DCEN (straight)			N/A				
TECHNIQUE (QW-410)								
String / weave bead.....	String & Weave Bead			N/A				
Orifice / gas cup.....	# 5 to # 10			None				
Contact tube to work....	N/A			None				
Oscillation.....	N/A			None				
Mult./Single electrode..	Single Electrode			N/A				
Other Technique Notes...				None				

Multiple or Single Pass (per side).... Multiple Passes
(n1)No Pass > 1/2" t
(n2)
(n3)WELD WIRE SHALL BE CLEANED SPECIAL AND HANDLED WITH POLY GLOVES.
(n4)GRINDING WITH ABRASIVE WHEELS IS "NOT ALLOWED".
(n5)WIRE BRUSHING IS "NOT ALLOWED".
(n6)
(n7)

WPS No.: 073-3 Date: 05/29/74 Revision No.: A Date: 04/23/96

JOINT (QW-402)

Single-V groove Backing : no backing Root Opening: .125-.1875 max. Groove Angle: 50 degree min. Root Face : .030-.060 max.	Single-Bevel groove Backing : no backing Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-.060 max.
Single-V groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 50 degree min. Root Face : .030-.060 max.	Double-Bevel groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-.060 max.
Double-V groove Backing : gouged & back welded Root Opening: .125-.1875 max. Groove Angle: 45 degree min. Root Face : .030-.060 max.	Single/Double Fillet Backing : Root Opening: 1/32" max. Weld Size : Required fillet plus root opening
Square groove Backing : T-joint Root Opening: 1/32" max.	Square groove Backing : no backing Root Opening: 3/32" max.

WELD JOINT DESCRIPTIONS SHOWN ARE NOT INCLUSIVE OF ALL OF THOSE FOUND ON THE JOB. WELD JOINT DESIGN REFERENCE IN AN ENGINEERING SPECIFICATION OR DESIGN DRAWING SHALL TAKE PREFERENCE OVER WELD JOINTS SHOWN IN THIS WPS.

Initial cleaning shall be in strict compliance with special job procedures. Method of back gouging must be accomplished with a carbide burr cutter.

(a) NON-FUSABLE RETAINERS MAY BE USED.

(b) WELD WIRE SHALL BE CLEANED SPECIAL IN ACCORDANCE WITH SPECIFIC JOB PROCEDURES. SEALED IN BAGS AND HANDLED WITH POLY GLOVES AT ALL TIMES.

(c) GRINDING AND WIRE BRUSHING ARE "NOT ALLOWED" ON THE LIGO JOB. DEFECT REMOVAL MUST BE ACCOMPLISHED WITH A CARBIDE BURR CUTTER.

(d) WELDING STARTS & STOPS MUST RAMP GRADUALLY UP & DOWN TO AVOID CRACKING. THE WELDER SHALL PROVIDE A POST (AFTER FLOW) GAS FLOW OF 10 SECONDS.

(e)

We certify that the statements in this record are correct and in accordance with the requirements of Sections IX and VIII of the ASME Code.

Prepared By: A Rollas (05/29/74) Weld Specialist

Accepted By: Allan Bradbook (05/29/74) QA Manager:

Process Systems International, Inc.
20 Walkup Drive Westborough, MA 01581
Procedure Qualification Record (PQR)

PQR No.: 073-H9 Date: 05/29/74 WPS No.: 073-3 Rev A

JOINT DESIGN (QW-402) WELD JOINT CONFIGURATION Single-V groove Gas backing was used Groove Angle : 75 Degrees Root Opening : 062-125 Inches Root Face : 030-062 Inches note:	BASE METAL (QW-403) Material form. Pipe / Tube Material Spec. SA-312, Grade TP304L To ..... SA-312, Grade TP304L P No. 8 Gr. 1 to P No. 8 Gr. 1 Thickness (in) 0.3750 Dia.(in) 5.5630 HEAT TREATMENT (QW-406, QW-407) Preheat Temperature: 50 Degrees F. Preheat Maintenance: None Interpass Temperature: 350 Degrees F. PWHT temperature ... : None Degrees F. PWHT Holding time(hr): *None* note:
POSITION (QW-405) Position of Joint : 6G - 45 Deg. Progression:Vertical Up note:	

	All pass(es)			None		
Weld Process / type	GTAW / manual					
GAS (QW-408)						
Shielding Gas / CFH.....	100% Argon	/ 17-20		None	/ -	
Trailing Gas / CFH.....	None	/ -		None	/ -	
Backing Gas / CFH.....	100% Argon	/ 18		None	/ -	
FILLER METAL (QW-404)						
AWS Classification.....	ER308L			None		
SFA Spec. No. & F No....	SFA#: 5.9	F#: 6		SFA#: None	F#: -	
A No. or Chem. Comp.....	8			None		
Filler Metal Trade Name.	SOLID FILLER METAL			None		
SAW Flux Trade Name/Type	N/A	/ -		None	/ -	
Weld Deposit 't' (in)...	0.3750			None		
Elec./Wire Size (in)....	1/16"	-	-	-	-	-
ELECTRICAL (QW-409)						
Amperage USED	110	-	-	-	-	-
Voltage USED	14	-	-	-	-	-
Travel Speed (ipm).....	5	-	-	-	-	-
Max. Heat Input (J/in)..	None			None		
Tungsten Type & Size....	EWTh-2 / 3/32"			N/A / -		
Current Type/Polarity...	DCEN (straight)			N/A		
TECHNIQUE (QW-410)						
String or Weave Bead....	String & Weave Bead			N/A		
Orifice/Gas Cup Size....	# 8			None		
Contact Tube to Work....	N/A			None		
Oscillation.....	N/A			None		
Mult./Single Electrodes.	Single Electrode			N/A		
Other Technique Notes...				None		

Multiple or Single Pass (per side).... Multiple Passes

(n1) Peening was not used with this weld test.
(n2) No pass > 3/16" t.
(n3)
(n4)
(n5)

Procedure Qualification Record (PQR)

PQR No.: 073-H9

TENSILE TEST (QW-150)

Specimen No.	Width (in.)	Thick. (in.)	Area (sq.in.)	Ultimate total load (lb)	Ultimate stress (psi)	Type of failure and location
1	0.750	0.300	0.225	19400	86200	Weld metal
2	0.753	0.302	0.227	20100	88500	Weld metal

GUIDED BEND TEST (QW-160)

Figure No. and Type	Result	Figure No. and Type	Result
QW-462.2 Side bend	Satisfactory	QW-462.2 Side bend	Satisfactory
QW-462.2 Side bend	Satisfactory	QW-462.2 Side bend	Satisfactory

TOUGHNESS TEST (QW-170)

Spec. No.	Notch Location	Notch Type	Test Temp. (F)	Impact Values (ft-lbs)	Lateral exp. Shear %	Lateral exp. Mils	Drop weight break
None							

HARDNESS TEST - No hardness test

Base metal	-1-	-2-	-3-	HAZ	-1-	-2-	-3-	WM	-1	-2-	-3-

(Heat Affected Zone=HAZ, Weld Metal=WM)

Notes:

Stamp: H9 Welder's Name: Anthony J. Rollas ID:
Tests conducted by: J.G.Sylvester Assoc.Inc. Laboratory Test No: 5944
PQR was done & welding of coupon was witnessed by : Process Systems

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Code.

Prepared By: A Rollas (05/29/74) Weld Specialist

Certified By: Allan R Bradbrook (05/29/74) QA Manager:

Title: **LIGO GENERAL REPAIR PROCEDURE FOR MATERIALS AND WELDING**

LIGO

GENERAL REPAIR PROCEDURE

FOR

MATERIALS AND WELDING

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Φ	ARB 3/26/96	ARS 3/27/96	ISSUED PER DEC 0107

Number

Rev

PROCESS SYSTEMS INTERNATIONAL, INC. | **SPECIFICATION**

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev
	ARBradford	3/26/96		3/26/96	A V049-2-074	Φ

1.0 SCOPE

1.1 This procedure covers the requirements for repairing all nonconformities in base metal surfaces, the repair of nonconformities in edge preparation and the repair of unacceptable defects in inspected weld joints.

1.2 Cleaning of repaired areas shall be performed in accordance with PSI Specification V-049-2-015.

2.0 GENERAL PROCEDURE

2.1 REPAIRS TO BASE METAL SURFACE NONCONFORMITIES

2.1.1 For Repairs Not Requiring Welding

A. Surface defects shall be removed by grinding with CARBIDE BURR CUTTERS only. Abrasive-type wheels and stones are not allowed on vacuum base metal surfaces.

B. Ground surface repairs shall be visually inspected to verify that the nonconformity has been removed or the indication reduced to an acceptable limit.

C. The reduced material thickness shall be checked by a depth micrometer or an ultrasonic thickness gauge.

2.1.2 For Repairs Requiring Welding

A. Remove the defect by grinding with CARBIDE BURR CUTTERS only or by chipping and grinding with CARBIDE BURR CENTERS to an acceptable level.. Abrasive-type wheels and stones are not allowed on vacuum welds.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with PSI Procedure Numbers:

WPS #150	P8-P8	PAW	Manual	
WPS #151	P8-P8	PAW	Manual	PWHT
WPS #153	P8-P8	GTAW	Manual	PWHT
WPS #073-3	P8-P8	GTAW	Manual	

D. Welded repairs shall be visually inspected after welding.

2.2 REPAIRS TO EDGE PREPARATION

2.2.1 For Repairs Not Requiring Welding

A. Defects shall be removed by grinding with CARBIDE BURR CUTTERS only. Abrasive-type wheels and stones are not allowed on vacuum materials, weld preps. The cavity shall be blended uniformly into the surrounding surfaces.

B. Ground surface repairs shall be visually inspected to verify that the nonconformity has been removed or the indication reduced to an acceptable limit.

2.2.2 For Repairs Requiring Welding

A. Remove the defect by grinding (as specified above) or by chipping and grinding (as specified above) to an acceptable level.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with PSI Procedure Numbers:

WPS #150	P8-P8	PAW	Manual	
WPS #151	P8-P8	PAW	Manual	PWHT
WPS #153	P8-P8	GTAW	Manual	PWHT
WPS #073-3	P8-P8	GTAW	Manual	

2.3 REPAIRS TO WELDS

2.3.1 For Repairs Not Requiring Welding

A. Weld defects shall be removed by grinding with CARBIDE BURR CUTTERS only. Abrasive-type wheels and stones are not allowed on the interior or the exterior of vacuum welds.

B. Visually inspect the area prepared for welding to ensure that the defect has been removed or the indication reduced to an acceptable limit.

C. The reduced material thickness shall be checked by a depth micrometer or an ultrasonic thickness gauge.

2.3.2 For Repair Requiring Welding

A. Remove the defect by grinding (as specified in A. above) or by chipping and grinding (as specified in A. above) to an acceptable level.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with PSI Procedure Numbers:

WPS #150	P8-P8	PAW	Manual	
WPS #151	P8-P8	PAW	Manual	PWHT
WPS #153	P8-P8	GTAW	Manual	PWHT
WPS #073-3	P8-P8	GTAW	Manual	

D. The repaired area can be left in the as-welded condition or can be blended by grinding. Grinding is restricted to the use of CARBIDE BURR CUTTERS only. The repaired area shall blend uniformly into the surrounding surface and shall be visually inspected after welding.

2.3.3 For Fillet Weld Repairs Requiring Welding

A. remove the unacceptable weld metal by an approved method (as specified in A. above).

B. If the full fillet weld is not completely removed, visually inspect the area prepared for welding.

C. Weld in accordance with PSI Procedure Numbers:

WPS #150	P8-P8	PAW	Manual	
WPS #151	P8-P8	PAW	Manual	PWHT
WPS #153	P8-P8	GTAW	Manual	PWHT
WPS #073-3	P8-P8	GTAW	Manual	

D. Welded repairs shall be visually inspected after welding.

3.0 BASE MATERIAL CLEANUP PROCEDURE

3.1 SCOPE

3.1.1 This procedure describes the acceptable methods of base meal cleanup (plate, pipe, forgings, etc.).

3.1.2 This includes the removal of such things as temporary attachments, clamp marks, fit-up weld marks, undercut, gouges, crater cracks and other imperfections.

3.2 REMOVAL METHODS

3.2.1 Cleanup of imperfections or items listed in 3.1.2 above are limited to chipping and grinding with a carbide burr cutter only. Abrasive-type wheels and stones are not allowed on vacuum vessel materials because of the binder material used in the manufacturing of the wheel. The binder is embedded in the metal and will off-gas causing a loss of vacuum over a period of time.

3.2.2 After removal, the affected area shall be repaired by blending or welding. Repair welding can be left in the as-welded condition. The repaired area shall blend uniformly into the surrounding surface and shall be visually inspected after welding.

LIGO VISUAL INSPECTION PROCEDURE

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY: Allan L Bradbrook

QUALITY ASSURANCE: Allan L Bradbrook

MANUFACTURING ENGR: Philip F. Thiel

TECHNICAL DIRECTOR: D.A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Φ	AHB 5/3/96		ISSUED PER DEO 0168 FOR PDR

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE
	ALBradbrook	5/3/96	ABG	5/3/96

Number A V049-2-128 | Rev. Φ

TABLE OF CONTENTS

1.0 SCOPE

This document contains the methods and acceptance criteria for visual inspection for the LIGO project.

2.0 GENERAL PROCEDURE

2.1 Control of Documents, Codes and Standards

2.1.1 The Quality Plan, the fabrication drawings and other procedures specify the required visual inspection and physical dimensions. It is not the intent of this procedure to duplicate those requirements. It is however, the intent of this procedure to provide a consistent method of performing visual inspection.

2.2 Technical Requirements

2.2.1 Illumination - lighting, natural or artificial shall be sufficient to illuminate the area being examined.

2.2.2 Personnel - Personnel performing visual examination shall be familiar with the welding technique being used, welding procedure requirements, machining operations, liquid penetrant testing, and the type of discontinuities that may occur in the weld or base material being examined.

2.2.3 Direct visual examination shall be used when access is sufficient to place the eye within 24 inches of the surface to be examined and at an angle not less than 30 degrees to the surface to be examined. Mirrors may be used to improve the angle of vision, and aids such as a magnifying lens may be used to assist examinations.

NOTE: *Unless impossible, direct visual examinations will be used for all visual examinations performed to this procedure.*

In some cases, remote visual examinations may have to be substituted for direct examination. Remote visual examinations may use visual aids such as mirrors, borescopes, cameras, or other suitable instruments.

2.3 Examination Requirements

2.3.1 Visual Examination of Welding

A. Equipment

1. Artificial Light Source
2. Mirrors
3. Magnifiers
4. Straight Edges or Rules
5. Weld Gages

B. Visual Inspection and Identification of Base Material and Joint Preparation as follows:

1. Base material type compatible with the detailed weld procedure.
2. Weld being made in accordance with drawing.
3. Weld preparation and adjacent base material clean free of paint, scale, rust, oil, grease and any other foreign material that would be deleterious to the process.
4. Weld preparation has fairly smooth surfaces free from deep notches, grooves, nicks, and other gross irregularities.
5. Weld preparation free from base material defects such as laminations, laps, non metallic inclusions, pin holes, porosity, that are open to the surface.

C. Visual Inspection of Weld Preparation Geometry as follows:

1. Alignment of parts to be welded.
2. Size of root face (land) and root gap.
3. Groove angle.
4. I.D. mismatch of Butt Joints.

D. Visual Inspection of Tack Welds as follows:

1. Tack welds are properly prepared to be incorporated into the weld or completely removed. When left in place, each end should be feathered.
2. Examine tacks for discontinuities.
3. Check for cleanliness.

E. Visual Inspection of Intermediate Weld Passes as follows:

1. Cleanliness
2. Weld spatter
3. ARC strikes
4. Slag

F. Visual Inspection of Final Surfaces of Welding shall be verified as follows:

1. Cleanliness
2. Weld spatter
3. ARC strikes
4. Butt weld reinforcement (1/8" max)
5. Fillet weld size
6. Fillet weld throat
7. Fillet weld length/spacing
8. Concavity/Convexity
9. Transition must be minimum of 3 to 1 taper
10. Surface porosity
11. Overlap
12. Undercut
13. Inadequate penetration
14. Cracks
15. Underfill

G. Visual Examination of Machined Surfaces shall be verified as follows:

1. Surface Finish
2. Discontinuities
3. Cleanliness

2.4 Acceptance Standards

2.4.1 Cleanliness

Reference should be made to the LIGO Cleaning Procedure, for specific methods. Prior to welding, the weld preparation and adjacent base material (1 inch minimum beyond each side of weld joints) shall be free of moisture, oil, grease, paint, scale, chips and other foreign matter on the final weld surface. The affected area shall be cleaned of slag and oxidation. Iridescent temper films and black, tightly adherent films resulting from welding, are acceptable on finished weld surfaces.

Prior To Welding

Weld preparations and adjacent base material (1 inch for carbon steel and 2 inches for stainless steel beyond each side of weld joint) shall be free of moisture, oil, grease, paint, scale, chips and other foreign matter.

After Welding

The affected area of the final weld surface shall be cleaned of slag and oxidation. Iridescent temper films resulting from welding are acceptable on finished weld surfaces.

2.4.2 Tack Welds

Tack welds shall show no cracks or linear indications. Slag deposits or indication of surface porosity shall also be cause for rejection. Edges of tack welds shall be feathered (when necessary) to provide a smooth transition during root pass welding.

2.4.3 Final Weld Condition

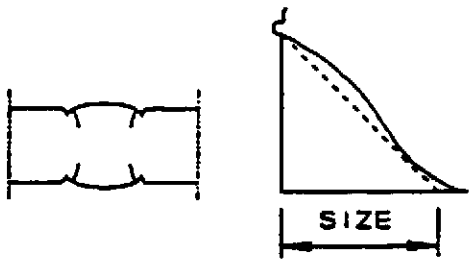
A. As welded, as-cast or as-forged surfaces are permitted, provided the surface of welds are sufficiently free form coarse ripples, overlaps and abrupt ridges and valleys.

B. Cracks or other linear indications are unacceptable.

C. Porosity open to the surface is unacceptable.

D. Undercut shall not exceed 1/32" in. depth.

E. Weld reinforcement on all butt welds may be flush with the surface or may have a crown up to 1/8" max.



EXCESSIVE UNDERCUT

F. Concavity on the root side of a single side welded circumferential butt weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two (2) sections being joined and the contour of the concavity is smooth.

G. Offset of final butt welded joints shall not be greater than the following:

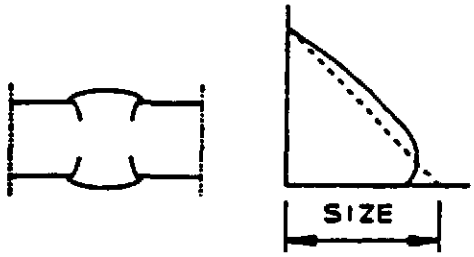
Nominal Wall Section Thickness. in. (mm)	Maximum Offset, in. (mm) All LIGO Project Joints
0.060" Thru 0.500"	1/4t

Note: t is the nominal thickness of the thinner section of the joint.

H. Any offset within the allowable tolerance shall be flared at a three to one taper over the width of the finished weld, or if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld.

2.4.4 Examples Of Conditions That Are Unacceptable.

OVERLAP
Welds shall be free from overlap.



OVERLAP

CRATERS
All craters shall be filled to the full cross section of the weld.

CRACKS
Welds shall have no cracks. When cracks are observed visually, the crack shall be completely removed and re-welded. Refer to repair procedure.

SLAG INCLUSIONS

Welds having slag inclusions larger than 3/32" are unacceptable. Also unacceptable are groups of slag inclusions when the sum of their greatest dimension exceeds 3/8" in any linear inch of weld.

INCOMPLETE FUSION

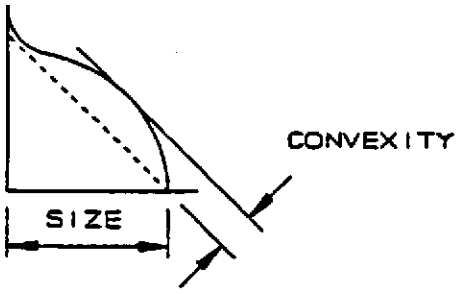
Acceptability requirements are the same as those for slag inclusions.

MISALIGNMENT AND WARPING

Tolerances shall be within the drawing tolerances governing the work. ASME Section VIII allows a maximum misalignment of 1/4" the thickness of the thinner section at the joint for thickness to 1/2".

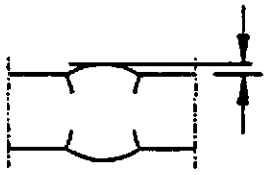
CONVEXITY FILLET

Convexity shall not exceed 0.1 S + 0.03", where S is the size of the fillet weld in inches.



CONVEXITY, GROOVE WELDS

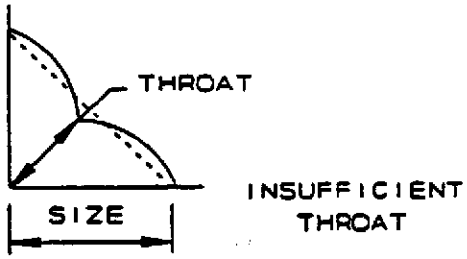
Reinforcement to be 1/8" max, and shall have a gradual transition to the plane of the base metal surface when the thinner base metal is less than 1/2" thick.



REINFORCEMENT

INSUFFICIENT THROAT, FILLETS

The throat shall not be under an imaginary profile line drawn form each leg end.



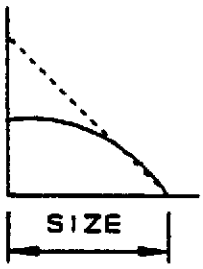
INSUFFICIENT THROAT, GROOVE WELDS

The weld shall be slightly convex.

INSUFFICIENT
THROAT

INSUFFICIENT LEG

The leg dimension of a fillet weld shall not be less than the thickness of the lighter of the two sections being welded, providing configurations allow this.



RAW MATERIAL HANDLING PROCEDURE

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY: Thomas A. Stern

QUALITY ASSURANCE: ALAN BRADBROOK/REB

MANUFACTURING ENGR:

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-4-96	D. McW	INITIAL RELEASE PER DEO # 0170 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-120	Rev.
	T.M.S	5-4-96	REB	5/4/96		0

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Number

Rev.

SPECIFICATION

Number A V049-2-120 Rev. Ø

1.0 PURPOSE

The purpose of this procedure is to define the requirements for handling and storing LIGO raw material.

2.0 GENERAL

This procedure is applicable to all LIGO vacuum boundary and vacuum internal component raw materials.

Contamination of LIGO vacuum surface materials must be prevented during receiving, storage and fabrication in order for the vacuum system to achieve its design goals. Contamination is defined as any foreign material (carbon steel, oil, grease, etc.) which could come in contact with the 304/304L S.S. and aluminum.

3.0 RESPONSIBILITIES

The receiving department is responsible for preventing contamination during receiving and storage of the raw material.

The manufacturing department is responsible for preventing contamination during the fabrication process.

4.0 PROCEDURE

4.1 Receiving

4.1.1 All LIGO Vacuum Boundary Material (304/304L S.S.) shall be handled (i.e. lifted, rolled, etc.) without coming in contact with carbon steel or other contaminants.

4.2 Storage

4.2.1 Vacuum Boundary material shall be stored indoors and shall be protected from carbon steel, hydrocarbon and other types of contamination.

4.3 Fabrication

4.3.1 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 - 200,000) with outside air purge to minimize contamination. Welding gases shall be collected in exhaust systems and vented outside.

4.3.2 No solvent wiping, grinding or wire brushing shall be done to the vacuum surfaces.

4.3.3 All machining fluids shall be water soluble and low in chlorides.

4.3.4 Welding wire and joints shall be cleaned with a CO_2 spray prior to welding.

4.3.4 After Ultra High Vacuum (UHV) cleaning, vacuum surfaces shall not be touched by skin or other contaminants. All cleaned vacuum boundary components shall be sealed (vessels with covers on), double plastic bagged or protected by a Class 100 Cleanroom atmosphere at all times.

4.4 Smoking is not allowed in any LIGO storage or manufacturing area.

SPECIFICATION FOR

CONTROL OF NON-CONFORMANCES

PREPARED BY: ALAN BRADBROOK

PROJECT ENGINEER: N/A

QUALITY ASSURANCE: Alan L Bradbrook

MANUFACTURING ENGR: Phillip F Eglund

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	5/1/96	RCB 5/1/96	RELEASED PER DEO 158

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-124	Rev. Ø
	A Bradbrook	5/1/96	RCB	5/1/96		

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1.0 SCOPE

This specification covers the minimum requirements for control, identification and the disposition of nonconforming items. This procedure applies to receiving inspection, in-process inspection, final inspection, testing documentation and procedural matters.

2.0 GENERAL PROCEDURE

2.1 A noncomformance is any condition that does not comply with a specific job specification or the customer specifications.

2.2. The Quality Assurance Engineer or the Quality Control Inspector places a Reject Tag or a Stop Work Tag (Exhibit 1) on the material which has failed to pass the required inspections and tests or on material that is determined to be otherwise nonconforming and generates a Discrepancy Report (Exhibit 2) for review by the MQA or the QAE.

2.3 The DR is then forwarded to the Project Manager for dispositions. The Project Manager reviews the nonconformance and enters a disposition appropriate for the product and its condition and processes the DR, as follows:

a. The Project Manager or a competent member of the project team, documents the technical justification for the acceptability of USE-AS-IS or REPAIR dispositions and obtains the customer's approval for those which do not comply with the customer's specification requirements.

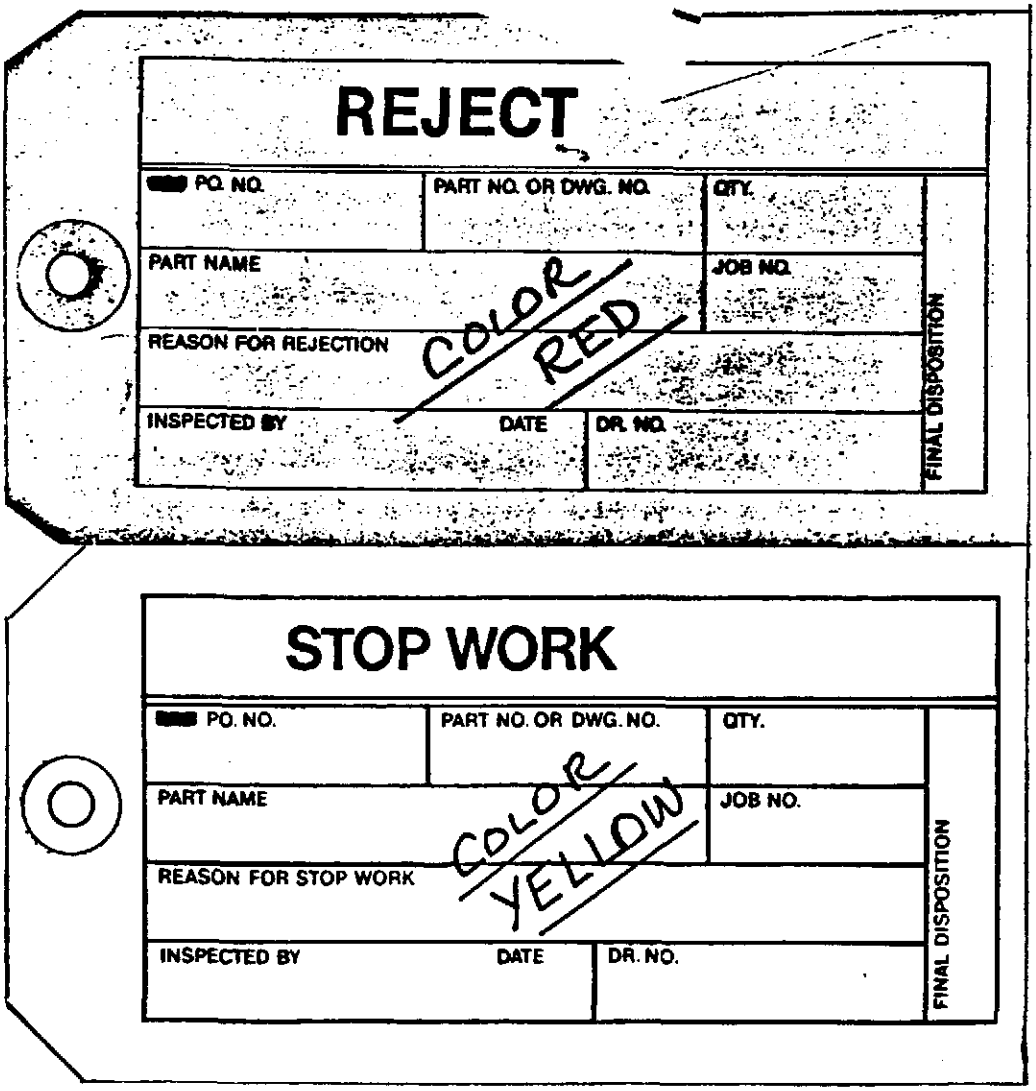
b. When the disposition is complete, the Project Manager or his designee shall sign and date in this space provided and return the DR to the MQA or the QAE.

2.4 Acceptance of the completed disposition is then documented by the MQA, the QAE or the Quality Control Inspector, on the bottom section of the DR. When all of the required signatures have been provided and the item is acceptable, the Reject Tag or the Stop Work Tag can be removed by the individual accepting the completed disposition on the DR. Once the nonconformance has been corrected, the item or component is considered to be acceptable.

2.5 When documentation or procedural matters are suspect of being nonconforming, a DR is initiated and forwarded to the MQA or the QAE for disposition.

a. DR's generated for documentation or procedural deficiencies will not require disposition concurrence from Engineering. However, when Engineering input is required, the MQA or the QAE obtains concurrence with the disposition from Engineering, as applicable.

EXHIBIT 1


REJECT
[redacted] PO. NO.
PART NO. OR DWG. NO.
QTY.
PART NAME
JOB NO.
REASON FOR REJECTION
COLOR RED
INSPECTED BY
DATE
DR. NO.
FINAL DISPOSITION
STOP WORK
[redacted] PO. NO.
PART NO. OR DWG. NO.
QTY.
PART NAME
JOB NO.
REASON FOR STOP WORK
COLOR YELLOW
INSPECTED BY
DATE
DR. NO.
FINAL DISPOSITION

Process Systems International, Inc.

DISCREPANCY REPORT

ROUTE TO _____

D.R. NUMBER 6589

JOB NUMBER	P.O. NO.	VENDOR	SHEET
T10001-	468500	ABC NUT & BOLT	1 OF 1

PROJECT	ORIGINATOR	DATE	REFER TO D.R. NUMBER
KOREA	J. JONES	6-1-95	—

ITEM	DWG. ZONE	DISCREPANCIES (LIST CHARACTERISTICS, SPECIFICATIONS AND ACTUAL)	NO. ACC.	FOR REVIEW	QTY. OF PCS./DISPOSITION: USE NO. CHGE	USE DWG. CHGE	RWK IN SHOP	RET. TO SUP.	SCRAP	REMARKS
1		1/2"-13 X 4" LONG - BOLTS SA-193 B7	0	50						
		WE RECEIVED								
		1/2"-13 X 3" LONG - BOLTS SA-490						X		WRONG LENGTH
										WRONG MATERIAL

EXHIBIT 2

DISPOSITION ---

(1) SA-490 WILL MEET THE REQUIREMENTS OF THE JOB HOWEVER THE 3" LENGTH IS - NO GOOD.

B. SMITH DESIGN ENG.

(2) RETURN TO SUPPLIER FOR REPLACEMENT.

IF SA-490 IS USED ADVISE ME PRIOR TO ORDER PLACEMENT SO AN RFC CAN BE WRITTEN AND APPROVED TO CHANGE DRAWING AND BILL OF MATERIAL.

SIGNATURE B. SMITH DATE 6-2-95

DISPOSITION CONCURRENCE

PROJECT MGR.	DATE	MFG. ENG.	DATE	QUALITY ASSURANCE	DATE
J. BOYD	6-2-95	N/A		J. JONES	6-2-95

REINSPECTION RETURNED TO SUPPLIER 6-2-95

REC'D. 1/2-13 X 4" LG. SA-193 B7 ON 6-3-95

SIGNATURE J. JONES DATE 6-3-95

CORRECTIVE ACTION --- VENDOR DID NOT SUPPLY CORRECT MATERIAL. NOTIFY VENDOR OF THIS PROBLEM AND HAVE THEM PERFORM TRAINING.

SIGNATURE J. JONES DATE 6-3-95

AI/ANI AI DATE 6-4-95

— CLOSED —

CONTAMINATION CONTROL PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stan

QUALITY ASSURANCE: ALAN BRADBROOK /RBB

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-4-96	REB 5/4/96	INITIAL RELEASE PER DEO # 0170 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-119	Rev. 0
	T.M.S.	5-4-96	REB	5/4/96		

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1.0 PURPOSE

This plan defines measures to be taken to limit contamination of the ultra high vacuum surfaces of the LIGO vacuum equipment during fabrication, assembly and installation by particulate and hydrocarbons.

2.0 RESPONSIBILITIES

2.1 Material vendors, PSI and its subcontractors shall handle materials in accordance with the various specifications relating to them. These specifications define measures to be taken to limit contamination, including by carbon steel.

2.2 Personnel performing cleaning operations shall be trained by the manufacturing engineering department in the proper procedures.

2.3 Personnel performing work inside cleanrooms shall be trained by the manufacturing engineering group in the required cleanroom procedures and behavior.

2.4 All personnel shall be trained by the manufacturing engineering department in the philosophy and specific provisions of this plan.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this plan:

PSI Specification V049-2-015, Cleaning Procedure
PSI Specification V049-2-118, Cleanroom Activities
PSI Material Specifications

4.0 GENERAL

While it is critical that all vacuum surfaces (internal surfaces and flange faces) be kept free of contamination, exterior surfaces must also be kept clean. This will not only facilitate keeping the interior surfaces clean, but it is necessary in order to maintain the cleanrooms at Class 100. Care shall be taken to minimize exposure to corrosive environments, such as those containing chloride compounds.

5.0 HYDROCARBON CONTROL

5.1 Material vendors, PSI and its subcontractors shall handle materials in accordance with the various specifications relating to them. These specifications define measures to be taken to limit contamination, including by carbon steel.

5.2 Contact of stainless steel by uncontrolled materials shall be avoided. This includes materials such as work gloves, work boots and unprotected shop floors.

5.3 Liquids, gases or vapors containing hydrocarbons or other contaminants shall not be allowed to come into contact with the stainless steel at any time. This includes fluids such as machining lubricants.

5.4 Leak testing shall be done only with the use of oil-free vacuum pumps.

6.0 PARTICULATE CONTROL

6.1 Material Protection

Materials shall be handled in such a manner as to limit contamination, including by carbon steel. This includes the following precautions:

6.1.1 No carbon steel hooks, fork lift forks, grapples or chains shall be allowed to contact the stainless steel.

6.1.2 Materials shall not be stored in direct contact with materials of different composition, but shall be separated by means such as wooden spacers or paper sheeting.

6.1.3 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.

6.1.4 During transportation, components shall be shrink wrapped in plastic and shipped in closed trucks or under tight fitting tarpaulins.

6.1.5 Finished components shall be shipped to the sites under vacuum.

5.2 Cleanrooms

From the time that a vessel or other component has received its final washing, it shall not be opened unless it is inside a Class 100 cleanroom.

5.2.1 During Assembly

Immediately after washing, components shall be moved directly into a cleanroom without being exposed to the shop atmosphere. In the cleanroom, the component shall be closed to protect it from particulate contamination. This closure may be by joining to a mating piece, installation of covers, or wrapping or double bagging in plastic. The closure shall not be breached unless the component is inside a cleanroom.

5.2.2 During Installation

Components shall be moved into position and prepared to the greatest extent possible before breaching the protective wrapping or bagging. The outer protection is then removed, and a portable soft-wall cleanroom is moved into position over the component before it is opened. Once the cleanroom is in position and a Class 100 environment is established, Class 100 air is used to break the vacuum inside the component. Once atmospheric pressure has been reached, covers may be removed for final installation of the component. The component and all of its access ports and openings shall be closed or connected to another component before the cleanroom can be moved or shut down.

Title: SPECIFICATION FOR SITE PIPING CLEANING PROCEDURE

SPECIFICATION FOR

SITE PIPING CLEANING PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M Stan

QUALITY ASSURANCE: ALAN BRADBROOK/KEB

TECHNICAL DIRECTOR: D.C. McWilliams

PROJECT MANAGER: Richard Bayer

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-5-96	RES 5/5/96	INITIAL RELEASE PER DEO # 0172 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-131	Rev.
	TMS	5-5-96	RES	5/5/96		0

SPECIFICATION TABLE OF CONTENTS

1.0 PURPOSE

This specification covers the minimum requirements for the on-site cleaning of piping for the LIGO vacuum system.

2.0 GENERAL

2.1 Piping is bought in a clean state (white pickled) and is prespooled at PSI. Therefore, full site cleaning should not normally be required.

2.2 Piping spools shall not be unsealed until the end is protected by a Class 100 cleanroom.

3.0 RESPONSIBILITIES

3.1 Cleaning shall be performed by an engineer, technician or shop worker familiar with this procedure and the cleaning area systems and equipment.

3.2 This procedure shall be maintained and modified as required by the cognizant engineer.

4.0 PROCEDURE

4.1 Before installing a piping spool, the exterior shall be wiped with a clean, lint-free cloth.

4.2 Piping shall be installed in sections, with the open end protected by a Class 100 cleanroom.

4.3 After completion of installation of a run of piping, it shall be blown out with clean, dry nitrogen gas.

4.4 If after testing the piping proves to require recleaning, it shall be removed off-site to be flushed with a detergent, flushed with city water, and flushed with DI water.

SPECIFICATION FOR

SITE VACUUM SURFACE RECLEANING PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stan

QUALITY ASSURANCE: _____

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: _____

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-5-96		INITIAL RELEASE PER DEO # 0172 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED DATE	Number V049-2-132	Rev. 0
	TMS	5-5-96			

SPECIFICATION TABLE OF CONTENTS

1.0 PURPOSE

This specification covers the minimum requirements for the on-site recleaning of vacuum surfaces of components for the LIGO vacuum system, should it prove to be required.

2.0 GENERAL

Components are fully cleaned at PSI. Therefore, full site cleaning should not normally be required.

3.0 RESPONSIBILITIES

3.1 Cleaning shall be performed by an engineer, technician or shop worker familiar with this procedure and the cleaning systems and equipment.

3.2 This procedure shall be maintained and modified as required by the cognizant engineer.

4.0 PROCEDURE

4.1 Should small areas of contamination need to be recleaned, they shall be cleaned by use of a CO_2 cleaning system. A vacuum vent system shall be used to remove the CO_2 gas and any entrained contaminants from the vessel being cleaned.

4.2 If major areas are contaminated, the component shall be removed off-site to be pressure washed with a detergent, rinsed with city water, and rinsed with DI water. These operations shall be completed in accordance with PSI Specification V049-2-085. The component shall be closed and packaged in a Class 100 cleanroom.

PROCEDURE FOR

CLEAN ROOM ACTIVITIES

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY: Thomas M. Stan

QUALITY ASSURANCE: Allan J Bradbear

MANUFACTURING ENGR:

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	TMS 5-3-96	REB 5/3/96	RELEASED PER DEO 167

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-118	Rev.
	T. M. S.	5-3-96	REB	5/3/96		Ø

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Number

Rev.

SPECIFICATION

Number A V049-2-118 Rev. Ø

1.0 PURPOSE

The purpose of this procedure is to define the operational procedures to effectively perform manufacturing and testing in a Class 100 Clean Room environment.

2.0 GENERAL

The LIGO vacuum system performance is greatly influenced by the level of cleanliness of the vacuum surfaces. All components must be shipped to the site and installed without allowing contamination of the vacuum surfaces (flange faces and interior surface).

Once LIGO components are cleaned to UHV standards, they must be protected by a Class 100 clean room environment. This applies to assembly operations after UHV cleaning and to any subsequent inspections or other entry into the components.

All personnel must be trained in clean room procedures before entering the LIGO clean room areas. This includes viewing the Micron video tapes "Basic Contamination Control", "Robing for the Cleanroom", and "Behavior in the Cleanroom".

All clean room clothing (boots, gloves, gowns, hat covers, hoods, etc. shall meet Class 100 clean room standards.

Safety glasses shall be worn at all times.

3.0 RESPONSIBILITIES

The manufacturing department is responsible for training and execution of clean room protocol per this procedure. The Q.A. department shall monitor manufacturing and testing activities for compliance to this clean room procedure.

4.0 PROCEDURE

4.1 *Clean Room Access*

4.1.1 All personnel shall put on clean room clothing systems in an attached gowning room prior to entry into the Class 100 Clean Room. Personnel shall move from the first sticky mat (dirty) to the second sticky mat (clean) as they put on each shoe cover. All joints (glove to sleeve, pants to shoe cover). After gowning, personnel shall wait two minutes prior to entering the Class 100 area.

4.1.2 All soiled or damaged clothing shall be discarded.

4.1.3 Only clean tools and components shall be allowed inside the Class 100 Clean Room. All equipment used inside the Class 100 clean room shall be oil free and shall not generate particles above Class 100 levels.

4.1.4 Clean Room particle levels shall be monitored during clean room operations where a component is open or about to be opened.

4.1.5 Clean Room particle levels must reach Class 100 level before a cleaned component maybe opened for inspection or assembly.

4.1.6 New personnel shall not enter the Class 100 Clean Room while a component is open.

4.1.7 Proper cleanroom behavior shall be observed while personnel arein the cleanroom.

4.2 *Clean Room Exit*

4.2.1 All personnel shall exit the Class 100 area onto the clean sticky mat.

4.2.2 Shoe covers shall be removed one at a time while moving over to the "dirty" sticky mat.

4.2.3 Personnel shall remove the remaining Class 100 clothing and store in a "used clothing" storage area if not soiled or torn. Once the Class 100 clothing is removed, personnel shall leave the gowning room immediately.

Title: SPECIFICATION FOR BLACK LIGHT INSPECTION PROCEDURE

SPECIFICATION FOR

BLACK LIGHT INSPECTION PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stan

QUALITY ASSURANCE: ALAN BRADBROOK/RES

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-5-96	RES 5/5/96	INITIAL RELEASE PER DEO # 0171 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-130	Rev.
	TMS	5-5-96	RES	5/5/96		0

SPECIFICATION TABLE OF CONTENTS

1.0 PURPOSE

This specification covers the procedure to be used for black light inspections of vessels and components cleaned for the LIGO vacuum system.

2.0 GENERAL

2.1 Cleaning shall be performed by an engineer, technician or shop worker familiar with this procedure and the manual for use of the ultraviolet lamp.

2.2 Inspection shall be done in a darkened area.

2.3 A 100 watt ultraviolet lamp with a wavelength of 365 nm shall be used.

3.0 RESPONSIBILITIES

3.1 Cleaning shall be performed by an engineer, technician or shop worker familiar with this procedure and the manual for use of the ultraviolet lamp.

3.2 This procedure shall be maintained and modified as required by the cognizant engineer.

4.0 PROCEDURE

4.1 Turn on the lamp and allow it to warm up for 3-5 minutes.

4.2 The operator shall enter the darkened area and allow 2-3 minutes for his eyes to adapt to the low light level.

4.3 Inspect the cleaned surfaces, holding the lamp 8-12 inches from the surface. Be careful to distinguish between ultraviolet fluorescence and reflected purple visible light.

4.4 Record the description and location of any detected contamination and issue a Discrepancy Report.

5.0 REQUIRED DOCUMENTATION

Inspection results shall be recorded on the component cleaning data sheet.

Title: SPECIFICATION FOR BAKE OUT PROCEDURE ISOLATABLE SECTION

SPECIFICATION FOR BAKE OUT PROCEDURE

FOR LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Roberto Thun

QUALITY ASSURANCE: Allan L Bradbook

TECHNICAL DIRECTOR: D. C. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	R.T. 5/1/96	RCB 5/2/96	INITIAL RELEASE PERDEO 157 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED DATE R. T. 5/1/96	Approved DATE RCB 5/2/96	Number: V049-2-116 A	Rev. 0

1.0 PURPOSE

The purpose of this is to define the necessary steps to perform a bakeout of an isolatable section at 150 °C. This includes the steps necessary to prepare for the bake out sequence.

2.0 GENERAL

The procedure will general apply to all isolatable sections of the stations.
Slight differences among each isolatable section will be due to different vacuum equipment, size of the isolatable section, and quantities involved relating instrumentation, equipment, etc. The stations are divided into the following bakeable sections:

Corner station WA	Vertex Section
	Diagonal Section
	Left Beam Manifold Section
	Right Beam Manifold Section

Mid station WA	One Section

End station WA	One Section

Corner station LA	Vertex Section
	Left Beam Manifold
	Right Beam Manifold

End station LA	One Section

Required References

A. Blanket System mechanical layout configuration and electric configuration drawings for vacuum envelope. All stations. All sections.
B. Bakeout System Control Cart Operating Manual & Procedure.
C. RGA Operating Manual
D. EDP200/EH2600 Roughing pumps Operating Manuals
E. STPH2000C Turbomolecular Pump Operating Manuals

F. QDP80 Dry Backing Pump Operating Manuals
G. Vacuum Gauges: Cold Cathode & Pirani Gauges Operating Manuals
IH 2500 L/s, 75L/s, 25 L/s Ion Pumps Operating Manuals

3.0 RESPONSIBILITY

The procedure is applicable to PSI Personnel.

4.0 PROCEDURE

4.1 Bakeout System

4.1.1 Bake out carts check out

Follow procedures for electric and data acquisition and control parameters checkout of the bake out control/electric system carts.
Refer to: Bakeout System Control Carts, Operating Manual & Setup Procedure.

4.1.2 Blanket installation

Each heating blanket is identified and will fit onto certain sections of the vacuum envelope. Install the assigned blankets according to the assigned locations per blanket system drawing layout and installation procedures.

In addition the following components will also be baked:
Cold cathode/ Pirani Gauge pairs on isolatable section.
RGA head with electronics removed.
Main Turbo Pump inlet.
The Main Ion pumps need to be warmed up also to ensure adequate warmup of the 14" gate.

Refer to: Blanket System mechanical layout configuration and electric configuration.
Refer to: Bakeout System Control Cart Operating Manual & Procedure.

4.1.3 Electrical and thermocouples connection and checkout

Connect each blanket power cable and thermocouple cable to the controlled cart according to procedures and drawing for connecting blankets electricals and instrumentation to control carts
Refer to: Blanket System mechanical layout configuration and electric configuration.

4.2 Vacuum System

4.2.1 Roughing Pump(s)

Do functional check of roughing pump system.
Refer to: EDP200/EH2600 Roughing pumps Operating Manuals

4.2.2 Turbomolecular Pump(s)

Do functional check of turbomolecular pump system.
Refer to: STPH2000C Turbomolecular Pump Operating Manuals
QDP80 Dry Backing Pump Operating Manuals

4.3 Vacuum Instrumentation

4.3.1 RGA

The RGA will be used before and after bakeout. The RGA itself needs to be baked. The RGA assembly will be mounted off a 2½ all metal UHV valve mounted on the vacuum envelope. The assembly will have a 2½" Tee or Cross Conflat fitting with an 1½" roughing valve on one end and the RGA on the other. A cross fitting is recommended so that a high vacuum gauge can be mounted on the fitting to serve as the pressure protection device for the RGA.
Isolate the 2½ UHV valve from the vacuum envelope and connect the aux. cart to the RGA to pumpdown the RGA assembly for RGA checkout.
Refer to: RGA Operating Manual

4.3.2 Pressure gauges: Pirani and cold cathode

There should be at least two pressure gauge pairs mounted on one isolatable section to ensure continuation of the bakeout in the event a gauge fails due to excess temperature during the bake.
Do not start warmup of pressure gauge until a pressure of less than $1X10^{-4}$ Torr has been reached.
Refer to: Cold Cathode & Pirani Gauges Operating Manuals

4.4 Bakeout Sequence

4.4.1 Pumpdown

4.4.1.1 Pumpdown using roughing system

Corner Stations:

Connecting the main turbo and Main roughing carts.
Follow procedures for connecting the main turbo and main roughing pumps.

Pumpdown the isolatable section following procedures for connecting and operating the roughing pump system. Pumpdown until a pressure of less 0.1 Torr is reached.
At the completion of roughing the section:
Close the 6" gate valve
Shutdown roughing pumps
Vent the rough line by opening the vent valve on the roughing cart.
Disconnect line and blankoff port.
Leak check the Conflat connection of the blankoff through the pumpout valve.
Evacuate the space between the blind and the gate using the aux turbo cart.
Open the 6" valve.

End/Mid stations:
Pumpdown the isolatable section following procedures for connecting and operating the turbo pump and backing pump system.
At the end of the roughing cycle using the roughing pump: close bypass valve and turn on the turbo.
Follow the operating procedure for operating the turbo pump cart.

4.4.1.2 Pumpdown using turbo molecular pump

Corner, End, and Mid stations:
Follow turbomolecular pump operating procedure for startup and operation of pump for pumpdown.
The turbomolecular pump will also be heated during bakeout.

4.4.2 RGA data

A residual gas analysis will be carried out as a reference point prior to start of bakeout.
Power up RGA only after pressure has dropped to less $5X\ 10^{-5}$ Torr

4.4.3 Ramp-up

Ramp rate:
Warm-up will occur over a period of 72 hours at a ramp rate of approximately 1.8°C/hr.
Set ramp rate for blanket system on control carts to 1.8°C/hr.
Set target setpoint to 150°C.

Pressure gauge pairs: Ramprate of the pressure gauge pairs will be at least 5 °C/hr to ensure that the gauges remain hotter than the vacuum envelope at all times.

Bake out of the gauge pair will be done with the electronics removed.
Set ramp rate for blanket system on control carts to 5°C/hr.
Set target setpoint to 250°C.
Do not start warmup until the pressure has dropped to less 5X 10^{-5} Torr.

RGA: The RGA needs to be baked also.
Bake the RGA independently i.e. isolated from the vacuum envelope bake.

This will be done using a 25L/s Ion pump.
Bake out of the RGA will be done with the electronics removed.
Bakeout temperature of the RGA will set at manufacturers recommended maximum (200°C)

4.4.4 Soak for 48 hours

The isolatable section will be heated to 150°C and soaked for 48 hours at 150°C±20°. The pressure gauge pairs will be soaked at 250°C.

4.4.5 Cooldown

Cooldown will be controlled by ramping the setpoints of the system to ambient temperature at a ramprate of -1.8°/hr. The heating jackets for the pressure gauge pair will remain of and turned off when the system has cooled down.

4.4.6 RGA data

With the system baked and cooled down, a residual gas analysis will be carried out to determine the presence of any air leaks and cleanliness of the system.

Title: **ACCEPTANCE TEST PROCEDURE - 80K PUMP SYSTEM**

ACCEPTANCE TEST PROCEDURE

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Louisiana

PREPARED BY: David Moore

QUALITY ASSURANCE: _____

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: _____

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
ϕ	DM 5/6/96	AS3 5/6/96	Released per DEO #173 for FDR

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED DM	DATE 5/6/96	Approved AS3	DATE 5/6/96	Number: A V049-2-102	Rev. ϕ

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of this piece of equipment in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all the stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

V049-2-014 Leak Test Plan

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST

5.1 80K Pump Field Joint Leak Test

The specification requires all leaks greater than 1x10E-9 torr-l/s of helium to be repaired in accordance with LIGO approved procedures. Prior to shipment to the site, the 80K pump will have been leak checked and all objectionable leaks will have been repaired. However, all joints and flanges on the 80K pump which are assembled in the field will be leak checked per the methods described in V049-2-014.

5.2 LN2 Dewar Site Acceptance Test

After dewar installation, but prior to filling it with LN2, the dewar shall be subjected to the following series of checks:

1) Visually inspect for damage that may have occured during shipment or installation.
2) Briefly exercise all manual valves to verify operation. The dewar inner vessel contains a dry nitrogen charge at 5-10 psig, so a small quantity of gas will escape when the valves are exercised.
3) Check the vacuum level in the dewar jacket annulus with a thermocouple gauge to verify vacuum integrity. Refer to the dewar operating manual for the required level.

After filling the dewar with liquid nitrogen, the following checks shall be made:

1) Verify that the locally mounted level and pressure gauges have stabilized. Refer to the dewar operating manual and 80K pump operating procedures for correct readings.

5.3 Regeneration Heater Acceptance Test

Prior to any operating checks, visually inspect the heater for any signs of damage that may have occurred during shipment or installation.

The acceptance test for the regen heater is a functional test to verify that the heater performs its intended function. It is recommended that in order to conserve liquid nitrogen, this test be performed prior cooling down the cryopump. The test sequence described below assumes the test is on one of the long cryopump regen heaters. Wherever the test for the short cryopump regen heater differs from that of the long cryopump heater, it is so noted. Equipment tag numbers are for cryopump WCP1 (Refer to drawing V049-0-006). The test procedure is as follows:

1) Verify that the manual globe valve (HVXX1) upstream of the heater is closed.

2) Open the dewar gaseous nitrogen supply valve, V-11, (refer to dewar operating manual for equipment tag numbers) upstream of the ambient vaporizer to admit nitrogen to the regen system.

3) Open the manual globe valve until the flowmeter indicator (FI104) upstream of the heater reads 10,600 SCFH (5,300 SCFH for the short pump regen system).

4) Set the heater conrols for a gas outlet temperature of 360 deg. F (375 deg. F for the short pump heater).

5) Verify that the heater controls maintain the gas outlet temperature (TE103A) at the selected temperature. This concludes the test. The sequence required for stopping the test is as follows

   1) Shut down the heater.
   2) Close the dewar gaseous nitrogen supply valve, V-11, upstream of the vaporizer.
   3) Close the manual globe valve, HVXX1.

5.4 Cryopump Acceptance Test

The acceptance test for the cryopump is a functional test to verify that the pump liquid level control valve performs its intended function. This may be verified by simply monitoring the liquid level in the pump over a 24 hour period. If the level control valve is functioning properly, then neither the high level alarm nor the low level alarm will have tripped.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION **Equip. Tag_____ S/N_____________**

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labelling Verification					
Bakeout					
Leak rate					
Factory Endurance Test					
Factory Speed Test					
Functional Test					
RGA Test					
Particle Count					
Pumpdown					

VC49-2-102
Rev 0
Pg 5 of 5

Title: SPECIFICATION FOR ACCEPTANCE TEST PROCEDURE FOR ROUGHING SYSTEM

ACCEPTANCE TEST PROCEDURE FOR ROUGHING PUMP SYSTEMS

LIGO VACUUM EQUIPMENT

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: S Morton

QUALITY ASSURANCE: Allan R Bradbrook

TECHNICAL DIRECTOR: D O m. Williams

PROJECT MANAGER: Rudolf Bayer

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	SM 5/1/96	REB 5/2/96	INITIAL RELEASE PER DEO 0157 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED SM	DATE 5/1/96	Approved REB DATE 5/2/96	Number: V049-2-104 A	Rev. 0

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of this piece of equipment in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The plan will apply to the main roughing pump systems for the corner stations.

2.2 Tests will be performed by PSI personnel, and will be witnessed and/ or the results reviewed and the equipment accepted by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

EDP200/EH2600 Roughing pumps Operating Manuals

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the PSI project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FACTORY TEST

5.1 Procedure

5.1.1 Speed Test

The Main Roughing system's individual vacuum pumps will be atmospheric air speed tested by EHVI at the point of manufacture in the U.K. A test certificate is provided with each pump.

The minimum required pumping speed at 1 Torr is 236 l/s, at 0.1 Torr is 472 l/s. The roughing pump set must be capable of evacuating a volume of 200 cubic meters from atmosphere to 1 Torr in 4 hours or less.

The Main Roughing Pumps are designed for continuous duty service at full load and will pump down a 2000 cubic meter volume from atmosphere to 1 Torr without overheating.

5.1.2 Functional Test

Main Roughing system functional tests will be done at EHVI's Grand Island, N.Y. facility

Besides the manufacturer's standard operating and safety features the following additional feature has been incorporated
a. Gate valve at inlet to Roots blower EH2600 fails close on lost of power or on shut down of EDP200.

6.0 FIELD TEST

6.1 Procedure

The main roughing pump equipment will have already been accepted by LIGO at the point of manufacture as part of the beam tube deliverables, and will have been used for beam tube pumpdown service.

After installation of the roughing system into the building, a functional checkout will be carried out prior to use, to determine operating status and mechanical condition of the pumping systems.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION
Equip. Tag_____ S/N_____

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labeling Verification		Grand Isle N.Y. PSI witness			
Bakeout		N/A			
Leak rate		Standard factory test			
Factory Endurance Test		N/A			
Factory Speed Test		Test in U.K Certificate supplied			
Functional Test		Grand Isle N.Y. PSI witness			
RGA Test		N/A			
Particle Count		N/A			
Ultimate Pressure Test		Standard Factory Test. U.K.			

Title: SPECIFICATION FOR ACCEPTANCE TEST PROCEDURE FOR TURBO PUMP SYSTEMS

ACCEPTANCE TEST PROCEDURE FOR THE

TURBOMOLECULAR PUMP SYSTEMS

LIGO VACUUM EQUIPMENT

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: S. Motter

QUALITY ASSURANCE: Allan L Budlong

TECHNICAL DIRECTOR: D A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	SM 5/1/96	REB 5/2/96	INITIAL RELEASE ECO 0157

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED SM	DATE 5/1/96	Approved REB DATE 5/2/96	Number: V049-2-105 A	Rev. 0

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of this piece of equipment in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The plan will general apply to all the main turbo molecular carts for all the stations. (Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.)

2.2 Tests will be performed by PSI personnel, and will be witnessed and/ or the results reviewed and the equipment accepted by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

STPH200C/ QDP80 pumps Operating Manuals

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the PSI project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FACTORY TEST

5.1 Procedure Main Turbomolecular Pump Sets

5.1.1 Speed Test

The Main turbomolecular pump systems are speed tested in accordance with American Vacuum Society AVS 4.1; Recommended procedure for measuring pumping speeds as revised in October 1986. The speed test is performed across the normal working range of the turbomolecular pump, from $1x10^{-6}$ torr to $1x10^{-3}$ torr.
The minimum required pumping speed at the inlet port of the Main Turbo pump is1400 l/s N_2 at an inlet pressure of $1x10^{-3}$ torr.

Throughput
The minimum required backing pump throughput is 5 torr-l/s with a backing pressure of 1 torr.

Duty
The Main Turbo Pump sets are designed for continuous duty service at full load and will pump down a 2000 cubic meter volume from 1 torr to 10^{-6} torr without overheating.

5.1.2 Functional Test

Besides the manufacturer's standard operating and safety shutdown features the following additional feature has been incorporated

a. The turbo pump cannot be started or will shutdown at a backing pressure higher than a preset value.
b. Emergency stop button on the backing pump electrical interface box and main control box.
c. Backing pump motor winding overtemp shutdown
d. Backing pump shut down on N2 seal gas low flow
c. Backing pump motor starter overload
d. Foreline safety valve closes on backing pump shutdown or turbo pump shutdown/failure.

5.2 Auxiliary Turbomolecular Pump Sets

5.2.1 Speed Test

The Auxiliary turbomolecular pump systems are speed tested in accordance with American Vacuum Society AVS 4.1; Recommended procedure for measuring pumping speeds as revised in October 1986. The speed test is performed across the normal working range of the turbomolecular pump, from $1x10^{-6}$ torr to $1x10^{-3}$ torr.

The minimum required pumping speed at the inlet port of the Auxiliary Turbo pump is 50 l/s N_2 at an inlet pressure of $1x10^{-3}$ torr. The Auxiliary Turbo pump set will be speed tested per AVS 4.1 procedure.

5.1.2 Functional Test

Besides the manufacturer's standard operating and safety shutdown features the following additional feature has been incorporated.

a. The inlet valve to the turbopump will will fail closed on power loss or turbo failure and the inlet side of the turbo will be vented. (Process side is isolated and will remain under vacuum by closing of the automatic inlet valve)

6.0 FIELD TEST

6.1 Procedure Main Turbomolecular Pump Sets

The main turbomolecular pump equipment will have already been accepted by LIGO at the point of manufacture as part of the beam tube deliverables, and will been used for beam tube pumpdown service.

After installation of the main turbomolecular system into the building, a functional checkout will be carried out prior to use, to determine the operating status and mechanical condition of the pumping systems.

6.2 Auxiliary Turbomolecular Pump Sets

A functional checkout will be carried out prior to use, during installation of the vacuum envelope.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION
Equip. Tag___STPH2000C_____ S/N_____

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labelling Verification		Grand Isle N.Y. PSI witness			
Bakeout		N/A			
Leak rate		$<5X10^{-9}$ Torr-L/s			
Factory Endurance Test *		Grand Isle N.Y. PSI witness			
Factory Speed Test		Grand Isle N.Y. PSI witness			
Functional Test		Grand Isle N.Y. PSI witness			
RGA Test		N/A			
Particle Count		N/A			
Ultimate Pressure		$<1X10^{-8}$ Torr			

* First article only

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION
Equip. Tag___EXT70H_____ S/N_____

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labelling Verification		Grand Isle N.Y. PSI witness			
Bakeout		N/A			
Leak rate		$<5X10^{-9}$ Torr-L/s			
Factory Endurance Test		N/A			
Factory Speed Test		Grand Isle N.Y. PSI witness			
Functional Test		Grand Isle N.Y. PSI witness			
RGA Test		N/A			
Particle Count		N/A			
Ultimate Pressure		$<1X10^{-8}$ Torr			

Title: SPECIFICATION FOR ION PUMPS ACCEPTANCE TEST PROCEDURE

ACCEPTANCE TEST PROCEDURE FOR ION PUMPS FOR LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Louisiana

PREPARED BY: F. Bark

QUALITY ASSURANCE: Allan L Sudbrock

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bazzle

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	F Bark 5.2.96	RCB 5/2/96	RELEASED FOR FDR PER DEO # 160

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED F. Bark	DATE 5.2.96	Approved RCB	DATE 5/2/96	Number: A V049-2-106	Rev. 0

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of main and annulus ion pumps and controllers in order to demonstrate that they meet the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all the stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The attached equipment acceptance test data/test verification form shall be filled out when performing the ATP and presented to LIGO.

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the PSI project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST PROCEDURE

5.1 Ion Pumps

5.1.1 Main Ion Pumps

a. Check for physical damage to the pump, controller and HV cables.

b. Prior to pump installation, verify that it still is under vacuum.

c. While still under vacuum,Install the controller, hook up control wires and HV cable(s) to the controller and feedthru(s). Then test controller functionality and all interlocks.

d. After pump installation, vacuum leak check it with isolation valve closed. Refer to PSI leak test procedure V049-2-014.

e. Speed test as documented in Specification V049-2-004 will be performed at the factory for only the first manufactured ion pump.

5.1.2 Annulus Ion Pumps

Refer to Section 5.1.1 (Main Ion Pumps).
Item e (speed test) is not applicable.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION
Equip. Tag (MAIN)_____ S/N_____

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection		PSI field check			
Labelling Verification		PSI field check			
Bakeout		Field. By PSI			
Leak rate		$<1X10^{-9}$ Torr-L/s			
Factory Endurance Test		N/A			
Factory Speed Test		Torino,Italy. PSI witness first only			
Functional Test		Torino,Italy. PSI witness first only. PSI, Field test all.			
Electrical continuity test		Field. By PSI			
System interlocks test		Field. By PSI			
Ultimate Pressure		$<1X10^{-9}$Torr			

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION
Equip. Tag (ANNULUS)_____ S/N_____

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection		PSI field check			
Labelling Verification		PSI field check			
Bakeout		Field. By PSI			
Leak rate		$<1X10^{-9}$ Torr-L/s			
Factory Endurance Test		N/A			
Factory Speed Test		N/A			
Functional Test		Field By PSI			
Electrical continuity test		Field. By PSI			
System interlocks test		Field. By PSI			
Ultimate Pressure		$<1X10^{-9}$Torr			

ACCEPTANCE TEST PROCEDURE FOR

LARGE GATE VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stan

INSTR/ELEC ENGINEER: N/A

QUALITY ASSURANCE: Alan R Bridbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Rachel Bayless

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-3-96	REB 5/4/96	INITIAL RELEASE PER DEO # 0165 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED TMS DATE 5-3-96	APPROVED REB DATE 5/4/96	Number A V049-2-107	Rev. 0

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1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-005, 112 cm and 122 cm Gate Valves

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

5.1 The first eight large gate valves will be acceptance tested at the manufacturer's shop prior to shipment. These are slated for early delivery to Washington to close the beam tube. All other large gate valves will be tested at the manufacturer's shop prior to shipment and accepted in the field as the sections of equipment that they isolate are tested and accepted. The field test will consist of a valve functional check and the leak test of the isolated section of equipment.

5.2 Procedure

5.2.1 Each valve shall be inspected for dimensional conformance to approved assembly drawings.

5.2.2 Each valve shall be inspected for cleanliness by black light. Valves shall be recleaned if any contamination is found.

5.2.3 Each valve shall be functionally tested. Prior to final gate seal leak testing, operation of each valve for 20 cycles shall be demonstrated. The valves shall be shown to be capable of stroking in either direction in 5 minutes or less.

5.2.4 Each valve shall be tested for leakage (using oil-free pumping equipment and leak detector) prior to shipment from the manufacturer. Each valve shall be baked at 150 C prior to leak checking. For dual gate seals and end seals, each seal shall be individually tested. For the end seals, the Vendor's test fixture shall allow testing of each seal individually. An RGA with calibrated leak shall be used in performing the leak testing. Partial pressures of hydrocarbons greater than 2.0×10^{-10} Torr for any species will be cause for rejection. Body and flange leakage shall be measured to be less than 10^{-10} torr liter/sec of helium before shipment. Leak checking procedures shall conform to ASTM E498.

5.2.5 One valve of each size and type of actuation shall be tested for shock. The valve shall be tested in the vertical position resting on a pad that deflects at least 0.1" under the static load of the valve, so as not to simulate a "hard mount". Testing shall be done both at atmospheric pressure and with the valve under vacuum. An accelerometer shall be mounted near a connecting flange (or weld stub) on the valve housing or near the edge of one of the flange covers. Separate measurements shall be taken in each of the three axes. Valve actuation shall be shown to induce no more than 0.01g peak-to-peak acceleration at any point on the valve mounting flanges or weld stubs.

6.0 DOCUMENTATION

The following documentation shall be provided prior to acceptance:

- Leak test procedure and report (including data).
- Shock test procedure and report (including data)
- Manufacturer's standard QA reports (including final functional test reports)

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION **Equip. Tag_____ S/N_____**

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection	5.2.1 5.2.2				
Labelling Verification					
Bakeout	5.2.4	150 C /			
Leak rate	5.2.4	1 x 10^{-10} torr l/sec He			
Factory Endurance Test	5.2.3	20 Cycles			
Factory Speed Test	5.2.3	Open <5 min. / Close <5 min. /			
Functional Test	5.2.3				
RGA Test	5.2.4	<2 x 10^{-10} torr for any HC /			
Particle Count	NA				
Pumpdown	NA				

ACCEPTANCE TEST PROCEDURE FOR

6", 10" AND 14" GATE VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stan

INSTR/ELEC ENGINEER: NA

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D. C. M. Williams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-3-96	RCB 5/4/96	INITIAL RELEASE PER DEO # 0165 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC. | **SPECIFICATION**

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-108	Rev.
	TMS	5-3-96	RCB	5/4/96		0

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-006, 6", 10" and 14" Gate Valves

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

5.1 Each valve shall be inspected for cleanliness by black light. Valves will be recleaned if any contamination is found.

5.2 All 6", 10" and 14" gate valves valves shall be leak tested (using oil-free pumping equipment and leak detector). An RGA with calibrated leak shall be used in performing the leak testing. Leak checking procedures shall conform to ASTM E498. Valve body and flange total leakage shall be measured to be less than 10^{-10} torr liter/sec of helium before shipment. Gate seal leakage shall be shown to be less than $1x\ 10^{-9}$ torr liter/sec of helium.

5.3 One valve of each size and type of actuation shall be tested for shock. The valve shall be tested in the vertical position resting on a pad that deflects at least 0.1" under the static load of the valve, so as not to simulate a "hard mount". Testing shall be done both at atmospheric pressure and with the valve under vacuum. An accelerometer shall be mounted near a connecting flange on the valve housing or near the edge of one of the flange covers. Separate measurements shall be taken in each of the three axes. Valve actuation shall be shown to induce no more than 0.01g peak-to-peak acceleration at any point on the valve mounting flanges.

5.4 Final acceptance will occur in the field. The field test will consist of a valve functional check and the leak test of the associated isolatable section of equipment.

6.0 DOCUMENTATION

The following documentation shall be provided prior to shipment:

- Leak test procedure and report (including data).
- Shock test procedure and report (including data).
- Manufacturer's standard QA reports (including final functional test reports)

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION **Equip. Tag_____ S/N_____**

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection	5.1				
Labelling Verification					
Bakeout	NA				
Leak rate	5.2	1×10^{-10} torr l/sec He			
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	NA				
RGA Test	5.2				
Particle Count	NA				
Pumpdown	NA				

ACCEPTANCE TEST PROCEDURE FOR

SMALL VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stan

INSTR/ELEC ENGINEER: NA

QUALITY ASSURANCE: Alan R Bridbury

TECHNICAL DIRECTOR: D O. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-3-96	REB 5/4/96	INITIAL RELEASE PER DEO# 0165

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED TMS	DATE 5-3-96	APPROVED REB	DATE 5/4/96	Number A V049-2-111	Rev. 0

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1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-059, Small Vacuum Valves

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

5.1 Each valve shall be inspected for cleanliness by black light. Valves shall be recleaned if any contamination is found. The vendor's standard inspections shall be performed.

5.2 All small vacuum valves valves shall be leak tested (using oil-free pumping equipment and leak detector). The vendor's standard leak checking procedures shall be used. Valve body and flange total leakage shall be measured to be less than 10^{-9} torr liter/sec of helium before shipment, or less if the vendor's standard is lower. Seat leakage shall be shown to be less than 1×10^{-9} torr liter/sec of helium, or less if the vendor's standard is lower.

5.3 Final acceptance will occur in the field. The field test will consist of a valve functional check and the leak test of the associated isolatable section of equipment.

6.0 DOCUMENTATION

The manufacturer's standard QA reports (including final functional test reports) will be submitted.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION **Equip. Tag_____ S/N_____**

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection	5.1				
Labelling Verification					
Bakeout					
Leak rate	5.2	1×10^{-9} torr l/sec He			
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	NA				
RGA Test	NA				
Particle Count	NA				
Pumpdown	NA				

ACCEPTANCE TEST PROCEDURE FOR

CLEAN AIR SUPPLIES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stein

INSTR/ELEC ENGINEER: _____

QUALITY ASSURANCE: Allan R. Bushbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: _____

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	JMS 5-3-96		INITIAL RELEASE PER DEO #0165 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC. — **SPECIFICATION**

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-109	Rev.
	JMS	5-3-96	REB	5/4/96		0

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1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-011, Clean Air Supply Systems

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

5.1 Each compressor system shall be functionally tested. A comprehensive operational test plan shall be developed and used to demonstrate proper operation of the compressors. Tests shall include normal operation plus simulation of unusual events (component failure, etc.) to ensure that individual skid controls bring the system to a safe condition.

5.2 For one of each size system, the delivered flowrate shall be shown to be at least 50 CFM or 200 CFM, the dewpoint shown to be no higher than -60 C (at atmospheric pressure), and hydrocarbon content shown to be no higher than the ambient air. In addition, a particle count of the delivered air shall be taken to confirm that it conforms to Class 100.

5.3 Final acceptance will occur in the field. The hydrocarbon content test and particle count will be repeated as part of the check for cleanliness of the installed piping system.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION **Equip. Tag_____ S/N_____**

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labelling Verification					
Bakeout	NA				
Leak rate	NA				
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	5.1				
RGA Test	NA				
Particle Count	5.2				
Pumpdown	NA				

ACCEPTANCE TEST PROCEDURE FOR

PORTABLE SOFT-WALL CLEANROOMS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stan

INSTR/ELEC ENGINEER: FADI BARK /REB

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D a. M Williams

PROJECT MANAGER: Rachel Bagby

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-3-96	REB 5/4/96	INITIAL RELEASE PER DEO # 0165 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED DATE: TMS 5-3-96	APPROVED DATE: REB 5/4/96	Number A V049-2-110	Rev. 0

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-010

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

5.1 One of each size portable cleanroom shall be fully assembled at the manufacturer's shop. It shall be inspected for dimensional specifications and the presence and proper operation of the windows to seal to the beam tube or nozzles, and to the BSC dome. Rigidity of both the frame and of the removable ceiling unit shall be verified. The operation of the sealing system used to mate two cleanrooms together shall be checked. The cleanroom will be operated and certified to produce a Class 100 environment.

5.2 Fianl acceptance of each cleanroom will occur at the point of first use: in the PSI shop or at the sites. Each cleanroom will be operated and certified to produce a Class 100 environment.

6.0 DOCUMENTATION

A system assembly and operating manual shall be provided.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION **Equip. Tag_____ S/N_____**

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labelling Verification					
Bakeout	NA				
Leak rate	NA				
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	5.1				
RGA Test	NA				
Particle Count	5.2	Class 100			
Pumpdown	NA				

Title: SPECIFICATION FOR BAKEOUT SYSTEM ACCEPTANCE TEST PROCEDURE

ACCEPTANCE TEST PROCEDURE FOR BAKEOUT SYSTEM BLANKETS AND CARTS FOR LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Louisiana

PREPARED BY: F. Bark

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D A W Williams

PROJECT MANAGER: Richard Bagley

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	F. Bark 5/2/96	RES 5/2/96	RELEASED FOR FDR PER DEO # 160

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	Approved	DATE	Number: A V049-2-112	Rev. 0
	F. Bark	5-2-96	RES	5/2/96		

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of the bakeout system blankets and carts in order to demonstrate that they meet the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all the stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The attached equipment acceptance test data/test verification form shall be filled out when performing the ATP and presented to LIGO.

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed, and meet all requirements. The data sheet shall also be signed by the project engineer or by someone designated by the PSI project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST

5.1 Bakeout System Blankets And Carts:

a. All bakeout carts will be tested per PSI fabrication specification V049-2-068 prior to shipment to the site.

b. All blankets will be tested for operation and performance at PSI during bakeout of all vacuum vessels.

Vacuum vessels will be cleaned, baked out, evacuated, and sealed prior to shipment to the site.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION
Equip. Tag _____ S/N_____

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection		PSI check at PSI PSI field check			
Labelling Verification		PSI check at PSI PSI field check			
Blanket Fit Test		PSI check at PSI PSI field check			
Electrical continuity test		PSI check at Vendor			
System interlocks test		PSI check at PSI PSI field check			
Functional Test		. PSI check at PSI PSI field check			
Vessel Bakeout		.			

Title: SPECIFICATION FOR SYSTEMS ACCEPTANCE TESTS PLAN, CORNER STATIONS

SYSTEMS ACCEPTANCE TEST PROCEDURE

LIGO VACUUM EQUIPMENT

CORNER STATIONS

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: Robert Thor

QUALITY ASSURANCE: Alan R Bradbrook

TECHNICAL DIRECTOR: D. a. m Williams

PROJECT MANAGER: Barbara Bazyn

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	DM 5/7/96	RES 5/7/96	Revised per DEO # 0178
0	R.T. 5/1/96	RES 5/2/96	INITIAL RELEASE PER DEO 0157 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED R.T. DATE 5/1/96	Approved RES DATE 5/2/96	Number: V049-2-113 A	Rev. 1

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for systems acceptance testing of the vacuum envelope and vacuum pumping system in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.
This document will be part of the Acceptance Test Report as required by CDRL No.06.

2.0 GENERAL

2.1 The plan will general apply to the corner stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

Corner station WA	Vertex Section
	Diagonal Section
	Left Beam Manifold Section
	Right Beam Manifold Section

Corner station LA	Vertex Section
	Left Beam Manifold
	Right Beam Manifold

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

Leak Check Procedure; Doc no:
Bakeout System Procedure; Doc no:
80K Cryopump Operating Procedure; Doc no:
Bakeout System Control Cart Operating Manual & Procedure; Doc no:
RGA Operating Manual
EDP200/EH2600 Roughing pumps Operating Manuals
STPH2000C Turbomolecular Pump Operating Manuals
QDP80 Dry Backing Pump Operating Manuals
Vacuum Gauges: Cold Cathode & Pirani Gauges Operating Manuals
2500 L/s, 75L/s, 25 L/s Ion Pumps Operating Manuals

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or someelse designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST PROCEDURES

5.1 Leakage Test

5.1.1 Chamber and Tube Section Leak Tests

The specification requires all component leaks greater than $1x10^{-9}$ Torr-l/s of helium to be repaired in accordance with LIGO approved procedures. Leak checking shall conform to ASTM E498 "Standard Test Methods for Leaks using the Mass Spectrometer Leak Detector". (Ref. Specification V049-2-014, Leak Test Procedure). The following is a summary of the field leak testing plan.

5.1.1.1 Prerequisites

The individual vacuum enclosures have completed their manufacturing cycle and have been cleaned, baked, factory leak tested, sealed and evacuated for shipment. O-ring annulus volumes are back filled with pure nitrogen gas and valved off. The unit is then wrapped and packaged for shipment.

Upon arrival at the installation site, the unit will be visually inspected for any shipping damage or vacuum seal disturbance that may have occurred during transit.

The vacuum level in the chamber is then measured and compared to the pre- shipment levels. The measured vacuum level in the chamber will be corrected for expected o-ring permeation. The pressure level in the o-ring annulus will also be measured. If the measured pressure levels in the chamber or annulus indicate that a leak has opened up during transit, the unit will be leak checked and repaired at or near the site.

5.1.1.2 Isolated Sections

Individual vacuum components are assembled into isolated sections which will be leaked checked as an independent volume. The procedures used to leak check the isolated sections are similar to the procedures used for individual components and in general follow the guidelines of ASTM E498.

Each isolated section has basically two types of vacuum volumes; the main chamber volume and the annulus volume between the dual o-ring seals. When leak checking the main chamber volume, it is important to prevent permeation of tracer gas(es) through the Viton o-rings. To eliminate this potential source of high background readings, the o-ring flanges will be bagged and purged with pure nitrogen gas.

When leak checking an annulus volume, it is important to know the permeation rate of the tracer gas through the Viton o-rings. The annulus volumes are small, and it is expected that significant leaks will present themselves quickly. Testing will be done on the BSC prototype to determine which tracer gas(es) is most effective in finding o-ring and annulus piping leaks. Helium, Argon, and Neon are candidate tracer gases.

Each isolated section will be leak checked by air signature method using an RGA. The maximum acceptable leak rate shall be consistent with the system requirements as determined by isolated volume size and RGA sensitivity, as mutually agreed upon by LIGO and PSI. Method and leak rate to be consistent with the BSC prototype chamber test results.

5.2 Pumpdown Time and Ultimate Pressure Test: Corner Station

The Pumpdown and ultimate pressure tests is performed on the largest isolatable section with an 80K pump. In the case of the Washington corner station the isolatable sections would be: 1. The Vertex section with one of the Beam Manifolds, and 2. The Diagonal section with one of the Beam Manifolds. In the case of the Louisiana corner station the isolatable section would be the Vertex section with one of the Beam Manifolds. Before a pumpdown and ultimate pressure test is performed, the sections that make up the largest isolatable section must be baked.

5.2.1 Annuli pumpdown

The annuli on the flanges will have been pumped during installation for leak checking. Any remaining flange annuli at atmosphere will be pumped prior to start of bakeout.

5.2.2 Vacuum equipment

The roughing carts, and main turbomolecular pumping system and main ion pump system will have been tested already. A functional test may be required prior to start of the bakeout to ensure proper operation of the equipment.
The main ion pumps will be evacuated and baked after installation onto the vacuum envelope. The main ion pumps will then started to ensure proper operation.

5.2.2.3 Residual gas analysis prior to bakeout.

Data will be taken prior to start of bakeout as a reference for checking outgassing rates / leaks after the bakeout.

5.2.2.4 System/Isolatable section bakeout.

The bakeout system will be installed on the isolatable section and baked out according to the bakeout procedures. Prior to the start of bakeout the system will be evacuated using the roughing system.

The isolatable section will be heated to 150°C and soaked for 48 hours at 150°C±20°.

Cooldown of the system will be carried out with the heating system operating to maintain temperature uniformity. This is done by ramping down the setpoints to ambient temperature.

Since the pumpdown tests will be carried on a isolatable section with a 80K cryopump, the beam manifold section will also need to be baked prior to vacuum pumpdown tests in the case of the corner stations. Execute bakeout for other sections as required.

5.2.2.5 Residual gas analysis after bakeout and cooldown

With the system baked and cooled down, a residual gas analysis will be carried out to determine the presence of any air leaks and cleanliness of the system.

5.2.2.6 Backfill with dry nitrogen

The system will be back filled with dry nitrogen (grade 0, to avoid hydrocarbon contamination) prior to vacuum pumpdown test.

5.2.2.7 Pumpdown of isolatable section with 80K cryopump

Corner station: Vertex & Beam manifold
Once two isolatable sections, a vertex section and beam manifold section have been baked and backed filled, the vacuum pumpdown test can be initiated.
Washington site: The Diagonal & one Beam manifold will makeup the other isolatable section.

5.2.2.7.1 Pumpdown from atmosphere to 0.1 Torr using the roughing system

Corner stations:
The isolatable section will be pumped using one main roughing system to a pressure below 0.1 Torr. The requirement is to be able to turn on the turbo pump in less than four hours. Acceptance will be when the pressure of 0.1 Torr is reached in less than 4 hours and the roughing system can be turned off and the turbo pump can be turned on.

5.2.2.7.2 Pumpdown from 0.1 Torr to 10^{-6} Torr using the main turbomolecular system

Corner stations: The isolatable section will be pumped using two main turbomolecular pump system. to a pressure of less than $5X10^{-6}$ Torr. Acceptance will be when the pressure of less than $5X10^{-6}$ Torr is reached in 24 hours.

5.2.2.7.3 80K cryopump

The cryopump will be turned on when a pressure of less than $5X10^{-6}$ Torr has been reached. To minimize cryotrapping of CO2, the cryopump should be cooled down as late as possible.

5.2.2.7.4 Main Ion pumps.

The main ion pumps will be turned on after the cryopump is cold and has been pumping for several hours. (between 24 hours to 30 hours into the pumpdown).

5.2.2.8 Ultimate Pressures after 100 hours.

The isolatable section shall attain a total pressure of $2X10^{-8}$ Torr, measured at the ion pumps after 100 hours of pumping. The partial pressure shall be measured with an RGA at a main ion pump pumpout port. If the hydrogen content of the steel prevents the attainment of this value, then the total pressure of the gasses, other than H_2 and H_2O shall not exceed $6X10^{-9}$ Torr.
The partial pressure goals of the following gasses shall be adjusted to reflect results that are consistent with the prototype chamber and design margins required for reliable implementation, but shall not be less than shown in the following table.

Table 5.2.2.8

Gas Species	Partial Pressure Goals Torr	Partial Pressure Acceptance Torr
H_2O	$5 X 10^{-9}$	
H_2	$5 X 10^{-9}$	
Total H_2O, H_2	**$1 X10^{-8}$**	
N_2	$5 X 10^{-10}$	
CO	$5 X 10^{-10}$	
CO_2	$2 X 10^{-10}$	
CH_4	$2 X 10^{-10}$	
All others	$5 X 10^{-10}$	
Total other	**$1.9 X10^{-9}$**	**$6X10^{-9}$**
Total	**$1.2 X10^{-8}$**	

Partial pressure of H_2O is expected to be higher at the ion pump because the ultimate pressure calculation is based on pressure of water at the cryopump. The partial pressure of water will be measured near the inlet of the cryopump.

5.3 Noise,Shock, and Vibration

During the commisioning process of the installations, measurements of vibration, shock, and noise generated by vacuum system equipment will be conducted. Meaurements are taken for data only, there is no acceptance criteria. Vibration measurements will be made on one each of the following chamber: HAM, BSC (WA site only).

At each chamber, normal vibration (i.e. single axis) measurements will be made at one location on the floor within 1 meter of the chamber. Tri-axis testing measurements will be made at two locations on each chamber. Measurements will be made with and without operatng auxiliary equipment for the purpose of establishing ambient levels. Additionally, sound pressure levels will be measured in the vicinity of each chamber with all vacuum system components in normal operation.

Shock measurements will be made on representative chambers during the operation of the gate valves. For baseline tests, the BSC located at the vertex will be instrumented for tri-axis shock measurements during the operation of the 35 cm and 15 cm gate valves on the beam manifold and of the nearby nearby 122 cm gate valve.

5.4 Interface to the CDS

All CDS cabinets are supplied and installed by LIGO. PSI will terminate all VE instruments and other system interlocks as shown on PSI electrical drawings. CDS cabinet locations are shown on the following drawings:

V049-3-123 (4 sheets)

V049-3-108 (2 sheets)

V049-3-308 (2 sheets)

V049-3-408 (1 sheets)

V049-3-508 (1 sheets)

Acceptance test for instrument loops and other wiring installed by PSI and terminated in the CDS's, will be performed as follows:

a. Check point to point continuity of each conductor to insure that wiring is intact and terminated at the proper place at both ends.

b. Verify wire connections are made in accordance with terminal wiring diagrams and schedules.

c. Using highlighter (transparent marker), indicate on terminal wiring diagram sheets that each wire and connection has been verified. These sheets will be made available to the buyer.

d. Replace defective wiring and retest.

e. Additional testing requirements are listed in V049-2-022 (Electrical and Instruments Construction Work).

PSI will supply LIGO with sufficient information for set up of the monitoring of the pressure gauges, the monitoring of the ion pumps, and control loops for the 80K cryopump level control valves.

ACCEPTANCE TEST: LEAKAGE ISOLATED SECTION

STATION:		
SECTION:		
BEFORE BAKE		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/s Helium equivalent
AFTER COOLDOWN		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
AFTER 100 HR PUMPDOWN		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
ACCEPTANCE:		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

INCLUDE ALL RAW DATA AND CALCULATION SHEETS

ACCEPTANCE TEST: PUMPDOWN ISOLATED SECTION, CORNER STATION

STATION:			
SECTION:		TIME	DATE
		24 hr clock hour : min	mm/dd/yy
ROUGHING 760 Torr to 0.1 Torr			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
PUMPDOWN from 0.1 Torr to < $5x10^{-6}$			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
80K CRYOPUMP			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
MAIN ION PUMPS			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	BEFORE BAKE / AFTER BAKE / 100 HR PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	ION CURRENT	Partial Pressure
	A	Torr
2		
4		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
24		
25		
26		
27		
28		
29		
30		
31		
32		

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	BEFORE BAKE / AFTER BAKE / 100 HR PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	ION CURRENT	Partial Pressure
	A	Torr
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
55		
57		
58		
59		
60		
78		
95		

RGA DATA / ULTIMATE PRESSURES

RESULTS OF THE RGA TEST	
RGA TEST :	100 HR PUMPDOWN, ULTIMATE PRESSURES
LOCATION OF RGA:	MAIN ION PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	Partial Pressure	ACCEPTANCE
	Torr	
H_2		
H_2O		
CO		
CO_2		
CH_4		
N_2		
Others		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

NOISE / VIBRATION MEASUREMENTS

RESULTS NOISE/VIBRATION	
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

	VIBRATION MEASUREMENTS	COMPLETED
1	a. Single -axis at on floor , 1m from one BSC, Corner Station without equipment operating b. Idim, with equipment operating c. Tri axis two locations on BSC	
2	a. Single -axis at on floor , 1m from one BSC, Corner Station without equipment operating b. Idim, with equipment operating c. Tri axis two locations on BSC	
3	Tri-axis measurements, BSC (WBSC2) during operation of 15 cm, 35cm, 122 cm gate valves	
4		
	NOISE MEASUREMENTS	
	Sound pressure levels measurments each chamber	

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

ELECTRICAL / INSTRUMENTS CHECK OUT & INTERFACE TO CDS

		COMPLETED
1	Wiring checkout	
2	Vacuum equipment instruments information for setup and scaling for control system.	
3		
4		
5		
6		
7		
8		
9		
10		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

Title: SPECIFICATION FOR SYSTEMS ACCEPTANCE TESTS PLAN , MID STATIONS

SYSTEMS ACCEPTANCE TEST PROCEDURE

LIGO VACUUM EQUIPMENT

MID STATIONS

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: Roberto Tran

QUALITY ASSURANCE: Alan L Budbrook

TECHNICAL DIRECTOR: D. O Mc Williams

PROJECT MANAGER: Ronald Bagby

1	BM 5/7/96	RES 5/7/96	Revised per DEO # 0178
0	R.T. 5/1/96	RES 5/2/96	INITIAL RELEASE PER DEO 0157 FOR RDS
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED DATE R.T. 5/1/96	Approved DATE RES 5/2/96	Number: V049-2-114 A	Rev. 1

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for systems acceptance testing of the vacuum envelope and vacuum pumping system in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.
This document will be part of the Acceptance Test Report as required by CDRL No.06.

2.0 GENERAL

2.1 The plan will apply to all the mid stations WA. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

Mid stations WA	One Section

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

Leak Check Procedure; Doc no:
Bakeout System Procedure; Doc no:
80K Cryopump Operating Procedure; Doc no:
Bakeout System Control Cart Operating Manual & Procedure; Doc no:
RGA Operating Manual
STPH2000C Turbomolecular Pump Operating Manuals
QDP80 Dry Backing Pump Operating Manuals
Vacuum Gauges: Cold Cathode & Pirani Gauges Operating Manuals
2500 L/s, 75L/s, 25 L/s Ion Pumps Operating Manuals

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST PROCEDURES

5.1.1 Chamber and Tube Section Leak Tests

The specification requires all component leaks greater than $1x10^{-9}$ torr-l/s of helium to be repaired in accordance with LIGO approved procedures. Leak checking shall conform to ASTM E498 "Standard Test Methods for Leaks using the Mass Spectrometer Leak Detector". (Ref. Specification V049-2-014, Leak Test Procedure). The following is a summary of the field leak testing plan.

5.1.1.1 Prerequisites

The individual vacuum enclosures have completed their manufacturing cycle and have been cleaned, baked, factory leak tested, sealed and evacuated for shipment. O-ring annulus volumes are back filled with pure nitrogen gas and valved off. The unit is then wrapped and packaged for shipment.

Upon arrival at the installation site, the unit will be visually inspected for any shipping damage or vacuum seal disturbance that may have occurred during transit.

The vacuum level in the chamber is then measured and compared to the pre- shipment levels. The measured vacuum level in the chamber will be corrected for expected o-ring permeation. The pressure level in the o-ring annulus will also be measured. If the measured pressure levels in the

chamber or annulus indicate that a leak has opened up during transit, the unit will be leak checked and repaired at or near the site.

5.1.1.2 Isolated Sections

Individual vacuum components are assembled into isolated sections which will be leaked checked as an independent volume. The procedures used to leak check the isolated sections are similar to the procedures used for individual components and in general follow the guidelines of ASTM E498.

Each isolated section has basically two types of vacuum volumes; the main chamber volume and the annulus volume between the dual o-ring seals. When leak checking the main chamber volume, it is important to prevent permeation of tracer gas(es) through the viton o-rings. To eliminate this potential source of high background readings, the o-ring flanges will be bagged and purged with pure nitrogen gas.

When leak checking an annulus volume, it is important to know the permeation rate of the tracer gas through the viton o-rings. The annulus volumes are small, and it is expected that significant leaks will present themselves quickly. Testing will be done on the BSC prototype to determine which tracer gas(es) is most effective in finding o-ring and annulus piping leaks. Helium, Argon, and Neon are candidate tracer gases.

Each isolated section will be leak checked by air signature method using an RGA. The maximum acceptable leak rate shall be consistent with the system requirements as determined by isolated volume size and RGA sensitivity, as mutually agreed upon by LIGO and PSI. Method and leak rate to be consistent with the BSC prototype chamber test results.

The Pumpdown and ultimate pressure tests is performed on the largest isolatable section with an 80K pump. The Mid stations have only one isolatable section. Before a pumpdown and ultimate pressure test is performed, the sections that make up the largest isolatable section must be baked.
In the case of the mid stations there are two 80K pumps.

5.2.1 Annuli pumpdown

The annuli on the flanges will have been pumped during installation for leak checking. Any remaining flange annuli at atmosphere will be pumped prior to start of bakeout.

5.2.2 Vacuum equipment

The main turbomolecular pumping system and main ion pump system will have been tested already. A functional test may be required prior to start of the bakeout to ensure proper operation of the equipment.
The main ion pumps will be evacuated and baked after installation onto the vacuum envelope. The main ion pumps will then started to ensure proper operation.

5.2.2.3 Residual gas analysis prior to bakeout.

Data will be taken prior to start of bakeout as a reference for checking outgassing rates / leaks after the bakeout.

5.2.2.4 System/Isolatable section bakeout.

The bakeout system will put on the isolatable section and baked out according to the bakeout procedures. Prior to the start of bakeout the the system will be evacuated using the roughing system.

The isolatable section will be heated to 150°C and soaked for 48 hours at 150°C±20°.

Cooldown of the system will be be carried out with the heating system operating to maintain temeperature uniformity. This is done by ramping down the setpoints to ambient temperature.

Execute bakeout for other sections as required.

5.2.2.5 Residual gas analysis after bakeout and cooldown

With the system baked and cooled down, a residual gas analysis will be carried out to determine the presence of any air leaks and cleanliness of the system.

5.2.2.6 Backfill with dry nitrogen

The system will be back filled with dry nitrogen (grade 0, to avoid hydrocarbon contamination) prior to vacuum pumpdown test.

5.2.2.7 Pumpdown of isolatable section with 80K cryopump

Mid station: There is only one isolatable section.

5.2.2.7.1 Pumpdown from atmosphere to 0.1 Torr using the roughing system

Mid stations:
The isolatable section will be pumped using the backing pump of the main turbo pump to a pressure of 0.2 Torr. Acceptance will be when the pressure of 0.2 Torr is reached in 15 hours and when the turbo pump can be turned on

5.2.2.7.2 Pumpdown from 0.1 Torr to 10^{-6} Torr using the main turbomolecular system

Mid stations: One pump main turbomolecular pump system is used to pump the isolatable section to a pressure of less than $5X10^{-6}$ Torr. The pumps will be started once a pressure of 0.2 Torr has been reached. Acceptance will be when the pressure of less than $5X10^{-6}$ Torr is reached in 24 hours.

5.2.2.7.3 80K cryopump

The cryopump will be turned on when a pressure of less than $5X10^{-6}$ Torr has been reached. To minimize cryotrapping of CO2, the cryopump should be cooled down as late as possible.

5.2.2.7.4 Main Ion pumps.

The main ion pumps will be turned on after the cryopump is cold and has been pumping for several hours. (between 24 hours to 30 hours into the pumpdown).

5.2.2.8 Ultimate Pressures after 100 hours.

The isolatable section shall attain a total pressure of $2X10^{-8}$ Torr, measured at the ion pumps after 100 hours of pumping. The partial pressure shall be measured with an RGA at an main ion pump pumpout port. If the hydrogen content of the steel steel prevents the attainment of this value, then the total pressure of the gasses, other than H_2 and H_2O shall not exceed $6X10^{-9}$ Torr.
The partial pressure goals of the following gasses shall be adjusted to reflect results that are consistent with the prototype chamber and design margins required for reliable implementation, but shall not be less than shown in the following table.

Table 5.2.2.8

Gas Species	Partial Pressure Goals Torr	Partial Pressure Acceptance Torr
H_2O	$5 X 10^{-9}$	
H_2	$5 X 10^{-9}$	
Total H_2O, H_2	**$1 X10^{-8}$**	
N_2	$5 X 10^{-10}$	
CO	$5 X 10^{-10}$	
CO_2	$2 X 10^{-10}$	
CH_4	$2 X 10^{-10}$	
All others	$5 X 10^{-10}$	
Total other	**$1.9 X10^{-9}$**	**$6X10^{-9}$**
Total	**$1.2 X10^{-8}$**	

Partial pressure of H_2O is expected to be higher at the ion pump because the ultimate pressure calculation is based on pressure of water at the cryopump. The partial pressure of water will be measured near the inlet of the cryopump.

5.3 Noise, Shock, and Vibration

During the commisioning process of the installations, measurements of vibration, shock, and noise generated by vacuum system equipment will be conducted. Meaurements are taken for data only, since there is no acceptance criteria.

Tri-axis vibration measurements will be made on one or End station BSC only. No vibration measurements will be made at the Mid stations.

5.4 Interface to the CDS

All CDS cabinets are supplied and installed by LIGO. PSI will terminate all VE instruments and other system interlocks as shown on PSI electrical drawings. CDS cabinet locations are shown on the following drawings:

V049-3-123 (4 sheets)

V049-3-108 (2 sheets)

V049-3-308 (2 sheets)

V049-3-408 (1 sheets)

V049-3-508 (1 sheets)

Acceptance test for instrument loops and other wiring installed by PSI and terminated in the CDS's, will be performed as follows:

a. Check point to point continuity of each conductor to insure that wiring is intact and terminated at the proper place at both ends.

b. Verify wire connections are made in accordance with terminal wiring diagrams and schedules.

c. Using highlighter (transparent marker), indicate on terminal wiring diagram sheets that each wire and connection has been verified. These sheets will be made available to the buyer.

d. Replace defective wiring and retest.

e. Additional testing requirements are listed in V049-2-022 (Electrical and Instruments Construction Work). PSI will supply LIGO with sufficient information for set up of the monitoring of the pressure gauges, the monitoring of the ion pumps, and control loops for the 80K cryopump level control valves.

ACCEPTANCE TEST: LEAKAGE ISOLATED SECTION

STATION:		
SECTION:		
BEFORE BAKE		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
AFTER COOLDOWN		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
AFTER 100 HR PUMPDOWN		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
ACCEPTANCE		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

ACCEPTANCE TEST: PUMPDOWN ISOLATED SECTION, MID STATION

STATION: MID			
SECTION:		TIME	DATE
		24 hr clock hour : min	mm/dd/yy
ROUGHING 760 Torr to 0.2 Torr			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
PUMPDOWN from 0.2 Torr to < $5x10^{-6}$			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
80K CRYOPUMP			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
MAIN ION PUMPS			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	BEFORE BAKE / AFTER BAKE / 100 HR PUMP
DATE:	
TIME:	
TESTI.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	ION CURRENT	Partial Pressure
	A	Torr
2		
4		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
24		
25		
26		
27		
28		
29		
30		
31		
32		

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	BEFORE BAKE / AFTER BAKE / 100 HR PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	ION CURRENT	Partial Pressure
	A	Torr
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
55		
57		
58		
59		
60		
78		
95		

RGA DATA / ULTIMATE PRESSURES

RESULTS OF THE RGA TEST	
RGA TEST :	100 HR PUMPDOWN, ULTIMATE PRESSURES
LOCATION OF RGA:	MAIN ION PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	Partial Pressure	ACCEPTANCE
	Torr	
H_2		
H_2O		
CO		
CO_2		
CH_4		
N_2		
Others		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

NOISE / VIBRATION MEASUREMENTS

RESULTS NOISE/VIBRATION	
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

	VIBRATION MEASUREMENTS	COMPLETED
1	Tri-axis measurements, BSC (WBSC?) during operation of 122 cm gate valves At one End or Mid station only	
	NOISE MEASUREMENTS	
	Sound pressure levels measurments each chamber	

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

ELECTRICAL / INSTRUMENTS CHECK OUT & INTERFACE TO CDS

		COMPLETED
1	Wiring checkout	
2	Vacuum equipment instruments information for setup and scaling for control system.	
3		
4		
5		
6		
7		
8		
9		
10		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

Equipment summary

Mid Stations

	Component	Quantity
Vacuum Envelope	BSC	1
	Interconnecting Spools	various
	Short 80K Pump Chamber	2
Vacuum Pumps	Main Ion Pump	1
	Main Turbo Pumpcart	1
	Aux Turbo Cart	1
	Annulus Pumps	5
Cryopumps	Short 80K Pump	2
	LN2 Dewar	2
Valves	44" Gate Valves	4
	14" Gate Valves	1
	10" Gate Valves	3
Clean Air System	Clean Air Compressor System 50 CFM	1
	Back to Air Valve Sytems	1
	Back to Air Portable Controller Box	1
Bakeout System	Blankets	From Corner station
	Control Cart	"
Vacuum Gauging	Cold Cathode / Pirani Gauge Pair	3

Title: SPECIFICATION FOR SYSTEM ACCEPTANCE TESTS PLAN, END STATIONS

SYSTEMS ACCEPTANCE TEST PROCEDURE

LIGO VACUUM EQUIPMENT

END STATIONS

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: Roberto Thau

QUALITY ASSURANCE: Alan L'Bradbrook

TECHNICAL DIRECTOR: D.A. Mc Williams

PROJECT MANAGER: Bill Bayless

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	~~D.W.~~ 5/7/96	R.E.B. 5/7/96	Revised per DEC #0178
0	R.T. 5/1/96	R.E.B. 5/2/96	INITIAL RELEASE PER DEC 0157 FOR PDR

PROCESS SYSTEMS INTERNATIONAL, INC. | **SPECIFICATION**

INITIAL APPROVALS	PREPARED DATE	Approved DATE	Number: V049-2-115	Rev.
	R.T. 5/1/96	R.E.B. 5/2/96	A	

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for systems acceptance testing of the vacuum envelope and vacuum pumping system in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The plan will general apply to all the End stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

End stations WA	One Section
End stations LA	One Section

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

Leak Check Procedure; Doc no:
Bakeout System Procedure; Doc no:
80K Cryopump Operating Procedure; Doc no:
Bakeout System Control Cart Operating Manual & Procedure; Doc no:
RGA Operating Manual
EDP200/EH2600 Roughing pumps Operating Manuals
STPH2000C Turbomolecular Pump Operating Manuals
QDP80 Dry Backing Pump Operating Manuals
Vacuum Gauges: Cold Cathode & Pirani Gauges Operating Manuals
2500 L/s, 75L/s, 25 L/s Ion Pumps Operating Manuals

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST PROCEDURES

5.1.1 Chamber and Tube Section Leak Tests

The specification requires all component leaks greater than $1x10^{-9}$ torr-l/s of helium to be repaired in accordance with LIGO approved procedures. Leak checking shall conform to ASTM E498 "Standard Test Methods for Leaks using the Mass Spectrometer Leak Detector". (Ref. Specification V049-2-014, Leak Test Procedure). The following is a summary of the field leak testing plan.

5.1.1.1 Prerequisites

The individual vacuum enclosures have completed their manufacturing cycle and have been cleaned, baked, factory leak tested, sealed and evacuated for shipment. O-ring annulus volumes are back filled with pure nitrogen gas and valved off. The unit is then wrapped and packaged for shipment.

Upon arrival at the installation site, the unit will be visually inspected for any shipping damage or vacuum seal disturbance that may have occurred during transit.

The vacuum level in the chamber is then measured and compared to the pre- shipment levels. The measured vacuum level in the chamber will be corrected for expected o-ring permeation. The pressure level in the o-ring annulus will also be measured. If the measured pressure levels in the chamber or annulus indicate that a leak has opened up during transit, the unit will be leak checked and repaired at or near the site.

5.1.1.2 Isolated Sections

Individual vacuum components are assembled into isolated sections which will be leaked checked as an independent volume. The procedures used to leak check the isolated sections are similar to the procedures used for individual components and in general follow the guidelines of ASTM E498.

Each isolated section has basically two types of vacuum volumes; the main chamber volume and the annulus volume between the dual o-ring seals. When leak checking the main chamber volume, it is important to prevent permeation of tracer gas(es) through the viton o-rings. To eliminate this potential source of high background readings, the o-ring flanges will be bagged and purged with pure nitrogen gas.

When leak checking an annulus volume, it is important to know the permeation rate of the tracer gas through the viton o-rings. The annulus volumes are small, and it is expected that significant leaks will present themselves quickly. Testing will be done on the BSC prototype to determine which tracer gas(es) is most effective in finding o-ring and annulus piping leaks. Helium, Argon, and Neon are candidate tracer gases.

Each isolated section will be leak checked by air signature method using an RGA. The maximum acceptable leak rate shall be consistent with the system requirements as determined by isolated volume size and RGA sensitivity, as mutually agreed upon by LIGO and PSI. Method and leak rate to be consistent with the BSC prototype chamber test results.

The Pumpdown and ultimate pressure tests is performed on the largest isolatable section with an 80K pump. The End stations have only one isolatable section. Before a pumpdown and ultimate pressure test is performed, the sections that make up the largest isolatable section must be baked.

5.2.1 Annuli pumpdown

The annuli on the flanges will have been pumped during installation for leak checking. Any remaining flange annuli at atmosphere will be pumped prior to start of bakeout.

5.2.2 Vacuum equipment

The main turbomolecular pumping system and main ion pump system will have been tested already. A functional test may be required prior to start of the bakeout to ensure proper operation of the equipment.
The main ion pumps will be evacuated and baked after installation onto the vacuum envelope. The main ion pumps will then started to ensure proper operation.

5.2.2.3 Residual gas analysis prior to bakeout.

Data will be taken prior to start of bakeout as a reference for checking outgassing rates / leaks after the bakeout.

5.2.2.4 System/Isolatable section bakeout.

The bakeout system will put on the isolatable section and baked out according to the bakeout procedures. Prior to the start of bakeout the the system will be evacuated using the roughing system.

The isolatable section will be heated to 150°C and soaked for 48 hours at 150°C±20°.

Cooldown of the system will be be carried out with the heating system operating to maintain temeperature uniformity. This is done by ramping down the setpoints to ambient temperature.

Execute bakeout for other sections as required.

5.2.2.5 Residual gas analysis after bakeout and cooldown

With the system baked and cooled down, a residual gas analysis will be carried out to determine the presence of any air leaks and cleanliness of the system.

5.2.2.6 Backfill with dry nitrogen

The system will be back filled with dry nitrogen (grade 0, to avoid hydrocarbon contamination) prior to vacuum pumpdown test.

5.2.2.7 Pumpdown of isolatable section with 80K cryopump

End station: There is only one isolatable section.

5.2.2.7.1 Pumpdown from atmosphere to 0.1 Torr using the roughing system

End stations:
The isolatable section will be pumped using the backing pump of the main turbo pump to a pressure of 0.2 Torr. Acceptance will be when the pressure of 0.2 Torr is reached in 15 hours and when the turbo pump can be turned on

5.2.2.7.2 Pumpdown from 0.1 Torr to 10^{-6} Torr using the main turbomolecular system

End stations: One pump main turbomolecular pump system is used to pump the isolatable section to a pressure of less than $5X10^{-6}$ Torr. The pumps will be started once a pressure of 0.2 Torr has been reached. Acceptance will be when the pressure of less than $5X10^{-6}$ Torr is reached in 24 hours.

5.2.2.7.3 80K cryopump

The cryopump will be turned on when a pressure of less than $5X10^{-6}$ Torr has been reached. To minimize cryotrapping of CO2, the cryopump should be cooled down as late as possible.

5.2.2.7.4 Main Ion pumps.

The main ion pumps will be turned on after the cryopump is cold and has been pumping for several hours. (between 24 hours to 30 hours into the pumpdown).

5.2.2.8 Ultimate Pressures after 100 hours.

The isolatable section shall attain a total pressure of $2X10^{-8}$ Torr, measured at the ion pumps after 100 hours of pumping. The partial pressure shall be measured with an RGA at an main ion pump pumpout port. If the hydrogen content of the steel steel prevents the attainment of this value, then the total pressure of the gasses, other than H_2 and H_2O shall not exceed $6X10^{-9}$ Torr.
The partial pressure goals of the following gasses shall be adjusted to reflect results that are consistent with the prototype chamber and design margins required for reliable implementation, but shall not be less than shown in the following table.

Table 5.2.2.8

Gas Species	Partial Pressure Goals Torr	Partial Pressure Acceptance Torr
H_2O	$5 X 10^{-9}$	
H_2	$5 X 10^{-9}$	
Total H_2O, H_2	**$1 X10^{-8}$**	
N_2	$5 X 10^{-10}$	
CO	$5 X 10^{-10}$	
CO_2	$2 X 10^{-10}$	
CH_4	$2 X 10^{-10}$	
All others	$5 X 10^{-10}$	
Total other	**$1.9 X10^{-9}$**	**$6X10^{-9}$**
Total	**$1.2 X10^{-8}$**	

Partial pressure of H_2O is expected to be higher at the ion pump because the ultimate pressure calculation is based on pressure of water at the cryopump. The partial pressure of water will be measured near the inlet of the cryopump.

5.3 Noise, Shock, and Vibration

During the commisioning process of the installations, measurements of vibration, shock, and noise generated by vacuum system equipment will be conducted. Meaurements are taken for data only, since there is no acceptance criteria.
Tri-axis vibration measurements will be made on one End station BSC. Single axis measurements will be made at one location on the floor within 1 meter of the chamber. Measurements will be made with and without operating auxiliary equipment for the purpose of establishing ambient levels.
Shock measurements will be made on representative chambers during the operation of the gate valves. Tri-axis shock measurements will be made on one End station BSC during operation of a nearby pneumatically operated 112 cm gate valve.
Acoustical testing will consist of sound pressure levels in the vicinity of each chamber with all vacuum system components in normal operation.

All CDS cabinets are supplied and installed by LIGO. PSI will terminate all VE instruments and other system interlocks as shown on PSI electrical drawings. CDS cabinet locations are shown on the following drawings:

V049-3-123 (4 sheets)

V049-3-108 (2 sheets)

V049-3-308 (2 sheets)

V049-3-408 (1 sheets)

V049-3-508 (1 sheets)

Acceptance test for instrument loops and other wiring installed by PSI and terminated in the CDS's, will be performed as follows:

a. Check point to point continuity of each conductor to insure that wiring is intact and terminated at the proper place at both ends.
b. Verify wire connections are made in accordance with terminal wiring diagrams and schedules.
c. Using highlighter (transparent marker), indicate on terminal wiring diagram sheets that each wire and connection has been verified. These sheets will be made available to the buyer.
d. Replace defective wiring and retest.

e. Additional testing requirements are listed in V049-2-022 (Electrical and Instruments Construction Work).

PSI will supply LIGO with sufficient information for set up of the monitoring of the pressure gauges, the monitoring of the ion pumps, and control loops for the 80K cryopump level control valves.

ACCEPTANCE TEST: LEAKAGE ISOLATED SECTION

STATION:		
SECTION:		
BEFORE BAKE		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
AFTER COOLDOWN		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
AFTER 100 HR PUMPDOWN		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
ACCEPTANCE		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

ACCEPTANCE TEST: PUMPDOWN ISOLATED SECTION, END STATION

STATION: END			
SECTION:		TIME	DATE
		24 hr clock hour : min	mm/dd/yy
ROUGHING 760 Torr to 0.2 Torr			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
PUMPDOWN from 0.2 Torr to < $5x10^{-6}$			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
80K CRYOPUMP			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
MAIN ION PUMPS			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	BEFORE BAKE / AFTER BAKE / 100 HR PUMP
DATE:	
TIME:	
TESTI.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	ION CURRENT	Partial Pressure
	A	Torr
2		
4		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
24		
25		
26		
27		
28		
29		
30		
31		
32		

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	BEFORE BAKE / AFTER BAKE / 100 HR PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	ION CURRENT	Partial Pressure
	A	Torr
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
55		
57		
58		
59		
60		
78		
95		

RGA DATA / ULTIMATE PRESSURES

RESULTS OF THE RGA TEST	
RGA TEST :	100 HR PUMPDOWN, ULTIMATE PRESSURES
LOCATION OF RGA:	MAIN ION PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	Partial Pressure	ACCEPTANCE
	Torr	
H_2		
H_2O		
CO		
CO_2		
CH_4		
N_2		
Others		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		