

**LIGO VACUUM EQUIPMENT  
FINAL DESIGN REPORT  
VOLUME IV  
INSTALLATION/COMMISSIONING**

L150-C960967-01-V

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<b>PSI DOCUMENT NO:</b>	<b>V049-1-100</b>
<b>PROGRAM I.D.</b>	<b>LIGO VACUUM EQUIPMENT</b>
<b>CDRL NO:</b>	<b>03</b>
<b>APPROVAL STATUS:</b>	<b>A</b>

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**LIGO PROJECT**

**FINAL DESIGN REPORT**  
**VOLUME IV**  
**INSTALLATION/COMMISSIONING**

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FINAL DESIGN REPORT  
CDRL 03  
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## **FDR VOLUME IV**

### ***ATTACHMENTS***

	<b><i>DOCUMENT NO.</i></b>	<b><i>REVISION</i></b>
<b>I. Procedures and Spec.</b>		
Anchor Bolt Installation Procedure	V049-1-101	0
Leak Check Procedure	V049-2-014	1
Installation/Commissioning Spec.	V049-2-021	1
Electrical and Instrument Construction Spec.	V049-2-022	1
Project Safety Plan	V049-2-023	1
Project Q.A. Plan	V049-2-029	1
Piping Design and Material Specification	V049-2-037	4
Welding Procedures	V049-2-070	0
	V049-2-071	2
	V049-2-072	2
	V049-2-073	0
Material/Welding Repair Procedure	V049-2-074	0
Isolatable Section Bakeout Procedure	V049-2-116	0
Clean Room Activities	V049-2-118	0
Contamination Control Plan	V049-2-119	1
Raw Material Handling Procedure	V049-2-120	0
Control of Non-Conformance	V049-2-124	0
Visual Inspection Procedure	V049-2-128	1
Black Light Test Procedure	V049-2-130	0
Site Piping Cleaning Procedure	V049-2-131	1
Site Vacuum Surface Re-Cleaning Procedure	V049-2-132	0
RGA Calibration	V049-2-137	0
Structural Carbon Steel Fabrication and Painting	V049-2-139	1
Thermal Insulation - Piping	V049-2-163	0
Conflat Flange Assembly Procedure	V049-2-168	0
O-Ring Installation and Flange Assembly Procedure	V049-2-169	0
Component Alignment Procedure	V049-2-174	0
Vacuum Pump Field Installation Procedure	V049-2-175	0

Note: (later) = This specification is being revised and will be updated at a later date.

## **FDR VOLUME IV**

### ***ATTACHMENTS***

	<b><i>DOCUMENT NO.</i></b>	<b><i>REVISION</i></b>
<b>II. Component Acceptance Tests Procedures</b>		
80K Pumps	V049-2-102	0
Roughing Pumps	V049-2-104	0
Turbomolecular Pumps	V049-2-105	0
Ion Pumps	V049-2-106	0
Large Gate Valves	V049-2-107	0
6, 10, 14" Gate Valves	V049-2-108	0
Clean Air Supplies	V049-2-109	0
Portable Soft Wall Cleanrooms	V049-2-110	0
Small Valves	V049-2-111	0
Bakeout System Blankets and Carts	V049-2-112	0
<b>III. System Acceptance Test Procedures</b>		
Corner Stations	V049-2-113	2 (later)
Mid Stations	V049-2-114	2 (later)
End Stations	V049-2-115	2 (later)



## 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 the attachments to 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 Equipment and System 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. The program will be executed using a group of home office Q.A. and engineering staff members. Training sessions and Q.A. audits will be used as part of the program.

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

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

Training and qualifications will be performed by PSI personnel. Formal class agendas and training material will be prepared and supplied by PSI.

### 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**

See The Monthly Vacuum Equipment Status Report (CDRL No. 09) For An Updated Schedule

## 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).

System turnover will be a topic at the installation readiness review meeting. System turnover documentation and PSI's system for organizing and controlling it will be presented and discussed.

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). Safety factors for weight and center of gravity will be factored into the design of the dolly system.

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.

Personnel will be trained in the use and safety considerations of the dolly system.





### **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.

The installation of major components will be controlled via a component installation instruction. This instruction will give specific instructions and process and safety considerations.

Each major component installation will be independently verified and signed off before proceeding to the next step of 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<sub>2</sub> 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<sub>2</sub> Supply Systems**

Install Right Mid Station LN<sub>2</sub> tanks, GN<sub>2</sub> equipment and LN<sub>2</sub> vaporizers.

Install VJ piping to WCP5 and WCP6.

Confirm the Right Mid Station oxygen monitoring system operational.

Commission LN<sub>2</sub> 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<sub>2</sub> Supply Systems**

Install Left Mid Station LN<sub>2</sub> tanks, GN<sub>2</sub> equipment and LN<sub>2</sub> vaporizers.

Install VJ piping to WCP3 and WCP4.

Confirm the Left Mid Station oxygen monitoring system operational.

Commission LN<sub>2</sub> 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<sub>2</sub> Supply System**

Install Right End Station LN<sub>2</sub> tank, GN<sub>2</sub> equipment and LN<sub>2</sub> vaporizer.

Install VJ piping to WCP8.

Confirm the Right End Station Oxygen monitoring system operational.

Commission LN<sub>2</sub> 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<sub>2</sub> Supply System**

Install Left End Station LN<sub>2</sub> tank, GN<sub>2</sub> equipment and LN<sub>2</sub> vaporizer.

Install VJ piping to WCP7.

Confirm the Left End Station oxygen monitoring system operational.

Commission LN<sub>2</sub> 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 Alignment**

All vessels and components will be aligned in accordance with Alignment Procedure V049-2-174.

### **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 hazards to personnel and equipment. PSI personnel will execute the commissioning program with labor support from the site contractor. All commissioning personnel will be trained in safety and execution of commissioning procedures.

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 isolatable 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. Special shipping precaution will be utilized to ensure that all components arrive safely at the site with all of the proper documentation.

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  $1 \times 10^{-9}$  torr - l/s of helium) prior to arriving at the site. These tests will not be repeated during site acceptance testing. 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, and sealed for shipment. 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 that may have occurred during transit.

#### **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  $1 \times 10^{-6}$  torr to  $1 \times 10^{-3}$  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 N<sub>2</sub> at an inlet pressure =  $1 \times 10^{-3}$  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  $1 \times 10^{-6}$  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 N<sub>2</sub> at an inlet pressure =  $1 \times 10^{-3}$  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 pair will be individually tested. A helium mass spectrometer leak detector with calibrated leak will be used in performing the leak testing. Partial pressures of hydrocarbons will be measured with an RGA, and outgassing rates greater than  $4 \times 10^{-8}$  Torr-l/s for any species will be cause for rejection. Body and flange leakage will be measured to be less than  $10^{-9}$  torr-l/s 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 helium mass spectrometer leak detector 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  $10^{-9}$  torr liter/sec of helium before shipment. Gate seal leakage will be shown to be less than  $1 \times 10^{-9}$  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  $1 \times 10^{-9}$  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  $1 \times 10^{-9}$  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 Ultimate Pressure and Pumpdown Time**

The proposed acceptance test will be to measure the pressure after the bakeout when the isolatable volume has reached room temperature, and prior to a backfill. This test will determine if the volume is clean and leak tight, removes any ambiguity created by the backfilling process.

In addition to measuring the pressure after bakeout the volume will be backfilled with dry air and purged for 24 hours. The volume will then be repumped for 100 hours to establish a baseline pressure. There is no acceptance criteria for this test, and it will be performed only on the largest isolatable volume in each station.

The pumpdown and ultimate pressure tests are 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 an 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 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 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 Ultimate Pressures after Bakeout.**

The isolatable section shall attain a total pressure of  $2 \times 10^{-8}$  torr or less ( $N_2$  equivalent), measured with a calibrated Granville-Phillips "stabil" ion gauge at a BSC RGA port after bakeout and cooldown to ambient temperature. The partial pressure shall be measured with an RGA at a BSC RGA port. If the hydrogen content of the steel prevents the attainment of this value, then the total pressure of the gases, other than  $H_2$  and  $H_2O$  shall not exceed  $3 \times 10^{-9}$  torr. Only the main ion pumps and 80K cryopumps are permitted during this test.

Table 5.2.2.5 shows the LIGO specification partial pressure goals and the corresponding proposed partial pressure acceptance criteria that are consistent with the prototype chamber test results, and design margins required for reliable implementation.

**Table 5.2.2.5**

<b>Gas Species</b>	<b>LIGO Partial Pressure Goals Torr</b>	<b>Predicted Partial Pressures Torr</b>	<b>Acceptance Partial Pressures Torr</b>
H <sub>2</sub>	5x10 <sup>-9</sup>	5x10 <sup>-9</sup>	
H <sub>2</sub> O	5x10 <sup>-9</sup>	1x10 <sup>-9</sup>	
Total H <sub>2</sub> O, H <sub>2</sub>	1x10 <sup>-8</sup>	6x10 <sup>-9</sup>	
N <sub>2</sub>	5x10 <sup>-10</sup>	-	
CO	5x10 <sup>-10</sup>	-	
Total N <sub>2</sub> , CO		1x10 <sup>-9</sup>	
CO <sub>2</sub>	2x10 <sup>-10</sup>	2x10 <sup>-10</sup>	
CH <sub>4</sub>	2x10 <sup>-10</sup>	5x10 <sup>-10</sup>	
All others	5x10 <sup>-10</sup>	5x10 <sup>-10</sup>	
Total other	1.9x10 <sup>-9</sup>	2.2x10 <sup>-9</sup>	3x10 <sup>-9</sup>
Total	1.19x10 <sup>-8</sup>	8.2x10 <sup>-9</sup>	2x10 <sup>-8</sup> *

\* Exclusion for H<sub>2</sub>

**5.2.2.6 Backfill, Dry Air Purge, and 100 Hour Pumpdown**

The system will be back filled with dry air from the Class 100 air system and purged for 24 hours prior to vacuum pumpdown test. This test will be done only on the largest isolatable volume in each station, and be for information only.

### 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.

#### 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  $5 \times 10^{-6}$  torr.

##### End/ Mid Stations:

One main turbomolecular pump system is used to pump the isolatable section to a pressure of less than  $5 \times 10^{-6}$  torr. The pumps will be started once a pressure of 0.2 torr has been reached.

#### 5.2.2.7.3 80K Cryopump

The cryopump will be turned on when a pressure of less than  $5 \times 10^{-6}$  torr has been reached. To minimize cryotrapping of  $\text{CO}_2$ , 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).

### 5.2.3 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**

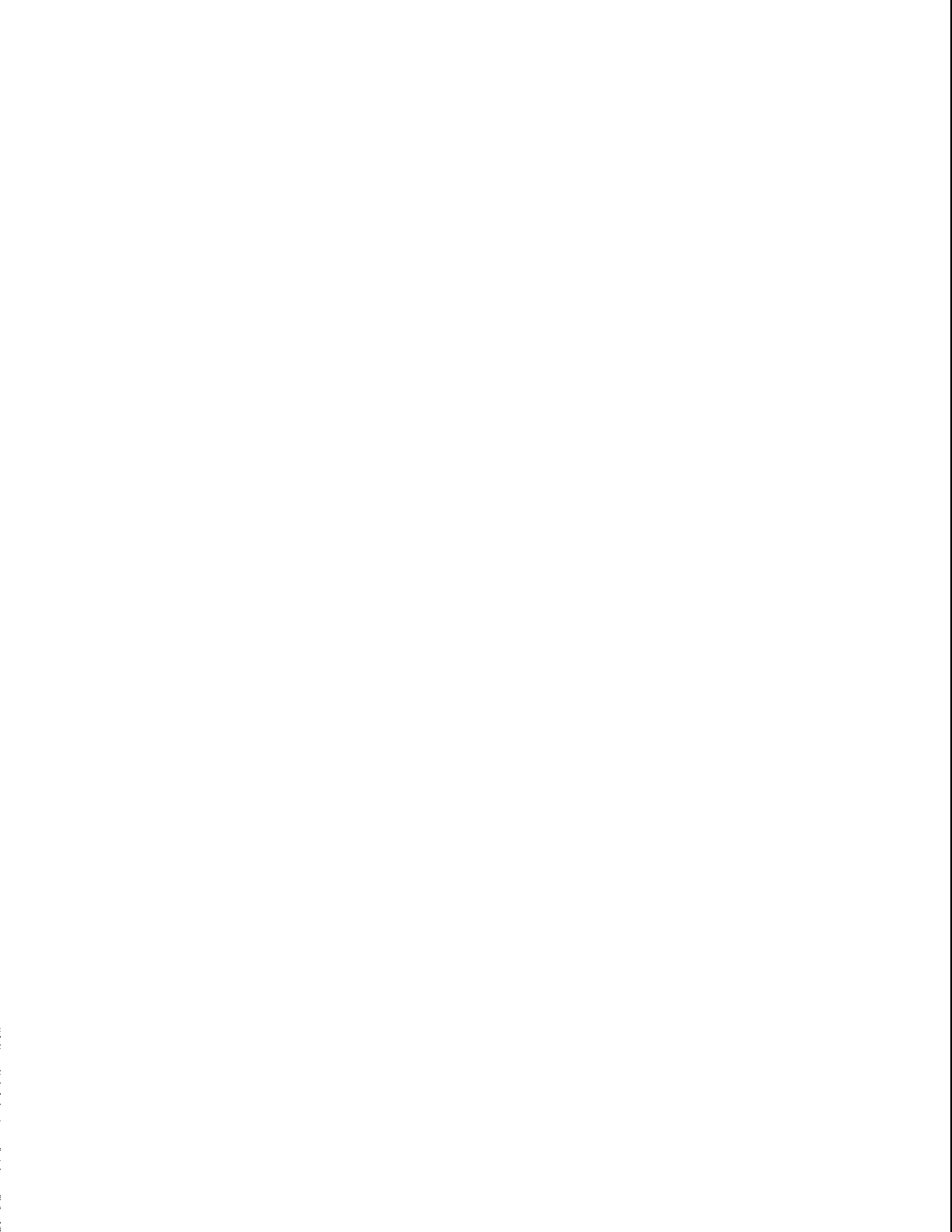
Cambridge Acoustical Associates has done some acoustical modeling of the interferometer end station for preliminary predictions of compliance with the LIGO specification with respect to noise (NC-20 at any location within the vacuum equipment and laser areas). This preliminary analysis predicts exceedence 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

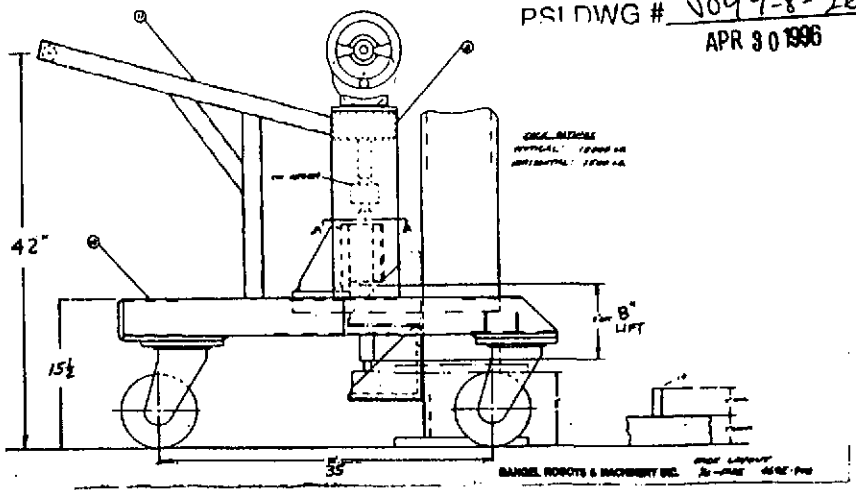
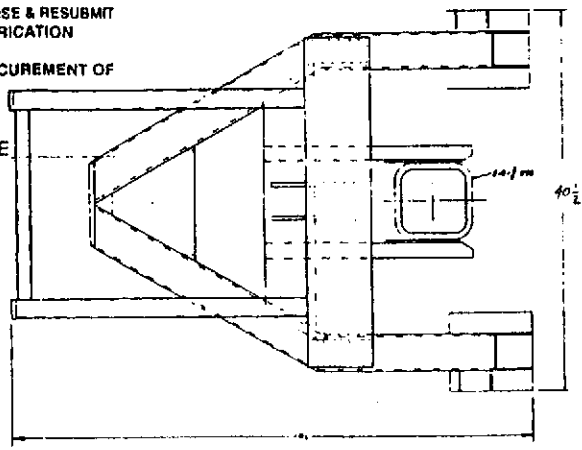
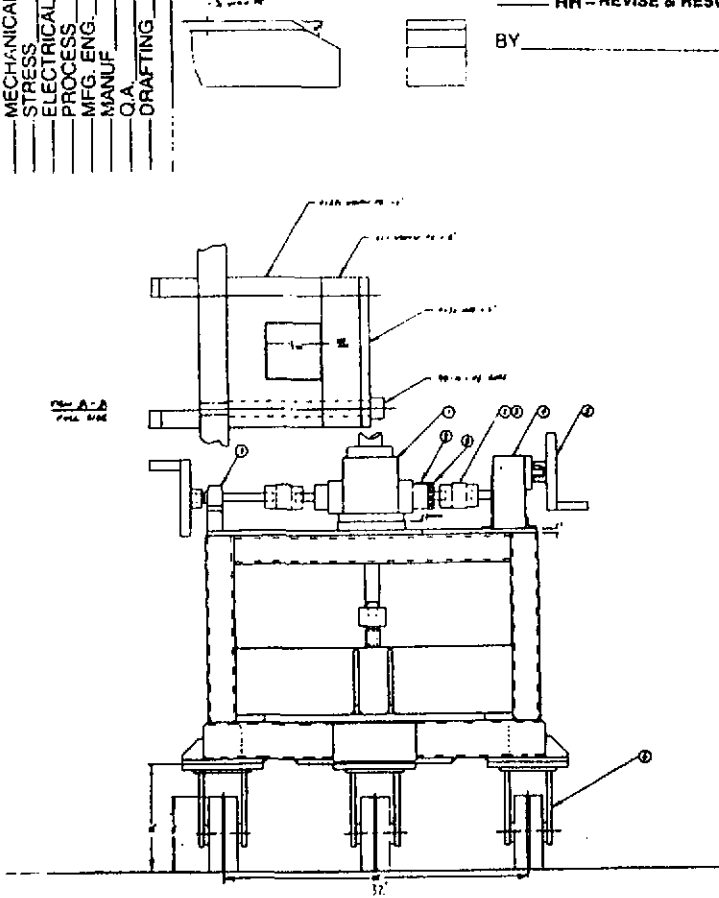
PROJECT NAME	
PSI DOC NO	
CHK	BY / DATE
PROJECT ENG	
MECHANICAL	
STRESS	
ELECTRICAL	
PROCESS	
MFG. ENG.	
MANUF.	
Q.A.	
DRAFTING	

PROCESS SYSTEMS INTERNAT 4L  
DOCUMENT APPROVAL CHECK  
PROJECT NAME: LTD  
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 \_\_\_\_\_



PSI DWG # 4049-8-260  
APR 30 1996

VENDOR NAME	<u>Bangal Robots</u>
REVISION NO.	<u>1st</u>
SUBMITTAL NO.	<u>1st</u>
STATUS	<u>Review &amp; Approval</u>



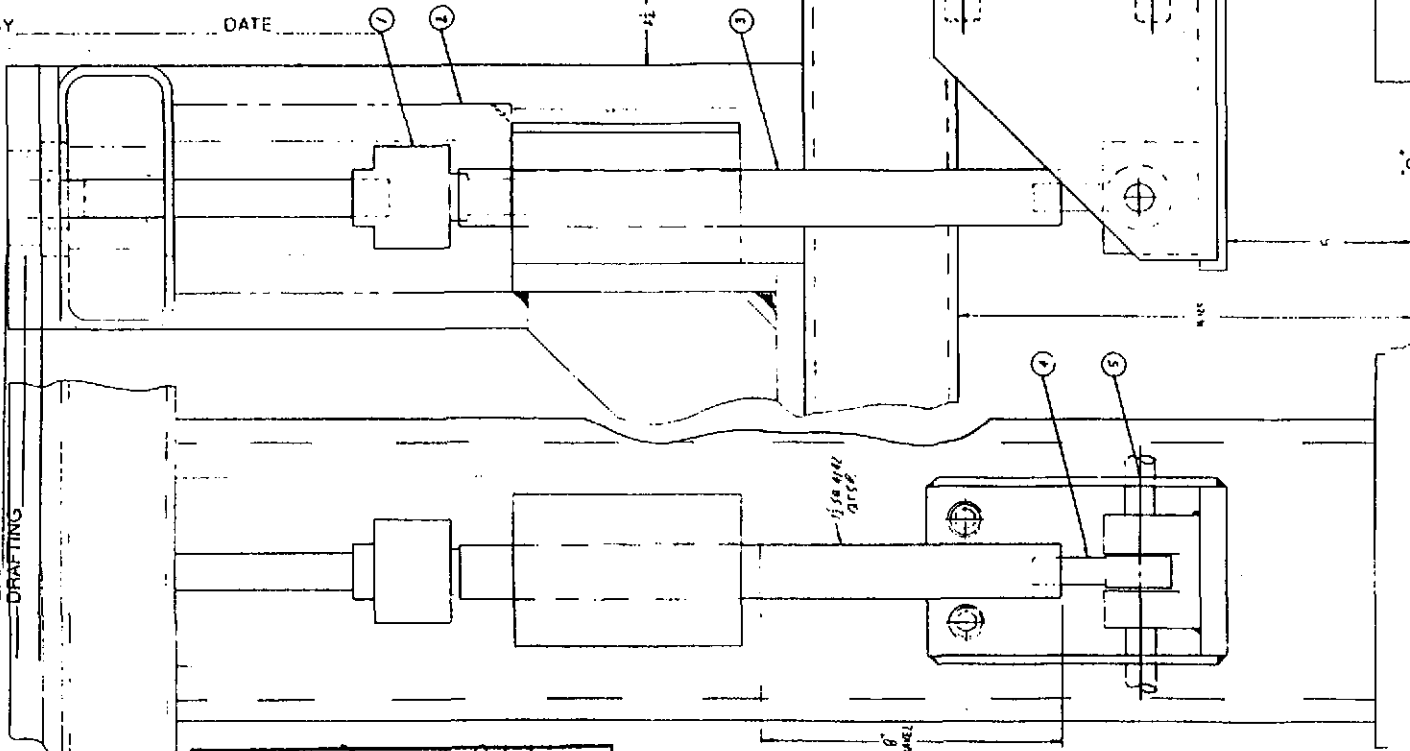
**ACCESS SYSTEMS INTERNATIONAL  
DOCUMENT APPROVAL CHECKLIST**

PROJECT NAME LIGO  
PSI DOC. NO. \_\_\_\_\_

NOTE THIS REVIEW DOES NOT RELIEVE THE SELLER OR CONTRACTOR OF ANY OBLIGATIONS UNDER THE PO OR CONTRACT

- \_\_\_ FA = FINAL APPROVAL
- \_\_\_ AS = APP'D AS NOTED - REVISE & RESUBMIT
- \_\_\_ AF = APPROVED FOR FABRICATION
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- \_\_\_ RR = REVISE & RESUBMIT

BY \_\_\_\_\_ DATE \_\_\_\_\_



PROJECT NAME: \_\_\_\_\_  
PSI DOC. NO. \_\_\_\_\_

CHK \_\_\_\_\_ BY / DATE \_\_\_\_\_

- PROJECT ENG \_\_\_\_\_
- MECHANICAL \_\_\_\_\_
- STRESS \_\_\_\_\_
- ELECTRICAL \_\_\_\_\_
- PROCESS \_\_\_\_\_
- MFG. ENG. \_\_\_\_\_
- MANUF \_\_\_\_\_
- O.A. \_\_\_\_\_
- DRAFTING \_\_\_\_\_

VENDOR NAME: Dangel Robots  
 REVISION NO: \_\_\_\_\_  
 SUBMITTAL NO: 1st  
 STATUS: Review & Approval

PSI DWG # 1049-8-261  
APR 30 1995

DANGEL ROBOTS & MACHINERY INC.		
DATE: <u>11</u>	APPROVED BY: _____	DRAWN BY: <u>D. JAMES</u>
LIGO PROJECT		
BSC LIFTING LAYOUT		DRAWING NUMBER: <u>469C-909</u>

### **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 from component to component, the beam tube centerline can be accurately aligned to the vessel nozzle.

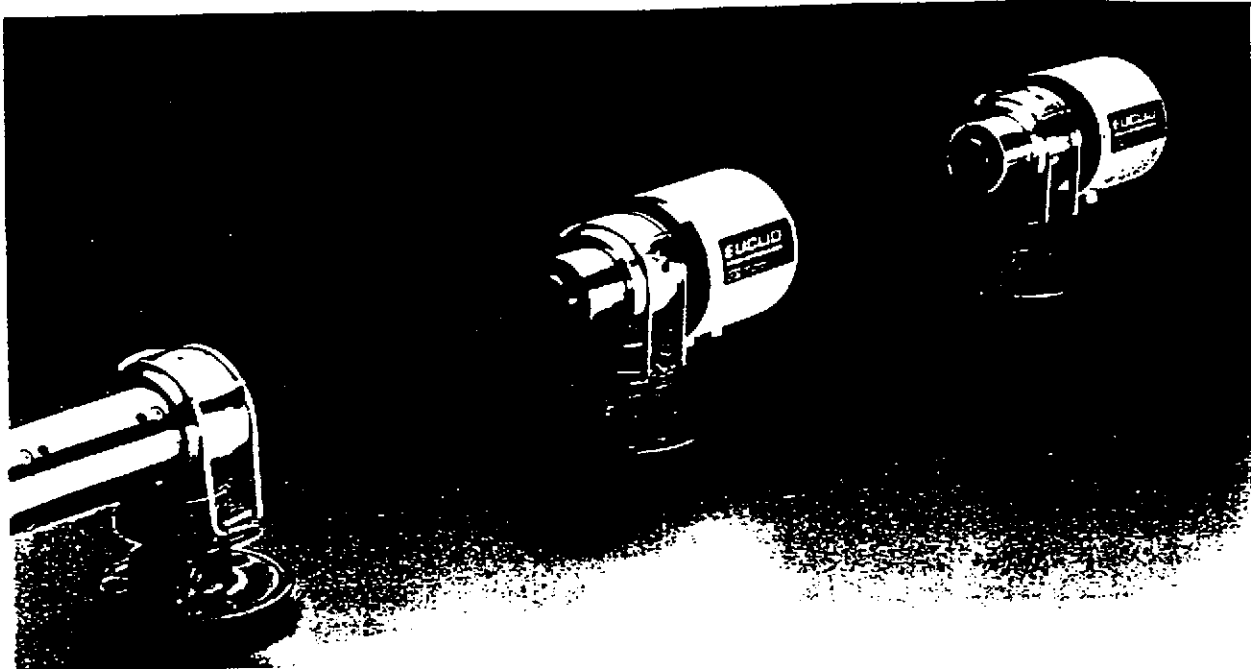
### **7.4 Optical Alignment Systems**

Optical alignment procedures are also being considered for the final component alignment. A final selection will be made after field contractor selection.

# **EUCLID™**

**Intelligent Laser Alignment System**

Model 300



## **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 de-

lays 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.

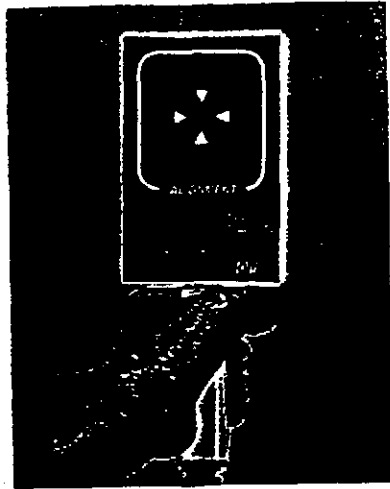
**QI** QUEST  
INTEGRATED, INC.

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### 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

### Industry Applications

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

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.

### System Specifications

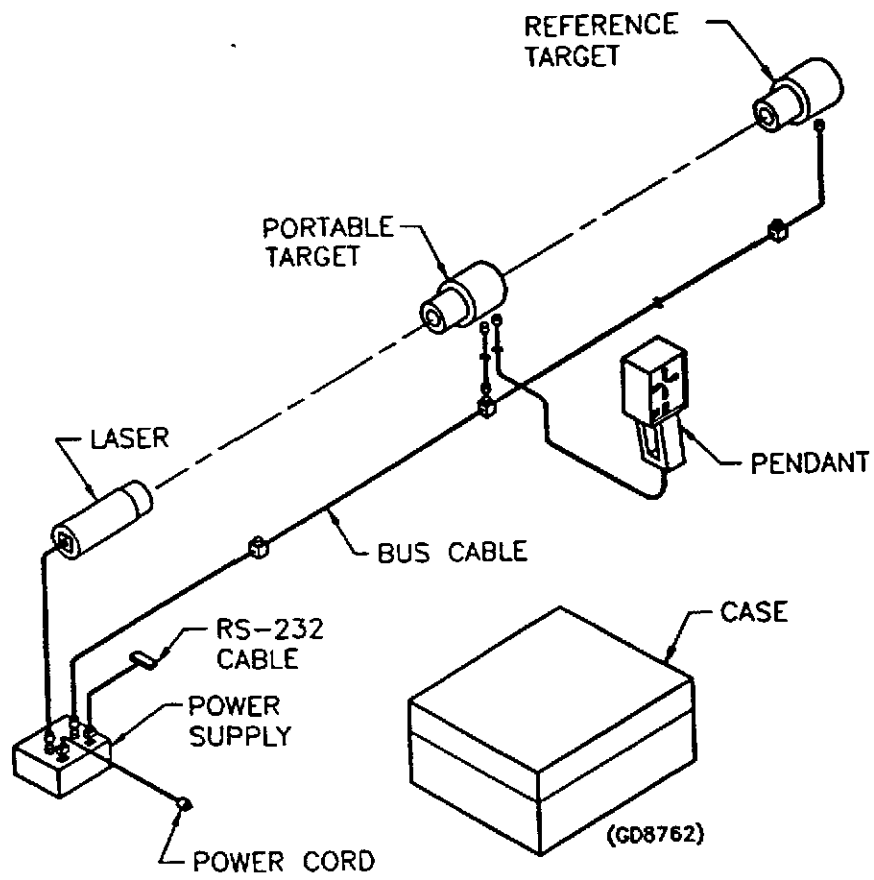
Laser:	Class IIA (<1 mW, visible red)
Operational Range:	up to 150 feet (standard)
Temperature Range:	0 to 40°C
Resolution:	0.0001 inch
System Accuracy:	± 0.003 inch
Target Active Area:	0.2 inch (radius from center)
Target Accuracy:	± 0.001 inch
Power:	110 VAC, 60 Hz
Shipping Case:	25L x 19W x 12H (inches)
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) 372-8967

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GD8762

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  $\pm 2 \text{ mm} + 2 \text{ ppm}$  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  $\pm 0.08$  mm ( $\pm 0.003$ " )

Target accuracy is  $\pm 0.025$  mm ( $\pm 0.001$ " )

**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

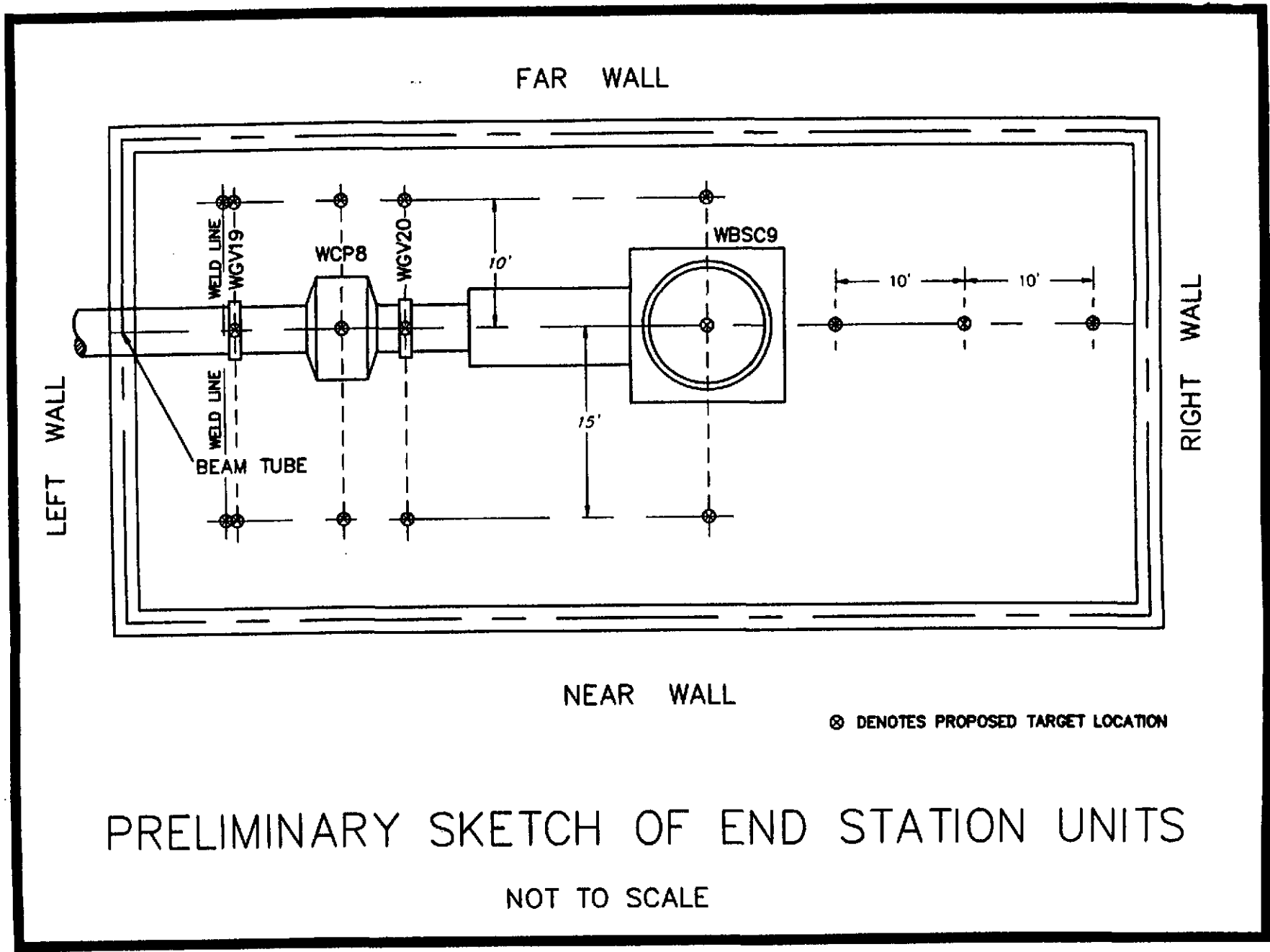


should end at their respective gate valve locations. The baselines can then be offset a distance equal to one half the distance between the beam lines. For example if the beam lines are thirty feet apart, the offset baseline would be fifteen feet. The main beam line baseline running through WHAM1, 2 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.

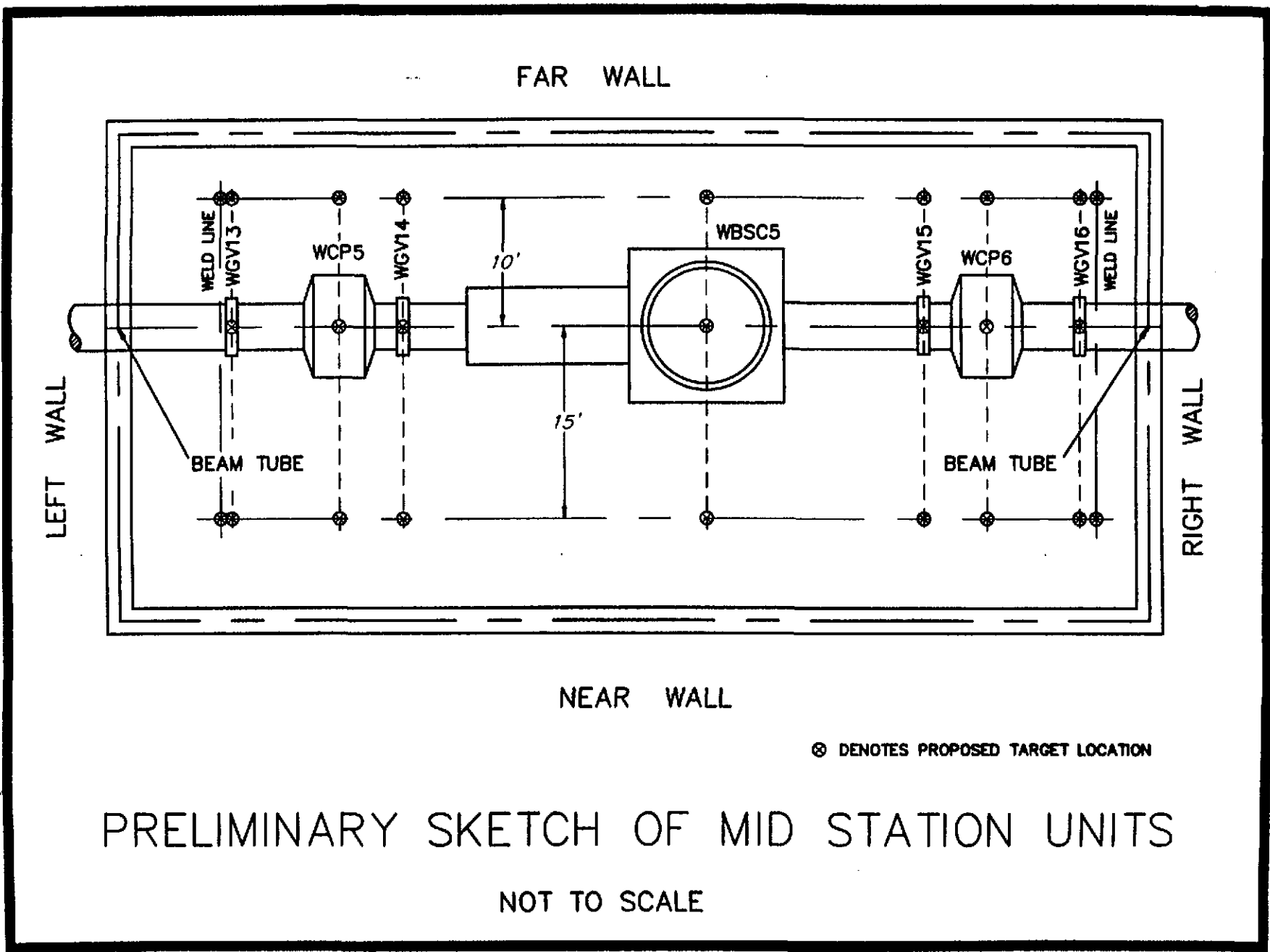
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# PRELIMINARY SKETCH OF END STATION UNITS

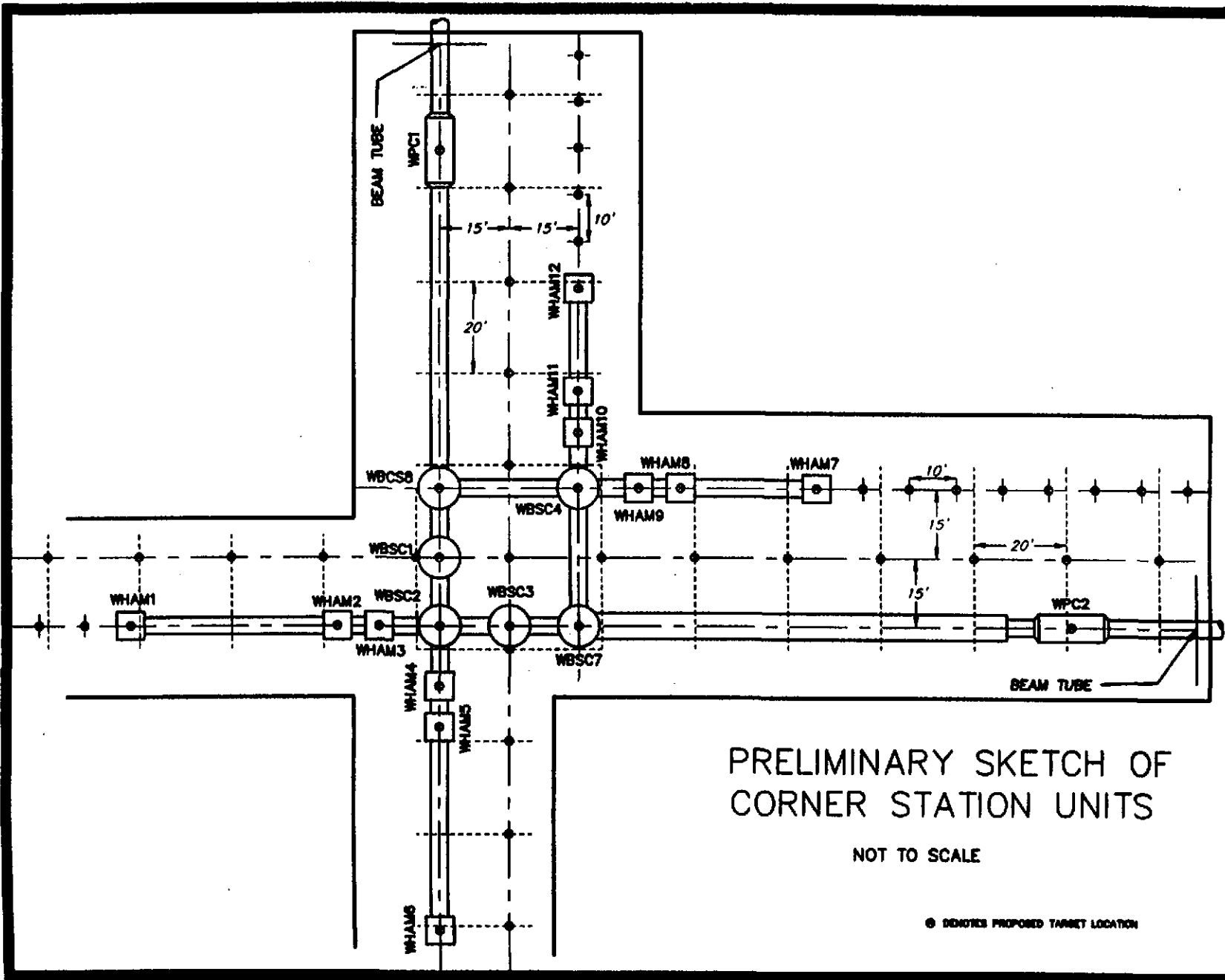
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# PRELIMINARY SKETCH OF MID STATION UNITS

NOT TO SCALE

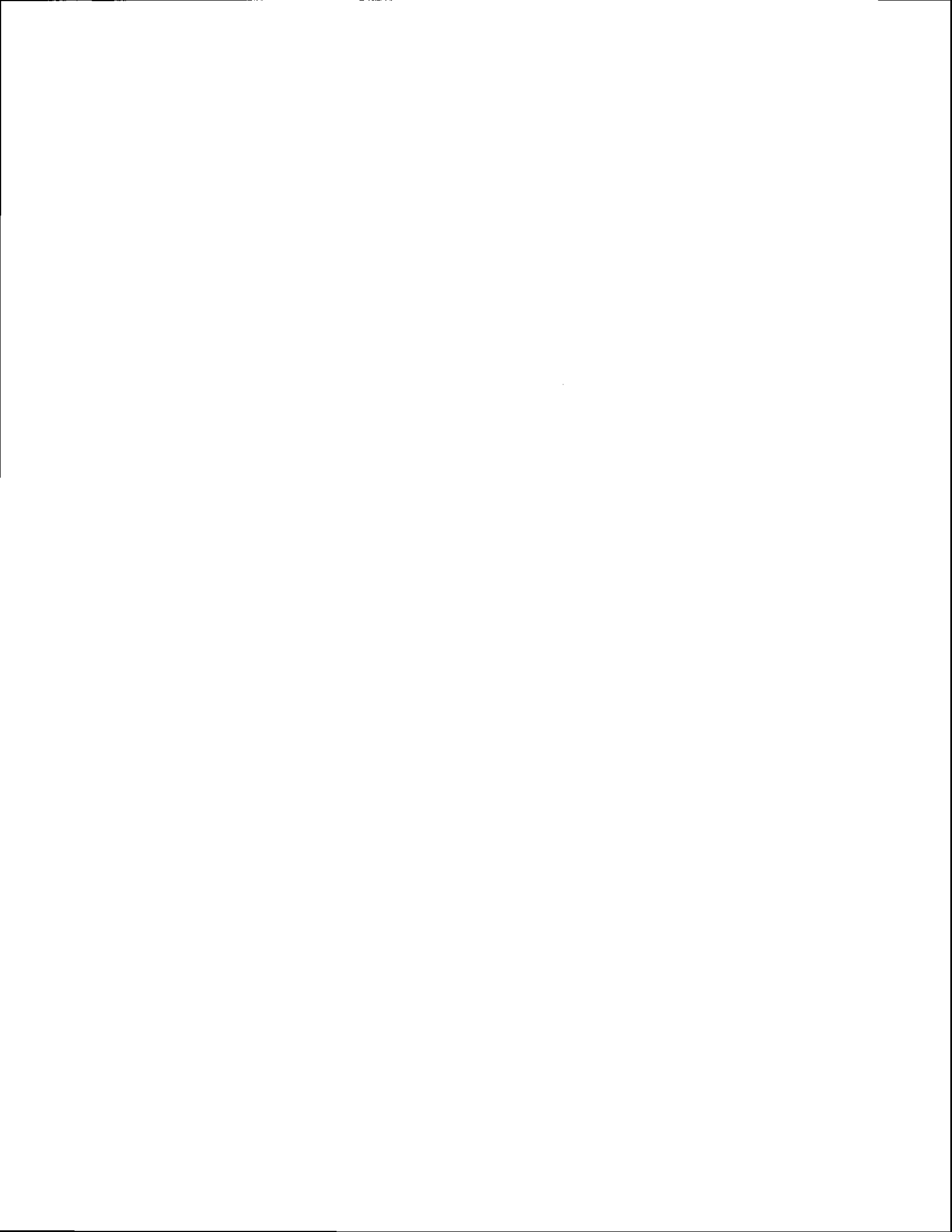


PRELIMINARY SKETCH OF  
CORNER STATION UNITS

NOT TO SCALE

⊙ DENOTES PROPOSED TARGET LOCATION

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## FDR VOLUME IV

### ATTACHMENTS

	<i>DOCUMENT NO.</i>	<i>REVISION</i>
<b>I. Procedures and Spec.</b>		
Anchor Bolt Installation Procedure	V049-1-101	0
Leak Check Procedure	V049-2-014	1
Installation/Commissioning Spec.	V049-2-021	1
Electrical and Instrument Construction Spec.	V049-2-022	1
Project Safety Plan	V049-2-023	1
Project Q.A. Plan	V049-2-029	1
Piping Design and Material Specification	V049-2-037	4
Welding Procedures	V049-2-070	0
	V049-2-071	2
	V049-2-072	2
	V049-2-073	0
Material/Welding Repair Procedure	V049-2-074	0
Isolatable Section Bakeout Procedure	V049-2-116	0
Clean Room Activities	V049-2-118	0
Contamination Control Plan	V049-2-119	1
Raw Material Handling Procedure	V049-2-120	0
Control of Non-Conformance	V049-2-124	0
Visual Inspection Procedure	V049-2-128	1
Black Light Test Procedure	V049-2-130	0
Site Piping Cleaning Procedure	V049-2-131	1
Site Vacuum Surface Re-Cleaning Procedure	V049-2-132	0
RGA Calibration	V049-2-137	0
Structural Carbon Steel Fabrication and Painting	V049-2-139	1
Thermal Insulation - Piping	V049-2-163	0
Conflat Flange Assembly Procedure	V049-2-168	0
O-Ring Installation and Flange Assembly Procedure	V049-2-169	0
Component Alignment Procedure	V049-2-174	0
Vacuum Pump Field Installation Procedure	V049-2-175	0

Note: (later) = This specification is being revised and will be updated at a later date.

## **FDR VOLUME IV**

### ***ATTACHMENTS***

***DOCUMENT  
NO.***                      ***REVISION***

#### **II. Component Acceptance Tests Procedures**

80K Pumps	V049-2-102	0
Roughing Pumps	V049-2-104	0
Turbomolecular Pumps	V049-2-105	0
Ion Pumps	V049-2-106	0
Large Gate Valves	V049-2-107	0
6, 10, 14" Gate Valves	V049-2-108	0
Clean Air Supplies	V049-2-109	0
Portable Soft Wall Cleanrooms	V049-2-110	0
Small Valves	V049-2-111	0
Bakeout System Blankets and Carts	V049-2-112	0

#### **III. System Acceptance Test Procedures**

Corner Stations	V049-2-113	2 (later)
Mid Stations	V049-2-114	2 (later)
End Stations	V049-2-115	2 (later)

Title: PROCEDURE FOR INSTALLATION OF CONCRETE ANCHORS

PROCEDURE FOR  
INSTALLATION OF CONCRETE ANCHORS  
FOR  
LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

PREPARED BY: R. D. Ciatto  
INSTALLATION MANAGER: Paul M. G.  
QUALITY ASSURANCE: Allen J. Bradbrook  
TECHNICAL DIRECTOR: D. A. W. Allen  
PROJECT MANAGER: Brent Bayler

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

			ISSUED PER DEU 138 FOR RDR
0	—	—	
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
PROCESS SYSTEMS INTERNATIONAL, INC.			PROCEDURE
INITIAL APPROVALS	PREPARED	DATE	APPROVED DATE
	RDC	4/24/96	R.E.B 4/24/96
			Number V049-1-101
			Rev. 0



Title

## CONCRETE ANCHOR INSTALLATION PROCEDURE

### 1.0 Purpose

The purpose of this procedure is to define the necessary installation steps required to ensure that concrete anchors meet all project requirements.

### 2.0 General

Hilti HVA adhesive anchors will be used to fasten LIGO vacuum equipment to concrete floor slabs. Concrete anchors have been sized and arranged to restrain the equipment against operating and seismic loads, including unbalanced vacuum loads that occur during normal operation. Proper installation of the anchors is required to ensure satisfactory performance of the vacuum equipment.

Component base plates will be fastened to the floor slabs that are constructed of 3000 psi concrete. It is the intent of this procedure that the anchors be installed in accordance with the manufacturer's requirements.

### 3.0 Responsibility

The installation contractor is responsible for implementing this procedure. Conflicts, if any, between this procedure and manufacturer's installation requirements shall be brought to the attention of PSI prior to the start of installation.

### 4.0 Procedure

#### 4.1 References:

1. Hilti Publication H-427, Technical Guide - Anchor and Powder Actuated Fastening, HVA Adhesive Anchor, Installation Instructions (HAS Threaded Rod - Option #1), Hilti Fastening Systems, Tulsa, OK, 1987, pp. 8-13.

2. Hilti Publication H-600, Systems and Solutions, Hilti Fastening Systems, Tulsa, OK, 1995, pp. 133-135.

4.2 Locate anchor holes in accordance with the installation drawings. The hole location tolerance is +/- 1/16 in of position marked on concrete floor. Holes shall be plumb to within 1° of vertical. Embedment depths shown on the installation drawings are minimum depths. Drill holes using approved equipment to ensure full design bond strength and to maintain project cleanliness requirements. A Hilti PMH bit may be used to core drill holes for the HVA adhesive anchors. Rebar cutting is permitted.

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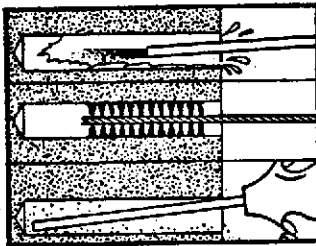
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Title

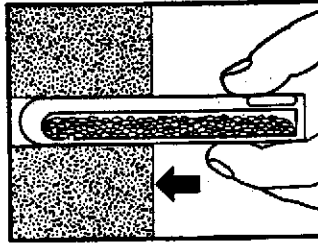
## CONCRETE ANCHOR INSTALLATION PROCEDURE

- 4.3 Use threaded rod or HFA inserts as shown on the installation drawings.
- 4.4 Adhere to curing time required by Hilti before loading or disturbing anchors.
- 4.5 Step by step instructions:

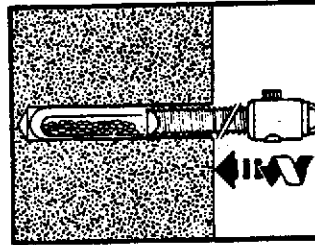
### Installation Instructions (HAS Threaded Rod — Option #1)



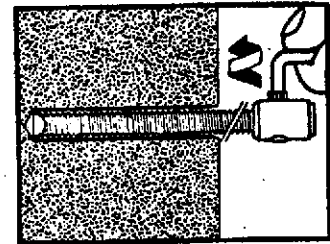
1. Set the drill depth gauge and drill the hole to the required hole depth. **IMPORTANT:** Clear out dust and fragments; preferably using a jet of water or compressed air and a wire brush. The hole may be damp, but the water should be blown out.



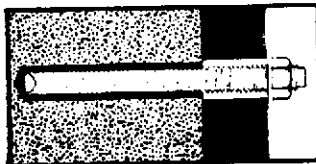
2. Insert the cartridge.



3. Insert the shaft in the rotary hammer chuck, screw the anchor rod in the adaptor and place the adaptor on the shaft. At the rotary hammer drilling setting, drive in the rod to the depth mark. Remove the drill and shaft assembly from the adaptor.



4. Rotate the hex bolt adaptor and unscrew the adaptor from the anchor rod immediately. When removing the adaptor, do not pull out the rod. If the adaptor is removed immediately, movement of the rod will not be detrimental to the fastening.



5. Setting and hardening time. The set anchor rod may not be disturbed or loaded during or before the end of the specified hardening time.

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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

RT Jones

PROJECT ENGINEER

S Motew

QUALITY ASSURANCE

Alan R. Bradbrook

TECHNICAL DIRECTOR

D. O. W. Wellens

PROJECT MANAGER

Bradley Bagley

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	SM 12/4/96	RTB 12/4/96	REVISED PER DEO 037B
Ø	GS 10/10/96	—	Release for tab Per DEO# 0302
Ø	SM 5/4/96	RTB 5/4/96	INITIAL RELEASE DEO 0162 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	Approved DATE	Number:	Rev.
	SM	5/4/96	RTB 5/4/96	A V049-2-014	1

**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.)

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**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.

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4.4 Leak Checking O-rings

**Category IV**

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

**Leak checking method**

An Ion vacuum gauge will be sensing the vacuum pressure in the pumped annulus volume between the atmospheric O-ring seal (Cat.IV) and the UHV O-ring (Cat.V). Air that leaks across or diffuses through the O-ring seals will be pumped by the annulus pumping system. The vacuum pressure, as measured by the Ion guage, in the annulus will be compared to previously successfully tested systems.If the vacuum pressure is comparable,the o-ring seals are considered to be good.

**Category V**

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

**Leak checking method**

Same as Category IV O-ring leak checking method described above.

**Outgassing of O-Rings (reference)**

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.

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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 : \_\_\_\_\_  
 \_\_\_\_\_

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Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

BSC LEAK TEST SUMMARY SHEET

Name							
Model No.							
Serial No.							
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
		Torr	Torr				
Annulus-1	IV		$1 \times 10^{-3}$				
Annulus-2	IV		$1 \times 10^{-3}$				
Annulus-3	IV		$1 \times 10^{-3}$				
Annulus-4	IV		$1 \times 10^{-3}$				
Annulus-5	IV		$1 \times 10^{-3}$				
Annulus-1	V		$1 \times 10^{-3}$				
Annulus-2	V		$1 \times 10^{-3}$				
Annulus-3	V		$1 \times 10^{-3}$				
Annulus-4	V		$1 \times 10^{-3}$				
Annulus-5	V		$1 \times 10^{-3}$				
		Torr-L/s	Torr-L/s				
Weld Joint	I		$1 \times 10^{-9}$				
Weld Joint	II		$1 \times 10^{-9}$				
Conflat	III		$1 \times 10^{-9}$				

Comments

Witnessed  
Signature  
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Date

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Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

HAM LEAK TEST SUMMARY SHEET

Name							
Model No.							
Serial No.							
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
		Torr	Torr				
Annulus-1	IV		$1 \times 10^{-3}$				
Annulus-2	IV		$1 \times 10^{-3}$				
Annulus-3	IV		$1 \times 10^{-3}$				
Annulus-4	IV		$1 \times 10^{-3}$				
Annulus-1	V		$1 \times 10^{-3}$				
Annulus-2	V		$1 \times 10^{-3}$				
Annulus-3	V		$1 \times 10^{-3}$				
Annulus-4	V		$1 \times 10^{-3}$				
		Torr-L/s	Torr-L/s				
Weld Joint	I		$1 \times 10^{-9}$				
Weld Joint	II		$1 \times 10^{-9}$				
Conflat	III		$1 \times 10^{-9}$				

Comments

Witnessed  
Signature  
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Date

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SPOOL SECTION LEAK TEST SUMMARY SHEET

Name							
Model No.							
Serial No.							
Drwg.No.							
Location	Category	Leak Rate Torr	Allowable Torr	Pass	Fail	Signature	Date
Annulus-1	IV		$1 \times 10^{-5}$				
Annulus-2	IV		$1 \times 10^{-5}$				
Annulus-1	V		$1 \times 10^{-5}$				
Annulus-2	V		$1 \times 10^{-5}$				
		Torr-L/s	Torr-L/s				
Weld Joint	I		$1 \times 10^{-9}$				
Weld Joint	II		$1 \times 10^{-9}$				
Conflat	III		$1 \times 10^{-9}$				

Comments

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- Attachment B..... Building Crane Coverage
- Attachment C..... Equipment Supplied by the Buyer
- Attachment D.....Electrical & Instrument Construction Work V049-2-022
- Attachment E Final Design Report Volume IV "Installation/Commissioning V049-1-100
- Attachment F ..... PSI Drawing Package
- Attachment G..... LIGO Building Drawing Package
- Attachment H.....Vendor Equipment Drawing Package
- Attachment I..... Carbon Steel Supports Supplied by The Buyer
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**1.0 INTRODUCTION**

- 1.1 This specification covers the installation and commissioning of the Vacuum Equipment for the LIGO Project at Hanford, WA. The LIGO (Laser Interferometer Gravitational-Wave Observatory) project is a scientific facility designed to detect gravitational waves. The vacuum equipment is installed in five buildings throughout the site.

The buildings, foundations and vacuum enclosures between each of the buildings is provided by others.

The location for the scope of work of this specification is the LIGO facility in Hanford, WA. (Actual location: Rt. 10, (Mile Marker 2), Richland, WA)

LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape (with 4 km long arms) installed inside a vacuum enclosure, vacuum pumping systems and other support facilities.

**2.0 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 California Institute of Technology and the 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.

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2.6 The term "Joint Occupancy" as used in this specification means the time the individual buildings can be occupied by the LIGO Project staff, its equipment contractors, including it's Construction Contractor to finish and close out the final inspection items. The Vacuum Equipment Contractor shall perform the installation effort under this Purchase Order on a "non-interference by others" basis.

**3.0 SITE VISIT**

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

Selected LIGO site building drawings are included in this package (Attachment G). Other building drawings will be provided on an as needed basis.

**4.0 CONTRACTOR CONTACTS**

4.1 After award, all Contractor questions should be directed to:  
 Mr. David Evers  
 Process Systems International, Inc.  
 20 Walkup Drive  
 Westborough, MA 01581  
 Phone: (508) 898-0206  
 FAX: (508) 898-0322

**5.0 PERMITS AND CODES**

5.1 Before starting work on this project, it shall be the responsibility of the Contractor to make certain that all necessary permit, license and approvals are obtain for performance of the work at the site. Contractor shall obtain such permits, license and approvals at their own expense and furnish copies to the Buyer. The Buyer will provide drawings stamped by a Washington state professional engineer for obtaining permits.

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

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**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

31.9 Building Services 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

Applicable - Local Codes and Standards

**5.4 Specification Compliance**

5.4.1 Work shall comply with drawings, data sheets, standards, codes and specifications referred to herein or attached as part of this specification. Applicable national, state or local codes, standards, and 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 be advised by the contractor of all scheduled inspections by regulatory agencies, and be allowed the option to witness such inspections.

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5.4.3 Conflicts between documents or incomplete technical information shall be brought to the attention of the Buyer and resolved at the time of quotation. After contract award, the contractor shall identify all conflicts for resolution prior to executing the work. The most stringent requirement will be considered to be incorporated into their lump sum price.

## 6.0 SAFETY REGULATIONS

6.1 A site specific safety plan shall be developed by the Contractor, 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 (including subcontractors).

6.4 The Contractor shall designate a person to be responsible for safety management at the site. Contractor shall conduct weekly safety meetings with their crew and send a representative to all site wide safety meetings.

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

## 7.0 GENERAL REQUIREMENTS

7.1 This specification covers installation and commissioning activities for the LIGO Vacuum Equipment systems. The vacuum equipment will be installed indoors (except for the LN<sub>2</sub> tanks and vaporizer systems) in five site buildings (provided by others). The buildings will be complete (except for minor punch list items) prior to vacuum equipment installation. The Contractor shall have joint occupancy of the buildings and LN<sub>2</sub> foundations as defined in Section 2.6.

7.2 It is the intent that the Work be executed in accordance with the Project Drawings and Project Specifications by qualified craft persons. 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.

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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, and problems due to lack of field verification or error shall be corrected at the Contractor's expense.

- 7.3 Bid shall state what work the Contractor intends to subcontract and their proposed subcontractors. The Contractor is responsible for the performance of subcontractor(s) and will assume the responsibility for supervising each subcontractor(s). The Buyer's written acceptance will be required of each Subcontractor. The Buyer will be furnished a copy of each subcontract.
- 7.4 Prevailing Davis-Bacon Rates shall be used to develop the proposal cost in accordance with the Project Labor Agreement LIGO-C950331-00-P. Any rate increases at a later date will be a change order to the contract.
- 7.5 The Contractor shall be responsible for examination and inspection of his Subcontractors' work to assure that it complies to the specifications and standards and that the work performed is of good workmanship quality.
- 7.6 Materials provided by the Buyer are detailed in Section 11.0.
- 7.7 "Hold" or "Later" shown on Drawings indicate that final dimensions and details have not been determined. Contractor shall include these areas in their Scope of Work or Bid Proposal to the extent presented on these Drawings.
- 7.8 The Contractor's Work must be coordinated in the field through the Buyer's Installation Manager.
- 7.9 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.

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- 7.10 Building cranes are not capable of lifting all vacuum equipment components (see Attachments B&C). The Buyer will provide one set (4) of special dollies for lifting and alignment of the components (see V049-1-100 Section 7.2). The Contractor is responsible for providing all other lifting devices, dollies and handling equipment.

NOTE: Inside the site buildings, only electric drive equipment is allowed (no propane or diesel equipment).

- 7.11 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 (including a list of the different union crafts to be utilized). The Contractor shall provide on site need dates for all Buyer supplied equipment and materials.
- 7.12 A representative of the Contractor will be required to attend weekly status meetings with the Buyer. Status meetings will be conducted by the Contractor with the Buyer's personnel to review the past week's progress and the next week's planned activities. A Two Week Look Ahead Schedule, (updated weekly) and staffing plan will be provided by the Contractor at weekly Progress Meetings (tentatively set for Monday mornings). Q.A. and safety reports shall also be reviewed. Meeting minutes shall be issued within two (2) working days of each meeting.
- 7.13 Buyer's field representatives and the Owner shall have the right to review Contractor's work, material, equipment and 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. As a minimum, the Buyer will verify the installation location of each vessel (HAM, BSC, etc.). See Alignment Procedure V049-2-174 in Attachment E.
- 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 events they wish to witness, and the Contractor shall furnish an agreed upon amount of notification prior to the start of each event.
- 7.15 Contractor's field representative shall confirm by examination and tests, specified or usually used for such purposes, and submit a written 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 Purchase Order
  - b) The Specifications
  - c) Applicable Codes and Standards

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- 7.16 The presence or activity of the Buyer's field representative shall not 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 shall conduct a safety meeting weekly with their staff.
- 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 work shift work and/or overtime to meet the completion dates in the Purchase Order at no additional cost to Buyer.
- 7.20 The Contractor's progress will be monitored on a weekly basis by the Buyer. If it becomes apparent to the Buyer during the monitoring of the progress of the work that a slippage in the schedule has occurred, the Buyer shall direct and the Contractor shall provide at no increase in cost to the Buyer, additional people, additional equipment, 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 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.
- 7.22 The Contractor's work, including testing is 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 plan and procedures no later than one month after he has been awarded the contract.
- 7.23 The Contractor shall take measurements to avoid damaging all structures, building walls, 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.

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

7.25 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 work, 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:

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

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

7.25.3 No alcohol or drugs of any kind will be allowed within or around the job site. Use of drugs or alcohol on the job site is grounds for dismissal.

7.26 Contractor shall maintain record drawings as follows:

7.26.1 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.

7.26.2 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.

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

7.27 Construction Installation Review

7.27.1 The Contractor shall participate in an installation readiness review (at the site) one month prior to mobilizing on the site. The Contractor shall present their plan (schedule, procedures, Q.A. plan, etc.) for Vacuum Equipment site installation for approval by the Buyer and the Owner.

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**7.28 Documentation**

7.28.1 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. A master set (with as-built information) shall be maintained throughout the installation contract.

7.28.2 Equipment/material identification tags shall not be removed.

**7.29 Temporary Construction Water**

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

**7.30 Temporary Sanitary Facilities**

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

**7.31 Temporary Storage Facilities/Parking**

The Buyer's representative will designate areas and locations for the temporary storage of personnel trailers, materials, tools, equipment and contractor parking.

**7.32 Vacuum Equipment Operation**

It shall be the responsibility of the Contractor to operate all vacuum equipment, in accordance with ultra high vacuum practice and vendor instructions.

**7.33 Disposition Of Debris Cleanup And Demobilization**

7.33.1 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 (daily cleanup is required).

7.33.2 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. This demobilization phase of the Work shall be accomplished before construction will be considered complete.

7.33.3 Parking areas must be kept clean and neat at all times.

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**7.34 FINAL ACCEPTANCE**

7.34.1 Final acceptance of the fixed price lump sum work required by the Specifications shall be on a building by building basis. This acceptance shall be given after all fix price lump sum cleanup operations and tests have been completed.

**7.35 BILLING**

7.35.1 Invoices for work performed under this specification shall be clearly identified with the Job Title, Job Number and Purchase Order Number. Prior to issuance of invoices, the invoice will be reviewed with the Buyer's Installation Manager for approval of progress achieved during the billing period. The Contractor shall propose payment milestones with their proposal.

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

Mr. Ron Bento  
Process Systems International  
20 Walkup Drive  
Westborough, MA. 01581-5003

**8.0 SCOPE OF WORK****8.1 General**

This specification covers the installation and commissioning of the LIGO Vacuum Equipment System. The system is installed into five site buildings provided by others.

The vacuum system consists of major vessels (BSC, HAM, 80K pumps, and spools) and support equipment (vacuum pumps, skids, class 100 air skids, utility headers, instrumentation, valves, etc.). Major vacuum equipment has been fabricated with flanged connections (double o-ring seals) which requires only alignment, bolting together and anchor bolts to install.

All major vessels and skids have been fabricated and tested by the Buyer prior to the start of installation. (See Attachment C).

The Contractor shall include all costs associated with providing labor including supervision and transportation labor, materials, construction equipment, tools, construction supplies, consumables, required warehousing, temporary

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facilities and services to offload, 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. Component shipping configurations are detailed in Attachment J.

The Contractor shall offload, receive, clean, inspect, assemble as required, erect, place and precision align, install anchor bolts, shim, bolt down, grout and test all required equipment as shown on P&ID, installation drawings and detailed in this specification.

The Contractor may also be asked to assist in additional 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 2-3 hours 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 (6-BSC type/1 HAM type/5 gowning type).

8.1.1 Lifting of major equipment items will be performed in accordance with specific requirements and shall be consistent with procedures or vendor drawings. Equipment sizes and weights are detailed in this installation package. Building crane capacity and coverage is detailed in Attachment B.

8.1.2 All equipment is shipped internally clean (to class 100) and closed with bolted shipping covers.

8.1.3 The Contractor shall detail, fabricate, paint and deliver miscellaneous structural steel and pipe supports as required in accordance with Contract Documents. All vessels or major spool supports are provided by the Buyer. (See Attachment I).

8.1.4 The Contractor shall include in his lump sum bid:

8.1.4.1 Costs of moving his equipment around the site.

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

8.1.4.3 Costs for building survey layouts required to properly locate and set equipment and the work (including WA registered land surveyor) from the Owner supplied benchmarks (per Specification V049-2-174).

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8.1.4.4 Contractor shall receive, clean, install and anchor the corner station pipe bridge.

8.1.4.5 Contractors shall perform touch-up painting on all carbon steel surfaces (per V049-2-139).

**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 external surfaces in the designated clean area before equipment is moved into the buildings and pre-positioned in Corner, Mid and End Stations (steam clean only).

The Contractor shall remove temporary shipping braces 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 Alignment by the Contractor**

8.3.1 Vacuum components along the beam line (BSC, HAM, 80K Pumps, Spools)

A. Vacuum Equipment along the beam line shall be aligned using optical alignment equipment per Procedure V049-2-174.

B. 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  $\pm 2$  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 components to avoid damage to the flange surfaces (32 RMS finishes) and bellows assemblies.

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- C. Ports shall be pre-cleaned and protected by a class 100 portable clean room anytime ports are opened. External surfaces of 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 documents.
- D. After initial alignment, concrete anchor bolts shall be installed (per Specification V049-1-101). Vessels shall then be lifted back into place, final aligned, bolted into place and grouted (per Paragraph 8.3.5).
- E. Anchor bolt sizes are shown in Table 8.3.

**8.3.2 Vacuum Equipment Skids and Carts**

- A. Due to manufacturing and construction tolerances, pump carts in the main vacuum equipment rooms must be connected to pipe connections along the vacuum headers and equipment to locate the anchor bolt locations. These anchor bolts should be installed per Specification V049-2-175 and mechanical drawings.

The following list details pump cart locations requiring anchor bolt installation in each building:

**Corner Station**

Turbo Carts	6
Roughing Cart	4

**Mid Station**

Turbo Carts	3
Roughing Cart	0

**End Station**

Turbo Carts	2
Roughing Carts	0

NOTE: These anchor bolts are **NOT** installed per V049-1-101.

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**TABLE 8.3 REQUIRED CONCRETE ANCHORS FOR VACUUM EQUIPMENT<sup>1</sup>**

Component Tag No.	Anchor Diameter	Minimum Embedment Depth	Notes
WBSC1	1"	8 1/4"	
WBSC2	1"	8 1/4"	
WBSC3	1"	8 1/4"	
WBSC4	1"	8 1/4"	
WBSC5	1"	8 1/4"	
WBSC6	1"	8 1/4"	
WBSC7	1"	12 3/8"	2
WBSC8	1"	12 3/8"	2
WBSC9	1"	8 1/4"	3
WBSC10	1"	8 1/4"	3
WHAM1	1"	8 1/4"	4
WHAM2	1"	8 1/4"	
WHAM3	1"	8 1/4"	
WHAM4	1"	8 1/4"	
WHAM5	1"	8 1/4"	
WHAM6	1"	8 1/4"	4
WHAM7	1"	8 1/4"	4
WHAM8	1"	8 1/4"	
WHAM9	1"	8 1/4"	
WHAM10	1"	8 1/4"	
WHAM12	1"	8 1/4"	4
WHAM13	1"	8 1/4"	
WCP1	1"	12 3/8"	
WCP2	1"	12 3/8"	
WCP3	1"	12 3/8"	
WCP4	1"	12 3/8"	
WCP5	1"	12 3/8"	
WCP6	1"	12 3/8"	
WCP7	1"	12 3/8"	
WCP8	1"	12 3/8"	
WGV1	3/4"	6 5/8"	
WGV2	3/4"	6 5/8"	
WGV3	3/4"	6 5/8"	
WGV4	3/4"	6 5/8"	
WGV5	3/4"	6 5/8"	
WGV6			5
WGV7	3/4"	6 5/8"	
WGV8			5
WGV9			5

Component Tag No.	Anchor Diameter	Minimum Embedment Depth	Notes
WGV10	3/4"	6 5/8"	
WGV11	3/4"	6 5/8"	
WGV12			5
WGV13			5
WGV14	3/4"	6 5/8"	
WGV15	3/4"	6 5/8"	
WGV16			5
WGV17	3/4"	6 5/8"	
WGV18	3/4"	6 5/8"	
WGV19			5
WGV20	3/4"	6 5/8"	
WA-7A	1"	8 1/4"	
WB-1A	1"	8 1/4"	
WB-1B	1"	8 1/4"	
WB-2A	1"	8 1/4"	
WB-2B	1"	8 1/4"	
WB-3A	1"	8 1/4"	
WB-5A	1"	8 1/4"	
WB-6	1"	12 3/8"	
WB-7	1"	12 3/8"	
WB-9A	1"	8 1/4"	
WB-9B	1"	8 1/4"	
WBE-5	1"	8 1/4"	
WBE-6	1"	8 1/4"	
Pipe Bridge	3/4"	6 5/8"	

**NOTES:**

1. Install Hilti HVA anchors in accordance with Specification V049-1-101.
2. Use 12 3/8" minimum embedment for all base plates of this component.
3. Use 12 3/8" minimum embedment for base plates at end of arm.
4. Use 12 3/8" minimum embedment for the four anchors at the end of the arm.

- B. Install all skided vacuum equipment in the corner station mechanical rooms per the mechanical drawings. Anchor bolt and vibration isolation requirements are also shown on the mechanical drawings. (These anchor bolts are **NOT** installed per V0409-1-101). Do not grout this equipment.
- C. Install all skided vacuum equipment in the mid and end station vacuum support equipment rooms per the mechanical drawings. Anchor bolt and vibration isolation requirements are also shown on the mechanical drawings. (These anchor bolts are **NOT** installed per V049-1-101). Do not grout this equipment.

### 8.3.5 Grout 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:

NOTE: Grout must be mixed outside the vacuum equipment areas and applied in a manner to minimize contamination.

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

Grout shall be mixed, placed and cured in accordance with the manufacturers instructions. Care shall be taken during grout installation to avoid voids in the grout pad (proper vent holes, vibration, etc.)

Curing shall continue for a minimum of 7 days.

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

- 8.3.6 Install main ion and annulus ion pumps and associated annulus tubing. Annulus tubing assemblies are preassembled by the Buyer and require only flange and bracket bolting installation to install.

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## 8.4 Vacuum Headers And Class 100 Air Piping

Vacuum headers and Class 100 piping shall be installed by the Contractor per the attached drawing list. In the vacuum building, vacuum headers and Class 100 piping run under the vacuum equipment. Piping shall be tested per this Specification. All vacuum headers and Class 100 piping will be supplied by the Buyer and are assembled using conflat flanges. Vacuum header and class 100 air piping materials are detailed in V049-2-037.

## 8.5 80K Pump System

The 80K pump system consists of an 80K pump vessel (shipped complete) and associated V.J. piping, S.S. piping (insulated), LN<sub>2</sub> tank, heater, vaporizer and miscellaneous valves and instruments (all provided by the Buyer for installation by the Contractor). The Contractor shall remove 80K pump shipping supports (in a Class 100 cleanroom). Shipping supports are bolted rods (8/pump) located inside on each pump and are accessible from each end. After the shipping supports are removed, four stainless steel plates are screwed into place (4/end) to close up the pump.

LN<sub>2</sub> lines outside buildings shall be SCH 5S stainless steel. Lines that require mechanical insulation shall be insulated by the Contractor with material (supplied by the Contractor) and thickness as indicated on the P&ID's (per Specification V049-2-163).

The Contractor shall install the 80K pump system (8 total), including LN<sub>2</sub> tanks, supply, return, and regeneration piping per the attached drawings. The Buyer will provide the V.J. piping and all valves. The remaining piping and fittings are to be provided and installed by the Contractor.

## 8.6 Testing

Per Section 9.0.

## 8.7 Electrical/Instrumentation Work

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

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8.8 Piping Systems (Water, Air, LN<sub>2</sub>)

The Scope of Work includes, but is not limited to, the fabrication and installation of various utility piping systems as shown on the Project Drawings and P&ID's. S. S. utility piping to be installed and tested in accordance with ANSI B31.3. Copper lines shall be installed and tested per ANSI B31.9 "Building Services Piping". See specification for Piping Design and Materials Specification V049-2-137 for materials and classes.

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 Contractor shall qualify welding procedures and welders in accordance with ASME Boiler and Pressure Vessel Code, Section IX, latest edition. Most welding must be done outside the laser/vacuum equipment areas.

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. VJ piping is assembled by connecting bayonet connections (no welding is required to install V.J. piping). One weld is required at the transition of V.J. to S.S. insulated piping.

8.8.4 Pipe penetrations are located in all walls. Walls will be closed after piping by others. The Contractor shall **not** cut any new holes in building walls without the owners approval.

8.8.5 The Contractor shall notify the Buyer, who will witness all tests, four (4) 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).

8.8.6 Utility piping systems shall be cleaned by the Contractor per the attached procedures (see V049-2-131).

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

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8.8.8 The Contractor shall pneumatically pressure and leak check test the air and water utility piping systems including; but not limited to; vents, drains, pipe caps, flanges and blind flanges. The Contractor shall provide, all test gases. The gases shall be bottled nitrogen.

8.8.9 Material and equipment provided by the Contractor shall be new.

8.8.10 The Contractor is responsible for installing Buyer furnished valves (with mounted actuators) as indicated on the Buyer lists (Attachment J).

Valves with socket weld or butt weld connections are to have their seats and seals removed prior to welding installation (in accordance with manufacturers requirements) and then reinstalled after the valve has cooled.

**8.9 Equipment And Piping Insulation**

8.9.1 Insulation shall be installed on equipment and piping as indicated on the Piping and Instrumentation Diagrams(P&ID's). The Contractor shall provide all insulation materials. Insulation to be installed by the Contractor per V049-2-163.

**8.10 Utilities**

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

**8.11 Pipe Cleaning - Vacuum Headers and Class 100 Piping**

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

**9.0 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 tests under the lump sum price.

9.1.1 Utility piping pneumatic and leak tests (in accordance with ANSI B31.3 requirements utilities).

9.1.2 Equipment alignment checks.

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9.2 The Contractor Shall assist the Buyer in other testing on a T&M basis as requested.  
Typical tests:

- Helium Leak Tests
- Equipment bakeout (including blanket installation)
- 100 hour pumpdown test
- RGA Leak Testing

9.3 Testing Equipment/Supplies

9.3.1 The Contractor shall provide equipment and gases/supplies required for leak testing on a T&M basis.

9.4 Leak Testing After Rework

9.4.1 Costs for additional pneumatic and leak testing due to defects or errors by the Contractor shall be performed at no additional cost to the Buyer.

9.5 Test Records

9.5.1 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.

**10.0 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 (gases, etc.) required to perform leak detection by Helium Sensitive Mass Spectrometer (on a T&M basis).

Quan: 2

Type: Mass spectrometers helium leak detector (dry type/no oil flooded pumps or bearings) with a minimum sensitivity of  $2 \times 10^{-10}$  torr-liters/sec.

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, test gases, concrete anchors, shimes and grout.

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10.2.2 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 and inspection reports shall be made available to the Buyer at his request.

**11.0 MATERIALS FURNISHED BY OTHERS/BUYER**

The following material and facilities are provided by others:

11.1 Major Equipment items as shown on P&ID's. (See Attachment C)

11.2 Control valves, relief valves, rupture discs, automatic on/off - valves 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 symbol on P&ID) 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 Instruments as shown on the P&ID.

11.7 Class 100 air piping and vacuum header piping (base bid).

11.8 Site buildings and roads.

11.9 Class 100 cleanrooms.

11.10 Corner station pipe bridge.

11.11 Site utilities (cooling water, electricity, etc.).

11.12 Liquid nitrogen.

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

**12.0 PROJECT DOCUMENTS LIST**

The Contract Documents shall be as shown in Attachment A.

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**13.0 SCHEDULE OF THE WORK**

The installation phase shall be completed in 26 weeks starting from joint occupancy. The joint occupancy is currently defined by a window with an early date of 8/1/97 and a late date of 9/1/97. The Contractor will be required to attend an Installation Readiness Review one month prior to joint occupancy. The Contractor is also expected to be mobilized prior to joint occupancy and ready to start work at joint occupancy.

**14.0 BASIS OF BID**

14.1.1 See Equipment Installation Commercial Requirements V049-2-170 for complete terms and conditions and project tax status.

14.1.2 The Firm Total Lump Sum Bid (subject to labor escalation only) is to include all 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 shall be per Spec. V049-2-170. Changes in labor rates from these levels will form a basis for changes to the lump sum price.

14.1.3 Price is to be fixed lump sum, valid for a period of 10 months from time of submittal to the Buyer.

14.1.3.1 The Fixed Lump Sum Price (L) and Equipment (E). Each building's work shall be broken out separately with direct labor hours specified. The Contractor will submit, separate Price Breakdowns as listed on the RFQ pricing sheet.

14.1.3.2 Scope change pricing formula is 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.

14.1.3.3 Contractor will propose a method/formula for changes in labor rates specified herein V049-2-170 Attachment B.

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**15.0 SELECTION OF THE CONTRACTOR**

Selection of a contract will be made from proposals submitted under this inquiry with special consideration given to the ability of the Contractor to who presents his understanding of what is required to perform this Scope of Work and complete the Work in accordance with the Schedule. Bidders under 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.

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**ATTACHMENT "A" SPEC. V049-2-021**  
**PROJECT INSTALLATION/COMMISSIONING**  
**DOCUMENT LIST**

<b>TITLE</b>	<b>DRAWING SIZE</b>	<b>DOCUMENT NUMBER</b>	<b>REV.</b>
<b>P&amp;ID's</b>	D		
Legend/Station Diagrams (3 Shts.)	D	V049-0-001	2
Beam Splitter Chamber All But Corner Vertex Arms	D	V049-0-002	2
Beam Splitter Chamber Corner Vertex Arms	D	V049-0-003	2
Horizontal Access Module	D	V049-0-004	2
112cm & 122cm Gate Valves	D	V049-0-005	2
80K Cryopump	D	V049-0-006	3
Chamber Pressurization System	D	V049-0-007	0
WA Left End Station	D	V049-0-010	2
WA Left Mid Station	D	V049-0-011	2
WA Left Beam Manifold	D	V049-0-012	2
WA Vertex Section	D	V049-0-013	2
WA Diagonal Section	D	V049-0-014	2
WA Right Beam Manifold	D	V049-0-015	2
WA Right Mid Station	D	V049-0-016	2
WA Right End Station	D	V049-0-017	2
WA Corner Station Mechanical Room	D	V049-0-018	2
LA Left End Station	D	V049-0-020	2
LA Left & Right Mid Joints	D	V049-0-021	2
LA Left Beam Manifold	D	V049-0-022	2
LA Vertex Section	D	V049-0-023	2
LA Right Beam Manifold	D	V049-0-024	2
LA Right End Station	D	V049-0-025	2
LA Corner Station Mechanical Room	D	V049-0-026	2
Washing Station	D	V049-0-031	0

**ELECTRICAL DRAWINGS**

For Electrical Drawing List See Drawing V049-3-001  
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<b>APPLICABLE SPECIFICATIONS</b>	<b>DOCUMENT NO.</b>	<b>REVISION</b>
Installation/Commissioning Spec.	V049-2-021	0
Electrical and Instrument Construction Spec.	V049-2-022	0
Project Q.A. Plan	V049-2-029	1
Project Safety Plan	V049-2-023	0
Component Alignment Procedure	V049-2-174	0
Leak Check Procedure	V049-2-014	0
Welding Procedures	V049-2-070	0
	V049-2-071	0
	V049-2-072	0
	V049-2-073	0
Material/Welding Repair Procedure	V049-2-074	0
Visual Inspection Procedure	V049-2-128	1
Raw Material Handling Procedure	V049-2-120	0
Control of Non-Conformance	V049-2-124	0
Contamination Control Plan	V049-2-119	1
Site Piping Cleaning Procedure	V049-2-131	0
Site Vacuum Surface Re-Cleaning Procedure	V049-2-132	0
Clean Room Activities	V049-2-118	0
Black Light Test Procedure	V049-2-130	0
Isolatable Section Bakeout Procedure	V049-2-116	0
O-Ring Installation and Flange Assembly Procedure	V049-2-169	0
Conflat Flange Assembly Procedure	V049-2-168	0
Anchor Bolt Installation Procedure	V049-1-101	0
Piping Design and Material	V049-2-037	4
Structural Carbon Steel Fab & Painting	V049-2-139	1
Thermal Insulation - Piping	V049-2-163	0
Vacuum Pump Field Installation Procedure	V049-2-175	0

<b><i>Title</i></b>	<b><i>DRAWING SIZE</i></b>	<b><i>DOCUMENT NUMBER</i></b>	<b><i>REV.</i></b>
<b><i>WASHINGTON SITE (Spec. cont.)</i></b>			
RGA Calibration	V049-2-137	0	
Component Acceptance Tests Procedures			
80K Pumps	V049-2-102	0	
Roughing Pumps	V049-2-104	0	
Turbomolecular Pumps	V049-2-105	0	
Ion Pumps	V049-2-106	0	
Large Gate Valves	V049-2-107	0	
6, 10, 14" Gate Valves	V049-2-108	0	
Small Valves	V049-2-111	0	
Clean Air Supplies	V049-2-109	0	
Portable Soft Wall Cleanrooms	V049-2-110	0	
Bakeout System Blankets and Carts	V049-2-112	0	
System Acceptance Test Procedures			
Corner Stations	V049-2-113	1	
Mid Stations	V049-2-114	1	
End Stations	V049-2-115	1	

<b>TITLE</b>	<b>DRAWING SIZE</b>	<b>DOCUMENT NUMBER</b>	<b>REV.</b>
<b>WASHINGTON SITE</b>			
<b>MECHANICAL DRAWINGS</b>			
BSC Over All Assembly	D	V049-4-001	1
BSC Shell Weldment/Maching (4 Sheets)	D	V049-4-003	2
Horizontal Access Module (HAM) (5 Sheets)	D	V049-4-002	3
80K Cryopump, Long Left Hand (2 Sheets)	D	V049-4-004	1
80K Cryopump, Short Right (2 Sheets)	D	V049-4-005	1
80K Cryopump, Long Right Hand (2 Sheets)	D	V049-4-006	0
80K Cryopump, Short Left Hand (2 Sheets)	D	V049-4-007	0
Roughing Pump Cart Arrangements	D	V049-4-010	1
Turbo Pump Cart Arrangements	D	V049-4-011	1
Base Extension - Turbo Pump Cart	D	V049-4-012	1
Cover, BSC Type I	D	V049-4-014	3
48 1/4" I.D. Flange Detail (Grooved)	C	V049-4-018	2
44 1/4" I.D. Flange Detail (Grooved)	C	V049-4-017	3
60 1/2" I.D. BSC Flange Detail (Grooved)	C	V049-4-019	3
72 1/4" I.D. Flange Detail (Grooved)	C	V049-4-020	2
84 1/4" I.D. Flange Detail (Grooved)	C	V049-4-021	3
104 1/2" I.D. Flange Detail (Grooved)	C	V049-4-022	5
BSC Support Assy.	D	V049-4-023	4
BSC Annulus Piping	D	V049-4-025	2
72 1/4" I.D. Flange Detail (Flat Faced)	C	V049-4-028	1
48 1/4" I.D. Flange Detail (Flat Faced)	C	V049-4-029	1
60 1/2" I.D. HAM Flange Detail (Grooved) Slt'd	C	V049-4-031	4
60 1/2" I.D. Flange Detail (Flat Faced)	C	V049-4-032	2
44" Gate Valve Support Frame	D	V049-4-033	1
48" Gate Valve Support Frame	D	V049-4-034	1
BSC Internal Platform Details	D	V049-4-036	0
HAM Tie Rod Assembly	D	V049-4-040	3
104 1/2" I.D. Flange Detail (Flat Faced)	C	V049-4-041	2
44 5/8" I.D. Flange Detail (Flat Face)	C	V049-4-042	1
Pipe Bridge - Corner Station	D	V049-4-043	0
BSC RGA/Aux. Turbo Conn. Assembly	C	V049-4-045	1
44 5/8" ID x 80 O.D. Flange Detail (Flat Faced)	C	V049-4-047	1
Vessel Support (HAM)	D	V049-4-052	3
Expansion Joint (HAM)	C	V049-4-053	1
HAM Annulus Piping	D	V049-4-054	3
60 1/2" I.D. Ring Detail Reducing Union	C	V049-4-055	1
30 1/2" x 68.25 O.D. Flange Detail (Flat Faced)	C	V049-4-056	1
30 1/2" x 68.25 O.D. Flange Detail (Grooved)	C	V049-4-057	3
44 5/8" ID x 60 1/2" ID Flange Detail	C	V049-4-058	1

<b>TITLE</b>	<b>DRAWING SIZE</b>	<b>DOCUMENT NUMBER</b>	<b>REV.</b>
<b>MECHANICAL DRAWINGS</b>			
Shipping & Test Cover 60 1/2" ID	D	V049-4-059	2
44/25 ID Flange Detail (Grooved/Slotted)	C	V049-4-060	4
3/4" O.D. Elbow x 2 3/4" C.F. Flg Annulus Conn	B	V049-4-061	0
60.5" ID x 68.5 OD BE-3A Flange (Flat)	C	V049-4-064	1
60.5" ID x 72.25 OD Offset Flange (BE3A)	C	V049-4-066	1
61.31" ID x 72.25 OD BE-3A Flange (Groved)	C	V049-4-067	2
48 1/4" ID x 60 1/2" ID Offset Flange	C	V049-4-068	1
48.81 ID x 68.25 OD Flg. Detail (Flat)	C	V049-4-070	1
48.81 ID x 80. OD Flg. Detail (Flat)	C	<del>V049-4-071</del>	0
PS-1 Pipe Support Tee Post (LN <sub>2</sub> Piping)	C	V049-4-072	0
PS-2 Pipe Support	C	V049-4-073	0
PS-3 Pipe Support Tee Post	C	V049-4-074	0
PS-4 Pipe/Electrical Support	C	V049-4-075	0
75 L/S Ion Pump/Manifolds	D	V049-4-077	1
25 L/S Ion Pump/Manifolds	D	V049-4-078	1
48 1/4" ID x 68.25 OD Flange Detail	C	V049-4-079	1
80K Pump Reservoir Suppt, Assy, Short	D	V049-4-094	0
80K Pump Reservoir Suppt, Assy, Long	D	V049-4-095	0
BSC Test/Ship Assembly-Two Door	D	V049-4-102	0
BSC Test/Ship Assembly-Three Door	D	V049-4-103	0
BSC Test/Ship Assembly-No Doors	D	V049-4-104	0
BSC Test/Ship Assembly-One Door	D	V049-4-105	0
25 L/S Annulus Tubing-44" G.V. Type III	C	V049-4-106	0
25 L/S Ion Pump Valve Support	D	V049-4-107	0
25 L/S Annulus Tubing 48" G.V. Type I	C	V049-4-108	0
Annulus Tubing & Ion Pump Assembly. 44" G.V.	D	V049-4-109	0
25 L/S Annulus Tubing 48"G.V. Type II	C	V049-4-110	0
Bellows Tie-Rod Assembly	D	V049-4-124	0
84.25 ID Access Cover - Ham	D	V049-4-127	2
Clean Room Assembly - BSC	D	V049-4-133	0
Clean Room Assembly - Ham	D	V049-4-136	0
16 1/2" OD Conflat Reducing Flanges	B	V049-4-142	2
LN2 Tank Base Template	D	V049-4-145	0
Gate Value Fin Clamp	B	V049-4-163	0
25 L/S Annulus Tubing - 44" G.V. Type I	C	V049-4-164	0
Annulus Tubing & Ion Pump Assy 48" G.V.	D	V049-4-165	0
25 L/S Annulus Tubing - 44" G.V. Type II	C	V049-4-166	0
RGA/Aux. Turbo/Gage Pair Assembly	C	V049-4-167	0



<b>TITLE</b>	<b>DRAWING SIZE</b>	<b>DOCUMENT NUMBER</b>	<b>REV.</b>
<b>MECHANICAL DRAWINGS</b>			
Assembly Reprssurization Cart, 50 CFM	D	V049-4-168	0
Assembly Reprssurization Cart, 100 CFM	d	V049-4-175	0
Adapter A-1, 44.62" ID x 72.25 ID, 3 Sheets	D	V049-4-A1	2
Adapter A-3, 48.25" ID x 60.5 ID, 2 Sheets	D	V049-4-A3	2
60" HAM Cover, Grooved Type A4, 2 Sheets	D	V049-4-A4	6
Adapter A-6, 48.25" ID x 60.5 ID, 2 Sheets	D	V049-4-A6	2
Adapter A-7A, 60.5" ID x 72.25 ID, 5 Sheets	D	V049-4-A7A	2
Adapter A-7B, 60.5" ID x 72.25 ID, 5 Sheets	D	V049-4-A7B	1
BSC End Cover 60.5" Type All	D	V049-4-A11	4
Adapter A-12, 48.25" ID x 60.5 ID, 2 Sheets	D	V049-4-A12	2
Adapter A-13, 60.5" ID x 72.25 ID, 2 Sheets	D	V049-4-A13	2
Adapter A-14, 44.62" ID x 60.5 ID, 2 Sheets	D	V049-4-A14	2
Adapter A-15, 48.25" ID x 60.5 ID, 2 Sheets	D	V049-4-A15	3
Spool B-1, 72.25 ID, 3 Sheets	D	V049-4-B1	3
Spool B-2A, 30.5 ID x 60.5 ID, 5 Sheets	D	V049-4-B2A	3
Spool B-2B, 30.5 ID x 60.5 ID, 5 Sheets	D	V049-4-B2B	3
Spool B-3A, 30.5 ID x 60.5 ID, 5 Sheets	D	V049-4-B3A	3
Spool B-4, 48.25" ID, 2 Sheets	D	V049-4-B4	2
Spool B-5A, 30.5 ID x 60.5 ID, 5 Sheets	D	V049-4-B5A	3
Spool B-6, 48.25" ID, 2 Sheets	D	V049-4-B6	4
Spool B-7, 48.25" ID, 2 Sheets	D	V049-4-B7	3
Spool B-8, 72.25" ID, 3 Sheets	D	V049-4-B8	2
Spool B-9, 72.25" ID, 4 Sheets	D	V049-4-B9	2
Spool BE-2, 60.5" ID, 2 Sheets	D	V049-4-BE2	2
Off Set Spool BE-3, 60.5" ID x 60.5 ID, 2 Sheets	D	V049-4-BE3	3
Off Set Spool BE-3A, 60.5" ID x 60.5 ID, 2 Sheets	D	V049-4-BE3A	3
Spool, BE-4, 44.62" ID, 2 Sheets	D	V049-4-BE4	2
Spool, BE-5, 72.25" ID, 5 Sheets	D	V049-4-BE5	4
Spool, BE-6, 72.25" ID, 5 Sheets	D	V049-4-BE6	4

<b>TITLE</b>	<b>DRAWING SIZE</b>	<b>DOCUMENT NUMBER</b>	<b>REV.</b>
<b>MECHANICAL DRAWINGS</b>			
Equipment Arr't. Plan, Corner Station WA Sht 1 of 2	D	V049-5-001	1
Equipment Arr't. Elevation, Sht 2 of 2	D	V049-5-001	1
Equipment Arr't ISO, Corner Station, WA	D	V049-5-002	1
Equipment Arr't , Right Mid Station, WA	D	V049-5-004	1
Equipment Arr't , Right End Station, WA	D	V049-5-005	1
Equipment Arr't , Left Mid Station, WA	D	V049-5-006	1
Equipment Arr't , Left End Station, WA	D	V049-5-007	1
Equipment Arr't ISO, Right Mid Station, WA	D	V049-5-010	1
Equipment Arr't ISO, Right End Station, WA	D	V049-5-011	1
Piping Arr't, Plan Corner Station/WA (4 Shts)	D	V049-5-012	1
Piping Arr't, Elevation, Corner Station/WA	D	V049-5-013	1
Piping Arr't, Sections, Corner Station/WA	D	V049-5-014	1
Piping Arr't, Plan, Right Mid Station/WA (4 Shts)	D	V049-5-017	1
Piping Arr't, Elevation, Right Mid Station/WA (2 Shts)	D	V049-5-018	1
Piping Arr't, Sections, Right Mid Station/WA	D	V049-5-019	1
Piping Arr't, Plan, Right End Station/WA (2 Shts)	D	V049-5-021	1
Piping Arr't, Elevation, Right End Station/WA	D	V049-5-022	1
Piping Arr't, Sections, Right End Station/WA	D	V049-5-023	1
Piping Arr't. Plan Left Mid Station/WA (4 Sheets)	D	V049-5-026	1
Piping Arr't Elevation Left Mid Station/WA (2 Sheets)	D	V049-5-027	1
Piping Arr't, Sections, Left Mid Station/WA	D	V049-5-028	1
Piping Arr't. Plan Left End Station/WA (2 Sheets)	D	V049-5-030	1
Piping Arr't Elevation Left End Station/WA	D	V049-5-031	1
Piping Arr't, Sections, Left End Station/WA	D	V049-5-032	1
Overall Flange Arr't, Corner Station, WA	D	V049-5-033	0
Overall Flange Arr't, Mid Station, WA	D	V049-5-035	0
Overall Flange Arr't, Type End Station	D	V049-5-036	0

**SPECIFICATION FOR INSTALLATION/COMMISSIONING**

**ATTACHMENT B**

**TO**

**V049-2-021**

**BUILDING CRANE COVERAGE**

**CRANE DATA SHEET-1**  
**(3-Interferometer Version)**

- |                              |  |
|------------------------------|--|
| 1. Location:                 | LVEA Corner Station  |
| 2. Number Required:          | One (1)  |
| 3. Tag No.:                  | W-CS-103-CR-01   |
| 4. Arrangement:              | Refer to Figures 3   |
| 5. Type:                     | Electric, Single-Girder Under-Running, 3-Runway            |
| 6. Number of Hoists:         | One(1)   |
| 7. Class:                    | CMAA, Class A  |
| 8. Capacity:                 | 5-Ton  |
| 9. Span:                     | 75'-6"   |
| 10. Height of Lift:          | 26'-6", true vertical lift                                 |
| 11. Bridge Travel Speed:     | Variable speed to 100 fpm, maximum                         |
| 12. Trolley Travel Speed:    | Variable speed to 75 fpm, maximum                          |
| 13. Hoisting Speed:          | Variable speed to 15 fpm, maximum                          |
| 14. Runway Rail:             | S 18 x 70 # (see Note below)                               |
| 15. Runway Length:           | 127'-0", approximately                                     |
| 16. Control:                 | Pendant, Traveling Type                                    |
| 17. Electrification:         | Cable festooning or cable reel                             |
| 18. Power Supply:            | 460-Volt, 3-Phase, 60 Hertz                                |
| 19. Environmental Condition: | Indoor, Clean Room, Temperature: 72°F, Humidity:<br>40% RH |
| 20. Interlock With:          | Crane W-CS-102-CR-01                                       |
| 21. Special Requirements:    | Lighting fixtures attached to underside of bridge          |

**NOTE:** "LOUDEN" Rail No. 605.1850 may be used instead the specified.

**CRANE DATA SHEET-1**  
**(3-Interferometer Version)**

- |                              |  |
|------------------------------|--|
| 1. Location:                 | LVBA Corner Station  |
| 2. Number Required:          | One (1)  |
| 3. Tag No.:                  | W-CS-104-CR-01   |
| 4. Arrangement:              | Refer to Figures 3   |
| 5. Type:                     | Electric, Single-Girder Under-Running                      |
| 6. Number of Hoists:         | One(1)   |
| 7. Class:                    | CMAA, Class A  |
| 8. Capacity:                 | 5-Ton  |
| 9. Span:                     | 37'-6"   |
| 10. Height of Lift:          | 26'-6", true vertical lift                                 |
| 11. Bridge Travel Speed:     | Variable speed to 100 fpm, maximum                         |
| 12. Trolley Travel Speed:    | Variable speed to 75 fpm, maximum                          |
| 13. Hoisting Speed:          | Variable speed to 15 fpm, maximum                          |
| 14. Runway Rail:             | S 18 x 70 # (see Note below)                               |
| 15. Runway Length:           | 100'-0", approximately                                     |
| 16. Control:                 | Pendant, Traveling Type                                    |
| 17. Electrification:         | Cable festooning or cable reel                             |
| 18. Power Supply:            | 460-Volt, 3-Phase, 60 Hertz                                |
| 19. Environmental Condition: | Indoor, Clean Room, Temperature: 72°F, Humidity:<br>40% RH |
| 20. Interlock With:          | Crane W-CS-102-CR-01                                       |
| 21. Special Requirements:    | Lighting fixtures attached to underside of bridge          |

**NOTE:** "LOUDEN" Rail No. 605.1850 may be used instead the specified.

**CRANE DATA SHEET-1**  
**(3-Interferometer Version)**

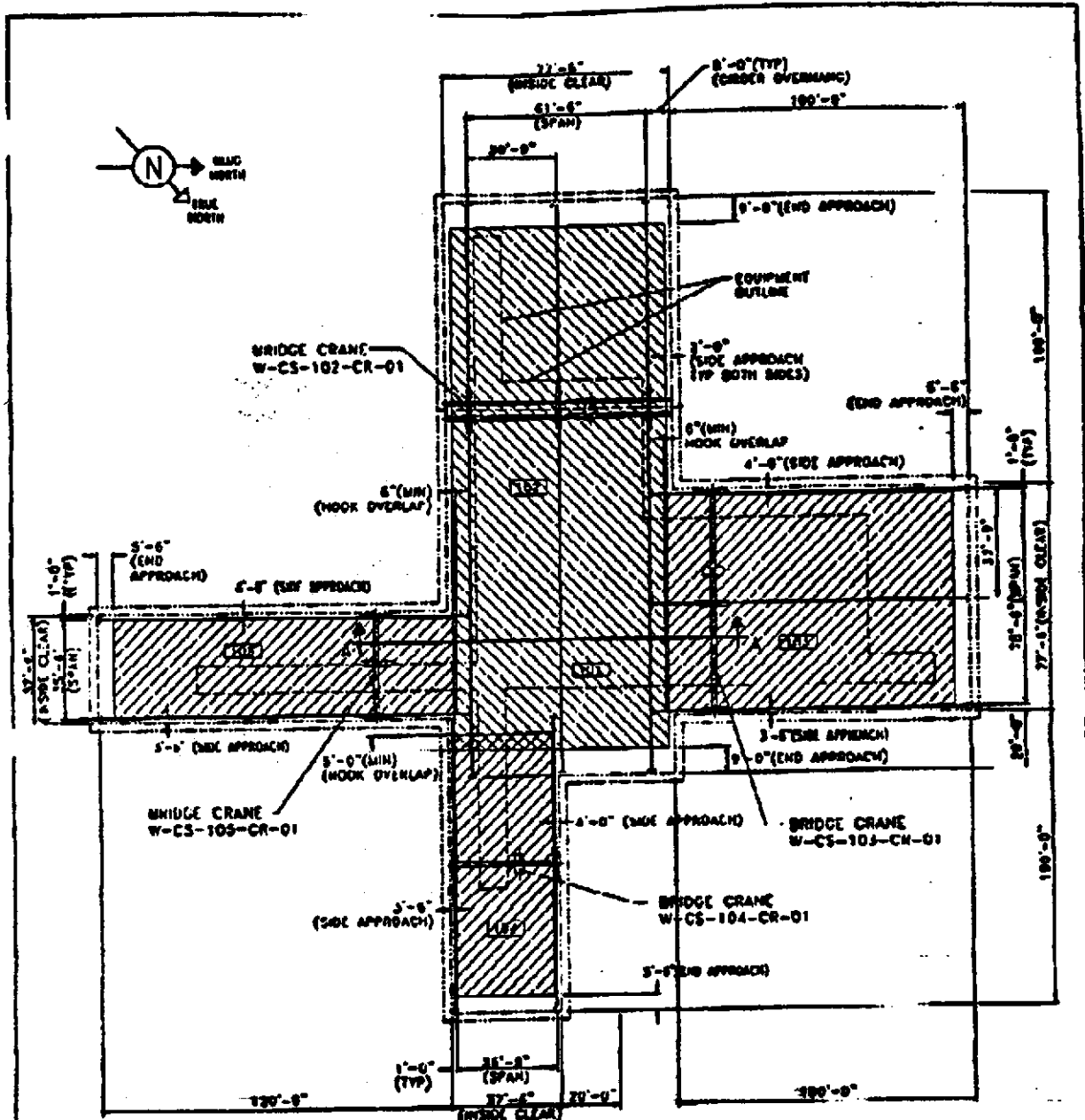
- |                              |  |
|------------------------------|--|
| 1. Location:                 | LVEA Corner Station  |
| 2. Number Required:          | One (1)  |
| 3. Tag No.:                  | W-CS-105-CR-01   |
| 4. Arrangement:              | Refer to Figures 3   |
| 5. Type:                     | Electric, Single-Girder Under-Running                      |
| 6. Number of Hoists:         | One(1)   |
| 7. Class:                    | CMAA, Class A  |
| 8. Capacity:                 | 5-Ton  |
| 9. Span:                     | 35'-6"   |
| 10. Height of Lift:          | 26'-6", true vertical lift                                 |
| 11. Bridge Travel Speed:     | Variable speed to 100 fpm, maximum                         |
| 12. Trolley Travel Speed:    | Variable speed to 75 fpm, maximum                          |
| 13. Hoisting Speed:          | Variable speed to 15 fpm, maximum                          |
| 14. Runway Rail:             | S 18 x 70 # (see Note below)                               |
| 15. Runway Length:           | 127'-0", approximately                                     |
| 16. Control:                 | Pendant, Travelling Type                                   |
| 17. Electrification:         | Cable festooning or cable reel                             |
| 18. Power Supply:            | 460-Volt, 3-Phase, 60 Hertz                                |
| 19. Environmental Condition: | Indoor, Clean Room, Temperature: 72°F, Humidity:<br>40% RH |
| 20. Interlock With:          | Crane W-CS-102-CR-01                                       |
| 21. Special Requirements:    | Lighting fixtures attached to underside of bridge          |

**NOTE:** "LOUDEN" Rail No. 605.1850 may be used instead the specified.

**CRANE DATA SHEET-1**  
**(3-Interferometer Version)**

- |                              |   |
|------------------------------|---|
| 1. Location:                 | LVEA Mid and End Stations   |
| 2. Number Required:          | Four (4)  |
| 3. Tag No.:                  | W-MA-202-CR-01, in Mid Station-A<br>W-MB-202-CR-01, in Mid Station-B<br>W-EA-302-CR-01, in End Station -A<br>W-EB-302-CR-01, in End Station-B |
| 4. Arrangement:              | Refer to Figures 4  |
| 5. Type:                     | Electric, Single-Girder Under-Running   |
| 6. Number of Hoists:         | One(1)  |
| 7. Class:                    | CMAA, Class A   |
| 8. Capacity:                 | 5-Ton   |
| 9. Span:                     | 33'-6"  |
| 10. Height of Lift:          | 26'-6", true vertical lift  |
| 11. Bridge Travel Speed:     | Variable speed to 100 fpm, maximum  |
| 12. Trolley Travel Speed:    | Variable speed to 75 fpm, maximum   |
| 13. Hoisting Speed:          | Variable speed to 15 fpm, maximum   |
| 14. Runway Rail:             | S 18 x 70 # (see Note below)  |
| 15. Runway Length:           | 57'-6", approximately   |
| 16. Control:                 | Pendant, Traveling Type   |
| 17. Electrification:         | Cable festooning or cable reel  |
| 18. Power Supply:            | 460-Volt, 3-Phase, 60 Hertz   |
| 19. Environmental Condition: | Indoor, Clean Room, Temperature: 72°F, Humidity:<br>40% RH  |
| 20. Special Requirements:    | Lighting fixtures attached to underside of bridge   |

**NOTE:** "LOUDEN" Rail No. 605.1850 may be used instead the specified.

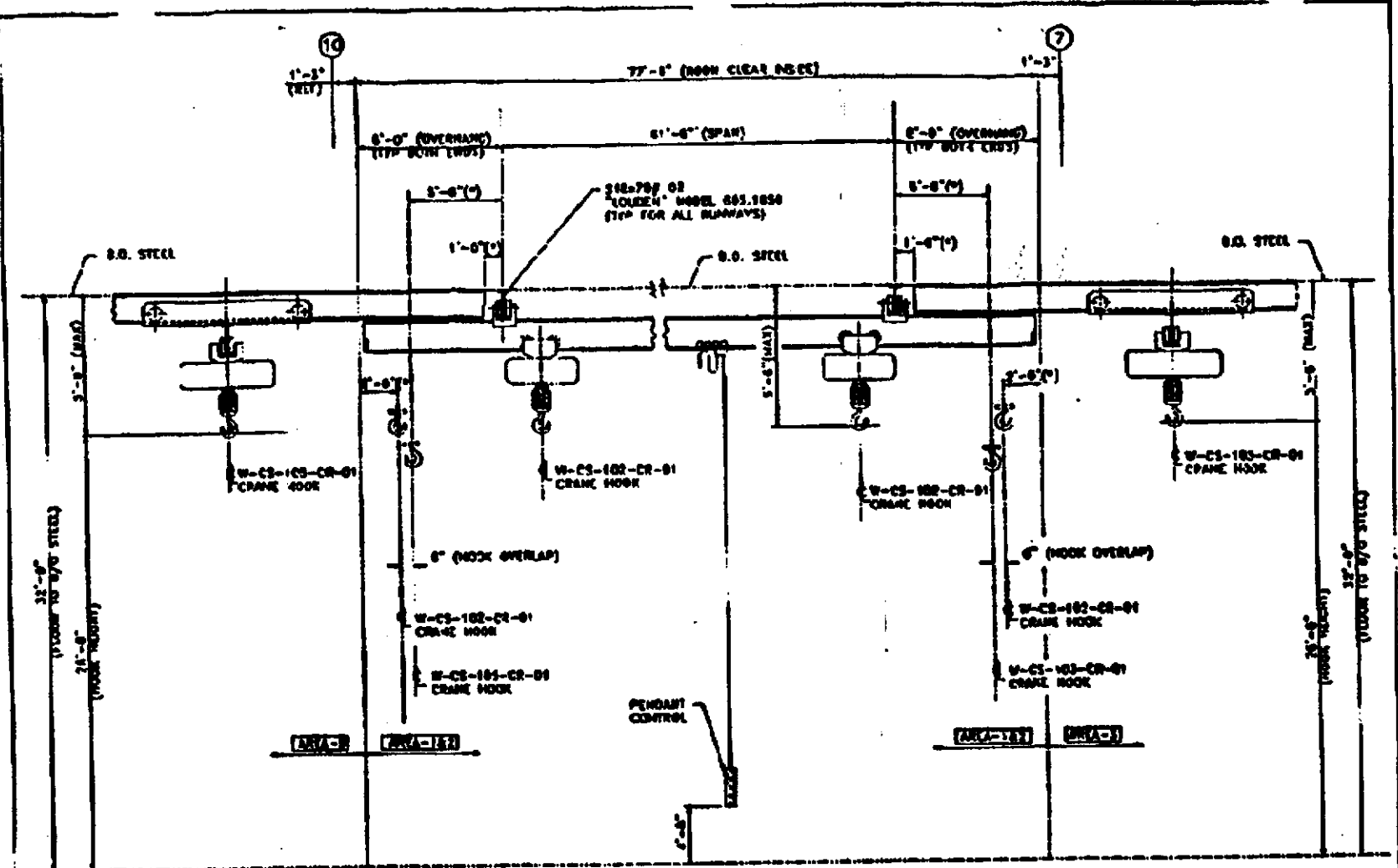


PLAN

- NOTES:  
 1. CROSS-HATCHED AREAS REPRESENT DIFFERENT CRANE HOOK COVERAGE AREAS.  
 2. DIMENSIONS ARE NOMINAL CONTRACTOR SHALL VERIFY ALL BUILDING AND CRANE DIMENSIONS.

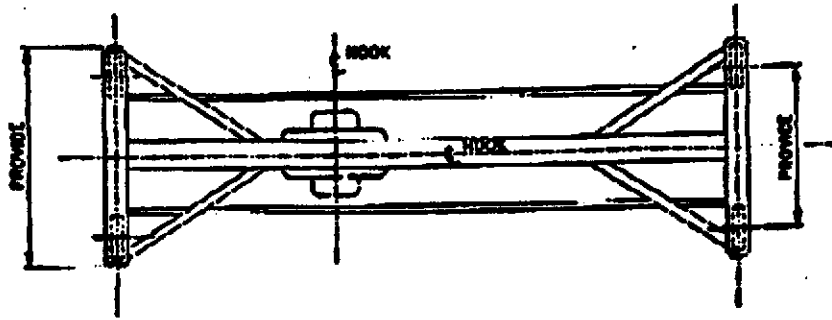
FIGURE 1 - CRANE ARRANGEMENT AND HOOK COVERAGE  
LVEA CORNER STATION  
[3-INTERFEROMETER VERSION]



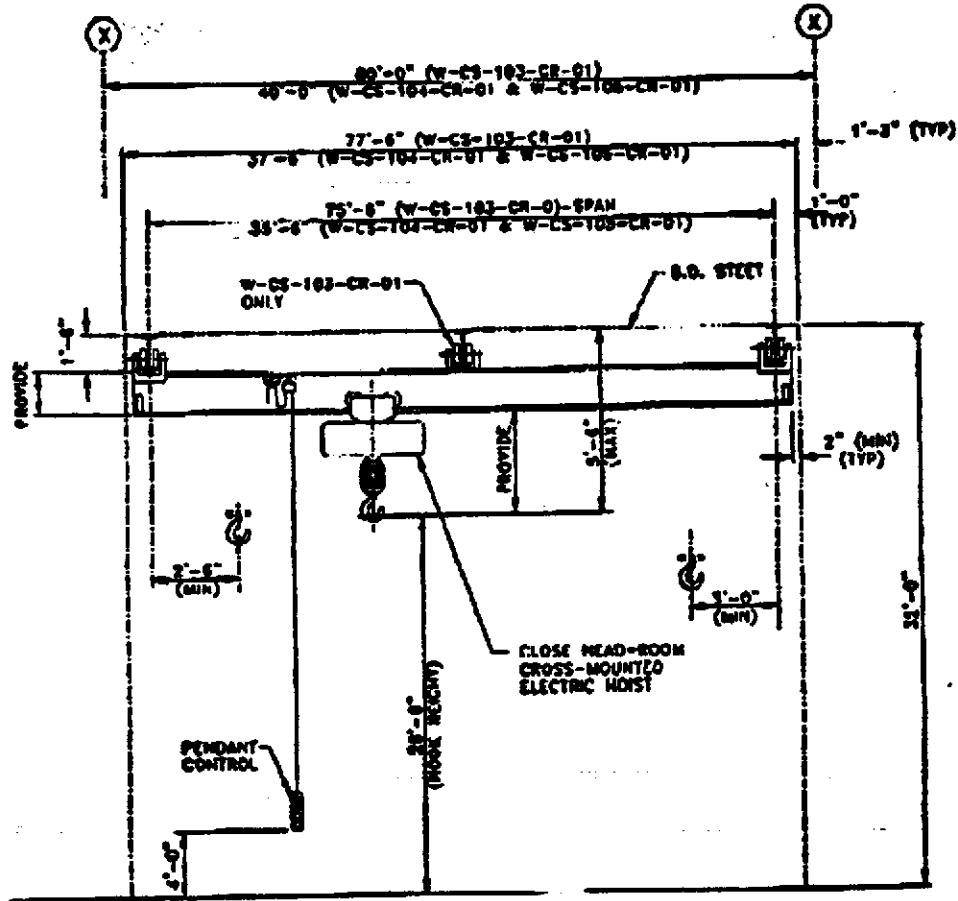


- NOTES:
1. DIMENSIONS ARE NOMINAL. CONTRACTOR SHALL VERIFY ALL BUILDING AND CRANE DIMENSIONS.
  2. DIMENSIONS INDICATED BY ASTERISKS(\*) TO BE ADJUSTED, IF REQUIRED, TO ACHIEVE THE SPECIFIED 6-INCH HOOK OVERLAPS.

FIGURE 2. - CRANE HOOK OVERLAPPING ARRANGEMENT  
LVEA CORNER STATION  
(3-INTERFEROMETER VERSION)



PLAN

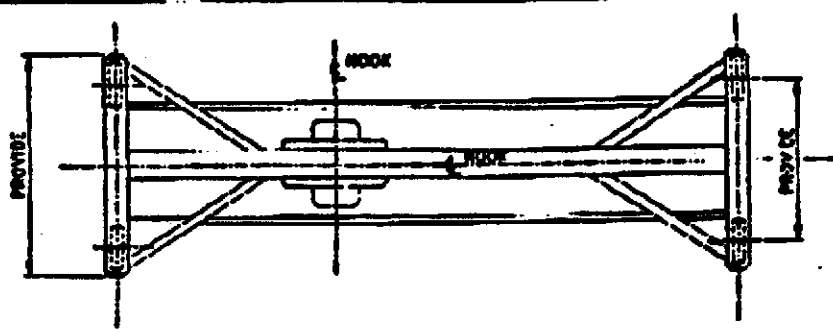


ELEVATION

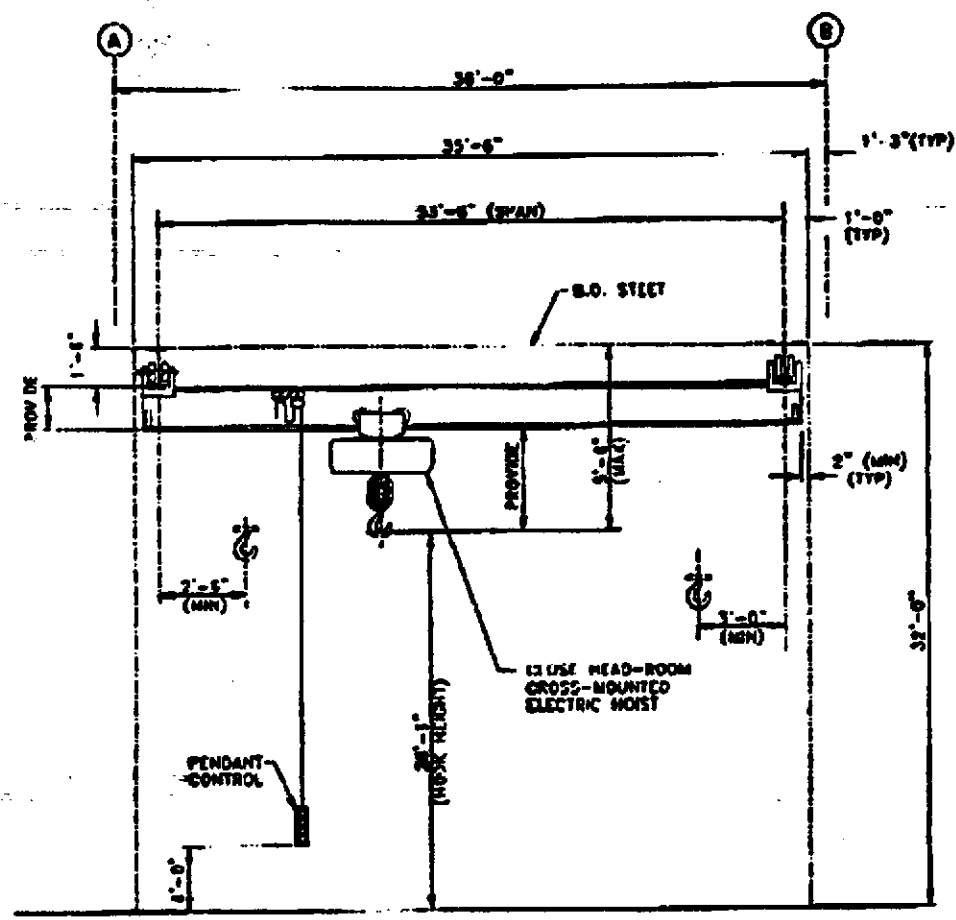
NOTES:

1. DIMENSIONS ARE NOMINAL. CONTRACTOR SHALL VERIFY ALL BUILDING AND CRANE DIMENSIONS.
2. SINGLE-GIRDER CRANE MAY BE WITH OR WITHOUT TRUSSES PROVIDING MEETS THE SPECIFIED DIMENSIONS.

FIGURE 3 - BRIDGE CRANE ARRANGEMENT  
LVEA CORNER STATION  
(3-INTERFEROMETER VERSION)



PLAN



ELEVATION

NOTES:

- 1. DIMENSIONS ARE NOMINAL. CONTRACTOR SHALL VERIFY ALL BUILDING AND CRANE DIMENSIONS.
- 2. SINGLE-GIRDER CRANE MAY BE WITH OR WITHOUT TRUSSES PROVIDING MEETS THE SPECIFIED DIMENSIONS.

FIGURE 4 - BRIDGE CRANE ARRANGEMENT  
LVEA MID & END STATIONS

**ATTACHMENT "C" SPEC. V049-2-021**  
**EQUIPMENT SUPPLIED BY THE BUYER**

**Equipment listed below is supplied by the Buyer for installation by the contractor**

**NOTE: All valves shown on piping Dwgs. or P&ID's are supplied by the Buyer.**

**"X" = Item Tag No., see equipment location plans for building location.**

<b>Item</b>	<b>Description</b>	<b>Qty.</b>	<b>Shipping Weight (lbs.)</b>
WBSCX	Beam Splitter Chamber	10	15,000
WHAMX	Horiz. Access Chamber	13	9,000
WCPX	80K Cryopump - Long	2	9,800
WCPX	80K Cryopump - Short	6	5,800
WIPX	Main Ion Pump (2500 l/s)	12	1,200
WGVX	44" Gate Valve	8	7,200
	(NOTE: (8) 44" gate valves exist installed by others)		
WGVX	48" Gate Valve	4	8,700
WTCX	Turbo Pump Cart	6	1,300
V049-4-012	Base Extension-Turbo Cart	6	500
WRCX	Roughing Pump Cart	2	3,300
V049-4-107	25 l/s Ion Pump Support at Gate Valves	12	50
V049-4-054	75 l/s Ion Pump/Valves-HAM	12	100
V049-4-077	75 l/s Ion Pump/Valves-BSC	10	150
V049-4-078	75 l/s Ion Pump-Support/Manifold	2	150
V049-4-106	25 Annulus Tubing-44" Gate Valve Type III	6	50
V049-4-108	25 Annulus Tubing 48" Gate Valve Type I	2	50
V049-4-109	Annulus Tubing/Ion Pump Assy-44"	8	100
	(NOTE: 8 Installations exist at site installed by others by others)		
V049-3-110	25 Annulus Tubing 48" Gate Valve Type II	2	50
V049-4-164	25 Annulus Tubing 44" Gate Valve Type I	2	50
V049-4-165	25 Annulus Tubing/Ion Pump Assy-48"	4	50
V049-4-166	25 Annulus Tubing 44" Gate Valve Type II	8	50
	6" Gate Valve w/ studs on both sides	4	50
	10" Gate Valve w/ studs on both sides	22	100
	14" Gate Valve w/ studs on both sides	12	350
V049-4-133	Clean Room Assy-BSC	6	5,500
V049-4-136	Clean Room Assy-HAM	1	4,500
Later	Gowning Clean Room	5	1,500

V049-4-043	Pipe Bridge	1	2,000
LWDX	LN <sub>2</sub> Tanks-14,000 Gal.	6	41,000
LWDX	LN <sub>2</sub> Tanks-17,260 Gal.	2	47,000
	Ambient Vaporizer 25,000 SCFH	2	2,200
	Ambient Vaproizer 10,000 SCFH	6	600
	50 CFM Compressor Skid	4	2,000
	200 CFM Compressor Skid	2	6,700

**NOTE:** Also see Attachment K - "Equipment Grouping for Shipping", for quantity, shipping cover size, and est. weight of combined spools as shipped to the site.

**SPECIFICATION FOR INSTALLATION/COMMISSIONING**

**ATTACHMENT D**

**TO**

**V049-2-021**

**ELECTRICAL AND INSTRUMENT CONSTRUCTION WORK V049-2-022**

*SHIPPED LOOK*

**SPECIFICATION FOR INSTALLATION/COMMISSIONING**

**ATTACHMENT E**

**TO**

**V049-2-021**

**FINAL DESIGN REPORT VOLUME IV  
INSTALLATION/COMMISSIONING V049-1-100**

*SHIPPED LOOSE*

**SPECIFICATION FOR INSTALLATION/COMMISSIONING**

**ATTACHMENT F**

**TO**

**V049-2-021**

**PSI DRAWING PACKAGE**

*SHIPPED LOOSE*



**SPECIFICATION FOR INSTALLATION/COMMISSIONING**

**ATTACHMENT G**

**TO**

**V049-2-021**

**LIGO BUILDING DRAWING PACKAGE**

*SHIPPED LOOSE*

**SPECIFICATION FOR INSTALLATION/COMMISSIONING**

**ATTACHMENT H**

**TO**

**V049-2-021**

**VENDOR EQUIPMENT DRAWING PACKAGE**

*SHIPPED LOOSE*

**SPECIFICATION FOR INSTALLATION/COMMISSIONING**

**ATTACHMENT I**

**TO**

**V049-2-021**

**CARBON STEEL SUPPORTS SUPPLIED BY THE BUYER**

<b>Item No.</b>	<b>Description</b>	<b>Qty</b>
1	V0494A7AP37	6
2	V0494A7BP37	6
3	V0494B1P17	12
4	V0494B2AP17	2
5	V0494B2AP18	2
6	V0494B2BP17	2
7	V0494B2BP18	2
8	V0494B3AP17	4
9	V0494B3AP18	4
10	V0494B5AP17	4
11	V0494B5AP18	4
12	V0494B6P7	2
13	V0494B7P7	2
14	V0494B9PR	8
15	V0494B9P13	8
16	V0494BE5P9	4
17	V0494BE6P9	4
18	V0494140	8
19	V0494141	16
20	V0494012	10

**ATTACHMENT "J"**  
**EQUIPMENT GROUPING FOR SHIPPING**

SHT 1 OF 2

**A. Chambers shipped separately:**

All BSC's - see drawings V049-4-102 thru 105 for door/shipping cover configurations.

All HAM's - NOTE: 4 HAMs are shipped with 1 permanent cover and 1 shipping cover

8 HAMs are shipped with 2 shipping covers.

Est. ship wt. of (1) HAM = 9,000 lbs.

**B. The following pieces of equipment will be shipped fully bolted together as listed below:**

These pieces will be shipped on wooden cradles with bolt-on support legs shipped loose for field assembly. See the individual spool drawings to determine the quantity of support legs to be field assembled.

**B.1 Corner Station**

The following spools will be shipped assembled as one piece.

Item	No. & Sz. of Shipping Covers	Est. Total Ship Weight
WA12, B4, B6, A6	(2) 60" shipping covers	6500 lbs
WA12, B4, B7, A6	(2) 60" shipping covers	6500 lbs
WA15, A3	(2) 60" shipping covers	2400 lbs
WA15, A3	(2) 60" shipping covers	2400 lbs
WB-5A	(2) 60" shipping covers	6800 lbs
WBE-3B	(2) 60" shipping covers	2400 lbs
WB-3A	(2) 60" shipping covers	6800 lbs
WBE-3A1	(2) 60" shipping covers	2400 lbs
WB-2A	(2) 60" shipping covers	6800 lbs
WBE-3A2	(2) 60" shipping covers	2400 lbs
WB-2B	(2) 60" shipping covers	6800 lbs
WBE-3A2	(2) 60" shipping covers	2400 lbs
WA1A, BE-4A	(1) 72" x (1) 44" shipping covers	3400 lbs
WCP1 (Long cryopump)	(2) 44" shipping covers	9700 lbs
WA1B, BE-4B	(1) 72" shipping covers	3400 lbs.
WCP2 (Long cryopump)	(2) 44" shipping covers	9700 lbs.
WA13A, B1A, B8A	(1) 72" x (1) 60" shipping covers	7400 lbs.
WA13B, B1B, B8B	(1) 72" x (1) 60" shipping covers	7400 lbs.
WBE-5	(2) 72" shipping covers	9000 lbs.
WBE-6	(2) 72" shipping covers	9000 lbs.
WB-9A	(2) 72" shipping covers	8500 lbs.
WB-9B	(2) 72" shipping covers	8500 lbs.
WBE-2A	(2) 60" shipping covers	1700 lbs.
WBE-2B	(2) 60" shipping covers	1700 lbs.

**ATTACHMENT "J"**  
**EQUIPMENT GROUPING FOR SHIPPING**

SHT 2 OF 2

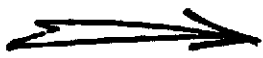
**B.2 Each Mid Station - 2 Required as shown**

<b>Item</b>	<b>No. &amp; Sz. of Shipping Covers</b>	<b>Est. Total Ship Weight</b>
WBE-4	(2) 44" shipping covers	2900 lbs.
Short Cryopump A	(2) 44" shipping covers	5900 lbs.
Short Cryopump B	(2) 44" shipping covers	5900 lbs.
WA1, A-7	(1) 44" X (1) 60" shipping covers	6500 lbs.
WA14, BE-4	(1) 44" X (1) 60" shipping covers	4700 lbs.
BSC	(2) 60" shipping covers	15,000 lbs.

**B.3 Each End Station - 2 Required as shown**

<b>Item</b>	<b>No. &amp; Sz of Shipping Covers</b>	<b>Est. Total Ship Weight</b>
WBE-4	(2) 44" shipping covers	2900 lbs.
Short Cryopump	(2) 44" shipping covers	5900 lbs.
WA1, A-7	(1) 44" X (1) 60" shipping covers	6500 lbs.
BSC	(1) 60" Shipping cover	15,000 lbs.

Title: SPECIFICATION FOR ELECTRICAL & INSTRUMENT CONSTRUCTION WORK



PRELIMINARY

SPECIFICATION

NOT for CONSTRUCTION

FOR

ELECTRICAL & INSTRUMENT CONSTRUCTION WORK

LIGO VACUUM EQUIPMENT

Hanford, Washington

PREPARED BY Daniel J. Parenti  
 ELECTRICAL Fadi Bayl WA REG # 33057  
 QUALITY ASSURANCE CR Baulhoo  
 TECHNICAL DIRECTOR D.A.M. Wilson  
 PROJECT MANAGER Fadi Bayl

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements and shall not be disclosed to any other party.

REV	LTR	BY-DATE	APPD-DATE	DESCRIPTION OF ACTION
1		DP 12/2/96	RES 12/2/96	RELEASED FOR CONSTR. RFG PER DEO 0377
0		DP 4/24/96	RES 4/24/96	Released for Review & comments per DEO 0149

PROCESS SYSTEMS INTERNATIONAL, INC				SPECIFICATION		
INITIAL APPROVALS	PREPARED BY	DATE	APPROVED BY	DATE	Number	Rev
	D. Parenti	4/24/96	RES	4/25/96	A V049-2-022	1

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**GENERAL REQUIREMENTS**

**1 CONSTRUCTION DOCUMENTS**

- 1.1 Specification for Installation/Commissioning V049-2-021
- 1.2 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 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.
- 2.4.2 Provide power, instrument, and control wiring installed in conduit or cable tray; receptacles and equipment connections as indicated. Panelboards and below grade conduits are provided by others unless otherwise indicated.
- 2.4.3 Install gages, switches, electronic transmitters, and other instruments; control cabinets; and other equipment furnished by others (see — ATTACHMENT B: *FURNISHED ELECTRICAL EQUIPMENT LIST*).
- 2.4.4 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.
- 2.4.5 Field Tests
  - Test power wiring for grounds and shorts.
  - Test instrument and control wiring for point-to-point continuity, grounds, and shorts.
  - Check instrument gas and process tubing for leaks.
  - Field Calibrations

**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.

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

3.4 All conflicts shall be brought to the attention of PSI's representative.

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 California Institute of Technology and The US Government

Owner's Persons designated by Owner

Representative

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.

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**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 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 or walls without written acknowledgment from the Owner obtained via PSI's representative. All wall penetrations shall be through wall block-outs provided by others.

7.2 Do not weld supports and equipment to building steel without written acknowledgment from the Owner obtained via 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

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beyond the cataloged product.

- 8.3 Submit proposed substitutions to PSI's representative for acceptance. 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 representative. 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 representative. 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 distribution of power as project needs require.

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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 representative.

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

**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 ladder type trays as indicated; ladder tray with rungs on 12 inch centers unless otherwise indicated.

12.3 MATERIAL: 6063-T6 aluminum

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 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 Submit product data of each cable tray component for review.

12.6.2 Submit shop drawings of support system for review.

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**12.7 INSTALLATION**

- 12.7.1 Support horizontal and vertical trays by each side rail using hold-down clamps to prevent lateral or vertical displacement. Provide support brackets, channels/struts,  $\frac{3}{8}$  inch or larger hanger rods, and fittings to best suit installation (see *SUPPORTS*, Article 22).
- 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 instrument, and control cable tray with vinyl, self-adhesive signs with one inch high lettering or, similarly, with stencil and paint. Lettering shall read *24VDC INSTRUMENT AND CONTROL*.
- 12.7.4 At approximate 10-foot intervals, identify channel tray with high voltage, ion pump wiring with vinyl, self-adhesive signs with one inch high lettering or, similarly, with stencil and paint. Lettering shall read *DANGER—HIGH VOLTAGE*.

**13 CONDUIT SYSTEMS  
(ELECTRICAL RACEWAY OF CIRCULAR CROSS SECTION)**

- 13.1 INTERMEDIATE METAL CONDUIT (IMC): Galvanized IMC conforming to UL 1242 standard may be provided as indicated on drawings..
- 13.2 ELECTRICAL METALLIC TUBING (EMT): At indoor locations, EMT conforming to ANSI C80.3 and UL 797 standards may be provided as indicated on drawings.
- 13.3 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.
- 13.4 ACCESSORIES:
- 13.4.1 Provide fittings to best suit each application.
- 13.4.2 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. Where conduit system is discontinuous, provide bonding jumper, #12 of larger conductor.
- 13.5 INSTALLATION:
- 13.5.1 Restrictions: Where practicable, keep instrument wiring at least 12 inches away from other wiring and minimize paralleling instrument wiring with power or control wiring.
- 13.5.2 Arrangement: Make raceway offsets and bends symmetrically and uniformly.
- 13.5.3 Supports:
- Fasten conduits to building with one-hole malleable iron conduit clamps with screw or bolt.

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- 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 1-1/2 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.

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

13.5.5 Terminating conduits:

- Attach 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.

13.5.6 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.
- Connect to instruments with 18 to 30 inches of FMC.

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

13.5.8 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 galvanized or finished with gray baked enamel boxes with screw-on covers unless otherwise required.
- 14.1.2 Where applicable, provide 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 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.

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**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 gaskets.

**14.4 WIREWAYS AND AUXILIARY GUTTERS:**

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

14.4.2 Where applicable, provide 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 with indelible felt tipped marker pen or as specified under wiring systems.
- Provide supports as specified under *SUPPORTS*, Article 22.
- When not accessing, close equipment to prevent rain, dirt, and debris from entering.

14.6.2 Wireway and gutters: Where wireway or gutter is discontinuous, bond each section 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

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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 #18 AWG single pair and #20 AWG multipair ANSI type (as indicated), solid thermocouple extension cable shielded, rated 105°C, 300 volts unless otherwise indicated.

**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** Install wiring without splices.

**15.6.3** Simultaneously install conductors and multiconductor cables which occupy same conduit .

**15.6.4** Only cable manufacturer approved pulling lubricant shall be used.

**15.6.5** Use woven cable grips.

**15.6.6** Do not to exceed manufacturer's recommended pulling tension and cable bending radius.

**15.6.7** 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. Do not 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:

<u>Line</u>	<u>208/120V</u>	<u>480/277V</u>
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.

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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-bolt 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.

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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.

**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 (Design: 200PSI @ -20F - +150F).

20.2 **PROCESS TUBING:** Provide 3/8 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 Set equipment in place and bolt free standing equipment to floor as specified under *SUPPORTS*, Article 22.

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 in electrical boxes 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.

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- 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 1/2 inch or larger bolts. Provide drilled concrete anchors where applicable.
- 22.6 Secure surface-mounted panels and cabinets weighing 75lbs. or less with at least four 1/2 inch or larger toggle 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 per PSI's representative.

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- 23.6 **RECEPTACLES TESTING:** PSI will test polarity and grounding of each receptacle device used with equipment furnished under this Work. Where necessary, correct circuit connections per PSI's representative.
- 23.7 **INSTRUMENT GAS AND PROCESS TUBING TESTING:**
  - 23.7.1 Check tubing and connectors for leaks.
  - 23.7.2 PSI will 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 Make electrical and pneumatic repairs as necessary and retest.
- 23.9 **CALIBRATION:**
  - 23.9.1 Calibrate instrumentation as required.
- 23.10 **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.

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**ATTACHMENT "A"**  
**DRAWING LISTS**

<u>DRAWING</u>	<u>DESCRIPTION</u>
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
V049-3-110	CABLE TRAY DETAILS-CORNER STATION
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
V049-3-120	DISTRIBUTION SYSTEM FEEDER SCHEDULE
V049-3-123	CDS INTERFACE DIAGRAM—CORNER STATION
V049-3-124	CONDUIT STUB-UP PLAN—CORNER STATION
V049-3-125	VACUUM CART INTERFACE PLAN—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

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<u>DRAWING</u>	<u>DESCRIPTION</u>
V049-3-130	DATA HIGHWAY PLAN— DIAGONAL STATION
V049-3-131	DATA HIGHWAY INTERCONNECT DIAGRAM— CORNER STATION
V049-3-133	GROUNDING PLAN - VERTEX SECTION
V049-3-134	GROUNDING PLAN - LEFT BEAM MANIFOLD
V049-3-135	GROUNDING PLAN - RIGHT BEAM MANIFOLD
V049-3-136	GROUNDING PLAN - DIAGONAL SECTION
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
V049-3-205	CONDUIT STUB-UP PLAN - LEFT MID STATION
V049-3-206	VACUUM CART INTERFACE PLAN—LEFT MID STATION
V049-3-208	CDS INTERFACE DIAGRAM—LEFT MID STATION
V049-3-209	GROUNDING PLAN—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
V049-3-308	CDS INTERFACE DIAGRAM—RIGHT MID STATION
V049-3-309	GROUNDING PLAN—RIGHT MID STATION
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
V049-3-405	CONDUIT STUB-UP PLAN - LEFT END STATION

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<u>DRAWING</u>	<u>DESCRIPTION</u>
V049-3-406	VACUUM CART INTERFACE PLAN—LEFT END STATION
V049-3-408	CDS INTERFACE DIAGRAM—LEFT END STATION
V049-3-409	GROUNDING PLAN—LEFT END STATION
V049-3-501	INSTRUMENT PLAN—RIGHT END STATION
V049-3-502	CABLE TRAY PLAN—RIGHT END STATION
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	GROUNDING PLAN—RIGHT END STATION

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<b>DRAWING</b>	<b>DESCRIPTION</b>
V049-3-001	GENERAL NOTES & LEGEND
V049-3-006	ELECTRICAL INSTALLATION DETAILS
V049-3-007	INSTRUMENT ELECTRICAL INSTALLATION DETAILS
V049-3-008	INSTRUMENT INSTALLATION DETAILS
V049-3-009	GROUNDING DETAILS

**REFERENCE DRAWING LIST**

<b>DRAWING</b>	<b>DESCRIPTION</b>
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

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

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**ATTACHMENT "B"**  
**FURNISHED ELECTRICAL EQUIPMENT LIST**

☞ 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.

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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, 102A, 102B	—	CRYOPUMP WCP1 THERMOCOUPLE (V049-3-102)
40	TE-153A, 152A, 152B	—	CRYOPUMP WCP2 THERMOCOUPLE (V049-3-103)
41	TE-203A, 202A, 202B	—	CRYOPUMP WCP3 THERMOCOUPLE (V049-3-201)
42	TE-253A, 252A, 252B	—	CRYOPUMP WCP4 THERMOCOUPLE (V049-3-201)
43	TE-303A, 302A, 302B	—	CRYOPUMP WCP5 THERMOCOUPLE (V049-3-301)

\* Furnished with accessories

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ITEM		INSTRUMENT TAG/EQUIPMENT DESIGNATION	
		V INDICATES VACUUM ENVIRONMENT LOCATION	
		DESCRIPTION (INDICATED ON DRAWING/SHEET)	
44	TE-353A, 352A, 352B	—	CRYOPUMP WCP6 THERMOCOUPLE (V049-3-301)
45	TE-403A, 402A, 402B	—	CRYOPUMP WCP7 THERMOCOUPLE (V049-3-401)
46	TE-503A, 502A, 502B	—	CRYOPUMP WCP8 THERMOCOUPLE (V049-3-501)

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**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 PSI's representative for acceptance. 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)

Product data of each cable tray component.  
Shop drawings of support systems.

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

Product data of each wire and cable.

5. Wiring identification (Article 16.3, page 12)

Product data of printed sleeve markers.

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

Product data of tubing and accessories.

7. Testing (Article 23.3.2, page 14)

- Written test report listing resistance by feeder and branch circuit.

**ATTACHMENT "C"**

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Title: PROJECT SAFETY PLAN

PROJECT SAFETY PLAN  
FOR  
LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

QUALITY ASSURANCE:

Alan L. Bradbrook

LIGO SAFETY OFFICER:

Janet M. Egan

PROJECT MANAGER:

Richard B. Bayly

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	D.m.c.w	R2B 11/15/96	RELEASED PER DEC 351
Ø	4/24/96		RELEASED PER DEC 137
PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION
INITIAL APPROVALS	PREPARED	DATE	APPROVED DATE
	NLS	25 APR 96	R2B 4/24/96
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# PROJECT SAFETY PLAN

## TABLE OF CONTENTS

- 1.0 Purpose
- 2.0 Scope
- 3.0 Applicable Documents
- 4.0 Plan Maintenance
- 5.0 Safety Philosophy
- 6.0 Safety Objections
- 7.0 Maintenance of Safety Controls
- 8.0 Site Safety Plan

## ATTACHMENTS

- 1. PSI Safety Manual

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## PROJECT SAFETY PLAN

### 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.

All facility and site managers report to the PSI president located in the Westbrough, MA facility.

Each PSI facility and site manager is responsible for safety at their location.

### 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.

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**PROJECT SAFETY PLAN**

**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.

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- 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. Each 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. Each PSI facility maintains its own safety committee.

- a. Each PSI facility and 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.

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# PROJECT SAFETY PLAN

- b. Supervisors/Team Leaders are responsible for assuring safe workmanship practices, including training, certification and qualification of personnel to approved training requirements. Supervisor/operators are trained in equipment operation (i.e. crane, forklift, welding) as well as general fabrication safety.
- 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 or to the LIGO safety officer 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 "as needed" basis and as a minimum monthly. Meeting minutes (with assigned action items) are issued to all supervisors and the PSI president.

## 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.

Subcontractor safety plans are evaluated based on OSHA requirements and the requirements of PSI's safety program.

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<b>SPECIFICATION</b>		
Number	A	V049-2-023
		Rev. 1

Title: SPECIFICATION FOR QUALITY ASSURANCE PLAN

SPECIFICATION FOR  
PROJECT QUALITY ASSURANCE PLAN  
FOR  
LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

MANUFACTURING ENGINEER:

Phillip F. Lewis

QUALITY ASSURANCE:

Alan L. Bradbrook

TECHNICAL DIRECTOR:

D. A. McWilliam

PROJECT MANAGER:

Richard Bayly

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

1	DMWJHIS	REB 11/15/95	RELEASED PER DED 351
Ø	4/24/96		RELEASED PER DEG 137
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
<b>PROCESS SYSTEMS INTERNATIONAL, INC.</b>			<b>SPECIFICATION</b>
INITIAL APPROVALS	PREPARED ALB	DATE 4-29-96	APPROVED DATE REB 4/24/96
			Number A V049-2-029
			Rev. 1

**Title**

**SPECIFICATION FOR PROJECT QUALITY ASSURANCE PLAN**

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- 1.0 Purpose
- 2.0 General
- 3.0 Responsibilities
- 4.0 Procedure

**ATTACHMENTS**

- 1. Final Document Summary Form

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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.

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**SPECIFICATION FOR PROJECT QUALITY ASSURANCE PLAN**

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.

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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.

For PSI fabricated equipment, the final documentation summary sheet shall indicate the drawing revisions which fabricated the component.

For purchased components, the purchase order indicates the revision level of procurement documents.

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.

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**SPECIFICATION FOR PROJECT QUALITY ASSURANCE PLAN**

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.

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Title

# SPECIFICATION FOR PROJECT QUALITY ASSURANCE PLAN

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:   | _____ | _____      |

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Title: SPECIFICATION FOR QUALITY ASSURANCE PLAN

SPECIFICATION FOR  
PROJECT QUALITY ASSURANCE PLAN  
FOR  
LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

MANUFACTURING ENGINEER:

Phillip F. ...

QUALITY ASSURANCE:

Alan L. Bradbrook

TECHNICAL DIRECTOR:

D. A. M. ...

PROJECT MANAGER:

Richard Bayly

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	DMW/MS	REB 11/15/95	RELEASED PER DED 351
Ø	4/24/96		RELEASED PER DEG 137

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION		
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	NumberA	Rev.
	ALB	4-24-96	REB	4/24/96	V049-2-029	1

Title

**SPECIFICATION FOR PROJECT QUALITY ASSURANCE PLAN**

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- 2.0 General
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- 4.0 Procedure

**ATTACHMENTS**

- 1. Final Document Summary Form

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**1**

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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.

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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.

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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.

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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.

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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.

For PSI fabricated equipment, the final documentation summary sheet shall indicate the drawing revisions which fabricated the component.

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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.

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**Title**

**SPECIFICATION FOR PROJECT QUALITY ASSURANCE PLAN**

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.

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Title

# SPECIFICATION FOR PROJECT QUALITY ASSURANCE PLAN

Attachment 1  
V049-2-029

## LIGO VACUUM EQUIPMENT FINAL DOCUMENTATION SUMMARY

Component

Date:

Model No.:

Prepared By:

Serial No.:

- |    |                               |       |      |       |
|----|-------------------------------|-------|------|-------|
| 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:   | _____ |      | _____ |

Notes:

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Title:

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**SPECIFICATION FOR  
PIPING DESIGN AND MATERIAL**

**FOR  
LIGO VACUUM EQUIPMENT**

Hanford, Washington  
And  
Livingston, Louisiana

PROCESS ENGINEER: Robert Tran

PROJECT ENGINEER: A. Moten

CIVIL/STRUC. ENGINEER: R. D. Curtis

MANUFACTURING ENGINEER: Phillip F. ...

QUALITY ASSURANCE ENGINEER: Alan ...

PROJECT MANAGER: Mark ...

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
4	RCE 11/27/96	D.M.W 11-28	REVISED T3 CLASS, MAT'L TO BE 304 3/8, IT WAS 304L. DEO 0369
3	BYM 10/16/96	D.M.W 10-17-96	Added "C2" Spec. sh for cryogenic copper lines. REVISED 181-FLANGES DEO # 317
2	RCE 8/24/96	PHN/DEB 8/28/96	REVISED "T4" SPEC. SH7.17, 178MS. DEO. 249 RELEASED FOR PURCHASE
1	RCE 7/25/96	PHN 8/15/96	REVISED "T4" SPEC. SH7.17 RELEASED FOR PURCHASE DEO # 0236
0	RCE 1-19-96	D.M.W	RELEASED FOR DESIGN & QUOTES DEO # 0094

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION		
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	R. Curtis	1-11-96	D.M.W	1-18-96	AV049-2-037	4

**Title:**

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

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1.0	SCOPE
2.0	CODES AND STANDARDS
3.0	MATERIAL/MANUFACTURING REQUIREMENTS
4.0	EXAMINATION AND TESTING
5.0	LINE NUMBER SYSTEM
6.0	VALVE AND INSTRUMENT NUMBERING SYSTEM
7.0	PIPING DESIGN AND MATERIAL SPECIFICATIONS
1B1	150# CLASS STAINLESS STEEL 304 - CRYOGENIC
1B2	150# CLASS STAINLESS STEEL 304 - NON-CRYOGENIC
C2	TYPE "L" COPPER TUBING - GENERAL NON-CRYOGENIC
T1	316 STAINLESS STEEL TUBING - CRYOGENIC
T2	304 STAINLESS STEEL TUBING - GENERAL NON-CRYOGENIC
T3	304 STAINLESS STEEL TUBING - VACUUM
T4	304L STAINLESS STEEL TUBING - ULTRA HIGH VACUUM
T5	304L STAINLESS STEEL TUBING - CLASS 100 CLEAN AIR
VJ	304 STAINLESS STEEL - CRYOGENIC VACUUM JACKETED SEE SPEC. V049-2-016
C1	TYPE "L" COPPER TUBING - CRYOGENIC

ATTACHMENT A

LIGO QUALITY ASSURANCE SUMMARY

**SPECIFICATION**

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**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**1.0 SCOPE**

The following piping and material specifications define the piping and fittings to be used for the LIGO Vacuum Equipment.

**2.0 CODES AND STANDARDS**

**2.1 Priority of Codes and Standards**

Priority of documents shall be as follows:

1. Codes (highest priority)
2. This specification

**2.2 Applicable Codes and Standards**

ANSI - American National Standards Institute

- B31.3 Chemical Plant and Petroleum Refinery Piping (for process piping only)
- B31.5 Refrigeration Piping
- B36.19 Stainless Steel Pipe
- B16.5 Pipe Flanges and Flange Fittings

ASTM - American Society of Testing and Materials

- A380-88 Standard Practice for Cleaning and Descaling Stainless Steel
- E427-71(81) Standard Practice for Testing for Leaks Using the Halogen Leak Detector
- E493-73(80) Standard Practice for Testing for Leaks Using the Mass Spectrometer Leak Detector in the inside-Out Testing Mode
- E498-73(80) Standard Test Method for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode
- E499-73(80) Standard Methods of Testing for Leaks Using the Mass Spectrometer Leak Detector Probe Mode

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Title

# SPECIFICATION FOR PIPING DESIGN AND MATERIAL

## 2.3 Specification Compliance

The equipment shall comply with any drawings, data sheets, specifications, codes and standards (latest editions) referred to or attached as part of this specification. State or local codes or regulations, if applicable, will be provided as an attachment to this specification. The Vendor is responsible for compliance with such standards, specifications, codes and regulations, if attached.

## 3.0 MATERIAL/MANUFACTURING REQUIREMENTS

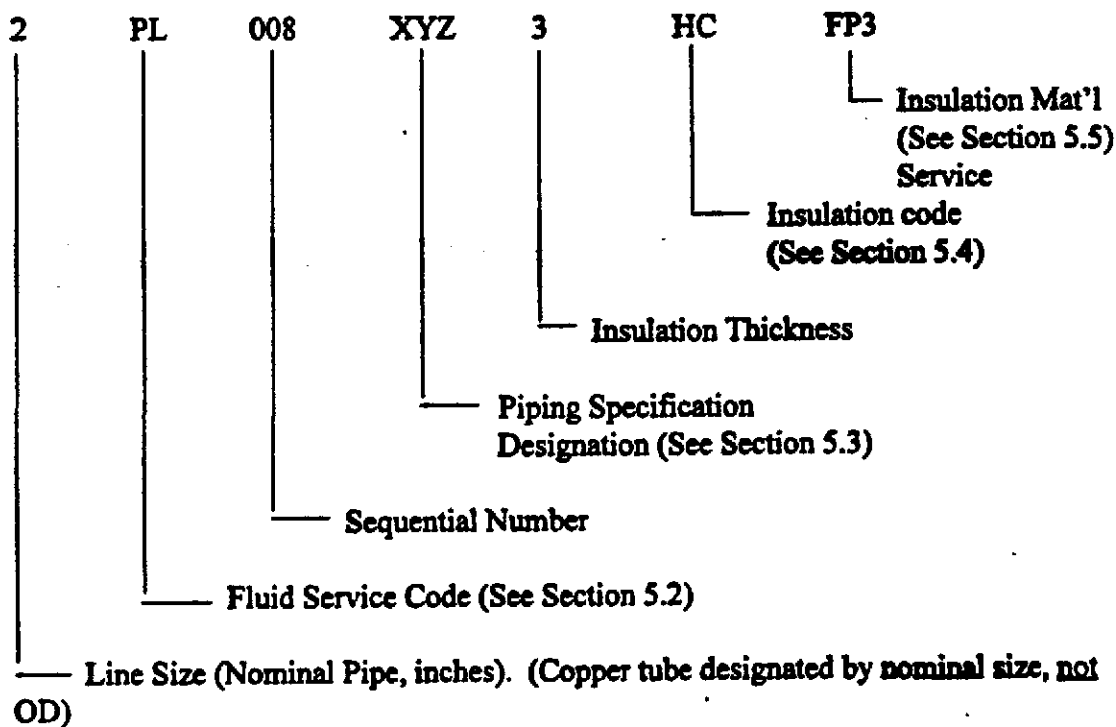
3.1 All materials used to manufacture the piping, tubing, flanges or fittings, as designated per this specification, are to be of U.S.A. origin and manufacture.

## 4.0 EXAMINATION AND TESTING

Examination and Pressure Testing as required by ANSI B31.3-1990 Chapter VI.

## 5.0 LINE NUMBER SYSTEM

4.1 Lines shall be numbered according to the following chart:



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# SPECIFICATION FOR PIPING DESIGN AND MATERIAL

## 5.2 Fluid Codes

<u>Code</u>	<u>Fluid</u>
IA	Instrument Air
CA	Class 100 Clean Air
CWS	Cooling Water Supply
CWR	Cooling Water Return
NGS	Natural Gas Supply
LN2	Liquid Nitrogen
GN2	Gaseous Nitrogen
PV	Process Vacuum
PUV	Process Ultra High Vacuum
VA	Vent and Relief To ATM
N2	Nitrogen Gas
N	Nitrogen (Either Gas or Liquid)

## 5.3 Piping Specification Designation

### 4.4.1 "X" First Digit Identifiers

1 = 150 # ANSI

### 4.4.2 "Y" Second Digit Identifiers

A = 6061 T6 Aluminum  
 B = 304 Stainless Steel  
 C = Type L Copper Tubing  
 T = Stainless Steel Tubing

### 4.4.3 "Z" Third Digit Identifiers

1 = Cryogenic  
 2 = Non-Cryogenic  
 3 = Vacuum  
 4 = Ultra High Vacuum  
 5 = Class 100 Clean Air

## 5.4 Insulation Service

<u>Insulation Symbol</u>	<u>Insulation Service</u>
HC	Hot and Cold
C	Cold Conservation
PC	Personnel Protection COLD
PH	Personnel Protection HOT
VJ	Vacuum Jacketed

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Number **A** V049-2-037

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# SPECIFICATION FOR PIPING DESIGN AND MATERIAL

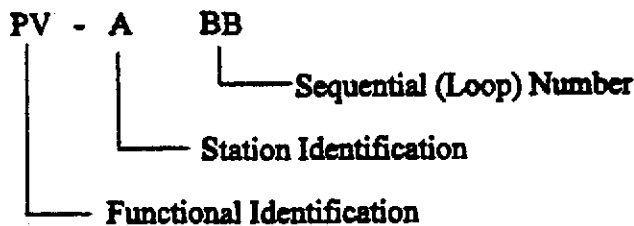
## 5.5 Insulation Material Codes

FP3	1" Fiberglass Inner	2" Polyisocyanurate Outer
FP3.5	1" Fiberglass Inner	2 1/2" Polyisocyanurate Outer
FP4	1" Fiberglass Inner	3" Polyisocyanurate Outer

If no insulation material code appears in the line number then it shall be understood that no insulation is required.

## 6.0 VALVE AND INSTRUMENT NUMBER SYSTEM

Control valves, manual valves and associated instruments shall be designated according to P&ID Drawing Symbols. If the required designation is not specified on the drawing, then ISA-S5.1, Table 1 will take precedence.



Manual valves that do not carry an instrument loop numbers (described above) shall be assigned one of the following valve type descriptions, preceded by the valve size in inches.

Type	Description
GVHV	Gate Valve, High Vacuum, SS, Viton Seals, Handwheel or Lever, CF Conn.
GVUH	Gate Valve, Ultra High Vacuum, SS, Viton Seals, Handwheel, CF Conn.
AVHV	Angle Valve, High Vacuum, SS, Viton Seals, Handwheel, ISOKF or K Conn.
AVUV	Angle Valve, Ultra High Vacuum, SS, Metal Seals, Handwheel, CF Conn.
IRV	Instrument Root Valve, SS
VJV	Vacuum Jacketed Valve, SS
BVCR	Ball Valve, Cryogenic, SS, 3 Piece
BVCA	Ball Valve, Class 100 Clean Air, SS, 3 Piece
GLV	Globe Valve
BVU	Ball Valve, Utility, Brass or Bronze
VSOV	Vacuum Seal-Off Valve, SS
VSOO	Vacuum Seal-Off Valve Operator, SS

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## SPECIFICATION

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Title

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

VSOV Vacuum Seal-Off Valve, SS  
VSOO Vacuum Seal-Off Valve Operator, SS

**IB1**

**PIPING DESIGN AND MATERIAL SPECIFICATION**

**Service:** Cryogenic  
**Primary Rating:** 150# ANSI 304 SSTL

**Design Conditions:**  
Pressure 0 to 192 psig  
Temperature -320°F to 350°F  
Corrosion Allowance Zero

**Pipe:**  
12" and smaller ASTM A312 TP304

**Pipe Schedule:**  
1 1/2" and smaller Schedule 10S SMLS  
8" and smaller Schedule 10S SMLS or EFW  
10" thru 12" Schedule 10S EFW

**Note:** Vacuum jacketed piping will be designed and fabricated in accordance with the manufacturer's standard, and PSI spec. V049-2-016.

**Fittings:**  
1 1/2" and smaller Socket Welded 3000#  
2" and larger Butt Weld  
ASTM A403 WP304 WPS, WPW  
O'Let's ASTM A182-F304

**Flanges:** Not allowed, except on atmospheric vent lines as indicated on P&ID's.

**Valves:** Valves shall be furnished under their own unique specification.

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Title

# SPECIFICATION FOR PIPING DESIGN AND MATERIAL

1B1

## Branch Connections:

Run Size"													
½	04												04 - Tee
¾	06	04											05 - Sockolet
1	12	06	04										06 - Tee Then
1½	05	05	06	04									Reducer or
2	05	05	06	06	04								Reducing Tee
3	05	05	05	05	06	04							12 - BW O'let
4	05	05	05	05	12	06	04						
6	05	05	05	05	12	12	06	04					
8	05	05	05	05	12	12	12	06	04				
10	05	05	05	05	12	12	12	12	06	04			
12	05	05	05	05	12	12	12	12	12	06	04		
Branch Size	½	¾	1	1½	2	3	4	6	8	10	12		

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Title

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**1B2**

**PIPING DESIGN AND MATERIAL SPECIFICATION**

**Service:** Non-Cryogenic - Clean

**Primary Rating:** 150# ANSI 304 SSTL

**Design Conditions:**  
Pressure 0 to 192 psig  
Temperature -20>°F to 350°F  
Corrosion Allowance Zero

**Pipe:**  
12" and smaller ASTM A312 TP304

**Pipe Schedule:**  
1 1/2" and smaller Schedule 10S SMLS  
8" and smaller Schedule 10S SMLS or EFW  
10" thru 12" Schedule 10S EFW

**Fittings:**  
1 1/2" and smaller Socket Welded 3000#  
2" and larger Butt Weld  
ASTM A403 WP304 WPS, WPW  
Elbow O'Let ASTM A182-F304

**Flanges:** 2" and larger ANSI 150# RF, ASTM A182 F304, Weldneck with o-ring gaskets.

**Gaskets:** O-ring, Viton non-lubricated, cleaned and sealed for shipment.

**Valves:** Valves shall be furnished under their own unique specification.

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Title

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**1B2**

**Branch Connections:**

Run Size"												
1/2	04											04 - Tee
3/4	06	04										05 - Sockolet
1	12	06	04									06 - Tee Then
1 1/2	05	05	06	04								Reducer or
2	05	05	06	06	04							Reducing Tee
3	05	05	05	05	06	04						12 - BW O'let
4	05	05	05	05	12	06	04					
6	05	05	05	05	12	12	06	04				
8	05	05	05	05	12	12	12	06	04			
10	05	05	05	05	12	12	12	12	06	04		
12	05	05	05	05	12	12	12	12	12	06	04	
Branch Size	1/2	3/4	1	1 1/2	2	3	4	6	8	10	12	

**Note:**

1. Piping and fittings to be internally cleaned, dried and ends sealed during shipping, storing and installation.
2. ID of pipe and fittings to be free of hydrocarbon contamination, or dirt, of any kind.
3. Surface finish to be standard white pickled ID and O.D.
4. Tube Bending - The following is not allowed: Sand packing, Mechanical scratches on tube I.D., Any type of lubricant.
5. Material manufactures certificate of compliance to applicable ASTM specifications are required and must accompany shipment.
6. Tubing, flanges and fittings to be etched or stamped with manufacturers name, part number and material type.

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Title

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**C2**

**PIPING DESIGN AND MATERIAL SPECIFICATION**

**Service:** Gaseous Nitrogen, Cooling Water, Instrument Air

**Design Conditions:**

Pressure 200 PSIG  
Temperature -20°F to 150°F  
Corrosion Allowance Zero

**Tube:** All sizes Type "L" Copper - Hard Drawn ASTM B88, B280, Copper Tube designated by its Nominal sizes, not OD on P&ID's and piping drawings..

**Note:** Copper tube and fittings are to be specified on PSI BOM's by the actual O.D. of the tube.

**Fittings:** All sizes Wrought Copper ASTM B75  
All Fittings to be female solder cup ends.  
Brass Parker CPI tube fittings (or equal).

**Unions:** 1/4" to 1" Brass Parker CPI tube fittings (or equal) may also be used.

**Valves:** Valves shall be furnished under their own unique specification.

**Soldering:** All joints in wrought copper fittings shall be soldered using 95-5 Tin-Antimony.

**Notes:**

1. Tubing is to be internally cleaned and the ends sealed during shipping, storing and installation. Spools are to have all flux residue, grit, splatters or dirt removed before installation.
2. Fittings are to be cleaned after manufacturing and sealed in plastic during shipping, storing and installation.

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Title

# SPECIFICATION FOR PIPING DESIGN AND MATERIAL

T1

## PIPING DESIGN AND MATERIAL SPECIFICATION

**Service:** Cryogenic

**Design Conditions:**

Pressure	0 to 300 psig
Temperature	-320°F to 350°F
Corrosion Allowance	Zero

**Tube:**

All sizes	ASTM A269 GR 304L SMLS Tube sizes designated by OD dimensions.
-----------	---

<b>Tube Size (OD):</b>	<b>Minimum Wall Thickness (Inches)</b>
------------------------	--

1/4"	0.035"
3/8"	0.035"
1/2"	0.049"
3/4"	0.049"
1"	0.065"

**Fittings:** All Fittings to be Parker Weld tube fittings SA479 or ASTM A276 GR TP316 and ASTM A182 GR TP316, or equal.

**Valves:** Valves shall be furnished under their own unique specification.

**Note:**

1. Tubing to be internally cleaned, dried and ends sealed during shipping, storing and installation. Tube ID to be free of hydrocarbon contamination.
2. Fittings to be cleaned after manufacturing and sealed in plastic bags during shipping, storing and installation.
3. Tubing surface finish to be standard white pickled I.D. & O.D.

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### SPECIFICATION

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Title

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**T2**

**PIPING DESIGN AND MATERIAL SPECIFICATION**

**Service:** Non-Cryogenic

**Design Conditions:**

Pressure	0 to 300 psig
Temperature	-20°F to 350°F
Corrosion Allowance	Zero

**Tube:**

All sizes	ASTM A269 GR TP304 SMLS Tube sizes designated by OD dimensions.
-----------	--

<b>Tube Size (OD):</b>	<b>Minimum Wall Thickness (Inches)</b>
------------------------	--

1/4"	0.035"
3/8"	0.035"
1/2"	0.049"
3/4"	0.049"
1"	0.065"

**Fittings:** All Fittings to be Parker A-LOK tube fittings SA479 or ASTM A276 GR TP316 and ASTM A182 GR TP316 or equal.

**Valves:** Valves shall be furnished under their own unique specification.

**Note:**

1. Tubing to be internally cleaned, dried and ends sealed during shipping, storing and installation. Tube ID to be free of hydrocarbon contamination.
2. Fittings to be cleaned after manufacturing and sealed in plastic bags during shipping, storing and installation.
3. Tubing surface finish to be standard white pickled I.D. & O.D.

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Title

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**T3**

**Fittings:** All fittings to be 304 butt weld or flanged O.D. tube, wall thickness to match tube wall thickness listed above.

**Valves:** Valves shall be furnished under their own unique specification.

**Notes:**

1. Tubing to be internally cleaned, dried and ends sealed during shipping, storing and installation. Tube ID to be free of hydrocarbon contamination.
2. Fittings to be cleaned after manufacturing and sealed in plastic bags during shipping, storing and installation.
3. Tubing surface finish to be standard white pickled I.D. & O.D.
4. Tube Bending - The following is not allowed: Sand packing, Mechanical scratches on tube I.D., or any type of lubricant.
5. Material manufactures certificate of compliance to applicable ASTM specifications are required and must accompany shipment.
6. Tubing, flanges and fittings to be etched or stamped with manufacturers name, part number and material type.
7. Conflat flanges to be made from either electro slag remelt, vacuum remelt or cross forged material.

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**SPECIFICATION**

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V049-2-037

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**4**

Title

# SPECIFICATION FOR PIPING DESIGN AND MATERIAL

T4

## PIPING DESIGN AND MATERIAL SPECIFICATION

**Service:** Process Ultra High Vacuum

**Design Conditions:**

Pressure	Vacuum $10^{-10}$ Torr to 2 psig
Temperature	-20°F to 150°F
Corrosion Allowance	Zero

**Tube:** (Tube sizes designated by OD dimensions)

All sizes up to 1"	ASTM A269 GR TP304L SMLS
1 1/2" and larger	ASTM A269 GRTP304L SMLS or welded.

Tube Size (OD):	Minimum Wall Thickness (Inches)	Conflat Flange Size	No. Bolts	B.C. Dia.	Thru Hole Dia.
1/4"	0.035"	1 1/3" Nom. O.D.	6	1.062"	.172"
3/8"	0.035"	1 1/3" Nom. O.D.	6	1.062"	.172"
1/2"	0.035"	1 1/3" Nom. O.D.	6	1.062"	.172"
3/4"	0.035"	2 1/8" Nom. O.D.	4	1.625"	.265"
1"	0.065"	2 3/4" Nom. O.D.	6	2.312"	.265"
1 1/2"	0.065"	2 3/4" Nom. O.D.	6	2.312"	.265"
2"	0.065"	3 3/8" Nom. O.D.	8	2.85"	.332"
2 1/2"	0.065"	4 1/2" Nom. O.D.	8	3.628"	.332"
4"	0.083"	6" Nom. O.D.	16	5.128"	.332"
6"	0.083"	8" Nom. O.D.	20	7.128"	.332"
8"	0.120"	10" Nom. O.D.	24	9.128"	.332"
10"	0.120"	12" Nom. O.D.	32	11.181"	.332"
12"	0.120"	14" Nom. O.D.	30	12.810"	.390"
14"	0.120"	16 1/2" Nom. O.D.	36	15.310"	.390"

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Title

## SPECIFICATION FOR PIPING DESIGN AND MATERIAL

T4

**Flanges:** All Flanges to be Conflat, 304L Stainless Steel. Flanges with 1/2 nipples to have a minimum wall thickness per table (page 16), also see note 7.

**Fittings:** All fittings to be 304L butt weld or flanged O.D. tube. Wall thickness to match tube wall thickness listed in Table (Page 16).

**Valves:** Valves shall be furnished under their own unique specification. Valves whose seats form part of the UHV boundary shall be all metal.

**Cleaning:** Surfaces exposed to vacuum shall be cleaned and protected by PSI approved procedures suitable for UHV service.

**Note:**

1. Tubing to be internally cleaned, dried and ends sealed during shipping, storing and installation. Tube ID to be free of hydrocarbon contamination.
2. Fittings and conflat - 1/2 nipples to be cleaned after manufacturing and sealed in plastic bags during shipping, storing and installation.
3. Tubing surface finish to be standard white pickled I.D. & O.D.
4. Material manufacturers Certificate of Compliance to applicable ASTM specifications are required and must accompany shipment.
5. Tubing, flanges and fittings to be etched or stamped with manufacturers name, part number, material type and customers PO number on the outside surface.
6. Conflats shall be made from 304L material suitable for ultra high vacuum service.
7. All welding exposed to vacuum shall be done by the tungsten-arc inert-gas (TIG) process. Exceptions may be allowed subject to PSI approval. Welding techniques shall be made in accordance with the best ultra high vacuum practice to eliminate any virtual leaks in the welds; i.e., all vacuum welds shall be, wherever possible, internal and continuous; all external welds added to these for structural purposes shall be intermittent to eliminate trapped volumes. Defective welds shall be repaired by removal to sound metal and rewelding. All vacuum weld procedures shall include steps to avoid contamination of the heat affected zone with air, hydrogen, or water. This requires that inert purge gas, such as argon, be used to flood the vacuum side of heated portions. Vendors to provide weld procedures, with weld cleaning procedures to PSI for approval.

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### SPECIFICATION

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Title

## SPECIFICATION FOR PIPING DESIGN AND MATERIAL

T5

## PIPING DESIGN AND MATERIAL SPECIFICATION

**Service:** Class 100 Clean Air**Design Conditions:**

Pressure	Vacuum to 2 psig
Temperature	-20°F to 150°F
Corrosion Allowance	Zero

**Tube:** (Tube sizes designated by OD dimensions)

All sizes up to 1"	ASTM A269 GR TP304 SMLS
1 1/2" and larger	ASTM A269 GRTP304 SMLS or Welded.

Tube Size (OD):	Minimum Wall Thickness (Inches)	Conflat Flange Size	No. Bolts	B.C. Dia.	Thru Hole Dia.
1/4"	0.035"	1 1/3" Nom. O.D.	6	1.062"	.172"
3/8"	0.035"	1 1/3" Nom. O.D.	6	1.062"	.172"
1/2"	0.035"	1 1/3" Nom. O.D.	6	1.062"	.172"
3/4"	0.035"	2 1/8" Nom. O.D.	4	1.625"	.265"
1"	0.065"	2 3/4" Nom. O.D.	6	2.312"	.265"
1 1/2"	0.065"	2 3/4" Nom. O.D.	6	2.312"	.265"
2"	0.065"	3 3/8" Nom. O.D.	8	2.85"	.332"
2 1/2"	0.065"	4 1/2" Nom. O.D.	8	3.628"	.332"
4"	0.083"	6" Nom. O.D.	16	5.128"	.332"
6"	0.083"	8" Nom. O.D.	20	7.128"	.332"
8"	0.120"	10" Nom. O.D.	24	9.128"	.332"
10"	0.120"	12" Nom. O.D.	32	11.181"	.332"
12"	0.120"	14" Nom. O.D.	30	12.810"	.390"
14"	0.120"	16 1/2" Nom. O.D.	36	15.310"	.390"

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## SPECIFICATION

Number **A** V049-2-037Rev. **4**

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Title

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**T5**

**Flanges:** All Flanges to be Conflat tube fittings 304 Stainless Steel.

**Fittings:** All Fittings to be 304 butt weld or flanged O.D. tube. Wall thickness to match the tube wall thickness.

**Valves:** Valves shall be furnished under their own unique specification

**Cleaning:** Internal surfaces shall be cleaned and protected by PSI approved procedures suitable for Class 100 air service.

**Note:**

1. Tubing to be internally cleaned, dried and ends sealed during shipping, storing and installation. Tube ID to be free of hydrocarbon contamination.
2. Fittings to be cleaned after manufacturing and sealed in plastic bags during shipping, storing and installation.
3. Tubing surface finish to be standard white pickled I.D. & O.D.
4. Material manufactures Certificate of Compliance to applicable ASTM specifications are required and must accompany shipment.
5. Tubing, flanges and fittings to be etched or stamped with manufacturers name, part number and material type.
6. Conflat flanges to be made from either electro slag remelt, vacuum remelt or crossforged material.

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**SPECIFICATION**

Number **A** V049-2-037

Rev. **4**

**Title:**

**SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

**C1**

**PIPING DESIGN AND MATERIAL SPECIFICATION**

**Service:** Cryogenic

**Design Conditions:**

**Pressure** 150 PSIG

**Temperature** -320°F to 350°F

**Corrosion Allowance** None

**Tube:**

**All sizes** Type "L" Copper - Hard Drawn  
ASTM B88, B280, copper tube designated by its  
nominal sizes, not OD (UON).

**Fittings:**

**All sizes** Wrought copper  
ASTM B75  
All fittings to be female solder cup ends.

**Valves:** Valves shall be furnished under their own unique specification.

**Brazing:**

All joints shall be brazed using brazing alloy BCuP-5 (American Welding Society Designation). No flux is required.

**SPECIFICATION**

Number

**A** V036-2-037

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**4**

**ATTACHMENT "A"  
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY**

LIGO VACUUM EQUIPMENT		VENDOR:				JOB NO.: V59049	
EQUIPMENT: PIPE, TUBING & FITTINGS		VENDOR ENG. OFFICE:				DWG. NO.:	
SI P.O. NO:		VENDOR FACTORY:				SPECNO: V049-2-037	
TESTING INSPECTION AND DOCUMENTATION RECORD		Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:
							Inspector:  Date:
VENDOR Q.A. PLAN				X	2	X	
CLEANING PROCEDURE				X	2	X	
REP FOR SHIPMENT PROCEDURE				X	2	X	
CERTIFICATE OF COMPLIANCE					2	X	

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 Rev. 4  
 09.20.  
 SPEC V049-2-037

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

WPS No.: 150  
 Supporting PQRs: 150 H48

Date: 02/08/96 Rev: 1 Date: 04/23/96

**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 None  
 Time range None  
 notes

Process / type .....	All pass(es) PAW / manual	None
Process thickness limit.	0.1875" to 1.0000"	None

<b>GAS (QW-408)</b>				
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	/ -
<b>FILLER METAL (QW-404)</b>				
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		-   -   -	-   -   -
<b>ELECTRICAL (QW-409)</b>				
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.

**WELDING PROCEDURE SPECIFICATION (WPS)**

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. Rollas                     ( 04/23/96 ) Weld Specialist  
 Accepted By:                     Alan B. Bledsoe                     ( 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. 7

**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

**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

note:

**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:

Weld Process / type	All pass(es)		None	
	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)





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

WPS No.: 151-1 Date: 05/06/96  
 Supporting PQRs: 151-1-H48

<b>BASE METAL (QW-403, QW-405)</b> P No. 8 to P No.:8 Thickness range. 0.1875" to 1.0000" Position(s). All positions Progression. Vertical Up notes	<b>JOINT (QW-402)</b> Joint design Groove/Fillet (see pg 2) Backing..... With or without backing Backing Matl Optional Fillet Weld Size All (QW-451.4) notes
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<b>PREHEAT (QW-406)</b> Minimum Temperature. 60 Degrees F. Interpass Temp. Max. 350 Degrees F. Preheat Maintenance. None	<b>POSTWELD HEAT TREATMENT (QW-407)</b> Temperature range 1000 DEG.F. <b>A</b> Time range 4.00 notes
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Process / type ..... Process thickness limit.	All pass(es) PAW / manual 0.1875" to 1.0000"	None None
<b>GAS (QW-408)</b> Shielding Gas / CFH..... Trailing Gas / CFH..... Backing Gas / CFH..... Plasma Gas / CFH.....	75% Argon, 25% He. / 20-30 None / - 100% Argon / 9-24 100% Argon / 1-3	None / - None / - None / - None / -
<b>FILLER METAL (QW-404)</b> AWS classification..... SFA Spec. No. & F No.... A No. or Chem. Comp..... Filler metal trade name. SAW flux trade name/type Elec./Wire size (in) ...	ER308L SFA#: 5.9 F#: 6 8 SOLID FILLER METAL N/A / - 1/16   3/32   1/8	None SFA#: None F#: - None None None / - -   -   - -   -   - -   -   - None N/A / - N/A
<b>ELECTRICAL (QW-409)</b> Welding amperage range.. Welding voltage range... Travel speed (ipm)..... Max. Heat Input (J/in).. Tungsten Type/Size..... Current & Polarity.....	30-100   75-160   100-200 12-18   14-21   16-26 Var.   Var.   Var None EWh-2 / 1/16"-3/16" DCEN (straight)	-   -   - -   -   - -   -   - None N/A / - N/A
<b>TECHNIQUE (QW-410)</b> String / weave bead..... Orifice / gas cup..... Contact tube to work.... Oscillation..... Mult./Single electrode.. Other Technique Notes... Multiple or Single Pass (per side)....	String & Weave Bead 3/8" to 5/8" N/A Transverse Single Electrode Keyhole & Melt-in used Multiple Passes	N/A None None None N/A None

- (n1) No pass > 1/2 " t.
- (n2) No supplementary filler 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 1000 DEG.F.
- (n7) PWHT RAMP DOWN AT 100 DEG.F./HR. TO 300 DEG.F. AND COOL IN STILL AIR.



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

PQR No.: 151-1-H48

Date: 05/06/96

WPS No.: 151-1

**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

**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

note:

**HEAT TREATMENT (QW-406, QW-407)**

Preheat Temperature: 60 Degrees F.  
 Preheat Maintenance: None  
 Interpass Temperature: 350 Degrees F.  
 PWHT temperature ... : 1000 Degrees F.  
 PWHT Holding time(hr): 4.00  
 note: +/- 50 DEG. F.

**POSITION (QW-405)**

Position of Joint : 1G - Flat  
 Progression: N/A

note:

Weld Process / type	All pass(es)			None		
	PAW	manual				
<b>GAS (QW-408)</b>						
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	/	-
<b>FILLER METAL (QW-404)</b>						
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	-		-
<b>ELECTRICAL (QW-409)</b>						
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		
<b>TECHNIQUE (QW-410)</b>						
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) Peening was not used with this weld test.

(n2) No supplementary filler will be used with this procedure.

(n3)

(n4) PWHT Ramp up to 300 Deg.F. then 100 Deg.F./Hr. up to 1000 Deg.F.

(n5) PWHT Ramp down at 100 Deg.F./Hr. to 300 Deg.F. and cool in still air.

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	0.513	0.382	34850	91200	Weld metal
2	0.745	0.505	0.376	34200	91000	Base 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-
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-----# (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: 14215  
 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 ( 05/06/96 ) Weld Specialist  
 Certified By: Alan S. Budbrook ( 05/06/96 ) Q.A. Manager:

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

WPS No.: 153-1 Date: 10/28/96  
Supporting PQRs: 153-1-H48

<b>BASE METAL (QW-403, QW-405)</b> P No. 8 to P No.:8 Thickness range. 0.1875" to 1.0000" Position(s). All positions Progression. Vertical Up notes	<b>JOINT (QW-402)</b> Joint design Groove/Fillet (see pg 2) Backing..... With or without backing Backing Matl Optional Fillet Weld Size All (QW-451.4) notes
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<b>PREHEAT (QW-406)</b> Minimum Temperature. 60 Degrees F. Interpass Temp. Max. 350 Degrees F. Preheat Maintenance. None	<b>POSTWELD HEAT TREATMENT (QW-407)</b> Temperature range 1000 Time range 4.0 notes Stress Relief 1000F.+/-50 F.
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Process / type ..... All pass(es) Process thickness limit. 0.1875" to 1.0000"	GTAW / manual None
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<b>GAS (QW-408)</b> Shielding Gas / CFH..... Trailing Gas / CFH..... Backing Gas / CFH.....	100% Argon / 18-36 None / - 100% Argon / 9-24	None / - None / - None / -
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<b>FILLER METAL (QW-404)</b> AWS classification..... SFA Spec. No. & F No.... A No. or Chem. Comp..... Filler metal trade name. SAW flux trade name/type Elec./Wire size (in) ... <b>ELECTRICAL (QW-409)</b> Welding amperage range.. Welding voltage range... Travel speed (ipm)..... Max. Heat Input (J/in).. Tungsten Type/Size..... Current & Polarity.....	ER308L SFA#: 5.9 F#: 6 8 SOLID FILLER METAL N/A / - 1/16   3/32   1/8 70-150   80-180   130-275 n/r   n/r   n/r Var.   Var.   Var. None EWTh-2 / 1/16" - 3/16" DCEN (straight)	None SFA#: None F#: - None None None / - -   -   - -   -   - -   -   - None N/A / - N/A
--	---	---

<b>TECHNIQUE (QW-410)</b> String / weave bead..... Orifice / gas cup..... Contact tube to work.... Oscillation..... Mult./Single electrode.. Other Technique Notes...	String & Weave Bead # 5 to # 10 N/A N/A Single Electrode	N/A None None None N/A None
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Multiple or Single Pass (per side).... Multiple Passes  
 (n1) No peening done with this procedure.  
 (n2) No pass > 1/2 " t.  
 (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 TO 1000 DEG.F, HOLD FOR 4 HR.  
 (n7) PWHT RAMP DOWN FROM 1000F. TO 300F. @100F/HR. THEN COOL TO ROOM TEMP.

WELDING PROCEDURE SPECIFICATION (WPS)

WPS No.: 153-1

Date: 10/28/96 Revision

JOINT (QW-402)

Single-V groove

Backing : no backing  
 Root Opening: 3/16" max.  
 Groove Angle: 50 degree min.  
 Root Face : 1/8" max.

Single-Bevel groove

Backing : no backing  
 Root Opening: 3/16" max.  
 Groove Angle: 45 degree min.  
 Root Face : 1/8" max.

Single-V groove

Backing : gouged & back welded  
 Root Opening: 1/4" max.  
 Groove Angle: 50 degree min.  
 Root Face : 3/16" max.

Double-Bevel groove

Backing : gouged & back welded  
 Root Opening: 1/4" max.  
 Groove Angle: 45 degree min.  
 Root Face : 3/16" max.

Double-V groove

Backing : gouged & back welded  
 Root Opening: 1/4" max.  
 Groove Angle: 45 degree min.  
 Root Face : 3/16" max.

Single/Double Fillet

Backing :  
 Root Opening: 3/16" 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 A JOB. WELD JOINT DESIGN REFERENCE IN AN ENGINEERING SPECIFICATION OR DESIGN DRAWING SHALL TAKE PRECEDENCE 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: Harold Klee ( 10/28/96 ) Weld Specialist

Accepted By: Alan R. Budbrook ( 10/28/96 ) Q.A. Manager:

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

PQR No.: 153-1-H48                      Date: 10/28/96                      WPS No.: 153-1                      Rev 0

<b>JOINT DESIGN (QW-402)</b> <b>WELD JOINT CONFIGURATION</b> Single-V groove Gas backing was used Groove Angle :        75                      Degrees Root Opening :        062-125                      Inches Root Face :            030-062                      Inches	<b>BASE METAL (QW-403)</b> 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
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note:  <b>POSITION (QW-405)</b> Position of Joint :    1G - Flat Progression: N/A note:	<b>HEAT TREATMENT (QW-406, QW-407)</b> Preheat Temperature:    60 Degrees F. Preheat Maintenance: None Interpass Temperature:    350 Degrees F. PWHT temperature ... :    1000 Degrees F. PWHT Holding time(hr): 4.00 note: Stress Relief 1000 Deg.F./-50 F.
--	--

	All pass(es)				
Weld Process / type	GTAW / manual			None	
GAS (QW-408)					
Shielding Gas / CFH.....	100% Argon	/	20-30	None	/ -
Trailing Gas / CFH.....	None	/	-	None	/ -
Backing Gas / CFH.....	100% Argon	/	10-20	None	/ -
<b>FILLER METAL (QW-404)</b>					
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"	-	-
<b>ELECTRICAL (QW-409)</b>					
Amperage USED .....	70-150		80-180		130-275
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"-1/8"		N/A	/ -
Current Type/Polarity...	DCEN (straight)			N/A	
<b>TECHNIQUE (QW-410)</b>					
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 > 1/2 " t.  
 (n3) PWHT Ramp up to 300 Deg.F then 100 Deg.F/Hr to 1000 Deg.F, Hold for 4 Hr.  
 (n4) PWHT Ramp down from 1000F.to 300F. @100F/Hr. then cool to room temp.  
 (n5)



Procedure Qualification Record (PQR)

PQR No.: 153-1-H48

Page 2 of 2

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	0.515	0.386	35850	92900	Base metal
2	0.750	0.515	0.386	36000	93300	Base 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-
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# (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: S06100-861  
 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: Harold Klee ( 10/28/96 ) Weld Specialist  
 Certified By: Alan R. Benbrook ( 10/28/96 ) Q.A.Manager:

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

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

<b>BASE METAL (QW-403, QW-405)</b> P No. 8 to P No.:8 Thickness range. 0.0625" to 0.7500" Position(s). All positions Progression. Vertical Up notes	<b>JOINT (QW-402)</b> Joint design Groove/Fillet (see pg 2) Backing..... With or without backing Backing Matl Optional Fillet Weld Size All (QW-451.4) notes
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<b>PREHEAT (QW-406)</b> Minimum Temperature. 50 Degrees F. Interpass Temp. Max. 350 Degrees F. Preheat Maintenance. None	<b>POSTWELD HEAT TREATMENT (QW-407)</b> Temperature range None Time range None notes
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Process / type .....	All pass(es) GTAW / manual	None
Process thickness limit.	0.0625" to 0.7500"	None
<b>GAS (QW-408)</b>		
Shielding Gas / CFH.....	100% Argon / 15-25	None / -
Trailing Gas / CFH.....	None / -	None / -
Backing Gas / CFH.....	100% Argon / 9-30	None / -
<b>FILLER METAL (QW-404)</b>		
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	-   -   -
<b>ELECTRICAL (QW-409)</b>		
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
<b>TECHNIQUE (QW-410)</b>		
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)

**WELDING PROCEDURE SPECIFICATION (WPS)**

WPS No.: 073-3

Date: 05/29/74 Revision No.:

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:                     Alan Bradburn                     ( 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

**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

**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

note:

**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

**POSITION (QW-405)**

Position of Joint : 6G - 45 Deg.  
 Progression: Vertical Up  
 note:

note:

	All pass(es) GTAW / manual		None	
<b>Weld Process / type</b>				
<b>GAS (QW-408)</b>				
Shielding Gas / CFH.....	100% Argon	/ 17-20	None	/ -
Trailing Gas / CFH.....	None	/ -	None	/ -
Backing Gas / CFH.....	100% Argon	/ 18	None	/ -
<b>FILLER METAL (QW-404)</b>				
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"	-   -	-	-   -
<b>ELECTRICAL (QW-409)</b>				
Amperage USED .....	110	-	-	-
Voltage USED .....	14	-	-	-
Travel Speed (ipm).....	5	-	-	-
Max. Heat Input (J/in)..	None		None	
Tungsten Type & Size....	EWh-2 / 3/32"		N/A / -	
Current Type/Polarity...	DCEN (straight)		N/A	
<b>TECHNIQUE (QW-410)</b>				
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)





**Title** **LIGO GENERAL REPAIR PROCEDURE FOR MATERIALS AND WELDING**

**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.

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**LIGO GENERAL REPAIR PROCEDURE FOR MATERIALS AND 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.

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**LIGO GENERAL REPAIR PROCEDURE FOR MATERIALS AND WELDING**

**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.

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**Title** LIGO GENERAL REPAIR PROCEDURE FOR MATERIALS AND WELDING

**3.0** BASE MATERIAL CLEANUP PROCEDURE

**3.1** SCOPE

3.1.1 This procedure describes the acceptable methods of base metal 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.

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**Title: SPECIFICATION FOR BAKE OUT PROCEDURE ISOLATABLE SECTION**

**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

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- 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.

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**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  $1 \times 10^{-4}$  Torr has been reached.  
Refer to: Cold Cathode & Pirani Gauges Operating Manuals

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**Title: SPECIFICATION FOR BAKE OUT PROCEDURE ISOLATABLE SECTION**

**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  $5 \times 10^{-5}$  Torr

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**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:** Ramp rate 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  $5 \times 10^5$  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 ramp rate of -1.8°/hr. The heating jackets for the pressure gauge pair will remain on 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.

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Title: **PROCEDURE FOR CLEAN ROOM ACTIVITIES**

**PROCEDURE FOR  
CLEAN ROOM ACTIVITIES  
LIGO VACUUM EQUIPMENT**

**Hanford, Washington**

**and**

**Livingston, Louisiana**

**PREPARED BY:**

*Thomas M. Stern*

**QUALITY ASSURANCE:**

*Allen J. Burdick*

**MANUFACTURING ENGR:**

*[Signature]*

**TECHNICAL DIRECTOR:**

*D. A. Williams*

**PROJECT MANAGER:**

*Brian Bayly*

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	TMS	5-3-96	REB	5/3/96	A V049-2-118	Ø

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**PROCEDURE FOR CLEAN ROOM ACTIVITIES**

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- 4.0 Procedure

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**PROCEDURE FOR CLEAN ROOM ACTIVITIES**

**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.

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**PROCEDURE FOR CLEAN ROOM ACTIVITIES**

- 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 are in 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.

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Title: CONTAMINATION CONTROL PLAN

CONTAMINATION CONTROL PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

PROJECT ENGINEER:

Thomas M. Stam

QUALITY ASSURANCE:

ALAN BRADBROOK / REB

TECHNICAL DIRECTOR:

D. A. McWilliam

PROJECT MANAGER:

Richard Bayly

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## CONTAMINATION CONTROL PLAN

### 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.

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**Title****CONTAMINATION CONTROL PLAN****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 Raw materials shall not be stored in direct contact with materials of different composition, but shall be separated by suitable spacers or sheeting. Depending on the parts level of cleanliness (raw material vs. cleaned part).
- 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.

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## CONTAMINATION CONTROL PLAN

### 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.

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## SPECIFICATION

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Title: RAW MATERIAL HANDLING PROCEDURE

RAW MATERIAL HANDLING PROCEDURE

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Louisiana

PREPARED BY: Thomas M. Stern  
QUALITY ASSURANCE: ALAN BRADBROOK/REB  
MANUFACTURING ENGR: [Signature]  
TECHNICAL DIRECTOR: D. A. McWilleis  
PROJECT MANAGER: Russell Brayley

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	T.M.S.	5-4-96	REB	5/4/96	A V049-2-120	Ø

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**RAW MATERIAL HANDLING PROCEDURE**

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**RAW MATERIAL HANDLING PROCEDURE**

**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.

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# RAW MATERIAL HANDLING PROCEDURE

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- 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<sub>2</sub> 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.

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## SPECIFICATION

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Title: SPECIFICATION FOR CONTROL OF NON-CONFORMANCES

**SPECIFICATION FOR  
CONTROL OF NON-CONFORMANCES**

PREPARED BY:

ALAN BRADBROOK

PROJECT ENGINEER:

N/A

QUALITY ASSURANCE:

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D. A. McWilliam

PROJECT MANAGER:

Richard Bagley

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	<u>A Bradbrook</u>	<u>5/1/76</u>	<u>REB</u>	<u>5/1/76</u>	
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**SPECIFICATION FOR CONTROL OF NON-CONFORMANCES**

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2.0 General Procedure

Exhibit 1 Tags

Exhibit 2 Discrepancy Report Form

Number

Rev.

**SPECIFICATION**

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Rev.

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Title

## SPECIFICATION FOR CONTROL OF NON-CONFORMANCES

### 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 nonconformance 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.

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EXHIBIT 1

REJECT			
PO. NO.	PART NO. OR DWG. NO.	QTY.	FINAL DISPOSITION
PART NAME	JOB NO.		
REASON FOR REJECTION			
INSPECTED BY	DATE	DR. NO.	

*COLOR RED*

STOP WORK			
PO. NO.	PART NO. OR DWG. NO.	QTY.	FINAL DISPOSITION
PART NAME	JOB NO.		
REASON FOR STOP WORK			
INSPECTED BY	DATE	DR. NO.	

*COLOR YELLOW*

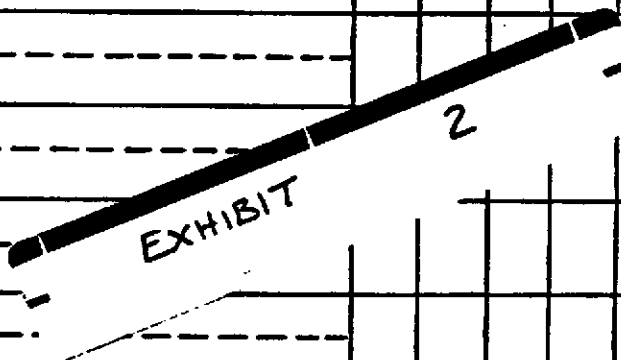
Process Systems International, Inc.  
**DISCREPANCY REPORT**

ROUTE TO \_\_\_\_\_

D.R. NUMBER  
**6589**

NUMBER <b>T10001-</b>	P.D. NO. <b>468500</b>	VENDOR <b>ABC NUT &amp; BOLT</b>	SHEET <b>1 OF 1</b>
SUBJECT <b>KOREA</b>		ORIGINATOR <b>J. JONES</b>	DATE <b>6-1-95</b>
REFER TO D.R. NUMBER _____			

ITEM	DWG. ZONE	DISCREPANCIES (LIST CHARACTERISTICS, SPECIFICATIONS AND ACTUAL)	NO. ACC.	FOR REVIEW	QTY. OF PCS./DISPOSITION					REMARKS
					USE NO. CHGE	USE DWG. CHGE	RWK IN SHOP	RET. TO SUP.	SCRAP	
1		<b>1/2"-13 X 4" LONG - BOLTS - SA-193 B7</b>	0	50						
		<b>WE RECEIVED</b>								
		<b>1/2"-13 X 3" LONG - BOLTS - SA-490</b>							X	<b>WRONG LENGTH</b>
										<b>WRONG MATERIAL</b>



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 DRAWINGS AND BILL OF MATERIAL.  
**B. SMITH 6-2-95**

DISPOSITION CONCURRENCE

PROJECT MGR <b>J. BOYD</b>	DATE <b>6-2-95</b>	MFG. ENG. <b>N/A</b>	DATE	QUALITY ASSURANCE <b>J. JONES</b>	DATE <b>6-2-95</b>
-------------------------------	-----------------------	-------------------------	------	--------------------------------------	-----------------------

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**

RECTIVE ACTION --- **VENDOR DID NOT SUPPLY CORRECT MATERIAL. NOTIFY VENDOR OF THIS PROBLEM AND HAVE THEM PROVIDE TRAINING.**

SIGNATURE **J. JONES** DATE **6-3-95**

AI/ANI **AI** DATE **6-4-95** - CLOSED -

Title: LIGO VISUAL INSPECTION PROCEDURE

LIGO VISUAL INSPECTION PROCEDURE

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Louisiana

PREPARED BY:

Alan L. Bradbrook

QUALITY ASSURANCE:

Alan L. Bradbrook

MANUFACTURING ENGR:

Phillip F. [unclear]

TECHNICAL DIRECTOR:

D. A. M. Williams

PROJECT MANAGER:

Barclay [unclear]

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REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	D M... 10/10/96	RES 11/15/96	RELEASED PER DEO 351
0	AKB 5/3/96		Release to fab Per DEO #0302
			ISSUED PER DEO 0168 FOR PDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	NumberA V049-2-128
	AKB	5/3/96	RES	5/3/96	Rev. 1

Title

# LIGO VISUAL INSPECTION PROCEDURE

## TABLE OF CONTENTS

- 1.0 Scope
- 2.0 General Procedure
  - 2.1 Control of Documents, Codes and Standards
  - 2.2 Technical Requirements
  - 2.3 Examination Requirements
  - 2.4 Acceptance Standards

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## SPECIFICATION

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**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

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## LIGO VISUAL INSPECTION PROCEDURE

**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
5. Oxide removal
6. Discontinuities

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**LIGO VISUAL INSPECTION PROCEDURE**

**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

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## 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**

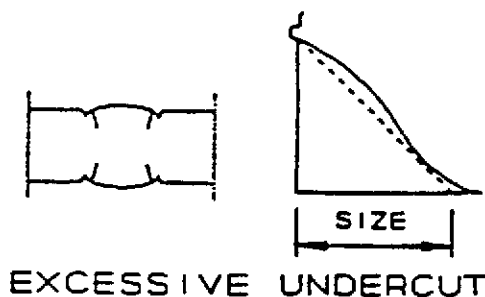
The affected area of the final weld surface shall be cleaned of slag and oxidation. Iridescent temper films resulting from welding are acceptable on finished weld surfaces.

## 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 from 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.

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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 Thickness, in. (mm)	Maximum Offset, in. (mm)
0.060" Thru 0.500"	1/4t

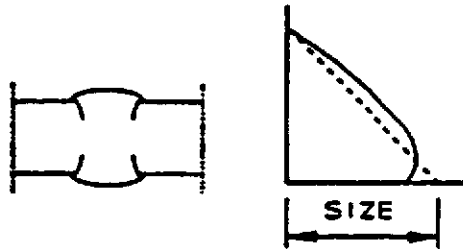
Note: t is the nominal thickness of the thinner section of the joint.

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.

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**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**

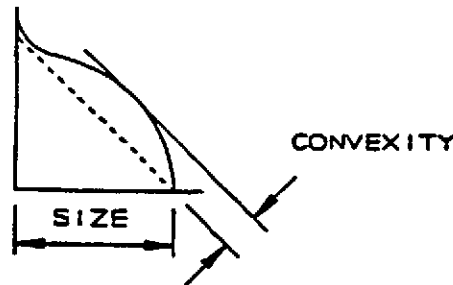
Acceptability requirements are the same as those for slag inclusions.

**MISALIGNMENT AND WARPING**

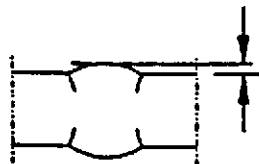
Tolerances shall be within the drawing tolerances governing the work. ASME Section VIII allows a maximum misalignment of 1/4" the thickness of the thinner section at the joint for thickness to 1/2".

**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

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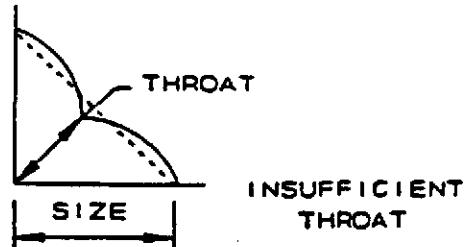
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Title

# LIGO VISUAL INSPECTION PROCEDURE

## INSUFFICIENT THROAT, FILLETS

The throat shall not be under an imaginary profile line drawn from each leg end.



## INSUFFICIENT THROAT, GROOVE WELDS

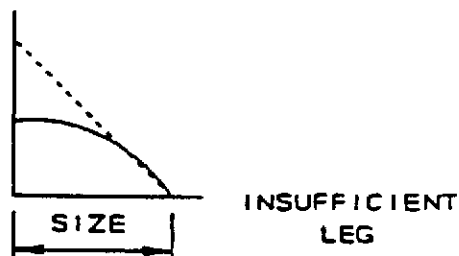
The weld shall be slightly convex.



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.



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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. McWilliam

PROJECT MANAGER:

Robert Bayly

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.


0	TMS 5-5-96	RES 5/5/96	INITIAL RELEASE PER DEC # 0171 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION		
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	TMS	5-5-96	RES	5/5/96	V049-2-130	0

Title

# SPECIFICATION FOR BLACK LIGHT INSPECTION PROCEDURE

## SPECIFICATION TABLE OF CONTENTS

- 1.0 Purpose
- 2.0 General
- 3.0 Responsibilities
- 4.0 Procedure
- 5.0 Required Documentation

### 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.

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# SPECIFICATION FOR BLACK LIGHT INSPECTION PROCEDURE

## 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.

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## SPECIFICATION

Number	A	V049-2-130	Rev.	0
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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. G. McWilliam

PROJECT MANAGER:

David Bay

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REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	D. McW 12-3-96		REVD PER DEO 0354 FOR FDR
0	TMS 5-5-96	KEB 5/5/96	INITIAL RELEASE PER DEO 0172 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Rev.
	TMS	5-5-96	KEB	5/5/96	1
				Number	V049-2-131

## SPECIFICATION TABLE OF CONTENTS

- 1.0 Purpose
- 2.0 General
- 3.0 Responsibilities
- 4.0 Procedure

**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 Vacuum 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 Vacuum piping spools shall not be unsealed until the end is protected by a Class 100 cleanroom.
- 2.3 Utility piping shall be cleaned by by a procedure submitted by the site installation contractor and approved by the buyer

**3.0 RESPONSIBILITIES**

- 3.1 Cleaning shall be performed by contractor personnel 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.

**SPECIFICATION**

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**SPECIFICATION FOR SITE PIPING CLEANING PROCEDURE**

4.4 If after testing the piping proves to require recleaning, it shall be removed off-site to be flushed with hot water and detergent(Oakite Impro-Clean 1300), flushed with city water for 5 minutes, and flushed with DI water for 5 minutes.

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**SPECIFICATION**

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**1**

Title: SPECIFICATION FOR SITE VACUUM SURFACE RECLEANING PROCEDURE

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. McWilliam

PROJECT MANAGER: \_\_\_\_\_

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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
	TMS	5-5-96	
Number		V049-2-132	Rev.
			0

## SPECIFICATION TABLE OF CONTENTS

- 1.0 Purpose
- 2.0 General
- 3.0 Responsibilities
- 4.0 Procedure

**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<sub>2</sub> cleaning system. A vacuum vent system shall be used to remove the CO<sub>2</sub> 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.

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**SPECIFICATION**

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Title: SPECIFICATION FOR RESIDUAL GAS ANALYZER (RGA) CALIBRATION

SPECIFICATION FOR  
RESIDUAL GAS ANALYZER (RGA) CALIBRATION  
FOR  
LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

PREPARED BY: S. Moter  
PROCESS ENGINEER: R. Ther  
QUALITY ASSURANCE: Alan R. Burdick  
TECHNICAL DIRECTOR: D.A. Williams  
PROJECT MANAGER: Burt B. ...

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REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
9	SM 7/15/96	RCS 8/5/96	Released per OEO 0221

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION		
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	SM	7/15/96	D.W.W.	8-5-96	V049-2-137	0

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2.0	GENERAL
3.0	REFERENCE DOCUMENTS
4.0	RESPONSIBILITY
5.0	BASIC CALIBRATION METHOD; RGA IN FARADAY CUP MODE
6.0	BASIC CALIBRATION METHOD; RGA IN ELECTRON MULTIPLIER
7.0	RGA CALIBRATION ACCURACY

**SPECIFICATION**

Number:	V049-2-137	Rev.
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**Title: SPECIFICATION FOR FOR RESIDUAL GAS ANALYZER (RGA) CALIBRATION**

**1.0 PURPOSE**

The purpose of this document is to define a system and procedure to be used for the calibration of a residual gas analyzer (RGA) or ion gauge to a NIST traceable standard.

**2.0 GENERAL**

This procedure applies to the calibration of quadrupole mass spectrometers with electron multipliers such as the Balzers QMS 200. This procedure is used to determine RGA sensitivities for various gasses. As a minimum the following gasses should be used: H<sub>2</sub>, He, CH<sub>4</sub>, N<sub>2</sub>, Ar, CO<sub>2</sub>. Gas sensitivities will be determined in the Faraday cup mode for pressures between 10<sup>-4</sup> and 10<sup>-8</sup> Torr and in the electron multiplier mode for pressures between 10<sup>-6</sup> and 10<sup>-8</sup> Torr. A Capacitance Manometer Gauge (CMG) will be used as the NIST traceable standard for this procedure.

This procedure is to be used for factory and field testing programs. In general, calibration is to be performed whenever the RGA has been exposed to the atmosphere or if the recent operating "history" of the RGA is unknown and the calibration is thus suspect.

**3.0 REFERENCE DOCUMENTS**

Operating manuals for: Balzers QMS200 RGA, MKS Baratron Capacitance Manometer, Granville Philips Stabil Ion Gauge, Edwards Vacuum Pumps, Varian Ion Pump.

PSI Specification V049-2-014, LEAK CHECK PLAN FOR LIGO VACUUM EQUIPMENT.

**4.0 RESPONSIBILITY**

This procedure is applicable to PSI personnel. the calibration will be performed by the assigned test engineer. Calibration records will be maintained by the PSI QA department.

**SPECIFICATION**

Number:	V049-2-137	Rev.
		0

**5.0 BASIC CALIBRATION METHOD; RGA IN FARADAY CUP MODE**

Pressure readings from the Stabil Ion gauge and ion current readings from the RGA in the Faraday mode are compared to pressure readings from the MKS Baratron Capacitance Manometer Gauge (CMG) in the pressure range of  $10^{-4}$  to  $10^{-5}$  Torr for each gas species.

Pressure correction curves for each gas species used will then be developed for the Stabil Ion Gauge.

Sensitivities factors (Torr/Amp) for each gas species used will then be developed for the QMS 200 RGA in the Faraday mode.

**LINEARITY CHECK using calibrated leak**

To check linearity of the RGA in the high vacuum range below  $10^{-6}$  Torr, the pumping speed needs to be determined. The check will be carried out using nitrogen as the gas. The pump speed is determined in the pressure range  $5 \times 10^{-4}$  Torr to  $5 \times 10^{-5}$  Torr using calibrated leak and the baratron. The RGA reading is compared at a lower pressure using a smaller calibrated leak and the determined pump speed for nitrogen.

**6.0 BASIC CALIBRATION METHOD; RGA IN ELECTRON MULTIPLIER MODE**

Ion current readings from the RGA in the electron multiplier mode will be compared to pressure readings from the calibrated Stabil Ion gauge (see above) in the pressure range  $10^{-6}$  to  $10^{-8}$  Torr for each gas species.

Sensitivities factors (Torr/Amp) for each gas species used will then be developed for the QMS 200 RGA in the electron multiplier mode.

**LINEARITY CHECK using calibrated leak**

To check linearity of the RGA in the high vacuum range below  $10^{-6}$  Torr, the pumping speed needs to be determined. The check will be carried out using nitrogen as the gas. The pump speed is determined in the pressure range  $5 \times 10^{-4}$  Torr to  $5 \times 10^{-5}$  Torr using calibrated leak and the baratron. The RGA reading is compared at a lower pressure using a smaller calibrated leak and the determined pump speed for nitrogen.

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**7.0 RGA CALIBRATION ACCURACY**

The contribution of the uncertainty in accuracy for the primary and secondary calibration standards are currently estimates until a more accurate number is obtained from the instrument vendor.

Stabil Ion gauge; assumes linear behaviour from  $1 \times 10^{-4}$  Torr to  $1 \times 10^{-8}$  Torr.

	Uncertainty $1 \times 10^{-4}$ Torr	Uncertainty $5 \times 10^{-5}$ Torr	Uncertainty $1 \times 10^{-6}$ Torr	Uncertainty $1 \times 10^{-8}$ Torr
<b>PRIMARY STANDARD</b>	3% estimate	3% estimate	3% estimate	3% estimate
<b>CALIBRATION STANDARD 2nd</b>	3% (SRG or DWT)	3% (SRG or DWT)	3% (SRG or DWT)	3% (SRG or DWT)
<b>CAPACITANCE MANOMETER</b>	1.2%	2.4%	1.2%	1.2%
<b>STABIL ION GAUGE G-P</b>			6%	6%
<b>Temperature correction</b>	0.3%	0.3%	0.3%	0.3%
<b>TOTAL : RGA</b>	7.5%	8.7%	13.5%	13.5%

SRG: Spinning Rotor Gauge

DWT: Dead Weight Tester

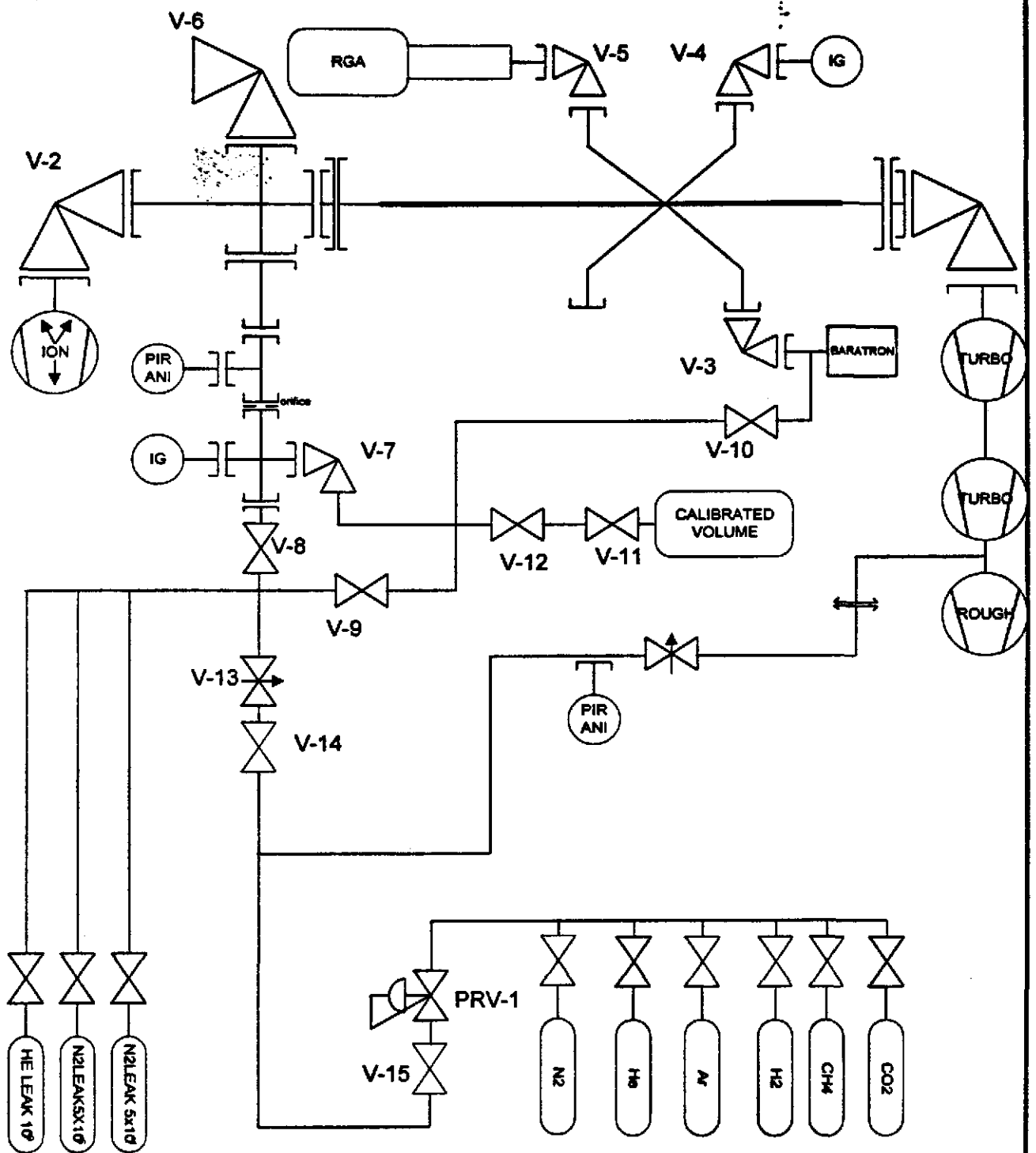
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FIGURE 1: RGA CALIBRATION SYSTEM



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**SPECIFICATION FOR STRUCTURAL STEEL FABRICATION AND PAINTING**

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- 1.0 Scope
- 2.0 Definitions
- 3.0 General
- 4.0 Applicable Publications
- 5.0 Materials
- 6.0 Fabrication
- 7.0 Delivery Schedule
- 8.0 Inspection and Testing
- 9.0 Cleaning and Painting
- 10.0 Piece Marking

Attachment "A"      LIGO Quality Assurance Requirement Summary

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**SPECIFICATION FOR STRUCTURAL STEEL FABRICATION AND PAINTING**

**1.0 SCOPE**

- 1.1 Furnish and fabricate, structural carbon steel in accordance with attached drawings and specification. In the event of conflict between referenced specifications, and requirements herein, these requirements shall take precedence.
- 1.2 Structural steel on the project will primarily consist of support structures, equipment, and miscellaneous items. All carbon steel will be shop and finish coat paint (see Section 9.0 for requirements) by the fabricator.
- 1.3 Bidding Instructions
  - 1.3.1 Responses to this inquiry shall be as per attached Instructions to Bidders.
- 1.4 Attachments
  - 1.4.1 Drawings as delineated.

**2.0 DEFINITIONS**

- 2.1 The following terms used in this specification shall be understood to mean:
  - 2.1.1 Engineer - refers to Process Systems International, Inc. (PSI)
  - 2.1.2 Fabricator - The corporation, partnership, or individual committed to furnish steel in accordance with this specification.

**3.0 GENERAL**

- 3.1 The fabricator shall furnish, as specified, all material and deliver structural and miscellaneous steel such as, but not limited to, columns, beams, bracing and all essential clips, gussets, and separators, as shown on contract drawings.
- 3.2 Substitutions of specified member size or change in details or dimensions of any kind shall not be permitted without the prior written approval of the engineer. Written proposals for substitutions of steel members in place of those specified may be submitted for consideration only if specified sizes are not readily available.
- 3.3 Questions regarding this specification or discrepancies and conflicts between this specification and drawings and the referenced specifications and codes shall be referred to the engineer for resolution.
- 3.4 Shop and erection drawings shall be submitted to the engineer for review and approval prior to starting work. A minimum of 10 working days shall be allowed for drawing review.

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**4.0 APPLICABLE PUBLICATIONS**

4.1 The latest editions of the following specification, codes, and standards, including revisions and supplements in effect at the time of award of the contract for the work of this specification, form a part of this specification in their entirety except as modified by this specification.

## 4.1.1 American Institute of Steel Construction (AISC)

1. Manual of Steel Construction, including the following:
  - a. Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings
  - b. Code of Standard Practice for Steel Buildings and Bridges
  - c. Specification for Structural Joints using ASTM A325 or A490 bolts
  - d. AISC Quality Certification Program
2. Structural Steel Detailing Manual

## 4.1.2 American Society for Testing and Materials (ASTM)

1. ASTM A36 Standard Specification for Structural Steel
2. ASTM A53 Standard Specification for Welded and Seamless Steel Pipe
3. ASTM A307 Standard Specification for Carbon Steel Externally and Internally Threaded Standard Fasteners
4. ASTM A325 Standard Specification for High-Strength Bolts for Structural Steel Joints
5. ASTM A490 Standard Specification for Quenched and Tempered Alloy Steel Bolts for Structural Steel
6. ASTM A500 Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shape
7. ASTM A501 Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
8. ASTM A563 Standard Specification for Carbon and Alloy Steel Nuts
9. ASTM E165 Recommended Practice for Liquid Penetrant Inspections
10. ASTM F436 Standard Specification for Hardened Steel Washers

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**Title****SPECIFICATION FOR STRUCTURAL STEEL FABRICATION AND PAINTING**

- 4.1.3 American Welding Society (AWS)
  - 1. D1.1 Structural Welding Code
- 4.1.4 Steel Structures Painting Council (SSPC)
  - 1. SSPC-SP6 Commercial Blast Cleaning

**5.0 MATERIAL**

- 5.1 All material shall be of domestic origin or from Canada, Germany or Japan.
- 5.2 Carbon steel structural steel shapes, plates, and bars shall conform to ASTM A36.
- 5.3 Steel pipe shall conform to ASTM A53, Grade B.
- 5.4 Structural steel tubing shall conform to ASTM A500, Grade B or ASTM A501.
- 5.5 High-strength bolts shall conform to ASTM A325, Type 1. Hot forged bolts will not be permitted.
- 5.6 Nuts shall conform to ASTM A563 for the recommended grade and style and the Supplementary Requirements S1.
- 5.7 Washers shall conform to ASTM F436.
- 5.8 Common bolts shall conform to ASTM A307, Grade A.
- 5.9 Weldable steel stud connectors shall be of the automatic-end-weld type conforming to AWS 1.1.
- 5.10 Stainless steel shapes shall conform to ASTM A479 Gr. 304; structural tubing to ASTM A554 Gr. 304; plate to ASTM A240 Gr. 304.
- 5.11 Certified material test reports (CMTRs) for structural steel shall be provided to the engineer prior to the start of fabrication.

**6.0 FABRICATION**

- 6.1 Shop fabricated structural steel shall be assembled into units as large as possible consistent with shipping limitations.
- 6.2 Workmanship and fabrication shall be in accordance with the referenced AISC publications except as specifically modified by this specification.

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**SPECIFICATION FOR STRUCTURAL STEEL FABRICATION AND PAINTING**

- 6.2.1 Materials shall have clean surfaces before fabricating. Joint surfaces, including those adjacent to washers, shall be free of dirt, loose scale, burrs, or other defects that would prevent solid seating of all parts.
- 6.2.2 Fabricated members shall be free of twists, bends, or loose joints.
- 6.2.3 Bolt holes shall be drilled or punched to locations 1/16 inch larger than the nominal diameter of bolt unless otherwise specified on the design drawings. If the thickness of the material is greater than the nominal diameter of the bolt plus 1/8 inch, the holes shall be drilled or sub-punched and reamed. Errors in hole size or location shall be cause for rejection.
- 6.2.4 Column baseplates exceeding 15/16 inch in thickness shall be thermal cut by machine to the size specified.
- 6.2.5 Welding shall be in accordance with AWS D1.1
  - 1. Welders, tackers, and welding operators shall hold current certification in accordance with AWS D1.1 to perform the type of welding required.
  - 2. The technique of welding employed, the appearance and quality of welds made, and methods used in correcting defective work shall conform to AWS D1.1.
  - 3. Except for stud connectors, welds shall be either by manual shielded metal-arc welding, submerged arc welding, or flux cored arc welding processes. Electrodes shall conform to AWS or A5.5, E70 series, for manual shielded metal-arc welding. For submerged arc welding, electrodes and granular flux shall conform to AWS 5.17, F7X-EXXX Classification. For flux cored arc welding, electrodes and flux shall conform to AWS A5.20, E70 T-X series.
  - 4. Tack welds which are not incorporated into the final weld and inadvertent arc strikes shall be removed and ground smooth.
  - 5. Welds run-off tabs shall be cut off and ground smooth at the ends of the finished member.
  - 6. Stud connectors shall be installed in accordance with and meet the requirements of AWS D1.1.
- 6.3 When field welding is specified on the engineer's drawings, the fabricator shall furnish and install suitable erection supports, subject to approval by the engineer, for erecting and welding of field connections.
- 6.4 Dimensional tolerances as shown on the PSI drawings are to be adhered to. Multiple assemblies made from the same drawing are to be interchangeable during field erection.

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**7.0 SCHEDULE**

- 7.1 See Attachment "B" for assembly quantities and delivery schedule.
- 7.2 All of the above items shall be shipped to the Buyer directly (Westborough, Massachusetts).

**8.0 INSPECTION AND TESTING**

- 8.1 The engineer, owner or his representative reserves the right to make reviews, inspection, or tests of the work included in this specification at times that he deems necessary to maintain schedule or quality. The fabricator shall provide cooperation and assistance with such reviews, inspections, or tests as the engineer may require.
- 8.2 The fabricator shall perform a 100% dimensional and visual inspection of all welds on each assembly. All dimensions shall be within established tolerances. All welds shall be free of splatter, slag, undercut, overlap and shall meet the requirements specified in AWS-D1.1. Reports on the above shall be provided with each shipment upon receipt at PSI. At PSI, the reports and the assembly will be verified during receipt inspection.
- 8.3 A certificate of compliance shall be furnished to the Buyer stating that the requirements of the applicable drawings and this specification have been met.

**9.0 PAINTING**

Fabricated parts shall be spray painted by the fabricator with one (1) prime coat and one (1) finish coat of Sherwin Williams Kem Hi-temp No. 500 semi-heat resistant coating in accordance with the manufacturer recommendation.

- 9.1 Surface Preparation.  
Fabricator shall sand blast all exposed surfaces in accordance with SSPC-SP-6.
- 9.1.2 Primer Coat. Kem Hi-Temp  
No. 500 Fast Dry primer shall be applied to a maximum dry film thickness of 1.5 mils.
- 9.1.3 Finish Coat. Kem Hi-Temp.  
No. 500 series No. 2 Silver shall be applied to a dry film thickness of 1 to 1.3 mils.

**10. PIECE MARKING**

Each fabricated part is to be tagged with a part number consisting of the drawing number and a "P" number. The part number will be shown on the PSI assembly drawings.

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ATTACHMENT "A"  
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:					JOB NO.: V59049
EQUIPMENT: CARBON STEEL FABRICATION/PAINTING	VENDOR ENG. OFFICE:					DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:					SPECNO: V049-2-139
TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:  Inspector:  Date:
MILESTONE SCHEDULE			X	2	X	
VENDOR Q.A. PLAN			X	2	X	
PREP FOR SHIPMENT PROCEDURE			X	2	X	
WELDING PROCEDURES			X	2	X	
ASSEMBLY DRAWINGS			X	2	X	
CERTIFIED MATERIAL TEST REPORTS			X	2	X	
IN-PROCESS INSPECTIONS			X	2	X	
OPERATION & MAINTENANCE MANUALS						
SHOP DIMENSIONAL INSPECTION			X	2	X	



Title:

**SPECIFICATION FOR THERMAL INSULATION - PIPING**

**ATTACHMENT A  
COLD INSULATION - ILLUSTRATIONS  
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TYPICAL PIPING INSULATION COLD SERVICE

FIGURE B-1 POLYISOCYANURATE INSULATION - TYPICAL PIPE SECTION

FIGURE B-2 POLYISOCYANURATE INSULATION - EXPANSION JOINT

FIGURE B-3 POLYISOCYANURATE INSULATION - ELBOW

FIGURE B-4 POLYISOCYANURATE INSULATION - FLANGE

FIGURE B-5 POLYISOCYANURATE INSULATION - VALVE

FIGURE B-6 POLYISOCYANURATE INSULATION - EXTENDED STEM VALVE

FIGURE C1 SAME AS B1 WITH FIBERGLASS INNER LAYER

FIGURE C2 SAME AS B2 WITH FIBERGLASS INNER LAYER

FIGURE C3 SAME AS B3 WITH FIBERGLASS INNER LAYER

FIGURE C4 SAME AS B4 WITH FIBERGLASS INNER LAYER

FIGURE C5 SAME AS B5 WITH FIBERGLASS INNER LAYER

FIGURE C6 SAME AS B6 WITH FIBERGLASS INNER LAYER

FIGURE D1 FIBERGLASS INSULATION TYPICAL PIPE SECTION

FIGURE D2 FIBERGLASS INSULATION ELBOW

FIGURE D3 FIBERGLASS INSULATION EXTENDED STEM VALVE

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- 1.0 SCOPE/GENERAL
- 2.0 MATERIALS
- 3.0 THICKNESS OF INSULATION
- 4.0 INSTALLATION

**ATTACHMENTS**

TYPICAL PIPING INSULATION COLD SERVICE

FIGURE B-1 POLYISOCYANURATE INSULATION -  
TYPICAL PIPE SECTION

FIGURE B-2 POLYISOCYANURATE INSULATION - EXPANSION  
JOINT

FIGURE B-3 POLYISOCYANURTE INSULATION - ELBOW

FIGURE B-4 POLYISOCYANURATE INSULATION - FLANGE

FIGURE B-5 POLYISOCYANURATE INSULATION -  
VALVE

FIGURE B-6 POLYISOCYANURATE INSULATION -  
EXTENDED STEM VALVE

FIGURE C1 SAME AS B1 WITH FIBERGLASS INNER LAYER

FIGURE C2 SAME AS B2 WITH FIBERGLASS INNER LAYER

FIGURE C3 SAME AS B3 WITH FIBERGLASS INNER LAYER

FIGURE C4 SAME AS B4 WITH FIBERGLASS INNER LAYER

FIGURE C5 SAME AS B5 WITH FIBERGLASS INNER LAYER

FIGURE C6 SAME AS B6 WITH FIBERGLASS INNER LAYER

FIGURE D1 FIBERGLASS INSULATION TYPICAL PIPE SECTION

FIGURE D2 FIBERGLASS INSULATION ELBOW

FIGURE D3 FIBERGLASS INSULATION EXTENDED STEM VALVE

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**SPECIFICATION FOR THERMAL INSULATION - PIPING**

**1.0 SCOPE/GENERAL**

1.1 This document outlines methods and procedures for the fabrication and installation of insulation systems which are defined as follows:

Cold Insulation - Polyisocyanurate foam  
(-320°F to 300°F)

Hot/Cold - Polyisocyanurate foam  
Insulation for Outer Layer, Fiberglass Blanket for Inner Layer (-320°F to 350°F)

1.2 All material shall be suitable for continuous outdoor and indoor service.

Ambient Temperature: 10°F to 100°F  
Relative Humidity: 50 to 100%

1.3 Insulation identification can be determined from the following legend:

Insulation Classes

C = Cold Conservation  
HC = Hot/Cold Conservation  
PC = Personnel Protection Cold  
PH = Personnel Protection Hot

1.4 The extent of surfaces to be insulated shall be defined by one or more of the following:

Piping and Instrumentation Diagrams  
General Piping Isometrics Arrangement Drawings  
This Specification

1.5 In addition to piping; insulation shall be applied to all pipe nipples, fittings, flanges, unions, valves and projections through the base insulation unless otherwise noted.

**1.6 SPECIFICATION COMPLIANCE**

The equipment shall comply with any drawings, data sheets, standards, codes and specifications referred to or attached as part of this specification. Any applicable national, state, or local codes or regulations shall be considered as part of this specification. The Vendor is responsible for compliance with such standards, specifications, codes and requirements.

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**2.0 MATERIALS**

Acceptable insulation materials are listed in Paragraph 5.5 of this specification. Vendor may quote equivalent materials. However, all "equivalent" materials must be approved by the Purchaser prior to use.

**3.0 THICKNESS OF INSULATION**

Insulation thickness shall be as designated on the Piping and Instrumentation Diagrams.

Any discrepancies shall be brought to the attention of PSI for resolution. The other documents provided are for arrangement and dimension information.

4.1 Special Insulation Codes

FP3	1" Fiberglass inner 2" Polyisocyanurate outer
F1.5	1 1/2" Fiberglass

**4.0 INSTALLATION**

4.1 **GENERAL**

1. The attached illustrations are included as a guide for fabrication and installation of insulation systems.
2. Insulating materials shall be protected from moisture at all times.
3. All insulation shall be installed butted together.
4. Insulation showing any evidence of moisture shall be rejected.
5. Insulation shall not be applied to any surface where there is any evidence of moisture or frost.
6. All material applied in one day shall have the vapor barrier applied in the same day. Exposed ends shall be temporarily protected by extending the vapor barrier over the exposed ends and onto the bare pipe or equipment.
7. All outer surfaces of insulation shall be covered with a continuous vapor barrier.
8. There shall be no discontinuities in the vapor barrier.

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9. Plastic pipe jacketing shall be installed as the final covering on the insulation.

**4.2 VALVES, FLANGES, AND PIPE FITTINGS**

- a. Valves and flanges shall be insulated to provide coverings that can be removed easily without destroying the covering or the pipe insulation and its vapor barrier. Pipe insulation shall extend to the flange or valve and shall be vapor sealed against the pipe. Insulation shall be beveled so that bolts may be removed without damage to adjacent insulation. Insulation thickness shall be equal to the pipe insulation thickness where clearances are sufficient. Where clearances are inadequate, the insulation may be trimmed as required.
- b. Valve stems on cryogenic valves shall be insulated half way between the pipe centerline and packing flange.

**4.3 PIPE SUPPORTS**

Piping shall be insulated in a normal manner around supports except when an attached figure is supplied to indicate more extensive application or insulation boundary is required.

**4.4 MATERIALS DESCRIPTION**

All materials must comply with the following requirements. Caution shall be exercised in job site storage and handling to assure that the completed system will be dry, mechanically sound and meet all requirements of this specification. Defective materials shall be replaced.

**4.4.1 Preformed Section 2 lb/cu. ft. Polyisocyanurate**

Acceptable Materials:

- a. Dow Trymer 2000 or PSI approved equal.

**4.4.2 Preformed Section Fiberglass**

Acceptable Material:

Owens Corning SSL-II Pipe Insulation

**4.4.3 Joint Sealant and Vapor Stop Mastic**

Acceptable Material:

- a. B.F. 95-44 Elastolar Sealant, manufactured by H.B. Fuller Company, Foster Division, Houston, Texas. To be purchased in both of the following container sizes:

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5 gallon containers - for trower

11 fluid ounce tubes - for hand caulking guns

- b. Dow Corning Silastic 736 or approved equal.
- c. Pittseal 111, manufactured by Pittsburgh Corning Corporation.
- d. Foamseal 30-45, manufactured by Foster Division of Amchem.
- e. S-31 Sealant, manufactured by Mastics and Adhesives Company.

4.4.4 Filament Tape 1" Wide Rolls

Acceptable Material:

- a. 3-M Scotch Brand Filament Tape No. 898 manufactured by Minnesota Mining and Manufacturing Company.
- b. Mystic Tape No. 6491, manufacturing by Mastik Tape, Division of Borden Chemicals, Borden, Inc., Northfield, Illinois.

4.4.5 Membrane

Polyester fabric cloth having an 8 x 8 or similar size weave pattern. Glass cloth is not suitable for use with the B.F. 60-30 vapor barrier mastic.

Acceptable Material:

MAST-A-FAB, polyester fabric, 8 x 8 weave pattern. Manufacture by Foster Division of Amchem Products.

4.4.6 Vapor Barrier Mastic

Acceptable Material:

- a. B.F. 60-30 (dark brown - trowel grade) manufactured by H.B. Fuller Company, Foster Products Division.
- b. Rust-Ban Vapalon FR manufactured by Matcole Company, Inc.
- c. Elastometric Coating EC-26 manufactured by Mastics and Adhesives Company

4.4.7 3 PCF Fiberglass Blanket

Industrial glass blanket without backing, 3 lb/cu. foot density, 1" thick or as required.

4.4.8 1 PCF Fiberglass Blanket

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Industrial glass blanket without backing, 1 lb/cu. foot density, 1/2" thick (to fill voids).

4.4.9 Tie Wire

16 gauge, soft annealed galvanized wire.

4.4.10 Plastic Pipe Jacketing

- a. Plastic pipe jacketing shall be Zeston 2000 PVC (white) or approved equal.
- b. Jacketing form and thickness to be used shall be as follows:
  - 1. Piping - 0.03" cut and curled.
  - 2. Fittings -0.03" preformed.
  - 3. Jacket bonding adhesive shall be Perma-bond solvent welding adhesive, or approved equal

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TYPICAL PIPING INSULATION COLD SERVICE

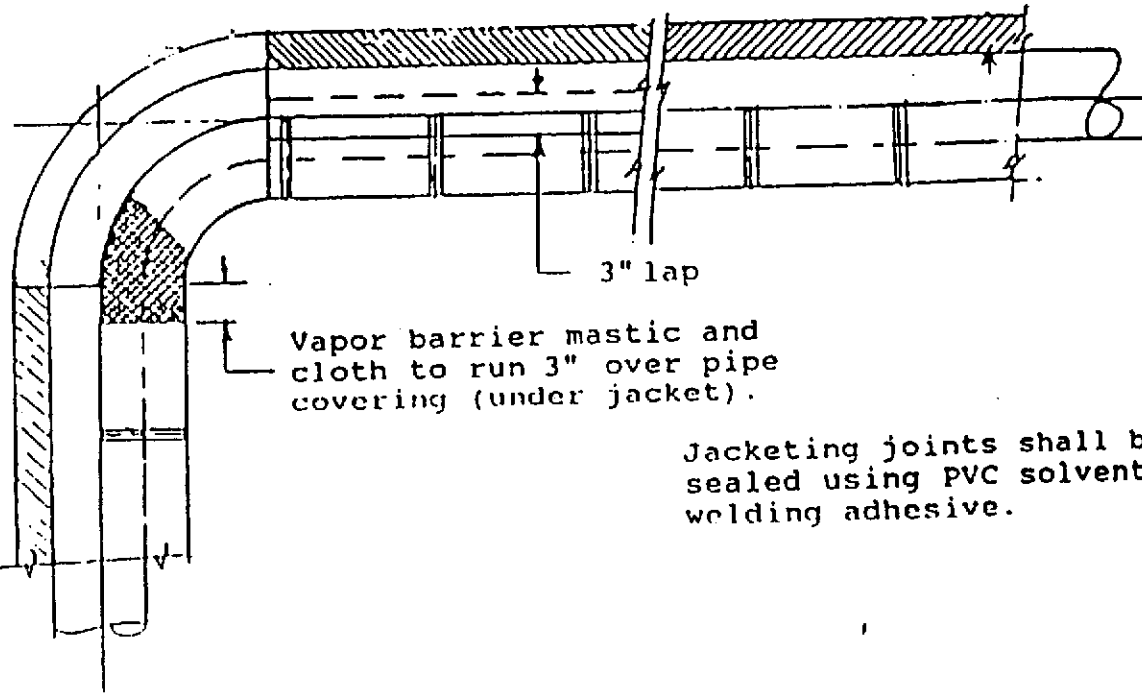
Metal must be clean, dry and free from frost, rust, etc.

Apply plastic jacketing over pipe and fittings per Para. 5.5.10. All laps to be at least 3" and sealed.

Insulation for fittings, valves, flanges, etc. shall be prefabricated using same material and thickness as adjacent piping. Install fitting covers before pipe insul. Seal joints with mastic joint sealer.

Longitudinal joints shall be 45° below horizontal centerline of pipe and lapped to shed water.

Thickness of insulation in accordance with the Piping and Instrumentation Diagrams.



Sharp edges of insulation shall be smoothed prior to application of finish.

Vapor barrier mastic and cloth to run 3" over pipe covering (under jacket).

Jacketing joints shall be sealed using PVC solvent welding adhesive.

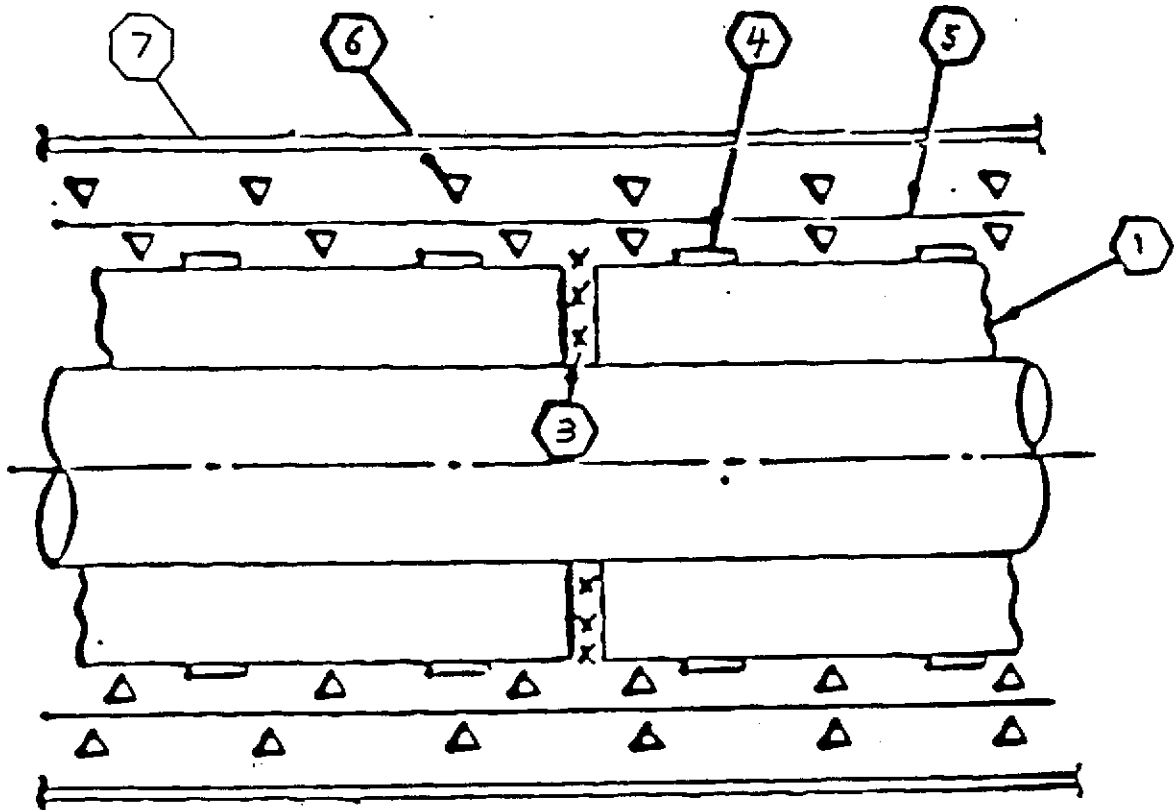
Use "S" clips to support jacket on vertical pipe.

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FIGURE B-1

## POLYISOCYANURATE INSULATION - TYPICAL PIPE SECTION



- [1] Polyisocyanurate
- [3] Joint Sealant and Vapor Stop Mastic
- [4] Filament Tape
- [5] Membrane
- [6] Vapor Barrier Mastic
- [7] PLASTIC PIPE JACKET

Use wire to secure inner layers and tape to secure outer layers of insulation. Use a minimum of 3 wraps per segment. Overlap tape ends 50% of pipe circumference.

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## SPECIFICATION

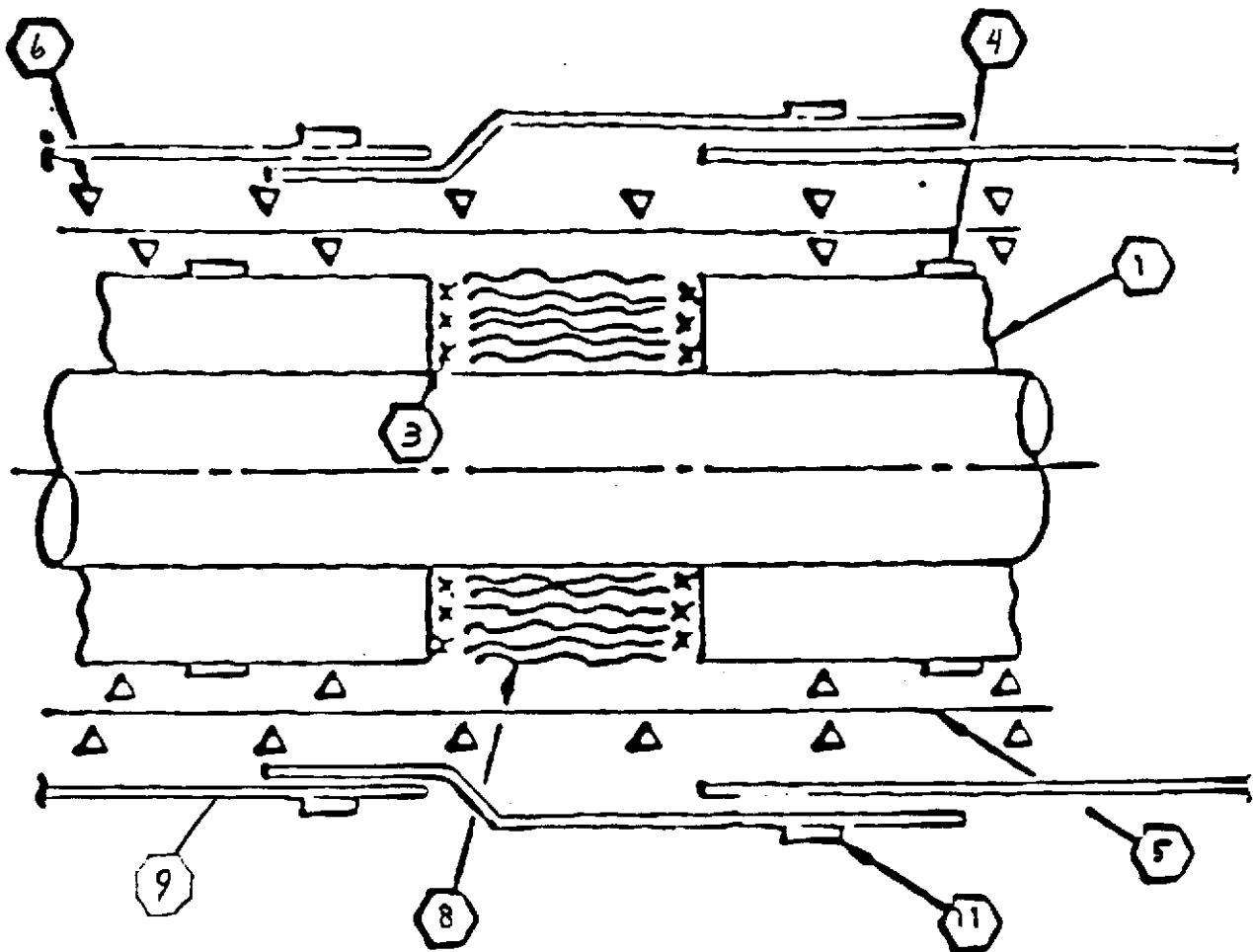
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**FIGURE B-2**  
**POLYISOCYANURATE INSULATION - EXPANSION JOINT**



**KEY**

- [1] Polyisocyanurate
- [3] Joint Sealant and Vapor Stop Mastic
- [4] Filament Tape
- [5] Membrane
- [6] Vapor Barrier Mastic
- [8] 1 PCF FIBERGLASS BLANKET
- [9] PLASTIC PIPE JACKET

Use wire to secure inner layers and tape to secure outer layers of insulation. Use a minimum of 3 wraps per segment. Overlap tape ends 50% of pipe circumference.

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Number **A** V049-2-163

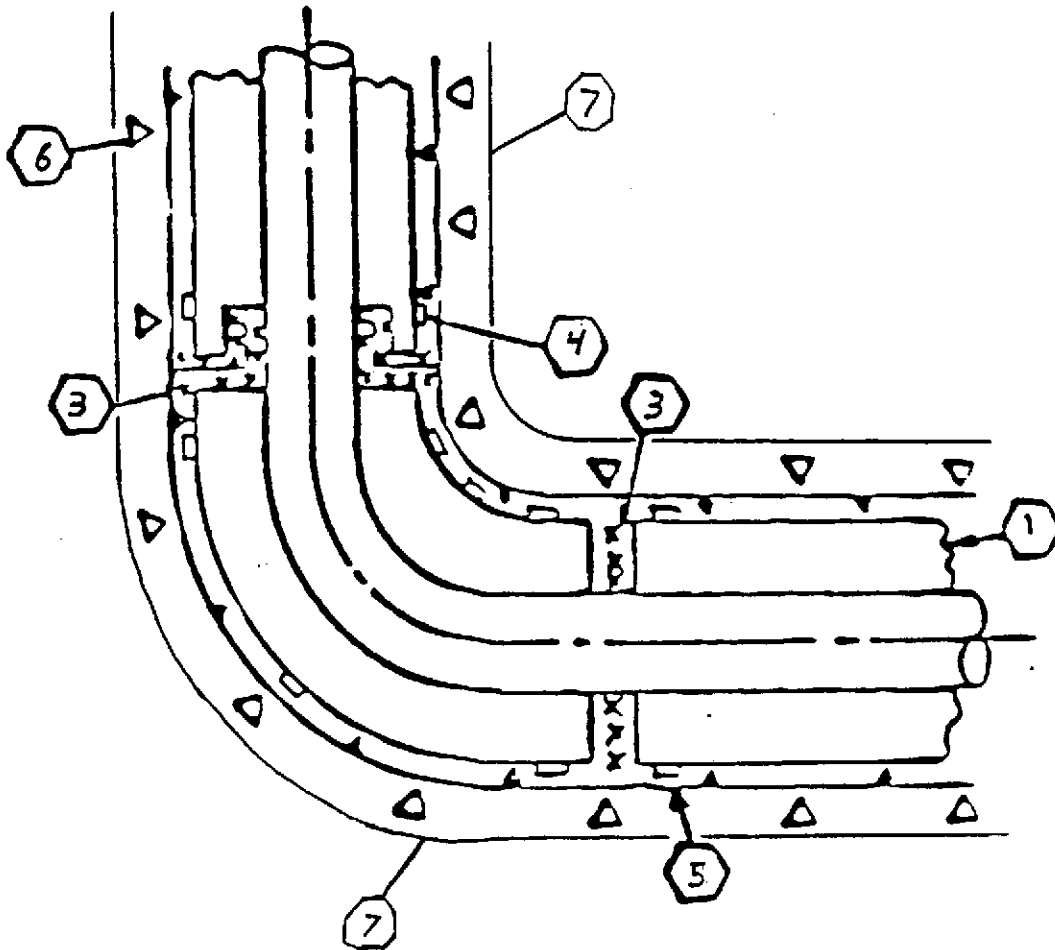
Rev. **0**

Number  
Rev.

Title

# SPECIFICATION FOR THERMAL INSULATION - PIPING

**FIGURE B-3**  
**POLYISOCYANURATE INSULATION ELBOW**



**KEY**

- [1] Polyisocyanurate
- [3] JOINT SEALANT AND VAPOR STOP MASTIC
- [4] FILAMENT TAPE
- [5] MEMBRANE
- [6] VAPOR BARRIER MASTIC
- [7] PLASTIC PIPE JACKET

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**SPECIFICATION**

Number - 17040 2 122

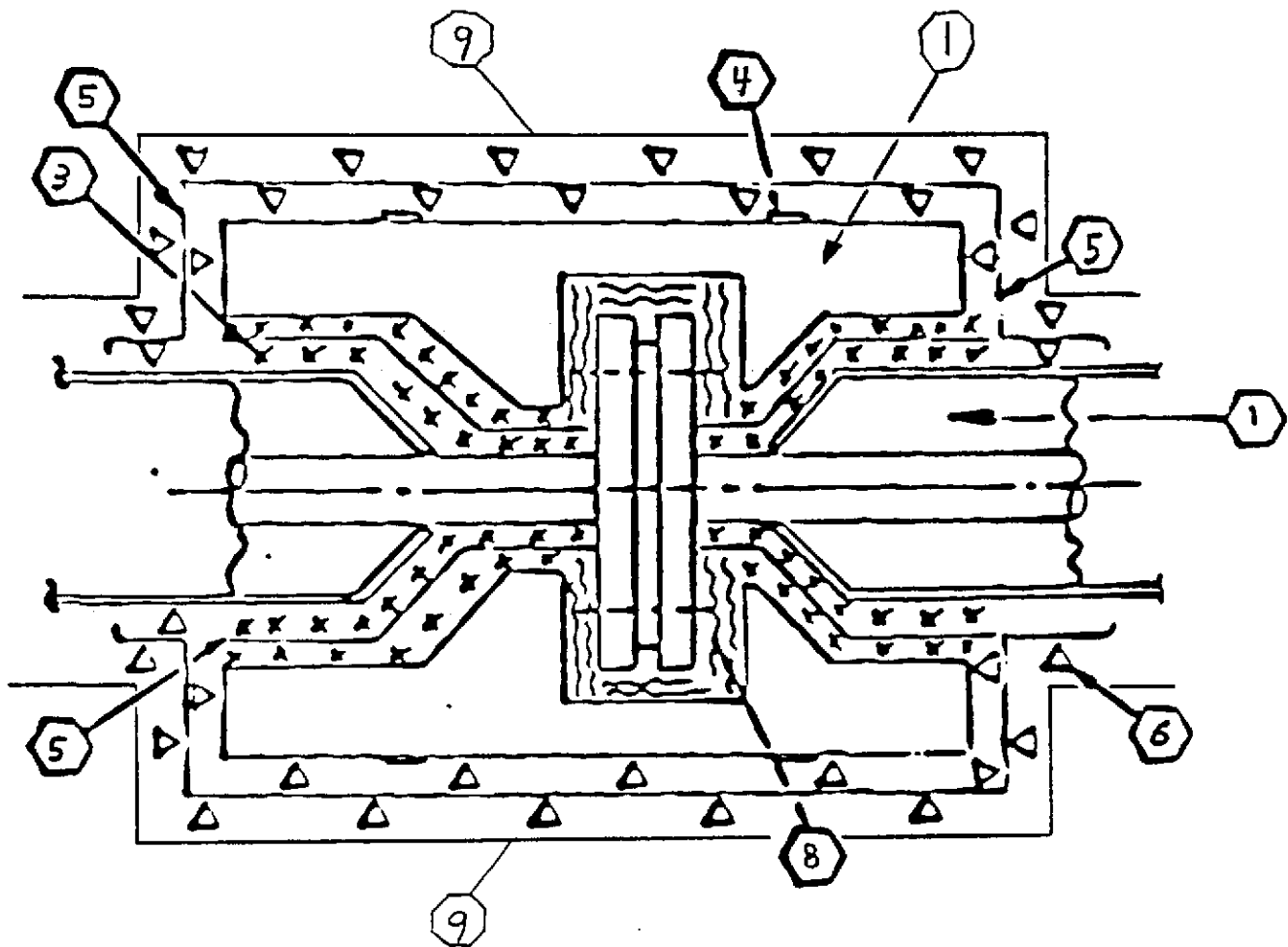
Rev.

Title

**SPECIFICATION FOR THERMAL INSULATION - PIPING**

**FIGURE B-4**

**POLYISOCYANURATE INSULATION FLANGE**



**KEY**

- [1] Polyisocyanurate
- [3] JOINT SEALANT AND VAPOR STOP MASTIC
- [4] FILAMENT TAPE
- [5] MEMBRANE
- [6] VAPOR BARRIER MASTIC
- [8] 1 PCF FIBERGLASS BLANKET
- [9] PLASTIC PIPE JACKET

Number

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**SPECIFICATION**

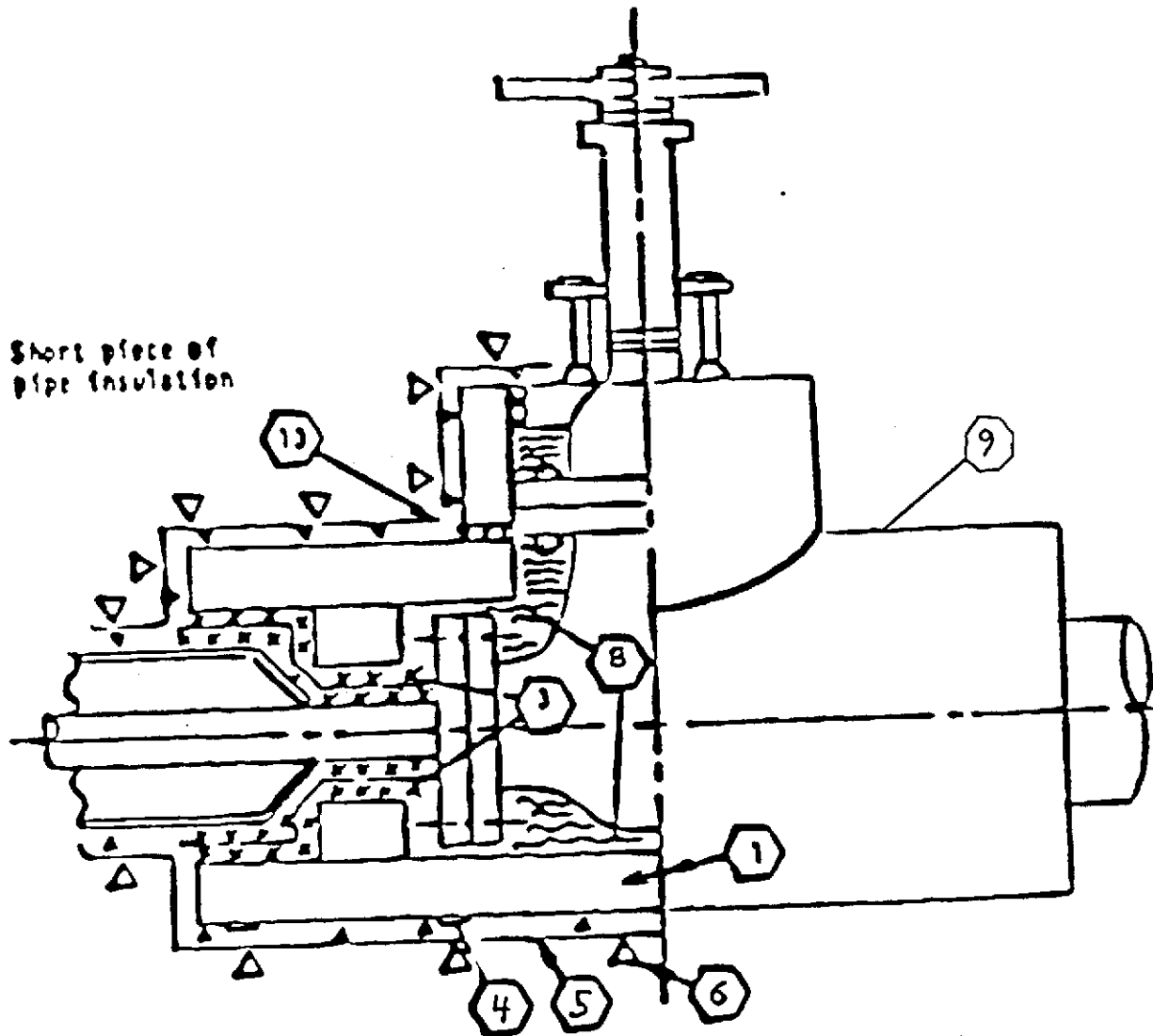
Number **A** V049-2-163

Rev. **0**

Title

**SPECIFICATION FOR THERMAL INSULATION - PIPING**

**FIGURE B-5**  
**POLYISOCYANURATE INSULATION VALVE**



**KEY**

- |   |                              |
|---|------------------------------|
| [1] Polyisocyanurate                    | [6] VAPOR BARRIER MASTIC     |
| [3] JOINT SEALANT AND VAPOR STOP MASTIC | [8] 1 PCF FIBERGLASS BLANKET |
| [4] FILAMENT TAPE                       | [9] PLASTIC PIPE JACKET      |
| [5] MEMBRANE                            | [13] SILICONE SEALANT        |

1. EXTEND JOINT SEALANT AND VAPOR STOP MASTIC AND GLASS CLOTH SEVERAL INCHES PAST THE INSULATION AND ONTO THE VALVE BONNET TO ASSURE THAT A GOOD VAPOR STOP IS FORMED.
2. INSULATION TO BE INSTALLED IN TWO HALVES. VAPOR SEALED AGAINST PIPE JACKET, BONNET, ETC.

**SPECIFICATION**

Number **A**

Rev. **0**

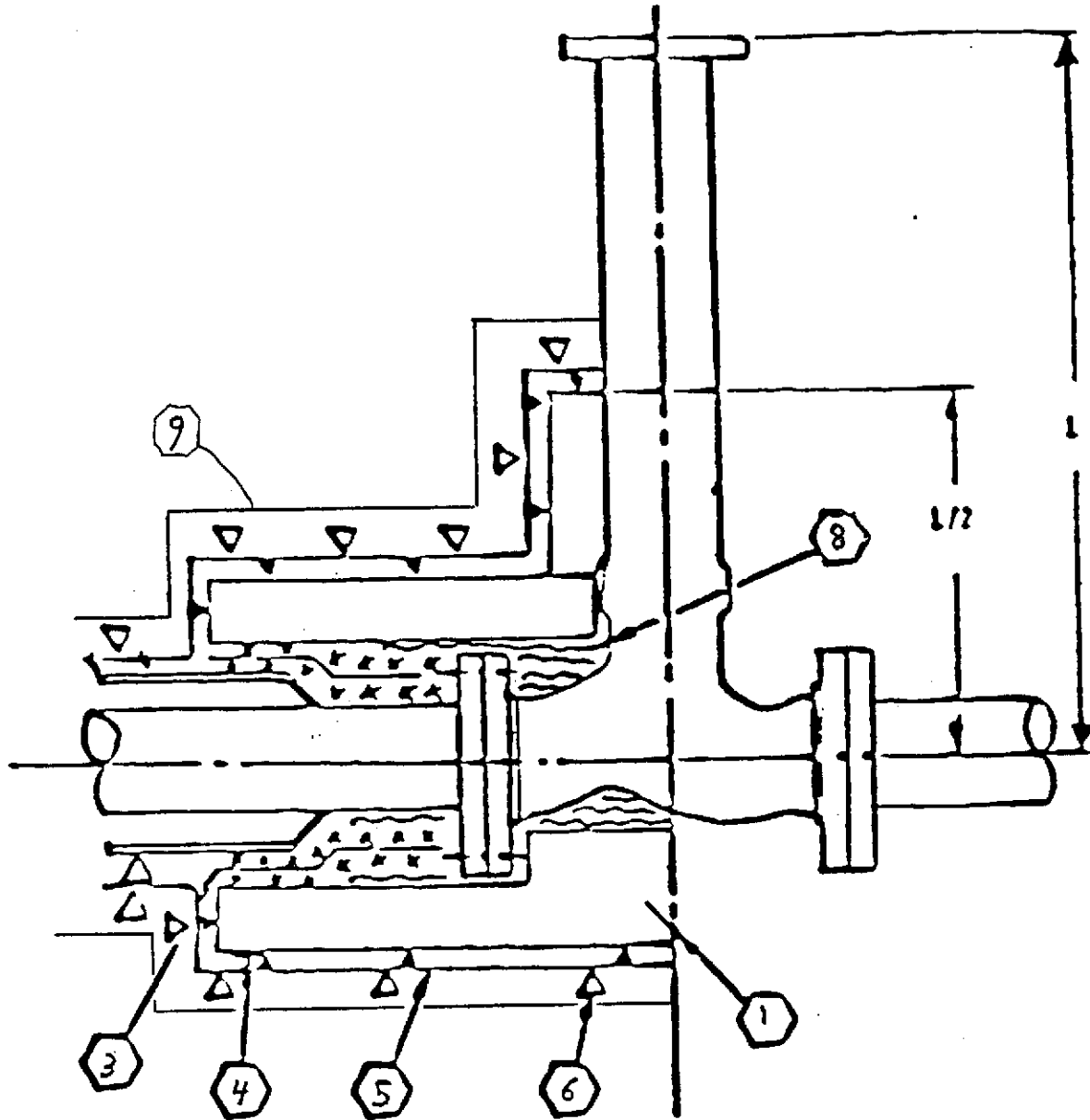
Number

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Title

# SPECIFICATION FOR THERMAL INSULATION - PIPING

**FIGURE B-6**  
**POLYISOCYANURATE INSULATION EXTENDED STEM VALVE**



**KEY**

- [1] Polyisocyanurate
- [3] JOINT SEALANT AND VAPOR STOP MASTIC
- [4] FILAMENT TAPE
- [5] MEMBRANE
- [6] VAPOR BARRIER MASTIC
- [8] 1 PCF FIBERGLASS BLANKET
- [9] PLASTIC PIPE JACKET

## SPECIFICATION

Number **A** V049-2-163

Rev. **0**

Number

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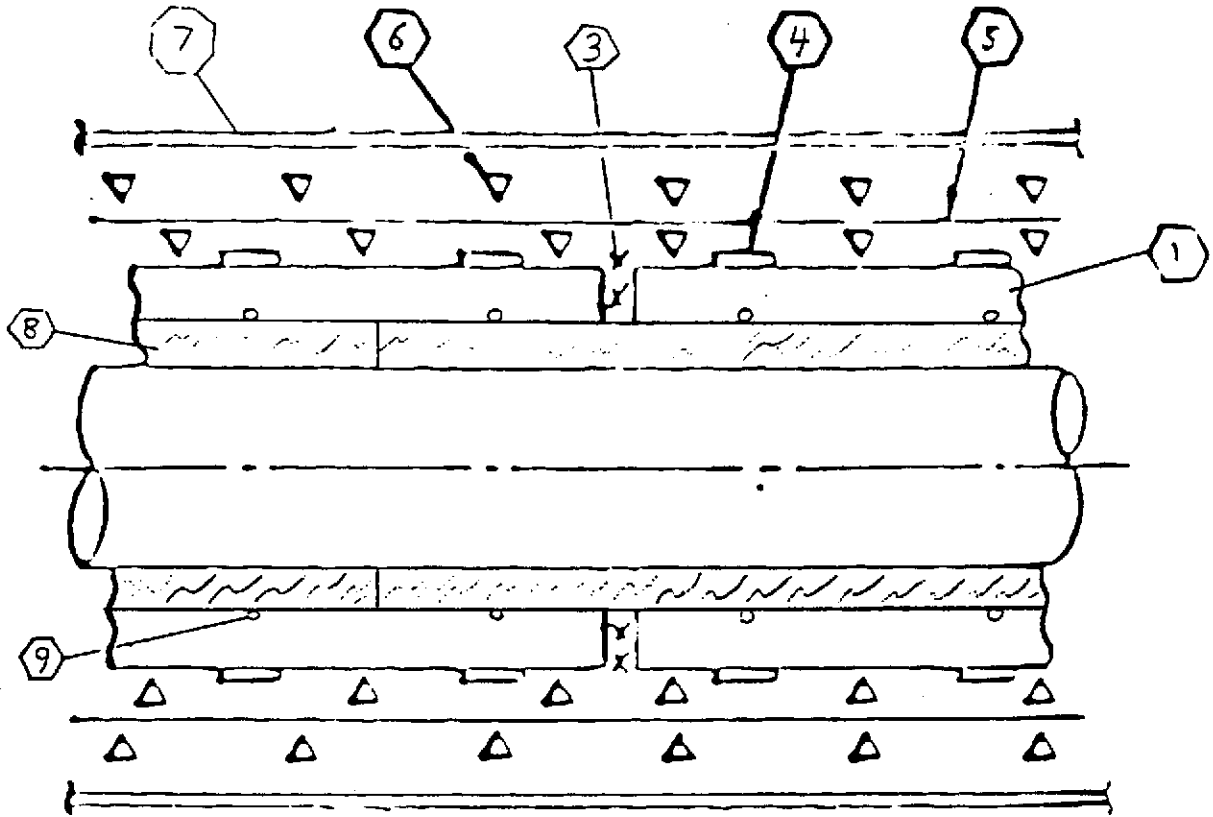


Title

# SPECIFICATION FOR THERMAL INSULATION - PIPING

FIGURE C 1

## POLYISOCYANURATE INSULATION - TYPICAL PIPE SECTION WITH FIBERGLASS INNER LAYER



- [1] Polyisocyanurate
- [3] Joint Sealant and Vapor Stop Mastic
- [4] Filament Tape
- [5] Membrane
- [6] VAPOR BARRIER MASTIC
- [7] PLASTIC PIPE JACKET
- [8] FIBERGLASS INNER LAYER
- [9] 16 GAUGE WIRE

Use wire to secure inner layers and tape to secure outer layers of insulation. Use a minimum of 3 wraps per segment. Overlay tape ends 50% of pipe circumference.

SPECIFICATION

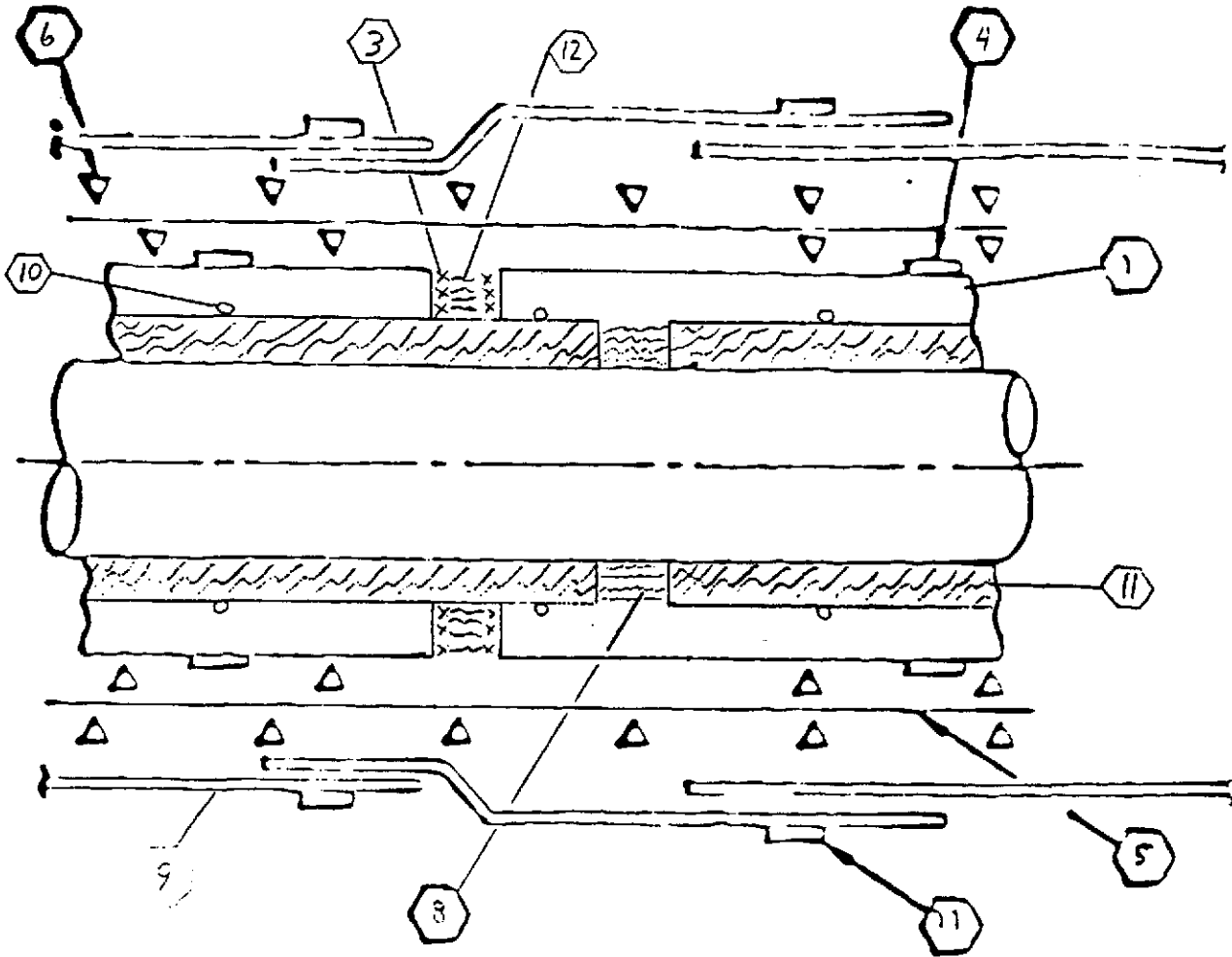
Number A V049-2-163

Rev 0

Planned

Approved  
A.H. Smith

**FIGURE C2**  
**POLYISOCYANURATE INSULATION - EXPANSION JOINT**



**KEY**

- |   |   |
|---|---|
| [1] Polyisocyanurate                        | Use wire to secure inner layers and tape to secure outer layers of insulation.    |
| [3] Joint Sealant and Vapor Stop Mastic     | Use a minimum of 3 wraps per segment. Overlap tape and 50% of pipe circumference. |
| [4] Filament Tape                           |   |
| [5] Membrane                                |   |
| [6] Vapor Barrier Mastic                    |   |
| [8] 3 Pcf Fiberglass Blanket (1" THICK MIN) |   |
| [9] PLASTIC PIPE JACKET                     |   |
| [10] 16 GAUGE WIRE                          |   |
| [7] FIBERGLASS INNER                        |   |
| [2] FIBERGLASS INNER                        |   |

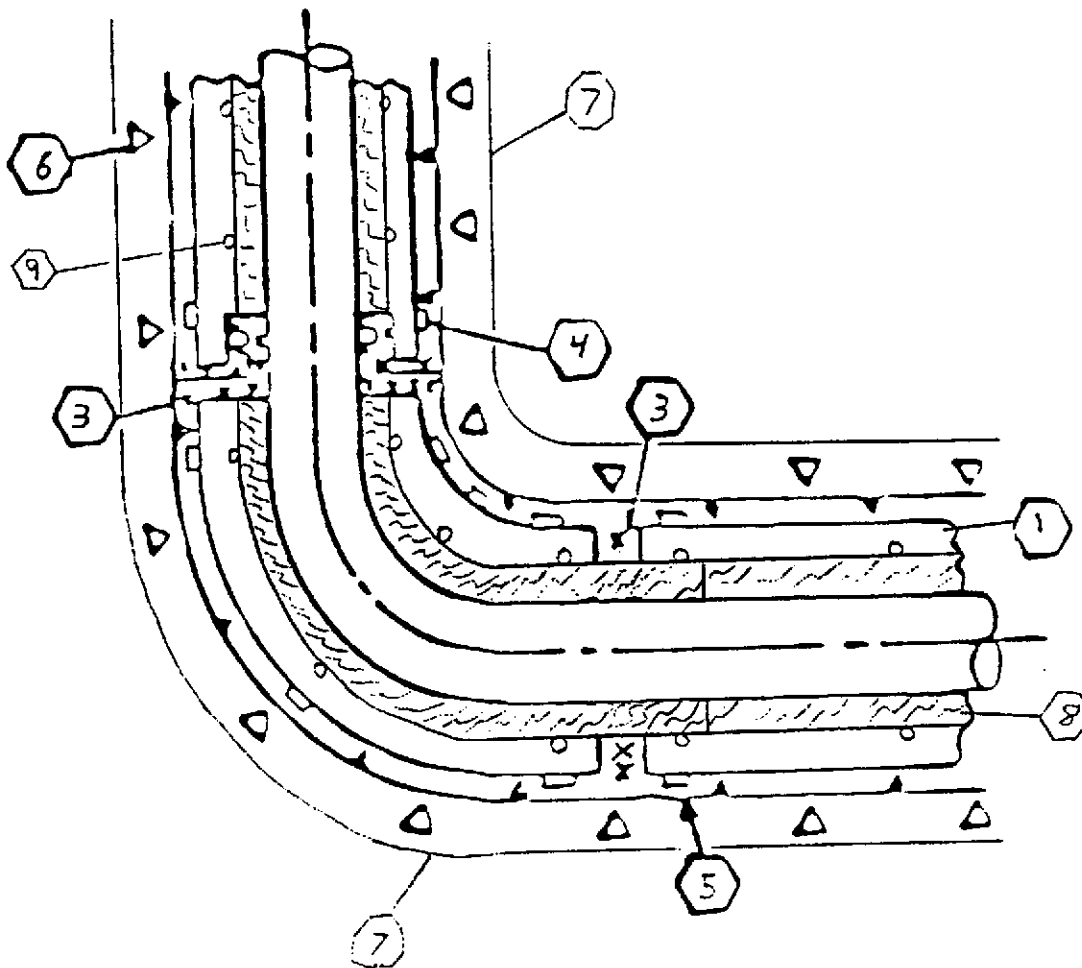
<b>SPECIFICATION</b>	
Number	Rev
<b>A</b> V049-2-163	0

Number  
 Date  
 Rev

Title

# SPECIFICATION FOR THERMAL INSULATION - PIPING

**FIGURE C3**  
**POLYISOCYANURATE INSULATION ELBOW**  
**WITH FIBERGLASS INNER LAYER**



**KEY**

- [1] Polyisocyanurate
- [3] JOINT SEALANT AND VAPOR STOP MASTIC
- [4] FILAMENT TAPE
- [5] MEMBRANE
- [6] VAPOR BARRIER MASTIC
- [7] PLASTIC PIPE JACKET
- [8] FIBERGLASS INNER LAYER
- [9] 6 GAUGE WIRE

## SPECIFICATION

Number **A** V049-2-163

Rev. **0**

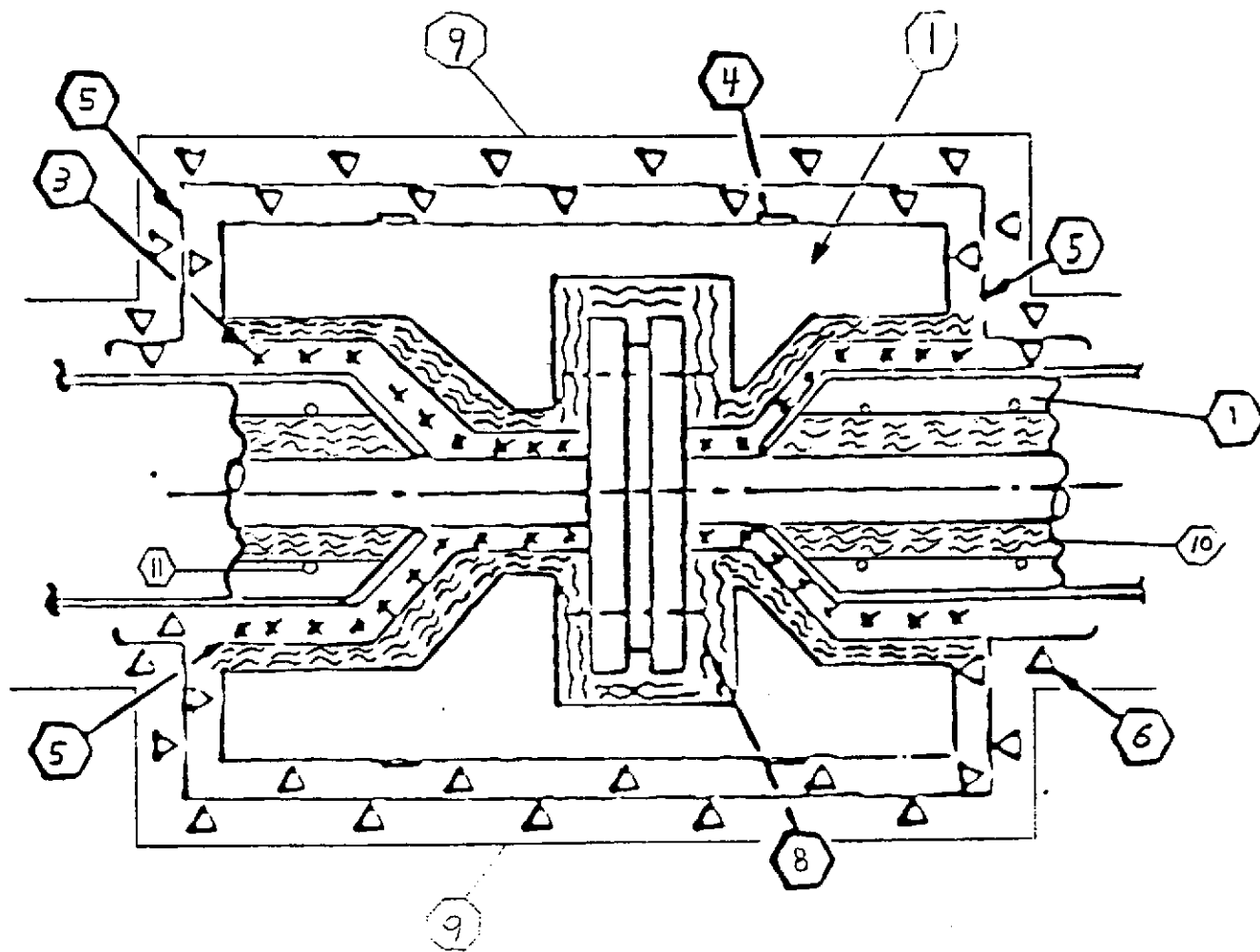
Approved  
Checked  
Date

Title

# SPECIFICATION FOR THERMAL INSULATION - PIPING

FIGURE C 4

## POLYISOCYANURATE INSULATION FLANGE WITH FIBERGLASS INNER LAYER



**KEY**

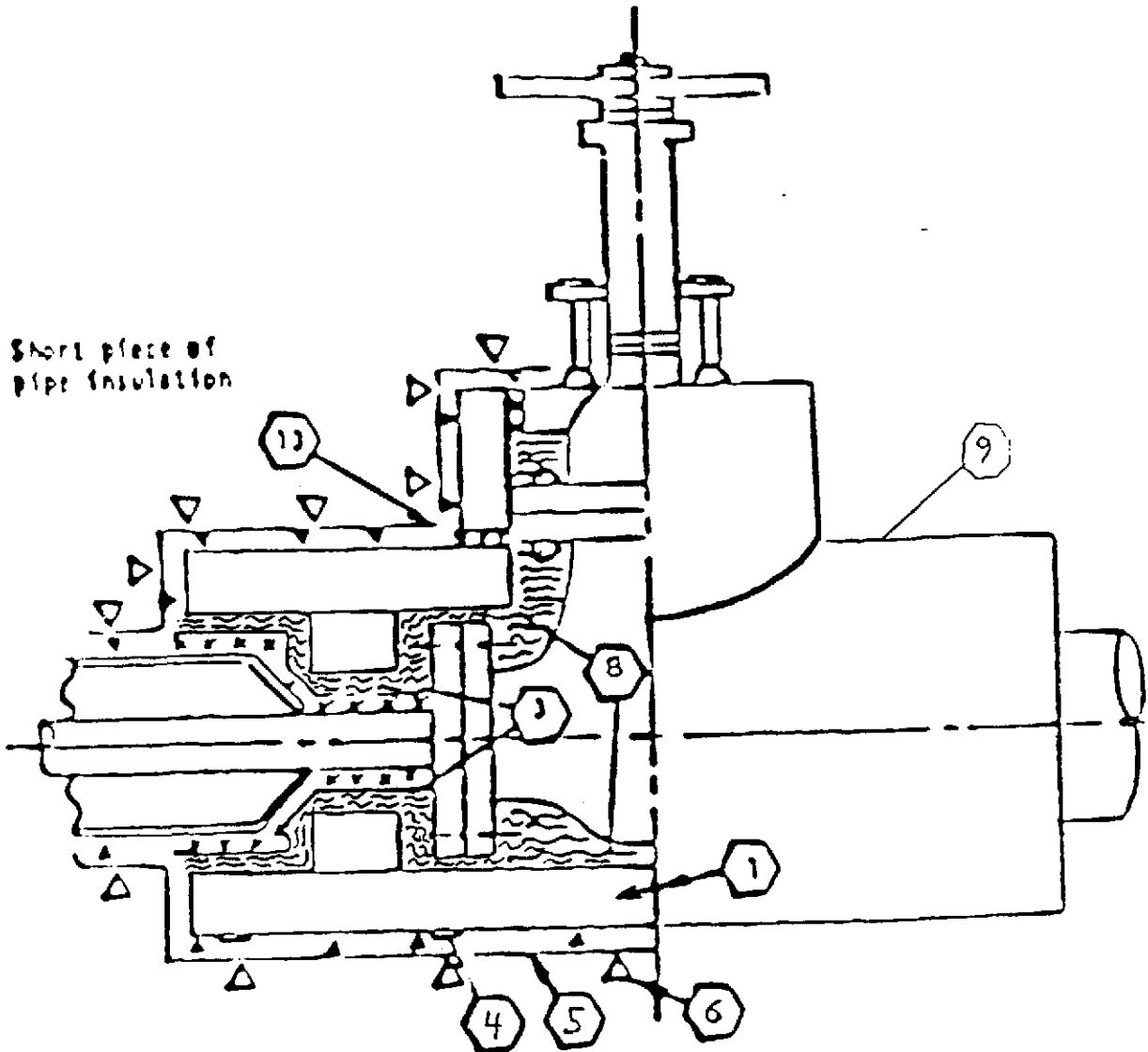
- [1] Polyisocyanurate
- [3] JOINT SEALANT AND VAPOR STOP MASTIC
- [4] FILAMENT TAPE
- [5] MEMBRANE
- [6] VAPOR BARRIER MASTIC
- [8] 3 PCF FIBERGLASS BLANKET (1" MIN THK)
- [9] PLASTIC PIPE JACKET
- [10] FIBERGLASS INNER LAYER
- [11] 1/2 GAUGE WIRE

### SPECIFICATION

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**FIGURE C5**  
**POLYISOCYANURATE INSULATION VALVE**  
**WITH FIBERGLASS INNER LAYER**

**KEY**

- |   |   |
|---|---|
| [1] Polyisocyanurate                    | [6] VAPOR BARRIER MASTIC                |
| [3] JOINT SEALANT AND VAPOR STOP MASTIC | [8] 3 PCF FIBERGLASS BLANKET (NEW YORK) |
| [4] FILAMENT TAPE                       | [9] PLASTIC PIPE JACKET                 |
| [5] MEMBRANE                            | [13] SILICONE SEALANT                   |

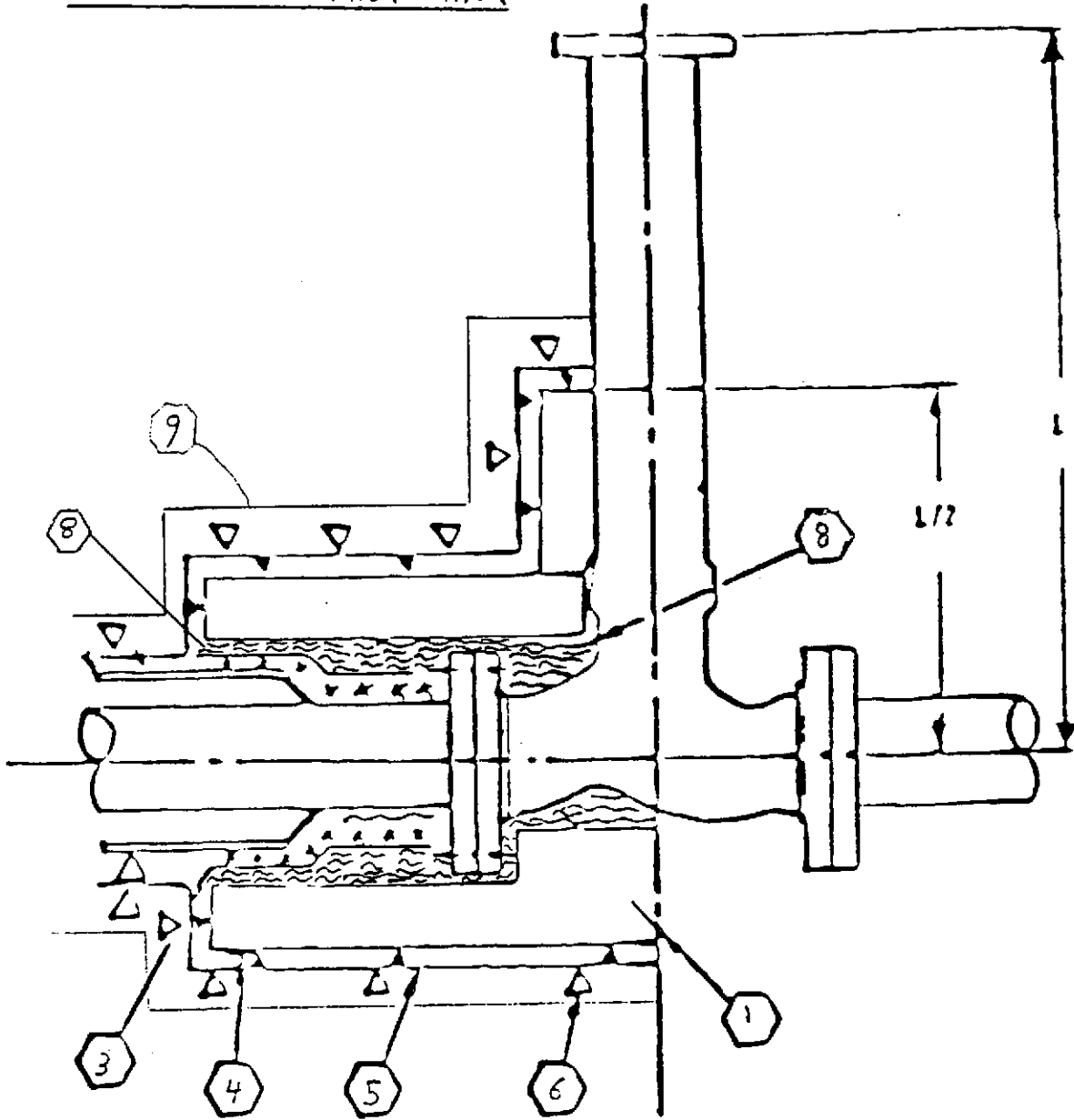
1. EXTEND JOINT SEALANT AND VAPOR STOP MASTIC AND GLASS CLOTH SEVERAL INCHES PAST THE INSULATION AND ONTO THE VALVE BONNET TO ASSURE THAT A GOOD VAPOR STOP IS FORMED.
2. INSULATION TO BE INSTALLED IN TWO HALVES. VAPOR SEALED AGAINST PIPE JACKET, BONNET, ETC.

**SPECIFICATION**Number **A** V049-2-163Rev  
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SPECIFICATION FOR THERMAL INSULATION - PIPING

FIGURE C 6  
POLYISOCYANURATE INSULATION EXTENDED STEM VALVE  
WITH FIBERGLASS INNER LAYER



KEY

- [1] Polyisocyanurate
- [3] JOINT SEALANT AND VAPOUR STOP MASTIC
- [4] FILAMENT TAPE
- [5] MEMBRANE
- [6] VAPOUR BARRIER MASTIC
- [8] 3 PLY FIBERGLASS BLANKET (1000 GSM)
- [9] PLASTIC PIPE JACKET

SPECIFICATION

Number  
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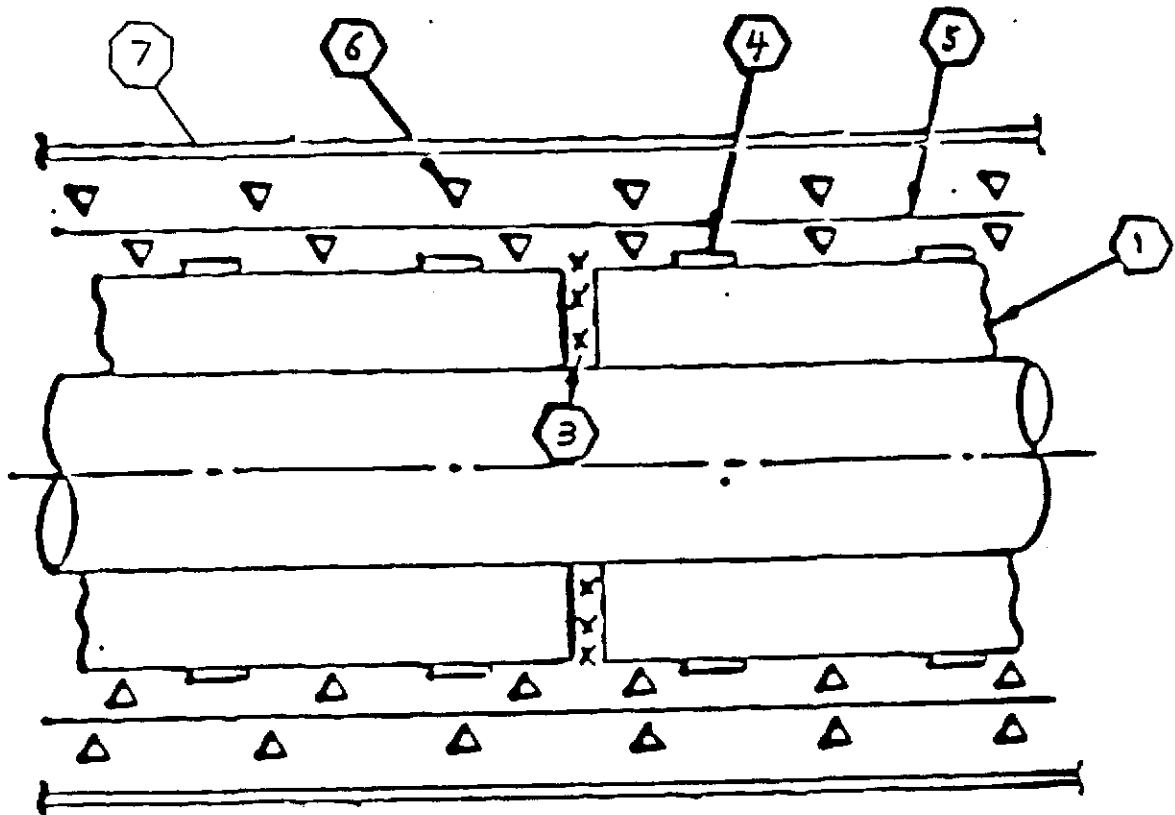
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Page

**FIGURE D-1**

**FIBERGLASS INSULATION - TYPICAL PIPE SECTION**



- [1] Fiberglass
- [3] Joint Sealant and Vapor Stop Mastic
- [4] Filament Tape
- [5] Membrane
- [6] Vapor Barrier Mastic
- [7] PLASTIC PIPE JACKET

Use wire to secure inner layers and tape to secure outer layers of insulation. Use a minimum of 3 wraps per segment. Overlap tape ends 50% of pipe circumference.

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**SPECIFICATION**

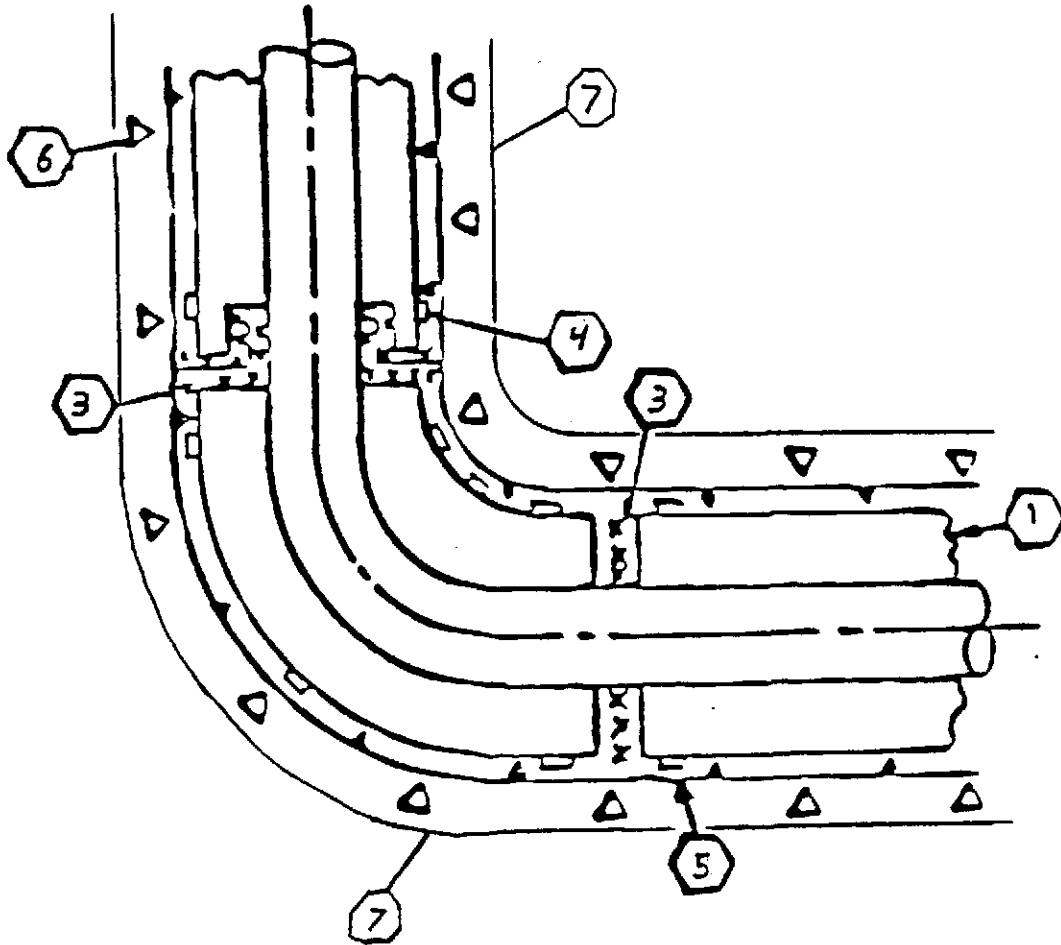
Number **A** V049-2-163

Rev. **G**

Title

**SPECIFICATION FOR THERMAL INSULATION - PIPING**

**FIGURE D-2**  
**FIBERGLASS INSULATION ELBOW**



**KEY**

- [1] Fiberglass
- [2] PIPE
- [3] JOINT SEALANT AND VAPOR STOP MASTIC
- [4] FILAMENT TAPE
- [5] MEMBRANE
- [6] VAPOR BARRIER MASTIC
- [7] PLASTIC PIPE JACKET

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**SPECIFICATION**

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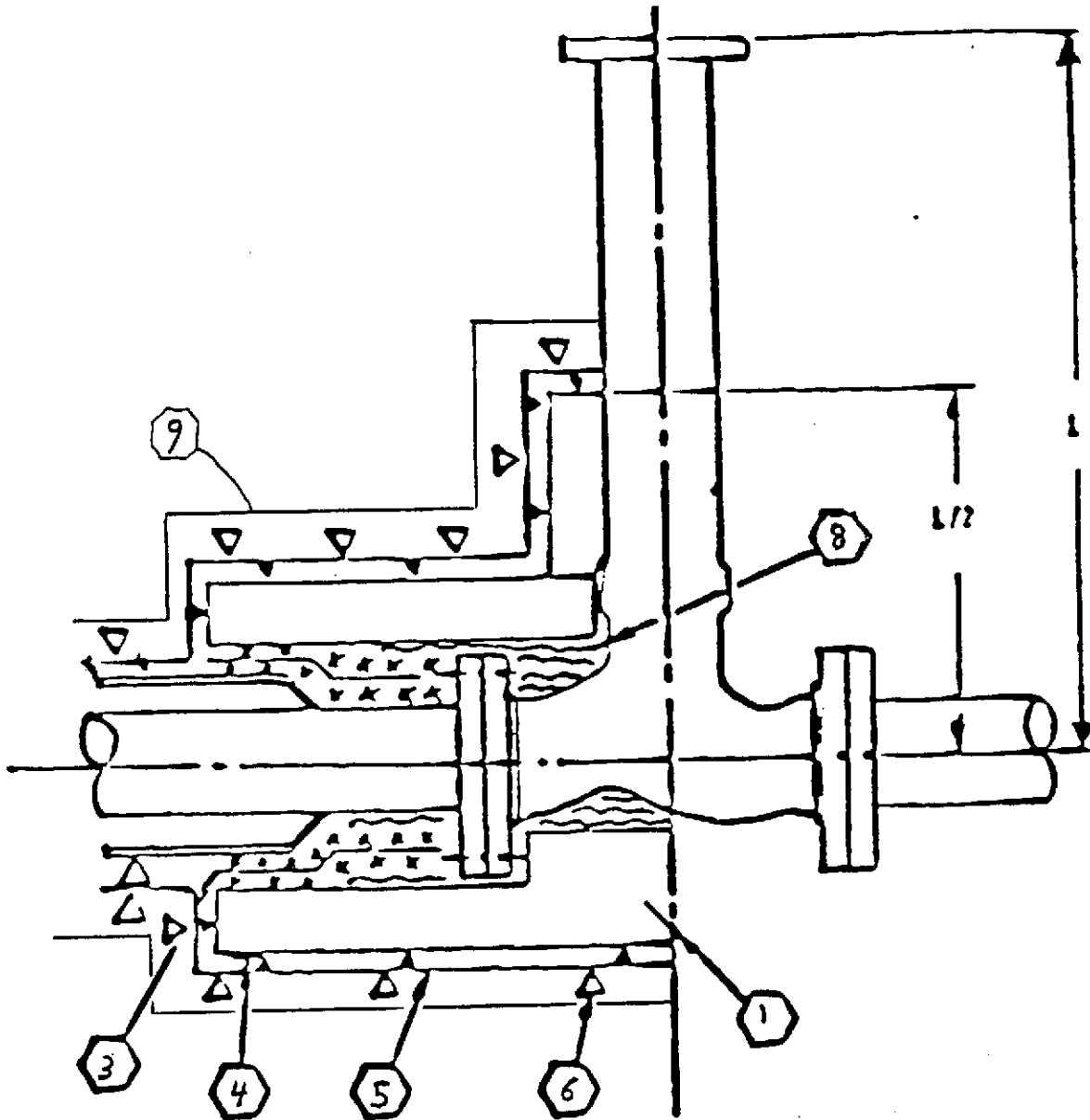
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Title

**SPECIFICATION FOR THERMAL INSULATION - PIPING**

**FIGURE D-3**  
**FIBERGLASS INSULATION EXTENDED STEM VALVE**



**KEY**

- [1] Fiberglass
- [3] JOINT SEALANT AND VAPOR STOP MASTIC
- [4] FILAMENT TAPE
- [5] MEMBRANE
- [6] VAPOR BARRIER MASTIC
- [8] 1 PCF FIBERGLASS BLANKET
- [9] PLASTIC PIPE JACKET

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**SPECIFICATION**

Number

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V049-2-163

Rev.

0

Title:

CONFLAT FLANGE ASSEMBLY PROCEDURE

CONFLAT FLANGE ASSEMBLY PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

PREPARED BY:

MANUFACTURING  
QUALITY ASSURANCE:

SMotew  
Philip Palak  
Core Secord

TECHNICAL DIRECTOR:

D. W. Williams

PROJECT MANAGER:

Richard Bray

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Φ	SM 10/29	REQ 11/14/96	Released per OEO 0335
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-168
	SM	10/29/96	REQ	11/12/96	Rev. Φ

Title

## CONFLAT FLANGE ASSEMBLY PROCEDURE

### 1.0 PURPOSE

This procedure controls the final assembly of conflat flanges.

### 2.0 GENERAL

All conflat flanges shall be assembled in class 100 cleanrooms after the component (i.e. BSC, HAM, door) has been final cleaned. Handling and assembly should be done wearing clean room clothing and gloves. The knife edges of each flange should be carefully inspected for nicks or other damage which might cause leaks.

#### Materials Req'd: (ref. BOM)

New copper gasket

SST bolts

Silicon bronze nuts

SST washers (2 per bolt)

Appropriate torque wrench

#### Recommended Torque

2 3/4"OD = 16 ft-lbs ( 192 in-lbs )

3 3/8" OD thru 16 1/2" OD = 26 ft-lbs ( 312 in-lbs )

### 3.0 RESPONSIBILITIES

The manufacturing group and the site contractors are responsible for installation of conflats.

PSI Q.A. is responsible for monitoring that procedures are being followed.

### 4.0 PROCEDURE

#### 4.1 Initial Assembly:

Washers should be used under each bolt head and each nut. It is critical that the copper gasket be properly positioned between the flanges. When properly positioned, the gasket is captured in a close tolerance groove formed by machined recesses in each of the mating flanges. With the gasket properly positioned and the bolts finger tight, a uniform gap of approximately 1/32" is visible between the flanges. Initial assembly is complete when all bolts are finger tight.

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Title

**CONFLAT FLANGE ASSEMBLY PROCEDURE**

**4.2 Torqueing:**

Bolt tightening is to be done in a cross-flange "star" pattern. The recommended final torque values are shown in sect. 3.0 above. The bolts should be torqued in ~25% increments ( see table I ).Note: as the copper gasket yields during the torqueing sequence, bolts may become loose, this is normal and the torqueing sequence should continue until the recommended torque value is reached.

Torque %	25%	50%	75%	100%
2 3/4"OD	4 ft-lbs	8 ft-lbs	12 ft-lbs	16 ft-lbs
3 3/8"-16 1/2"OD	7 ft-lbs	13 ft-lbs	20 ft-lbs	26 ft-lbs

Table I

**4.3 Final Torque Check:**

The last step in the bolt tightening procedure is a final torque check done in a sequential fashion going around the flange. The cross-flange "star" pattern is not required for the final torque check.

**5.0 TAGGING**

After the final torque check has been done, the assembled flanged joint should be tagged with a label indicating the date of assembly, final torque value, and assembler's signature. The metal tag shall be attached to each conflats with a stainless steel wire.

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**SPECIFICATION**

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**A**

V049-2-168

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**5**

Title: O-Ring-Installation And Flange Assembly Procedure

## O-RING INSTALLATION AND FLANGE ASSEMBLY PROCEDURE

FOR

### LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

PREPARED BY:

MANUFACTURING  
QUALITY ASSURANCE:

S. Mateer  
Philip F. Fehel  
Gene S. ...

TECHNICAL DIRECTOR:

D. A. Williams

PROJECT MANAGER:

Robert Bayly

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REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	SM 10/29	RFB 11/7/96	Released per OEU 0336

PROCESS SYSTEMS INTERNATIONAL, INC.

SPECIFICATION

INITIAL APPROVALS	PREPARED DATE	APPROVED DATE	Number	Rev.
	SM 10/29/96	RFB 11/7/96	V049-2-169	0

Title

## O-RING INSTALLATION AND FLANGE ASSEMBLY PROCEDURE

### 1.0 PURPOSE

This procedure controls the final installation of viton o-rings and flanges on vacuum equipment.

### 2.0 GENERAL

Installation of the o-rings should be done in class 100 clean room areas. Handling and assembly should be done wearing the appropriate clean room protective clothing and clean gloves. The vessel receiving the o-rings should be clean and dry.

The o-ring grooves and mating flat face flange should be inspected for local contamination including dirt, water, metal chips, detergent or washing process residue etc.

#### Spot Cleaning

Spot cleaning of small local dirty areas (such as the bottom of the o-ring groove) may be done using lint free wipers and isopropyl alcohol or a CO<sub>2</sub> cleaning gun.

#### Vacuum Baked O-Rings

Each size flange has two o-ring grooves. Each groove has a specific o-ring( PSI part number )designed for an exact fit. These part numbers are referenced in O-Ring Spec. V049-2-045.

The o-rings that are to be used for final flange assembly must be vacuum baked (by PSI) to remove volatile compounds prior to installation. Before installing the o-ring, the assembler must verify that the o-ring has been vacuum baked by PSI. The o-ring package will state that the o-ring is baked. O-rings will be given a different part number after baking.

### 3.0 RESPONSIBILITIES

The manufacturing group and site contractors are responsible for installation of o-rings and flanges.

PSI Q.A. is responsible for monitoring that procedures are being followed.

### 4.0 PROCEDURE

#### 4.1 O-ring Installation

Due to the large flange diameters, three people are required to hold the o-ring in position during installation. The o-rings are easily inserted into the groove by starting at the top and working down. They fit snugly on their ID and are held in place by the groove dovetail. Care should be taken not to roll or twist the o-ring during installation.

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Title

**O-RING INSTALLATION AND FLANGE ASSEMBLY  
PROCEDURE**

**4.2 Mating Flange Installation**

After the o-rings are installed, the mating flange is carefully positioned parallel to the o-ring flange. A centering pin is used in one bolt hole to align the flange for bolting. The bolts are inserted with a washer under the head and under the nut. All bolts should be installed hand tight. The mating flange should be in contact with the o-rings but not compressing the o-rings. After contact with the o-rings is made, it is important not to move the mating flange to preclude rolling or twisting the o-ring.

**4.3 Torqueing the Flange**

Bolt tightening for 7/8 in. bolts is to be done in a cross-flange "star" pattern. The recommended final torque value is 220 ft-lbs. The bolts should be torqued in ~25% increments:

Torque %	25%	50%	75%	100%
	55 ft-lbs	110 ft-lbs	165 ft-lbs	220 ft-lbs

The last step in the bolt tightening procedure is a final torque check done in a sequential fashion going around the flange. The cross-flange "star" pattern is not required for the final torque check.

**4.4 Tagging**

After the final torque check has been done, the assembled flanged joint should be tagged with a label indicating the date of assembly, final torque value, and assembler's signature. The metal tag shall be attached to a flange bolt using stainless steel wire.

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**SPECIFICATION**

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**A**

**V049-2-169**

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**0**

Title: COMPONENT ALIGNMENT PROCEDURE

COMPONENT ALIGNMENT PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington

PREPARED BY:

R. Bray

STRUCTURAL ENG:

R. O. Ciatto

QUALITY ASSURANCE:

Gene Sussal

TECHNICAL DIRECTOR:

D. A. M. Williams

PROJECT MANAGER:

R. Bray

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REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	D. A. M. W.	RES 12/5/96	RELEASED PER DEO 0377

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION		
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	RES	12/5/96	RES	12/5/96	V049-2-174	Ø



**Title**

**COMPONENT ALIGNMENT PROCEDURE**

**TABLE OF CONTENTS**

- 1.0 Purpose
- 2.0 General
- 3.0 Responsibilities
- 4.0 Procedure

**ATTACHMENTS:**

- A. LIGO Building Benchmark Locations
- B. Component Installation Data Sheet

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**1.0 PURPOSE**

The purpose of this procedure is to define the requirements for aligning and positioning vacuum equipment components for the LIGO project.

**2.0 GENERAL**

The major vacuum component anchor bolts are located, drilled and installed after the component has been pre-aligned with the beam line in each building. This requires that each major vacuum boundary component (BSC, HAM, 80K Pump, Spools, etc.) be located in its final location and precision aligned (with optical surveying equipment) so that the centerline of the beam line nozzles are within  $\pm 2$  mm of the actual beam line.

The actual beam line location is established by locating target benchmarks (at removable spool locations) using the Buyer supplied floor bench marks (see Attachment A). Once the target bench marks are located along the beam line, the surveying equipment sites on two adjacent targets to establish the beam line. The component is then adjusted until it is aligned with the established beam line.

The Customer/Buyer will verify each component location as part of the installation process.

The class 100 air skid must be installed and operational prior to component alignment.

The component alignment data sheet shall be filled out as each component is installed. (S/off = data signoff point).

**3.0 RESPONSIBILITIES**

The Contractor is responsible for establishing the target bench marks and aligning and installing each component.

The Buyer/Owner is responsible for verifying each component location and alignment.

**4.0 PROCEDURE**

1. Establish the target bench marks in the building being worked using the Buyer supplied floor bench marks (see Attachment A).
2. Set up the surveying equipment to site on two adjacent target bench marks to establish the beam line.

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**COMPONENT ALIGNMENT PROCEDURE**

3. Move the component into the installed position using the referenced dimensions on the installation documents.
4. Connect class 100 air to the component being aligned (using hoses from the mechanical room).
5. Verify that all shipping door cross hairs are located at the centerline of the nozzles (s/off).
6. Using alignment dollies, align each shipping door cross hair with the established beam line. The alignment shall be +/- 2 mm of the beam line.
7. Mark the floor to establish the anchor bolt locations by scribing one hole in each component leg pad on to the floor (s/off).
8. Move the component back from its installed position to allow anchor bolt hole drilling.
9. Using a component anchor bolt template (supplied by the Buyer) mark and drill each anchor bolt hole (using a core drilling system capable of cutting rebar) per Specification V049-1-101.
10. Install anchor bolts and let cure per V049-1-101.
11. Lift the component to clear the installed anchor bolts and reposition the component to once again align the cross hairs on the shipping covers with the beam line.
12. Adjust anchor bolt nuts and washers to hold the component in the aligned position and lock into place.
13. Remove the lifting tension on the alignment dollies and allow the anchor bolts to support the component.
14. Verify with the surveying equipment that the nozzle centerlines are within +/- 2 mm of the beam line (s/off).
15. Notify the Buyer to witness and signoff the final alignment (s/off).
16. Verify that the vessel cross hair ports are closed and disconnect the class 100 air.
17. Repeat for each major component until all of the major components are aligned. Spools that fit between major components are aligned automatically by bolting up the spool using the centering pins (provided by the Buyer).
18. Components shall be grouted into place (per V049-2-021) after approval by the Buyer (s/off).

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**SPECIFICATION**

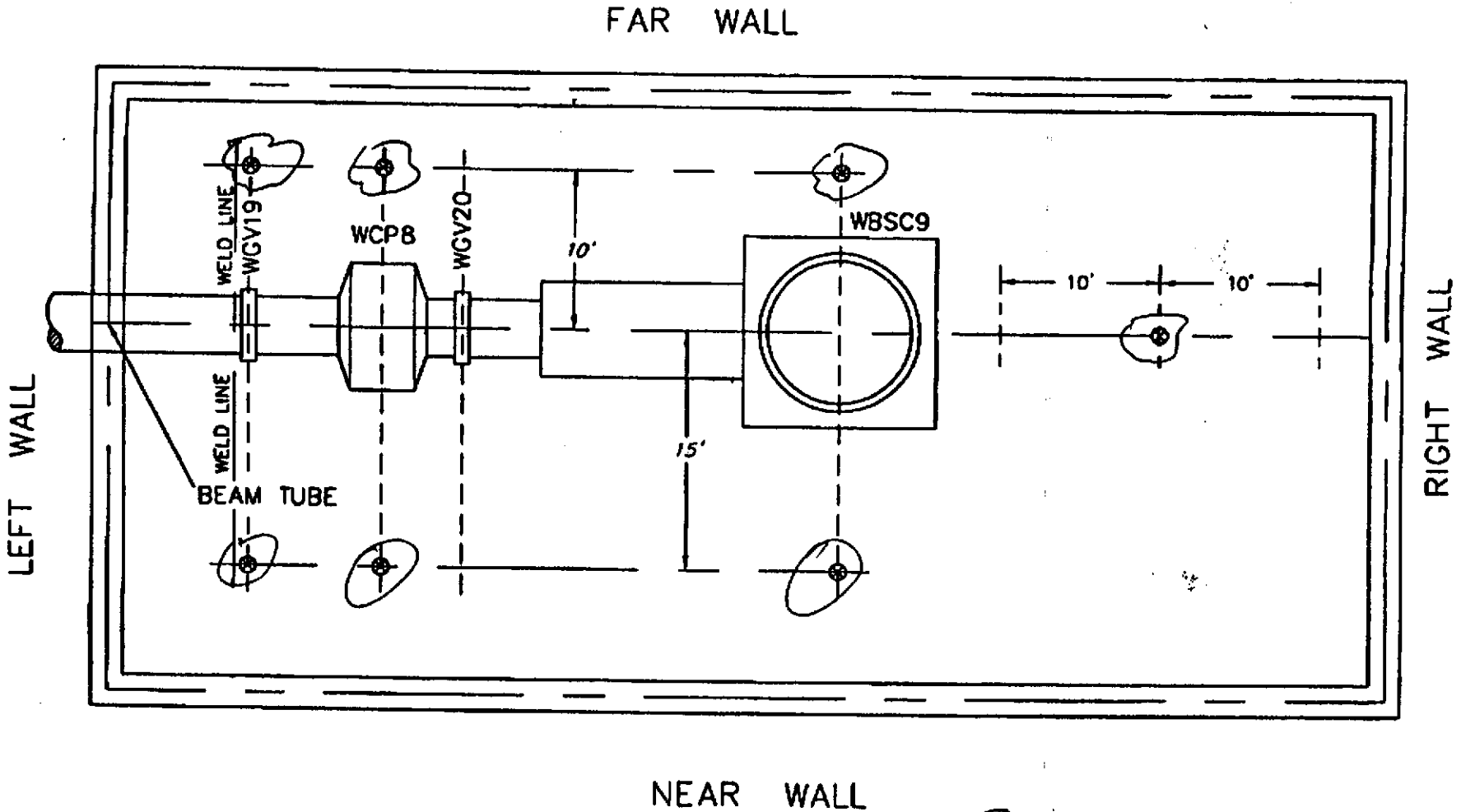
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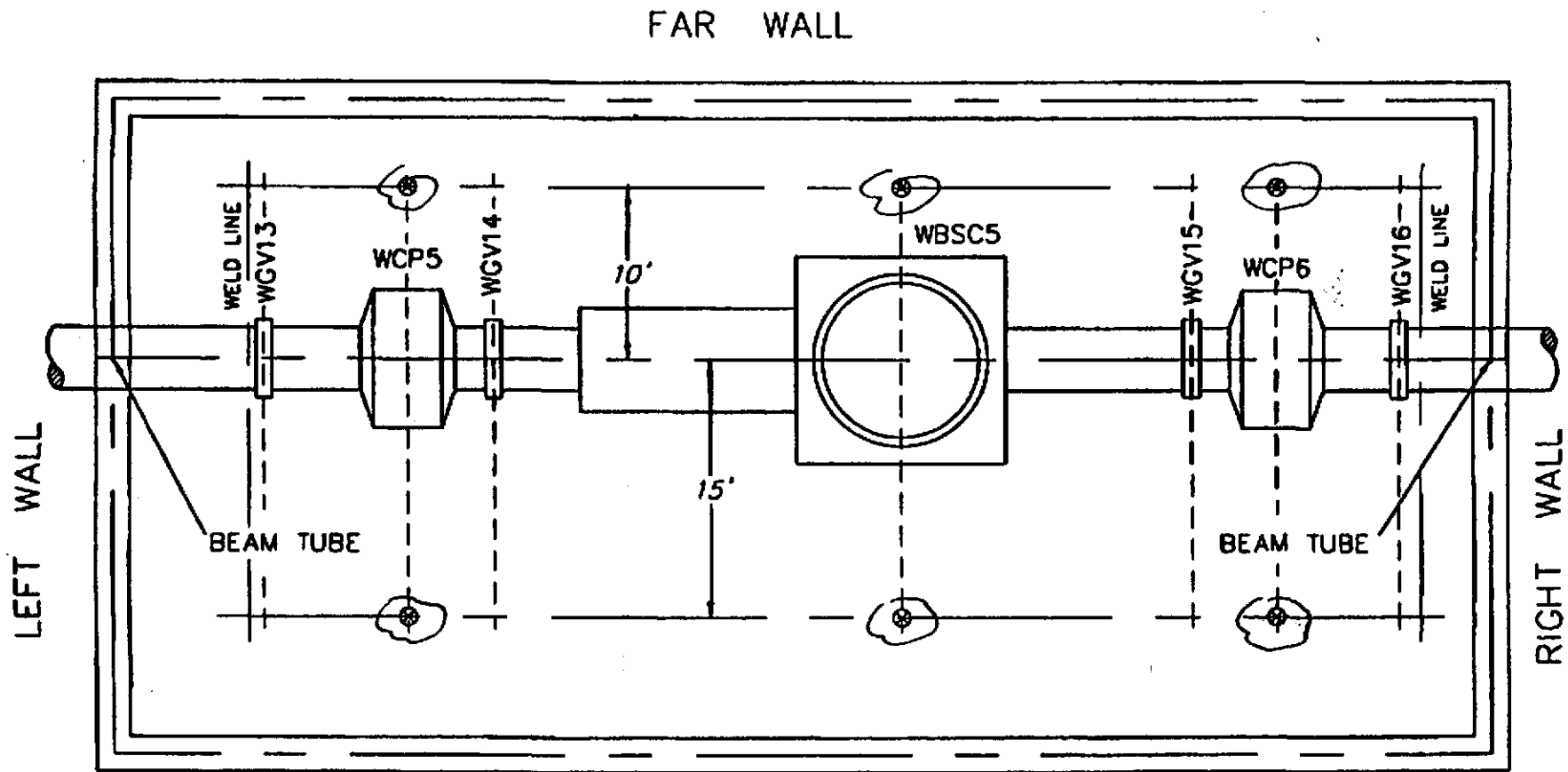
⊗ DENOTES PROPOSED TARGET LOCATION  
 (FLOOR BENCH MARKS BY THE BUYER)

# PRELIMINARY SKETCH OF END STATION UNITS

NOT TO SCALE

ATTACHMENT A  
 V049-2-174

PG 1 of 2

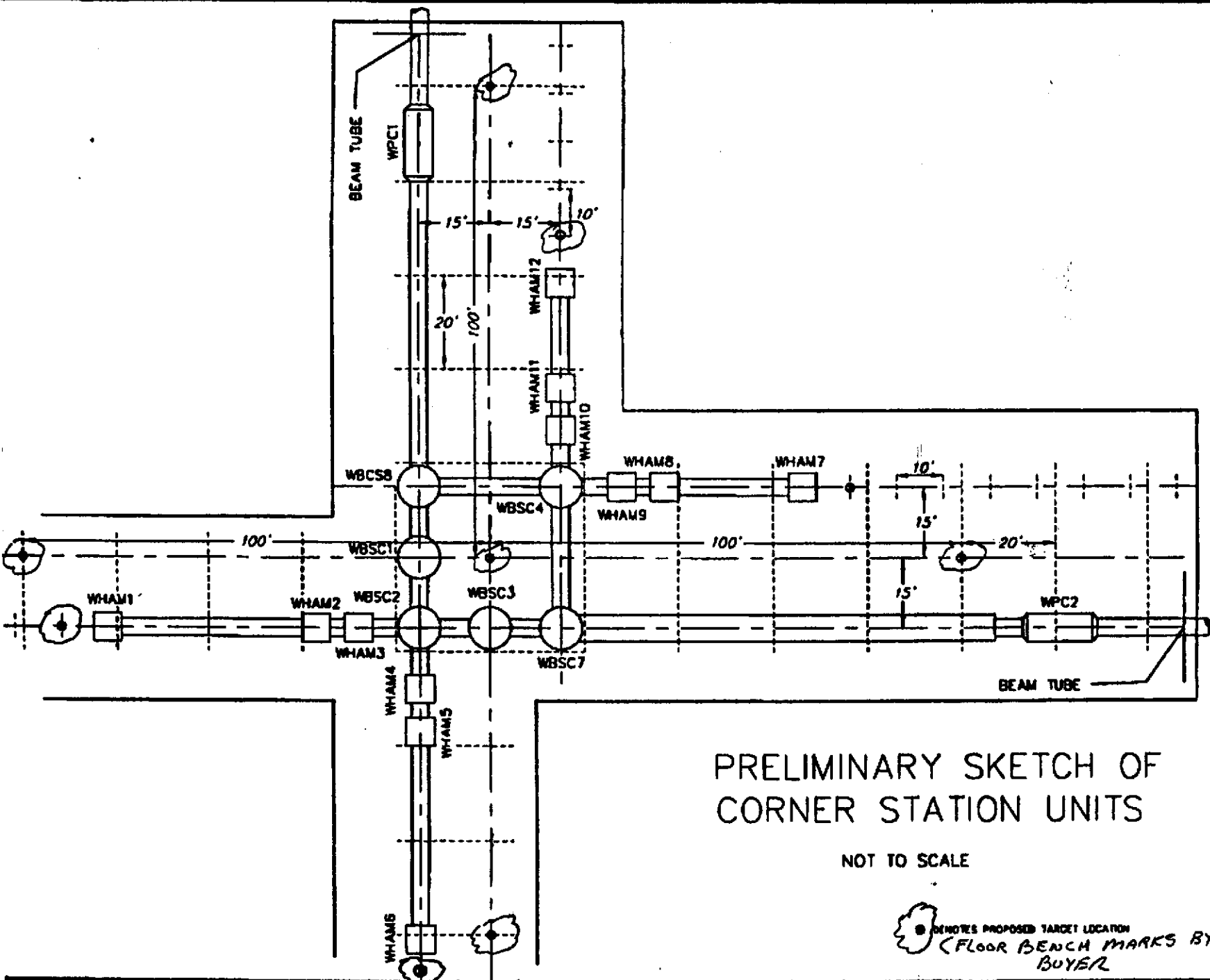


⊗ DENOTES PROPOSED TARGET LOCATION  
(FLOOR BENCH MARK BY THE BUYER)

# PRELIMINARY SKETCH OF MID STATION UNITS

NOT TO SCALE

ATTACHMENT A  
V649-2-174  
Pg 20F3



PRELIMINARY SKETCH OF  
CORNER STATION UNITS

NOT TO SCALE

 DENOTES PROPOSED TARGET LOCATION  
 ( FLOOR BENCH MARKS BY THE BUYER )

ATTACHMENT A  
 V049-2-174  
 Pg 3 of 3

Title

**COMPONENT ALIGNMENT PROCEDURE**

**ATTACHMENT B**

**COMPONENT INSTALLATION DATA SHEET**

Component Tag Number \_\_\_\_\_

Component Name \_\_\_\_\_

Component S/N \_\_\_\_\_

Component Installation Weight (lb.) \_\_\_\_\_

Component Installation Position  
(Ref. Build Grid)

Signoffs (Contractor Unless Otherwise Noted)		By	Date
1.	Shipping Cover Cross Hairs Verified		
2.	Component Located For Anchor Bolt Marking		
	Buyer		
3.	Final Component Location Complete		
	Buyer		

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Title

**SPECIFICATION FOR VACUUM PUMP FIELD INSTALLATION  
PROCEDURE**

**TABLE OF CONTENTS**

- 1.0 Purpose
- 2.0 General
- 3.0 Responsibilities
- 4.0 Procedure
- 5.0 Purging and Backfilling Headers and Pumps  
(Ref PSI Dwgs V049-5-014,019,023,028,032)

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**SPECIFICATION**

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Title

# SPECIFICATION FOR VACUUM PUMP FIELD INSTALLATION PROCEDURE

## 1.0 PURPOSE

This procedure controls the field installation of the Edwards High Vacuum Inc. (EHVI) vacuum pumps supplied by PSI for the LIGO project. These pumps include the Main Roughing, Main Turbo, and the Auxiliary Turbo pumps. This procedure does not cover startup or operation of the vacuum pumps.

## 2.0 GENERAL

Prior to installing (or operating) any vacuum pump, the appropriate EHVI "System Operation Manual" must be studied and thoroughly understood. Installation of the vacuum pumps must also be done in accordance with the latest revisions of the P&ID, piping and equipment arrangement drawings.

## 3.0 RESPONSIBILITIES

The site operating engineer is responsible for overseeing the installation of the vacuum pumps.

## 4.0 PROCEDURE

### 4.1 Main Turbo Cart

#### 4.1.1 Rolling and Lifting

The Main Turbo cart is comprised of two vacuum pumps (STPH 2000C turbo, QDP80 dry pump) that can be rolled as a single assembled cart or, when separated, each pump has its own casters and thus can be rolled independently. The Main Turbo vacuum pump carts are designed to be rolled on smooth level floors and are not equipped with brakes or caster locks. The Main Turbo cart cannot be lifted as a single unit with both vacuum pumps together. The Main Turbo cart can be lifted only as two separate assemblies. The carts can also be separately carried by a fork truck. Caution must be exercised when fork moving the STPH 2000C turbo cart due to the relatively high center of gravity.

#### 4.1.2 Anchoring (Ref PSI dwgs V049-4-011, V049-4-012)

The Main Turbo pumps must be properly anchored to the floor prior to operation. Refer to the appropriate EHVI System Operation Manual and applicable PSI installation drawings for anchoring details.

NOTE: The STPH2000C turbo pump cart must be anchored for safety reasons due to the large amount of energy stored in the rotor during operation. The QDP80 dry pump must be anchored to prevent it from moving during operation.

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Title

## SPECIFICATION FOR VACUUM PUMP FIELD INSTALLATION PROCEDURE

When the STPH2000C turbo pump is to be located on the frame extension (Ref. Dwg. V049-4-011, V049-4-012) the frame extension must be anchored to the floor prior to setting the turbo cart on top of the frame extension. The STPH2000C turbo pump cart is anchored to the frame extension after the turbo pump piping connections have been completed and the STPH2000C turbo pump cart is in its final position on the frame extension.

### 4.1.3 Piping Connections (Ref PSI Dwg's V049-4-011, V049-4-012)

The inlet connection to the STPH2000C turbo pump is a 12" OD conflat flange. See specification V049-2-168 "Conflat Flange Assembly Procedure" for conflat flange make-up instructions. The outlet connection from the STPH2000C turbo pump is a NW40 (1 1/2") quick flange. A stainless steel flexible hose(s) connects the turbo outlet to the QDP80 backing pump or the turbo header leading to the mechanical room.

### 4.1.4 Utilities

Electric power, cooling water, instrument air, and purge gas connections must be done in accordance with the EHVI "System Operation Manual" instructions.

### 4.2 Main Roughing Pump

The main roughing pump is comprised of two separate pump carts (EH2600 booster, EDP200 chemical pump) working as a single system. Please refer to the EHVI "System Operation Manual" and PSI Dwgs. for detailed descriptions and installation requirements.

#### 4.2.1 Rolling and Lifting

The Roughing vacuum pump carts are designed to be rolled on smooth level floors and are not equipped with brakes or caster locks. Due to the relatively large size and heavy weight of these carts, caution must be taken when rolling the carts to preclude runaway accidents. The carts are also designed to be carried by a fork truck or lifted for transport.

#### 4.2.2 Anchoring (Ref PSI Dwg V049-4-010)

The Roughing pump carts must be anchored to the floor prior to operation to eliminate any potential for movement when the pumps are operating.

#### 4.2.3 Piping Connections (Ref PSI Dwgs V049-4-010 )

Please refer to the EHVI "System Operation Manual" and PSI dwgs. for detailed descriptions and installation requirements. Note: The exhaust silencer mounted on the EDP200 discharge flange does not need to be supported unless there are additional forces or moment loads being imposed on the pump flange from the muffler discharge piping.

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# SPECIFICATION FOR VACUUM PUMP FIELD INSTALLATION PROCEDURE

## 4.3.4 Utilities

Electric power, cooling water, instrument air, and purge gas connections must be done in accordance with the EHVI "System Operation Manual" instructions.

## 4.4 Auxiliary Turbo Pump

The auxiliary turbo cart is designed to be rolled on smooth level floors. The casters do have wheel locks that, when properly employed, eliminate the need to hard anchor the cart to the floor prior to operation.

The auxiliary turbo cart only requires electric power and instrument air for operation. Please refer to the EHVI "System Operation Manual".

## 5.0 PURGING AND BACKFILLING HEADERS AND PUMPS (REF PSI DWGS V049-5-014, 019, 023, 028, 032)

Piping and valves have been provided to allow purge gas to flow from the clean air supply header into the turbo header and into the roughing header. Manual isolation and throttling valves allow a controlled backfill and purge flow to be admitted to each header at its "dead end" point, thus, the headers can be effectively swept with purge gas their entire length. Backfilling and purging in this manner will keep water and atmospheric contaminants out of the vacuum system during shutdown. Keeping the vacuum system headers clean and dry will facilitate pumpdown and protect equipment from corrosion.

NOTE: The recommended procedure for shutting down the roughing pumps requires a 15 minute gas purge to prevent moisture corrosion problems in the pumps. After the roughing pumps have been purged and shutdown, the exhaust pipe should be covered with a plastic cap. Please refer to the EHVI "System Operation Manual" for detailed purging requirements.

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Title

**SPECIFICATION FOR VACUUM PUMP FIELD INSTALLATION  
PROCEDURE**

**TABLE OF CONTENTS**

- 1.0 Purpose
- 2.0 General
- 3.0 Responsibilities
- 4.0 Procedure
- 5.0 Purging and Backfilling Headers and Pumps  
(Ref PSI Dwgs V049-5-014,019,023,028,032)

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**Title SPECIFICATION FOR VACUUM PUMP FIELD INSTALLATION  
PROCEDURE**

**1.0 PURPOSE**

This procedure controls the field installation of the Edwards High Vacuum Inc. (EHVI) vacuum pumps supplied by PSI for the LIGO project. These pumps include the Main Roughing, Main Turbo, and the Auxiliary Turbo pumps. This procedure does not cover startup or operation of the vacuum pumps.

**2.0 GENERAL**

Prior to installing (or operating) any vacuum pump, the appropriate EHVI "System Operation Manual" must be studied and thoroughly understood. Installation of the vacuum pumps must also be done in accordance with the latest revisions of the P&ID, piping and equipment arrangement drawings.

**3.0 RESPONSIBILITIES**

The site operating engineer is responsible for overseeing the installation of the vacuum pumps.

**4.0 PROCEDURE**

**4.1 Main Turbo Cart**

**4.1.1 Rolling and Lifting**

The Main Turbo cart is comprised of two vacuum pumps (STPH 2000C turbo, QDP80 dry pump) that can be rolled as a single assembled cart or, when separated, each pump has its own casters and thus can be rolled independently. The Main Turbo vacuum pump carts are designed to be rolled on smooth level floors and are not equipped with brakes or caster locks. The Main Turbo cart cannot be lifted as a single unit with both vacuum pumps together. The Main Turbo cart can be lifted only as two separate assemblies. The carts can also be separately carried by a fork truck. Caution must be exercised when fork moving the STPH 2000C turbo cart due to the relatively high center of gravity.

**4.1.2 Anchoring (Ref PSI dwgs V049-4-011, V049-4-012)**

The Main Turbo pumps must be properly anchored to the floor prior to operation. Refer to the appropriate EHVI System Operation Manual and applicable PSI installation drawings for anchoring details.

**NOTE:** The STPH2000C turbo pump cart must be anchored for safety reasons due to the large amount of energy stored in the rotor during operation. The QDP80 dry pump must be anchored to prevent it from moving during operation.

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Title

## SPECIFICATION FOR VACUUM PUMP FIELD INSTALLATION PROCEDURE

When the STPH2000C turbo pump is to be located on the frame extension (Ref. Dwg. V049-4-011, V049-4-012) the frame extension must be anchored to the floor prior to setting the turbo cart on top of the frame extension. The STPH2000C turbo pump cart is anchored to the frame extension after the turbo pump piping connections have been completed and the STPH2000C turbo pump cart is in its final position on the frame extension.

### 4.1.3 Piping Connections (Ref PSI Dwg's V049-4-011, V049-4-012)

The inlet connection to the STPH2000C turbo pump is a 12" OD conflat flange. See specification V049-2-168 "Conflat Flange Assembly Procedure" for conflat flange make-up instructions. The outlet connection from the STPH2000C turbo pump is a NW40 (1 1/2") quick flange. A stainless steel flexible hose(s) connects the turbo outlet to the QDP80 backing pump or the turbo header leading to the mechanical room.

### 4.1.4 Utilities

Electric power, cooling water, instrument air, and purge gas connections must be done in accordance with the EHVI "System Operation Manual" instructions.

### 4.2 Main Roughing Pump

The main roughing pump is comprised of two separate pump carts (EH2600 booster, EDP200 chemical pump) working as a single system. Please refer to the EHVI "System Operation Manual" and PSI Dwgs. for detailed descriptions and installation requirements.

#### 4.2.1 Rolling and Lifting

The Roughing vacuum pump carts are designed to be rolled on smooth level floors and are not equipped with brakes or caster locks. Due to the relatively large size and heavy weight of these carts, caution must be taken when rolling the carts to preclude runaway accidents. The carts are also designed to be carried by a fork truck or lifted for transport.

#### 4.2.2 Anchoring (Ref PSI Dwg V049-4-010)

The Roughing pump carts must be anchored to the floor prior to operation to eliminate any potential for movement when the pumps are operating.

#### 4.2.3 Piping Connections (Ref PSI Dwgs V049-4-010 )

Please refer to the EHVI "System Operation Manual" and PSI dwgs. for detailed descriptions and installation requirements. Note: The exhaust silencer mounted on the EDP200 discharge flange does not need to be supported unless there are additional forces or moment loads being imposed on the pump flange from the muffler discharge piping.

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**SPECIFICATION FOR VACUUM PUMP FIELD INSTALLATION  
PROCEDURE**

4.3.4 Utilities

Electric power, cooling water, instrument air, and purge gas connections must be done in accordance with the EHVI "System Operation Manual" instructions.

4.4 Auxiliary Turbo Pump

The auxiliary turbo cart is designed to be rolled on smooth level floors. The casters do have wheel locks that, when properly employed, eliminate the need to hard anchor the cart to the floor prior to operation.

The auxiliary turbo cart only requires electric power and instrument air for operation. Please refer to the EHVI "System Operation Manual".

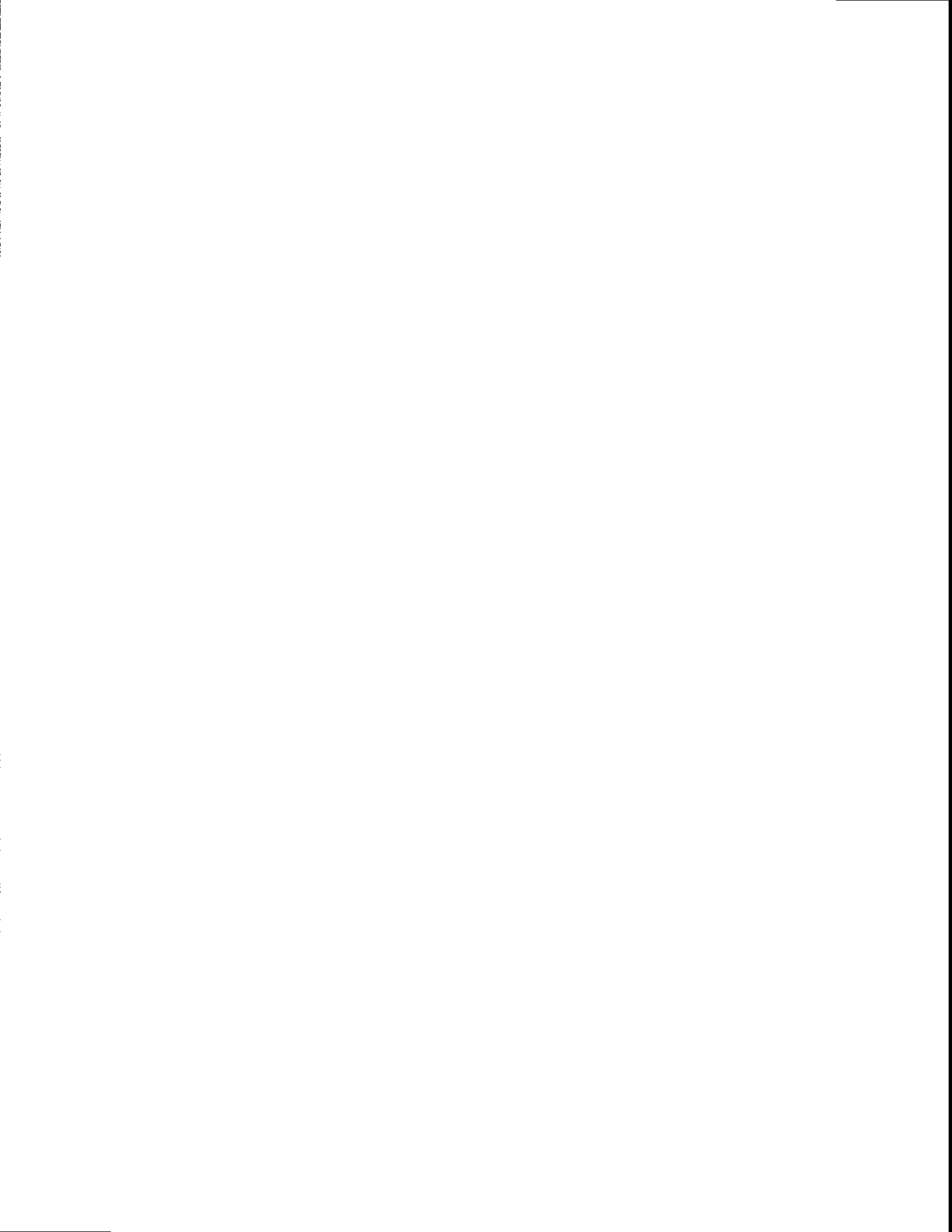
**5.0 PURGING AND BACKFILLING HEADERS AND PUMPS (REF PSI DWGS V049-5-014, 019, 023, 028, 032)**

Piping and valves have been provided to allow purge gas to flow from the clean air supply header into the turbo header and into the roughing header. Manual isolation and throttling valves allow a controlled backfill and purge flow to be admitted to each header at its "dead end" point, thus, the headers can be effectively swept with purge gas their entire length. Backfilling and purging in this manner will keep water and atmospheric contaminants out of the vacuum system during shutdown. Keeping the vacuum system headers clean and dry will facilitate pumpdown and protect equipment from corrosion.

NOTE: The recommended procedure for shutting down the roughing pumps requires a 15 minute gas purge to prevent moisture corrosion problems in the pumps. After the roughing pumps have been purged and shutdown, the exhaust pipe should be covered with a plastic cap. Please refer to the EHVI "System Operation Manual" for detailed purging requirements.

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	V049-2-175	0



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: Richard Bay


Ø	DM 5/6/96	A 93 5/19/96	Released per DEO #173 for FDR
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

<b>PROCESS SYSTEMS INTERNATIONAL, INC.</b>					<b>SPECIFICATION</b>	
INITIAL APPROVALS	PREPARED	DATE	Approved	DATE	Number:	Rev.
	DM	5/6/96	A 93	5/6/96	A V049-2-102	Ø

**Title: ACCEPTANCE TEST - 80K PUMP SYSTEM**

**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.

<b>SPECIFICATION</b>	
Number:	Rev.
<b>A V049-2-102</b>	<b>0</b>

**Title: ACCEPTANCE TEST - 80K PUMP SYSTEM**

**5.0 FIELD TEST**

**5.1 80K Pump Field Joint Leak Test**

The specification requires all leaks greater than  $1 \times 10^{-9}$  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 occurred 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.

<b>SPECIFICATION</b>	
Number:	Rev.
<b>A V049-2-102</b>	<b>Ø</b>

**Title: ACCEPTANCE TEST - 80K PUMP SYSTEM**

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 controls 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.

<b>SPECIFICATION</b>	
Number:	Rev.
<b>A V049-2-102</b>	<b>0</b>

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					

V049-2-102  
REV 5  
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:**

SM

**QUALITY ASSURANCE:**

Alan R. Sandbrook

**TECHNICAL DIRECTOR:**

D. A. McWilliam

**PROJECT MANAGER:**

Richard Bagby


<u>0</u>	<u>SM 5/1/96</u>	<u>RES 5/2/96</u>	<u>INITIAL RELEASE PER DEC 0157 FOR FDR</u>
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

<b>PROCESS SYSTEMS INTERNATIONAL, INC.</b>				<b>SPECIFICATION</b>	
INITIAL APPROVALS	PREPARED	DATE	Approved DATE	Number: V049-2-104	Rev. 0
	<u>SM</u>	<u>5/1/96</u>	<u>RES 5/2/96</u>	<u>A</u>	



**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.

**SPECIFICATION**

Number: V049-2-104  
**A**

Rev.0

**Title: SPECIFICATION FOR ACCEPTANCE TEST PROCEDURE FOR ROUGHING SYSTEM**

**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.

**SPECIFICATION**

Number: V049-2-104

**A**

Rev.0

**Title: SPECIFICATION FOR ACCEPTANCE TEST PROCEDURE FOR ROUGHING 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					
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.			

**SPECIFICATION**

Number: V049-2-104

**A**

Rev.0

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. Meter

**QUALITY ASSURANCE:**

Alan L. Bradbrook

**TECHNICAL DIRECTOR:**

D. A. McWilleen

**PROJECT MANAGER:**

Bruce Bagby


Ø	SM 5/1/96	REB 5/2/96	INITIAL RELEASE UED 0157
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

<b>PROCESS SYSTEMS INTERNATIONAL, INC.</b>				<b>SPECIFICATION</b>	
INITIAL APPROVALS	PREPARED	DATE	Approved	DATE	Number: V049-2-105 A
	SM	5/1/96	REB	5/2/96	Rev. 0

**Title: SPECIFICATION FOR ACCEPTANCE TEST PROCEDURE FOR TURBO PUMP SYSTEMS**

**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.

<b>SPECIFICATION</b>	
Number: V049-2-105 <b>A</b>	Rev.0

**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  $1 \times 10^{-6}$  torr to  $1 \times 10^{-3}$  torr.

The minimum required pumping speed at the inlet port of the Main Turbo pump is 1400 l/s N<sub>2</sub> at an inlet pressure of  $1 \times 10^{-3}$  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 N<sub>2</sub> seal gas low flow
- c. Backing pump motor starter overload
- d. Foreline safety valve closes on backing pump shutdown or turbo pump shutdown/failure.

**SPECIFICATION**

Number: V049-2-105

**A**

Rev.0

**Title: SPECIFICATION FOR ACCEPTANCE TEST PROCEDURE FOR TURBO PUMP SYSTEMS**

**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  $1 \times 10^{-6}$  torr to  $1 \times 10^{-3}$  torr.

The minimum required pumping speed at the inlet port of the Auxiliary Turbo pump is 50 l/s N<sub>2</sub> at an inlet pressure of  $1 \times 10^{-3}$  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 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 be 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.

**SPECIFICATION**

Number: V049-2-105

**A**

Rev.0

Title: SPECIFICATION FOR ACCEPTANCE TEST PROCEDURE FOR TURBO PUMP SYSTEMS

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		$<5 \times 10^{-9}$ 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		$<1 \times 10^{-8}$ Torr			

\* First article only

<b>SPECIFICATION</b>	
Number: V049-2-105 <b>A</b>	Rev.0



Title: SPECIFICATION FOR ACCEPTANCE TEST PROCEDURE FOR TURBO PUMP SYSTEMS

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		$<5 \times 10^{-9}$ 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		$<1 \times 10^{-8}$ Torr			

**SPECIFICATION**

Number: V049-2-105

**A**

Rev.0

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: Alan L. Bradbrook

TECHNICAL DIRECTOR: D. A. Williams

PROJECT MANAGER: Richard Bayliss


0	F. Bark 5/2/96	R 2/3 5/2/96	RELEASED FOR FDR PER DED # 160
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

<b>PROCESS SYSTEMS INTERNATIONAL, INC.</b>				<b>SPECIFICATION</b>	
INITIAL APPROVALS	PREPARED	DATE	Approved	DATE	Number:
	F. Bark	5.2.96	R 2/3	5/2/96	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.

### SPECIFICATION

Number:		Rev.
<b>A</b>	V049-2-106	0

## 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.

## SPECIFICATION

Number:	V049-2-106	Rev.
<b>A</b>		<b>0</b>

Title: SPECIFICATION FOR ION PUMPS ACCEPTANCE TEST PROCEDURE

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 <sup>-9</sup> 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 <sup>-9</sup> Torr			

**SPECIFICATION**

Number: <b>A</b>	V049-2-106	Rev. 0
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**Title: SPECIFICATION FOR ION PUMPS ACCEPTANCE TEST PROCEDURE**

**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		$<1 \times 10^{-9}$ 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		$<1 \times 10^{-9}$ Torr			

**SPECIFICATION**

Number: <b>A</b>	<b>V049-2-106</b>	Rev. <b>0</b>
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Title: ACCEPTANCE TEST PROCEDURE FOR LARGE GATE VALVES

ACCEPTANCE TEST PROCEDURE FOR  
LARGE GATE VALVES  
FOR  
LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stern  
INST/ELEC ENGINEER: N/A  
QUALITY ASSURANCE: Alan R. Burdick  
TECHNICAL DIRECTOR: D. A. Williams  
PROJECT MANAGER: Richard Bayly

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.


0	TMS 5-3-96	REB 5/4/96	INITIAL RELEASE PER DEO # 0165 FOR FDA
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION		
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-107	Rev.
	TMS	5-3-96	REB	5/4/96		0

Title

# ACCEPTANCE TEST PROCEDURE FOR LARGE GATE VALVES

## TABLE OF CONTENTS

- 1.0 Purpose
- 2.0 General
- 3.0 Reference Documents
- 4.0 Responsibility
- 5.0 Test
- 6.0 Documentation

Attachment Acceptance Test Data Sheet

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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 equipment, 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.

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**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  $2.0 \times 10^{-10}$  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.

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Title

**ACCEPTANCE TEST PROCEDURE FOR LARGE GATE VALVES**

**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)

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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	$1 \times 10^{-10}$ 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	$<2 \times 10^{-10}$ torr for any HC /			
Particle Count	NA				
Pumpdown	NA				



Title

# ACCEPTANCE TEST PROCEDURE FOR 6", 10" & 14" GATE VALVES

## TABLE OF CONTENTS

- 1.0 Purpose
- 2.0 General
- 3.0 Reference Documents
- 4.0 Responsibility
- 5.0 Test
- 6.0 Documentation

Attachment Acceptance Test Data Sheet

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## SPECIFICATION

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Title

**ACCEPTANCE TEST PROCEDURE FOR 6", 10" & 14" GATE VALVES**

**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 equipment, 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.

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Title

## ACCEPTANCE TEST PROCEDURE FOR 6", 10" & 14" GATE VALVES

### 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 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  $1 \times 10^{-9}$  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)

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## 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	$1 \times 10^{-10}$ torr 1/sec He			
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	NA				
RGA Test	5.2				
Particle Count	NA				
Pumpdown	NA				

Title: ACCEPTANCE TEST PROCEDURE FOR CLEAN AIR SUPPLIES

ACCEPTANCE TEST PROCEDURE FOR  
CLEAN AIR SUPPLIES  
FOR  
LIGO VACUUM EQUIPMENT

Hanford, Washington  
and  
Livingston, Louisiana

PROJECT ENGINEER:

Thomas M. Stone

INST/ELEC ENGINEER:

QUALITY ASSURANCE:

Alan R. Goodbrock

TECHNICAL DIRECTOR:

D. A. McIlwain

PROJECT MANAGER:

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	JMS 5-3-96		INITIAL RELEASE PER DEO #0165 FOR FDR

ROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION		
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	NumberA	Rev.
	JMS	5-3-96	REB	5/4/96	V049-2-109	0

Title

**ACCEPTANCE TEST PROCEDURE FOR CLEAN AIR SUPPLIES**

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- 1.0 Purpose
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- 3.0 Reference Documents
- 4.0 Responsibility
- 5.0 Test

Attachment Acceptance Test Data Sheet

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V049-2-109

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**0**

**ACCEPTANCE TEST PROCEDURE FOR CLEAN AIR SUPPLIES****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 equipment, 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.

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Title

**ACCEPTANCE TEST PROCEDURE FOR CLEAN AIR SUPPLIES**

**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.

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<b>SPECIFICATION</b>		
Number	<b>A</b>	V049-2-109
Rev.		<b>0</b>

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				

**Title: ACCEPTANCE TEST PROCEDURE FOR PORTABLE SOFT-WALL CLEANROOMS**

**ACCEPTANCE TEST PROCEDURE FOR  
PORTABLE SOFT-WALL CLEANROOMS**

**FOR**

**LIGO VACUUM EQUIPMENT**

Hanford, Washington  
and  
Livingston, Louisiana

**PROJECT ENGINEER:**

Thomas M. Stan

**INST/ELEC ENGINEER:**

FAD I BARK I AEB

**QUALITY ASSURANCE:**

Alan L. Burdood

**TECHNICAL DIRECTOR:**

D.A. McWilliam

**PROJECT MANAGER:**

Richard Begly

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-3-96	REB 5/4/96	INITIAL RELEASE PER DED # 0165 FOR FDR

**ROCESS SYSTEMS INTERNATIONAL, INC.**

**SPECIFICATION**

<b>INITIAL APPROVALS</b>	<b>PREPARED</b>	<b>DATE</b>	<b>APPROVED</b>	<b>DATE</b>	<b>NumberA V049-2-110</b>	<b>Rev.</b>
	TMS	5-3-96	REB	5/4/96		0

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**ACCEPTANCE TEST PROCEDURE FOR PORTABLE CLEANROOMS**

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- 1.0 Purpose
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**ACCEPTANCE TEST PROCEDURE FOR PORTABLE CLEANROOMS****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 equipment, 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.

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**ACCEPTANCE TEST PROCEDURE FOR PORTABLE CLEANROOMS**

**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 Final 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.

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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: ACCEPTANCE TEST PROCEDURE FOR SMALL VALVES

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. Bullock

TECHNICAL DIRECTOR:

D. C. M. Williams

PROJECT MANAGER:

Richard Bagby

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

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	DATE	APPROVED	DATE	Number	Rev.
	TMS	5-3-96	REB	5/4/96	A V049-2-111	0

Title

# ACCEPTANCE TEST PROCEDURE FOR SMALL VALVES

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## ACCEPTANCE TEST PROCEDURE FOR SMALL VALVES

### 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 equipment, 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.

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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	$1 \times 10^{-9}$ torr l/sec He			
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	NA				
RGA Test	NA				
Particle Count	NA				
Pumpdown	NA				

Title

## ACCEPTANCE TEST PROCEDURE FOR SMALL VALVES

### 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 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  $1 \times 10^{-9}$  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.

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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. Beadlock

TECHNICAL DIRECTOR: D. C. Williams

PROJECT MANAGER: Richard Bayley

REV	LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE		
0		F. Bark 5/2/96	REB 5/2/96	REVERSED FOR FDR PER DED# 160		
PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION		
INITIAL APPROVALS	PREPARED	DATE	Approved	DATE	Number:	Rev.
	F. Bark	5/2/96	REB	5/2/96	A V049-2-112	0

**Title: SPECIFICATION FOR BAKEOUT SYSTEM ACCEPTANCE TEST PROCEDURE**

**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.

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**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.

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**Title: SPECIFICATION FOR BAKEOUT SYSTEM ACCEPTANCE TEST PROCEDURE**

**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					

**SPECIFICATION**

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