LIGO VACUUM EQUIPMENT
FINAL DESIGN REPORT
VOLUME IV
INSTALLATION/COMMISSIONING

CONTRACT NO:	PC 175730
PSI DOCUMENT NO:	V049-1-100
PROGRAM I.D.	LIGO VACUUM EQUIPMENT
CDRL NO:	03
APPROVAL STATUS:	A

Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581

CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

LIGO-C960967-03-V

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ISSUE DATE:	**July 21, 1997**
CDRL NO:	**03**
APPROVAL STATUS:	**A**

SUBMITTED TO:

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REVISION 2
7/1/97

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

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II. Component Acceptance Tests Procedures

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1.0 INSTALLATION PLAN SUMMARY

1.1 General

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

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

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

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

During the Final Design Phase, PSI has evaluated various options for aligning the vacuum equipment to the Beam Tube centerline. PSI has hired Metrowest Engineering Co. to assist PSI in selecting optical 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. Optical 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 optical 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.

An optical 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. This system uses an optical 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 optical alignment procedure will be developed after the optical alignment system is selected.

2.4 Vessel Installation and Precision Alignment

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.

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 optical 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, WBE-4A, WBE-4B, WA-1A and WA-1B

Position spools WB-9, WB-9B, WBE-5, WB-1A, WB-1B, WB-8A, WB-8B, WBE-6, WBE-2A, WBE-2B, WBE-3A1, WBE-3B, WA-13A and WA-13B.

Position WHAM7 and WHAM12.

Position WHAM1 and WHAM6.

Position Mode Cleaner Tubes WB-2A and WB-2B

Position Mode Cleaner Tubes WB-3A and WB-5A.

Position WHAM2 and WHAM3.

Position WHAM11 and WHAM10.

Position WHAM9 and WHAM8.

Position spools WA-13A, WA-13B, WBE-3A and WBE-3B.

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

Position WHAM4 and WHAM5.

Position spools WA-15A, WA-15B, WA-3A, WA-3B, WA-6A, WA-6B, WB-7, WB-4A, WA-12A, WA-12B, WBE-2A, WBE-2B, WBE-3A2 and WBE-3B.

Assemble and position 2ea. BSC Clean Rooms.

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

Install Mode Cleaner WB-5A (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 WB-3A (Anchor bolts - no grout).

Install Mode Cleaner Tube WB-3A to WHAM2 (Anchor bolts - no grout).

Install WBE-3B at WBSC2.

Install WBE-2B at WBSC2.

Install Ion pumps WIP3, WIP4 and gauges at WHAM5.

Install WA-3A at WBSC3 and WA-3B 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 CDS rack.

Grout all components

3.2.2 Washington Corner Station-Right Beam Manifold

Assemble and set-up portable Clean Room.

Install WCP2, WGV7, WA-1A, and WBE-4A (Anchor bolts - no grout).

Install Cryopump burst disk.

Install Beam Tube manifold WA-13A, WB-8A, WB-1A, WBE-5 and WB9 (Anchor bolts - no grout).

Install adapters WA-13A, WA-12A, WB-4A to WGV4 and WB-7.

Install 6" and 10" hand valves.

Install WRC2 and WTC2 at WB-7 anchor bolt to floor.

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

Install Right Beam Manifold I/O wiring to LIGO CDS 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, WB4, WB6, WA-12B and WB-6B.

Install Mode Cleaners WB-2A and WB-2B (Anchor bolts - no grout).

Install 6" hand valve at WB6.

Install adapters WA-6B and WBE-3A2.

Grout all components.

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

Install Diagonal I/O wiring to LIGO CDS 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 Cryopump burst disk.

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

Install spools WA-1B, WA-13B, WB-8B, WB-1B, WBE-6 and WB-9B (Anchor bolts - no grout).

Install 6" and 10" hand valves at WBE-6.

Install WRC1 and WTC1 at WBE-6 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 CDS rack.

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

Grout all components.

3.2.5 Corner Station Mechanical Room

Install Main Roughing and Turbo Backing pumps.

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

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install condensate blow down lines.

Install Air Drier blowdown vent line.

3.2.6 Washington Corner Station LN2 Supply System Installation

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

Install VJ piping to WCP2.

Pressure test LN2 system.

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

Install VJ piping to WCP1.

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

Pressure test LN2 system.

Commission and test WCP1.

3.2.7 Corner Station Laydown Area Requirements

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

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

3.3 Right Mid Station Installation

3.3.1 Vacuum Vessels

Assemble and install portable clean room.

Install WBSC5 (Anchor bolts - no grout).

Install WCP5 (Anchor bolts - no grout).

Install WCP6 and WBE-4E (Anchor bolts - no grout).

Install Cryopump burst disks.

Install 10" hand valve.

Install WGV14 and spools WA-1C, WA-7A1.

Install spool WBE-4C between WCP5 and WGV13.

Install WGV15 and spool WA-14A.

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 CDS rack.

Grout all components.

3.3.2 Right Mid Station Mechanical Room

Install and Turbo Backing pumps.

Install Clean Air compressor.

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install condensate blow down lines.

Install Air Drier blowdown vent line.

3.3.3 Right Mid Station LN_2 Supply Systems

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

Install VJ piping to WCP5 and WCP6.

Confirm the Right Mid Station oxygen monitoring system operational.

Commission LN2 systems.

Commission and test WCP5, WCP6.

3.3.4 Right Mid Station Laydown Area Requirements

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

3.4 Left Mid Station Installation

3.4.1 Vacuum Vessels

Assemble and install portable clean room.

Install WBSC6 (Anchor bolts - no grout).

Install WCP3 (Anchor bolts - no grout).

Install WCP4 (Anchor bolts - no grout).

Install Cryopump burst disks.

Assemble and install portable clean room.

Install WGV10 and spools WA-1D, WA-7B1 .

Install spool WBE-4D between WGV9 and WCP3.

Install spool WA-14B and WGV11.

Install spool WBE-4F 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 CDS rack.

Grout all components.

3.4.2 Left Mid Station Mechanical Room

Install Turbo Backing pumps.

Install Clean Air compressor.

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install condensate blow down lines.

Install Air Drier blowdown vent line.

3.4.3 Left Mid Station LN_2 Supply Systems

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

Install VJ piping to WCP3 and WCP4.

Confirm the Left Mid Station oxygen monitoring system operational.

Commission LN_2 systems.

Commission and test WCP3 and WCP4.

3.4.4 Left Mid Station Laydown Area Requirements

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

3.5 Right End Station Installation

3.5.1 Vacuum Vessels

Assemble and install portable clean room.

Install WCP8 (Anchor bolts - no grout).

Install Cryopump burst disk.

Install WBSC9 (Anchor bolts - no grout).

Install WGV20 and spools WA-1E.

Install spool WA-7A2

Install spool WBE-4G 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 CDS rack.

3.5.2 Right End Station Mechanical Room

Install and Turbo Backing pumps.

Install Clean Air compressor.

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install condensate blow down lines.

Install Air Drier blowdown vent line.

3.5.3 Right End Station LN_2 Supply System

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

Install VJ piping to WCP8.

Confirm the Right End Station Oxygen monitoring system operational.

Commission LN2 system.

Commission and test WCP8.

3.5.4 End Station Laydown Area Requirements

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

3.6 Left End Station Installation

3.6.1 Vacuum Vessels

Assemble and install portable clean room.

Install WBSC10 (Anchor bolts - no grout).

Install WCP7 (Anchor bolts - no grout).

Install Cryopump burst disk.

Assemble and install portable clean room.

Install spool WA-1E and WGV18.

Install spool WBE-4H between WCP7 and WGV17.

Install spool WA-7B2

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 CDS rack.

Grout all components.

3.6.2 Left End Station Mechanical Room

Install Turbo Backing pumps.

Install Clean Air compressor.

Install Air Drier.

Install electrical cabinets.

Install cooling water system.

Connect vent header.

Install electrical systems.

Connect Clean Air piping.

Energize electrical panels.

Install blow down lines.

3.6.3 Left End Station LN_2 Supply System

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

Install VJ piping to WCP7.

Confirm the Left End Station oxygen monitoring system operational.

Commission LN_2 system.

Commission and test WCP7.

3.6.4 Left End Station Laydown Area Requirements

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

3.7 Grouting Requirements

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

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

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

Acceptable grout products are:

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

2. Masterflow 928 - manufactured by: Masterbuilders

3. Masterflow 713 - manufactured by: Masterbuilders

Application:
The undersides of all base plates shall be clean and the concrete surface be clean and dampened prior to placing grout.
Grout shall be mixed, placed and cured in accordance with the manufacturers instructions.
Curing shall continue for a minimum of 7 days.
Grout test and QC inspection reports shall be provided to the Owner.

3.8 Vessel and Component Optical Alignment

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

3.9 Anchor Bolt Installation

All anchor bolts will be installed in accordance with Anchor Bolt Installation Procedure V049-1-101. (See Attachment "M")

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

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

4.2 Control of Contamination

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

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

4.3 Acceptance Testing

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

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

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

5.0 ACCEPTANCE TESTING

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

Some components (ion pumps, roughing and turbo pump, etc.) are performance tested at the vendors facility. Vacuum vessel and tube sections have been vacuum leak tested at PSI and have met LIGO requirements. These tests will not be repeated during site testing. 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 1×10^{-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 $1x10^{-6}$ torr to $1x10^{-3}$ torr.

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

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

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

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

5.1.2.3 Ion Pumps

5.1.2.3.1 **Main Ion Pumps**

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

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

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

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

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 x 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 $1x\ 10^{-9}$ torr liter/sec of helium.

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

The following documentation will be provided prior to shipment:

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

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

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

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

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

5.1.4 80K Cryopump System Site Acceptance Test

5.1.4.1 80K Pump Field Joint Leak Test

The specification requires all leaks greater than 1×10^{-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 2×10^{-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 3×10^{-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

Gas Species	LIGO Partial Pressure Goals Torr	Predicted Partial Pressures Torr	Acceptance Partial Pressures Torr
H_2	5x10-9	5x10-9	
H_2O	5x10-9	1x10-9	
Total H_2O, H_2	1x10-8	6x10-9	
N_2	5x10-10	-	
CO	5x10-10	-	
Total N2, CO		1x10-9	
CO_2	2x10-10	2x10-10	
CH_4	2x10-10	5x10-10	
All others	5x10-10	5x10-10	
Total other	1.9x10-9	2.2x10-9	3x10-9
Total	1.19x10-8	8.2x10-9	2x10-8 *

* Exclusion for H2

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 $5x10^{-6}$ torr.

End/ Mid Stations:

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

5.2.2.7.3 80K Cryopump

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

5.2.2.7.4 Main Ion pumps.

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

5.2.3 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 excedence 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 Optical Alignment System

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

7.2.2 Metrowest Preliminary Alignment Report

May 2, 1995

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

Re: Procedure for vessel alignment for the LIGO project.

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

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

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

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

1. Equipment selection:

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

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

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

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

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

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

Topcon DL-101 Electronic Digital Level:
An electronic level complete with a digital readout which has the ability to achieve first order leveling. Minimum units for reading is 0.01 mm.
Accuracy is 0.4 mm with an Invar staff.

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

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

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

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

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

The Model L-723 Triple Scan™ Laser
Hamar Laser Instruments, Inc. - Wilton, CT.
The ability to measure flatness, straightness and squareness simultaneously with a single setup. The unit is completely self contained and can be used as is, or with a tilt and leveling base. The Model L-120 leveling base provides a complete and accurate way to level the unit while the Model L-104A Lift Stand allows the user to raise or lower the laser in controlled, accurate increments to any desired height from 20 to 60 inches. The unit is powered by a 9VDC battery pack attached to the unit or a 115VAC adapter is available. Three laser turrets positioned 90° apart are set in either a scanning or through-beam mode. In the scanning mode, rotating laser turrets simultaneously sweep three completely flat planes calibrated to be perpendicular to one another. With a slight adjustment on each rotating laser turret the laser beams project straight through the center of each turret and form a virtual x,y,z axis in space.

Advantage:
Extremely accurate.
Unit is small, lightweight and very portable. It weighs only 4.25 lbs.
Can operate as 1,2 or 3 beams and or 1,2 or 3 scanned planes in any combination.

Disadvantage:
A visible diode beam is used with a beam diameter of 4 mm.
Limited to an effective operating distance of 100 feet.

2. Vessel alignment procedures.

A. Baseline procedures for end station units.

(see accompanying sketch)

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

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

B. Baseline procedures for mid station units.

(see accompanying sketch)

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

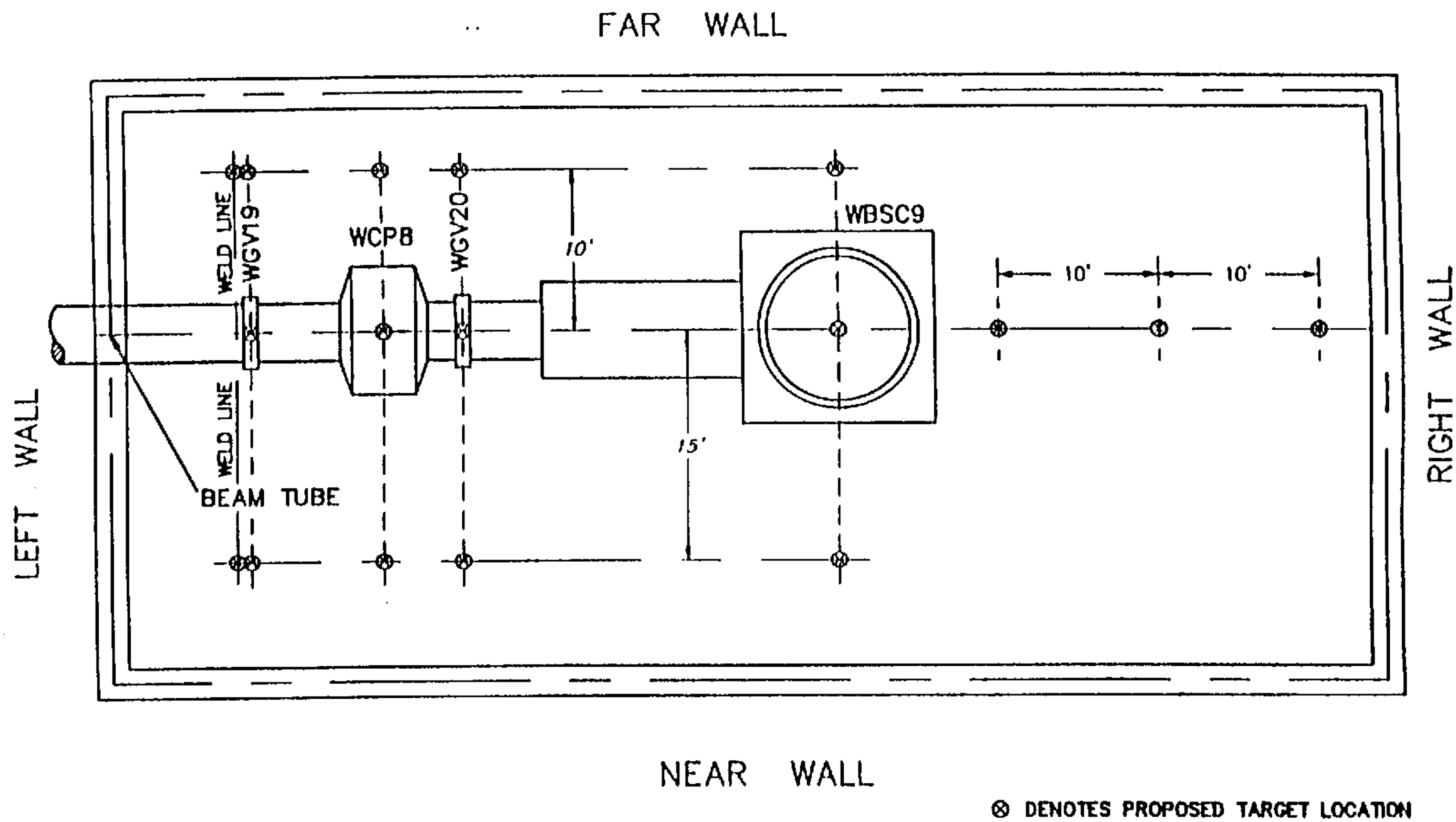
C. Baseline procedures for corner station units.

(see accompanying sketch)

This area offers the biggest challenge. There are four separate beam lines that need to be established and offset. The beams are parallel and perpendicular to each other which will aid in the offsetting of the baselines. Again the beam line baselines should be established with the critical vessel locations marked. The baselines should be extended at least thirty feet with markings at ten foot intervals and preferably until they intersect with the left wall and the near wall. This would be the beam line baseline extending from unit WHAM1 toward the left wall and the beam line baseline extending from unit WHAM6 toward the near wall. The beam tubes will again mark the end points of these baselines. The shorter beam line baselines should also be extended. From unit WHAM7 that baseline should be extended until it intersects with the right wall, with markings at ten foot intervals. From unit WHAM12, that baseline should be extended until it intersects with the far wall, again with markings at ten foot intervals. The intersection points of the shorter beam line baselines with the longer beam line baselines need not be marked as this will only add an already confusing situation. You do not want the intersection of these baselines to be confused with the center of the vessels. These shorter baselines should end at their respective gate valve locations. The baselines can then be offset a distance equal to one half the distance between the beam lines. For example if the beam lines are thirty feet apart, the offset baseline would be fifteen feet. The main beam line baseline running through WHAM1, 2 and 3 would be offset toward the far wall while the beam line baseline running through WHAM4, 5 and 6 would be offset toward the right wall. Because of the many units involved within this corner section, it would not be sensible to attempt to offset each individual unit. Instead we recommend the two baselines be marked off in twenty foot intervals, in both directions, starting with the intersection of the two baselines. The offset points can then be assigned a coordinate value along with the vessels. The vessels can then be set in place using either multiple instrument triangulation or a total station equipped with distance measuring capabilities. Again because of the number of units involved, it is suggested the shorter beam line vessels be put in place first. You will want to maintain as long a sight line as possible while installing the vessels, for as long as possible. Once you have installed the units WBSC3 and WBSC1, you will have limited your line of sight toward the near wall and left wall respectively. However, we do not foresee this as a problem as long as the line of sight is maintained toward the rear wall and the right wall. The connecting tubes between vessels WBSC8, WBSC4 and WBSC1 should be the last thing installed, again due to the fact that you will want to maintain that sight line. Vertical reference marks should be consistent with the previous recommendations for the end station units and mid station units. Vertical reference marks should be established somewhere along each wall of the building. The intersection of the beam line baselines with the near wall and the left wall offer excellent positions for a combined horizontal and vertical reference mark. The beam tubes offer the vertical reference at the far wall and the right wall. Because of the cluster of units involved within the center of the building, additional vertical reference marks should be made available to insure a clear sight between the technicians and the vessels. The wall corners nearest to units WBSC4, WBSC8, WBSC2 and WBSC7 should also have a vertical reference mark made available. Again we recommend that targets be used in referencing the vertical marks and brass discs be used for the offset baseline.

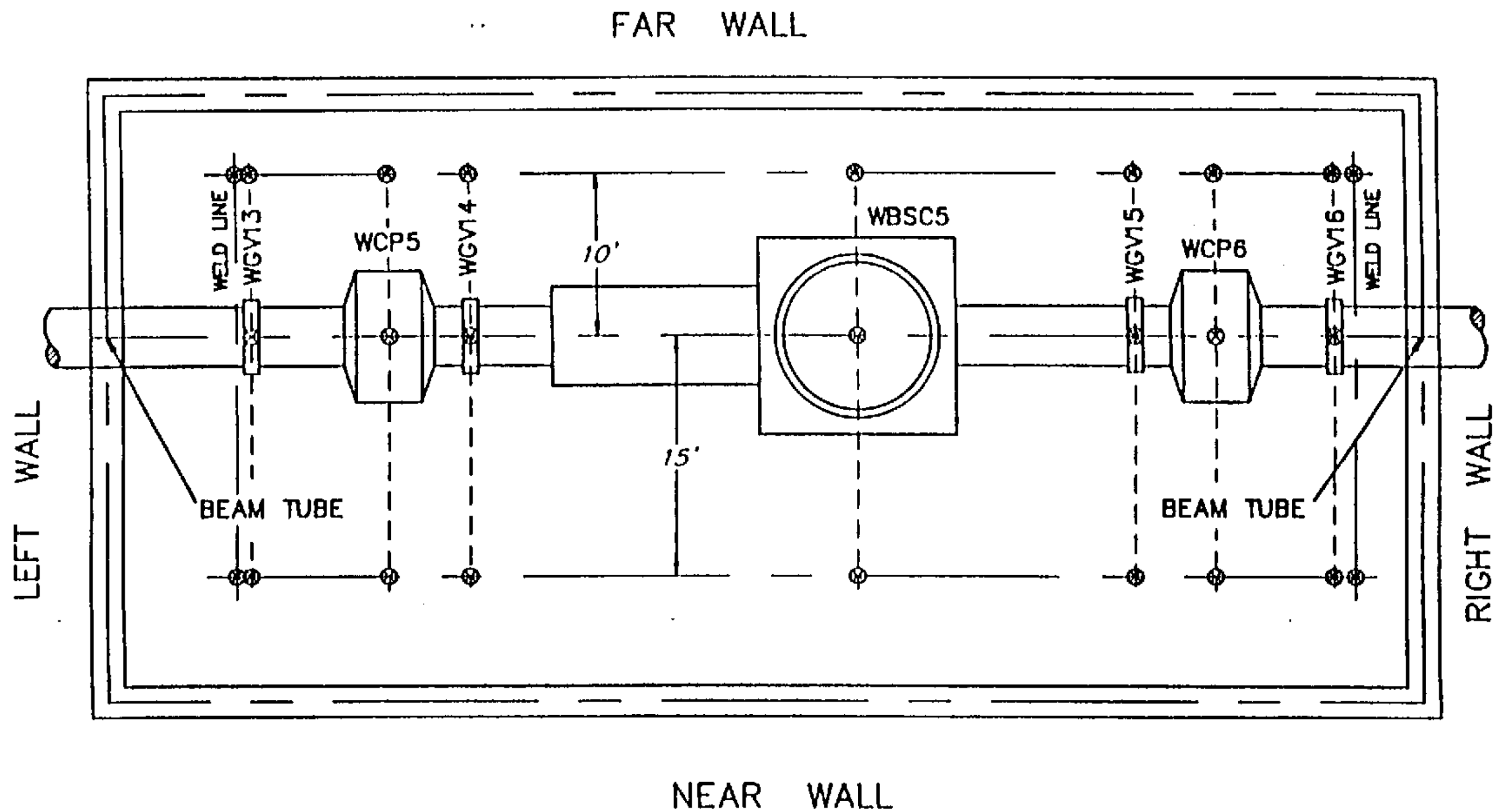
3. Recommendations / Action Items:

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



PRELIMINARY SKETCH OF END STATION UNITS

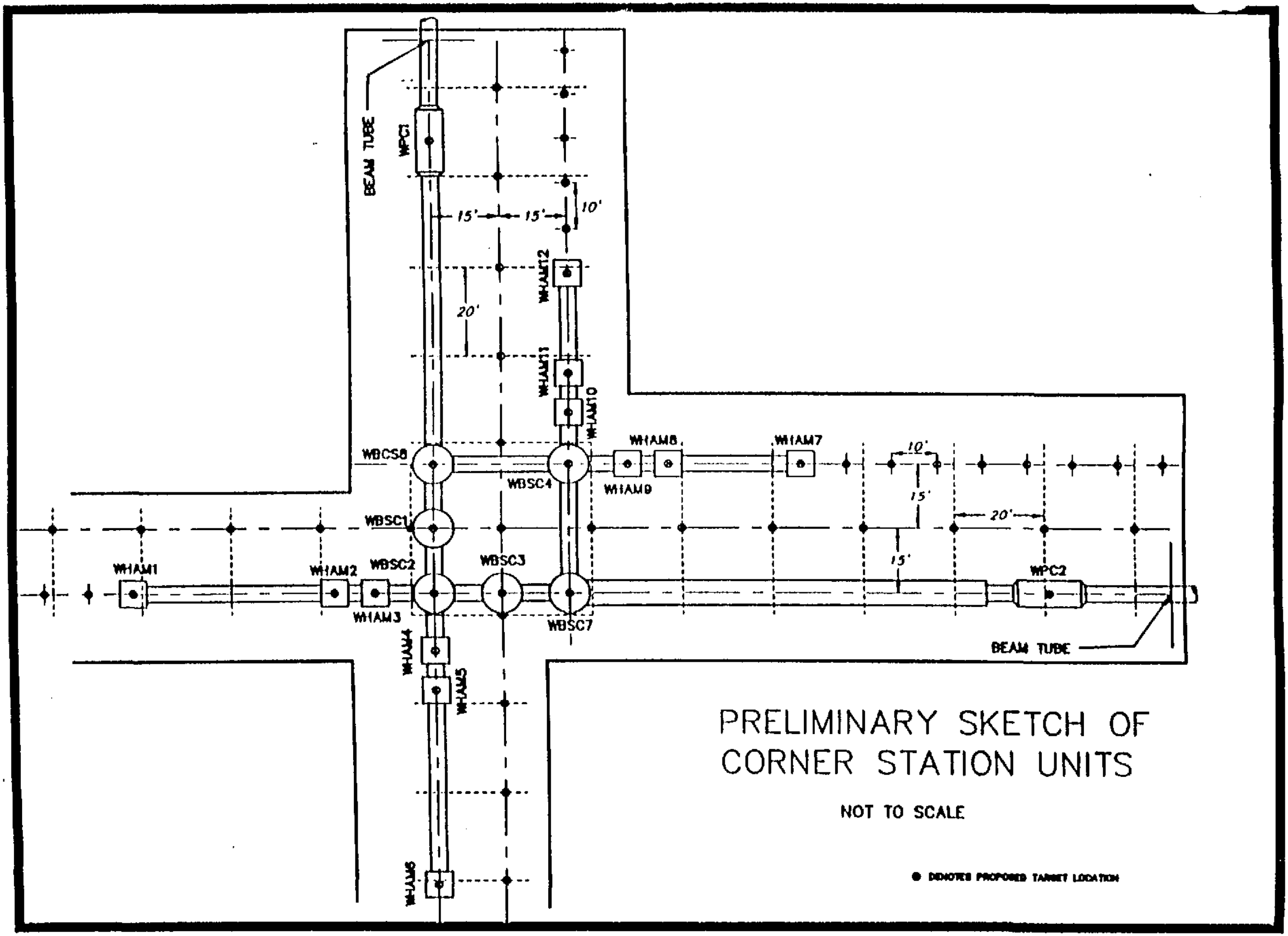
NOT TO SCALE



⊗ DENOTES PROPOSED TARGET LOCATION

PRELIMINARY SKETCH OF MID STATION UNITS

NOT TO SCALE



PRELIMINARY SKETCH OF CORNER STATION UNITS

NOT TO SCALE

FDR VOLUME IV

ATTACHMENTS	*DOCUMENT NO.*
For Spec. Revision Level see Gen.Doc. List	
V049-0-000	

I. Procedures and Spec.

Anchor Bolt Installation Procedure	V049-1-101
Leak Check Procedure	V049-2-014
Vacuum Equipment Installation/Commissioning Spec.	V049-2-021
Electrical and Instrument Construction Spec.	V049-2-022
Project Safety Plan	V049-2-023
Project Q.A. Plan	V049-2-029
Piping Design and Material Specification	V049-2-037
Small Vacuum Valves	V049-2-059
Clean Quarter Turn Valves	V049-2-060
Welding Procedures	V049-2-070
	V049-2-071
	V049-2-072
	V049-2-073
Material/Welding Repair Procedure	V049-2-074
Isolatable Section Bakeout Procedure	V049-2-116
Clean Room Activities	V049-2-118
Contamination Control Plan	V049-2-119
Raw Material Handling Procedure	V049-2-120
Control of Non-Conformance	V049-2-124
Visual Inspection Procedure	V049-2-128
Black Light Test Procedure	V049-2-130
Site Piping Cleaning Procedure	V049-2-131
Site Vacuum Surface Re-Cleaning Procedure	V049-2-132
RGA Calibration	V049-2-137
Structural Carbon Steel Fabrication and Painting	V049-2-139
Thermal Insullation - Piping	V049-2-163
Conflat Flange Assembly Procedure	V049-2-168
O-Ring Installation and Flange Assembly Procedure	V049-2-169
Component Alignment Procedure	V049-2-174
Vacuum Pump Field Installation Procedure	V049-2-175
Prefabricated Vacuum and Class 100 Air Piping	V049-2-178

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

FDR VOLUME IV

ATTACHMENTS	*DOCUMENT NO.*
For Spec. Revision Level see Gen.Doc. List	
V049-0-000	
II. Component Acceptance Tests Procedures	
80K Pumps	V049-2-102
Roughing Pumps	V049-2-104
Turbomolecular Pumps	V049-2-105
Ion Pumps	V049-2-106
Large Gate Valves	V049-2-107
6, 10, 14" Gate Valves	V049-2-108
Clean Air Supplies	V049-2-109
Portable Soft Wall Cleanrooms	V049-2-110
Small Valves	V049-2-111
Bakeout System Blankets and Carts	V049-2-112
III. System Acceptance Test Procedures	
Corner Stations	V049-2-113 (Later)
Mid Stations	V049-2-114 (Later)
End Stations	V049-2-115 (Later)

Title: PROCEDURE FOR INSTALLATION OF CONCRETE ANCHORS

RAYMOND D. CIATTO
STATE OF WASHINGTON
15714
REGISTERED
PROFESSIONAL ENGINEER
9/18/97
EXPIRES 8/6/99

PROCEDURE FOR

INSTALLATION OF CONCRETE ANCHORS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington

PREPARED BY: R. D. Ciatto

INSTALLATION MANAGER: [illegible]

QUALITY ASSURANCE: [illegible]

TECHNICAL DIRECTOR: [illegible]

PROJECT MANAGER: [illegible]

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	[illegible] 7/18/97	REB 7/18/97	RELEASED FOR CONSTRUCTION PER DEO #0537
0	—	—	ISSUED PER DEO 138 FOR EDR

PROCESS SYSTEMS INTERNATIONAL, INC. — **PROCEDURE**

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	RDC	4/26/96	REB	4/26/96	**V049-1-101**	**1**

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.

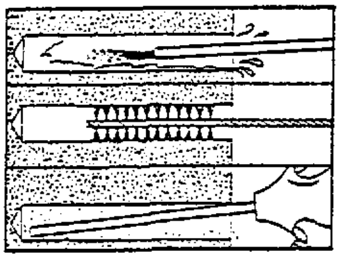
4.2 Critical equipment shall be aligned per procedures V049-2-021 section 8.3 and V049-2-174 prior to drilling the anchor bolt hole. Critical equipment anchor bolt requirements are detailed in attachment A of this specification.

4.3 Locate and install anchor bolts in accordance with the this specification and 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 in this specification are minimum depths for the equipment listed. 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.

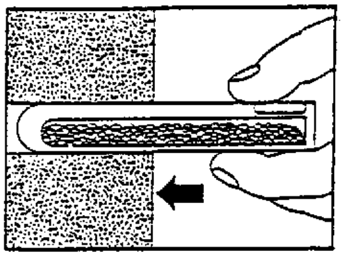
4.4 Adhere to curing time required by Hilti before loading or disturbing anchors.

4.5 Step by step instructions:

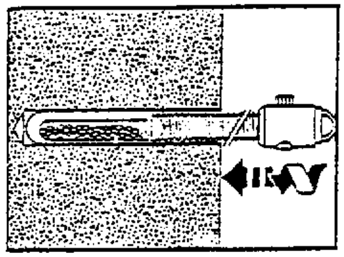
Installation Instructions (HAS Threaded Rod — Option #1)



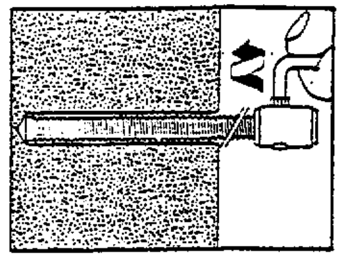
1. Set the drill depth gauge and drill the hole to the required hole depth. IMPORTANT: Clear out dust and fragments: preferably using a jet of water or compressed air and a wire brush. The hole may be damp, but the water should be blown out.



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.

Number

Rev.

SPECIFICATION

Number A V049-1-101 Rev. 1

11/88 PS-997

ATTACHMENT "A" TO V049-1-101

REQUIRED CONCRETE ANCHORS FOR VACUUM EQUIPMENT

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"	8 1/4"	
WBSC8	1"	12 3/8"	2
WBSC9	1"	12 3/8"	2
WBSC10	1"	8 1/4"	3
WHAM1	1"	8 1/4"	3
WHAM2	1"	8 1/4"	4
WHAM3	1"	8 1/4"	
WHAM4	1"	8 1/4"	
WHAM5	1"	8 1/4"	
WHAM6	1"	8 1/4"	
WHAM7	1"	8 1/4"	4
WHAM8	1"	8 1/4"	4
WHAM9	1"	8 1/4"	
WHAM10	1"	8 1/4"	
WHAM11	1"	8 1/4"	
WHAM12	1"	8 1/4"	4
WHAM13	1"	12 3/8"	
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	¾"	6 5/8"	6
WGV2	¾"	6 5/8"	6
WGV3	¾"	6 5/8"	6
WGV4	¾"	6 5/8"	6

Component Tag No.	Anchor Diameter	Minimum Embedment Depth	Notes
WGV5	¾"	6 5/8"	7
WGV6			5
WGV7	¾"	6 5/8"	7
WGV8			5
WGV9			5
WGV10	¾"	6 5/8"	7
WGV11	¾"	6 5/8"	7
WGV12			5
WGV13			5
WGV14	¾"	6 5/8"	7
WGV15	¾"	6 5/8"	7
WGV16			5
WGV17	¾"	6 5/8"	7
WGV18	¾"	6 5/8"	7
WGV19			5
WGV20	¾"	6 5/8"	7
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"	8
WB-7	1"	12 3/8"	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	¾"	6 5/8"	

1. Install Hilti HVA anchors with HEA capsules and HAS standard rods, unless otherwise noted, 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.
5. These gate valves are supported by others.
6. See Dwg. V049-4-034, for 48" gate valve anchor bolt locations.
7. See Dwg. V049-4-033 for 44" gate valve anchor bolt locations.
8. Use Hiliti HAS Super Threaded Rod

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 [signature]

PROJECT ENGINEER S Motew

QUALITY ASSURANCE Alan L Bradbrook

TECHNICAL DIRECTOR D. A. McWilliams

PROJECT MANAGER Richard Bagley

2	GS 1/14/97	RGB 1/14/97	Revised Per DEO # 0407
1	SM 12/4/96	RGB 12/4/96	REVISED PER DEO 0378
Ø	GS 10/10/96	—	Release for fab Per DEO # 0302
φ	SM 5/4/96	RGB 5/4/96	INITIAL RELEASE DEO 0162 FOR FDR
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

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

1.0 PURPOSE

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

2.0 GENERAL

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

3.0 RESPONSIBILITY

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

4.0 PROCEDURE

4.1 Joint Categories:

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

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

Category III
CF flange joint.

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

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

4.2 Leak Checking Welded Joints

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

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

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

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

4.3 Leak Checking Conflats

Category III
Conflats.

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

4.4 Leak Checking O-rings

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

Leak checking method
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.

LEAK TEST DATA SHEET

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

Remarks : ______________________________

BSC LEAK TEST SUMMARY SHEET

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

Comments

Witnessed
Signature
Title
Date

HAM LEAK TEST SUMMARY SHEET

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

Comments

Witnessed
Signature
Title
Date

SPOOL SECTION LEAK TEST SUMMARY SHEET

Name							
Model No.							
Serial No.							
Drwg.No.							

Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
		Torr	Torr				
Annulus-1	IV		$1x10^{-5}$				
Annulus-2	IV		$1x10^{-5}$				
Annulus-1	V		$1x10^{-5}$				
Annulus-2	V		$1x10^{-5}$				
		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET
80K CRYOPUMP RESERVOIR

	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 1x10-E-9 Torr		Pass	Fail	
Measured				
Calculated				
Allowable				
Performed By :	Date :			
Witnessed By :	Date :			
Signature :	Date :			
Title :				

Remarks : ______________________________

____

SPECIFICATION

Number: V049-2-014 A

Rev. 2

LEAK TEST DATA SHEET
FOR
80K CRYOPUMP WELDMENT ASSY

	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 1x10 E-9 Torr		Pass	Fail	
Measured				
Calculated				
Allowable				
Performed By :	Date :			
Witnessed By :	Date :			
Signature :	Date :			
Title :				

Remarks : ____

____

LEAK TEST DATA SHEET
FOR
LN2 BAYONET ON 80K CRYOPUMP WELDMENT ASSEMBLY

	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 1x10 E-9 Torr		Pass	Fail	
Measured				
Calculated				
Allowable				
Performed By :	Date :			
Witnessed By :	Date :			
Signature :	Date :			
Title :				

Remarks :

ATTACHMENT V049-2-021
TO
V049-1-100
LIGO VACUUM EQUIPMENT
FINAL DESIGN REPORT
VOLUME IV
INSTALLATION/COMMISSIONING

"Shipped Loose"

SPECIFICATION

FOR

ELECTRICAL & INSTRUMENT CONSTRUCTION WORK

LIGO VACUUM EQUIPMENT

Hanford, Washington

FADI A. BARK
STATE OF WASHINGTON
No. 33057
REGISTERED
PROFESSIONAL ENGINEER
EXPIRES July 1998

Fadi Bark

PREPARED BY Daniel J. Parenti Jr.

ELECTRICAL Fadi Bark

QUALITY ASSURANCE Al Bradbrook

TECHNICAL DIRECTOR D. A. McWilliams

PROJECT MANAGER Richard Bagley

2	[illegible] 6/30/97	REB 7-1-97	RELEASED FOR CONSTRUCTION DEO #0510
1	RJW 12/2/96	REB 12/2/96	Released for Constr. RFQ per DEO #0377
0	DP 4/29/96	REB 4/29/96	Released for Review and Comment per DEO #0149
REV LTR	BY—DATE	APPD—DATE	DESCRIPTION OF ACTION

PROCESS SYSTEMS INTERNATIONAL, INC					SPECIFICATION	
INITIAL APPROVALS	PREPARED BY D. Parenti	DATE 4/29/96	APPROVED BY REB	DATE 4/29/96	Number A V049-2-022	Rev 2

CONTENTS

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 <u>SUMMARY OF ELECTRICAL WORK</u>

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 <u>Field Tests</u>

- 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.

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 Representative	Persons designated by Owner
Permitted	As by code, Contract Documents, or PSI.
Provide	Furnish and install.
Required	As by code, Contract Documents, or prevailing conditions.
Submittal	Information required to show that the proposed equipment complies with project requirements.
Use	Provide material or equipment referenced.
Work	Material and equipment and their installation and other requirements as established in the Contract Documents.
Wire (Verb)	Connect to equipment indicated and provide wiring required for connection.
Wiring	Conductors, raceways, and accessories as required for a complete installation.

5 CODES, STANDARDS, AND PERMITS

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

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

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

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

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.

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, $^3/_8$ 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.

- 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.14.

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.

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 otherwise indicated.

15.3 INSTRUMENT WIRE (analog signals):

15.3.1 4-20 mA: 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:

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

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

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

16.2 INSTRUMENT AND CONTROL WIRE:

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

16.2.2 Tag each spare cable end with unique identification.

16.2.3 Use printed sleeve markers.

16.3 SUBMITTALS: Provide product data of printed sleeve markers.

17 WIRING TERMINATIONS

17.1 POWER WIRE:

17.1.1 Splices:

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

17.1.2 Terminations:

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

17.1.3 Motor Leads: To connect to motor leads, use split-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.

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.

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 $\frac{1}{2}$ 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 $\frac{1}{2}$ 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.

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.

—END—

ATTACHMENT "A"

DRAWING LISTS

DRAWING	DESCRIPTION
V049-3-002	OVERALL SITE PLAN
V049-3-101	INSTRUMENT PLAN—VERTEX SECTION
V049-3-102	INSTRUMENT PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-103	INSTRUMENT PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-104	INSTRUMENT PLAN—DIAGONAL SECTION
V049-3-106	CABLE TRAY PLAN—VERTEX SECTION
V049-3-107	CABLE TRAY PLAN—LEFT BEAM MANIFOLD SECTION
V049-3-108	CABLE TRAY PLAN—RIGHT BEAM MANIFOLD SECTION
V049-3-109	CABLE TRAY PLAN—DIAGONAL SECTION
V049-3-110	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

DRAWING	DESCRIPTION
V049-3-129	DATA HIGHWAY PLAN— RIGHT BEAM MANIFOLD STATION
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

DRAWING	DESCRIPTION
V049-3-404	POWER PLAN—LEFT END STATION
V049-3-405	CONDUIT STUB-UP PLAN - LEFT END STATION
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

DRAWING	DESCRIPTION
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*

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

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

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.

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

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)

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.

SPECIFICATION FOR

PROJECT QUALITY ASSURANCE PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

MANUFACTURING ENGINEER: Philip Feilard

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bayly

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

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

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ATTACHMENTS

1.0 PURPOSE

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

2.0 GENERAL

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

3.0 RESPONSIBILITIES

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

4.0 PROCEDURE

4.1 Quality Review And Planning

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

4.2 Receiving Inspection

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

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

4.3 Material Certification

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

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

4.4 In-Process Inspection

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

4.5 Cleaning

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

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

4.6 Welding

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

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

4.7 Final Inspection

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

4.8 Testing

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

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

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

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

4.9 Documentation

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

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.

4.11 Engineering Plan Review

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

4.12 Procurement Specification Review

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

Attachment 1
V049-2-029

LIGO VACUUM EQUIPMENT
FINAL DOCUMENTATION SUMMARY

Component
Model No.:
Serial No.:

Date:
Prepared By:

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

Notes:

Title: PROJECT SAFETY PLAN

PROJECT SAFETY PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

QUALITY ASSURANCE:

LIGO SAFETY OFFICER:

PROJECT MANAGER:

1	D. McW	REB 11/15/96	RELEASED PER DEO 351
Ø	4/24/96		RELEASED PER DEO 137
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED DATE 25APR96	APPROVED DATE REB 4/24/96	Number A V049-2-023	Rev. 1

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ATTACHMENTS

1.0 PURPOSE

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

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

2.0 SCOPE

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

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

4.0 PLAN MAINTENANCE

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

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

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

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

6.0 SAFETY OBJECTIVES

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

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

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

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

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

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

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

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

6.2 Organization

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

6.3 Responsibilities

Throughout the performance of this project, responsibilities have been established to carry out the requirements of this plan. 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.

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.

SPECIFICATION FOR
PIPING DESIGN AND MATERIAL
FOR
LIGO VACUUM EQUIPMENT

Hanford, Washington
And
Livingston, Louisiana

RAYMOND D. CIATTO
STATE OF WASHINGTON
15714
REGISTERED
PROFESSIONAL ENGINEER
EXPIRES 8/5/99
7/21/97

STATE OF LOUISIANA
RAYMOND D. CIATTO
REG. No. 26750
REGISTERED
PROFESSIONAL
ENGINEER
IN
CIVIL ENGINEERING

PROCESS ENGINEER: Robert Than

PROJECT ENGINEER:

CIVIL/STRUC. ENGINEER: R. D. Ciatto

MANUFACTURING ENGINEER:

QUALITY ASSURANCE ENGINEER:

PROJECT MANAGER:

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
5	RM 1/14/97	D.M.W 1-15-97	Clarified 1B1 flange/gasket requirements DEO # 0411
4	REC 11/27/96	D.M.W 11-27	REVISED T3 CLASS, MAT'L TO BE 304S/S, IT WAS 304L. DEO 0369
3	RM 10/16/96	D.M.W 10-17-96	Added "C1", spec. sht for cryogenic copper lines. REVISED 1B1-FLANGES DEO # 0310
2	REC 8/24/96	PAH/REB 8/28/96	REVISED "T4" SPEC SHT. 17, ITEM 5. RELEASED FOR PURCHASE. DEO. 249
1	REC 7/25/96	REB 8/13/96	REVISED "T4" SPEC. SHT. 17 RELEASED FOR PURCHASE DEO # 0236
0	REC 1-19-96	D.M.W	RELEASED FOR DESIGN & QUOTES DEO # 0044

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED R. Ciatto	DATE 1-11-96	APPROVED D.M.W	Number A V049-2-037	Rev. 5
			DATE 1-18-96		

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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

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:

2 PL 008 XYZ 3 HC FP3

- FP3 — Insulation Mat'l (See Section 5.5) Service
- HC — Insulation code (See Section 5.4)
- 3 — Insulation Thickness
- XYZ — Piping Specification Designation (See Section 5.3)
- 008 — Sequential Number
- PL — Fluid Service Code (See Section 5.2)
- 2 — Line Size (Nominal Pipe, inches). (Copper tube designated by nominal size, not OD)

5.2 Fluid Codes

Code	Fluid
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

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

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.

PV - A BB

- BB — Sequential (Loop) Number
- A — Station Identification
- PV — Functional Identification

Manual valves that do not carry an instrument loop numbers (described above) shall be assigned one of the following valve type descriptions, preceeded 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

VSOO Vacuum Seal-Off Valve Operator, SS

1B1

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. Flanges on the vent line, (which mate to a flat faced flange on the vacuum equipment) shall be stainless steel raised-face design. Flanged joints shall have spiral wound, stainless steel gaskets, Flexitallic or equal.

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

Continued on Next Page

1B1

Branch Connections:

Run Size "											
½	04										
¾	06	04									
1	12	06	04								
1½	05	05	06	04							
2	05	05	06	06	04						
3	05	05	05	05	06	04					
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

04 - Tee
05 - Sockolet
06 - Tee Then Reducer or Reducing Tee
12 - BW O'let

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.

Continued on next page.

1B2

Branch Connections:

Run Size "												
½	04											04 - Tee
¾	06	04										05 - Sockolet
1	12	06	04									06 - Tee Then Reducer or Reducing Tee
1½	05	05	06	04								
2	05	05	06	06	04							
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	

Note:

1. Piping and fittings to be internally cleaned, dryed 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.

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.

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.

Tube Size (OD):	Minimum Wall Thickness (Inches)
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, dryed 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.

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.

Tube Size (OD):	Minimum Wall Thickness (Inches)
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, dryed and ends sealed during shiping, 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.

T3

PIPING DESIGN AND MATERIAL SPECIFICATION

Service: Process Vacuum

Design Conditions:

Pressure	Vacuum 10^{-5} 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 TP304 SMLS
1 1/2" and larger	ASTM A26 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"

Flanges: All Flanges to be Conflat, ISO Large Flange or KF tube fittings 304 Stainless Steel.

Continued on next page.

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, dryed 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.

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"

Continued on next page.

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, dryed 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.

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"

Continued on next page.

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, dryed and ends sealed during shiping, 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.

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.

ATTACHMENT "A"
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: PIPE, TUBING & FITTINGS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO: 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		
PREP FOR SHIPMENT PROCEDURE			X	2	X		
CERTIFICATE OF COMPLIANCE				2	X		

SPEC V049-2-037
Pg. 20.
REV. 5

SPECIFICATION FOR

SMALL VACUUM VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Starr

PROCESS ENGINEER: Roberto Thom.

QUALITY ASSURANCE: Alan H Bradbrook

TECHNICAL DIRECTOR: D. O. McWilliams

PROJECT MANAGER: Richard Bayley

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	TMS 7-19-96	D McW	REVISED FOR PURCHASE PER DEO 0224
0	TMS 2-29-96	D McW	RELEASED FOR QUOTE PER DEO 0075

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED T. Starr	DATE 2-29-96	APPROVED KEB	DATE 2/21/96	Number V049-2-059	Rev. 1

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of small (1 1/2" and 2 1/2") high vacuum and ultra high vacuum angle valves for the LIGO vacuum system.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

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.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date	PSI Part No.
1 1/2" High Vac	137	9/30/96	V049AVHV15
2 1/2" High Vac	70	9/30/96	V049AVHV25
1 1/2" Ultra High Vac	77	9/30/96	V049AVUV15
2 1/2" Ultra High Vac	26	9/30/96	V049AVUV25

2.2 All valves shall be delivered to Process Systems International, Inc. at 20 Walkup Drive, Westboro, Massachusetts, 01581.

2.3 Acceptances at the sites are expected to occur on a staggered basis, with final acceptance at Washington expected to occur about May 31, 1998, and about November 30, 1998 in Louisiana.

3.0 DESIGN REQUIREMENTS

3.1 Angle valves shall be 304L or 316L stainless steel (304 or 316 stainless steel is acceptable if the valves are unavailable in L grade SS).

3.2 End connections shall be CF flanges.

3.3 The valves shall have stainless steel metal bellows stem feedthroughs.

3.4 Neither the body leakage not the seat leakage shall exceed 1 x 10^{-9} torr liters/sec of helium.

3.5 The valves shall be designed to seal in both directions.

3.6 The internal valve mechanisms shall be non-lubricated.

3.7 Valves shall be manually actuated by a handwheel.

3.8 Valves shall be bakeable to 150 C +/-20 C (170 C maximum).

3.9 The valves shall be cleaned in accordance with the Vendor's standard procedures applicable to the valve service.

4.0 REQUIRED DOCUMENTATION

Engineering drawings shall be submitted for approval prior to fabrication. Manufacturer's standard QA reports shall be provided prior to shipment:

5.0 SHOP TESTING

Each valve shall be tested for leakage (using oil-free pumping equipment and leak detector) prior to shipment from the manufacturer

6.0 INSPECTION

The Vendor's standard inspections shall be performed. Also, each valve shall be inspected for cleanliness by black light prior to shipment. Valves shall be recleaned if any contamination is found.

SPECIFICATION FOR

CLEAN QUARTER-TURN VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stan

PROCESS ENGINEER: Roberto Thern

QUALITY ASSURANCE: Alan L Burdbrook

TECHNICAL DIRECTOR: D.C. McWilliams

PROJECT MANAGER: Bob Bayly

2	REG 07/10/97	D.McW 7-10-97	REVISED FOR PURCHASE TO ADD QTY. 12 - 1½" VALVES. DEO 0520
1	TMS 9-25-96	D.McW 9-26-96	REVISED FOR PURCHASE PER DEO 0274
0	TMS 3-1-96	D.McW 3-5-96	RELEASED FOR QUOTE PER DEO 077
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED T.M.Stan	DATE 3-1-96	APPROVED RES	DATE	Number A V049-2-060	Rev. 2

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of 2" clean quarter-turn valves for the LIGO vacuum system. These valves will be used in Federal Standard 209 Class 100 air service.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

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.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date	PSI Part No.
PSI, Westboro, MA:	21	11/29/96	V049BVCA20
PSI, Westboro, MA.	12	07/30/97	V049BVCA15 (80K purge)

2.2 Deleted

3.0 DESIGN REQUIREMENTS

3.1 The valves shall be either butterfly style, MDC Model No. BFV-200, MDC Part No. 360002.

3.2 The valves shall be 304 stainless steel.

3.3 End connections shall be CF flanges.

3.4 The valves shall be designed to seal in both directions.

3.5 The internal valve mechanisms shall be non-lubricated.

3.6 The valves shall be cleaned in accordance with the Vendor's standard procedure for valves intended for use in Federal Standard 209 Class 100 clean air service..

3.7 Valves shall be manually actuated.

4.0 REQUIRED DOCUMENTATION

Engineering drawings shall be submitted for approval prior to fabrication. Manufacturer's standard QA reports shall be provided prior to shipment:

5.0 SHOP TESTING

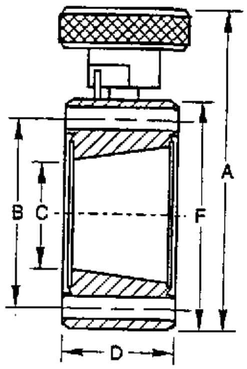
Manufacturer's standard testing shall be performed.

6.0 INSPECTION

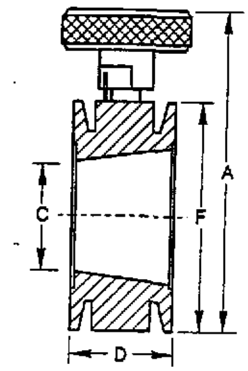
The Vendor's standard inspections shall be performed. Also, each valve shall be visually inspected for cleanliness prior to shipment. Valves shall be recleaned if any contamination is found.

ATTACHMENT A
TO V045-J-060

Valves



Del-Seal Flange



Kwik-Flange Flange

ORDERING INFORMATION

Please order by Part Number

Valve Nom I.D. Size	Reference	Part Number	Flange F	Flange O.D.	Bolt Holes No.	Ref ISO	Height A	Bolt Circle B	C	Thickness D	Wt Lbs	Unit Price
3/4	BFV-075	360000	*Del-Seal* 1-1/3	1.33	6	-	1.96	1.062	.60	.75	1	$250
3/4	KBFV-075	360010	*Kwik-Flange*	1.18	-	NW16	1.81	-	.56	1.25	1	$250
1	KBFV-100	360011	*Kwik-Flange*	1.57	-	NW25	2.32	-	.87	1.25	1	$255
1-1/2	BFV-150	360001	*Del-Seal* 2-3/4	2.73	6	-	3.81	2.312	1.33	1.00	1	$260
1-1/2	KBFV-150	360012	*Kwik-Flange*	2.16	-	NW40	3.81	-	1.31	1.34	1	$260
2	BFV-200	360002	*Del-Seal* 3-3/8	3.37	8	-	4.46	2.850	1.84	1.00	2-1/2	$360
2	KBFV-200	360013	*Kwik-Flange*	2.95	-	NW50	4.46	-	1.87	1.68	2-1/2	$360

Dimensions are in inches

ATTACHMENT "A"
TO V049-2-060

Pg 1 of 2

Butterfly Valves

Del•Seal Metal Seal Flange

Kwik•Flange ISO O-Ring Flange

FEATURES

- *Quick open/Quick close*
- Positive lock both positions
- Positive Viton® O-Ring vacuum seal
- High conductance
- Choice of *Del-Seal* or *Kwik-Flange*

Valves

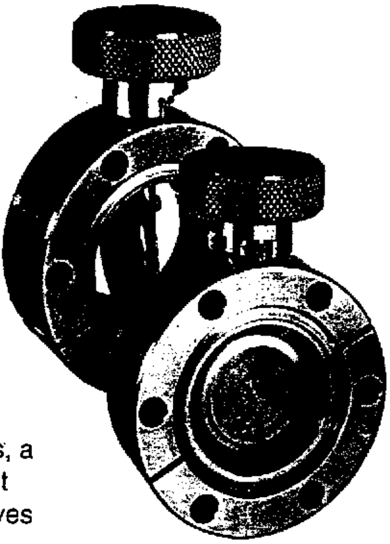
DESCRIPTION

MDC Butterfly Valves require only one-quarter turn rotation of the handle to go from fully open to the fully closed position. In the 1-1/3 Mini *Del-Seal* flange series, a spring loaded ball bearing becomes seated in an indent providing a positive mechanical stop. All other size valves employ a roll pin stop method.

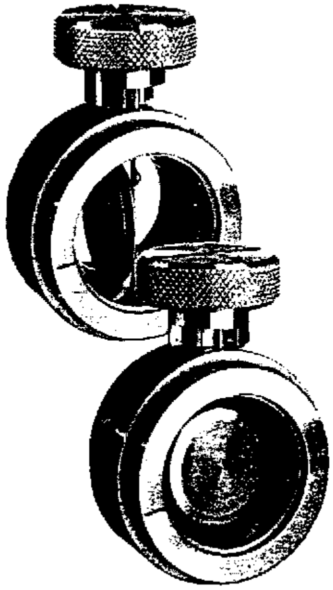
These quick-acting Butterfly Valves feature an improved sealing action. The opening in the body of the valve has been machined at a slight angle to the plane of the flapper. The flapper is set to rotate slightly off-center. On closure, this causes the sealing pressure to be applied more uniformly all around the O-ring. A reliable, positive seal is made and the tendency of previous designs to roughen the surface of the O-ring and eject it from its groove is eliminated.

MDC Butterfly Valves are low outgassing. All internal surfaces are machined from solid stainless steel bar stock. The handle is made of aluminum. A small O-ring on the stem prevents shaft leakage.

The valves are offered with a choice of *Del-Seal* ultra-high vacuum metal-seal flanges or ISO *Kwik-Flange* O-ring seal flanges.



Del-Seal Flange
BFV-150



Kwik-Flange Flange
KBFV-150

LIGO- V049-2-070 Rev

Process Systems International, Inc.

20 Walkup Drive Westborough, MA 01581

WELDING PROCEDURE SPECIFICATION (WPS)

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

BASE METAL (QW-403, QW-405)
P No. 8 to P No.:8
Thickness range. 0.1875" to 1.0000"
Position(s).All positions
Progression.Vertical Up
notes

JOINT (QW-402)
Joint design Groove/Fillet(see pg 2)
Backing..... With or without backing
Backing Matl Optional
Fillet Weld Size All (QW-451.4)
notes

PREHEAT (QW-406)
Minimum Temperature. 60 Degrees F.
Interpass Temp. Max. 350 Degrees F.
Preheat Maintenance. None

POSTWELD HEAT TREATMENT (QW-407)
Temperature range None
Time range None
notes

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

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

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 Rollar (04/23/96) Weld Specialist

Accepted By: Alan Barkbrook (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 R[illegible]

JOINT DESIGN (QW-402)
WELD JOINT CONFIGURATION
Single-V groove
Gas backing was used

Groove Angle :	75	Degrees
Root Opening :	0-125"	Inches
Root Face :	030-062"	Inches

note:

BASE METAL (QW-403)

Material form.	Plate
Material Spec.	SA-240, Type 304L
To	SA-240, Type 304L

P No. 8 Gr. 1 to P No. 8 Gr. 1
Thickness (in) 0.5000

HEAT TREATMENT (QW-406, QW-407)
Preheat Temperature: 60 Degrees F.
Preheat Maintenance: None
Interpass Temperature: 350 Degrees F.
PWHT temperature ... : None Degrees F.
PWHT Holding time(hr): None
note:

POSITION (QW-405)
Position of Joint : 1G - Flat
Progression: N/A
note:

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

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

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

Procedure Qualification Record (PQR)

PQR No.: 150 H48

TENSILE TEST (QW-150)

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

GUIDED BEND TEST (QW-160)

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

TOUGHNESS TEST (QW-170)

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

HARDNESS TEST - No hardness test

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

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

Notes:

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

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

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

Certified By: Alan R Bradbrook (2/ 8/96) QA Manager:

LIGO V049-2-071 Rev 2

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

WPS No.: 151-1 Date: 05/06/96 [illegible] 0
Supporting PQRs: 151-1-H48

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

PREHEAT (QW-406)	POSTWELD HEAT TREATMENT (QW-407)
Minimum Temperature. 60 Degrees F.	Temperature range 1000 DEG.F.
Interpass Temp. Max. 350 Degrees F.	Time range 4.00
Preheat Maintenance. None	notes

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

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

(n1)No pass > 1/2 " t.
(n2)No supplementary filler 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.

WELDING PROCEDURE SPECIFICATION (WPS)

WPS No.: 151-1 Date: 05/06/96 Revision No.: 0

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: A. Rollier (05/06/96) Weld Specialist

Accepted By: Alan L Bradbook (05/06/96) Q.A.Manager:

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
note:

BASE METAL (QW-403)
Material form. Plate
Material Spec. SA-240, Type 304L
To .... SA-240, Type 304L
P No. 8 Gr. 1 to P No. 8 Gr. 1
Thickness (in) 0.5000

POSITION (QW-405)
Position of Joint : 1G - Flat
Progression: N/A
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.

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

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

n1) Peening was not used with this weld test.
) No supplementary filler will be used with this procedure.
3)
(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.

PQR No.: 151-1-H48

Procedure Qualification Record (PQR)

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-

(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 Rillos (05/06/96) Weld Specialist

Certified By: Alan L Bullock (05/06/96) Q.A.Manager:

LIGO- V049-2-072
Rev. 2

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

WPS No.: 153-1 Date: 10/28/96 [illegible]: 0
Supporting PQRs: 153-1-H48

BASE METAL (QW-403, QW-405)
P No. 8 to P No.:8
Thickness range. 0.1875" to 1.0000"
Position(s).All positions
Progression.Vertical Up
notes

JOINT (QW-402)
Joint design Groove/Fillet(see pg 2)
Backing..... With or without backing
Backing Matl Optional
Fillet Weld Size All (QW-451.4)
notes

PREHEAT (QW-406)
Minimum Temperature. 60 Degrees F.
Interpass Temp. Max. 350 Degrees F.
Preheat Maintenance. None

POSTWELD HEAT TREATMENT (QW-407)
Temperature range 1000
Time range 4.0
notes Stress Relief 1000F.+/-50 F.

	All pass(es)			None		
Process / type	GTAW / manual					
Process thickness limit.	0.1875" to 1.0000"			None		
GAS (QW-408)						
Shielding Gas / CFH.....	100% Argon	/ 18-36		None	/ -	
Trailing Gas / CFH......	None	/ -		None	/ -	
Backing Gas / CFH.......	100% Argon	/ 9-24		None	/ -	
FILLER METAL (QW-404)						
AWS classification......	ER308L			None		
SFA Spec. No. & F No....	SFA#: 5.9	F#: 6		SFA#: None	F#: -	
A No. or Chem. Comp.....	8			None		
Filler metal trade name.	SOLID FILLER METAL			None		
SAW flux trade name/type	N/A	/ -		None	/ -	
Elec./Wire size (in) ...	1/16	3/32	1/8	-	-	-
ELECTRICAL (QW-409)						
Welding amperage range..	70-150	80-180	130-275	-	-	-
Welding voltage range...	n/r	n/r	n/r	-	-	-
Travel speed (ipm)......	Var.	Var.	Var.	-	-	-
Max. Heat Input (J/in)..	None			None		
Tungsten Type/Size......	EWTh-2 / 1/16" - 3/16"			N/A / -		
Current & Polarity......	DCEN (straight)			N/A		
TECHNIQUE (QW-410)						
String / weave bead.....	String & Weave Bead			N/A		
Orifice / gas cup.......	# 5 to # 10			None		
Contact tube to work....	N/A			None		
Oscillation.............	N/A			None		
Mult./Single electrode..	Single Electrode			N/A		
Other Technique Notes...				None		

Multiple or Single Pass (per side).... Multiple Passes
(n1) No 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 Revis..

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 Bradbrook (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

JOINT DESIGN (QW-402)	BASE METAL (QW-403)
WELD JOINT CONFIGURATION	Material form. Plate
Single-V groove	Material Spec. SA-240, Type 304L
Gas backing was used	To .... SA-240, Type 304L
Groove Angle : 75 Degrees	P No. 8 Gr. 1 to P No. 8 Gr. 1
Root Opening : 062-125 Inches	Thickness (in) 0.5000
Root Face : 030-062 Inches	HEAT TREATMENT (QW-406, QW-407)
note:	Preheat Temperature: 60 Degrees F.
POSITION (QW-405)	Preheat Maintenance: None
Position of Joint : 1G - Flat	Interpass Temperature: 350 Degrees F.
Progression: N/A	PWHT temperature ... : 1000 Degrees F.
note:	PWHT Holding time(hr): 4.00
	note: Stress Relief 1000 Deg.F.+/-50 F.

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

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

(n1) Peening was not used with this weld test.
(n2) No pass > 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)

QR No.: 153-1-H48

Procedure Qualification Record (PQR)

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-

(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 -- Section IX of the ASME Code.

Prepared By: Harold Klee (10/28/96) Weld Specialist

Certified By: Alan L Bradbrook (10/28/96) Q.A.Manager:

LIGO- V049-2-073 Rev 0

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

BASE METAL (QW-403, QW-405)	JOINT (QW-402)
P No. 8 to P No.:8	Joint design Groove/Fillet(see pg 2)
Thickness range. 0.0625" to 0.7500"	Backing..... With or without backing
Position(s).All positions	Backing Matl Optional
Progression.Vertical Up	Fillet Weld Size All (QW-451.4)
notes	notes

PREHEAT (QW-406)	POSTWELD HEAT TREATMENT (QW-407)
Minimum Temperature. 50 Degrees F.	Temperature range None
Interpass Temp. Max. 350 Degrees F.	Time range None
Preheat Maintenance. None	notes

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

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

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: Al Rollas (05/29/74) Weld Specialist

Accepted By: Alan Bradbrook (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

note:

BASE METAL (QW-403)
Material form. Pipe / Tube
Material Spec. SA-312, Grade TP304L
To .... SA-312, Grade TP304L
P No. 8 Gr. 1 to P No. 8 Gr. 1
Thickness (in) 0.3750 Dia.(in) 5.5630

HEAT TREATMENT (QW-406, QW-407)
Preheat Temperature: 50 Degrees F.
Preheat Maintenance: None
Interpass Temperature: 350 Degrees F.
PWHT temperature ... : None Degrees F.
PWHT Holding time(hr): None
note:

POSITION (QW-405)
Position of Joint : 6G - 45 Deg.
Progression:Vertical Up
note:

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

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

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

Procedure Qualification Record (PQR)

PQR No.: 073-H9

TENSILE TEST (QW-150)

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

GUIDED BEND TEST (QW-160)

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

TOUGHNESS TEST (QW-170)

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

HARDNESS TEST - No hardness test

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

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

Notes:

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

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

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

Certified By: Alan K Bradbrook (05/29/74) QA Manager:

Title: LIGO GENERAL REPAIR PROCEDURE FOR MATERIALS AND WELDING

LIGO

GENERAL REPAIR PROCEDURE

FOR

MATERIALS AND WELDING

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	GS 10/10/96		Release for fab Per DEO #0302
Ø	ARB 3/26/96	RES 3/27/96	ISSUED PER DEO 0107

PROCESS SYSTEMS INTERNATIONAL, INC. — SPECIFICATION

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev
	A Brudnak	3/26/96	RES	3/26/96	A V049-2-074	Ø

1.0 SCOPE

1.1 This procedure covers the requirements for repairing all nonconformities in base metal surfaces, the repair of nonconformities in edge preparation and the repair of unacceptable defects in inspected weld joints.

1.2 Cleaning of repaired areas shall be performed in accordance with PSI Specification V-049-2-015.

2.0 GENERAL PROCEDURE

2.1 REPAIRS TO BASE METAL SURFACE NONCONFORMITIES

2.1.1 For Repairs Not Requiring Welding

A. Surface defects shall be removed by grinding with CARBIDE BURR CUTTERS only. Abrasive-type wheels and stones are not allowed on vacuum base metal surfaces.

B. Ground surface repairs shall be visually inspected to verify that the nonconformity has been removed or the indication reduced to an acceptable limit.

C. The reduced material thickness shall be checked by a depth micrometer or an ultrasonic thickness gauge.

2.1.2 For Repairs Requiring Welding

A. Remove the defect by grinding with CARBIDE BURR CUTTERS only or by chipping and grinding with CARBIDE BURR CENTERS to an acceptable level.. Abrasive-type wheels and stones are not allowed on vacuum welds.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with PSI Procedure Numbers:

WPS #150	P8-P8	PAW	Manual	
WPS #151	P8-P8	PAW	Manual	PWHT
WPS #153	P8-P8	GTAW	Manual	PWHT
WPS #073-3	P8-P8	GTAW	Manual	

D. Welded repairs shall be visually inspected after welding.

2.2 REPAIRS TO EDGE PREPARATION

2.2.1 For Repairs Not Requiring Welding

A. Defects shall be removed by grinding with CARBIDE BURR CUTTERS only. Abrasive-type wheels and stones are not allowed on vacuum materials, weld preps. The cavity shall be blended uniformly into the surrounding surfaces.

B. Ground surface repairs shall be visually inspected to verify that the nonconformity has been removed or the indication reduced to an acceptable limit.

2.2.2 For Repairs Requiring Welding

A. Remove the defect by grinding (as specified above) or by chipping and grinding (as specified above) to an acceptable level.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with PSI Procedure Numbers:

WPS #150	P8-P8	PAW	Manual	
WPS #151	P8-P8	PAW	Manual	PWHT
WPS #153	P8-P8	GTAW	Manual	PWHT
WPS #073-3	P8-P8	GTAW	Manual	

2.3 REPAIRS TO WELDS

2.3.1 For Repairs Not Requiring Welding

A. Weld defects shall be removed by grinding with CARBIDE BURR CUTTERS only. Abrasive-type wheels and stones are not allowed on the interior or the exterior of vacuum welds.

B. Visually inspect the area prepared for welding to ensure that the defect has been removed or the indication reduced to an acceptable limit.

C. The reduced material thickness shall be checked by a depth micrometer or an ultrasonic thickness gauge.

2.3.2 For Repair Requiring Welding

A. Remove the defect by grinding (as specified in A. above) or by chipping and grinding (as specified in A. above) to an acceptable level.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with PSI Procedure Numbers:

WPS #150	P8-P8	PAW	Manual	
WPS #151	P8-P8	PAW	Manual	PWHT
WPS #153	P8-P8	GTAW	Manual	PWHT
WPS #073-3	P8-P8	GTAW	Manual	

D. The repaired area can be left in the as-welded condition or can be blended by grinding. Grinding is restricted to the use of CARBIDE BURR CUTTERS only. The repaired area shall blend uniformly into the surrounding surface and shall be visually inspected after welding.

2.3.3 For Fillet Weld Repairs Requiring Welding

A. remove the unacceptable weld metal by an approved method (as specified in A. above).

B. If the full fillet weld is not completely removed, visually inspect the area prepared for welding.

C. Weld in accordance with PSI Procedure Numbers:

WPS #150	P8-P8	PAW	Manual	
WPS #151	P8-P8	PAW	Manual	PWHT
WPS #153	P8-P8	GTAW	Manual	PWHT
WPS #073-3	P8-P8	GTAW	Manual	

D. Welded repairs shall be visually inspected after welding.

3.0 BASE MATERIAL CLEANUP PROCEDURE

3.1 SCOPE

3.1.1 This procedure describes the acceptable methods of base meal cleanup (plate, pipe, forgings, etc.).

3.1.2 This includes the removal of such things as temporary attachments, clamp marks, fit-up weld marks, undercut, gouges, crater cracks and other imperfections.

3.2 REMOVAL METHODS

3.2.1 Cleanup of imperfections or items listed in 3.1.2 above are limited to chipping and grinding with a carbide burr cutter only. Abrasive-type wheels and stones are not allowed on vacuum vessel materials because of the binder material used in the manufacturing of the wheel. The binder is embedded in the metal and will off-gas causing a loss of vacuum over a period of time.

3.2.2 After removal, the affected area shall be repaired by blending or welding. Repair welding can be left in the as-welded condition. The repaired area shall blend uniformly into the surrounding surface and shall be visually inspected after welding.

Title: SPECIFICATION FOR BAKE OUT PROCEDURE ISOLATABLE SECTION

SPECIFICATION FOR BAKE OUT PROCEDURE

FOR LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Robert Theen

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bayley

0	R.T. 5/1/96	REB 5/2/96	INITIAL RELEASE PERDED 157 FOR FDR
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED R.T.	DATE 5/1/96	Approved DATE REB 5/2/96	Number: V049-2-116 A	Rev. 0

1.0 PURPOSE

The purpose of this is to define the necessary steps to perform a bakeout of an isolatable section at 150 °C. This includes the steps necessary to prepare for the bake out sequence.

2.0 GENERAL

The procedure will general apply to all isolatable sections of the stations.
Slight differences among each isolatable section will be due to different vacuum equipment, size of the isolatable section, and quantities involved relating instrumentation, equipment, etc. The stations are divided into the following bakeable sections:

Corner station WA	Vertex Section
	Diagonal Section
	Left Beam Manifold Section
	Right Beam Manifold Section

Mid station WA	One Section

End station WA	One Section

Corner station LA	Vertex Section
	Left Beam Manifold
	Right Beam Manifold

End station LA	One Section

Required References

A. Blanket System mechanical layout configuration and electric configuration drawings for vacuum envelope. All stations. All sections.
B. Bakeout System Control Cart Operating Manual & Procedure.
C. RGA Operating Manual
D. EDP200/EH2600 Roughing pumps Operating Manuals
E. STPH2000C Turbomolecular Pump Operating Manuals

F. QDP80 Dry Backing Pump Operating Manuals
G. Vacuum Gauges: Cold Cathode & Pirani Gauges Operating Manuals
IH 2500 L/s, 75L/s, 25 L/s Ion Pumps Operating Manuals

3.0 RESPONSIBILITY

The procedure is applicable to PSI Personnel.

4.0 PROCEDURE

4.1 Bakeout System

4.1.1 Bake out carts check out

Follow procedures for electric and data acquisition and control parameters checkout of the bake out control/electric system carts.
Refer to: Bakeout System Control Carts, Operating Manual & Setup Procedure.

4.1.2 Blanket installation

Each heating blanket is identified and will fit onto certain sections of the vacuum envelope. Install the assigned blankets according to the assigned locations per blanket system drawing layout and installation procedures.

In addition the following components will also be baked:
- Cold cathode/ Pirani Gauge pairs on isolatable section.
- RGA head with electronics removed.
- Main Turbo Pump inlet.
- The Main Ion pumps need to be warmed up also to ensure adequate warmup of the 14" gate.

Refer to: Blanket System mechanical layout configuration and electric configuration.
Refer to: Bakeout System Control Cart Operating Manual & Procedure.

4.4 Bakeout Sequence

4.4.1 Pumpdown

4.4.1.1 Pumpdown using roughing system

Corner Stations:

Connecting the main turbo and Main roughing carts.
Follow procedures for connecting the main turbo and main roughing pumps.

Pumpdown the isolatable section following procedures for connecting and operating the roughing pump system. Pumpdown until a pressure of less 0.1 Torr is reached.
At the completion of roughing the section:
Close the 6" gate valve
Shutdown roughing pumps
Vent the rough line by opening the vent valve on the roughing cart.
Disconnect line and blankoff port.
Leak check the Conflat connection of the blankoff through the pumpout valve.
Evacuate the space between the blind and the gate using the aux turbo cart.
Open the 6" valve.

End/Mid stations:
Pumpdown the isolatable section following procedures for connecting and operating the turbo pump and backing pump system.
At the end of the roughing cycle using the roughing pump: close bypass valve and turn on the turbo.
Follow the operating procedure for operating the turbo pump cart.

4.4.1.2 Pumpdown using turbo molecular pump

Corner, End, and Mid stations:
Follow turbomolecular pump operating procedure for startup and operation of pump for pumpdown.
The turbomolecular pump will also be heated during bakeout.

4.4.2 RGA data

A residual gas analysis will be carried out as a reference point prior to start of bakeout.
Power up RGA only after pressure has dropped to less $5X\ 10^{-5}$ Torr

4.4.3 Ramp-up

Ramp rate:
Warm-up will occur over a period of 72 hours at a ramp rate of approximately 1.8°C/hr.
Set ramp rate for blanket system on control carts to 1.8°C/hr.
Set target setpoint to 150°C.

Pressure gauge pairs: Ramprate of the pressure gauge pairs will be at least 5 °C/hr to ensure that the gauges remain hotter than the vacuum envelope at all times.
Bake out of the gauge pair will be done with the electronics removed.
Set ramp rate for blanket system on control carts to 5°C/hr.
Set target setpoint to 250°C.
Do not start warmup until the pressure has dropped to less 5X 10^{-5} Torr.

RGA: The RGA needs to be baked also.
Bake the RGA independently i.e. isolated from the vacuum envelope bake.
This will be done using a 25L/s Ion pump.
Bake out of the RGA will be done with the electronics removed.
Bakeout temperature of the RGA will set at manufacturers recommended maximum (200°C)

4.4.4 Soak for 48 hours

The isolatable section will be heated to 150°C and soaked for 48 hours at 150°C±20°. The pressure gauge pairs will be soaked at 250°C.

4.4.5 Cooldown

Cooldown will be controlled by ramping the setpoints of the system to ambient temperature at a ramprate of -1.8°/hr. The heating jackets for the pressure gauge pair will remain of and turned off when the system has cooled down.

4.4.6 RGA data

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

PROCEDURE FOR

CLEAN ROOM ACTIVITIES

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY:	
QUALITY ASSURANCE:	
MANUFACTURING ENGR:	
TECHNICAL DIRECTOR:	
PROJECT MANAGER:	

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	TMS 5-3-96	REB 5/3/96	RELEASED PER DEO 167

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A V049-2-118	Rev.
	T.M.S.	5-3-96	REB	5/3/96		Ø

Title

PROCEDURE FOR CLEAN ROOM ACTIVITIES

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Number

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SPECIFICATION

Number A V049.2.118

Rev. Ø

11/88

PS-997

1.0 PURPOSE

The purpose of this procedure is to define the operational procedures to effectively perform manufacturing and testing in a Class 100 Clean Room environment.

2.0 GENERAL

The LIGO vacuum system performance is greatly influenced by the level of cleanliness of the vacuum surfaces. All components must be shipped to the site and installed without allowing contamination of the vacuum surfaces (flange faces and interior surface).

Once LIGO components are cleaned to UHV standards, they must be protected by a Class 100 clean room environment. This applies to assembly operations after UHV cleaning and to any subsequent inspections or other entry into the components.

All personnel must be trained in clean room procedures before entering the LIGO clean room areas. *This includes viewing the Micron video tapes "Basic Contamination* Control", "Robing for the Cleanroom", and "Behavior in the Cleanroom".

All clean room clothing (boots, gloves, gowns, hat covers, hoods, etc. shall meet Class 100 clean room standards.

Safety glasses shall be worn at all times.

3.0 RESPONSIBILITIES

The manufacturing department is responsible for training and execution of clean room protocol per this procedure. The Q.A. department shall monitor manufacturing and testing activities for compliance to this clean room procedure.

4.0 PROCEDURE

4.1 *Clean Room Access*

4.1.1 All personnel shall put on clean room clothing systems in an attached gowning room prior to entry into the Class 100 Clean Room. Personnel shall move from the first sticky mat (dirty) to the second sticky mat (clean) as they put on each shoe cover. All joints (glove to sleeve, pants to shoe cover). After gowning, personnel shall wait two minutes prior to entering the Class 100 area.

4.1.2 All soiled or damaged clothing shall be discarded.

4.1.3 Only clean tools and components shall be allowed inside the Class 100 Clean Room. All equipment used inside the Class 100 clean room shall be oil free and shall not generate particles above Class 100 levels.

4.1.4 Clean Room particle levels shall be monitored during clean room operations where a component is open or about to be opened.

4.1.5 Clean Room particle levels must reach Class 100 level before a cleaned component maybe opened for inspection or assembly.

4.1.6 New personnel shall not enter the Class 100 Clean Room while a component is open.

4.1.7 Proper cleanroom behavior shall be observed while personnel arein the cleanroom.

4.2 *Clean Room Exit*

4.2.1 All personnel shall exit the Class 100 area onto the clean sticky mat.

4.2.2 Shoe covers shall be removed one at a time while moving over to the "dirty" sticky mat.

4.2.3 Personnel shall remove the remaining Class 100 clothing and store in a "used clothing" storage area if not soiled or torn. Once the Class 100 clothing is removed, personnel shall leave the gowning room immediately.

CONTAMINATION CONTROL PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stan

QUALITY ASSURANCE: ALAN BRADBROOK/REB

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bayley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	DMIW 11-15-96	REB 11/15/96	RELEASE PER DEO 351
0	TMS 5-4-96	REB 5/4/96	INITIAL RELEASE PER DEO + CIDJ FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED TMS	DATE 5-4-96	APPROVED REB	DATE 5/4/96	Number A V049-2-119	Rev. 1

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1.0 PURPOSE

This plan defines measures to be taken to limit contamination of the ultra high vacuum surfaces of the LIGO vacuum equipment during fabrication, assembly and installation by particulate and hydrocarbons.

2.0 RESPONSIBILITIES

2.1 Material vendors, PSI and its subcontractors shall handle materials in accordance with the various specifications relating to them. These specifications define measures to be taken to limit contamination, including by carbon steel.

2.2 Personnel performing cleaning operations shall be trained by the manufacturing engineering department in the proper procedures.

2.3 Personnel performing work inside cleanrooms shall be trained by the manufacturing engineering group in the required cleanroom procedures and behavior.

2.4 All personnel shall be trained by the manufacturing engineering department in the philosophy and specific provisions of this plan.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this plan:

PSI Specification V049-2-015, Cleaning Procedure
PSI Specification V049-2-118, Cleanroom Activities
PSI Material Specifications

4.0 GENERAL

While it is critical that all vacuum surfaces (internal surfaces and flange faces) be kept free of contamination, exterior surfaces must also be kept clean. This will not only facilitate keeping the interior surfaces clean, but it is necessary in order to maintain the cleanrooms at Class 100. Care shall be taken to minimize exposure to corrosive environments, such as those containing chloride compounds.

5.0 HYDROCARBON CONTROL

5.1 Material vendors, PSI and its subcontractors shall handle materials in accordance with the various specifications relating to them. These specifications define measures to be taken to limit contamination, including by carbon steel.

5.2 Contact of stainless steel by uncontrolled materials shall be avoided. This includes materials such as work gloves, work boots and unprotected shop floors.

5.3 Liquids, gases or vapors containing hydrocarbons or other contaminants shall not be allowed to come into contact with the stainless steel at any time. This includes fluids such as machining lubricants.

5.4 Leak testing shall be done only with the use of oil-free vacuum pumps.

6.0 PARTICULATE CONTROL

6.1 Material Protection

Materials shall be handled in such a manner as to limit contamination, including by carbon steel. This includes the following precautions:

6.1.1 No carbon steel hooks, fork lift forks, grapples or chains shall be allowed to contact the stainless steel.

6.1.2 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.

5.2 Cleanrooms

From the time that a vessel or other component has received its final washing, it shall not be opened unless it is inside a Class 100 cleanroom.

5.2.1 During Assembly

Immediately after washing, components shall be moved directly into a cleanroom without being exposed to the shop atmosphere. In the cleanroom, the component shall be closed to protect it from particulate contamination. This closure may be by joining to a mating piece, installation of covers, or wrapping or double bagging in plastic. The closure shall not be breached unless the component is inside a cleanroom.

5.2.2 During Installation

Components shall be moved into position and prepared to the greatest extent possible before breaching the protective wrapping or bagging. The outer protection is then removed, and a portable soft-wall cleanroom is moved into position over the component before it is opened. Once the cleanroom is in position and a Class 100 environment is established, Class 100 air is used to break the vacuum inside the component. Once atmospheric pressure has been reached, covers may be removed for final installation of the component. The component and all of its access ports and openings shall be closed or connected to another component before the cleanroom can be moved or shut down.

Title: **RAW MATERIAL HANDLING PROCEDURE**

RAW MATERIAL HANDLING PROCEDURE

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY: Thomas M. Stern

QUALITY ASSURANCE: ALAN BRADBROOK/RSB

MANUFACTURING ENGR: [illegible]

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

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 5-4-96	D.A.W.	INITIAL RELEASE PER DEO # 0170 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED T.M.S.	DATE 5-4-96	APPROVED RES	DATE 5/4/96	Number A V049-2-120	Rev. Ø

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Title 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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4.3.2 No solvent wiping, grinding or wire brushing shall be done to the vacuum surfaces.

4.3.3 All machining fluids shall be water soluble and low in chlorides.

4.3.4 Welding wire and joints shall be cleaned with a CO_2 spray prior to welding.

4.3.4 After Ultra High Vacuum (UHV) cleaning, vacuum surfaces shall not be touched by skin or other contaminants. All cleaned vacuum boundary components shall be sealed (vessels with covers on), double plastic bagged or protected by a Class 100 Cleanroom atmosphere at all times.

4.4 Smoking is not allowed in any LIGO storage or manufacturing area.

Title: SPECIFICATION FOR CONTROL OF NON-CONFORMANCES

SPECIFICATION FOR

CONTROL OF NON-CONFORMANCES

PREPARED BY: ALAN BRADBROOK

PROJECT ENGINEER: N/A

QUALITY ASSURANCE: Alan Bradbrook

MANUFACTURING ENGR: Philip Fisher

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Robert Bagly

∅	5/1/96	REB 5/1/96	RELEASED PER DEO 158
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

'ROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED ABradbrook	DATE 5/1/96	APPROVED REB	DATE 5/1/96	Number A V049-2-124	Rev. ∅

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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 noncomformance is any condition that does not comply with a specific job specification or the customer specifications.

2.2. The Quality Assurance Engineer or the Quality Control Inspector places a Reject Tag or a Stop Work Tag (Exhibit 1) on the material which has failed to pass the required inspections and tests or on material that is determined to be otherwise nonconforming and generates a Discrepancy Report (Exhibit 2) for review by the MQA or the QAE.

2.3 The DR is then forwarded to the Project Manager for dispositions. The Project Manager reviews the nonconformance and enters a disposition appropriate for the product and its condition and processes the DR, as follows:

a. The Project Manager or a competent member of the project team, documents the technical justification for the acceptability of USE-AS-IS or REPAIR dispositions and obtains the customer's approval for those which do not comply with the customer's specification requirements.

b. When the disposition is complete, the Project Manager or his designee shall sign and date in this space provided and return the DR to the MQA or the QAE.

2.4 Acceptance of the completed disposition is then documented by the MQA, the QAE or the Quality Control Inspector, on the bottom section of the DR. When all of the required signatures have been provided and the item is acceptable, the Reject Tag or the Stop Work Tag can be removed by the individual accepting the completed disposition on the DR. Once the nonconformance has been corrected, the item or component is considered to be acceptable.

2.5 When documentation or procedural matters are suspect of being nonconforming, a DR is initiated and forwarded to the MQA or the QAE for disposition.

a. DR's generated for documentation or procedural deficiencies will not require disposition concurrence from Engineering. However, when Engineering input is required, the MQA or the QAE obtains concurrence with the disposition from Engineering, as applicable.

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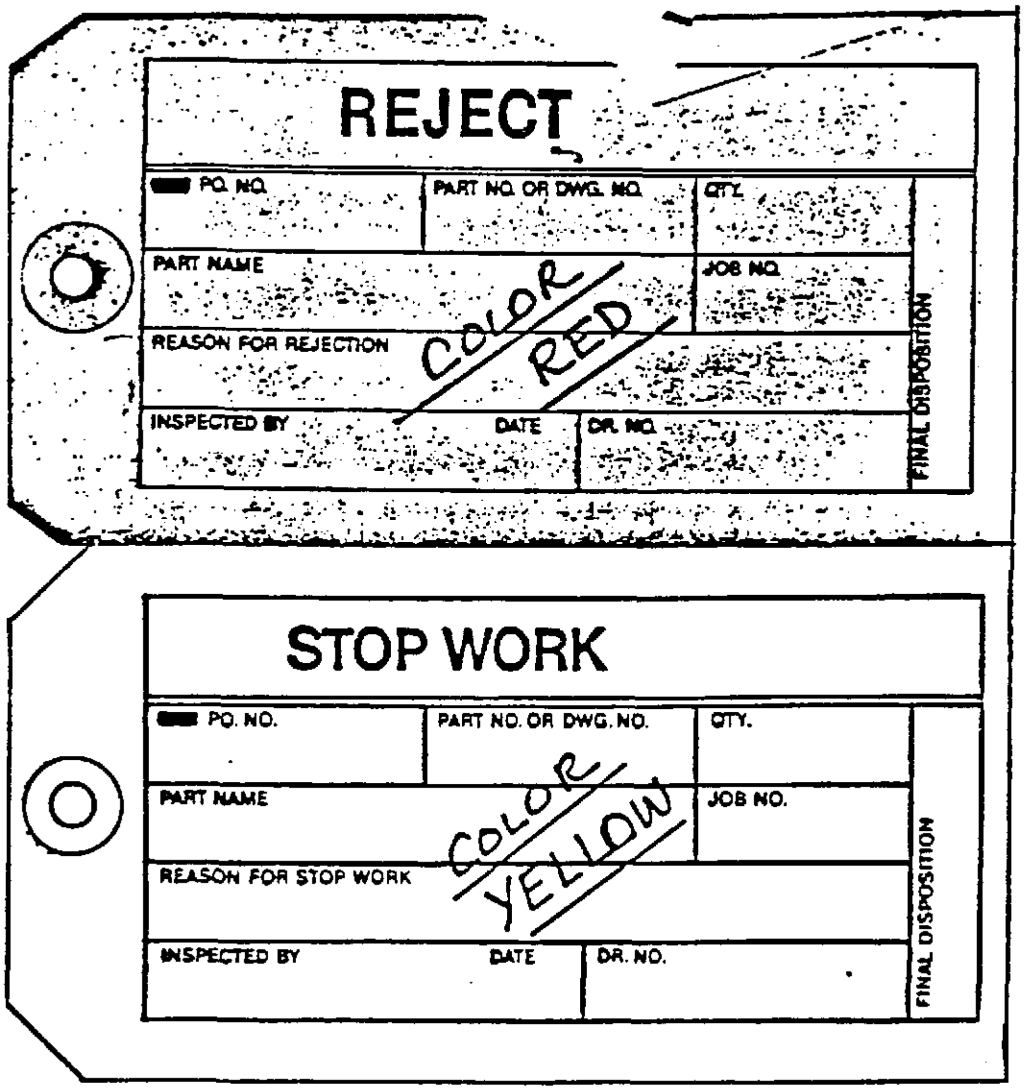
EXHIBIT 1


REJECT

[redacted] 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

[redacted] 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

LIGO VISUAL INSPECTION PROCEDURE

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY:	Alan L Bradbrook
QUALITY ASSURANCE:	Alan L Bradbrook
MANUFACTURING ENGR:	Philip Flood
TECHNICAL DIRECTOR:	D.G. McWilliams
PROJECT MANAGER:	[illegible]

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	D M[illegible]	REB 11/15/96	RELEASED PER DEO 35[illegible]
	G[illegible] 10/10/96		Release for fab Per DEO #0302
ϕ	AKB 5/3/96		ISSUED PER DEO 0168 FOR PDR

[PR]OCESS SYSTEMS INTERNATIONAL, INC.		SPECIFICATION	
INITIAL APPROVALS	PREPARED AKBradbrook DATE 5/3/96	APPROVED REB DATE 5/3/96	Number A V049-2-128	Rev. 1

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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

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

F. **Visual Inspection of Final Surfaces of Welding shall be verified as follows:**

1. Cleanliness
2. Weld spatter
3. ARC strikes
4. Butt weld reinforcement (1/8" max)
5. Fillet weld size
6. Fillet weld throat
7. Fillet weld length/spacing
8. Concavity/Convexity
9. Transition must be minimum of 3 to 1 taper
10. Surface porosity
11. Overlap
12. Undercut
13. Inadequate penetration
14. Cracks
15. Underfill

G. **Visual Examination of Machined Surfaces shall be verified as follows:**

1. Surface Finish
2. Discontinuities
3. Cleanliness

2.4 Acceptance Standards

2.4.1 Cleanliness

Reference should be made to the LIGO Cleaning Procedure, for specific methods. Prior to welding, the weld preparation and adjacent base material (1 inch minimum beyond each side of weld joints) shall be free of moisture, oil, grease, paint, scale, chips and other foreign matter on the final weld surface. The affected area shall be cleaned of slag and oxidation. Iridescent temper films and black, tightly adherent films resulting from welding, are acceptable on finished weld surfaces.

Prior To Welding

Weld preparations and adjacent base material (1 inch for carbon steel and 2 inches for stainless steel beyond each side of weld joint) shall be free of moisture, oil, grease, paint, scale, chips and other foreign matter.

After Welding

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

2.4.2 Tack Welds

Tack welds shall show no cracks or linear indications. Slag deposits or indication of surface porosity shall also be cause for rejection. Edges of tack welds shall be feathered (when necessary) to provide a smooth transition during root pass welding.

2.4.3 Final Weld Condition

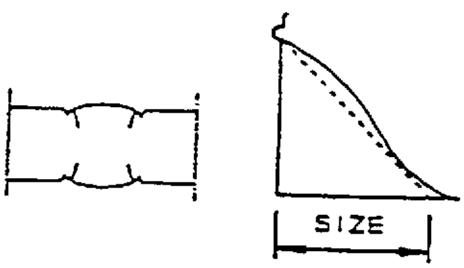
A. As welded, as-cast or as-forged surfaces are permitted, provided the surface of welds are sufficiently free form coarse ripples, overlaps and abrupt ridges and valleys.

B. Cracks or other linear indications are unacceptable.

C. Porosity open to the surface is unacceptable.

D. Undercut shall not exceed 1/32" in. depth.

E. Weld reinforcement on all butt welds may be flush with the surface or may have a crown up to 1/8" max.



EXCESSIVE UNDERCUT

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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:

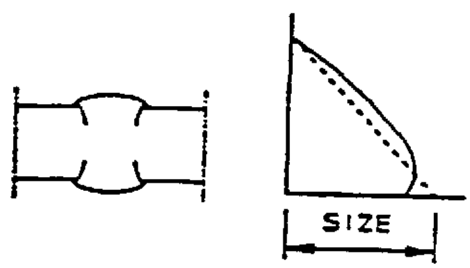
Nominal Wall Section Thickness. in. (mm)	Maximum Offset, in. (mm) All LIGO Project Joints
0.060" Thru 0.500"	1/4t

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

H. Any offset within the allowable tolerance shall be flared at a three to one taper over the width of the finished weld, or if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld.

2.4.4 Examples Of Conditions That Are Unacceptable.

OVERLAP
Welds shall be free from overlap.



OVERLAP

CRATERS
All craters shall be filled to the full cross section of the weld.

CRACKS
Welds shall have no cracks. When cracks are observed visually, the crack shall be completely removed and re-welded. Refer to repair procedure.

SLAG INCLUSIONS

Welds having slag inclusions larger than 3/32" are unacceptable. Also unacceptable are groups of slag inclusions when the sum of their greatest dimension exceeds 3/8" in any linear inch of weld.

INCOMPLETE FUSION

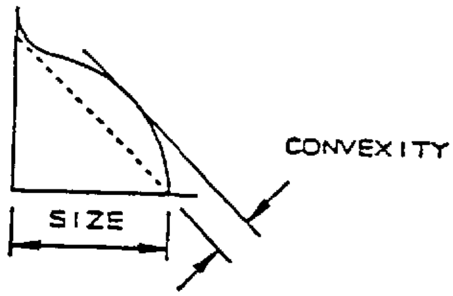
Acceptability requirements are the same as those for slag inclusions.

MISALIGNMENT AND WARPING

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

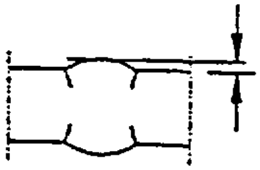
CONVEXITY FILLET

Convexity shall not exceed 0.1 S + 0.03", where S is the size of the fillet weld in inches.



CONVEXITY, GROOVE WELDS

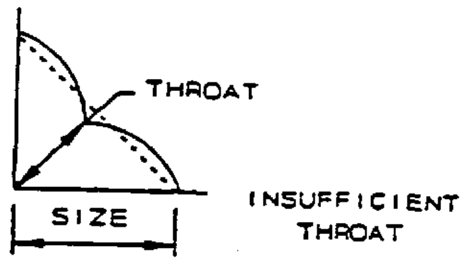
Reinforcement to be 1/8" max, and shall have a gradual transition to the plane of the base metal surface when the thinner base metal is less than 1/2" thick.



REINFORCEMENT

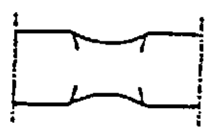
INSUFFICIENT THROAT, FILLETS

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



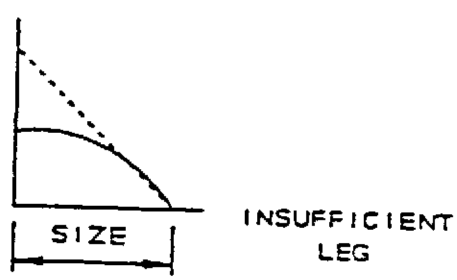
INSUFFICIENT THROAT, GROOVE WELDS

The weld shall be slightly convex.



INSUFFICIENT 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.



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/RED

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [illegible signature]

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

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

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1.0 PURPOSE

This specification covers the procedure to be used for black light inspections of vessels and components cleaned for the LIGO vacuum system.

2.0 GENERAL

2.1 Cleaning shall be performed by an engineer, technician or shop worker familiar with this procedure and the manual for use of the ultraviolet lamp.

2.2 Inspection shall be done in a darkened area.

2.3 A 100 watt ultraviolet lamp with a wavelength of 365 nm shall be used.

3.0 RESPONSIBILITIES

3.1 Cleaning shall be performed by an engineer, technician or shop worker familiar with this procedure and the manual for use of the ultraviolet lamp.

3.2 This procedure shall be maintained and modified as required by the cognizant engineer.

4.0 PROCEDURE

4.1 Turn on the lamp and allow it to warm up for 3-5 minutes.

4.2 The operator shall enter the darkened area and allow 2-3 minutes for his eyes to adapt to the low light level.

4.3 Inspect the cleaned surfaces, holding the lamp 8-12 inches from the surface. Be careful to distinguish between ultraviolet fluorescence and reflected purple visible light.

4.4 Record the description and location of any detected contamination and issue a Discrepancy Report.

5.0 REQUIRED DOCUMENTATION

Inspection results shall be recorded on the component cleaning data sheet.

Title: SPECIFICATION FOR SITE PIPING CLEANING PROCEDURE

SPECIFICATION FOR

SITE PIPING CLEANING PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stan

QUALITY ASSURANCE: ALAN BRADBROOK/KEB

TECHNICAL DIRECTOR: D.C. McWilliams

PROJECT MANAGER: [signature]

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 TMS	DATE 5-5-96	APPROVED KEB	DATE 5/5/96	Number V049-2-131	Rev. 1

SPECIFICATION TABLE OF CONTENTS

1.0 PURPOSE

This specification covers the minimum requirements for the on-site cleaning of piping for the LIGO vacuum system.

2.0 GENERAL

2.1 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.

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.

SPECIFICATION FOR

SITE VACUUM SURFACE RECLEANING PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stam

QUALITY ASSURANCE:

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER:

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	TMS 5-5-96		INITIAL RELEASE PER DEO # 0172 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC. — SPECIFICATION

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	TMS	5-5-96			V049-2-132	0

SPECIFICATION TABLE OF CONTENTS

1.0 PURPOSE

This specification covers the minimum requirements for the on-site recleaning of vacuum surfaces of components for the LIGO vacuum system, should it prove to be required.

2.0 GENERAL

Components are fully cleaned at PSI. Therefore, full site cleaning should not normally be required.

3.0 RESPONSIBILITIES

3.1 Cleaning shall be performed by an engineer, technician or shop worker familiar with this procedure and the cleaning systems and equipment.

3.2 This procedure shall be maintained and modified as required by the cognizant engineer.

4.0 PROCEDURE

4.1 Should small areas of contamination need to be recleaned, they shall be cleaned by use of a CO_2 cleaning system. A vacuum vent system shall be used to remove the CO_2 gas and any entrained contaminants from the vessel being cleaned.

4.2 If major areas are contaminated, the component shall be removed off-site to be pressure washed with a detergent, rinsed with city water, and rinsed with DI water. These operations shall be completed in accordance with PSI Specification V049-2-085. The component shall be closed and packaged in a Class 100 cleanroom.

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. Motur

PROCESS ENGINEER: R. Than.

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D.a. mcWilliams

PROJECT MANAGER: [illegible]

φ	Sm 7/15/96	RB 8/5/9[illegible]	Released per DCO 0221
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

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

TABLE OF CONTENTS

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: H2, He, CH4, N2, Ar, CO2. Gas sensitivities will be determined in the Faraday cup mode for pressures between 10^{-4} and 10^{-8} Torr and in the electron multiplier mode for pressures between 10^{-6} and 10^{-8} 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.

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 $5X10^{-4}$ Torr to $5X10^{-5}$ 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 $5X10^{-4}$ Torr to $5X10^{-5}$ 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.

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 1x10^{-4} Torr to 1x10^{-8} Torr.

	Uncertainty 1x10^{-4} Torr	**Uncertainty 5x10^{-5} Torr**	**Uncertainty 1x10^{-6} Torr**	**Uncertainty 1x10^{-8} Torr**
PRIMARY STANDARD	3% estimate	3% estimate	3% estimate	3% estimate
CALIBRATION STANDARD 2nd	3% (SRG or DWT)	3% (SRG or DWT)	3% (SRG or DWT)	3% (SRG or DWT)
CAPACITANCE MANOMETER	1.2%	2.4%	1.2%	1.2%
STABIL ION GAUGE G-P			6%	6%
Temperature correction	0.3%	0.3%	0.3%	0.3%
TOTAL : RGA	7.5%	8.7%	13.5%	13.5%

SRG: Spinning Rotor Gauge

DWT: Dead Weight Tester

SPECIFICATION FOR

STRUCTURAL CARBON STEEL FABRICATION AND PAINTING

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

RAYMOND D. CIATTO
STATE OF WASHINGTON
15714
REGISTERED
PROFESSIONAL ENGINEER
R. D. Ciatto 10/3/96
EXPIRES 6/5/97

STATE OF LOUISIANA
RAYMOND D. CIATTO
REG. No. 26750
REGISTERED
PROFESSIONAL
ENGINEER
IN
CIVIL ENGINEERING

PREPARED BY: R. E. Curtis 9/30/96

STRUCTURAL ENGINEER: R. D. Ciatto 9/30/96

QUALITY ASSURANCE: A. L. Bradbrook 9/30/96

TECHNICAL DIRECTOR: D. A. McWilliams 10-2-96

PROJECT MANAGER: R. A. Bey 10/3/96

2	Sin 1/30/97	REB 1/30/97	9.0, 9.1.2, 9.1.3, 9.1.4, 9.1.5 DEO 0425
1	RDC 10/10/96	REB 10/11/96	4.1.2.3 - CORRECTED TYPO. 6.2.5.3 - DELETED LAST SENTENCE RE: FLUX-CORE.
0	REC 9/30/96	REB 10/3/96	RELEASED FOR PURCHASE/FABRICATION DEO#0242
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED R. Curtis	DATE 9/30/96	APPROVED REB	DATE 10/3/96	Number V049-2-139	Rev. 2

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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.

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

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.

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 are 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.

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 asembly. All dimesions 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 Thurmalox 260 self priming heat resistant coating manufactured by Dampney Co., Everett, Ma. in accordance with the manufacturers' recommendation.

9.1 Surface Preparation.
Fabricator shall sand blast all exposed surfaces in accordance with SSPC-SP-6.

9.1.2 Prime coat:Thurmalox 260 prime coat shall be applied to a dry film thickness of 2.0- 2.5 mils.

9.1.3 Finish coat:Thurmalox 260 finish coat shall be applied to a dry film thickness of 2.0- 2.5 mils.

9.1.4 Total film thickness: 4.0-5.0 mils.

9.1. 5 Color:Thurmalox 1-07 "Spring Gray".

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.

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:	SPEC NO.: 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		

SPECIFICATION FOR THERMAL INSULATION - PIPING FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: David Moore

QUALITY ASSURANCE [signature]

TECHNICAL DIRECTOR: D. A. McWilliam

PROJECT MANAGER: [signature]

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	DM 1/14/97	DMW 1-15-97	Added Figure B-7 for insulating filter, Fig. D-3, & revised Fig. D-1 DEO # Ø411
Ø	DM 10/25/96	BGB 10/23/96	Initial release DEO # Ø334
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED DMoore	DATE 10/25/96	APPROVED BGB	DATE 10/23/96	Number A V049-2-163	Rev. 1

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ATTACHMENTS

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 (-)320^0F to 300^0F

Hot/Cold - Insulation Polyisocyanurate foam for Outer Layer, Fiberglass Blanket for Inner Layer (-)320^0F to 350^0F

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

Ambient Temperature: 10^0F to 100^0F
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.

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.

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:

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

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

ATTACHMENT A
COLD INSULATION - ILLUSTRATIONS
TABLE OF CONTENTS

TYPICAL PIPING INSULATION COLD SERVICE

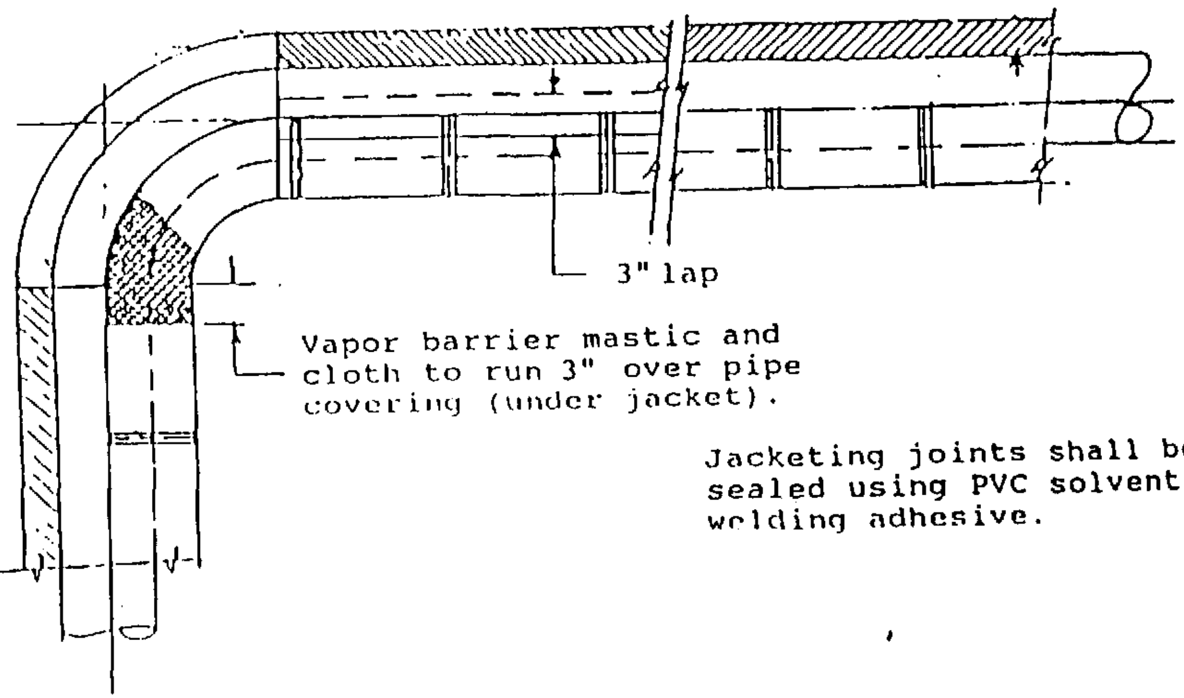
Metal must be clean, dry and free from frost, rust, etc.

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.

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

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.



3" lap

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

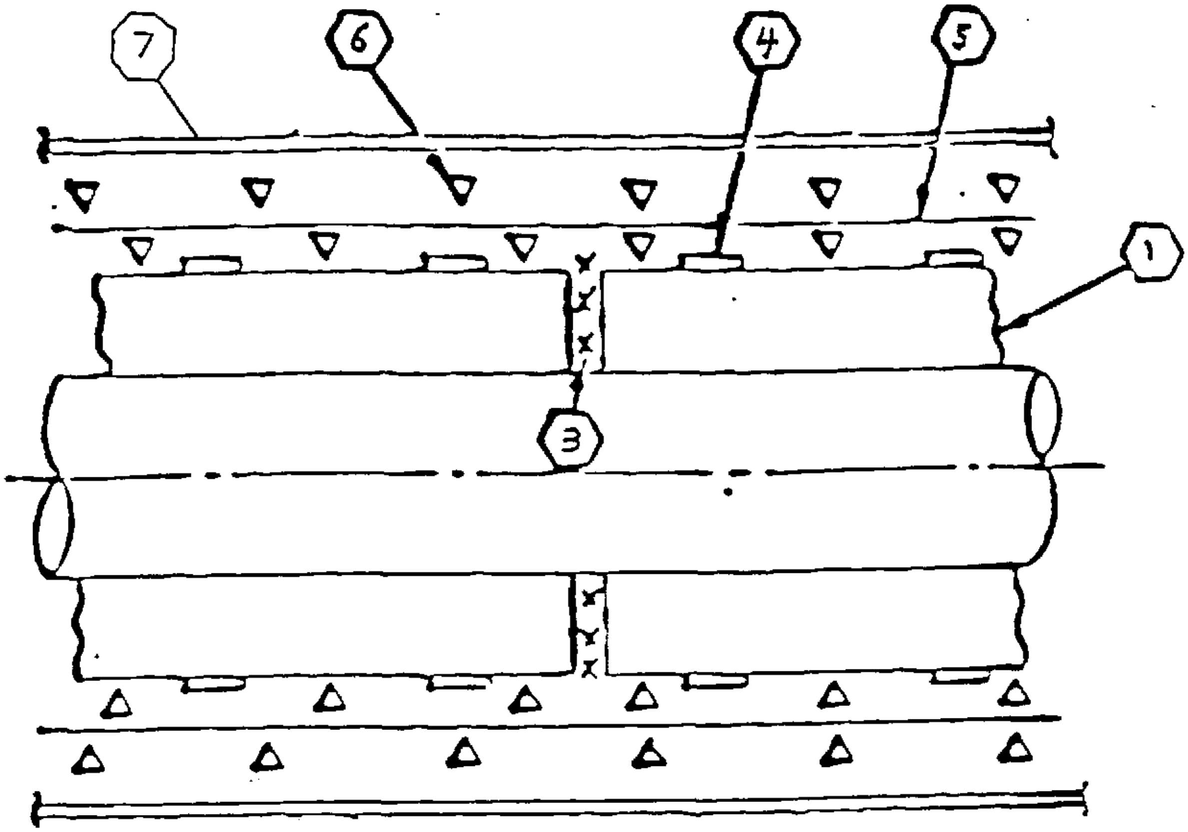
Vapor barrier mastic and cloth to run 3" over pipe covering (under jacket).

Jacketing joints shall be sealed using PVC solvent welding adhesive.

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

FIGURE B-1

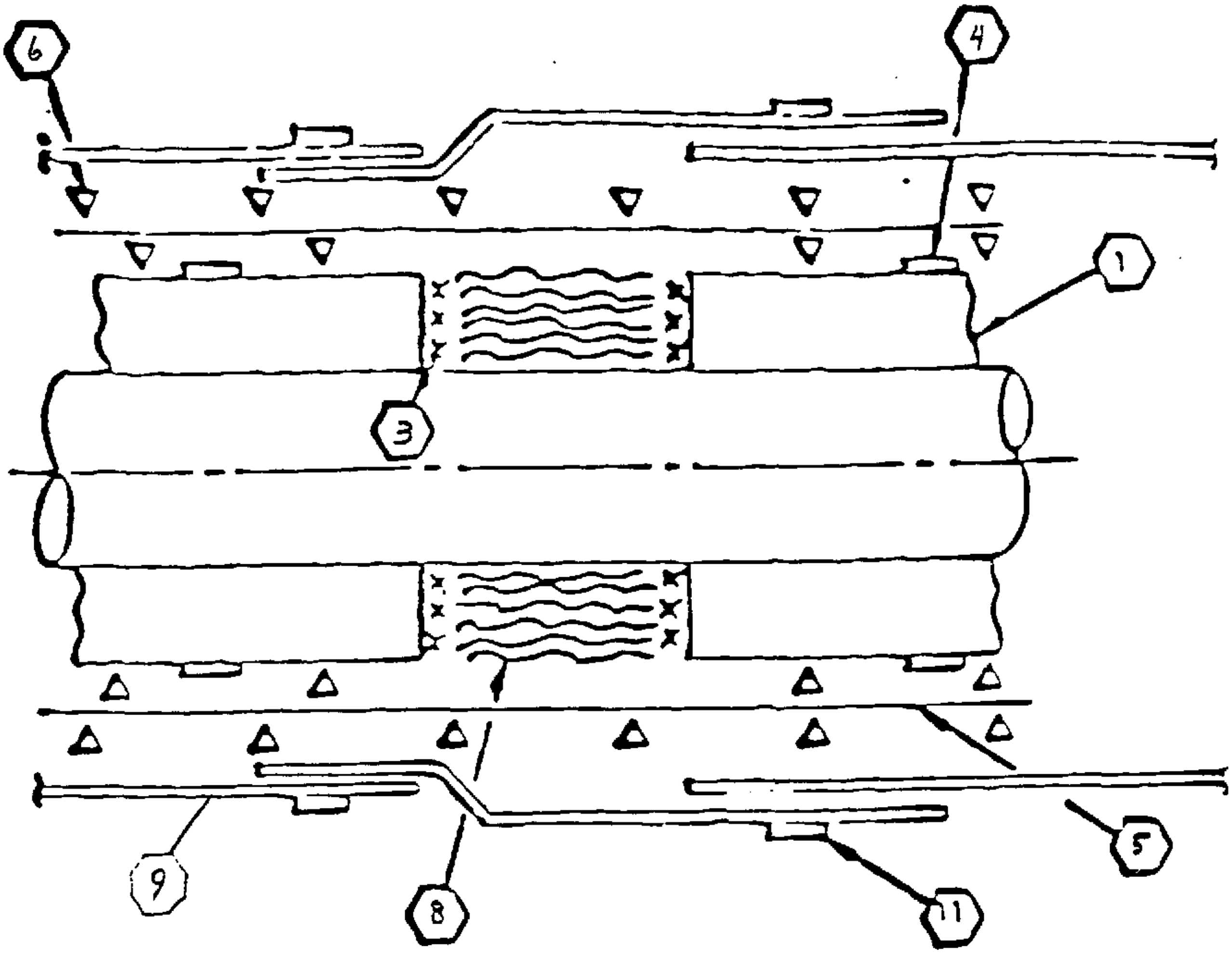
POLYISOCYANURATE INSULATION - TYPICAL PIPE SECTION



[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.

FIGURE B-2
POLYISOCYANURATE INSULATION - EXPANSION JOINT

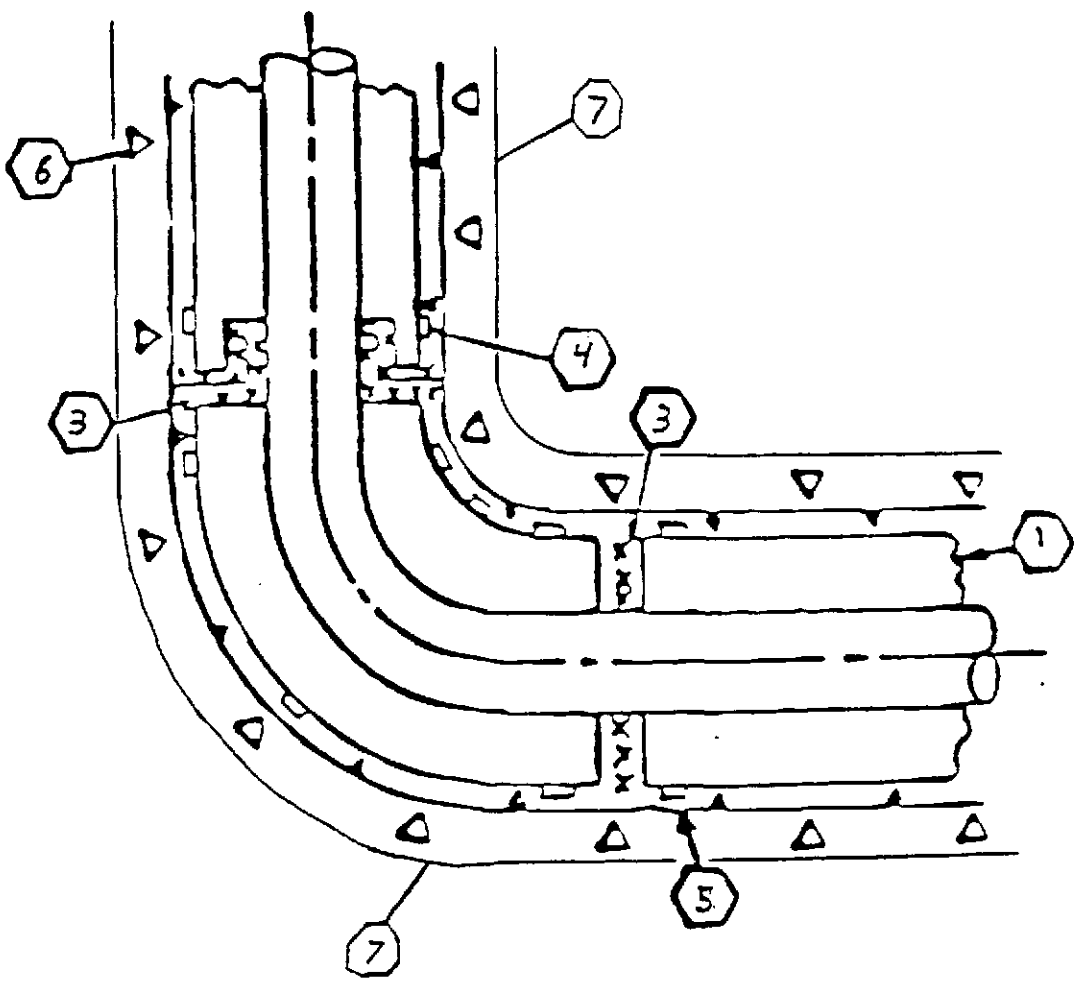


KEY

[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.

FIGURE B-3
POLYISOCYANURATE INSULATION ELBOW

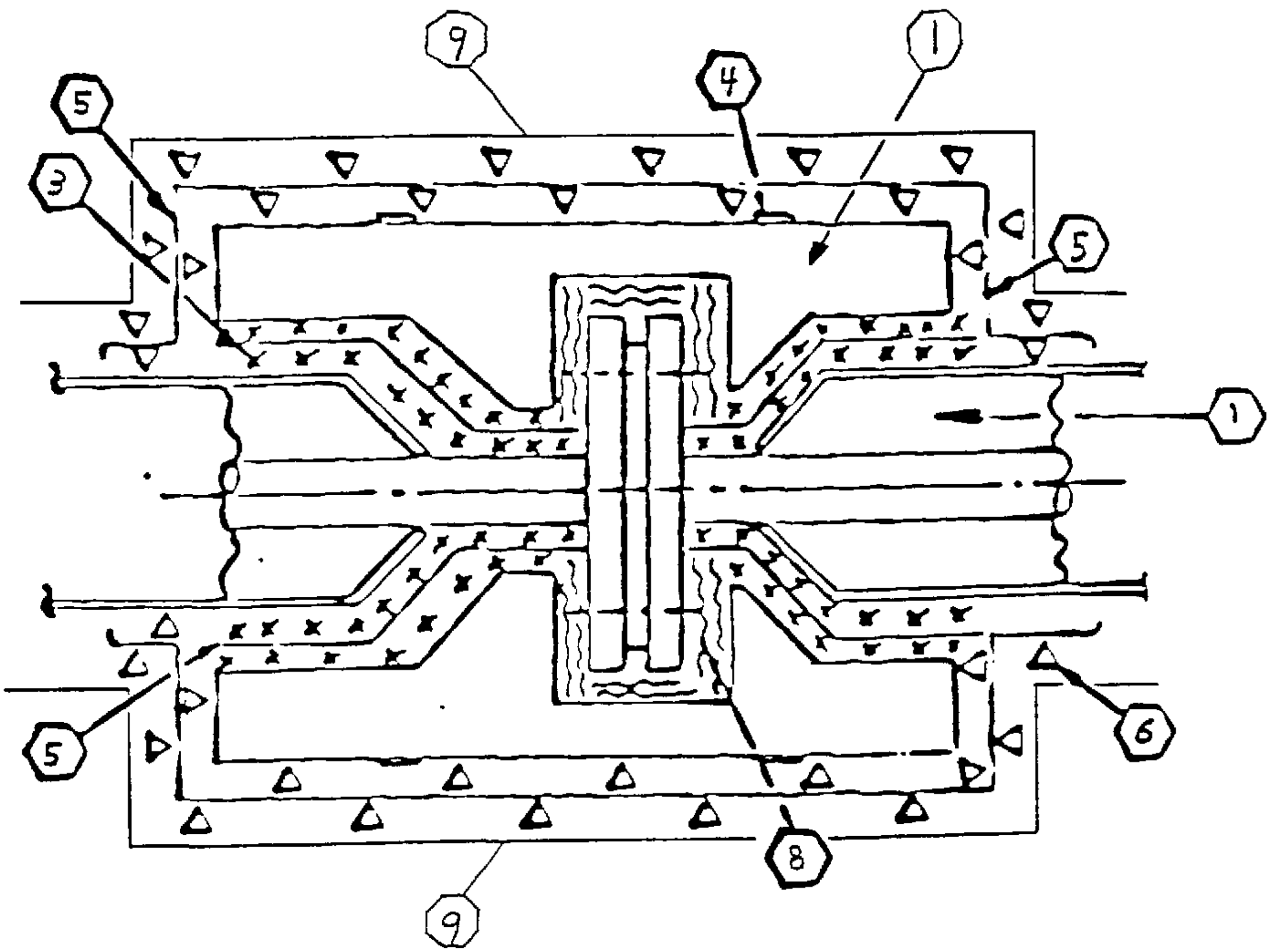


KEY

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

FIGURE B-4

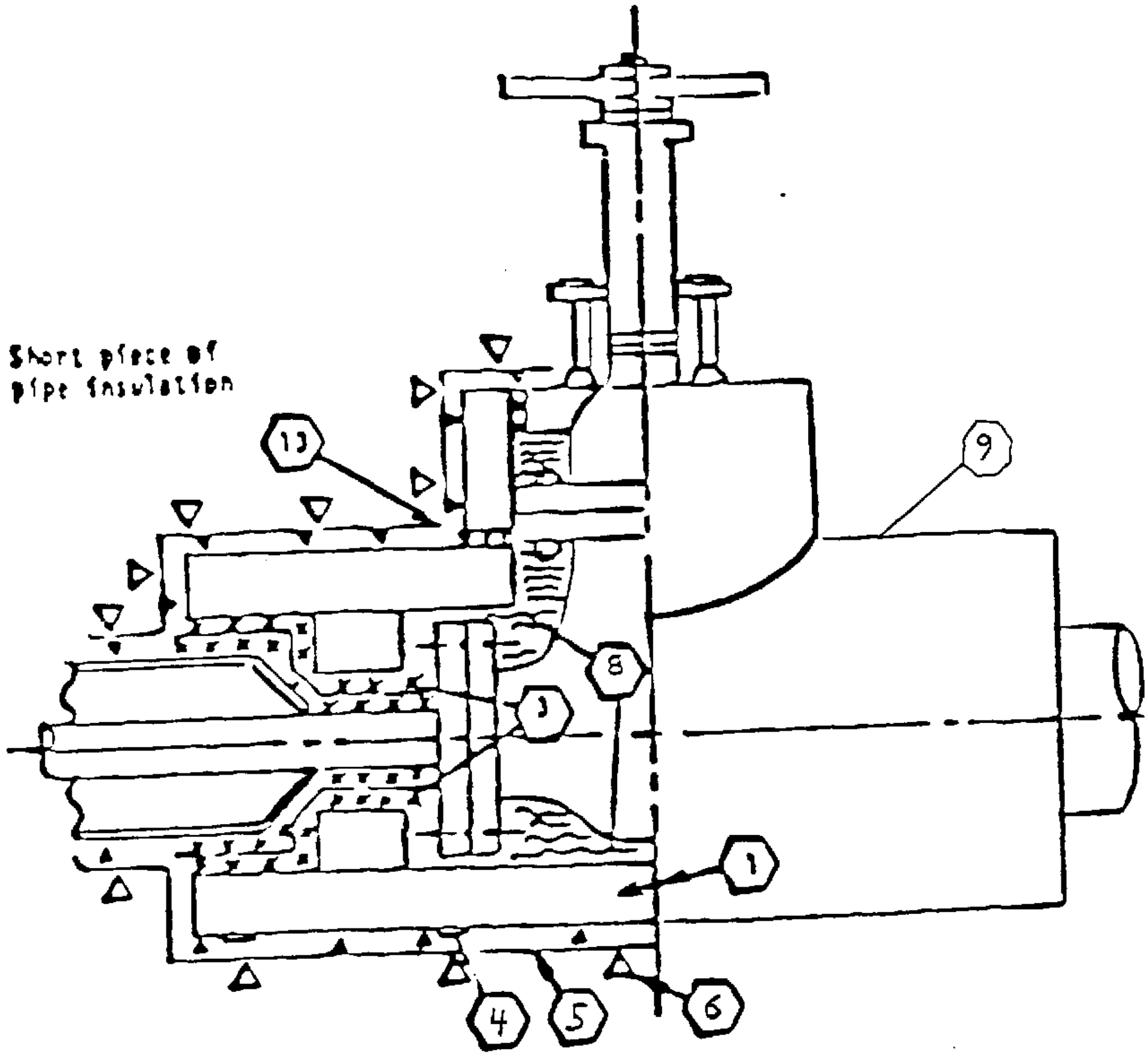
POLYISOCYANURATE INSULATION FLANGE



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

FIGURE B-5
POLYISOCYANURATE INSULATION VALVE



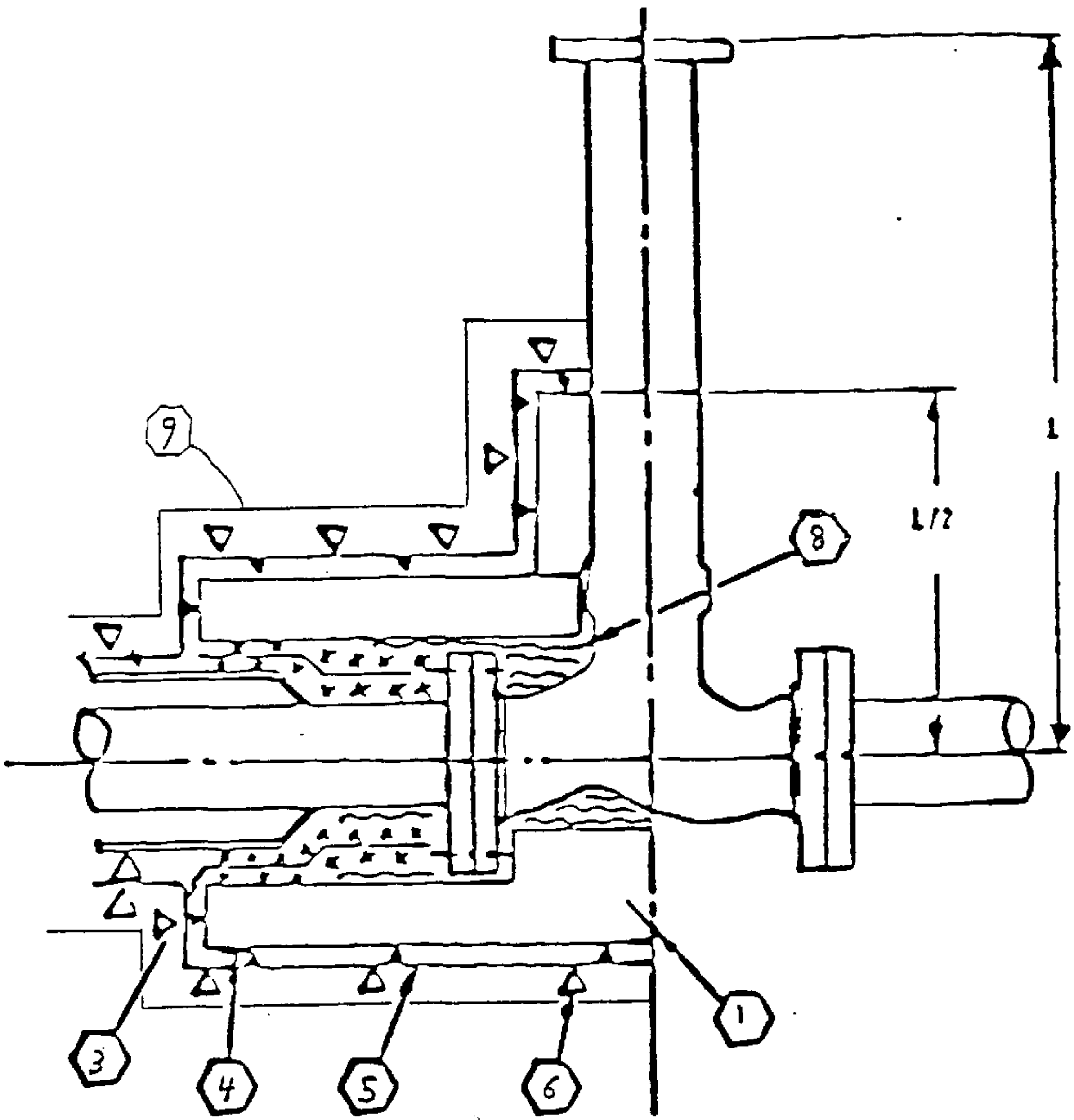
KEY

[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
[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.

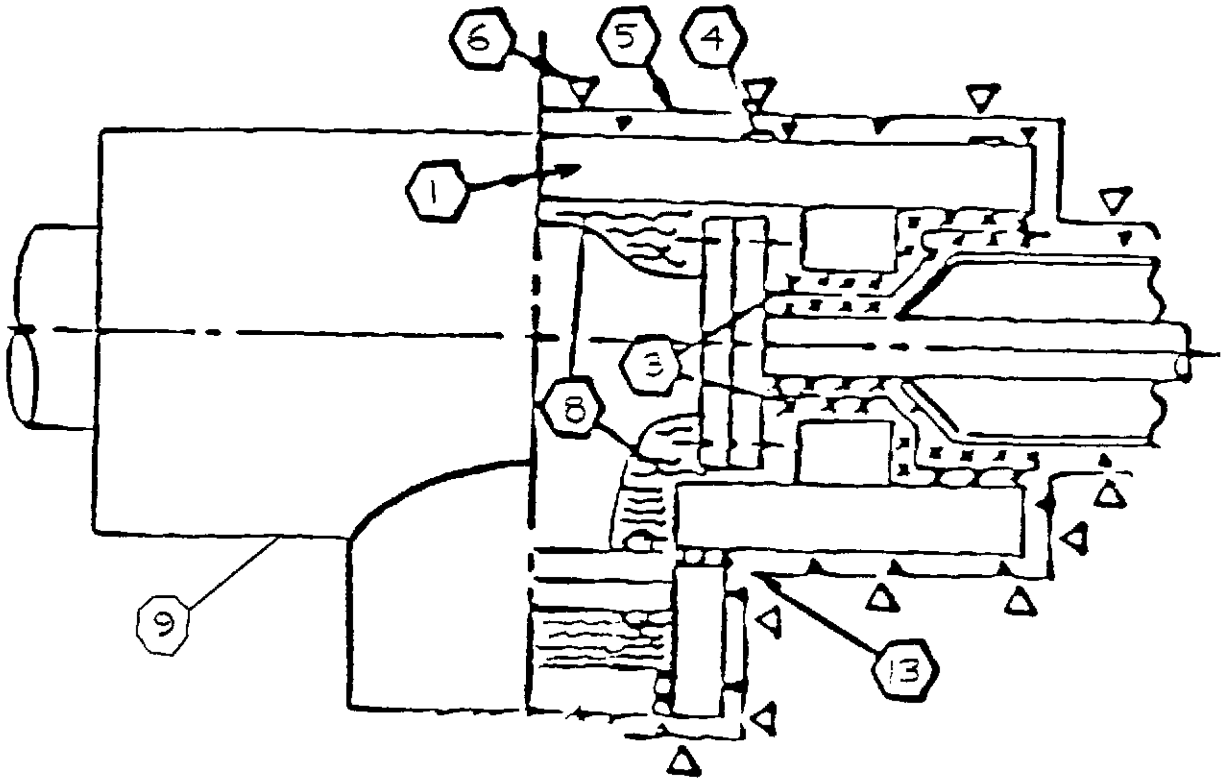
FIGURE B- 6
POLYISOCYANURATE INSULATION EXTENDED STEM VALVE



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

FIGURE B-7
POLYISOCYANURATE INSULATION- FILTER

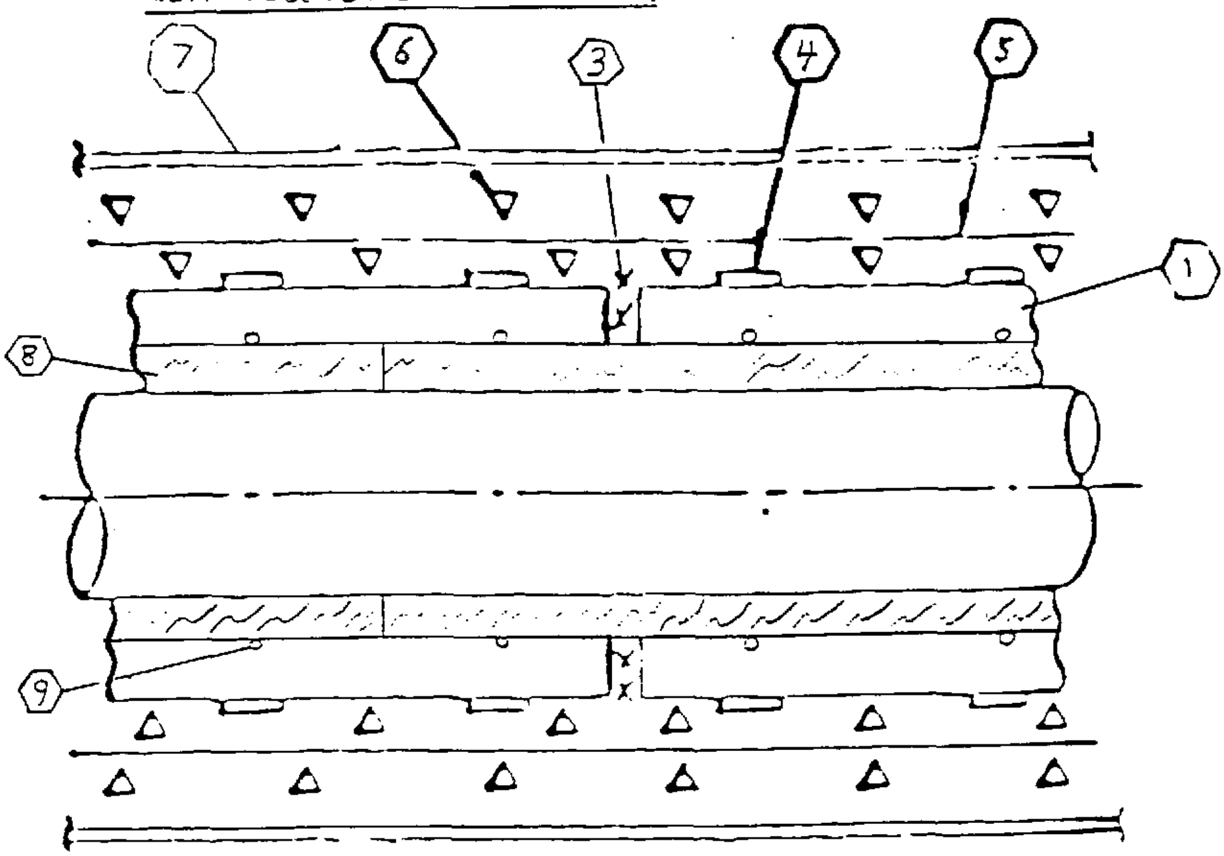


KEY

[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
[13] SILICONE SEALANT

FIGURE C1

POLYISOCYANURATE INSULATION - TYPICAL PIPE SECTION
WITH FIBERGLASS INNER LAYER

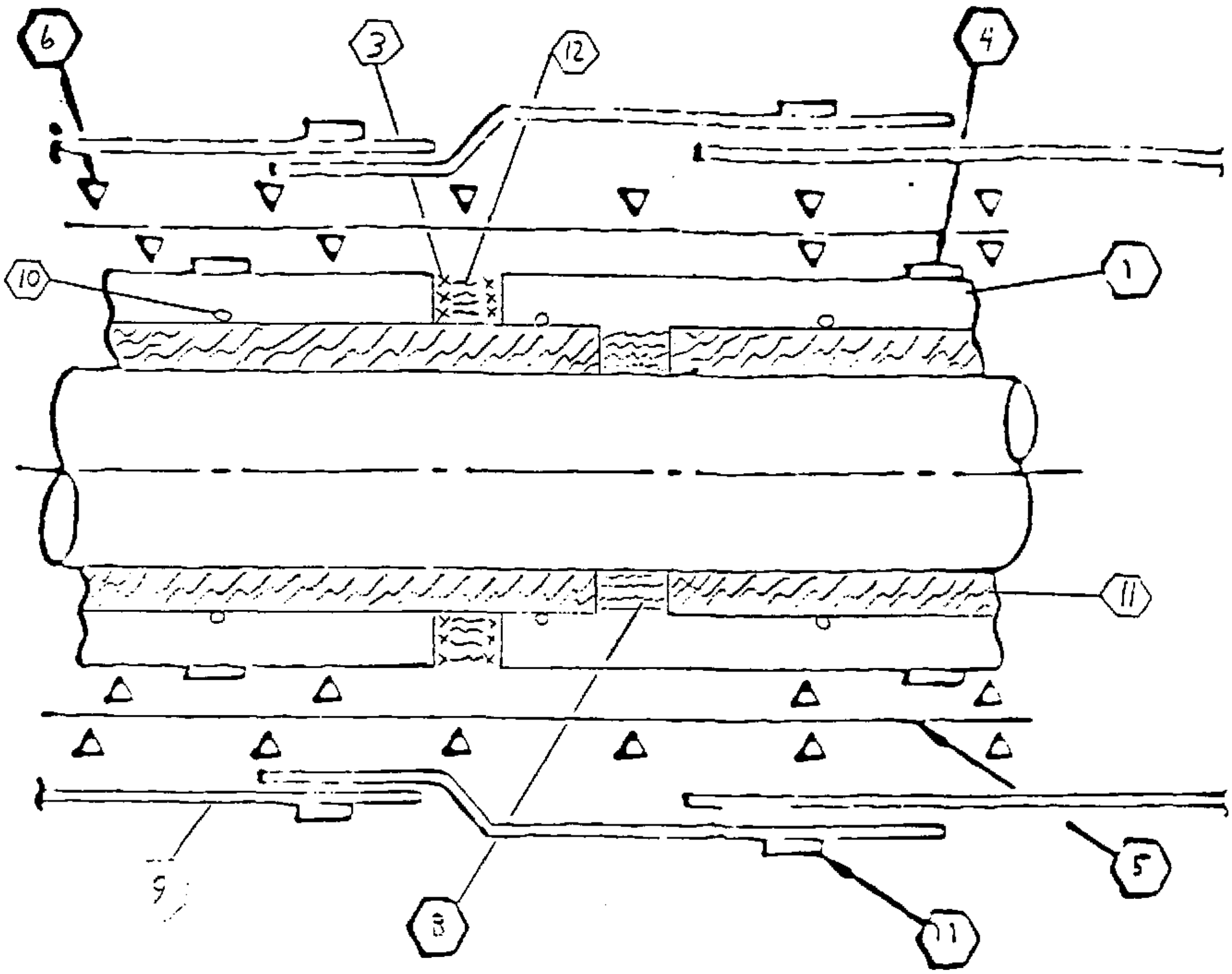


(1) Polyisocyanurate
(3) Joint Sealant and Vapor Stop Mastic
(4) Filament Tape
(5) Membrane
(6) VAPOR BARRIER MASTIC
[7] PLASTIC PIPE JACKET
[8] FIBERGLASS INNER LAYER
[9] 16 GAUGE WIRE

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

Attach. A

FIGURE C2
POLYISOCYANURATE INSULATION - EXPANSION JOINT

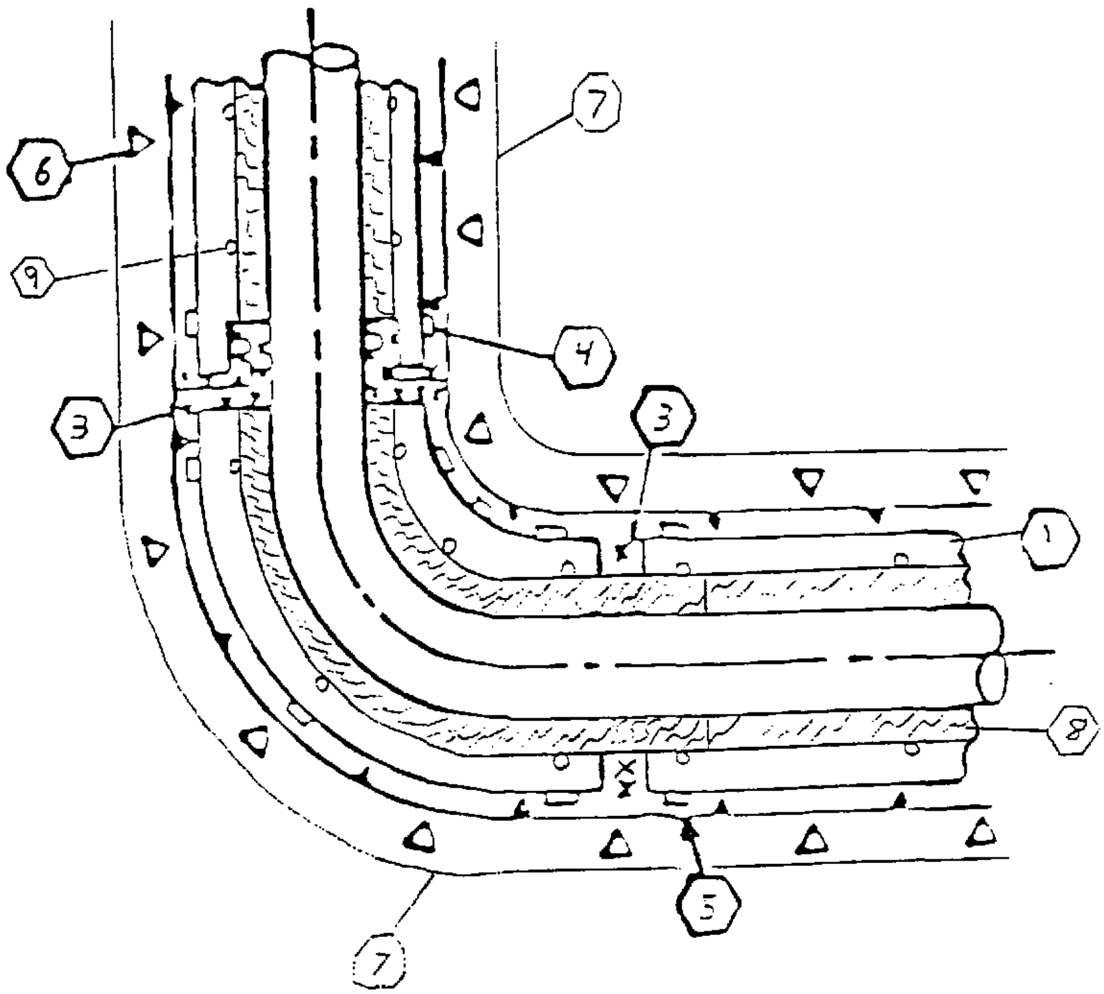


KEY

[1] Polyisocyanurate
[3] Joint Sealant and Vapor Stop Mastic
[4] Filament Tape
[5] Membrane
[6] Vapor Barrier Mastic
[8] 3 PCF FIBERGLASS BLANKET ([illegible] THK. MIN)
[9] PLASTIC PIPE JACKET
[10] 16 GAUGE WIRE
[11] FIBERGLASS INNER
[12] FIBERGLASS [illegible] SAME THK. AS POLYISOCYANURATE

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.

FIGURE C3
POLYISOCYANURATE INSULATION ELBOW
WITH FIBERGLASS INNER LAYER

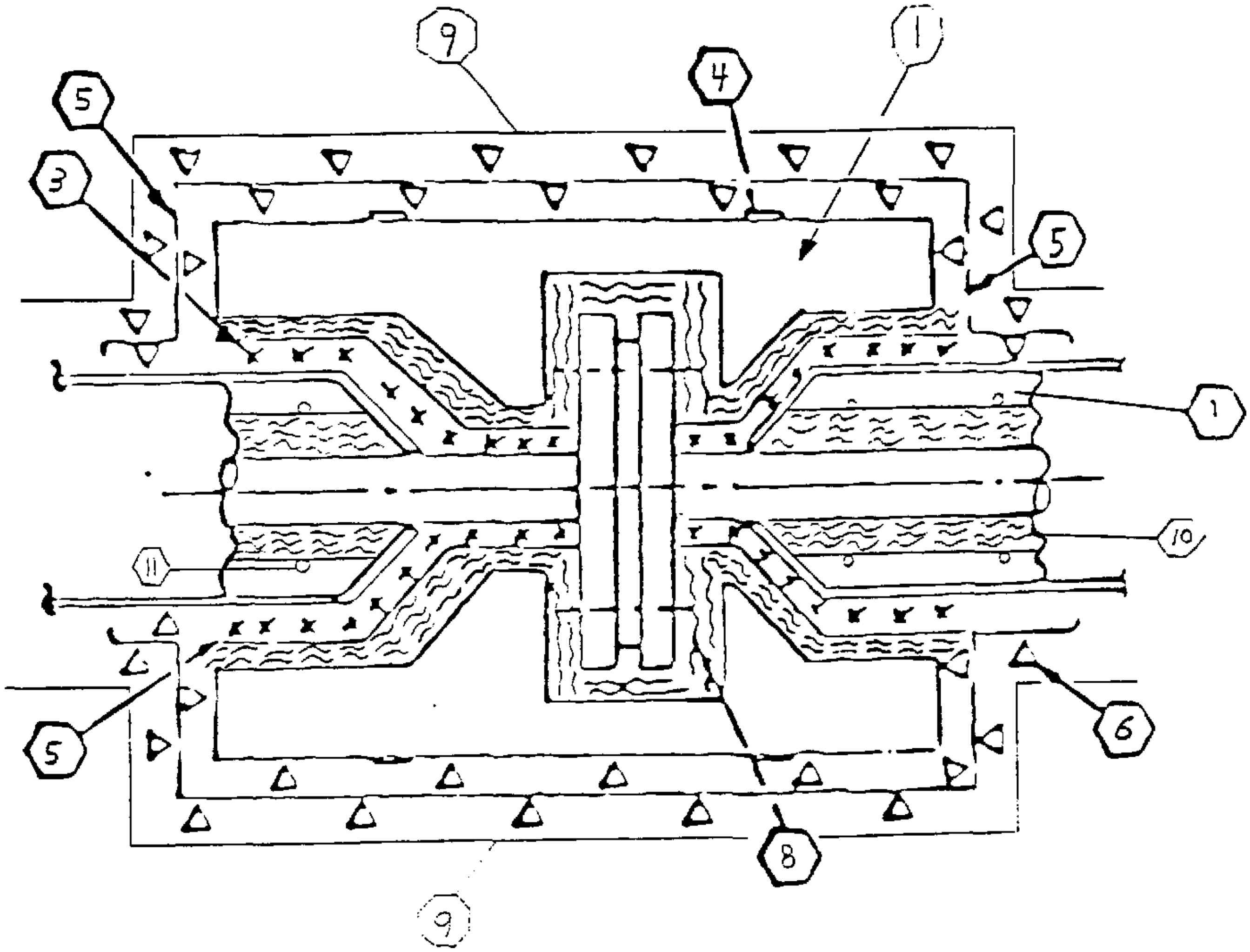


KEY

[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

FIGURE C4

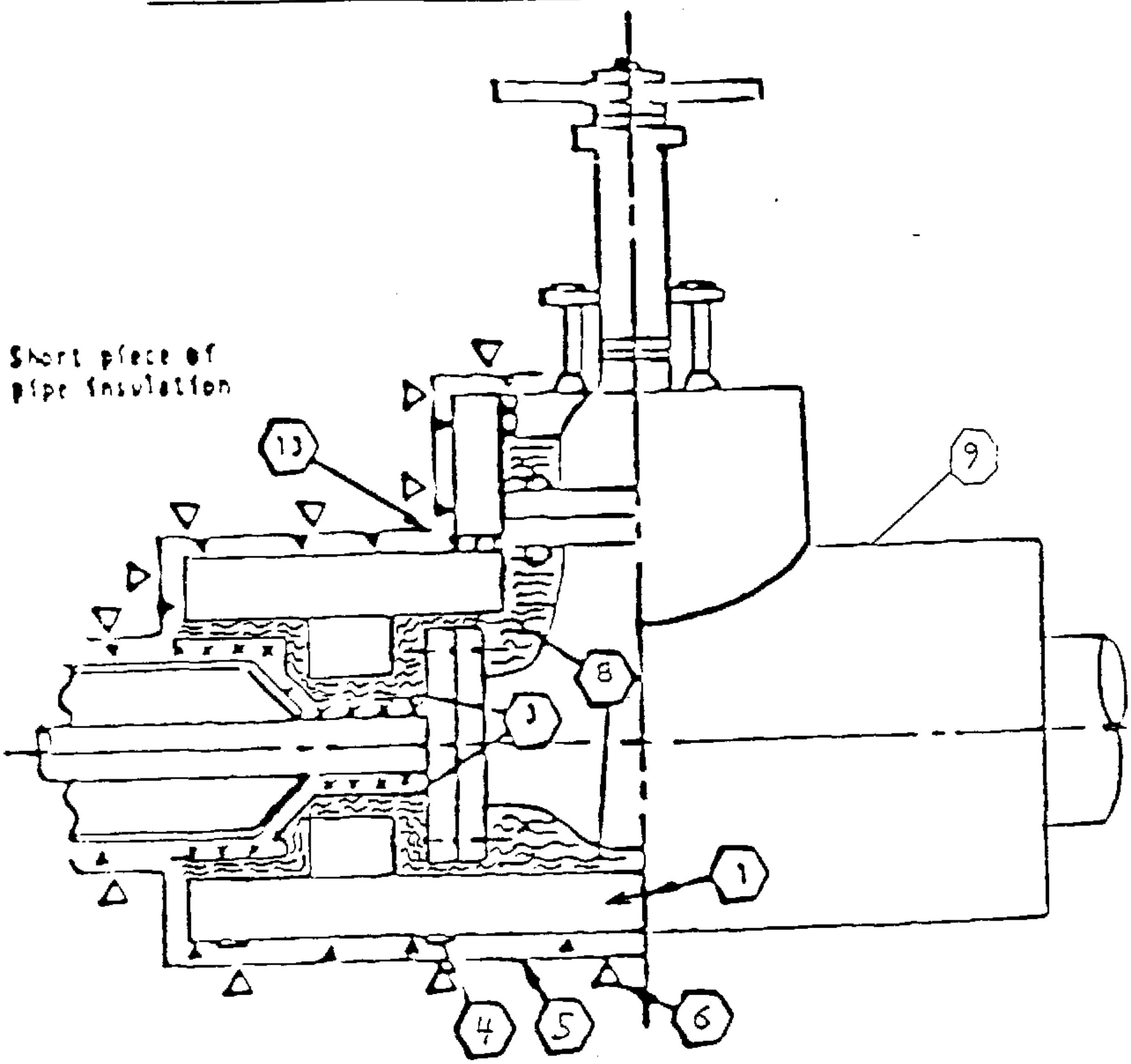
POLYISOCYANURATE INSULATION FLANGE
WITH FIBERGLASS INNER LAYER



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] 16 GAUGE WIRE

FIGURE C5
POLYISOCYANURATE INSULATION VALVE
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 (...)
[9] PLASTIC PIPE JACKET
[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.

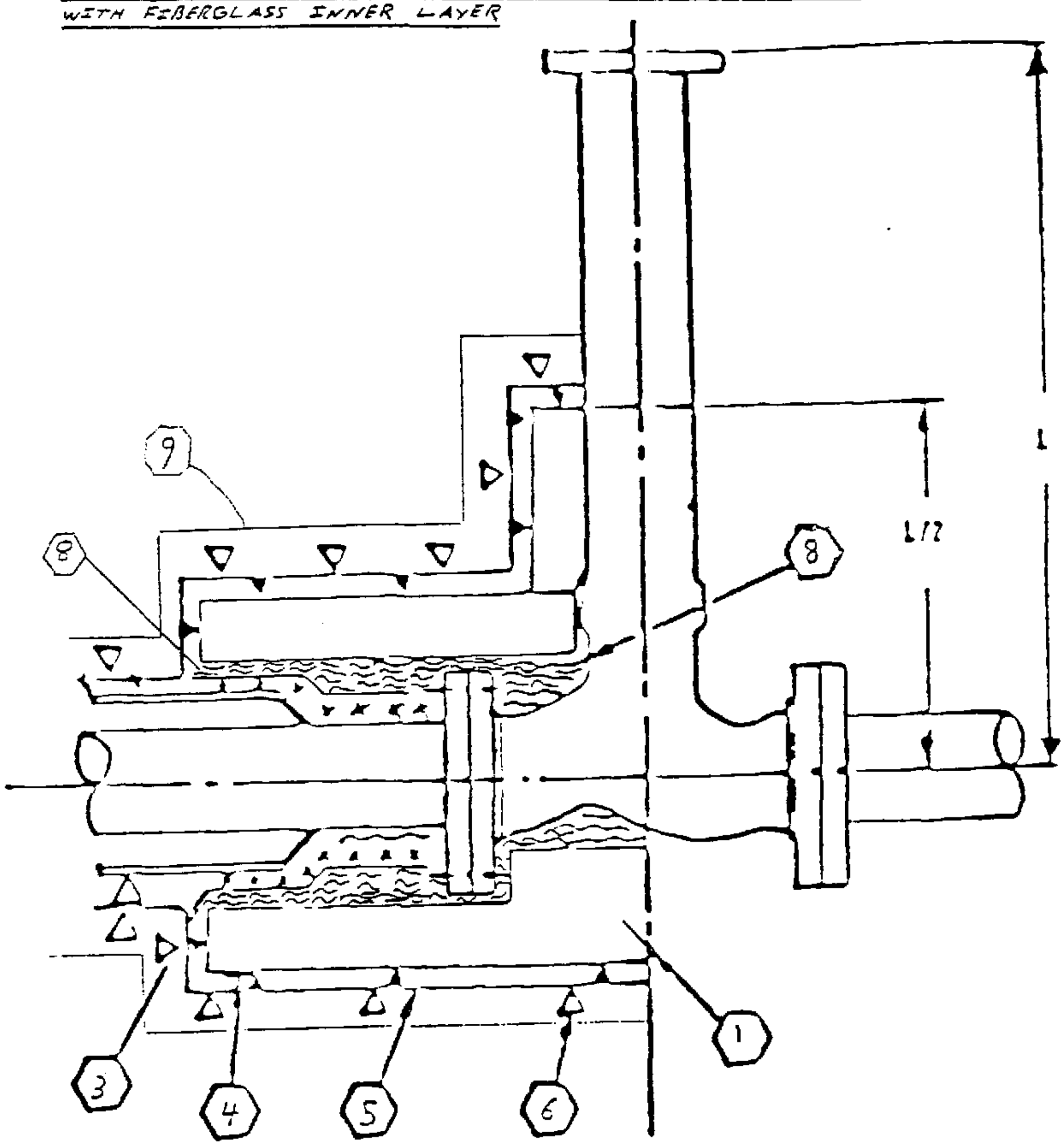
2. INSULATION TO BE INSTALLED IN TWO HALVES. VAPOR SEALED AGAINST PIPE JACKET, BONNET, ETC.

Attachment A

FIGURE C6

POLYISOCYANURATE INSULATION EXTENDED STEM VALVE

WITH FIBERGLASS INNER LAYER

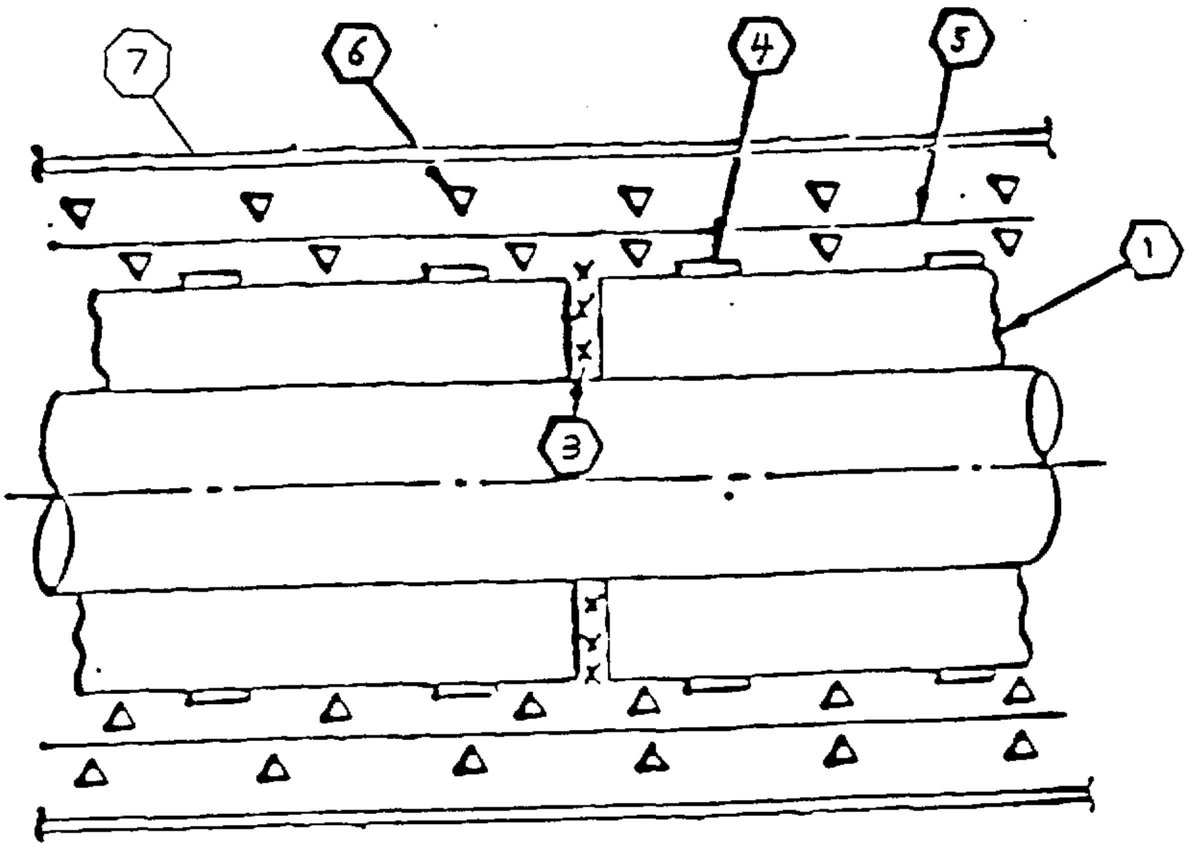


KEY

[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*

FIGURE D-1

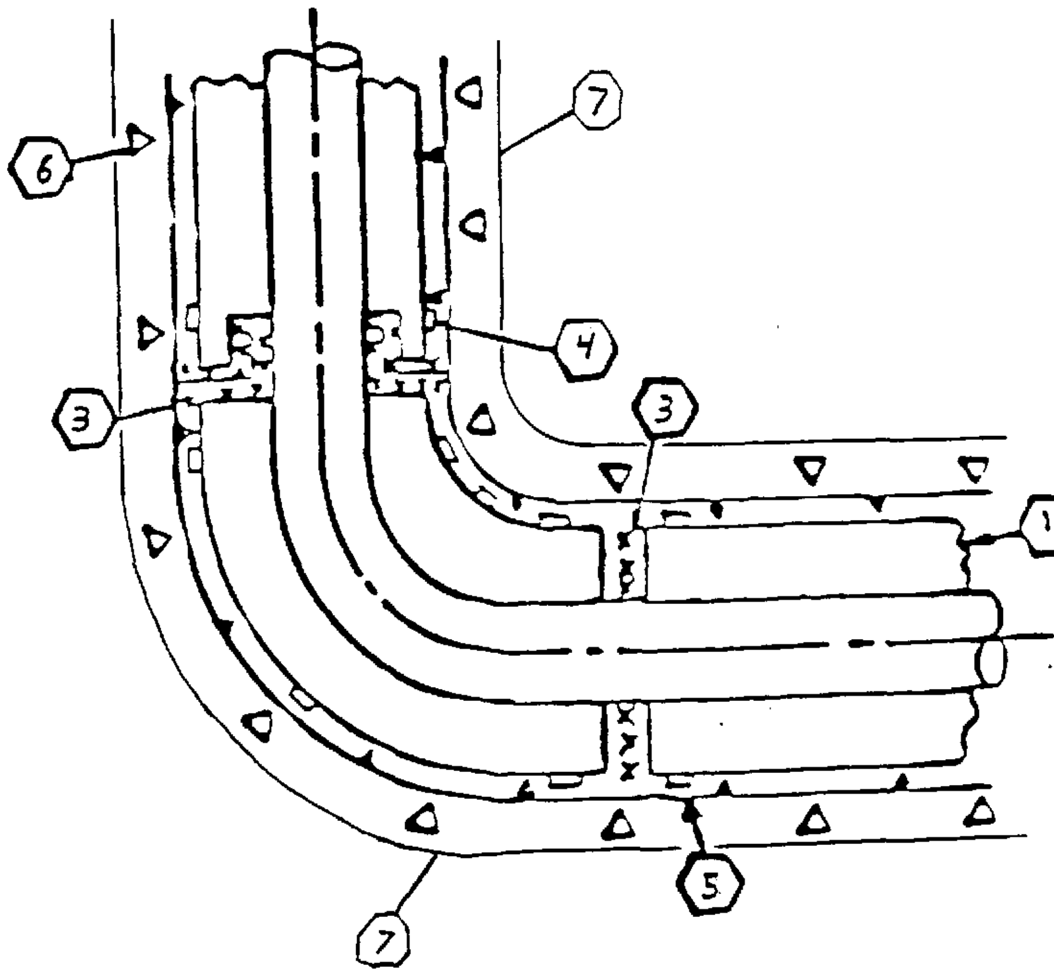
FIBERGLASS INSULATION - TYPICAL PIPE SECTION



[1] Fiberglass
[3] Joint Sealant and Vapor Stop Mastic
[4] Filament Tape
[5] Membrane
[6] Vapor Barrier Mastic
[7] PLASTIC PIPE JACKET, SUBSTITUTE METALLIC PIPE JACKET WHEN INSULATING ELECTRIC HEATERS.

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.

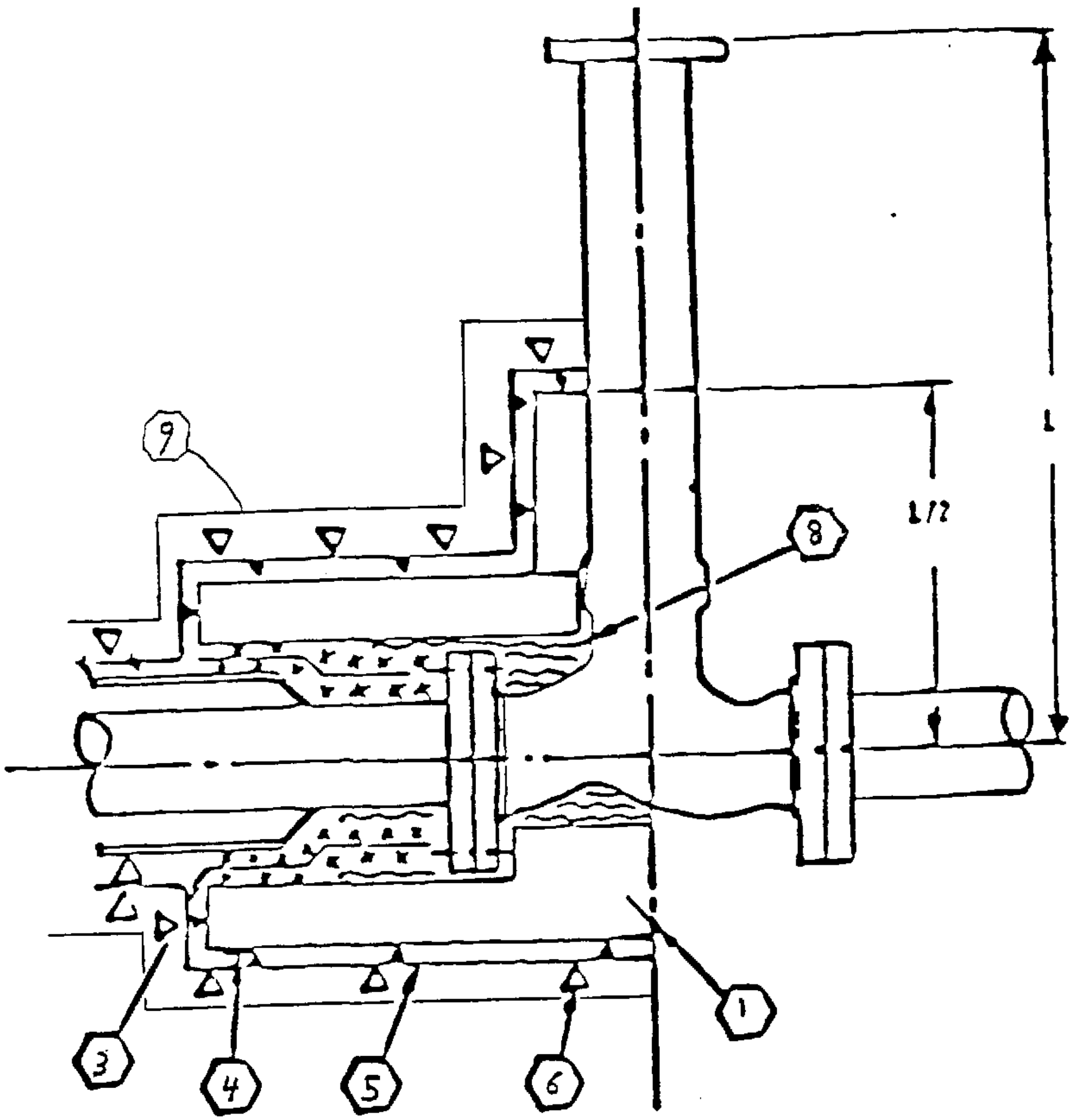
FIGURE D-2
FIBERGLASS INSULATION ELBOW



KEY

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

FIGURE D-3
FIBERGLASS INSULATION EXTENDED STEM VALVE

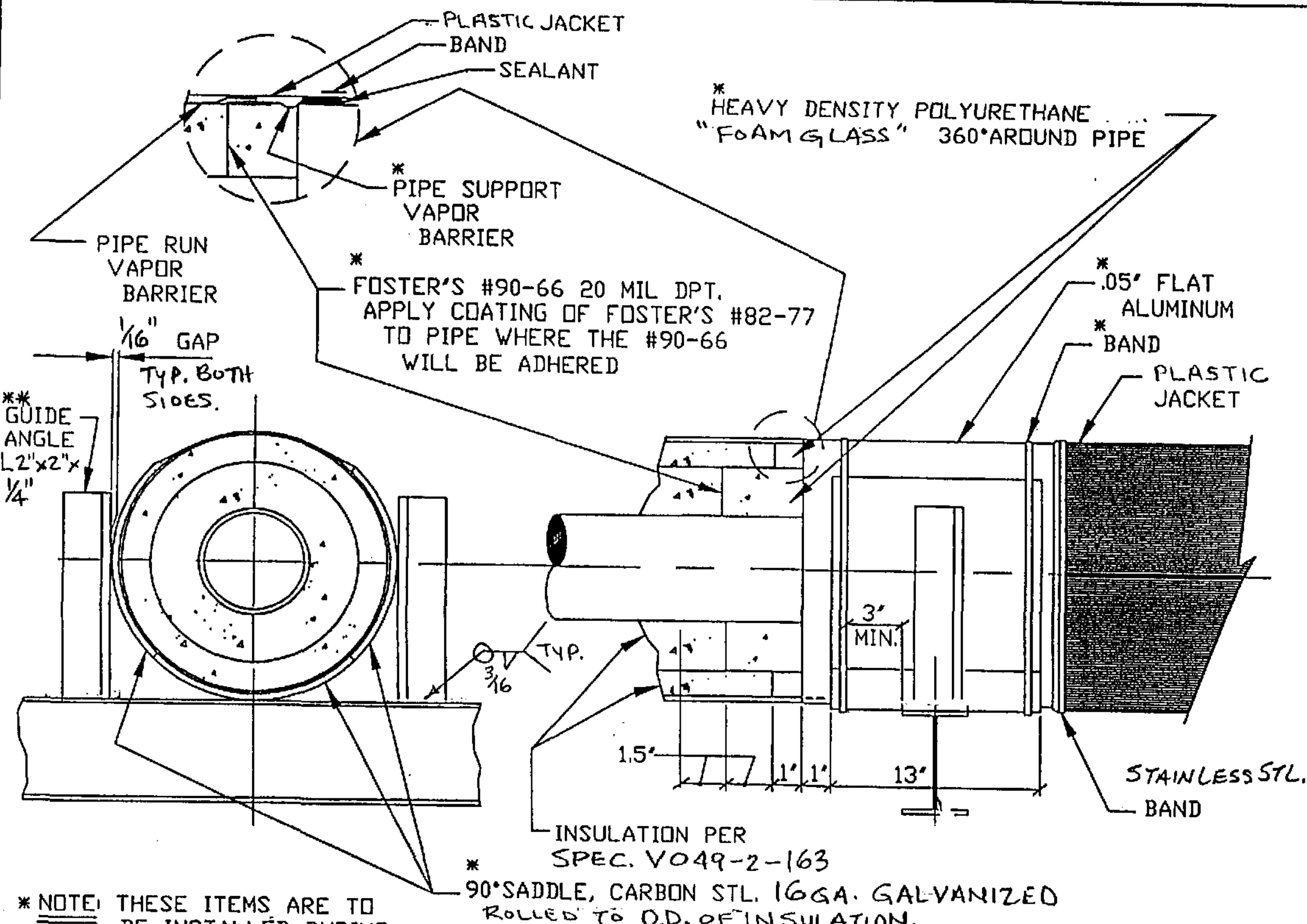


KEY

[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

TYPICAL PIPE SUPPORT - FIGURE D4

LOW TEMPERATURE INSULATION



* NOTE: THESE ITEMS ARE TO BE INSTALLED DURING PIPE ERECTION.

** ONLY AT SUPPORTS OUTSIDE OF BUILDING.

TYPICAL PIPE GUIDE - FIGURE D4

PAGE

REV.

V049-2-163 Attach. A

Title: CONFLAT FLANGE ASSEMBLY PROCEDURE

CONFLAT FLANGE ASSEMBLY PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: S Moten
MANUFACTURING Phillip [illegible]
QUALITY ASSURANCE: [illegible]
TECHNICAL DIRECTOR: D. A. McWilliams
PROJECT MANAGER: [illegible]

Ø	SM 10/25	BEF 11/12/96	Released per DCO 0335
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

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

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.

Number

Rev.

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 conflat with a stainless steel wire.

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: [illegible]

MANUFACTURING [illegible]

QUALITY ASSURANCE: [illegible]

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [illegible]

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Φ	SM 10/29	RGB 11/7/96	Released per DEC 0336

PROCESS SYSTEMS INTERNATIONAL, INC. — SPECIFICATION

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

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_2 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 role or twist the o-ring during installation.

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.

COMPONENT ALIGNMENT PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington

PREPARED BY: R Bayly

STRUCTURAL ENG: R. O. Ciatto

QUALITY ASSURANCE: Gene Sowal

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Randall Bayly

1	DMS		RELEASED FOR CONSTRUCTION PER DEO # 531
∅	D. McW	REB 12/5/96	RELEASED PER DEO 0377
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED REB	DATE 12/5/96	APPROVED REB	DATE 12/5/96	Number V049-2-174	Rev. 1

Title: LIGO VACUUM EQUIPMENT COMPONENT ALIGNMENT PROCEDURE

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.

Title: LIGO VACUUM EQUIPMENT COMPONENT ALIGNMENT PROCEDURE

TABLE OF CONTENTS

ATTACHMENTS:

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.
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 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, 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 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).

Title COMPONENT ALIGNMENT PROCEDURE

ATTACHMENT B

COMPONENT INSTALLATION DATA SHEET

Component Tag Number ______________________

Component Name ______________________

Component S/N ______________________

Component Installation Weight (lb.) ______________________

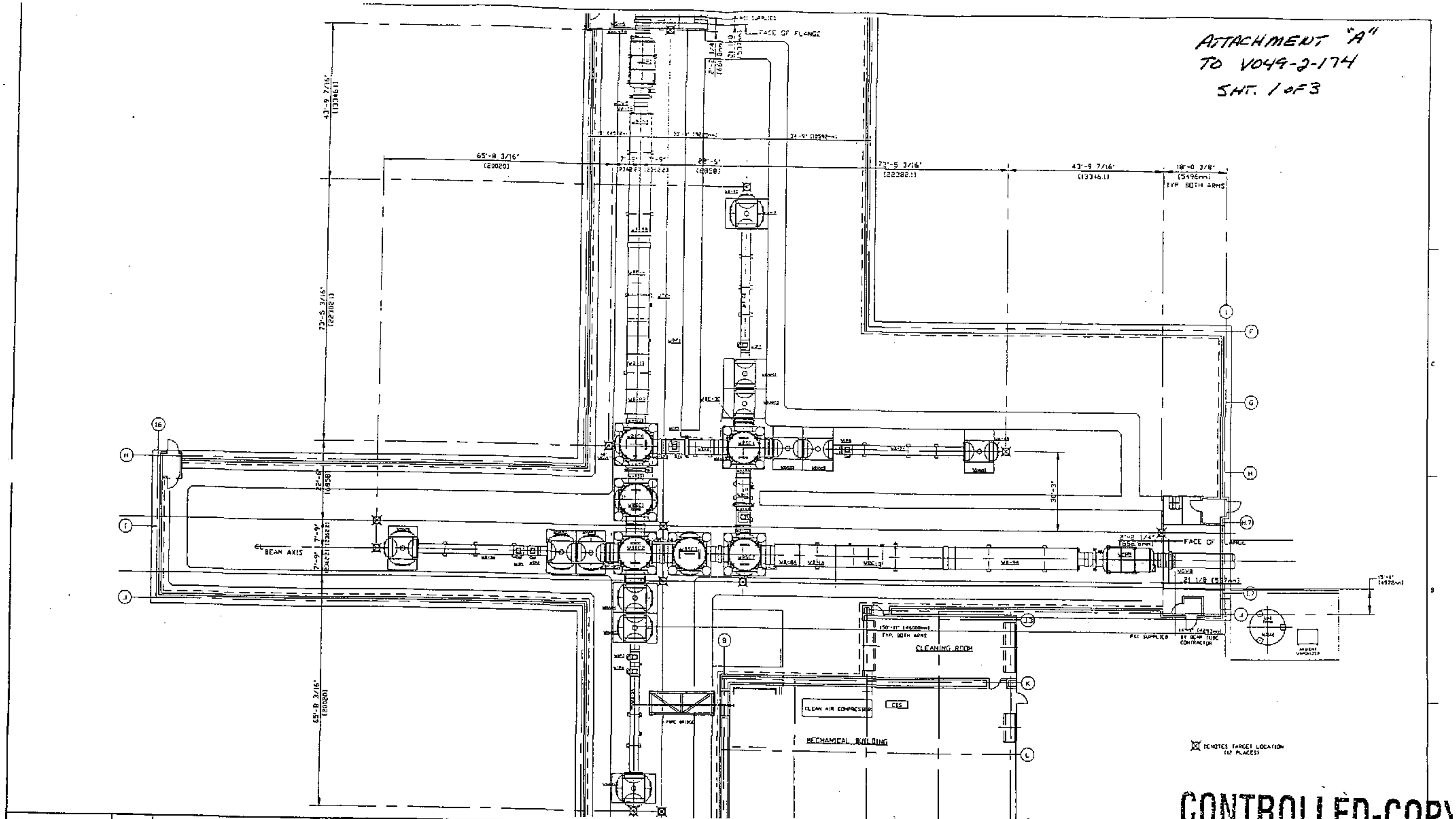
Component Installation Position (Ref. Build Grid)

	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		

Number

Rev.

ATTACHMENT "A"
TO V049-2-174
SHT. 1 OF 3



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REFERENCE DRAWINGS

DWG. NO.	DESCRIPTION
V049-0-001	P&ID LIGO VACUUM EQUIPMENT
V049-2-021	SPEC. FOR INSTALLATION & COMMISSIONING
VA-A-501	PARSONS ARCHITECTURAL CORNER STATIONS
	LVEA FLOOR PLAN
1101100	LIGO VACUUM EQUIPMENT CORNER STATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR/MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
FINISHED SURFACE
BREAK CORNERS IN OUT
REMOVE ALL BURRS

DO NOT SCALE THIS DRAWING
USED ON
NEXT ASS'Y

REV	DESCRIPTION		CHKD	DRWN	DATE	DEDN
0	ISSUED FOR INFORMATION	KEB	AEC	JR	4/17/97	DATE

ISSUE DESCRIPTION

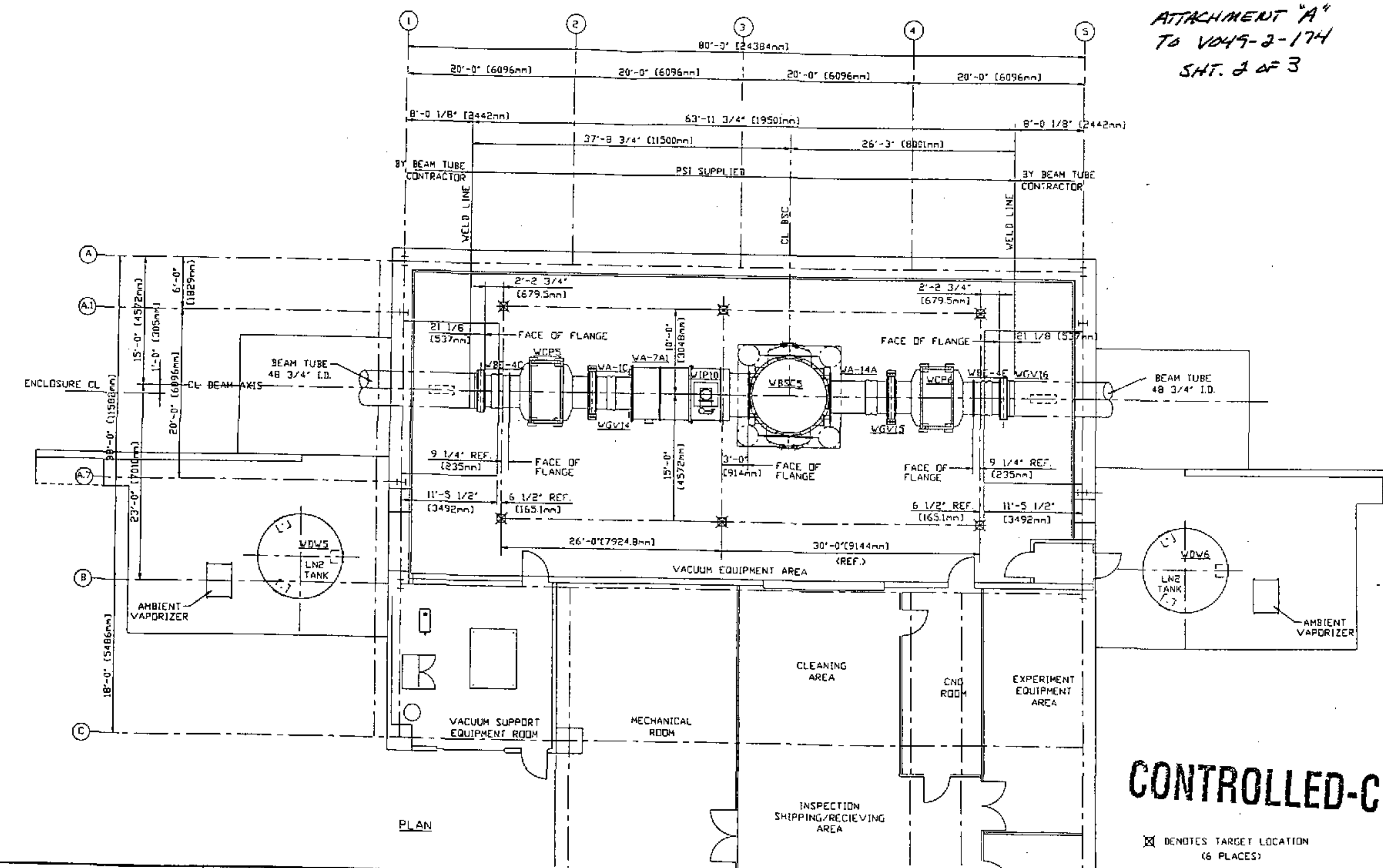
PROCESS SYSTEMS INTERNATIONAL, INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

SURVEY BENCHMARK LAYOUT
CORNER STATION
WASHINGTON STATION
LIGO VACUUM EQUIPMENT

CAD FILE: V0495050 | SIZE: D | DWG. NO.: V049-5-050 | REV.: 0
SCALE: 1"=10' | SHEET: 1 OF 1

Feb 07, 1997 - 17:43:18

ATTACHMENT "A"
TO V049-2-174
SHT. 2 OF 3



CONTROLLED-COPY

☒ DENOTES TARGET LOCATION (6 PLACES)

DWG. NO.	DESCRIPTION
V049-0-001	P&ID FOR LIGO VACUUM EQUIPMENT
V049-2-021	SPEC. FOR INSTALLATION/COMMISSIONING
WA-A-201	PARSONS ARCHITECTURAL MID STATIONS FLOOR PLAN
1101103	LIGO VACUUM EQUIPMENT MID STATIONS

REFERENCE DRAWINGS

DO NOT SCALE THIS DRAWING

REV	DESCRIPTION	CHKD	DRWN	DATE	DEO#
0	ISSUED FOR INFORMATION		JR	4/17/97	

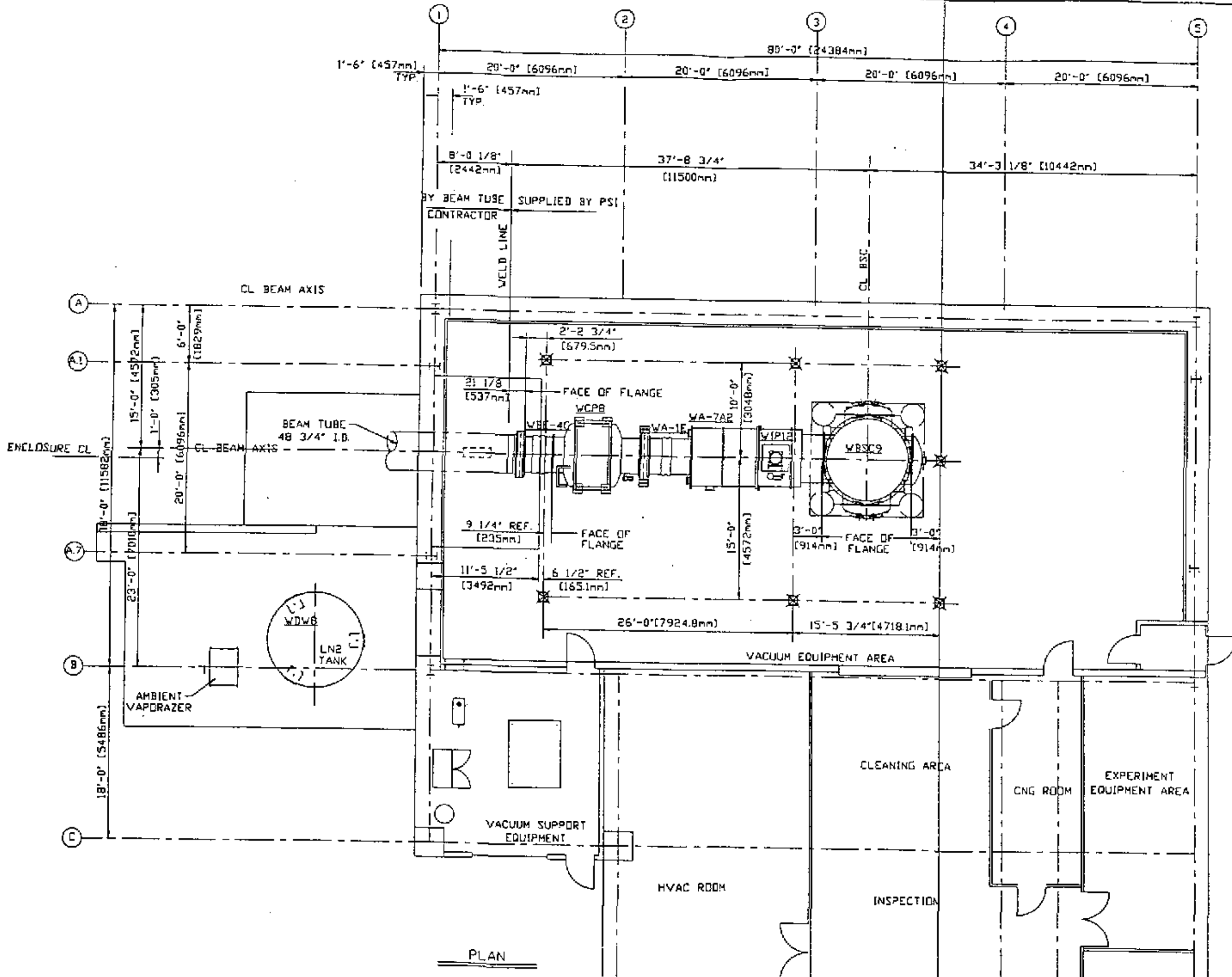
ISSUE DESCRIPTION

PROCESS SYSTEMS INTERNATIONAL INC.

SURVEY BENCHMARK LAYOUT
RIGHT/LEFT MID STATIONS
WASHINGTON SITE
LIGO VACUUM EQUIPMENT

CAD FILE V0495051 | SIZE D | DWG NO. V049-5-051 | REV. 0
SCALE NONE | SHEET 1 OF 1

ATTACHMENT "A"
TO V049-2-174
SHT. 3 OF 3



PLAN

CONTROLLED-COPY

☒ DENOTES TARGET LOCATION.
(7 PLACES)

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REFERENCE DRAWINGS

DWG. NO	DESCRIPTION	DWG. NO.	DESCRIPTION
		V049-2-021	SPEC. FOR INSTALLATION/COMMISSIONING
		V049-0-001	P&ID LIGO VACUUM EQUIPMENT
		WA-A-202	PARSONS ARCHITECTURAL END STATIONS FLOOR PLAN
		1101102	LIGO VACUUM EQUIPMENT END STATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR/MACH ABOVE ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
FINISHED SURFACE
BREAK CORNERS OR OUT-
REMOVE ALL BURRS

DO NOT SCALE THIS DRAWING
USED ON:
NEXT ASS'Y:

ISSUE DESCRIPTION

REV	DESCRIPTION	CHKD	DRWN	DATE	DECN
0	ISSUED FOR INFORMATION	[signature]	JR	4/17/97	0471

PROCESS SYSTEMS INTERNATIONAL INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

SURVEY BENCHMARK LAYOUT
RIGHT/LEFT END STATIONS
WASHINGTON SITE
LIGO VACUUM EQUIPMENT

CAD FILE: V0495052
SIZE: D
DWG NO: V049-5-052
REV: 0
SCALE: 1/8"=1'-0"
SHEET: 1 OF 1

Apr 22, 1997 - 10:53:43

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

SPECIFICATION FOR

VACUUM PUMP FIELD INSTALLATION PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington

PREPARED BY: S Matur

STRUCTURAL ENG: A. J. Citti

QUALITY ASSURANCE: Gene Snead

TECHNICAL DIRECTOR: D. O. McWilliams

PROJECT MANAGER: Richard Bayly

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
φ	SM 12/4/96	RES 12/4/96	Released per NEO 0371

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED SM	DATE 12/4/96	APPROVED RES	DATE 12/4/96	Number V049-2-175	Rev. φ

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Number

Rev.

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.

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.

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.

Title: SPECIFICATION FOR PREFABRICATED VACUUM AND CLASS 100 AIR PIPING

SPECIFICATION FOR

PREFABRICATED VACUUM AND CLASS 100 AIR PIPING

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington

RAYMOND D. CIATTO
STATE OF WASHINGTON
15714
REGISTERED
PROFESSIONAL ENGINEER

Raymond D. Ciatto 7/21/97

EXPIRES 8/5/99

INSTALLATION MANAGER: [signature]

STRUCTURAL ENGINEER: R. D. Ciatto

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [signature]

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.

Ø	DMG 16JUL97	REB 7/21/97	RELEASED FOR CONSTRUCTION PER DEO # 0575
P1	REB 12/20/96	12/20/96	ISSUED FOR QUOTES DEO 0393
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED REB	DATE 12/20/96	APPROVED REB	DATE 12/20/96	Number V049-2-178	Rev. Ø

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ATTACHMENTS:

A. Drawing List - See Attached List

B. V049-2-037 " Specification for Piping Design and Material"

C. V049-2-060 Specification for Clean Quarter Turn Valves

D. V049-2-059 Specification for Small Vacuum Valves

1.0 PURPOSE

This specification defines the scope of work to be provided by the contractor for the supply of the optional prefabricated Vacuum and Class 100 Air piping for the LIGO Vacuum Equipment. All requirements of V049-2-021 "Specification for Installation/Commissioning for LIGO Vacuum Equipment " applicable to this work.

2.0 SCOPE

2.1 The contractor is to provide all material and labor to detail design, procure, fabricate, test, and deliver to the site Vacuum and Class 100 Air piping and pipe supports as shown on the piping arrangement drawings and P&I Diagrams listed in Attachment A.

2.2 The Vacuum piping is comprised of the following:

Roughing Header (Corner Station only)

Turbo Headers

Annulus Piping

3.0 MATERIALS

All materials shall be in accordance with V049-2-037 "Specification for Piping Design and Materials"

4.0 FABRICATION AND TESTING

4.1 Pipe spool sections shall be prefabricated using only approved welding procedures in lengths appropriate to allow installation in the vacuum equipment area without requiring welding. Fabrication shall be done in accordance with specified codes.

4.2 Each spool section run shall have one fixed and one rotatable CF flange to permit easy assembly of the piping system. Flex sections shall be provided as necessary. Branches shall terminate in fittings as designated on the P&I Diagrams. Blind flanges shall be provided as indicated including gaskets and hardware. Spool drawings shall be submitted to PSI for approval prior to fabrication.

4.3 Each spool section is to be helium leak checked after welding by evacuating and spraying with helium, and show no detectable with a helium mass spectrometer at a sensitivity of 1x10-9 torr l/s. Spools shall be given unique serial numbers (1 to ___) to control testing documentation.

4.4 Each spool section shall be pressure washed with hot water using approved detergent (Oakite Inpro-Clean 1300)* and then rinsed with dionized water to remove all dirt and hydrocarbons. After drying with clean, filtered hydrocarbon free air or nitrogen, the section shall be checked for contamination using a white glove. Any discoloration shall be cause for rejection and the piece shall be rewashed. If contamination is localized, the area may be cleaned using isopropyl alcohol and lint free cloths.

* Per manufacturer's specifications and not to exceed 5% inpro-clean in solution.

4.5 After drying the section shall be properly labeled and capped to provide an airtight seal. The seal shall be maintained up to the time the section is to be installed.

5.0 DOCUMENTATION

The following documentation shall be provided.

- Material certification of all materials on pipe and fittings
- Leak Test Report
- Cleaning Report
- As built drawings

ATTACHMENT "A" SPEC. V049-2-178

DOCUMENT LIST

TITLE	*DRAWING SIZE*	*DOCUMENT NUMBER*	*REV.*
P&ID's	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

QTY	TITLE	DRAWING SIZE	DOCUMENT NUMBER	REV.
	MECHANICAL DRAWINGS			
6	25 L/S Annulus Tubing-44" G.V. Type III	C	V049-4-106	0
2	25 L/S Annulus Tubing 48" G.V. Type 1	C	V049-4-108	0
8	Annulus Tubing & Ion Pump Assembly. 44" G.V.	D	V049-4-109	0
2	25 L/S Annulus Tubing 48"G.V. Type II	C	V049-4-110	0
2	25 L/S Annulus Tubing - 44" G.V. Type I	C	V049-4-164	0
4	Annulus Tubing & Ion Pump Assy 48" G.V.	D	V049-4-165	0
8	25 L/S Annulus Tubing - 44" G.V. Type II	C	V049-4-166	0
-	Left & Right Beam Manifold Annulus Headers	D	V049-5-012	Sht 1
1	Right Beam Manifold Annulus Header Per Line No. 2 1/2-PV-1174-T3			
1	Left Beam Manifold Header Per Line No. 2 1/2-PV-1158-T3			

Title SPECIFICATION FOR PREFABRICATED VACUUM AND CLASS 100 AIR PIPING

TITLE	*DRAWING SIZE*	*DOCUMENT NUMBER*	*REV.*
MECHANICAL DRAWINGS			
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

Number

Rev.

ATTACHMENT "B"

TO

V049-2-178

SPECIFICATION FOR PIPING AND MATERIAL FOR LIGO VACUUM EQUIPMENT

V049-2-037

Title: SPECIFICATION FOR PIPING DESIGN AND MATERIAL

SPECIFICATION FOR
PIPING DESIGN AND MATERIAL
FOR
LIGO VACUUM EQUIPMENT

Hanford, Washington
And
Livingston, Louisiana

RAYMOND D. CIATTO
STATE OF WASHINGTON
15714
REGISTERED
PROFESSIONAL ENGINEER

Raymond D. Ciatto
7/21/97
EXPIRES 8/5/99

STATE OF LOUISIANA
RAYMOND D. CIATTO
REG. No. 26750
REGISTERED
PROFESSIONAL
ENGINEER
IN
CIVIL ENGINEERING

PROCESS ENGINEER: Robert Than

PROJECT ENGINEER: S. Motaw

CIVIL/STRUC. ENGINEER: R. D. Ciatto

MANUFACTURING ENGINEER: Phillip Fabel

QUALITY ASSURANCE ENGINEER: Alan L Bradbrook

PROJECT MANAGER: [illegible]

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
5	RM 1/14/97	D.M.W 1-15-97	Clarified 1B1 flange/gasket requirements DEO # 0411
4	REC 11/27/96	D.M.W 11-27	REVISED T3 CLASS, MAT'L TO BE 304S/S, IT WAS 304L. DEO 0369
3	RM 10/16/96	D.M.W 10-17-96	Added "C1", Spec. sht for cryogenic copper lines. REVISED 1B1-FLANGES DEO # 0317
2	REC 8/24/96	PHH/REB 8/28/96	REVISED "T4" SPEC SHT. 17, ITEM 5. RELEASED FOR PURCHASE. DEO 249
1	REC 7/25/96	REB 8/13/96	REVISED "T4" SPEC. SHT. 17 RELEASED FOR PURCHASE DEO #0236
0	REC 1-19-96	D.M.W	RELEASED FOR DESIGN & QUOTES DEO #0044

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED R. Ciatto	DATE 1-11-96	APPROVED D.M.W	DATE 1-18-96	Number A V049-2-037	Rev. 5

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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

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:

2 PL 008 XYZ 3 HC FP3

- FP3 — Insulation Mat'l (See Section 5.5) Service
- HC — Insulation code (See Section 5.4)
- 3 — Insulation Thickness
- XYZ — Piping Specification Designation (See Section 5.3)
- 008 — Sequential Number
- PL — Fluid Service Code (See Section 5.2)
- 2 — Line Size (Nominal Pipe, inches). (Copper tube designated by nominal size, <u>not</u> OD)

Number

Rev.

5.2 Fluid Codes

Code	Fluid
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

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

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.

PV - A BB

- BB — Sequential (Loop) Number
- A — Station Identification
- PV — Functional Identification

Manual valves that do not carry an instrument loop numbers (described above) shall be assigned one of the following valve type descriptions, preceeded 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

VSOO Vacuum Seal-Off Valve Operator, SS

1B1

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. Flanges on the vent line, (which mate to a flat faced flange on the vacuum equipment) shall be stainless steel raised-face design. Flanged joints shall have spiral wound, stainless steel gaskets, Flexitallic or equal.

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

Continued on Next Page

1B1

Branch Connections:

Run Size "	½	¾	1	1½	2	3	4	6	8	10	12
½	04										
¾	06	04									
1	12	06	04								
1½	05	05	06	04							
2	05	05	06	06	04						
3	05	05	05	05	06	04					
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

04 - Tee
05 - Sockolet
06 - Tee Then Reducer or Reducing Tee
12 - BW O'let

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.

Continued on next page.

1B2

Branch Connections:

Run Size "											
½	04										
¾	06	04									
1	12	06	04								
1½	05	05	06	04							
2	05	05	06	06	04						
3	05	05	05	05	06	04					
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

04 - Tee
05 - Sockolet
06 - Tee Then Reducer or Reducing Tee
12 - BW O'let

Note:

1. Piping and fittings to be internally cleaned, dryed 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.

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.

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.

Tube Size (OD):	Minimum Wall Thickness (Inches)
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, dryed 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.

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.

Tube Size (OD):	Minimum Wall Thickness (Inches)
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, dryed and ends sealed during shiping, 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.

Title **SPECIFICATION FOR PIPING DESIGN AND MATERIAL**

T3

PIPING DESIGN AND MATERIAL SPECIFICATION

Service: Process Vacuum

Design Conditions:

Pressure	Vacuum 10^{-5} 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 TP304 SMLS
1 1/2" and larger	ASTM A26 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"

Flanges: All Flanges to be Conflat, ISO Large Flange or KF tube fittings 304 Stainless Steel.

Continued on next page.

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, dryed 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.

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"

Continued on next page.

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, dryed 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.

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"

Continued on next page.

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, dryed and ends sealed during shiping, 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.

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.

ATTACHMENT "A"

LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: PIPE, TUBING & FITTINGS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: 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		
PREP FOR SHIPMENT PROCEDURE			X	2	X		
CERTIFICATE OF COMPLIANCE				2	X		

SPEC V049-2-037

Pg. 20

Rev. 5

ATTACHMENT "C"

TO

V049-2-178

SPECIFICATION FOR CLEAN QUARTER TURN VALVES

V049-2-060

Title: SPECIFICATION FOR CLEAN QUARTER-TURN VALVES

SPECIFICATION FOR

CLEAN QUARTER-TURN VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Starr

PROCESS ENGINEER: Roberto Theu

QUALITY ASSURANCE: Alan L Bunlbrook

TECHNICAL DIRECTOR: D.C. McWilliams

PROJECT MANAGER: Bud 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
2	REC 07/10/97	D.McW 7-10-97	REVISED FOR PURCHASE TO ADD QTY. 12 - 1½" VALVES. DEO 0520
1	TMS 9-25-96	DMcW 9-26-96	REVISED FOR PURCHASE PER DEO 0274
0	TMS 3-1-96	D.McW 3-5-96	RELEASED FOR QUOTE PER DEO 077

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED: T.M.Starr	DATE: 3-1-96	APPROVED: REB	DATE:	Number: V049-2-060 A	Rev. 2

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of 2" clean quarter-turn valves for the LIGO vacuum system. These valves will be used in Federal Standard 209 Class 100 air service.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

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.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date	PSI Part No.
PSI, Westboro, MA:	21	11/29/96	V049BVCA20
PSI, Westboro, MA.	12	07/30/97	V049BVCA15 (80K purge)

2.2 Deleted

3.0 DESIGN REQUIREMENTS

3.1 The valves shall be either butterfly style, MDC Model No. BFV-200, MDC Part No. 360002.

3.2 The valves shall be 304 stainless steel.

3.3 End connections shall be CF flanges.

3.4 The valves shall be designed to seal in both directions.

3.5 The internal valve mechanisms shall be non-lubricated.

3.6 The valves shall be cleaned in accordance with the Vendor's standard procedure for valves intended for use in Federal Standard 209 Class 100 clean air service..

3.7 Valves shall be manually actuated.

4.0 REQUIRED DOCUMENTATION

Engineering drawings shall be submitted for approval prior to fabrication. Manufacturer's standard QA reports shall be provided prior to shipment:

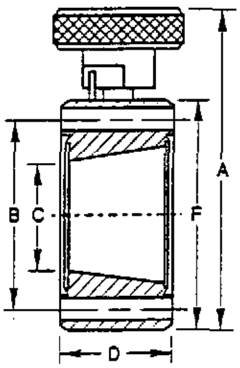
5.0 SHOP TESTING

Manufacturer's standard testing shall be performed.

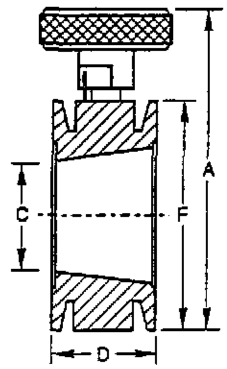
6.0 INSPECTION

The Vendor's standard inspections shall be performed. Also, each valve shall be visually inspected for cleanliness prior to shipment. Valves shall be recleaned if any contamination is found.

Butterfly Valves



Del-Seal Flange



Kwik-Flange Flange

ORDERING INFORMATION

Please order by Part Number

Valve Nom I.D. Size	Reference	Part Number	Flange F	Flange O.D.	Bolt Holes No.	Ref ISO	Height A	Bolt Circle B	C	Thickness D	Wt Lbs	Unit Price
3/4	BFV-075	360000	*Del-Seal* 1-1/3	1.33	6	-	1.96	1.062	.60	.75	1	$250
3/4	KBFV-075	360010	*Kwik-Flange*	1.18	-	NW16	1.81	-	.56	1.25	1	$250
1	KBFV-100	360011	*Kwik-Flange*	1.57	-	NW25	2.32	-	.87	1.25	1	$255
1-1/2	BFV-150	360001	*Del-Seal* 2-3/4	2.73	6	-	3.81	2.312	1.33	1.00	1	$260
1-1/2	KBFV-150	360012	*Kwik-Flange*	2.16	-	NW40	3.81	-	1.31	1.34	1	$260
2	BFV-200	360002	*Del-Seal* 3-3/8	3.37	8	-	4.46	2.850	1.84	1.00	2-1/2	$360
2	KBFV-200	360013	*Kwik-Flange*	2.95	-	NW50	4.46	-	1.87	1.68	2-1/2	$360

Dimensions are in inches

Valves

ATTACHMENT "A"
TO V049-2-060

Pg 1 of 2

Butterfly Valves

Del•Seal Metal Seal Flange **Kwik•Flange** ISO O-Ring Flange

FEATURES

- Quick open/Quick close
- Positive lock both positions
- Positive Viton® O-Ring vacuum seal
- High conductance
- Choice of *Del-Seal* or *Kwik-Flange*

Valves

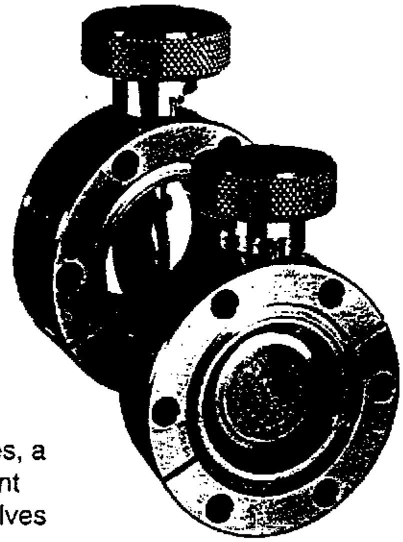
DESCRIPTION

MDC Butterfly Valves require only one-quarter turn rotation of the handle to go from fully open to the fully closed position. In the 1-1/3 Mini *Del-Seal* flange series, a spring loaded ball bearing becomes seated in an indent providing a positive mechanical stop. All other size valves employ a roll pin stop method.

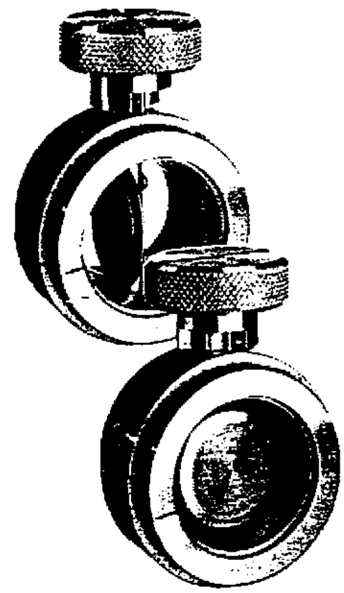
These quick-acting Butterfly Valves feature an improved sealing action. The opening in the body of the valve has been machined at a slight angle to the plane of the flapper. The flapper is set to rotate slightly off-center. On closure, this causes the sealing pressure to be applied more uniformly all around the O-ring. A reliable, positive seal is made and the tendency of previous designs to roughen the surface of the O-ring and eject it from its groove is eliminated.

MDC Butterfly Valves are low outgassing. All internal surfaces are machined from solid stainless steel bar stock. The handle is made of aluminum. A small O-ring on the stem prevents shaft leakage.

The valves are offered with a choice of *Del-Seal* ultra-high vacuum metal-seal flanges or ISO *Kwik-Flange* O-ring seal flanges.



Del-Seal Flange
BFV-150



Kwik-Flange Flange
KBFV-150

ATTACHMENT "D"
TO
V049-2-178

SPECIFICATION FOR SMALL VACUUM VALVES

V049-2-059

SPECIFICATION FOR

SMALL VACUUM VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas N. Stan

PROCESS ENGINEER: Roberto Thom.

QUALITY ASSURANCE: Alan H Bradbrook

TECHNICAL DIRECTOR: D. O. McWilliams

PROJECT MANAGER: Burkel Bayly

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	TMS 7-19-96	DMcW	REVISED FOR PURCHASE PER DEO 0224
0	TMS 2-29-96	DMcW	RELEASED FOR QUOTE PER DEO 0075

PROCESS SYSTEMS INTERNATIONAL, INC. | **SPECIFICATION**

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	T. Stan	2-29-96	KEB	2/21/96	V049-2-059	1

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of small (1 1/2" and 2 1/2") high vacuum and ultra high vacuum angle valves for the LIGO vacuum system.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

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.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date	PSI Part No.
1 1/2" High Vac	137	9/30/96	V049AVHV15
2 1/2" High Vac	70	9/30/96	V049AVHV25
1 1/2" Ultra High Vac	77	9/30/96	V049AVUV15
2 1/2" Ultra High Vac	26	9/30/96	V049AVUV25

2.2 All valves shall be delivered to Process Systems International, Inc. at 20 Walkup Drive, Westboro, Massachusetts, 01581.

2.3 Acceptances at the sites are expected to occur on a staggered basis, with final acceptance at Washington expected to occur about May 31, 1998, and about November 30, 1998 in Louisiana.

3.0 DESIGN REQUIREMENTS

3.1 Angle valves shall be 304L or 316L stainless steel (304 or 316 stainless steel is acceptable if the valves are unavailable in L grade SS).

3.2 End connections shall be CF flanges.

3.3 The valves shall have stainless steel metal bellows stem feedthroughs.

3.4 Neither the body leakage not the seat leakage shall exceed 1×10^{-9} torr liters/sec of helium.

3.5 The valves shall be designed to seal in both directions.

3.6 The internal valve mechanisms shall be non-lubricated.

3.7 Valves shall be manually actuated by a handwheel.

3.8 Valves shall be bakeable to 150 C +/-20 C (170 C maximum).

3.9 The valves shall be cleaned in accordance with the Vendor's standard procedures applicable to the valve service.

4.0 REQUIRED DOCUMENTATION

Engineering drawings shall be submitted for approval prior to fabrication. Manufacturer's standard QA reports shall be provided prior to shipment:

5.0 SHOP TESTING

Each valve shall be tested for leakage (using oil-free pumping equipment and leak detector) prior to shipment from the manufacturer

6.0 INSPECTION

The Vendor's standard inspections shall be performed. Also, each valve shall be inspected for cleanliness by black light prior to shipment. Valves shall be recleaned if any contamination is found.

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: [signature]

∅	DM 5/6/96	A93 5/6/96	Released per DEO #173 for FDR
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED DM	DATE 5/6/96	Approved A93	DATE 5/6/96	Number: A V049-2-102	Rev. ∅

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of this piece of equipment in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all the stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

V049-2-014 Leak Test Plan

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST

5.1 80K Pump Field Joint Leak Test

The specification requires all leaks greater than 1x10E-9 torr-l/s of helium to be repaired in accordance with LIGO approved procedures. Prior to shipment to the site, the 80K pump will have been leak checked and all objectionable leaks will have been repaired. However, all joints and flanges on the 80K pump which are assembled in the field will be leak checked per the methods described in V049-2-014.

5.2 LN2 Dewar Site Acceptance Test

After dewar installation, but prior to filling it with LN2, the dewar shall be subjected to the following series of checks:

1) Visually inspect for damage that may have occured during shipment or installation.
2) Briefly exercise all manual valves to verify operation. The dewar inner vessel contains a dry nitrogen charge at 5-10 psig, so a small quantity of gas will escape when the valves are exercised.
3) Check the vacuum level in the dewar jacket annulus with a thermocouple gauge to verify vacuum integrity. Refer to the dewar operating manual for the required level.

After filling the dewar with liquid nitrogen, the following checks shall be made:

1) Verify that the locally mounted level and pressure gauges have stabilized. Refer to the dewar operating manual and 80K pump operating procedures for correct readings.

5.3 Regeneration Heater Acceptance Test

Prior to any operating checks, visually inspect the heater for any signs of damage that may have occurred during shipment or installation.

The acceptance test for the regen heater is a functional test to verify that the heater performs its intended function. It is recommended that in order to conserve liquid nitrogen, this test be performed prior cooling down the cryopump. The test sequence described below assumes the test is on one of the long cryopump regen heaters. Wherever the test for the short cryopump regen heater differs from that of the long cryopump heater, it is so noted. Equipment tag numbers are for cryopump WCP1 (Refer to drawing V049-0-006). The test procedure is as follows:

1) Verify that the manual globe valve (HVXX1) upstream of the heater is closed.

2) Open the dewar gaseous nitrogen supply valve, V-11, (refer to dewar operating manual for equipment tag numbers) upstream of the ambient vaporizer to admit nitrogen to the regen system.

3) Open the manual globe valve until the flowmeter indicator (FI104) upstream of the heater reads 10,600 SCFH (5,300 SCFH for the short pump regen system).

4) Set the heater conrols for a gas outlet temperature of 360 deg. F (375 deg. F for the short pump heater).

5) Verify that the heater controls maintain the gas outlet temperature (TE103A) at the selected temperature. This concludes the test. The sequence required for stopping the test is as follows

    1) Shut down the heater.
    2) Close the dewar gaseous nitrogen supply valve, V-11, upstream of the vaporizer.
    3) Close the manual globe valve, HVXX1.

5.4 Cryopump Acceptance Test

The acceptance test for the cryopump is a functional test to verify that the pump liquid level control valve performs its intended function. This may be verified by simply monitoring the liquid level in the pump over a 24 hour period. If the level control valve is functioning properly, then neither the high level alarm nor the low level alarm will have tripped.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION Equip. Tag_____ S/N___________

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labelling Verification					
Bakeout					
Leak rate					
Factory Endurance Test					
Factory Speed Test					
Functional Test					
RGA Test					
Particle Count					
Pumpdown					

V049-2-102
Rev B

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: SMoten

QUALITY ASSURANCE: Alan R Bradford

TECHNICAL DIRECTOR: D.A. McWilliams

PROJECT MANAGER: Richard Bagley

0	SM 5/1/96	REB 5/2/96	INITIAL RELEASE PER DEO 0157 FOR FDR
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

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

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of this piece of equipment in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The plan will apply to the main roughing pump systems for the corner stations.

2.2 Tests will be performed by PSI personnel, and will be witnessed and/ or the results reviewed and the equipment accepted by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

EDP200/EH2600 Roughing pumps Operating Manuals

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the PSI project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FACTORY TEST

5.1 Procedure

5.1.1 Speed Test

The Main Roughing system's individual vacuum pumps will be atmospheric air speed tested by EHVI at the point of manufacture in the U.K. A test certificate is provided with each pump.

The minimum required pumping speed at 1 Torr is 236 l/s, at 0.1 Torr is 472 l/s. The roughing pump set must be capable of evacuating a volume of 200 cubic meters from atmosphere to 1 Torr in 4 hours or less.

The Main Roughing Pumps are designed for continuous duty service at full load and will pump down a 2000 cubic meter volume from atmosphere to 1 Torr without overheating.

5.1.2 Functional Test

Main Roughing system functional tests will be done at EHVI's Grand Island, N.Y. facility

Besides the manufacturer's standard operating and safety features the following additional feature has been incorporated

a. Gate valve at inlet to Roots blower EH2600 fails close on lost of power or on shut down of EDP200.

6.0 FIELD TEST

6.1 Procedure

The main roughing pump equipment will have already been accepted by LIGO at the point of manufacture as part of the beam tube deliverables, and will have been used for beam tube pumpdown service.

After installation of the roughing system into the building, a functional checkout will be carried out prior to use, to determine operating status and mechanical condition of the pumping systems.

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. Moten

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Bill Bagley

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

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

5.0 FACTORY TEST

5.1 Procedure Main Turbomolecular Pump Sets

5.1.1 Speed Test

The Main turbomolecular pump systems are speed tested in accordance with American Vacuum Society AVS 4.1; Recommended procedure for measuring pumping speeds as revised in October 1986. The speed test is performed across the normal working range of the turbomolecular pump, from $1x10^{-6}$ torr to $1x10^{-3}$ torr.
The minimum required pumping speed at the inlet port of the Main Turbo pump is1400 l/s N_2 at an inlet pressure of $1x10^{-3}$ torr.

Throughput
The minimum required backing pump throughput is 5 torr-l/s with a backing pressure of 1 torr.

Duty
The Main Turbo Pump sets are designed for continuous duty service at full load and will pump down a 2000 cubic meter volume from 1 torr to 10^{-6} torr without overheating.

5.1.2 Functional Test

Besides the manufacturer's standard operating and safety shutdown features the following additional feature has been incorporated

a. The turbo pump cannot be started or will shutdown at a backing pressure higher than a preset value.
b. Emergency stop button on the backing pump electrical interface box and main control box.
c. Backing pump motor winding overtemp shutdown
d. Backing pump shut down on N2 seal gas low flow
c. Backing pump motor starter overload
d. Foreline safety valve closes on backing pump shutdown or turbo pump shutdown/failure.

5.2 Auxiliary Turbomolecular Pump Sets

5.2.1 Speed Test

The Auxiliary turbomolecular pump systems are speed tested in accordance with American Vacuum Society AVS 4.1; Recommended procedure for measuring pumping speeds as revised in October 1986. The speed test is performed across the normal working range of the turbomolecular pump, from 1×10^{-6} torr to 1×10^{-3} torr.

The minimum required pumping speed at the inlet port of the Auxiliary Turbo pump is 50 l/s N_2 at an inlet pressure of 1×10^{-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 will fail closed on power loss or turbo failure and the inlet side of the turbo will be vented. (Process side is isolated and will remain under vacuum by closing of the automatic inlet valve)

6.0 FIELD TEST

6.1 Procedure Main Turbomolecular Pump Sets

The main turbomolecular pump equipment will have already been accepted by LIGO at the point of manufacture as part of the beam tube deliverables, and will been used for beam tube pumpdown service.

After installation of the main turbomolecular system into the building, a functional checkout will be carried out prior to use, to determine the operating status and mechanical condition of the pumping systems.

6.2 Auxiliary Turbomolecular Pump Sets

A functional checkout will be carried out prior to use, during installation of the vacuum envelope.

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. Bach

QUALITY ASSURANCE: Alan L Bradford

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bayer

0	F. Bach 5-2-96	RGB 5/2/96	RELEASED FOR FDR PER DCO # 160
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED F. Bach	DATE 5-2-96	Approved RGB	DATE 5/2/96	Number: A V049-2-106	Rev. 0

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of main and annulus ion pumps and controllers in order to demonstrate that they meet the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all the stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The attached equipment acceptance test data/test verification form shall be filled out when performing the ATP and presented to LIGO.

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or by someone designated by the PSI project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST PROCEDURE

5.1 Ion Pumps

5.1.1 Main Ion Pumps

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

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

c. While still under vacuum,Install the controller, hook up control wires and HV cable(s) to the controller and feedthru(s). Then test controller functionality and all interlocks.

d. After pump installation, vacuum leak check it with isolation valve closed. Refer to PSI leak test procedure V049-2-014.

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

5.1.2 Annulus Ion Pumps

Refer to Section 5.1.1 (Main Ion Pumps).
Item e (speed test) is not applicable.

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		$<1X10^{-9}$ Torr-L/s			
Factory Endurance Test		N/A			
Factory Speed Test		Torino,Italy. PSI witness first only			
Functional Test		Torino,Italy. PSI witness first only. PSI, Field test all.			
Electrical continuity test		Field. By PSI			
System interlocks test		Field. By PSI			
Ultimate Pressure		$<1X10^{-9}$Torr			

SPECIFICATION

Number:	Rev.
A V049-2-106	0

ACCEPTANCE TEST PROCEDURE FOR

LARGE GATE VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stan

INSTR/ELEC ENGINEER: N/A

QUALITY ASSURANCE: Alan R Burdbook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Rudolf Bay

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

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

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-005, 112 cm and 122 cm Gate Valves

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

5.1 The first eight large gate valves will be acceptance tested at the manufacturer's shop prior to shipment. These are slated for early delivery to Washington to close the beam tube. All other large gate valves will be tested at the manufacturer's shop prior to shipment and accepted in the field as the sections of equipment that they isolate are tested and accepted. The field test will consist of a valve functional check and the leak test of the isolated section of equipment.

5.2 Procedure

5.2.1 Each valve shall be inspected for dimensional conformance to approved assembly drawings.

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

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

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

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

6.0 DOCUMENTATION

The following documentation shall be provided prior to acceptance:

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

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION Equip. Tag____ S/N____________

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection	5.2.1 5.2.2				
Labelling Verification					
Bakeout	5.2.4	150 C /			
Leak rate	5.2.4	1 x 10^{-10} torr l/sec He			
Factory Endurance Test	5.2.3	20 Cycles			
Factory Speed Test	5.2.3	Open <5 min. / Close <5 min. /			
Functional Test	5.2.3				
RGA Test	5.2.4	<2 x 10^{-10} torr for any HC /			
Particle Count	NA				
Pumpdown	NA				

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1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-006, 6", 10" and 14" Gate Valves

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

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

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

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

5.4 Final acceptance will occur in the field. The field test will consist of a valve functional check and the leak test of the associated isolatable section of equipment.

6.0 DOCUMENTATION

The following documentation shall be provided prior to shipment:

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

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION Equip. Tag_____ S/N____________

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection	5.1				
Labelling Verification					
Bakeout	NA				
Leak rate	5.2	1 x 10^{-10} torr l/sec He			
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	NA				
RGA Test	5.2				
Particle Count	NA				
Pumpdown	NA				

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. Stern

INSTR/ELEC ENGINEER: NA

QUALITY ASSURANCE: Alan R. Bradbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [signature]

1	D.McW 12-18-96	REB 12/20/96	REV PER DEO #0390
0	TMS 5-3-96		INITIAL RELEASE PER DEO #0165 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED TMS	DATE 5-3-96	APPROVED REB	DATE 5/4/96	NumberA V049-2-109	Rev. 1

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-011, Clean Air Supply Systems

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

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

5.2 For one of each size system, the delivered flowrate shall be shown to be at least 50 CFM or 200 CFM, the dewpoint shown to be no higher than -60 C (at atmospheric pressure), and hydrocarbon content shown to be no higher than the ambient air. In addition, a particle count of the delivered air shall be taken to confirm that it conforms to Class 100(at 0.5micrometers).

5.3 Final acceptance will occur in the field. The hydrocarbon content, dewpoint, and particle count will be repeated as part of the check for cleanliness of the installed piping system in each station. Measurements shall be made at each outlet connection using the sampling fixture connected to the branch outlet.

5.4 The following instruments, or equal, shall be used for testing:

Dewpoint:	Kahn Ceramic Portable Hygrometer Range: -80Cto +20C
Hydrocarbon Content:	MSA Passport PID2 Organic Vapor Monitor
Particle Count:	MET One Model HPS227B Portable Airborne Particle Counter

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				
DEWPOINT	5.2				
Particle Count	5.2				
HYDROCARBON CONTENT	5.2				

V049-2-109 ATT 1 REV 1

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

INSTR/ELEC ENGINEER: FADI BARK /REB

QUALITY ASSURANCE: Alan L Bradbook

TECHNICAL DIRECTOR: D.A. McWilliams

PROJECT MANAGER: Richard Bagby

1	D.M.W 12-18-96	REB 12/20/96	REV PER DEO 391
0	TMS 5-3-96	REB 5/4/96	INITIAL RELEASE PER DEO # 0165 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED TMS	DATE 5-3-96	APPROVED REB	DATE 5/4/96	Number A V049-2-110	Rev. 1

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1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-010

FED-STD 209E, 1992

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

5.0 TEST

5.1 One of each size portable cleanroom shall be fully assembled at the manufacturer's shop. It shall be inspected for dimensional specifications and the presence and proper operation of the windows to seal to the beam tube or nozzles, and to the BSC dome. Rigidity of both the frame and of the removable ceiling unit shall be verified. The operation of the sealing system used to mate two cleanrooms together shall be checked. The cleanroom will be operated and certified to produce a Class 100 (at 0.5 micrometers)environment at rest for nonunidimensional flow after balancing, sealing and cleaning.

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 (at 0.5 micrometers)environment at rest using a discrete particle counter(DPC) in accordance with Section 5 of FED-STD 209E, 1992. Sample locations and number shall be in accordance with Section 5.1.3.2 for nonunidirectional flow. For the BSC cleanroom it is permissible to block out the non filtered center core with clean room curtains to simulate the presence of the BSC.

5.3 The following instruments, or equal, shall be used for testing:

Particle Count: MET One, Model HPS227B Portable Airborne Particle Counter

Thermal Anemometer: Datametrics, Model ADM-870

Pressure Gauge: Dwyer, Model 2000-00
Range: 0-.25"WC

6.0 DOCUMENTATION

A system assembly and operating manual shall be provided.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION Equip. Tag_____ S/N____________

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labelling Verification					
Bakeout	NA				
Leak rate	NA				
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	5.1				
RGA Test	NA				
Particle Count	5.2	Class 100			
Pumpdown	NA				

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:	[illegible]
INSTR/ELEC ENGINEER:	NA
QUALITY ASSURANCE:	[illegible]
TECHNICAL DIRECTOR:	[illegible]
PROJECT MANAGER:	[illegible]

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

ROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED TMS	DATE 5-3-96	APPROVED REB	DATE 5/4/96	Number A V049-2-111	Rev. 0

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5.0 TEST

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

5.2 All small vacuum valves valves shall be leak tested (using oil-free pumping equipment and leak detector). The vendor's standard leak checking procedures shall be used. Valve body and flange total leakage shall be measured to be less than 10^{-9} torr liter/sec of helium before shipment, or less if the vendor's standard is lower. Seat leakage shall be shown to be less than $1x\ 10^{-9}$ 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.

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP)is to define the overall plan for acceptance testing of this component in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all of the stations. Differences between the stations will be due to different vacuum equiipment, size of the isolatable sections, surfaces, volumes and quantities of instrumentation and equipment.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent (with sign-off authority) designated by LIGO.

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

PSI Specification V049-2-059, Small Vacuum Valves

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all of the procedures required by this ATP are performed and that the LIGO witness signs the data sheet/test certification (attached to this procedure) verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer, or other PSI person designated by the project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "NA" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on the data sheet.

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 x 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: SPECIFICATION FOR BAKEOUT SYSTEM ACCEPTANCE TEST PROCEDURE

ACCEPTANCE TEST PROCEDURE
FOR BAKEOUT SYSTEM BLANKETS AND CARTS
FOR LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Louisiana

PREPARED BY: F. Bark

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bayley

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

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED F. Bark	DATE 5-2-96	Approved KEB	DATE 5/2/96	Number: A V049-2-112	Rev. 0

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for acceptance testing of the bakeout system blankets and carts in order to demonstrate that they meet the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

2.0 GENERAL

2.1 The procedure applies to all the stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

3.0 REFERENCE DOCUMENTS

The attached equipment acceptance test data/test verification form shall be filled out when performing the ATP and presented to LIGO.

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that a person from LIGO designated as the witnessing agent, and who has signoff authority, shall sign the data sheet /test certification attached to this procedure, verifying that the procedures have been performed, and meet all requirements. The data sheet shall also be signed by the project engineer or by someone designated by the PSI project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing "N/A" in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST

5.1 Bakeout System Blankets And Carts:

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

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

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

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	
Number: A V049-2-112	Rev. 0